



















A TREATISE  
ON  
WOODEN TRESTLE BRIDGES

AND THEIR CONCRETE SUBSTITUTES

ACCORDING TO THE PRESENT PRACTICE  
ON AMERICAN RAILROADS

BY  
WOLCOTT C. FOSTER

*FOURTH REVISED AND ENLARGED EDITION*  
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NEW YORK:  
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LONDON: CHAPMAN & HALL, LIMITED

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THE SCIENTIFIC PRESS  
ROBERT DRUMMOND AND COMPANY  
BROOKLYN, N. Y.



## PREFACE TO FOURTH EDITION.

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IN revising this work it is believed that it has been brought down to the present time. While at first glance it might seem as though the wooden trestle bridge was losing its importance in railroad work, it and its substitutes have in reality been growing in importance. Wooden trestles may be gradually disappearing from main lines of heavy traffic, but the increased growth of branch lines or feeders and of trestles at manufacturing plants and for electric railways have probably more than kept pace with its abandonment on main lines.

Many of the railway clubs and engineering associations have permanent committees on wooden bridges and trestles, and much good work has been done by them during the past ten years. Their proceedings have been drawn on heavily in this revision. New matter has been added to every chapter. Various standards and rules of practice adopted by the different associations have been included in their proper places. Two new chapters, one giving a short outline of timber preservation and one on concrete trestles, have been added to the book.

The plates in Part II have been nearly doubled in number and include many examples of the latest practice, especially for heavy traffic.

An entire new part, giving a very extensive bibliography of the subject and of related matters of interest in trestle building and maintenance, has been added.

It is hoped that this revision will prove of benefit and use, not only to those engaged in steam railroad work, but also to those engaged in electric railway work and to manufacturing plants having or desiring to construct elevated tracks for the cheap handling and unloading of materials.







## PREFACE TO THIRD EDITION.

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THE author has endeavored to revise this work and bring the various parts of it up to the present time. New matter and data have been added to nearly every chapter and the number of plates of trestle designs increased.

An entirely new section giving some examples of electric-railroad trestles has been added to comply with numerous requests for such information.

Among the more important new matter is the following:

Chapter II. Additional data as to life of piles, pile-rings and their use, pile-driving records, and cost of pile-driving.

Chapter III. Tool equipment for pile-drivers, a description of an easily constructed temporary overhanging pile-driver, and the result of experiments on hammer-ropes.

Chapter XI. Detailed descriptions of the methods of inspection followed on several railroads.

Chapter XII. The conclusions reached, and unit stresses recommended for timber by the Committee on the "Strength of Bridge and Trestle Timbers" of the Association of Railway Superintendents of Bridges and Buildings.

Chapter XIV. An entirely new chapter on temporary trestles and methods of procedure in case of accidents, burnouts, washouts, and other breaks in the track.

Chapter XV. An entirely new chapter on renewal and replacing of trestles, giving descriptions of different methods of replacing trestles and some of the difficulties encountered.

Part II, Sec. I, Plate VIII A. Details of a trestle with a ballasted floor.

Sec. III, Plates XLVI, XLVII. An entirely new section, giving examples of electric-railroad trestles.







## PREFACE TO SECOND EDITION.

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**THE** favor with which this work was received encouraged the author to make a thorough revision upon the exhaustion of the first edition. Much new matter has been added and an endeavor made to embrace any new ideas, improvements, or knowledge derived since its first appearance, in fact to make it exhaustive as to the present knowledge and practice of trestle building.

Among the more important additions of new matter are the following :

To Chap. II much has been added as to the life of piles on different roads; many examples quoted of particular cases of the bearing power of piles; effects of shoeing and overdriving piles; formulas for the bearing power of piles and rules to be observed in pile driving; and additional records of cost and rate of pile-driving.

To Chap. III have been added plans and a description of a water-jet pile-driver and data relating to the use of this method.

To Chap. V has been added a section on rail-spiking, giving a method of preventing the creeping of rails on bridges.

To Chap. VI much has been added on the subject of trestles on curves and methods of elevating the outer rail.

Chap. XII, treating of some of the timbers suitable for bridge building, is entirely new.

Chap. XIII, on the Theoretical Considerations of Design, is also new and was kindly contributed by Mr. W. W. Crehore, Assoc. M. Am. Soc. C. E. In this chapter will be found some very useful tables on dimensions of stringers and safe loads on posts, as well as a table giving the sizes of steel I beams equivalent under the same conditions to different sizes of wooden stringers.

In Part II, under the head of Standard Trestle Plans, Plates XXXIX to XLV are new. Attention is particularly called to the Two Medicine Bridge and the Mountain Creek Bridge, two very high structures. In the descriptive matter of the latter the details of cost are given.

Plate XLV gives the plans of a light trestle built on a very sharp curve and a very steep hillside.

The index has been revised and is believed to be complete and thoroughly cross-referenced.







## PREFACE TO FIRST EDITION.

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IN collecting the data for this work, a circular letter was sent to each chief engineer throughout the country of whom the author could obtain the address. These letters met with many hearty responses, and resulted in the collection of a very complete set of plans of the standard trestles in use on the different roads.

Tables embodying the details of all the different parts were compiled, and the deductions made from these. Every effort has been put forth to make the work as valuable and complete as possible, without making it too bulky. Neither time, pains, nor expense have been spared in its preparation.

As far as possible credit has been given in the body of the work to the originators of any special design; but as oversights may have unintentionally occurred, a list of those engineers who have aided the author is appended.

It is the earnest hope of the author that the results of his labors will prove worthy of the courtesy and aid so generously extended to him by the members of the profession at large, many of whom were perfect strangers.

### LIST OF THE ENGINEERS TO WHOM THE AUTHOR IS INDEBTED FOR AID IN PREPARING THIS WORK.

Alger, Chas. E.	Fitch, A. B.	Nelson, J. P.
Ansart, Felix.	Fratt, F. W.	Nettleton, G. A.
Bates, Onward.	Gore, Th.	Nicholson, G. B.
Becker, M. J.	Greenleaf, J. L.	Patton, E. B.
Berg, Walter G.	Griggs, J.	Perris, Fred. T.
Bissel, F. E.	Hawks, J. D.	Reed, A. L.
Blunt, Jno. E.	Howe, W. B. W., Jr.	Rich, W. W.
Boiton, C. M.	Hoyt, Wm. E.	Riffle, F.
Booker, B. F.	Kennedy, H. A.	Rowe, S. M.
Bowen, A. L.	Kriegshaber, V. H.	Sage, I. Y.
Briggs, R. E.	Levings, Chas.	Schenck, A. A.
Buxton, C.	Lum, D. W.	Smith, P. A.
Canfield, E.	Martin, M. A.	Spofford, Parker.
De Caradene, A.	McVean, J. J.	Swift, A. J.
Curtis, F. S.	Miller, N. D.	Weeks, I. S. P.
Davery, R. A.	Mills, A. L.	Wheeler, D. M.
Dick, H. B.	Molesworth, A. N.	White, H. F.
Dorsey, W. H., Jr.	Monroe, J. A.	Whittemore, D. J.
Elliott, R. H.	Montfort, R.	Woods, J. E.
Fisher, J. B.	Morton, T. L.	Zook, F. K.







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## TECHNICAL TERMS, NAMES, AND DEFINITIONS.

THE following list gives the names and their synonyms of some of the more important parts of wooden trestles. In connection with this list see Figs. 1 and 2, to which the numbers opposite the names refer.

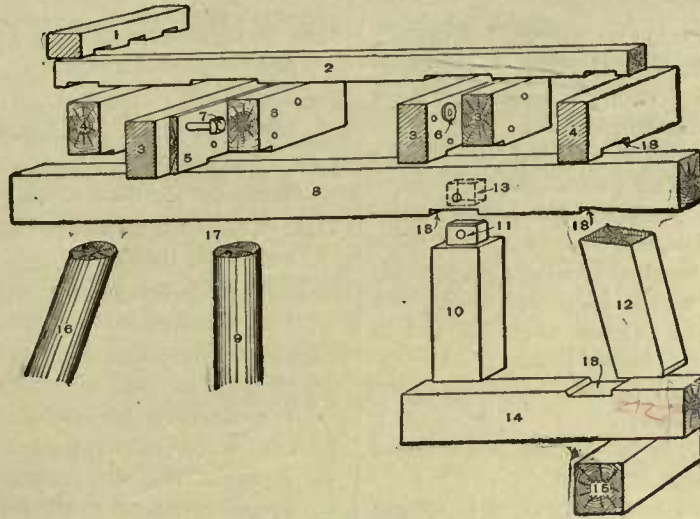


FIG. 1.

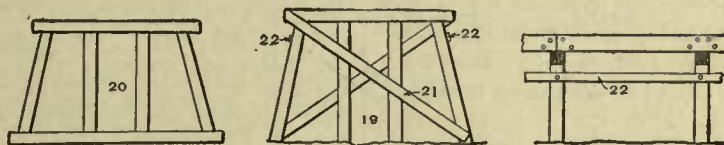


FIG. 2.

- |  |  |
|--|--|
| <p><b>Bent, Framed,</b> 20.<br/> <b>Pile,</b> 19.<br/>           Cluster.</p> <p><b>Bent Brace,</b> see Sway-brace.</p> <p><b>Block,</b> see Sub-sill.</p> <p><b>Bolster,</b> see Corbel.</p> <p><b>Cap,</b> 3.</p> <p><b>Chord,</b> see Stringer.</p> <p><b>Corbel,</b> Bolster.</p> <p><b>Cross-tie,</b> 2.</p> <p><b>Cut-off,</b> 17.</p> <p><b>Dapping,</b> see Notching.</p> <p><b>Fender,</b> Guard-rail, 1.</p> <p><b>Gaining,</b> see Notching.</p> <p><b>Girt,</b> see Longitudinal Brace.</p> <p><b>Girder,</b> see Stringer.</p> <p><b>Guard-rail,</b> Fender, Ribbands, 1.</p> <p><b>Jack-stringer,</b> see Stringer.</p> <p><b>Longitudinal Brace,</b> Girt, Waling-strip, 22.</p> <p><b>Mortise,</b> 13.</p> <p><b>Mud-sill,</b> see Sub-sill.</p> <p><b>Notching,</b> Gaining, Dapping, 18.</p> | <p><b>Outside Stringer,</b> see Stringer.</p> <p><b>Packing-block,</b> Packing piece, 5.</p> <p><b>Packing-bolt,</b> 7.</p> <p><b>Packing-piece,</b> see Packing-block.</p> <p><b>Packing-washers,</b> see Separator.</p> <p><b>Piles,</b> Batter, Inclined Brace, 16.<br/>           Vertical, Plumb, Upright, 9.</p> <p><b>Posts,</b> Batter, Inclined, 12.<br/>           Vertical, Plumb, Upright, 10</p> <p><b>Ribbands,</b> see Guard-rail.</p> <p><b>Separator,</b> Packing-washer, Thimble Spool, 6.</p> <p><b>Sill,</b> 14.</p> <p><b>Spool,</b> see Separator.</p> <p><b>Stringer,</b> Chord, Girder.<br/>           Track, 3.<br/>           Outside, Jack, 4.</p> <p><b>Sub-sill,</b> Mud-sill, Blocks, 15.</p> <p><b>Sway-brace,</b> Bent Bracc, 21.</p> <p><b>Tenon,</b> 11.</p> <p><b>Thimble,</b> see Separator.</p> <p><b>Track-stringer,</b> see Stringer.</p> <p><b>Waling-strip,</b> see Longitudinal Brace.</p> |
|--|--|



## DEFINITIONS.

The following definitions relative to Trestles have been adopted as standard by the American Railway Engineering and Maintenance of Way Association on the recommendation of the Committee on Wooden Bridges and Trestles (Bulletin No. 79, September, 1906, and Bulletin No. 107, January, 1909).

## WOODEN BRIDGES AND TRESTLES.

- WOODEN TRESTLE.**—A structure composed of upright members, supporting simple horizontal members or beams, the whole forming a support for loads applied to the horizontal members.
- FRAME TRESTLE.**—A structure in which the upright members or supports are framed timbers.
- PILE TRESTLE.**—A structure in which the upright members or supports are piles.
- BENT.**—The group of members forming a single vertical support of a trestle, designated as pile bent where the principal members are piles, and as framed bent where of framed timbers.
- POSTS.**—The vertical and battered members of the bent of a framed trestle.
- PILES.**—Timbers driven in the ground, and intended generally to support a structure.
- BATTER.**—The deviation from the vertical in upright members of a bent.
- CAP.**—The horizontal member upon the top of piles or posts, connecting them in the form of a bent.
- SILL.**—The lower horizontal member of a framed bent.
- SUB-SILLS.**—Timbers bedded in the ground to support framed bents.
- INTERMEDIATE SILL.**—A horizontal member in the plane of the bent between the cap and sill, to which the posts are framed.
- SWAY BRACES.**—Members bolted or spiked to the bent and extending diagonally across its face.
- LONGITUDINAL STRUTS OR GIRTS.**—Stiff members running horizontally, or nearly so, from bent to bent.
- LONGITUDINAL X BRACES.**—Members extending diagonally from bent to bent in vertical or battered planes.
- SASH BRACES.**—Horizontal members secured to the posts or piles of a bent.
- STRINGERS.**—The longitudinal members extending from bent to bent and supporting the ties.
- JACK STRINGERS.**—A single line of stringers placed outside of the main stringers.
- TIES.**—Transverse timbers resting on the stringers and supporting the rails.
- GUARD RAILS.**—Longitudinal members, either iron or wood, secured on top of ties.
- PACKING BLOCKS.**—Small members, usually wood, used to secure the parts of a composite member in their proper relative positions.
- PACKING SPOOLS OR SEPARATORS.**—Small castings used in connection with packing bolts to secure the several parts of a composite member in their proper relative position.
- DRIFT BOLT.**—A piece of round or square iron of specified length, with or without head or point, driven as a spike.
- DOWEL.**—An iron or wood pin, extending into, but not through, two members of the structure to connect them.
- SHIM.**—A small piece of wood or metal placed between two members of a structure to bring them to a desired relative position.
- FISH-PLATE.**—A short piece lapping a joint, secured to the side of several members which are butt-jointed.
- BULKHEAD.**—Timber placed against the side of an end bent for the purpose of retaining the embankment.

## PILES AND PILE DRIVING.

- PILE.**—A member usually driven or jettied into the ground and deriving its support from the underlying strata, and by the friction of the ground on its surface. The usual functions of a pile are: (a) To carry a superimposed load; (b) To compact the surrounding ground; (c) To form a wall to exclude water and soft material, or to resist the lateral pressure of adjacent ground.
- HEAD OF PILE.**—The upper end of a pile.
- FOOT OF PILE.**—The lower end of a pile.
- BUTT OF PILE.**—The larger end of a pile.
- TIP OF PILE.**—The smaller end of a pile.
- BEARING PILE.**—One used to carry a superimposed load.
- SCREW PILE.**—One having a broad-bladed screw attached to its foot to provide a larger bearing area.



- DISC PILE.**—One having a disc attached to its foot to provide a larger bearing area.
- SPUR PILE.**—One driven at an inclination to resist the resultant of vertical and horizontal forces.
- SHEET PILES.**—Piles driven in close contact in order to provide a tight wall, to prevent leakage of water and soft materials, or driven to resist the lateral pressure of adjacent ground.
- PILE-DRIVER.**—A machine for driving piles.
- HAMMER.**—A weight used to deliver blows to a pile to secure its penetration.
- DROP-HAMMER.**—One which is raised by means of a rope and then allowed to drop.
- STEAM-HAMMER.**—One which is automatically raised and dropped a comparatively short distance by the action of a steam cylinder and piston supported in a frame which follows the pile.
- LEADS OR LEADERS.**—The upright parallel members of a pile-driver which support the sheaves used to hoist the hammer and piles, and which guide the hammer in its movement.
- CAP, HOOD, BONNET.**—A metal block used to protect the head of a pile and to hold it in the leads during driving.
- RING.**—A metal hoop used to bind the head of a pile during driving.
- SHOE.**—A metal protection for the point or foot of a pile.
- FOLLOWER.**—A member interposed between the hammer and a pile to transmit the blows to the latter when below the foot of the leads.

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## ABBREVIATIONS.

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- A. & P. R. R.;** Atlantic & Pacific Railroad.
- B., C. R. & N. R. R.;** Burlington, Cedar Rapids & Northern Railroad.
- B. & M. R. R. R. in Neb.;** Burlington & Missouri River Railroad in Nebraska.
- C. & A. Ry.;** Chicago & Atlantic Railway.
- C., B. & Q. R. R.;** Chicago, Burlington & Quincy Railroad.
- C., C. & C. R. R.;** Charleston, Cincinnati & Chicago Railroad.
- C., M. & St. P. Ry.;** Chicago, Milwaukee & St. Paul Railway.
- C., N. O. & T. P. Ry.;** Cincinnati, New Orleans & Texas Pacific Railway.
- C. & S. Ry.;** Charleston & Savannah Railway.
- C. & W. M. Ry.;** Chicago & West Michigan Railway.
- D., T. & Ft. W. R. R.;** Denver, Texas & Fort Worth Railroad.
- G., C. & S. F. R. R.;** Gulf, Colorado & Santa Fe Railroad.
- K. C., Ft. S. & M. R. R.;** Kansas City, Fort Scott & Memphis Railroad.
- K., G. B. & W. R. R.;** Kewaunee, Green Bay & Western Railroad.
- L. & N. R. R.;** Louisville & Nashville Railroad.
- M., K. & T. Ry.;** Missouri, Kansas & Texas Railway.
- N. Y., P. & B. R. R.;** New York, Providence & Boston Railroad.
- N. Y., W. S. & B. R. R.;** New York, West Shore & Buffalo Railroad.
- R. & D. R. R.;** Richmond & Danville Railroad.
- St. P., M. & M. R. R.;** St. Paul, Minneapolis & Manitoba Railroad.
- S. F. & N. P. R. R.;** San Francisco & North Pacific Railroad.
- S., F. & W. Ry.;** Savannah, Florida & Western Railway.
- T., St. L. & K. C. R. R.;** Toledo, St. Louis & Kansas City Railroad.







# A TREATISE ON WOODEN TRESTLE BRIDGES.

## PART I.

### CHAPTER I.

#### INTRODUCTION.

THE amount of Wooden Trestling in this country is very large, but few probably realizing its extent unless they have thoroughly studied the subject. At the present time there are about 2400 miles of single-track railway-trestle in the United States,\* of which we can consider about one quarter as only temporary, to be replaced by embankment. "Of the remaining 1800 miles, at least 800 miles will be maintained in wood." This 2400 miles is composed of about 150,000 separate structures having about 730,000 spans or more. Table I gives the general data as to the amount of bridges and trestles, and the average rate per mile of track on some of the more important systems.

TABLE I.

Amount of Bridging and Trestling in Different Parts of the United States, and the Rate per Mile of Track.

(COOPER'S TABLE NO. 3.)

System of Railroad or State.	Miles of Road.	Total Length of Bridges and Trestles in feet.	Lin. ft. of Bridges and Trestles per Mile of Road.
New York Central and West Shore Railroads, . . . . .	2,894	364,722	126
New York, Lake Erie & Western Railroad, . . . . .	1,514	95,509	63
Other roads in New York, . . . . .	3,586	445,900	130
Roads in Pennsylvania, . . . . .	4,352	336,957	77
"    "    New England, . . . . .	2,199	176,700	80
Wabash System, . . . . .	1,636	160,025	98
Missouri Pacific System, . . . . .	4,707	566,953	120
Chicago, Milwaukee & St. Paul Railroad, . . . . .	5,727	614,736	107
St. Louis & San Francisco Railway, . . . . .	1,441	130,075	90
Denver & Rio Grande Railroad, . . . . .	1,458	102,195	70
Union Pacific Railroad, . . . . .	4,754	276,032	58
Louisville & Nashville Railroad, . . . . .	2,495	322,679	123
Queen and Crescent System, . . . . .	1,139	299,222	231 †
Roads in Illinois, . . . . .	8,539	707,535	83
"    "    Michigan, . . . . .	4,151	249,345	60
"    "    Iowa, . . . . .	7,778	1,049,386	135
Central Railroad and Banking Co. of Georgia, . . . . .	1,487	173,975	117
Totals, . . . . .	59,857	6,071,946	101

\*In the first part of this chapter a considerable portion of the matter relating to statistics was taken from a paper by Theodore Cooper on American Railroad Bridges, Trans. Amer. Soc. C. E., July 1889.

T. C. Clark in *Scribner's Magazine* for June 1888 gives the length of wooden trestling in the United States at about 2127 miles.

† Includes the crossing of Lake Pontchartrain, a trestle 22 miles long.



"It shows that the relative amount of bridges and trestles varies in different localities from 58 feet per mile to 231 feet per mile. This last, however, is excessive from including the crossing of Lake Pontchartrain, near New Orleans, on a trestle 22 miles long. Omitting this, we would get only 162 feet per mile as the maximum."

"These variations are not entirely due to geographical location, as might appear at first thought. They are also affected by principles governing the original location of each road or division of a system. The alignment and grade may have been sacrificed to the avoidance of bridges and trestles, or the contrary."

"From the large mileage covered by our table, we can rely with considerable confidence upon our average. Taking, therefore, 100 feet per mile as our basis of estimate, we have for the 160,000 miles of railroad in the United States, 16,000,000 feet or 3030 miles of bridges and trestles. Table II gives the distribution of the bridges upon 26,000 miles of railroad into spans of different length."

TABLE II.

Distribution of Bridges and Trestles in Spans of Different Lengths, in Totals of Lineal Feet.

(COOPER'S TABLE NO. 4.)

Miles of Road.	Trestles and Spans under 20 feet.	Spans 20 to 50 feet.	Spans 50 to 100 feet.	Spans 100 to 150 feet.	Spans 150 to 200 feet.	Spans 200 to 300 feet.	Spans 300 to 400 feet.	Spans 400 to 500 feet.	Spans over 500 feet.	Total.	Average per Mile of Road.
26,288	2,299,758	85,181	94,165	149,121	80,551	29,542	5,677	1,211	1,040	2,746,246	104.7

"Using this as a basis of estimate, the 3030 miles of trestles and bridges in the United States should be distributed as follows:

Trestles and Spans under 20 feet, . . . . .	Miles.	No of Spans.
Spans 20 to 50 feet, . . . . .	2,424	727,200
" 50 to 100 " . . . . .	121	18,150
" 100 to 150 feet, . . . . .	130	9,100
" 150 to 200 " . . . . .	190	8,000
" over 200 feet . . . . .	109	3,300
	56	1,150
	<u>3,030</u>	<u>766,900</u>

The above includes all bridges of either wood or iron."

In order that we may more fully comprehend the meaning of these figures, let us find the money value. Taking the amount of trestling at an even 2400 miles = 12,672,000 lineal feet. Now about \$6 per lineal foot is a fair average for the cost, with timber at \$30 per M. B. M., erected. At this rate the trestling represents an expenditure of \$76,032,000. With an average life of eight years, which is perhaps a little too long taking everything into consideration, the annual expenditure for repairs and renewals alone amount to \$9,504,000, necessitating the use of 316,800,000 feet (B. M.) of timber. Capitalizing this annual expenditure at 4 per cent, we find it represents \$237,600,000. Now, if, as Cooper estimates, two thirds of the total amount of trestling is capable of being replaced, we will be justified in spending \$168,400,000, with interest at 4 per cent, in accomplishing this end. As one third, or 800 miles, will, of necessity, remain as it is, there will be a continual annual expenditure of \$3,168,000 for repairs and renewals, requiring 105,600,000 feet (B. M.) of timber, and representing a capitalized value of \$79,200,000 at 4 per cent. These figures



do not take into account any increase in the milcage from the building of new roads. From the above we can see what an enormous annual drain there is upon our forests merely for the maintenance of what has been considered one of the smaller and less important of railway properties, and these figures, large as they are, are rather too low than otherwise.

Converting these capitalized values into earthwork, we find that we could build the following number of miles of embankment, twenty feet high, complete, ready for the rails

TABLE II (a).

Amount of Embankment, 20 Feet high, which can be built for the Capitalized Value of the Annual cost of Repairs for the 1600 miles of Replaceable Trestle.

Ties, . . . . . 2640 per mile, @ 45 cents each.  
Ballast, . . . . . 2738 cubic yards per mile, @ 50 cents per cubic yard.

Cost of earth per cubic yard, . . . . .	16 c.	18 c.	20 c.	22 c.
Miles, . . . . .	5,262	4,722	4,283	3,918

But of this replaceable two thirds or 1600 miles, only about 600 miles is capable of being replaced by embankment. Now taking the cost of replacing this 600 miles in, say, 20-foot earth embankment, we would have the amount left as indicated in Table III. for replacing the remaining 1000 miles with other permanent structures.

TABLE III.

Showing Cost of 600 Miles of 20-foot Embankment Complete, and Balances.

Capitalized value 4%, . . . . .	\$158,400,000.			
Cost of earth per cubic yard, . . . . .	16 c.	18 c.	20 c.	22 c.
Cost of 600 miles of road complete except rails, . . . . .	\$18,058,800	\$20,124,000	\$22,189,800	\$24,255,600
Balance, applicable to replacing 1000 miles of trestles by other structures such as iron or masonry bridges, etc., . . . . .	\$140,341,200	\$138,276,000	\$136,210,200	\$134,144,400

NOTE.—In this table the same data have been used as in Table II. (a), viz.:

Cost of earth per cubic yard, . . . . .	16 c.	18 c.	20 c.	22 c.
Ties per mile, . . . . .	\$1,188	\$1,188	\$1,188	\$1,188
Ballast, 1' x 14', per mile, . . . . .	1,369	1,369	1,369	1,369
Embankment, 14' x 20', (172, 128 cubic yards), per mile, . . . . .	27,541	30,983	34,426	37,869
Total cost per mile of road, . . . . .	\$30,098	\$33,540	\$36,983	\$40,426

There are many other reasons, in addition to the above, which would justify a much larger expenditure than this to secure the replacement of the trestles.

Notwithstanding the great importance of the subject, and the fact that a large part of



the expense of building many new roads is chargeable to these structures, no effort of any moment has been made to collect and publish together any considerable amount of data relating to it; the most extensive and important paper so far published on trestling probably being that by Prof. Jameson in *The Engineering and Railroad Journal* for the latter part of 1889 and early part of 1890.

A *good* wooden structure is preferable to the *cheap* iron ones that some roads seem determined to erect. They have proven the salvation of many a new enterprise, when, had it been absolutely necessary to resort to the use of stone or iron, or to make enormous fills, the project must have been abandoned on account of the lack of capital wherewith to erect these costly works. Wooden trestles for the most part are, of course, built with the idea of their being only temporary expedients, to be replaced in time, as rapidly as the finances of the company may permit, by something more permanent. However, a well-built trestle of good material will last a long time, depending to a certain extent on climatic conditions. If properly designed and cared for they form an efficient portion of the roadway. They require constant watching; and the moment any sign of weakness or injurious amount of decay appears it should be remedied immediately. The inspection should be regular and frequent, and placed in careful, trustworthy, and competent hands. It is the practice on some roads, and a very pernicious one which cannot be too strongly condemned, to allow these structures to deteriorate until they are just about ready to fall every time a train passes over them, before the management will attempt to make any repairs, thinking perhaps that they are accomplishing wonders in the way of economy. In consequence of this way of conducting affairs there is scarcely a week that passes but we read of one or more trestle accidents.

\* The great extent to which timber trestling has been adopted in this country is one of the principal factors in the economy of construction and rapidity of completion which have been characteristic of American railway work. The use of such temporary structures has been justified by the necessity of keeping the first cost of long lines as low as possible, and by the importance of putting the companies in a position to earn money by carrying freight as soon as possible. When once a railway is open, attention should be given to the work of gradually substituting solid banks (with culverts or metal bridges over streams) for timber trestles, as the banks will be permanent and will require practically no repair or attention—under ordinary circumstances. This filling can almost invariably be done much more quickly and cheaply by work trains after the completion of the road than by the ordinary plant used while the line is under construction.

The importance of this system of rapid first construction with temporary works and subsequent replacement of such works by permanent works has been shown very strongly by the experience of the Canadian Pacific Railway. This company made a contract with the Canadian Government on October 21, 1880, to complete the line to the Pacific coast in ten years, and the work was pushed with such energy that trains passed between the St. Lawrence River and the Pacific Ocean in November, 1885. According to a statement made by Mr. P. Alex. Peterson, Chief Engineer, it was decided, in carrying out the construction

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\* *Engineering News*, Nov. 28, 1895.



through an almost inaccessible wilderness, to construct a large amount of temporary work, which would carry the traffic safely for some years, and would subsequently be of material use in the economical construction of the permanent works. This method of carrying out the work enabled the company to open the line five years earlier than it could otherwise have done; it saved a large amount of money in first cost and interest, it will effect a large saving in the ultimate cost, and it enabled the company to earn \$20,000,000 in the year fixed for the completion of the contract.

The height at which it becomes more economical to replace embankment by trestling varies in different locations, depending upon the cost of lumber, labor, and the facilities for obtaining, and the nature of, the material wherewith to make the fill (see Table IV). There are many places where an embankment would be altogether out of the question, such as across water-ways, swamps with deep, soft mud, etc.; and the only resort then is either to wooden or iron structures.\*

TABLE IV.

Showing Approximate Relative Cost of Embankment and Trestle in sections of 100 feet, excluding Rails, Ties, and Ballast on former, and Rails, Guard-rails, and Ties on latter.

Height from Surface of Ground to Grade (Sub-grade) in Feet.	Embankment per Cubic Yard in Cents. Road-bed 14 feet wide, Slope 1½ to 1.				TRESTLE. Timber erected (including iron) per M., B. M.					
					Pile-trestle—piling 35 c. per lin. ft. in place; average penetration 10 ft.			Framed Trestles.		
	16	18	20	22	\$30	\$35	\$40	\$30	\$35	\$40
5	\$64	\$72	\$80	\$88	\$376	\$407	\$439	\$283	\$330	\$378
10	113	127	141	155	441	476	512	385	449	514
15	325	366	406	447	508	544	580	464	541	618
20	521	587	652	718	576	613	651	541	631	721
25	764	859	955	1050	748	803	858	796	928	1060
30	1049	1180	1312	1443	816	872	928	872	1017	1163
35	1380	1552	1725	1897	990	1065	1140	1058	1234	1410
40	1754	1974	2193	2412	1057	1132	1218	1133	1322	1510
45	2174	2446	2717	2989				1202	1404	1606

If it is necessary to place a masonry structure through a portion of the embankment, then the height at which it will be more economical to build a trestle will be considerably lowered.

While the cost of an embankment increases in a vastly greater ratio than its height, the cost of trestling does not increase nearly as rapidly as its height, especially when under fifty feet. This fact is very clearly shown in Table V.

A few engineers have advocated the use of mathematics in the designing of trestles, but as wood is an article whose strength and properties vary rather widely with every piece, no dependence whatever can be placed on the results, and such practice is to be condemned. It is far wiser to merely follow one's judgment and the results of the experience of others as to the proper proportioning of the various parts, gained from experience in dealing with the wood, than to follow any special set of mathematical formulas.†

\* Since this was written the use of concrete trestles has come into vogue, which subject will be treated in a later chapter.

† Of late years our knowledge of the strength of timber has been greatly increased by numerous tests on full-sized pieces, and hence mathematical formulas for designing are of greater use.



TABLE V.

Cost of Pile and Framed Trestles complete, including Floor Systems, for Different Heights, in Sections of 100 feet.

Height.	Pile.			Framed.		
	\$30	\$35	\$40	\$30	\$35	\$40
5	\$546	\$605	\$665	\$453	\$528	\$604
10	611	674	738	555	647	740
15	678	742	806	634	739	844
20	746	811	877	711	829	947
25	918	1001	1084	966	1126	1286
30	986	1070	1154	1042	1215	1389
35	1160	1263	1366	1228	1432	1636
40	1227	1332	1444	1303	1520	1736
45				1372	1602	1832

It will probably be impossible to ever thoroughly standardize the plan of trestle design, as there are about as many styles as designers.\* There also appears to be a tendency to draw up the specifications relating to this subject in a loose and slipshod manner. This is to be much regretted; as great care and attention in proportion to the importance of the subject should be devoted to this part of the railway's property as to any other.†

All structures of this kind, especially those of any extent whatever, should be protected by a re-railing device of some kind, though there are still few that are so protected. Not only should this be the case, but they should also have some kind of fire protection and convenient means for the extinguishment of fires.

There may be said to be two general classes of wooden trestle bridges, namely, those in which the bents consist exclusively of piles and a cap, and hence are known as PILE-TRESTLES, and those in which the timbers composing the bents are squared, and framed together, and known as FRAMED TRESTLES. Pile-trestles are seldom used for heights above thirty feet, and it is only occasionally that they are built as high as this. Framed trestles may be of almost any height, though requiring special designs for those above thirty to forty feet. For trestles above forty feet high the cluster-bent form seems to be quite a favorite class of design.

\* Efforts have been made by several railroad associations in late years to standardize trestle design and construction, but on account of the widely varying local conditions it has been found impracticable to do so up to the present time.

† Though the efforts of the Association of Railway Superintendents of Bridges and Buildings, now the American Railway Bridge and Building Association, in the past fifteen years and the American Railway Engineering and Maintenance of Way Association during the past ten years, much good and a great improvement has been accomplished both in the design and specifications for wooden trestle bridges.



## CHAPTER II.

### PILE-BENTS.

PILE-BENTS are generally used where the ground is quite soft, and may either occasionally or constantly be covered with water; also where the distance from the rails to the surface of the ground is not very great. There is one grave objection to high pile-trestles, and that is that the top end of the tree, and hence the poorest timber, is in the ground, and is liable to very rapid destruction by the elements at the ground-line. In order to retard this decay as much as possible, it is recommended in the Report of the Ohio Railway Commissioners for 1884 that the piles be painted for a short distance above and below the ground-line with hot tar. It has also been said that a coat of whitewash is beneficial where there is no water other than rain to wash it off.

The timber used for piles varies with the location, depending very largely upon the kind growing in the surrounding country. Among the varieties employed are the following, to be preferred in the order named, the first being the most durable:

Red Cedar.	White Pine.	Post Oak.
Red Cypress.	Redwood.	Red Oak.
Pitch Pine.	Elm.	Black Oak.
Yellow Pine (close-grained, long leaf).	Spruce.	Hemlock.
	White Oak.	Tamarac.
Order not known:		
Red Ash.	Beech.	Red or Norway Pine.
White Ash.	Scrub Oak.	Norway Spruce.
White Cedar.	Buttonwood.	Canadian Spruce.
Chestnut.		

They should be of straight, sound, live heart timber, perfectly free from windshakes, wanes; large, loose, black, or decayed knots; cracks, worm-holes, and all descriptions of decay; and should be stripped of bark. Some engineers prefer the piles to be hewed or sawed square. If piles are squared, they should be hewed rather than sawed, and be as free as possible from axe-marks. Squared piles ought to be at least 12 inches across each face, and not show more than 2 inches of sap at the corners.

Round piles are, as a rule, from 12 inches to 15 inches across the butt after being cut off, and when they are wider than the cap, the portion which projects on either side should be adzed off to an angle of at least  $45^{\circ}$  (Fig. 7).

In a paper read before the Iowa Society of Civil Engineers and Surveyors (see *Engineering Record*, June 24, 1893, p. 58) J. C. Sheeley states that red-cedar piles have an average life of 27 years where conditions are not unfavorable, and have been known to last 50 years without decay beyond usage. White-oak piles are said to last 13 to 18 years. For trestles white or burr oak is the best. Cedar at first would seem to be economy, but as oak will last as long as the overhead work it would seldom be economy to use cedar. Cedar will not do in water on account of being easily broken by ice. Where the strata are very hard, cedar will not penetrate, and hence becomes useless, and oak would be recommended as a substitute. In the



Proceedings of the American International Association of Railroad Superintendents of Bridges and Buildings for 1893 and 1894 the experience of a number of members as to the life of various pile-timbers in their respective districts is given as follows: According to Mr. W. A. McGonagle of the Duluth and Iron Range R. R., Norway-pine piling has an extreme life of about 8 years, and in many cases but 6 years, while they have white pine that has been in use 11 years and is still good. Mr. A. C. Olney of the Savannah, Florida & Western Ry.: Altamaha River cypress lasts 12 to 14 years, Georgia long-leaf yellow pine 6 to 8 years. Joseph M. Staten, Chesapeake & Ohio R. R.: Virginia bull pine is perfectly worthless for piles, but lasts well for stringers, caps, etc.; white oak lasts from 7 to 13 years. G. M. Reid, Lake Shore & Michigan Southern R. R.: Rock-tamarack piles have lasted in service 10 years; there are white-oak piles on this road that have been in use 16 years, and some swamp-oak (white oak) piles for 22 years. Mr. Reid's experience is that the life of a pile in sandy loam is much shorter than in cold or swamp lands, and that the more fertilizer used in enriching sandy loam the quicker it burns the pile. J. E. Wallace, Wabash R. R., says that white cypress is of no use at all for piles, but expects red cypress to last 14 years. W. M. Noon says the Duluth, South Shore & Atlantic R. R. has some cedar piles that are sound after having been driven 17 years, while white Norway pine lasts from 5 to 6 years. G. W. Hinman of L. & N. R. R. says: "We never allow our piles made of cedar driven in by heavy blows; it injures or cripples them."

Table Va\* gives some further data as to the life of piles of different kinds of timber under different conditions from actual experience, as given in a committee report presented to the 1899 convention of the Association of Railway Superintendents of Bridges and Buildings.

In addition to the table (Va) the following information was given by various members: J. B. Snow of the Boston and Maine Railroad gives as his experience that "white and yellow bark oaks for piles have about the same durability as chestnut. Red oak about the same as tamarack or perhaps a little less. Much depends on the character of the soil, the water, and the exposure to the sun. If decaying matter in considerable amount is carried by the soil or water in which piles are driven, at least 25 per cent must be taken from the figures given." S. F. Patterson of the Boston and Maine Railroad says piles (kind not stated) thirty years old in the Bay bridge, over salt water, on the Portsmouth Railroad, were still good, and attributes it to the caps covering the entire head. R. W. Hutchings of the Southern Railway says: "Oak piles driven fourteen years ago are now decaying very fast at about one foot above ground level. Timber was cut in the fall on the ridges on this line in Mississippi. In 1892 I drove 100 round post oak piles in seepy river slough, in Fayette County, Alabama, that are now (1899) in a perfect state of preservation, and in the early part of the 1893 I drove twenty of the same piles in Clay County, Mississippi, and they are ready to come out (1899). This difference is caused by mineral substances." T. H. Kelleher, New Orleans and North Eastern Railroad: "Long-leaf yellow pine piles, when creosoted, last 25 years when driven in salt water." W. E. Smith, Chicago, Milwaukee, and St. Paul Railroad: "White cedar piles, 12 inches to 14 inches diameter at

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\* *Engineering News*, October 26, 1899. Proceedings Association of Railway Superintendents of Bridges and Buildings, 1899.



TABLE V a.

Showing Life of Different Kinds of Piles Employed in Railway Bridges and Trestles in United States.

Kind of Timber.	Average Life in Years When Driven in			State.	Railway Company Furnishing Report.
	Water.		Dry Land.		
	Salt.	Fresh.			
Cedar, white.....			Over 20	Wisconsin.....	Chicago, Milwaukee & St. Paul.
“.....		28	16 to 20	“.....	Chicago & Northwestern.
“.....			20	“.....	“.....
“.....		20	20	Wyoming.....	Union Pacific.
Chestnut.....	40	20	15 to 18	Me., N. H., Vt., Mass..	Boston & Maine.
“.....	15	15	12	Rhode Island.....	New York, New Haven & Hartford.
Cypress.....			7	Illinois.....	St. Louis, Peoria & Northern.
Oak.....	35 to 40	8 to 10	About 12	Massachusetts.....	Boston & Maine.
“.....		20	14	New Hampshire.....	“.....
“.....	9	9	8	Rhode Island.....	New York, New Haven & Hartford.
“ white.....		8 (wtr line)	10	Ohio, Ind., Ill.....	Toledo, St. Louis & Kansas City.
“.....		15 to 30	8 to 12	Illinois.....	Chicago & Eastern Illinois.
“.....			8	“.....	St. Louis, Peoria & Northern.
“.....			5 to 20	S. Dak., Minn.....	Chicago & Northwestern.
“ white (best quality).....			20	Wisconsin.....	Chicago, Milwaukee & St. Paul.
“.....		25	10 to 14	“.....	Chicago & Northwestern.
“ (northern grown).....		20	15	“.....	“.....
“ (southern grown).....		10	8	“.....	“.....
“.....		20	12	Wyoming.....	Union Pacific.
Pine, long-leaf yellow.....	10	10	10	Miss., La.....	New Orleans & Northeastern.
“ Norway.....			6	Wisconsin.....	Chicago, Milwaukee & St. Paul.
“.....		7	6	Minnesota.....	Duluth & Iron Range.
“ white.....		8	7	“.....	“.....
“.....		15	8	Wyoming.....	Union Pacific.
Spruce.....			7 to 8	Me., N. H., Vt., Mass..	Boston & Maine.
“.....	8 to 10	4 to 6	4 to 6	Massachusetts.....	“.....
“ red.....		10 to 15	8 to 10	Colorado.....	Denver & Rio Grande.
“.....			7	“.....	Colorado & Southern.
Tamarack.....		18	10 to 12	Me., N. H., Vt., Mass..	Boston & Maine.
“.....			8	Wisconsin.....	Chicago, Milwaukee & St. Paul.
“.....			8	Minnesota.....	Duluth & Iron Range.

ground, will easily wear out two timber floors, and will last longer than white oak. The very best white oak piles, 12 inches to 14 inches diameter at ground, will wear out two timber floors. Neither tamarack nor Norway pine will last the life of one timber floor.” A. H. King, Union Pacific Railway: “In some cases we dig down around piling and coat them with heavily with coal-tar, after removing all rotted timber, but this is not common practice.” C. S. Thompson, Denver and Rio Grande Railroad: “We use red spruce piles entirely. We peel them and char them before driving. There is a great variety in the life of what appear to be similar piles, and also there is a great variety in the preservative power of the soil within short distances, so piles in one bridge may last ten years and in another bridge not half a mile away they may last fifteen years under what appears to be similar circumstances.” In the report of a committee\* rendered in 1908 the following data are given and remarks made: “The material used is white or burr oak on twelve roads; white cedar on seven roads; creosoted pine on three roads; red cedar on two roads.”

\* Name changed to American Railway Bridge and Building Association, Committee on Pile and Trestle Bridges.



“The average life is as follows:

“White or burr oak, average of ten roads, ten years.

“White cedar, average of six roads, seventeen years.

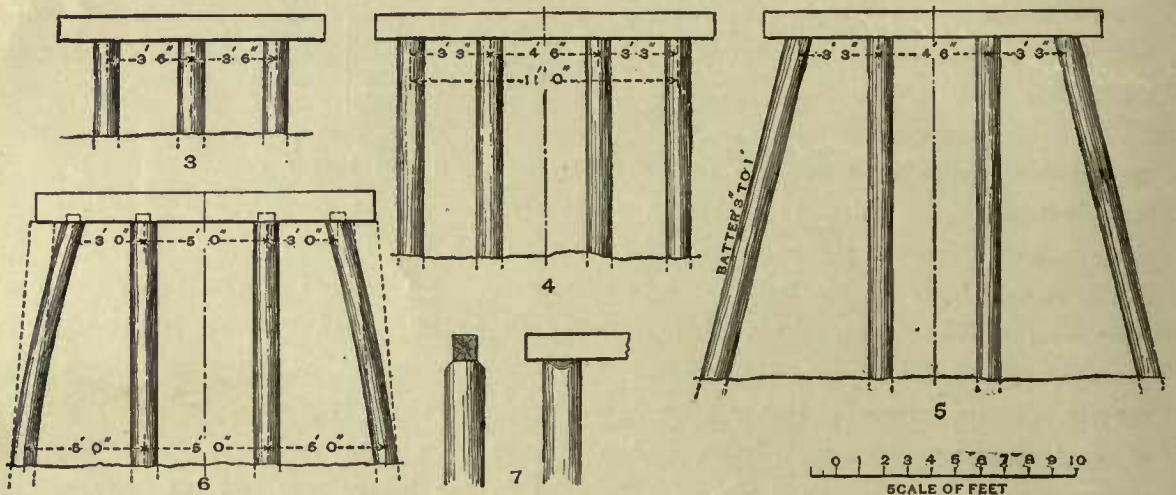
“Red cedar, average of two roads, twelve years.

“Treated pine, average of two roads, fourteen years.”

“For piling the better species are becoming too scarce to supply the demand, and as they are of extremely slow growth, use will have to be made of the cheaper grades treated. The government forestry bureau states that it takes 190 years to grow a white cedar large enough for a telegraph pole, and the northern white and burr oak are of very slow growth, so that when forestry is relied on to meet the demand, the quicker growing trees will have to be planted.”

The arrangement of the piling varies considerably, almost every constructor having his own plan and ideas. The nature and amount of the traffic should be carefully considered. For bents up to five feet in height, where the traffic is not very heavy, but three piles driven vertically are required. One should be placed on the centre-line, and one on either side from 3 feet 6 inches to 5 feet out (Fig. 3).

When the bents are from 5 feet to 10 feet high, and on lower ones on trunk lines, or where the traffic is heavy, four piles driven vertically should be used. The inner ones may be spaced from 4 feet to 5 feet between centres, and the outer ones about 11 feet from centre to centre (Fig. 4). If the piles can be driven into the ground for a depth of 8 feet or 10 feet, and have a good bearing, it will not in general be necessary to use sway-bracing.



FIGS. 3 TO 7.—PILE-BENTS.

Above 10 feet in height it is well to drive the outside piles at a batter. According to present practice, this varies from 1 inch to 3 inches per foot. From  $2\frac{1}{2}$  to 3 inches is to be preferred, as it gives a broader base and greater stiffness to the structure (Fig. 5). The outer piles then perform to a certain extent the function of sway-braces and guys as well as supports. Bents between 10 feet and 20 feet high should be braced with one set of



sway-braces, while above this it is advisable to divide the bent into two stories, so far as the bracing goes, making use of two X's, with two horizontal sticks between them. It is frequently well also to use longitudinal girts. But this subject of bracing will be thoroughly discussed in a succeeding chapter.

Instead of driving the outside piles at their full batter, the Burlington & Missouri River R. R. in Nebraska\* drive them with a batter of 1 inch per foot, and then spring the top ends to place (Fig. 6). The following table gives the spacing:

TABLE VI.  
Spacing of Piles, Burlington & Missouri River R. R. in Nebraska.

Height of Bent.	Inside Piles (vertical).		Outside Piles. Driven batter 1 in. per ft.	
	<i>c - c.</i>	Distance either side centre-line.	<i>c - c</i> at ground.	Distance either side of centre-line.
Up to 10 feet, . . . . .	5 ft.	2 ft. 6 in.	11 ft. †	5 ft. 6 in.
10 to 16 feet, . . . . .	5 "	2 " 6 "	15 "	7 " 6 "
16 to 22 " . . . . .	5 "	2 " 6 "	17 "	8 " 6 "
All at top immediately beneath cap, . . . . .	5 ft.	2 ft. 6 in.	11 ft.	5 ft. 6 in.

Owing to the rapidly increasing engine and train loads many roads have found it necessary to increase the number of piles per bent to from five to six piles for each track. Some examples of such bents will be found in Part II.

Where soft ground extends to a great depth two or more piles may be fastened together end to end, if necessary. The first pile is driven until the top is nearly to the surface of the ground or water, when it is cut off, trimmed up, and the second pile stood upon and fastened to it. The driving is then continued as before, and more piles added in the same way if required. The splice (Fig. 8) was used in the false-work for the erection of the Poughkeepsie Bridge, and is said to have proven very stiff and strong, and to have given great satisfaction.

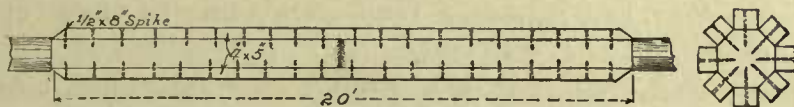


FIG. 8.—PILE-SPLICE, POUGHKEEPSIE BRIDGE.

Piles are also joined together by a long iron dowel (Fig. 9). The dowel is only of use to prevent lateral movement, and cannot be expected to keep the piles in line at all, on account

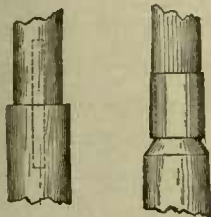


FIG. 9. FIG. 10.  
PILE-SPLICES.

of the great leverage. A wrought-iron dowel 1½ inches in diameter by 2 feet long is of good proportions. It is also better to band the end of the larger pile with a wrought-iron ring to prevent its being split. A broad band encircling a portion of both piles (Fig. 10) is not very serviceable unless it be fastened so securely that it cannot move from one pile to the other, as unless this is done it is usually found to be wholly on either one of the two piles after the first few blows. If a few track spikes are driven into the piles above and below the ring, this movement will be prevented. The abutting end of the upper pile should be as large as practicable, and where the piles are of such timber as to require the wasting of a large part of the pile to secure a

\* I. S. P. Weeks, Chief Engineer C., B. & Q. R. R., west of the Missouri River.  
† Outside piles vertical.



reasonable diameter, the contract should name a price for such wasted material. However no waste should be paid for as such which can be used in any other place on the same contract, and that which is paid for should be considered as belonging to the company, and the contractor not be allowed to remove it unless he is willing to repurchase it.

It has sometimes been found, where the ground is very soft and runny, and it is difficult to drive the piles to a firm foundation, that if, after driving to a moderate depth, they are allowed to stand quiet for a day or so, the surrounding material will settle against them, and they will safely bear their load, being supported by the friction on their sides.

Even in cases where piles have given a penetration of 1 foot to 2 feet at the last blow they have still borne a very heavy load. An interesting example of this was at the bridge across the Mobile River on the Mobile & Montgomery R. R., where it was found that such a pile, 60 feet long, after standing overnight would require heavy driving to start it.\* In deep tenacious mud it is often found to be easier to pull piles down by applying a heavy load than it is to drive them, and such piles remain unmoved under any load which does not approach too closely to that by which they were forced down.† In February 1893 Mr. H. C. Holmes, Chief Engineer of the San Francisco Harbor Commissioners, made some tests to determine the bearing value of piles driven in mud. He drove a pile 92 feet long, and 16 inches and 8 inches in diameter at the two ends. The hammer used weighed 2900 lbs., and at the last blow, with a 20-ft. fall of hammer, the pile sank 3 inches. The pile was then 73 feet in the mud. A platform was then built around the pile and loaded with 90,000 lbs. of pig iron, but after an interval of 24 hours under this load no sinking of the pile was perceptible.‡ A case is mentioned by Mr. W. B. W. Howe, Jr.,§ where a pile in a temporary trestle, driven in mud, having a penetration of 40 feet and settling 26 inches under the last blow, bore a load of about 18,000 lbs. many times a day for two years, and no settlement could be detected at the end of this time. After a rest of 24 hours the settlement under the first blow in similar test piles was but a little over 5 inches.

In || *Engineering News*, Feb. 23, 1893, p. 172, is given a list of a number of cases of piles driven in mud, from which the following are taken:

Pile-trestle at Aquia Creek, Va., 1871. Creek bottom almost fluid mud over 80 feet deep. Tide-water 6 feet deep. Trestle-bents six piles each,  $12\frac{1}{2}$  feet between centres and about 15 feet high. Piles 15 to 18 inches diameter at butt, 50 to 56 feet long, cut off just above low-water mark. Under a 2000-lb. hammer with 4-ft. fall pile settled  $8\frac{1}{2}$  inches, with 9.7-ft. fall 22 inches. Another instance in this trestle was where a pile 40 feet long, after sinking some 30 feet with its own weight and that of a 2000-lb. hammer, was given a blow of 2 feet fall, after which it sank  $6\frac{1}{2}$  inches further in one minute under its own weight and that of the hammer, and then stopped. Four weeks later a 5-ft. blow failed to move it, and a blow of 14 feet drove it on  $4\frac{1}{2}$  inches. A pile 43 feet long received two blows of 2 feet each, and then settled under 2000-lb. hammer  $1\frac{1}{2}$  inches in two minutes. Four weeks later it settled but  $2\frac{3}{4}$  inches under a 10-ft. fall and  $8\frac{1}{2}$  inches under a 28-ft. fall. These piles bore without failure a load of 13,333 lbs. each.

\* *Eng. News*, vol. xiii. p. 210.

† *Eng. News*, May 18, 1893, p. 462.

‡ *Eng. News*, vol. xx. p. 510.

§ *Eng. News*, Dec. 8, 1892, p. 543.

| Discussion of Foster Crowell's paper on "Uniform Practice in Pile-driving," *Trans. Amer. Soc. C.E.*, 1892.



Lake Pontchartrain Trestle, La. About 6 miles of trestle crossed the lake proper, and 16 miles crossed the adjoining sea swamp. Four pile-bents, 15 feet between centres. Material of swamp, several feet of soft, black vegetable mould, lying upon soft clay, with occasional strata 1 to 2 feet thick of sand. Piles sank from five to eight feet of their own weight, and then about as much more with the hammer (about 2500 lbs.) resting on the head of the pile. Two piles 65 feet long were driven, one on top of the other, and penetrated over 9 inches with over 100 feet driven; but a 30-ft. fall 30 minutes after driving a pile gave only 3 inches penetration. Load on each pile has probably not exceeded 22,400 lbs.



FIG. 11.  
PILE-  
POINT.

As to the advisability of sharpening piles before driving, the question seems to be that the practice should be governed by the circumstances surrounding each individual case. Experience seems to point to the fact that in driving piles through gravel they should be sharpened (see Fig. 11); but where close to a stratum of rock or through earth not containing obstructions, square-ended piles can be driven just as readily as those which have been sharpened, and give better results. In driving piles with a water-jet they will follow the jet better if sharpened.

Whenever the pile is likely to encounter logs, bowlders, or any material likely to split it, or to broom the point to an injurious degree, it is usual to protect it either by a cast- or a wrought-iron shoe. These shoes, however, are apt to strip off in driving.

In driving some piles for the New York City Department of Docks, at the foot of Canal Street it became necessary to drive them through some old cribwork, the nature of which was unknown. At first the piles were shod with cast-iron shoes, but failed, as shown in Fig. 11a. The piles were then driven with the point cut off square, but broomed points and split and broomed heads appeared to such an extent that the method of pointing was resorted to with very favorable results. The piles used were sound and straight spruce and yellow-pine sticks, the latter giving much better results, and withstanding the 60 to 70 blows of a 3900-lb. hammer falling 10 feet, much better than the spruce.\*

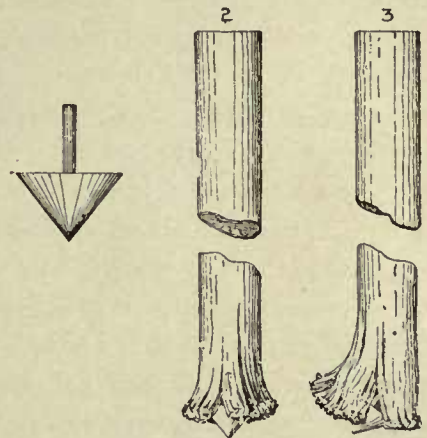


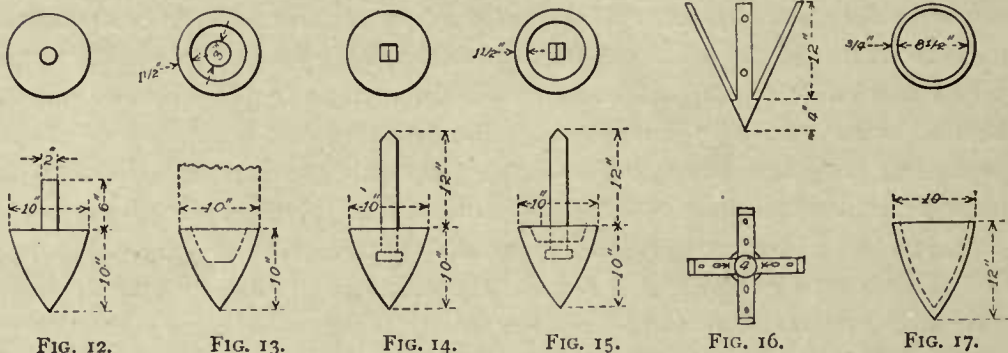
FIG 11a.—EFFECT OF SHOES ON PILES.

Figs. 12 to 15 show some of the different forms of cast-iron shoes used, and Figs. 16 and 17 some of those of wrought-iron. The one in Fig. 14 is cast around a 1-inch square drift-bolt. This is preferable to the one in Fig. 12, in which the pin is of cast-iron as well as the point, as the pin is liable to break off just where it joins the point. Fig. 15 shows probably the best form of cast shoe. The dowel is a drift-bolt, as in Fig. 14; while in addition there is a recess about 2 inches deep, with walls from 1 inch to 1½ inches thick, cast in the top of the point. The ring so formed not only helps to keep the shoe from being forced off laterally, and thus relieves the pin of some of the strain, but it also aids in preventing the pin from splitting the end of the pile in case much lateral force is exerted against the

\* *Eng. News*, Jan. 5, 1893. p. 14.



point. Fig. 16 shows a wrought-iron shoe. The point is of small size and has four straps



CAST- AND WROUGHT-IRON SHOES FOR PILES.

extending up the faces of the point of the pile, each of which is fastened to pile by two spikes.

Whenever the top of the pile is likely to be injured by the hammer it should be encircled by a heavy wrought-iron ring while being driven. Such a ring is shown in Fig. 18. These rings may be removed as soon as the driving is completed, and used over and over again. A committee of the Association of Railway Superintendents of Bridges and Buildings \* recommend that where a railway has a steam-hammer in its shops pile-rings be made of hammered iron from old car-axles. The life of such rings is much longer than when they are made of the best bar iron. A ring made of hammered iron will last to drive about 75 oak piles or 300 cedar piles, while one made of the best bar iron will only last to drive about 50 oak piles or 200 cedar piles. The cost of a ring 1" x 3" x 14" in diameter is about \$1.75 if made of old iron, and about \$2 if made of new iron. The rings should be one inch thick, three inches wide, and of various diameters. The following diameters have been found to be those most commonly needed: 13 inches, 13 1/2 inches, 14 inches, 15 inches.

A common practice is to lay the ring on top of the pile and let the first blow of the hammer drive it in. This, however, is liable to injure the piles by causing them to sliver if the ring is too small. Especially is this the case with cedar and red-oak piles. A far better way is to saw off the head of the pile square and chamfer the edges down for 5 to 6 inches back to a size just a little larger than the inside diameter of the ring and then settle it into place with the hammer.

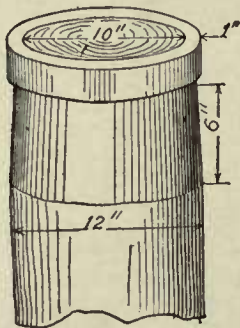


FIG. 18.—RING FOR PILE.

The temperature at the time of driving appears to have considerable influence over the tendency of the piles to split, and especially is this the case with certain kinds of timber, such as white and Norway pine. The colder the weather the greater the tendency. This is probably the case only when the temperature is below freezing. When the piles have been driven with the butts up in water, the elevation of the surface of which is liable to much change, the ice in the winter-time has been known to draw them in very cold climates.

Fig. 18a shows a device for removing a ring from the head of a pile after driving. The short end of the stick is placed on top of the pile and the iron hook caught under the ring.

\* Proceedings Assoc. Ry. Supts. B. & B., 1898, p. 60.



The hauling-rope of the driver is then attached by a hook to the ring at the other end of the stick, and the engine started, when the ring is pulled off.

An improvement upon the ring is the pile-anvil or cap. Both the brooming and splitting of the head are avoided by this device. The cap

carries a recess on the under side, into which the pile is driven at the first blow of the hammer. The cap moves in the leads of the driver, which act as guides, and carries a short oak block on its top to receive the blows of the hammer. By this arrangement the head of the pile is not only protected, but the pile itself is guided.

The importance of keeping the heads of piles free from becoming broomed in driving is shown by the results obtained by Mr. D. J. Whittemore \* in driving some green Norway-pine piles in river silt with a Nasmyth steam-hammer. The third foot of penetration required 5 blows, the sixth 29 blows, the ninth 61, the twelfth 153, and the fourteenth 684. The bruised portion of the head was then adzed off, and the next foot required only 275 blows, but this rapidly increased so that the eighteenth foot required 825 blows. The head was then sawed off, and the nineteenth foot was driven with but 213 blows, and the twenty-second foot with 378, or a total of 5228 blows. Another pile with no adzing required 9923 blows, or nearly twice as many.

In driving it is always preferable to have a heavy hammer with a short fall, but difficulties of transportation prevent the use of very heavy hammers in some cases. Ordinarily a hammer of 2000 lbs. weight falling 25 feet is a good proportion, but a heavier hammer with less fall is better. The piles should not settle more than from 1 inch to 3 inches at the last blow, and better if much less.

That it is dangerous to attempt to drive piles to a very small settlement under the last blow of the hammer has been well demonstrated.† A case occurred on the Boston, Hoosac Tunnel & Western Ry. clearly illustrating the bad effects from overdriving. In two places this road passed under the Troy & Greenfield R. R., both of which crossings were at embankments of sand. For the proposed openings, to be spanned by iron bridges on masonry abutments, temporary bents of piles were driven in the embankments to about 22 feet below track-level of the T. & G. R. R. to allow excavation for the abutments, etc., at the under crossing. The fine compact sand caused hard and slow driving. In the subsequent excavation which soon followed it was found that over one half of these piles were next to worthless, being split or broken from the driving at depths below 8 feet in one or more of the three ways shown in Fig. 18*b*. Most of the piles failed as shown in 1, some as in 2, and only a few as in 3.

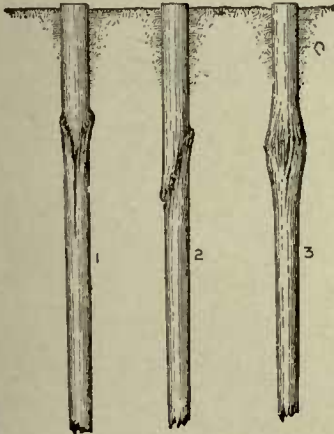


FIG. 18*b*.—EFFECT OF OVERDRIVING PILES.

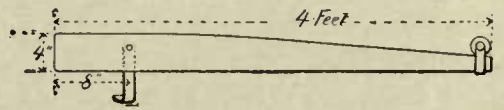


FIG. 18*a*.—RING-REMOVER.

\* Trans. Am. Soc. C. E., vol. xii., p. 442; *Engineering News*, Feb. 21, 1891, p. 185.

† Robt. L. Harris, *Engineering News*, Dec. 8, 1892, p. 543.

In a case\* where a trestle was built of a 15-in. I beam resting on a cast-iron plate placed on a pine cap on the piles, the piles being driven to solid rock, several piles broke off at an angle below the surface of the ground after being in use for three years. There were no indications of an old break, but all the indications of a new one. The failure took place 6 feet below the bottom of the stringer, and was attributed to the pounding action caused by the trains.

Fig. 18c † shows the effect of overdriving piles on the Fourth Avenue Subway in Brooklyn. The piles were principally spruce and were driven by a 2000-lb. hammer falling ordinarily

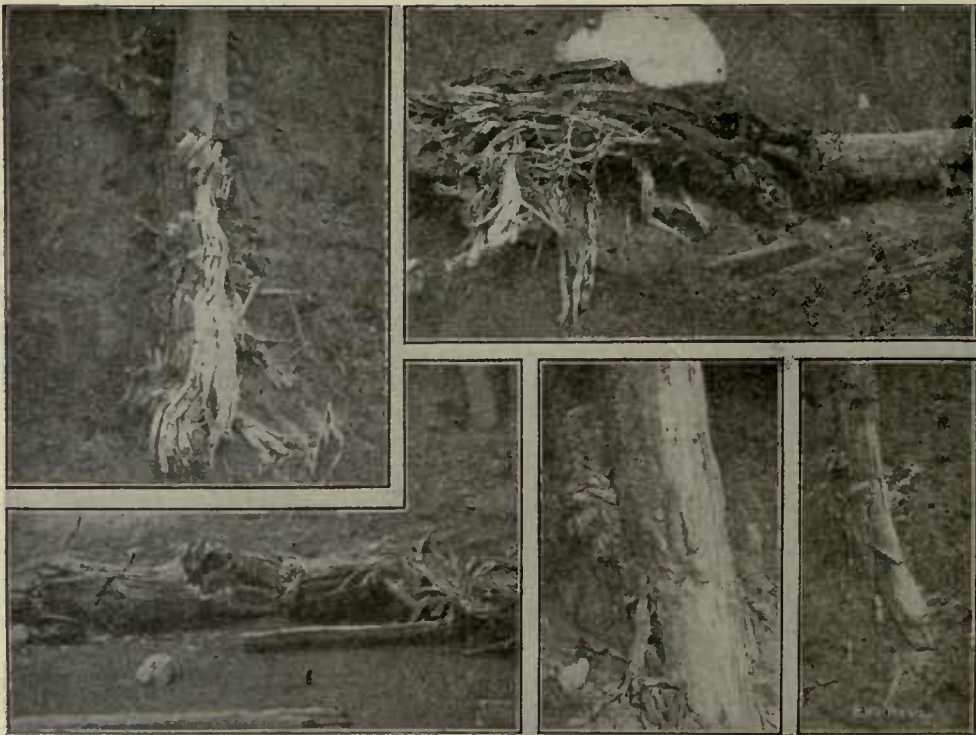


FIG. 18c.—FIVE EXAMPLES OF OVER-DRIVEN PILES.

about 25 feet. The soil was high, dry ground, containing much sand, gravel, boulders and indurated strata.

Figs. 18d, e, f, and g ‡ show the effect of overdriving or hard driving on some piles used in temporary work on the Norfolk & Western Railway in the subway construction over the Graveport pike near Columbus, Ohio. The driving was done with a 3800-lb. hammer by an ordinary railway track pile-driver with 40-foot leads. The piles were well-seasoned white or chestnut oak shod with cast-iron points.

The following remarks on overdriving piles are taken from the report of the Committee

\* Proc. Am. Inter. Assoc. Ry. Supts. of B. & B., 1893, pp. 24 and 25.

† S. P. Brown, *Engineering News*, Feb. 23, 1911.

‡ Julian Griggs, *Engineering News*, Jan. 14, 1909.





FIG. 18d.—PILE TELESCOPED IN DRIVING.



FIG. 18e.—PILE TELESCOPED IN DRIVING.



FIG. 18f.—PILE BUCKLED IN DRIVING.



FIG. 18g.—PILE BUCKLED, SLIVERED, AND BENT IN TWO DIRECTIONS.

on Wooden Bridges and Trestles of the American Railway Engineering and Maintenance of Way Association (Bulletin No. 107, January, 1909).

“The most prevalent bad practice in pile driving is overdriving, i.e., injuring the material of a pile by too violent or too continued hammering. When such injury occurs above ground, in the form of brooming or splitting, and can be prevented by the use of rings or caps, it is regarded as an indication of overdriving. The use of such protective appliances as rings, caps, or shoes is a legitimate means for securing the necessary penetration of soft-wood timber and of even hardwood timber in difficult ground. When, however, the resulting injury occurs below the surface of the ground, and therefore in that portion of the pile which will be a part of the finished structure, the pile may be said to be overdriven. Injuries of this nature may consist of a slight brooming of the foot of the pile and so be negligible, or they may be of sufficient importance to imperil the stability of the structure.

“It is frequently claimed by contractors and their foremen, and with apparent reason, that engineers specify conditions regarding penetration due to the last blows which are too severe. Pile-driving can never be an exact science, and the ‘practical man’ seems to have some reason for his poor opinion of a specification which applies with equal force to every known and unknown condition of the ground.

“Unfortunately it is sometimes difficult to distinguish between the action of an overdriven pile and that of a perfectly sound pile in certain ground. Practice in the art and some investigation of the underlying conditions are perhaps the surest guides to success.

“In general, overdriving may be due to one or more of the following causes: (1) The use of the word ‘refusal’ in the specifications. (2) A belief in the prevalence of intermediate or floating hard strata. (3) The use of a light hammer and a long drop. (4) Attempting to force aside mythical boulders. (5) An unnecessary effort to make the pile-driving record suit a formula which was not intended by the proposer thereof to apply to such cases.

“It is usually claimed, in cases of overdriving, that no evidence of injury was shown during the driving. This claim is open to considerable doubt, and a more careful examination of the underlying strata should prevent many failures.

“A pile passing through soft material and bringing up on rock cannot be driven into the rock. This condition indicates that another type of foundation may be needed. Pile foundations in ground hard enough to broom and split hardwood piles can often be otherwise designed with advantage.

“Many kinds of ground, easily penetrated under continual driving, develop a skin friction in excess of the probable requirements. Short, quick blows of a heavy hammer produce the best results. A sudden change in the amount of penetration should be considered a suspicious occurrence. Finally, pile-driving is a means, not an end, and a whole pile in almost any ground is better than pieces of a pile in good ground.”

The following formulas \* for the safe bearing-power of piles are very simple, have become

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\* *Engineering News*, Nov. 17, 1892, p. 469; also in book form, “Piles and Pile-driving.”



generally known as the *Engineering News* formulas, and are due to Mr. A. M. Wellington. They give excellent results if properly applied. The discussion given below has been taken from that paper.

For piles driven by the ordinary driver, i.e., a hammer falling free, with an interval of several seconds between the blows,

$$L = \text{safe load} = \frac{2wh}{s + 1} \dots \dots \dots (1)$$

In this and the following formulas a factor of safety of 5 has been allowed, and the letters are as follows :

- $w$  = the weight of the hammer in any unit of weight ;
- $L$  = the safe load in same unit of weight ;
- $h$  = the fall of the hammer in feet as below defined and limited ;
- $s$  = the set of the pile under last blow, in inches, as below defined and limited.

As to  $w$ : The effective weight of the hammer is decreased about 1 per cent by wind resistance, and perhaps  $\frac{1}{2}$  per cent by guide friction, even when the guides are truly vertical and in good order. When pile and guides are inclined the effective weight is decreased (1) to  $h \cos I$  (in which  $I$  = the angle of inclination from the vertical) and (2) by the guide friction caused by the force  $w \sin I$  pressing the hammer against the guides. With vertical guides this force is theoretically zero.

As to  $h$ : The full fall must only be counted (1) when there is no sensible bounce after the blow, and (2) when the head of the pile is in good condition. Bouncing in effect divides a single blow into two weaker ones, the energy of the first blow being diminished by an amount of fall equal to the height of the bounce, even if pile and hammer be assumed to be perfectly elastic. As neither is perfectly elastic, at least twice the height of the bounce should be deducted from  $h$  to determine its true value for use in the formula.

Condition of head: According to the best existing information a broomed head will destroy from half to three quarters of the effect of a blow, even if the brooming be only a half inch to an inch deep. No formula can be safely applied if the last blows be given with the head in such condition ; but the remedy is to adze off or saw off the heads before giving the last blows, at least for a few sample piles, and if a very considerable difference is observed, then for all of them, if it is desired to determine and utilize their full bearing-power.

As to  $s$ : The proper value can only be determined by taking the mean of the sets for a number of blows, nor then unless—

- (a) The penetration has been at a reasonably uniform or uniformly decreasing rate, and
- (b) There is reasonable assurance that the penetration would continue uniform if driven several feet further (which may be known from test-piles driven to an extra depth, or from general knowledge or evidence as to the nature of the soil—as that it is all sand, gravel, or alluvial deposit). Also,
- (c) The head must be in good condition as above ; and also,

(d) The penetration must be at a reasonably quick as well as uniform rate—not less than  $\frac{1}{4}$  inch for a 3000-lb. hammer falling 30 ft. Any smaller penetrations under such a blow should be assumed to be due to mashing of the point and neglected, and any penetration of less than  $\frac{1}{2}$  in. is to be looked on with grave suspicion, and disregarded unless it has been uniform for many blows. With soft-wood piles any penetrations of less than 1 in. under such a blow is likely to involve destructive strains within the pile, and hence should be disregarded in computing bearing-power.

As to interval of time between blows: There is nearly always an increase of resistance and decrease of set per blow as an effect of an interval of rest, permitting the earth to settle firmly around the pile. The increase of resistance from a few minutes' to a few hours' rest may vary from 50 per cent to several hundred or even thousand per cent. This effect is usually most pronounced in the finer soft and wet earths, and least pronounced in coarse gravel and sand. No values of  $s$  should therefore be accepted as trustworthy without testing occasional piles for various intervals of rest, and the mean penetration for the first few blows after such an interval of rest should be taken as the value of  $s$ .

As to piles acting as columns: Assuming a blow of  $3000 \times 20 = 60\,000$  ft.-lbs., a pile which penetrates through soft material to a comparatively hard stratum is not, as a rule, safe as a column (with a factor of safety of 6) for any heavier load than is given by the safe load formula (1). That is to say, for a set of

1 in.	2 in.	3 in.	4 in.	5 in.	6 in.,
the safe load in pounds by (1) is					
60 000	40 000	30 000	24 000	20 000	17 140,

which is about  $\frac{1}{6}$  of the ultimate breaking load of a 10-in. round column of soft wood, of a height

8 ft.	14 ft.	18 ft.	21 ft.	24 ft.	26 ft.
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In cases where the length of column without side support is greater than this or the safe load by (1) is less, the safe load by the latter formula will exceed the load on the pile as a column.

Crushing Strength: No pile can be relied on to bear without crushing over 500 to 1000 lbs. per sq. in., unless of superior hard-wood timber; or 50 000 to 100 000 lbs. in all, assuming the average section of pile to be 100 sq. in. This is the safe load by (1) for a pile settling 1.4 to 0.2 in. under a 20-ft. blow from a 3000-lb. hammer. Therefore penetrations of soft-wood piles of less than  $1\frac{1}{2}$  in. under such a blow (or proportionately for weaker blows) are to be looked on with some suspicion on this account, and penetrations of less than  $\frac{1}{2}$  to  $\frac{1}{4}$  in. are to be disregarded wholly in computing bearing-power, and  $s$  taken as = 0.5 to 0.25.

Bearing-piles should be spaced at least 3 ft. c. to c. each way if this gives a sufficient number to carry the load, and they are worse than wasted if driven less than  $2\frac{1}{2}$  ft. c. to c.

Variations of load for varying conditions. No experimental evidence exists that (1) does not give a safe load under all conditions of service, within the limits of usual values for  $w$ ,  $h$ , and  $s$ . The load, therefore, need never be made less than (1) permits, unless for some special case of treacherous or dubious soil under an important structure subject to vibratory



strains. An extra allowance, if made, should ordinarily be made by reducing the spacing between piles, down to a limit of 2½ ft. c. to c. On the other hand, the load should only be made greater than warranted by (1) with extreme caution, under favorable conditions for high bearing-power only, and with care that the properties of the pile as a column and as to crushing as given before be not exceeded.

Computations of Loads: All extra loads which may result from winds, locomotive counterweight strains, or other temporary loadings are to be considered in computing the load on each pile. In pile-trestles, it is none too great an allowance to assume that the entire weight of the driving-wheel base falls upon each bent in succession.

When the weight of the hammer has not only to set the hammer in motion, but also the hoisting rope and drum, the energy of the blow (=  $wh$ ) is in inverse ratio to the time taken for the hammer to fall a given distance free or attached to the rope, which may be observed experimentally or computed, assuming the mass of the drum to be concentrated at its radius of gyration from the centre. It will usually be found to be diminished nearly one half, which requires a corresponding reduction in the value of  $h$ , that variable being supposed to equal the height of free fall.

Deception is often resorted to in contract work under this method of pile-driving; the fall of the hammer being checked by the brake in a way which it is difficult to guard against by inspection. It is therefore a method to be avoided in contract work.

As a rule, piles sunk only by a dead load placed on them will not sustain safely much more than the load which sunk them, but will do that (and sometimes much more) after they have stood for a time, to let the material settle closely upon them. In very soft and semi-fluid muds, the safe bearing-power may be many times the weight which originally sunk them. The only certain test is to try some of the piles with a hammer after they have been driven some time, and then compute the bearing-power by (1).

For piles driven by the Nasmyth or similar pile-drivers

$$L = \text{safe load} = \frac{2wh}{s + 0.1} \cdot \dots \dots \dots (2)$$

For piles driven by gunpowder or similar pile-drivers

$$L = \text{safe load} = \frac{4wh}{s + 0.1} \cdot \dots \dots \dots (3)$$

The diagrams \* given in Figs. 18*h* and 18*i* were developed by Mr. Arthur S. Millinowski, Assistant Engineer, New York State Barge Canal, for determining the safe bearing loads on piles according to the *Engineering News* formulas just discussed. Fig. 18*h* refers to piles driven with an ordinary drop hammer and Fig. 18*i* to those driven with a steam hammer. Care should be exercised to keep within the limits of the formulas, otherwise absurd results may be obtained. Any three of the four elements of the formulas being known the fourth can be obtained. The diagrams are drawn for the safe load,  $L$ , in tons; the weight of the hammer,  $w$ , in tons; the height of the fall,  $h$ , in feet; and the average penetration of

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\* *Engineering News*, Feb. 2, 1911; Sept. 21, 1911.

the last blows,  $s$ , in inches. To use the diagram, Fig. 18*h*, as an example assume  $h=20$  feet and  $s=\frac{5}{8}$  inch under a 1500-lb. hammer. Connect the point indicating  $\frac{5}{8}$  inch on the 1500-lb. scale with the point  $Q$ . From the intersection of the continuation of this line with a horizontal line from the 20-foot point on the "drop of hammer" scale, let fall a perpendicular. Where this latter hits the "safe load" scale, we find 18.5 tons as the safe load.

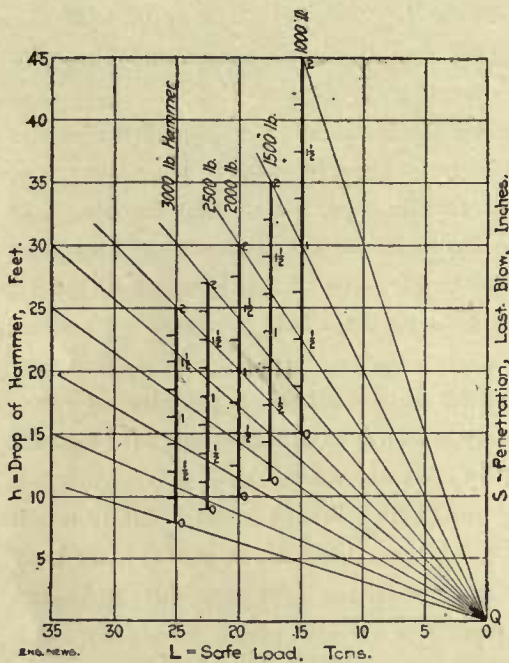


FIG. 18*h*.—ENGINEERING NEWS FORMULA,  $L = \frac{2wh}{s+1}$ , FOR SAFE LOAD ON PILES IN GRAPHICAL FORM.

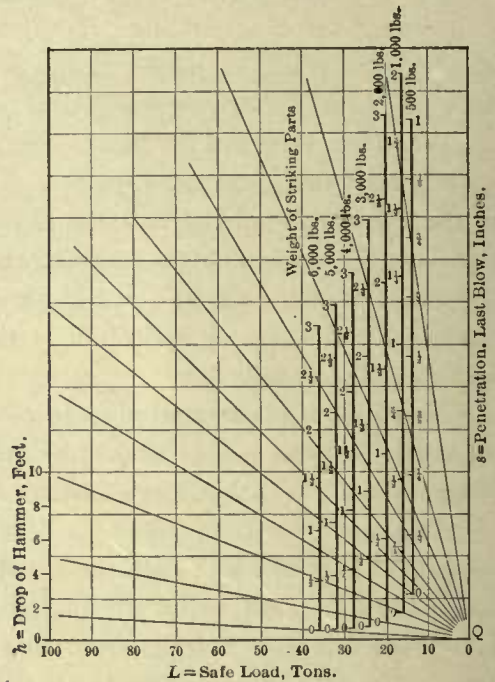


FIG. 18*i*.—ENGINEERING NEWS FORMULA,  $L = \frac{2wh}{s+0.1}$  FOR SAFE LOAD ON PILES IN GRAPHICAL FORM.

The radial lines are drawn as guides, and in practice the diagram is used without actually drawing a line of any sort.

The use of diagram 18*i* is similar to that of 18*h*.

The following general principles of pile-driving practice were drawn up by a committee on wooden bridges and trestles after an extended study of the subject and adopted by the American Railway Engineering and Maintenance of Way Association at their meeting in 1911.\*

1. A thorough exploration of the soil by borings, or preliminary test piles, is the most important prerequisite to the design and construction of pile foundations.

2. The cost of exploration is frequently less than that otherwise required merely to revise the plans of the structures involved, without considering the unnecessary cost of the structures due to lack of information.

3. Where adequate exploration is omitted, it may result in the entire loss of the structure, or in greatly increased cost.

\* *Engineering Record*, April 1, 1911, p. 369. Bulletin American Railway Engineering and Maintenance of Way Association.



4. The proper diameter and length of pile, and the method of driving, depend upon the results of the previous exploration, and the purpose for which they are intended.

5. Where the soil consists wholly or chiefly of sand, the conditions are most favorable to the use of the water jet.

6. In harder soils containing gravel the use of the jet may be advantageous, provided sufficient volume and pressure be provided.

7. In clay it may be economical to bore several holes in the soil with the aid of the jet before driving the pile, thus securing the accurate location of the pile, and its lubrication while being driven.

8. In general the water jet should not be attached to the pile, but handled separately.

9. Two jets will often succeed where one fails, in special cases a third jet extending a part of the depth aids materially in keeping loose the material around the pile.

10. Where the material is of such a porous character that the water from the jets may be dissipated and fail to come up in the immediate vicinity of the pile, the utility of the jet is uncertain, except for a part of the penetration.

11. A steam or drop hammer should be used in connection with the water-jet, and used to test the final rate of penetration.

12. The use of the water-jet is one of the most effective means of avoiding injury to piles by overdriving.

13. There is danger from overdriving when the hammer begins to bounce. Overdriving is also indicated by the bending, kicking or staggering of the pile.

14. The brooming of the head of a pile dissipates a part, and in some cases all, of the energy due to the fall of the hammer.

15. The weight or the drop of the hammer should be proportioned to the weight of the pile, as well as to the character of the soil penetrated.

16. The steam hammer is more effective than the drop hammer in securing the penetration of a pile without injury, because of the shorter interval between blows.

17. Where shock to surrounding material is apt to prove detrimental to the structure the steam hammer should always be used instead of the drop hammer. This is especially true in the case of sheet-piling which is intended to prevent the passage of water. In some cases, also, the jet should not be used.

18. In general, the resistance of piles, penetrating soft material, which depend solely upon skin friction, is materially increased after a period of rest. This period may be as short as fifteen minutes, and rarely exceeds twelve hours.

19. In tidal waters the resistance of a pile driven at low tide is increased at high tide on account of the extra compression of the soil.

20. Where a pile penetrates muck or soft, yielding material, and bears upon a hard stratum at its foot, its strength should be determined as a column or beam; omitting the resistance, if any, due to skin friction.

21. Unless the record of previous experience at the same site is available the approximate bearing power may be obtained by loading test piles. The results of loading test piles should





The fall of the hammer given is for the last ten, twenty, or thirty blows. Each pile was intended to be driven until it fulfilled the requirements of the specifications; i.e., penetration not to exceed 1 inch under the last blow of a 2000 lbs. hammer, with a fall of 20 feet or equivalent. The notes relating to the size and driving of the piles were taken by the inspector at the time; elevations by the engineer afterwards. A profile was then made up from these notes, and the piles ordered according to the lengths measured upon it. It was found that this method gave excellent results, there being but few discrepancies between the actual material when in place and that ordered. The waste of material was consequently reduced to a minimum.

A permanent record of all the final work, in detail, should always be made at the time construction is going on, for the future use of the Maintenance of Way-Department. An excellent form of such a record, as used on the above work, is given below.\*

NORTHERN PACIFIC RAILROAD COMPANY.  
PILE-DRIVING RECORD, BRIDGE NO. 160.

Date and Station.	Number of Bent.	Number of Pile.	Kind of Timber.	Length of Pile.	Diameter of Butt.	Diameter of Top.	Length below Cut-off.	Length of Cut-off.	Elevation of Ground.	Elev. of Point of Pile.	Distance driven.	Fall.	Number of Blows.	Penetration for given number of Blows.					
														ft.	ins.	ins.	ft.	ft.	ft.
Dec. 27. 114+30	42	1	Wh. P.	40.0	17	14	31.4	8.6	76.2	66.4	9.8	20	85	20	10"	10"	5"	4"	1"
114+30 Jan. 10.	42	4	Wh. P.	40.0	16	11	33.0	7.0	76.2	64.8	11.3	20	60	20	10"	7"	7"	7"	
112+65	53	3	Wh. P.	42.0	15	13	36.0	6.0	74.8	61.8	13.0	18	50		30	40	11"	11"	9"
																20	30	40	50

The actual cost and rate of driving the piles on this trestle was as follows :

SUMMARY OF WORK OF ONE DRIVER.

Dates.	Number of Days.	Number of Piles Driven.	Lin. ft. of Piles driven.	Number of Piles driven Daily.	Lin. ft. of Piles driven Daily.	Contractor's Cost of Driving.	Average Cost of Driving per lin. ft.
1884. Piles 23' to 45' long, Dec. 11 to 31.	10½	202	6520½	19½	621	\$454.43	\$0.06969 †
1885. Jan. 1 to 5 and 10 to 14. Piles over 45' long.	5½	134	5785	23¾	1006	212.57	0.0367
Jan. 5 to 10 and 14 to 31.	14½	364	21535	25½	1485	539.61	0.02506
Feb. 1 to 28.	19½	379	25036	19½	1268	747.74	0.0298
March 1 to 5.	3½	73	4789	22½	1473	135.75	0.0284

Average cost per lin. ft., piles less than 45 feet long. . . . . \$0.0542

" " " " " over " 45 " " . . . . . 0.0277

This is the actual cost of driving after the piles were delivered at the pile-driver.

The best record was 120 piles = 6600 ft. in four consecutive days. Contractors were Winston Bros. of Minneapolis.

\* This form has been very slightly modified by the author.

† Some delay on shore.





TABLE VI (a).

Detail Statement of Work of Car Pile driver for 46 Days, Omaha & St. Louis Railway.

Date, 1889.	No. of Piles Driven.	Average Depth Driven-Feet.	Time with Leads in Position.		Leads Raised or Lowered.		Total Time at Work.	
			Hours.	Minutes	No.	Minutes Lost.	Hours.	Minutes.
October 22.....	25	12	7	..	6	20	7	20
23.....	32	14	7	46	6	18	8	04
24.....	26	14	7	35	8	25	8	..
25.....	27	15	8	10	6	20	8	30
26.....	32	14	7	42	6	18	8	..
28.....	29	14	7	50	8	25	8	15
29.....	26	15	7	10	6	20	7	30
31.....	33	15	8	14	6	18	8	32
November 2.....	32	14	7	20	8	24	7	44
4.....	33	15	6	10	8	17	6	27
5.....	37	16	8	20	8	27	8	47
6.....	28	16	5	20	6	20	5	40
7.....	30	14	5	46	8	27	6	13
8.....	25	15	4	23	8	20	4	43
9.....	26	15	6	08	10	25	6	33
11.....	13	15	5	10	6	13	5	23
12.....	16	14	5	28	6	18	5	46
13.....	18	14	3	40	6	15	3	55
14.....	22	15	7	08	6	17	7	25
15.....	19	15	7	15	6	12	7	27
16.....	34	12	6	35	6	15	6	50
18.....	34	12	6	30	8	12	6	42
19.....	13	12	3	40	8	10	3	50
20.....	22	12	6	15	10	22	6	37
21.....	26	15	6	30	8	12	6	42
22.....	17	15	6	20	8	15	6	35
23.....	11	15	6	15	8	16	6	31
25.....	13	15	5	40	6	14	5	54
26.....	21	15	5	17	8	22	5	39
27.....	24	15	5	27	10	24	5	51
29.....	28	15	6	25	12	30	6	55
30.....	34	15	6	57	8	27	7	24
December 2.....	42	18	7	55	6	15	8	10
3.....	21	16	4	44	6	15	4	59
4.....	36	13	7	..	4	9	7	09
5.....	37	12	7	55	8	21	8	16
25.....	46	10	6	15	10	18	6	33
7.....	25	16	6	55	10	19	7	14
9.....	45	14	7	32	6	14	7	46
10.....	26	16	5	40	8	18	5	58
11.....	33	16	7	42	8	19	8	01
12.....	28	13	7	05	8	17	7	22
13.....	21	13	5	30	8	17	5	47
14.....	32	14	6	05	10	20	6	25
16.....	35	12	8	20	8	18	8	38
17.....	34	12	7	45	6	14	7	59
Total, 46.....	1267	14	301	49	344	14.12	316	01

Number of days worked.....46  
 Average time worked per day.....6 hours 52 min.  
 Average time required to drive one pile..14.965 "  
 Average time required to either raise or  
 lower leads..... 2.477 "  
 Length of piles from 14 to 52 feet; average  
 length, 24 feet; driven..... 14 feet.

Average cost per foot of piles..... 15c.  
 Expenses for 46 days' labor.....\$1,683.72  
 Expenses for fuel and supplies.. 262.28—\$1,946.00  
 Average cost of a pile in place..... \$5.14  
 Trestles driven..... 41  
 Average length of trestle..... 101 feet.

On the\* Ohio & Mississippi R. R., Mr. L. C. Fritch, Eng'r Maintenance of Way, drove seven bents of four piles each in three hours. Piles were driven to an average depth of 15 feet. Including all labor in handling, etc., the actual cost of driving was 2c. per foot of pile, and the cost per pile driven averaged 30c. Of the 28 piles, 8 were 25 feet long, 8 were 16 feet, and 12 were 22 feet long. Material not specified, but probably easy to drive through.

With a water-jet pile driven the following rates of driving have been obtained.

† Missouri River, on the jetties and dikes built by Missouri River Commission, the material usually encountered being sand, but sometimes containing pockets of gravel and layers of "gumbo," with a driver having a single pair of leads from 16 to 28 piles were sunk per day; with a driver having three sets of leads from 20 to 34 piles per day. The total number of piles driven was 1243, and the average penetration 18.9 feet.

In making up approximate estimates of the cost of piling and trestles, when exact data is not at hand, the following figures may be used with a very close approach to accuracy, as they are based on actual contract prices:

TABLE VII.  
Prices of Trestle Material in Different Sections of North America.

Material.	Texas.	Virginia.		Indiana.	Washington.	Halifax Harbor.
	1888.	1889.	1890.	1879-81.	1888.	1884-85.
Average penetration of Piles on land.	*	†	‡	§		¶
Piles per lin. ft. in place.	35c.			12 ft. <sup>2</sup>		
Round Timber per lin. ft. erected (round-timber trestle)				25c.		
Dimension Timber per M. B. M., erected.	\$40				9c.	{ Hemlock, \$16.47 Wh. \$26.00
Oak.		\$30 <sup>1</sup>	\$30 <sup>1</sup>	\$25 to \$30	\$23	
Pine.				\$13 to \$16		
Heart Pine (Va. Pine).		\$30 <sup>1</sup>	\$30 <sup>1</sup>			
Cattle-guard Timber per M. B. M., erected.	\$30					
Bolts and Nuts per lb.				5½c.	6c. to 7c.	

<sup>1</sup> Includes iron.

<sup>2</sup> This may be taken as the average penetration of piles in the clay of the Indiana prairies. On the Illinois prairies the average penetration may be taken at about 18 feet.

\* C. A. Wilson.

† Maintenance of Way Dept., Norfolk & Western R. R.

‡ New River Plateau R. R., an extension of the N. & W. R. R.

§ I., D. & S. Ry., E. A. Hill. On Indiana section lumber is very scarce, and oak bridge-timber twenty to fifty feet long costs from \$13.50 to \$50 per M. B. M.

Not erected materials cost as follows, f.o.b.; Piles in ordinary lengths, and from 10 to 12 in. in diameter at the smaller end, from 13¼c. to 15c. per lin. ft. Bolts 3c. and cast washers 2c. per lb.

|| Vancouver, Klickitat & Yakima R. R., *Eng. News*, June 9, 1888.

¶ See *R. R. Gazette*, 1886, p. 242.

On the Columbia River jetty at the mouth of the Columbia River, Oregon, piles 55 to 65 feet in length cost 8c. per foot delivered on the work in 1891.

‡ In Iowa, according to J. C. Sheeley, piling can be purchased delivered at almost any depot at a cost of 14c. to 18c. for oak, 23c. to 27c. for red cedar, and 9c. to 12c. for white cedar. For bridge work he estimates the cost as follows (Table VII, (a)) on an average local job requiring 1000 feet of piles, and using a horse-power pile-driver with a 1500-lb. hammer and leads 30 feet long.

\* *Eng. News*, Jan. 25, 1894, p. 77.

† *Eng. News*, Dec. 6, 1890, p. 498.

‡ Paper before Iowa Soc. C. E.'s & Surveyors, reprinted in *Engineering Record*, June 24, 1893, p. 58.



TABLE VII (a).

Cost of Driving Piles in Iowa by Horse Power.

	Oak @ 16c.	Red Cedar @ 23c.-27c.	White Cedar @ 9c.-12c.
1000 feet piles.....	\$160.00	\$230 to \$270	\$90 to \$120
Hauling 5 miles (team make two trips and haul 100 feet at a load), 5 days @ \$3.....	15.00	15 15	15 15
Average driving 110 feet for 4 men and 2 teams = 9 $\frac{1}{2}$ days @ \$3 for foreman, \$3 for team and teamster, \$2 for men = \$11 per day.....	100.00	100 100	100 100
Total.....	\$275.00	\$345 to \$385	\$205 to \$235
Cost per foot.....	27 $\frac{1}{2}$ c.	34 $\frac{1}{2}$ c. to 38 $\frac{1}{2}$ c.	20 $\frac{1}{2}$ c. to 23 $\frac{1}{2}$ c.

For the cost of 27 $\frac{1}{2}$ c. per foot the contract price would be from 35c. to 40c.

Table VII (b) gives the cost of pile-driving in different sections of the country as compiled from the discussion printed in the Proceedings of the American International Association of Railway Superintendents of Bridges and Buildings for 1894.

TABLE VII (b).

Cost of Pile-driving in Trestles.

Name of Railroad.	Feet of Piles.	Cost.	Remarks.
Ohio and Miss. Ry.....	6538	3c. to 4.136c. per ft.	Pile-driver, \$5 per day; locomotive \$25 per day.
P., F. W. & C. Ry., Western Division.....		6c. per ft.	Estimate for repairs, sometimes runs above this.
Louisville & Nashville R. R.....	5500 piles	\$40 per day	Average driven, 22 per day. Maximum number in any one day, 60.
K. C., F. S. & M. Ry.....		8c. per ft.	Used in estimating.
Wabash Ry. ....		\$2 per pile	Up to 30 ft. long. Very small expense for additional feet.
St. L. & S. F. Ry.....		2c. per ft.	Penetrate 4 ft., when possible 6 ft., very little 10 ft.
L. S. & M. S. Ry....	150000 ft.	6.32c. per ft.	
U. P., D. & G. R. R.....		3c. to 6 $\frac{1}{2}$ c. per ft.	Pile-driver, \$5 per day; locomotive, \$25 per day.

As soon as the pile-driving has advanced a short distance, the preparation of the top of the piles for the reception of the cap is begun. The elevation of the top of the pile is marked by a line on the face of one or two piles in each bent by the engineer.

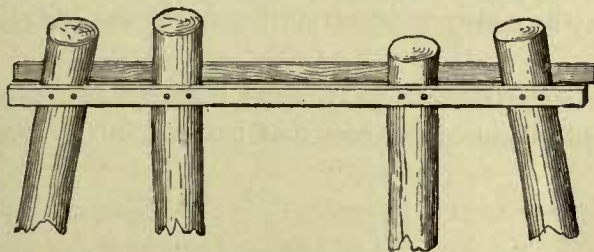


FIG. 19.—MARKING PILES FOR CUTTING OFF.

A narrow plank having a straight upper edge, and long enough to extend entirely across the bent, is then nailed on each side of the piles (Fig. 19), and the top cut off level or cut in far

enough to form the tenon. A cross-cut saw worked by two men is very convenient for this work.

There are several ways of fastening the caps to the piles,—by mortise and tenon, by drift-bolts, or by dowels. For solid caps, a tenon 3 ins. thick, 8 ins. wide, and 5 ins. long is a very good size. The edges around the top of the tenon should be chamfered (Fig. 20). When tenons are employed, it is customary to use wooden pins (treenails) for fastening the parts together. The pins may be of any tough hard wood. White oak and locust answer all the requirements very well. They ought to be from 1 in. to  $1\frac{1}{2}$  in. in diameter, and slightly tapered—say  $\frac{1}{8}$  in. to  $\frac{1}{4}$  in. (Fig. 20). The hole in the tenon should be somewhat nearer the top of the pile than that in the cap is to the edge, so that the pin when driven in will draw the two parts tightly together. Bolts,  $\frac{3}{4}$  in. in diameter, have been sometimes used in place of pins, but are not as desirable; in fact, their use should be discouraged. When drift-bolts or dowels are employed the top of the pile is cut off square. Dowels frequently extend through the cap; generally one, sometimes two, drift-bolts or dowels per pile are used; one is amply sufficient. Details of the different kinds of drift-bolts and of dowels are given in full in the chapter on iron details.

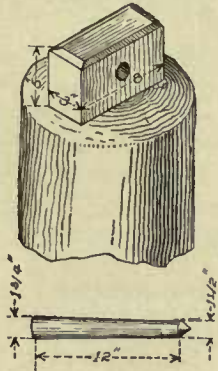


FIG. 20.—PILE TENON AND TREENAIL.

Sometimes a mortise-and-tenon joint is employed for the outer piles, with the inner piles cut off square, and drift-bolted as shown in Fig. 21.

There is still another method of fastening the caps to the piles, which is rapidly becoming the general practice, which is by the use of split caps. Instead of using a single piece of timber for the cap, two pieces, each half the size, are employed. For instance, a single 12-in. by 12-in. stick is replaced by two 6-in. by 12-in. sticks. A tongue or tenon about 3 in. thick and the full width of the pile is formed on its top, and one of these pieces placed on either side and held in place by one, or better two,  $\frac{3}{4}$ -in. or 1-in. bolts passed through at each pile. The sticks should not be notched, and they should rest evenly on the edges formed on top of the piles. This form of cap is claimed to have many advantages, among which may be mentioned—

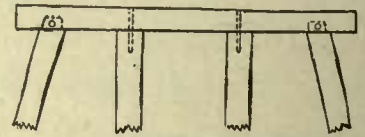


FIG. 21.—FASTENING CAP TO PILES.

- 1st. On account of smaller size, better timber may be obtained and at less cost.
- 2d. Repairs may be made with ease and great economy in time and labor.
- 3d. Traffic need not be interfered with or endangered while repairs are being made.
- 4th. The caps may be replaced without cutting or injuring any other part of the structure in the least.

5th. Economy in material, because it is not necessary to replace the whole cap unless both sticks are decayed or injured, but only that part which is no longer in a serviceable condition.



## CHAPTER III.

### PILE-DRIVERS.

WHILE there are a great many forms and styles of pile-driving apparatus, there are but three principal methods of sinking piles in general use. These are :

1st. To force the piles into the ground by allowing a heavy weight to fall upon them when in an upright position, or by striking heavy blows by some means upon their heads or tops.

2d. To sink the piles by means of a jet of water.

3d. To screw the piles (which are either of iron or else have a special shoe) into the ground.

As the first of these methods is the one most extensively used, we may say almost universally,—and the one most generally applicable to trestle-building, we will confine ourselves strictly to a description of several different forms of apparatus for accomplishing the desired end by this means.

The particular kind of machine to be used will depend upon the special conditions surrounding the case.

In very rough and bad country the simpler and lighter the machines consistent with the requirements of the work the better. Sometimes merely a pair of leads with the necessary stays or back-bracing to give them the required stiffness, a common hoisting-machine (usually horse-power in such a case as this), with the hammer, ropes, and blocks, are all that are carried from place to place. Everything is made as simple as possible, and so that it can be taken apart for transportation. Sometimes the apparatus is mounted upon wheels, so that it may be folded down and drawn around by a team of horses. When the scene of action is reached the leads are merely raised up. This lifts the wheels off the ground. The base is then lashed to a couple of 12-in. logs, and as soon as the hoister is put in position and the tackle arranged, everything is ready for the commencement of the driving.

Where transportation is not too difficult, it is preferable to use a more complete driver. A steam-boiler and hoister is substituted for the horse-power one. With this arrangement the driving proceeds more rapidly and at less cost.

When many piles have to be driven in navigable waters the driver is mounted on a scow.

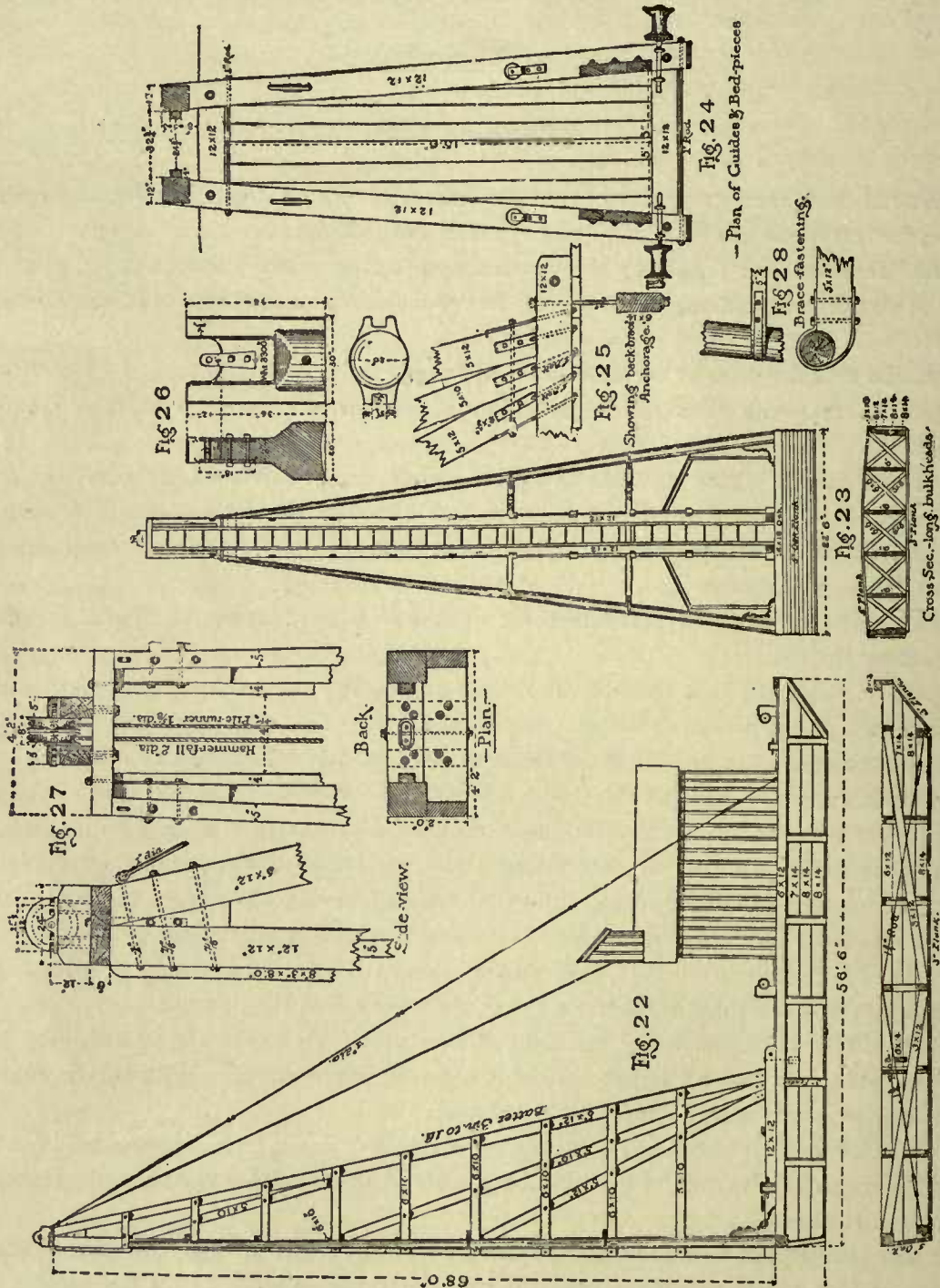
Figs. 22 to 28 illustrate a machine of the very latest model, and one of the heaviest in New York Harbor.\*

"The hull is 56 ft. 6 in. long, and 23 ft. 6 in. wide, over all; each of the sides of the hull is made of four pieces of yellow pine, the two lower each 8 in. × 14 in., the third 7 in. × 14 in., the top piece 6 in. × 14 in., all securely tied by through-bolts; the bow planking is

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\* From "Bearing Piles," by Rudolph Hering, N. Y., 1887.

oak 5 in. thick, the bottom and end plank yellow pine 3 in. thick. The bow is further strengthened by a 16-in. X 16-in. cross-timber at top, and at the stern is an 8-in. X 12-in. cross-timber of yellow pine. Oak is used on the bow, as being better adapted to stand the



FIGS. 22-28. — FLOATING PILE-DRIVERS.

constant wear of the piles hauled against it; and to prevent knots or inequalities on the piles interfering with their position under the hammer, the bow planking overhangs 6 in. in its total height.



"The chief end in the design of a hull for a floating pile-driver is to obtain longitudinal stiffness, so that the strains between the bow and engine may be properly distributed. To this end our hull is strengthened lengthwise by four wooden bulkheads or kelsons, each 6 in. thick (Fig. 23), and braced laterally by four sets of X braces of 6-in.  $\times$  6-in. timber. The hull is further braced in the centre by two 3-in.  $\times$  12-in. Y. P. braces, and tie-rods or 'hog-chains' of iron  $1\frac{3}{4}$  in. in diameter. Wale-pieces and fender-plank 3 in. thick protect the outside of the hull against chafing, the deck has a 'crown' of about 6 in. in its total width."

"The hammer-guides are made of two pieces of 12-in.  $\times$  12-in. Y. P. 67 ft. long from out to out, with inside guides of 5 in.  $\times$  4 in. stuff protected by plate-iron  $\frac{1}{4}$  in. thick;  $\frac{5}{8}$ -in. bolts with countersunk heads fasten the inner guides to the main sticks, and at the same time secure the iron-work to the same. The bottom of the main guides are connected with the 12-in.  $\times$  12 in. bed-pieces, shown in Fig. 24, by two timber-knees, and are tied at top by the cap shown in Fig. 27.

"The dimensions and general arrangement of the back-bracing is fully shown in Figs. 22 and 24; the bolts used in this portion of the framework are  $\frac{7}{8}$  in. diameter. The side-braces are round timbers 16 in. diameter at the butt, and they are anchored to the hull by two heavy timber-knees to each. The bed-pieces, as shown at Fig. 24, are fastened down to the hull by four bolts, each 1 in. in diameter, the forward bolts passing through the 16-in.  $\times$  16-in. oak piece on bow, and the after-bolts passing into a cross-timber 6 in.  $\times$  14 in., as shown at Fig. 25. The foot of the back-bracing is secured to the bed-timbers by one 1-in. strap-bolt in each timber, the strap portion of bolt being 2 in.  $\times$   $\frac{1}{2}$  in. in section. A  $\frac{7}{8}$ -in. through-bolt ties the three braces together.

"The iron stay-rods running from head of guides to after part of hull are two in number, and are each 1 in. in diameter.

"The hoisting-sheaves on top are two in number, placed side by side. They are 12 in. in working diameter,  $15\frac{1}{2}$  in. from out to out, and  $3\frac{1}{2}$  in. wide; and the pin passing through them is  $2\frac{1}{2}$  in. diameter at the sheaves, and 2 in. diameter in the boxes. Experience teaches that these proportions are none too great to stand the severe work frequently put upon it in hoisting heavy weights and tearing out timber. The fall-rope attached to the hammer is 2 in. in diameter, and the 'runner' used in hoisting up piles is  $1\frac{3}{8}$  in. diameter.

"The hoisting-engine is a double-drummed Mundy engine of a nominal 25 horse-power.

"Fig. 26 shows the hammer used with this machine. The drawing is sufficient to show its general design. The weight is 3300 lbs.

"Fig. 28 shows the method of attaching the two 5-in.  $\times$  12-in. horizontal braces to the round side-braces, as further shown in Fig. 23."

In double-tracking a single-track road, or in repairing trestles in use, a form of driver mounted on a flat-car is found to be very convenient and economical. Figs 29 to 32 show the details of one of the latest designs for a driver of this kind.\*

It was constructed by the Missouri Pacific Railway, "with the purpose of obtaining a machine which could work effectively on piles at a further distance from the road-bed than usual. The design was worked out jointly by the Bridge and Building Department and the Car Department.

\* *Railway Review*, October 25th and November 8th, 1890. For description and illustrations of many different forms of railroad track pile-drivers, see committee report Proceedings Association of Railway Superintendents of Bridges and Buildings, 1902, pp. 163-220.







“ Fig. 30 shows the framing of the upper deck of the pile-driver and of the cab. It will be noticed that the main timbers are very long—57 ft. 8 in., and are 5 in.  $\times$  12½ in. in thickness. The side-sills are 6⅞ in.  $\times$  12½ in., and 43 feet long. From the centre of the track on which the platform revolves to the centre of the leads is a distance of 33 ft., and in order to reach work which is located 16 ft. to one side of the centre of the track the driver must swing to an angle of about 30° from the track. The upper platform travels upon three circular tracks. The first is a complete circle, having a diameter of nearly 9 ft., and as the car is 9 ft. wide and the upper platform 10 ft., this track is fixed. The next circle has a diameter of 13 ft. 3 in., and is composed of four pieces of rail of the ordinary section, two of which are firmly secured to the car platform, while the other two pieces overhang the sides of the car, and are removed while the pile-driver is in transit. When in use they are supported in position by two wrought-iron swing-brackets fastened to the outside face of each side-sill, and are also secured to fixed sections by fish-plates. The third circular track has a radius of 14 ft. 5 in., and is a bar of iron 4  $\times$  1 in. This track is not carried beyond the sides of the car. The wheels which bear upon the two smaller circles are attached directly to a heavy flooring on the under side of the platform, and as far as possible they are placed in the vicinity of a longitudinal sill, so as to give them as solid a bearing as possible. The rollers which bear on the outer one of the three tracks are secured to the under side of a heavy transverse bolster, which is composed of three pieces of wood with three wrought-iron plates 6 in.  $\times$  ⅞ in. in section intervening between them, the bolster being 6 in.  $\times$  10½ in. in section. The bolster at the centre-pin is wood 12 in. wide and 9 in. deep, and is trussed by two rods each an inch in diameter.

“ The construction of the leads and ladder will be best understood by a reference to Fig. 29. The leads are 36 ft. long, and are hinged to a heavy triangular framework, a detail of which is shown in Fig. 31. A sole-plate 10 in.  $\times$  ⅝ in. in section is secured to the upper face

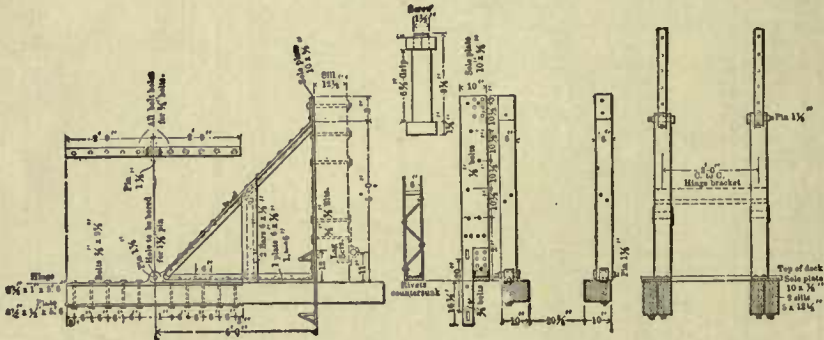


FIG. 31.—CAR PILE-DRIVER, MISSOURI PACIFIC RY. (DETAILS OF LEADS.)

of the longitudinal sills which support the beam. The hinge-frame is secured to this plate, and consists of plates 6 in.  $\times$  ⅞ in., reinforced by angle-irons. The inner faces of the leads are protected by steel channel-irons extending up from the bottom end for a distance of 26 ft. These afford a good bearing for the hammer, which is planed out to fit them.

“ The car upon which the pile-driver is carried is shown in Fig. 32. It is an exceedingly heavy car, as will be seen from an inspection of the drawing. It is 30 ft. long and 9 ft. wide, and very strongly trussed. The rack for moving the upper deck is seen in this view, and



requires no explanation. When the car is in transit, four jack-screws, one at each corner of the car, are adjusted against suitable sockets on the under side of the upper deck, so as to steady the entire superstructure. At the same time the upper deck is prevented from swinging out of a longitudinal position by means of suitable hooks attached to the upper deck, which engage eye-bolts in the ends of the car. When the pile-driver is at work these jack-screws are released, and the heavy screws seen extending down through the floor of the car are made to bear upon the truck frames. This prevents any undue strain on the trucks springs, and also any unsteadiness which might be caused from their elasticity."

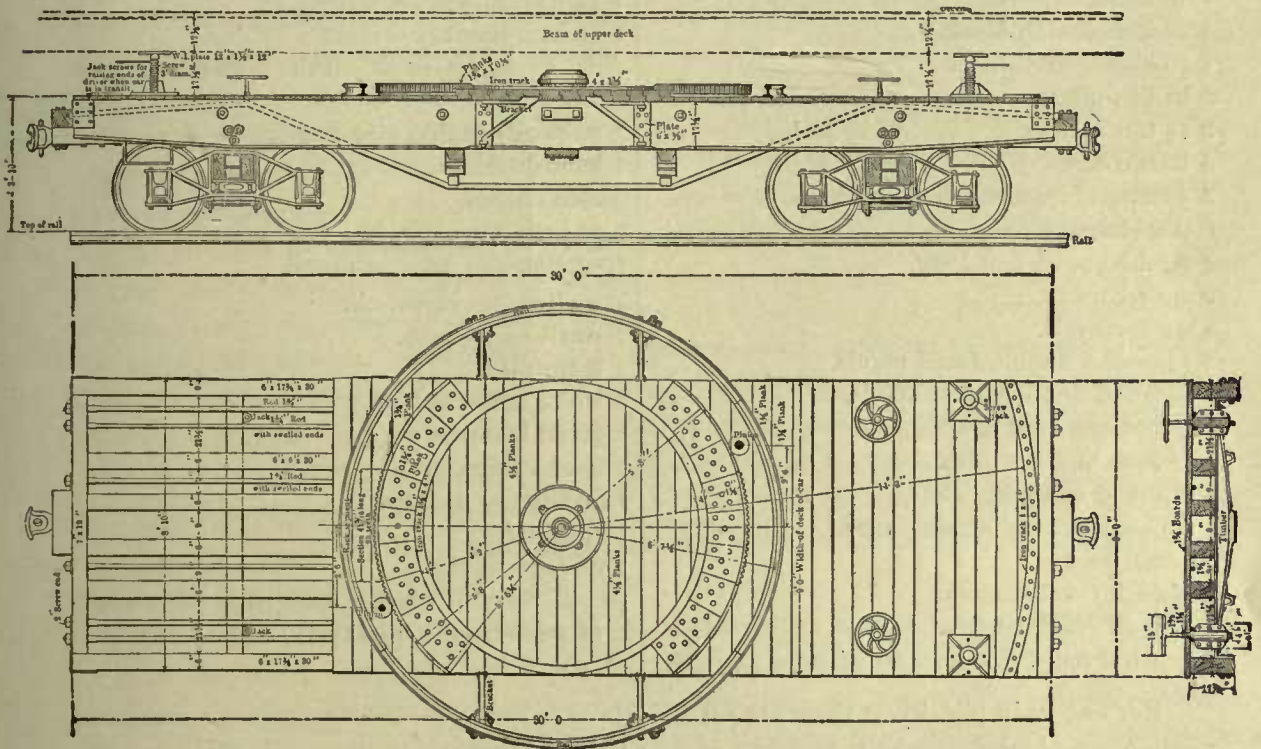


FIG. 32.—CAR PILE-DRIVER, MISSOURI PACIFIC RY. (DETAILS OF CAR.)

"The hammer weighs 2397 lbs., and is operated by a Lidgerwood hoisting-engine. As will be seen from the illustrations, the upper platform of the pile-driver is so long in comparison with the car which carries it that a flat-car at each end is necessary for its transportation. One of these cars is constructed for the purpose, and carries a supply of water and coal, and any other material which may be necessary. This is attached at the cab end of the pile-driver, and the one at the other end is a common flat-car."

On the Louisville & Nashville R. R. a tool-car always accompanies the pile-driver. Twenty-four feet of this car is boxed up for tools, ten feet is open for coarse tools, pile-rings, and a hand-car, which is always carried.\*

The tool-car contains the following tools:

- 500 feet of  $2\frac{1}{2}$ -inch-diameter best four-strand Manila rope.
- 250 feet of 2-inch-diameter best four-strand Manila rope.

\* G. W. Hinman, Proc. Assoc. Ry. Supts. B. & B., 1896.

1 coil of $\frac{1}{4}$ -inch ( $1\frac{1}{4}$ ?) diameter rope, 800 feet.	1 keg 30d nails.
300 feet of 1-inch rope.	2 kegs track-spikes.
300 feet of $\frac{7}{8}$ -inch rope.	2 kegs $8 \times \frac{3}{8}$ -inch boat-spikes.
2 good switch-ropes.	2 spike-mauls.
1 pair 8-inch patent, double-sheave tackle-blocks.	1 track-auger.
1 pair 12-inch patent, double-sheave tackle-blocks.	2 $\frac{7}{8}$ -inch S wrenches.
1 pair 16-inch patent, double-sheave tackle-blocks.	4 $\frac{3}{4}$ -inch S wrenches.
1 12-inch snatch-block.	2 $\frac{5}{8}$ -inch S wrenches.
1 16-inch snatch-block.	1 12-inch monkey-wrench.
2 band-pullers.	1 15-inch monkey-wrench.
2 15-ton hydraulic, foot-lifting jacks.	1 18-inch monkey-wrench.
4 10-ton screw-jacks, 18 inches high.	And wrenches to fit all the nuts on the pile-driver.
2 5-ton screw-jacks, 12 inches high.	3 pairs adjustable pipe-tongs.
6 steel bars $5\frac{1}{2}$ feet long.	1 hand-hammer.
4 steel bars, $4\frac{1}{2}$ feet long.	3 cold-chisels.
2 claw-bars.	2 12-inch flat files.
4 track-chisels.	10-gallon-can lubricating-oil.
2 14-pound double-faced mauls.	10-gallon-can signal-oil.
2 8-pound double-faced mauls.	2 small oiling-cans.
6 5-foot cross-cut saws.	1 lamp-filter.
12 8-inch mill saw-files.	8 white lanterns.
8 6-pound chopping-axes.	2 green lanterns.
2 ship carpenters' hewing-axes.	2 red lanterns.
10 cant-hooks.	1 grindstone and frame.
3 $1\frac{5}{8}$ -inch crank-augers.	1 hand-car.
2 $1\frac{1}{8}$ -inch crank-augers.	1 velocipede-car.
1 keg 10d nails.	50 pile-rings of various sizes to fit piles, made of good iron, 1 inch thick, $2\frac{1}{2}$ inches wide.

For engine in pile-driver there are carried:

5-gallon can of lubricating-oil.	1 soft hammer.
2-gallon can of cylinder-oil.	1 packing-hook.
1 pint oil-can, locomotive pattern.	And wrenches to fit all the nuts on the engine.
1 squirt-can.	

The cost of running a pile-driver per day on the Louisville and Nashville R. R. when building short trestles is as follows: \*

Foreman and ten men.....	\$22.00
Engineer, fireman, and watchman.....	6.80
Conductor and two flagmen.....	7.00
Coal, oil, and waste.....	2.50
Use of locomotive.....	12.00
For use of driver and tools.....	2.50
	\$52.80

When building long trestles the crew consists of a foreman and fourteen men.

\* G. W. Hinman, Supervisor B. & B., L. & N. R. R., Proc. Assoc. Ry. Supts. B. & B., 1896, p. 199.



For driving the piles of a trestle across the Kansas River at Topeka, Kan., Horace E. Horton, M. Am. Soc. C. E., Chief Engineer of the Chicago Bridge and Iron Company, designed and used a special apparatus that saved time and labor and "worked without the least difficulty from the first." Fig. 32a.\* The trestle bents were  $37\frac{1}{2}$  feet apart, connected by girder spans of  $6 \times 30$ -inch Oregon-fir stringers, and the pile-driver was designed to run along on the completed trestle and overhang it far enough to drive the piles for the next bent in advance. Two  $12'' \times 12'' \times 90'$ -beams were built up of four  $3'' \times 12'' \times 90'$  pieces each, and braced together by X bracings and cross-ties so as to form a horizontal Howe truss  $90 \times 11$  feet, which was partly covered by a floor platform and trussed in the planes of the beams by vertical posts and diagonal rods. It was then pivoted near one end at *C*, so as to swing horizontally on an iron bearing-plate *E*, sliding on a circular segment of rail *DD*. Both rail and pivot were fixed on a long supporting truck *T*, which travelled on four lines of rails laid along the completed trestle. When advanced to the last bent the truck carried the front of the overhanging platform over the centre of the next bent. On this end of the platform was established an ordinary pile-driver frame *F*, which was operated and balanced by the engine, boiler, etc., at the opposite extremity of the platform. By winding up with the hoisting-engine on a line *AB*, attached at *A* to the extremity of the forward cross-beam of the truck, the platform is swung through a horizontal angle sufficient to carry the pile-driver into the position shown by dotted lines in the plan over the centre line of the outer pile on either side. It can then be moved forward until exactly right and drive that pile, and by the use of the rope *AB* and adjusting the truck *T* easily shifted for every pile in the bent.

The following is a description of the pile-driver used in and the method of building a permanent trestle on the Ogden-Lucin cut-off of the Southern Pacific Company across an arm of the Great Salt Lake.†

The original plans of the portion of the Ogden-Lucin Cut-off that crosses the western arm of the Great Salt Lake called for 11 miles of permanent ballasted-deck trestle with 5.8 and 2.4-mile solid embankment approaches from the east and west shores respectively. These approaches were to be made by gravel trains dumping from a temporary trestle (4-pile bents) which was constructed at the same time as the permanent trestle (5-pile bents).

The last pile in the permanent trestle as originally planned was driven Oct. 26, 1903, and tracklaying was rushed across the trestle as fast as the decking was placed, so that by the middle of the following month steel had been laid on the cut-off without any break from Ogden to Lucin. While the work of filling in the temporary trestles was still in progress, early in 1904, the operation of freight trains over the partially completed cut-off was commenced.

It is of interest to note that the filling in of the western approach between June 2 and Dec. 12, 1903, proceeded at the average rate of 14,625 cubic yards per day.

The profile grade of the permanent trestle was El. 4217, and from each end of the permanent trestle the grade ran down to El. 4212 at the rate of 0.1 per cent. The surface of the water in the lake at this time averaged El. 4200, and the depth in the vicinity of the permanent trestle was 20 to 30 feet.

\* *Eng. Record*, May 19, 1894, p. 395.

† C. M. Kurtz, *Engineering News*, Sept. 21, 1911.

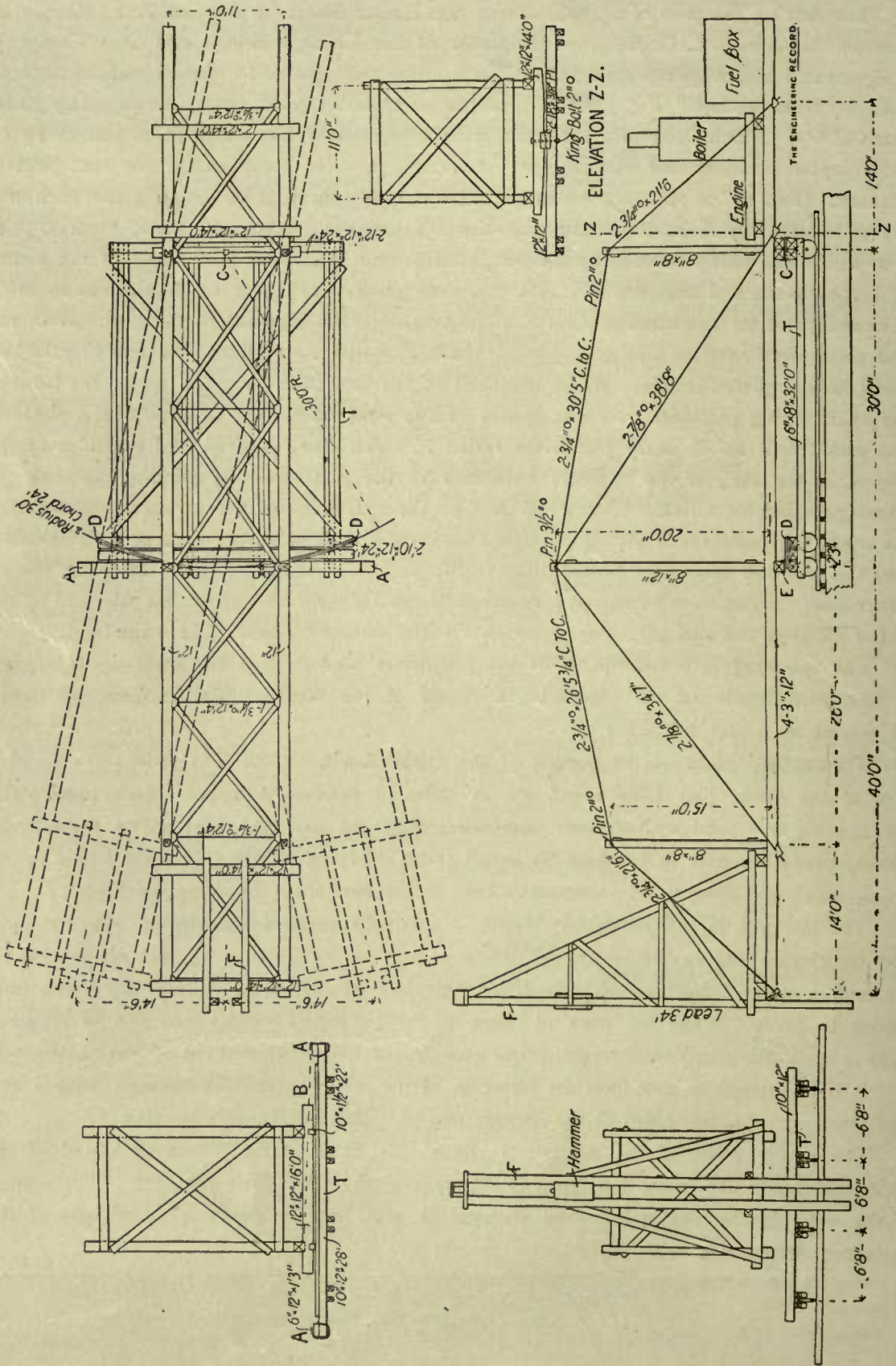


FIG. 32a.—AN OVERHANGING PIVOTED PILE-DRIVER.





piles from the side of a trestle. A car driver would have done the work perhaps, but would have been employed in actually driving piles a few hours only each day on account of having to take a siding one to two miles west of the work to let traffic pass.

The "roller-case" pile-driver was, therefore, designed by Mr. Roberts, to operate along the side of the temporary trestle on a low falsework consisting of two-pile bents, piles  $24\frac{1}{2}$  feet center to center, and bents 15 feet center to center, capped and connected up by  $8 \times 17$ -inch  $\times 30$ -foot trestle-stringers. This driver and its falsework are shown by drawing in Fig. 32*b* and in photograph by Figs. 32*c* and 32*d*.

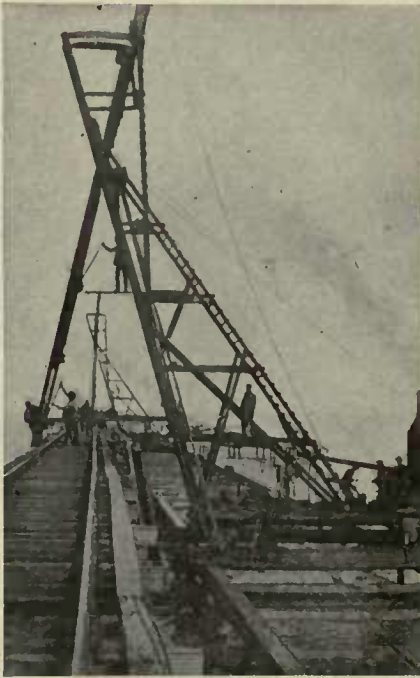


FIG. 32*c*—DRIVING OUTSIDE BATTER PILES,  
OGDEN-LUCIN CUT-GFF.

Briefly described, the framework of the driver consisted of stationary gins, built of two  $6 \times 10$ -inch  $\times 57$ -foot pieces of Oregon pine, framed so as to set at a proper batter to bring the king pins directly over the center of the trestle and 33 feet above the cut-off (pile) elevation. These stationary gins were rigidly held in place by two  $4 \times 6$ -inch  $\times 55$ -foot backstays,  $4 \times 6$ -inch wind braces and two  $\frac{3}{4}$ -inch wire cable guys as shown in Fig. 32*b*. The swinging gins were constructed of two  $6 \times 8$ -inch  $\times 52$  foot pieces of Oregon pine, faced with  $6 \times \frac{1}{4}$ -inch strap iron, and framed so as to be  $18\frac{1}{2}$  inches apart face to face of irons. These gins were also reinforced with  $6 \times 8$ -inch  $\times 40$ -foot timbers bolted to them as shown by a detail section in Fig. 32*b*. The swinging gins were hinged to the inside of the stationary gins by means of two  $2\frac{1}{2}$ -inch king pins set in two sets of swivel irons, and further guided in swinging by two  $1\frac{1}{2}$ -inch pins sliding on a  $3 \times 1\frac{1}{4}$ -inch

strap iron bolted to the upper surface of the moon beams, as shown in the side elevation and detail in Fig. 32*b*. This strap iron was bent to a curve of  $14\frac{1}{2}$ -foot radius and each end was bent upwards so as to prevent the gins from going too far in either direction. The swinging gins were held in their proper positions for driving the five piles of the bents by two  $4 \times 6$ -inch  $\times 18$ -foot planks bolted to the bottom of the swinging gins, and extending over to a cross-brace on the stationary gins. These planks were bored with five holes properly spaced, so that by placing a 1-inch pin in the hole over the lower cross strut of the stationary gins, the swinging gins were securely held as desired.

Two sets of four rollers each, and operating at right angles to each other, were set under the sills of the driver; the lower set to allow the driver to be moved longitudinally on the falsework, parallel to the trestle, and the upper set, at right angles to the trestle, to place the driver entirely in the clear of passing trains. The rollers, 10 inches in diameter and 6 feet long, were made of oak and were set in "cases" made up of two  $8 \times 17$  inch timbers, 30 feet long for the lower rollers and 22 feet long for the upper set. Several 1-inch holes



were bored in the projecting portion of the rollers, so that a final adjustment of the position of the driver could readily be made by inserting bars and turning the rollers by hand.

Two drivers, as described above, were constructed and they made satisfactory and excellent progress, as well, in fact, as that made by any one of the dozen or so skid drivers that were employed in driving the original permanent trestle. The driving of the 3000-foot extension by these two drivers was completed in about two months' time.

Fig. 32*c* shows the near driver driving an outside batter pile. Fig. 32*d* shows a freight

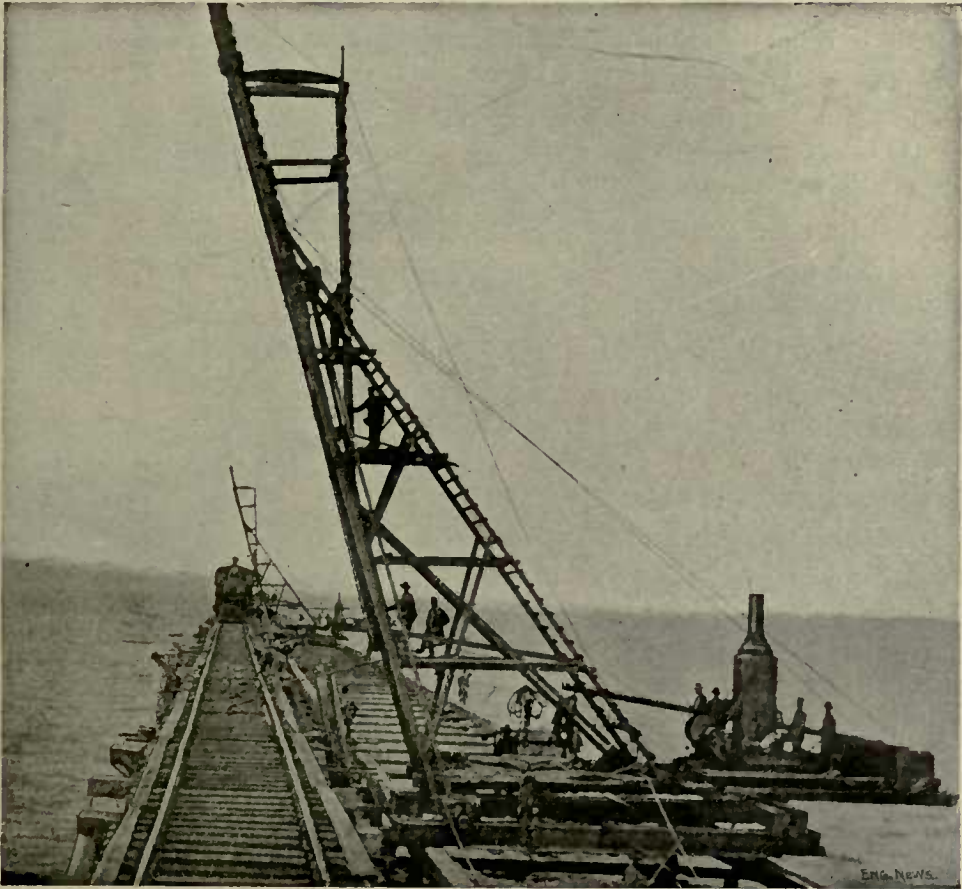


FIG. 32*d*.—THE ROLLER CASE PILE-DRIVERS SWUNG BACK FOR PASSAGE OF A FREIGHT TRAIN.

train about to pass the two drivers, the swinging gins of each being swung back between the stationary gins and the drivers themselves rolled out to clear.

The physical conditions that make the "roller case" driver, as described in this article, best adapted to the work, are shallow water, so that reasonably steady falsework may be cheaply constructed, and soft ground, so that the driving will not be hard.

In use the ordinary drop-hammer tends to batter the heads and split the piles. It is claimed that the steam pile-hammer overcomes this objection to a very large extent, and that it will drive the piles more rapidly.

"After the steam-hammer begins operation the blows are so rapid—70 to 100 per minute—that the earth once disturbed has no time to settle, and the pile sinks through it in somewhat the same manner as it would when the earth is loosened and held in suspension by a water-jet."\*

Messrs. Ross & Sanford drove on an average 83 piles, having a penetration of 17 feet, in material mostly sand and oyster-shells, per day of ten hours, with one of these steam-hammers. There were 1459 piles in all in the work, which was a pile-dike in the Passaic River, N. J. The best ten-hours' work was 121 piles. The best work in the same time with an ordinary driver was 63 piles. In the matter of expense the steam-hammer costs more for steam than the ordinary driver, but this is more than offset by the saving in pile-bands, rope, and the number of men on the machine.

Figs. 33 to 37 show such a hammer, and the method of using it. The following reference-letters will aid in enabling one to understand the construction of the machine:

A. A. Ten inch I-beams forming the sliding-frame within which the hammer H L slides.

B. Cross-girder riveted to the upper ends of the I-beams (A) by means of which and the bail (S) the whole apparatus is raised or lowered for adjustment to the head of the pile.

C. Hollow piston-rod hung loosely on a collar through a hole in the cross-girder (B).

D. The steam-chest, supported by the cross-girder (B) and covering the opening of the piston-rod (C).

E. Piston-head and plug of the end of the hollow piston-rod (C).

F. Steam-openings in the hollow piston-rod (C) through which steam passes to the space (G) surrounding the rod.

G. Annular space (between the piston-rod and the interior of the hammer) which forms the steam-cylinder.

H. Hammer-cylinder.

I. Cylinder-cover with stuffing-box.

J. Foot-block or bonnet casting riveted to the lower ends of the I-beams and forming the lower part of the sliding-frame.

K. Conical opening through the foot-block (J) shaped to receive the head of the pile.

L. Cylindrical prolongation of the hammer-cylinder (H), forming the hammer-head.

M. Lever which works the steam-valve.

N. Fulcrum for the lever (M) bolted to the face of the girder (B).

O. Attachment of the lever to the valve-stem.

P. Upper trip, which throws the valve-stem in and supplies steam to the cylinder (G).

Q. Lower trip, which throws the valve-stem out and exhausts the steam. (P and Q are both attached to the hammer-cylinder.)

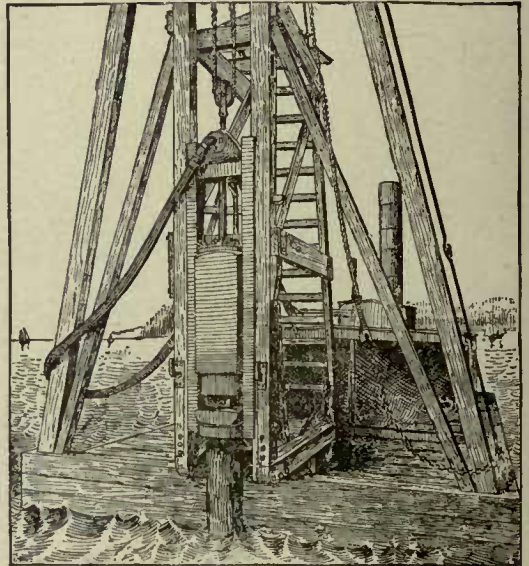


FIG. 33.—STEAM PILE-HAMMER IN OPERATION.

\* "Builders and Contractors' Engineering and Plant:" *The Sanitary Engineer.*



- R. Vent for air and condensed water.
- S. Bail by which the whole machine is lifted.
- T. Connection of steam-hose with steam-chest.
- U. Springs to guard foot-block.
- V. Balanced steam-valve.
- W. Set-screw regulating travel of steam-valve.
- X. Mouth of steam-chest (D).

" Fig. 33 is a part general view of a scow pile-driver, with the machine lowered and resting on a pile.

" Fig. 34 is a rear elevation of the machine, showing the valve-tripping apparatus, also a sectional plan on line **A A**.

" Fig. 35 is a central vertical section on line **B B**.

" Fig. 36 is a side view, also section on **C C**.

" In use the whole apparatus slides on a pair of ordinary ways or 'leaders,' being raised or lowered by means of the bail (s).

" When ready for use, as shown in Fig. 33, the hammer is at the bottom of the frame resting on the springs U,—or, if the pile is set up, on the pile,—the piston-head being at the top of the cylinder.\* These springs U serve to catch any chance blow and prevent injury to the foot-block (J). The hammer-head, of course, projects through the orifice (K) in the foot-block, and as much as the pile-head enters the orifice, so much is the hammer-cylinder pushed up, so that its whole weight rests on the pile.

" On the admission of steam through the flexible hose attached to the inlet (T), it passes through the piston-rod into the cylinder (G), the hammer slides upwards in its frame A B J to the extent of its stroke (or about 40 inches for a large machine); then the steam is exhausted through the tripping of the valve, and the hammer falls, giving a free blow. The upper trip at once admits steam, and the operation is quickly repeated."

" Fig. 37 shows details of the valve and steam-chest.

" The valve itself is shown in end projection at A, and side projection at B, and is a hollow cylinder, with open ends and a ring Y cast around its periphery, with a slot Z cut through its shell near the ring, and with the socket by which it is held upon the valve-stem supported by four radial webs (1) extending the length of the valve and attached to its shell. The jamb-nuts (2) hold it firmly upon the valve-stem, where the valve is shown in place in section of steam-chest between lines v v. The upper wall of the steam-chest at (3) is made hollow to preserve equal thickness of metal for uniform expansion, etc., and is connected by openings (4) with interior of steam-chest, so that steam finds constant admission and can circulate from end to end of steam-chest in this way as well as through the hollow valve.

" The cylindrical box (5) is cast so as to surround the valve, and connects, first, through slot 6 with the opening 7, which joins the hollow piston-rod leading to the hammer cylinder, and, second, with the exhaust orifice 8 through 9, which opens to the air. The tongue (10) separates the box into two portions used for exhaust and supply respectively, each of which has an annular slot (8 and 6) through the steam-chest shell surrounding the valve-shell.

\* Corrected from original.

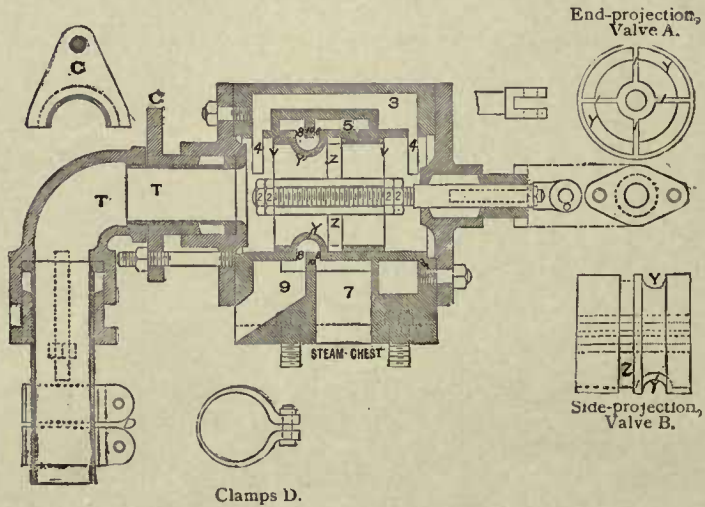
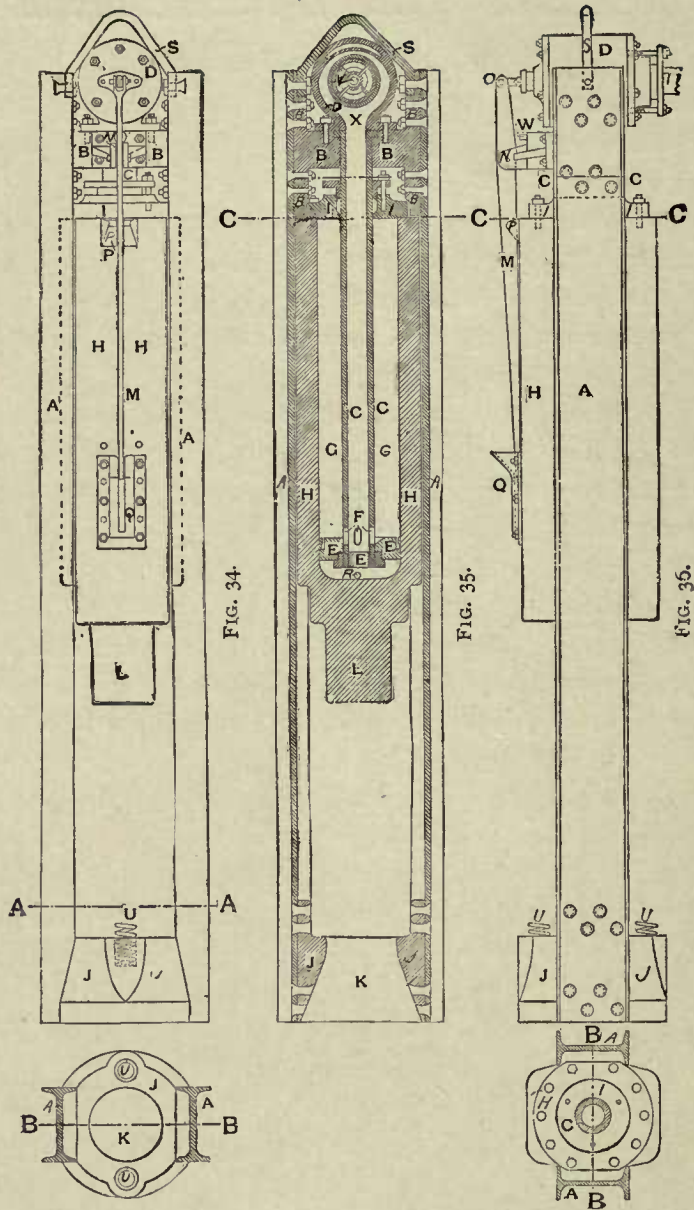


FIG. 37.—BALANCE-VALVE.

FIGS. 34 TO 37.—DETAILS OF CRAM'S STEAM PILE-HAMMER.



"It will be noticed that the only steam-pressure on the valve is outward from within the cylindrical valve-shell, and can exert no influence toward producing friction. In other words, the valve is so perfectly balanced that it works readily, whether with or without steam supplied.

"In the drawing the valve is slid out, or as it would be thrown by the trip Q acting upon the lever M when it is ready to fall. In other words, the steam is being exhausted as the ring Y straddles the two slots 6 and 8, and steam from within the hammer cylinder finds vent up the hollow piston-rod and out the exhaust-port (9).

"The complete action is then: The hammer falling, the valve is thrown so the slot Z covers 6, while the exhaust-slot 8 is covered by metal. The steam from steam-hose connection T through the hollow valve-slot, Z, 6 and 7, and hollow piston-rod finds admission to the interior of the hammer, which causes it to rise until the lever throws out the valve, and steam is exhausted as before.

"The hammer-cylinder weighs 5500 lbs., and with 60 to 75 lbs. steam gives 75 to 80 blows per minute. With 41 blows a large unpointed pile was driven 35 feet into a hard-clay bottom in half a minute.

"The steam-valve has a travel of five eighths of an inch in a steam-jacketed chest. The length of its movement is adjustable, so as to suit the force of the blows to the work in hand."

The cost of these drivers varies according to size and weight of ram, as follows:

Size.	Weight of Ram.	Price.	Width between Leaders.	Length of Stroke.	Total Weight.	Total Length.
B	5500 lbs.	\$800	27 inches	40 inches	8400 lbs.	12 feet
C	3000 "	700	20 "	40 "	5500 "	12 "
D	2000 "	500	20 "	24 "	4200 "	8½ "

Including 30 feet of steam-hose and couplings.

The following is a description of a water-jet pile-driver, Fig. 37A, used in building the jetty at the mouth of the Columbia River, Oregon, as given by Mr. G. B. Hegardt, the engineer in charge\*:

The whole upper portion is mounted upon a car composed of trussed wooden beams, connected and bolted together, forming a strong rectangular framework 17 ft. long and 19 ft. wide, thus extending over and running on both tracks. This car-frame is supported at each of the four corners by a double truck of 8 wheels, making 32 wheels in all.

The axles run in brass bearings in pedestals, which are bolted to two square frames of 7-in. channel-bars; and resting across the top of these frames are two 12-in. bars, from which are suspended the centre-pins of the trucks. The two centre-pins of a pair of trucks extend down through and support a box-girder of plates and I-beams about 6 ft. long, and upon this girder rests the wood framework of the car. Upon the car is a roller-path 16 ft. in diameter, of 30-lb. rail; a similar one, but inverted, is secured to the upper or revolving portion of the driver. This turntable runs upon 48 steel rollers.

The upper portion of the driver consists of a braced platform, supported at the ends by hog-stays, and carrying the gins at one end and the boiler, tanks, fuel, etc., at the other. The pump is carried on a frame which is suspended over the side of the track; the steam for work-

\* *Engineering News*, Apr. 18, 1891, p. 368.

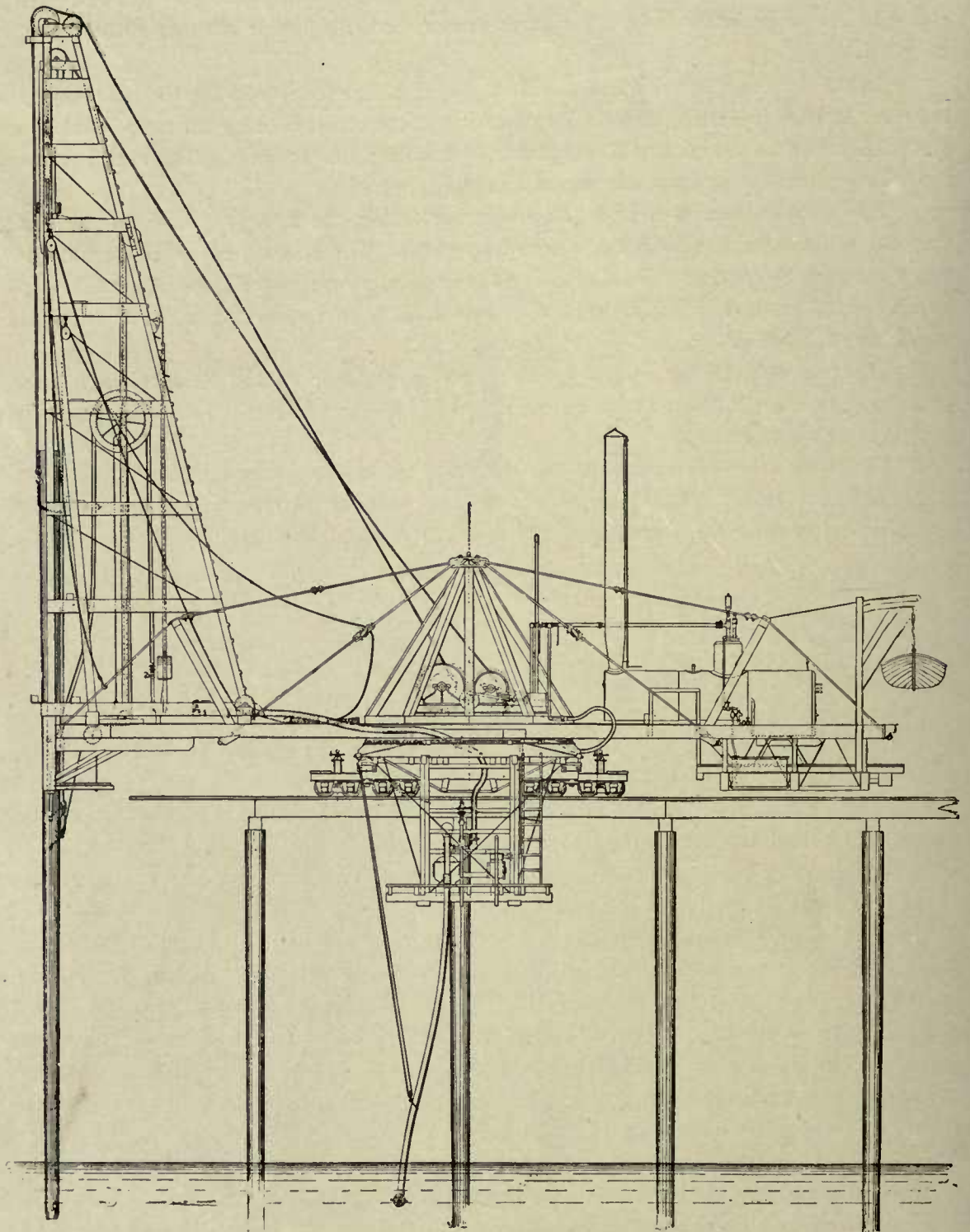


FIG. 37A.—WATER-JET PILE DRIVER.



ing it is passed through pipes, which are connected by flexible hose with couplings for detaching when the driver revolves. Couplings are also provided on the water-discharge hose for the same purpose.

The discharge-hose ( $4\frac{1}{2}$  inches) is connected to a Y pipe which has two  $2\frac{1}{2}$ -in. branches, each having a gate-valve; the two pipes lead upward and connect with two lengths of hose passing over large pulleys running in a frame, which slides in vertical guides; the other ends have couplings to connect with the jet-pipes on the piles. The jet-pipes are  $1\frac{1}{2}$  in. in diameter, and two of them are secured to each pile by means of staples.

The method of working is as follows: The driver is revolved by means of a pinion and toothed segment until the gins are opposite the tender-car, which contains material for construction. A line is attached to the large end of the pile, and, passing over sheaves at the gin top, lead to a drum on the engine. Another line is attached to the small end of the pile and leads through a block on the gins, then down to a guide-pulley on the platform, and thence to a capstan head on one of the engine shafts. The pile is lifted horizontally off the tender-car, the driver is then revolved and secured in the required position, the small end of the pile is lowered, and the line detached, leaving the pile suspended between the leaders.

The hose-pipes are then coupled to the jet-pipes, which have permanently fastened to each of them a short piece of chain terminating in a ring and dowel. The ends of the chains are brought together and the dowels lightly driven into the pile; a 4-in. line is made fast to

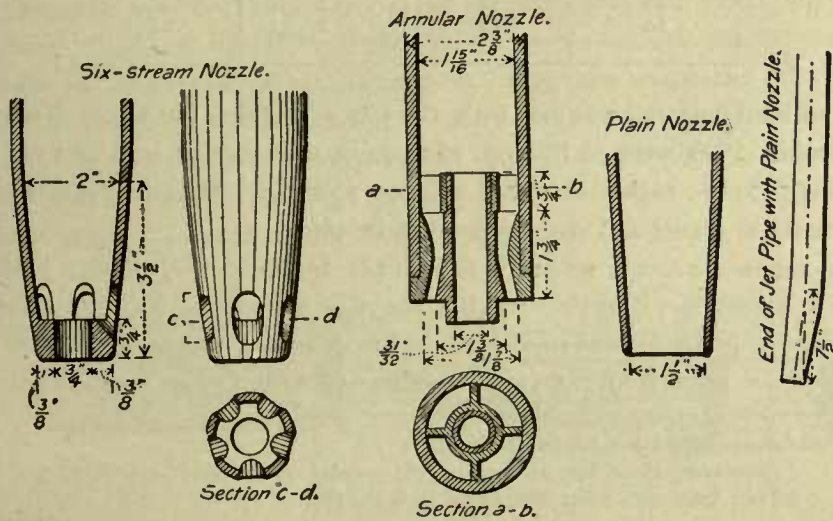


FIG. 37B.—NOZZLES FOR WATER-JET PILE-DRIVER.

the rings, and, leading up, passes through a block on the gins; another smaller line is hooked to the rings, and, passing over guide-pulleys, depresses the hose pulley-frame and relieves the hose-pipes from tension, when the pile sinks to the bottom. The hammer is then lowered and allowed to rest on the pile, the pump is started, and the pile begins to sink into the sand.

When the head of the pile has come within five or six inches of its required level the pump is stopped, the hammer raised, and the 4-in. line hauled up, pulling out the dowels and drawing up the two jet-pipes through the staples clear of the pile. A few light blows of the hammer bring the head of the pile to grade. When a row of four piles has been driven a cap

is bolted across; the stringers and rails are then extended, and the driver moved forward for the next bent.

Fig. 37B\* shows three forms of nozzles as used in sinking piles by a jet driver on work under the Missouri River Commission. The 1½-in. plain nozzle, for general service, proved most satisfactory. For "gumbo" the annular nozzle proved best, and the six-stream nozzle gave very satisfactory results in penetrating gravel.

In driving piles by water-jet for the Inter-State Bridge, Omaha, the following data were arrived at by experiment and observation for determining the volume of water and the sizes of pipes and nozzles †: The approximate volume of water required can be obtained by using 16 gals. per inch of average diameter of pile per minute. This will give good results for a penetration of 40 ft. After that increase the volume of water at the rate of 4 gals. per inch diameter of pile per minute for each additional 10 ft. of penetration.

With this pump (Deane compound duplex 8 × 12 and 7 × 10, nominal capacity of 350 gals. per min.) capacity, use for various depths the number and sizes of pipes given below:

Depth of Penetration, feet.	Size of Pipes, in.	No. of Pipes.	Diam. of Nozzle, in.
20	2	1	1
30	2½	1	1½
40	2½	2	1½
50	2½	2	1
60	2½	2	1½

Where no hard material was met with, the pile would sink the whole distance of 50 ft. in from 4 to 6 min. Piles were 70 ft. long, 16 to 24 in. diameter at butt and 10 in. at top, and weighed about 7000 lbs. each. Hammer weighed 3000 lbs. Material penetrated consisted of sand, silt, streaks of gravel and clay 12 in. to 18 in. thick.

**Hammer-ropes.**—From a series of tests made by Mr. Geo. J. Bishop ‡ of the Chicago, Rock Island & Pacific Ry. it would seem that the most economical rope for use with a 3000-lb. hammer is common 3-ply Manila rope 1½ inches in diameter, weighing about 74 lbs. to 125 ft. This conclusion was reached after trying a number of different ropes under the same conditions.

\* *Engineering News*, Dec. 6, 1890, p. 498.

† *Engineering News*, Apr. 19, 1894, p. 316, contains cut and description of driver.

‡ Proc. Amer. Int. Assoc. Ry. Supts. B. & B., 1897, p. 250.



## CHAPTER IV.

### FRAMED BENTS.

FRAMED BENTS are built upon a foundation of some kind, the object of which is to raise the sill from the ground and thus lengthen its life—which at the best is short enough—as much as possible. When the sill is partly or wholly buried in the ground decay soon sets in and proceeds with great rapidity, and the practice either of allowing the sill to rest upon the ground or of partially or wholly covering it with earth is to be very strongly condemned.

The foundations may be divided into seven classes: masonry, pile, mud-sill or sub-sill, grillage, crib, solid rock, and loose rock.

Masonry foundations are of third-class masonry, and are built of such material as may be found near at hand. The stones should be as large and flat as possible, all those with any rounded surfaces being carefully excluded. The masonry should penetrate the ground to below the frost-line so as to prevent heaving, which would tend to rapid disintegration and destruction. It should also rest upon a firm bed. For low trestles, where the sills are short, the masonry may extend the whole length of the sill, but where the bents are over 10 ft. in height it becomes more economical to divide it into three sections, placing one part under the centre-posts and one under either batter-post. The part under the centre-posts should be long enough to give a good solid bearing to each of them, and to extend some little distance beyond them. The faces of the foundation should have a slight batter, thus giving it the shape of a truncated pyramid. Figs. 38 and 39 show the shape, size, and arrangement of the masonry foundations as used on the New York, Ontario & Western Railroad.

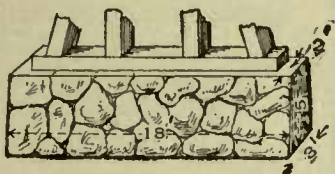


FIG. 38.

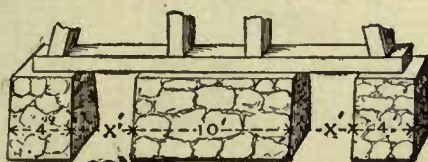


FIG. 39.

MASONRY FOOTINGS.

Masonry forms excellent foundations—more durable than any other kind. They are practically indestructible if well built, not being liable to decay, and are very economical in maintenance, as the life of the sills is greatly prolonged, and the repairs to the foundation amount to practically nothing. It is well (but hardly the general rule) to fasten the sills to the foundations by means of iron rods built into the masonry. This prevents vibration to a very considerable extent.

These rods should be from  $\frac{3}{4}$  in. to 1 in. in diameter and about 3 ft. long. If desired, a head may be formed on the lower end and anchor-plates employed, though this is not essential.

In pile-foundations one pile is usually placed under each post. The sill is fastened to

the piles in any of the ways previously described for fastening on the caps of pile-bents. In very high trestles it is at times found desirable to place two piles under each post. It is often convenient, especially where pile-timber is plenty, and desirable framing timber of a considerable length is difficult to obtain, to use a pile-bent of from 10 to 20 feet high, and then place a framed one on top of it. On some roads when the trestle is over a water-way, a pile-foundation is surmounted by a framed bent, the piles being of such a height as to always remain entirely submerged. By this means the decay due to the alternate wetting and drying of the timber is almost wholly confined to the framed portion, which is easily replaced: hence it is said that this style of structure is very economical over bays and inlets affected by the tides.

The practice as to mud-sills or sub-sills varies a great deal. Some prefer thin planks only 3 in. or 4 in. thick; others, material 12 in. by 12 in. The thicker material is the better, as it raises the sill higher from the ground, and is not so rapidly weakened by decay. Sub-sills should only be used when the surface is rock or where the ground is quite hard. In

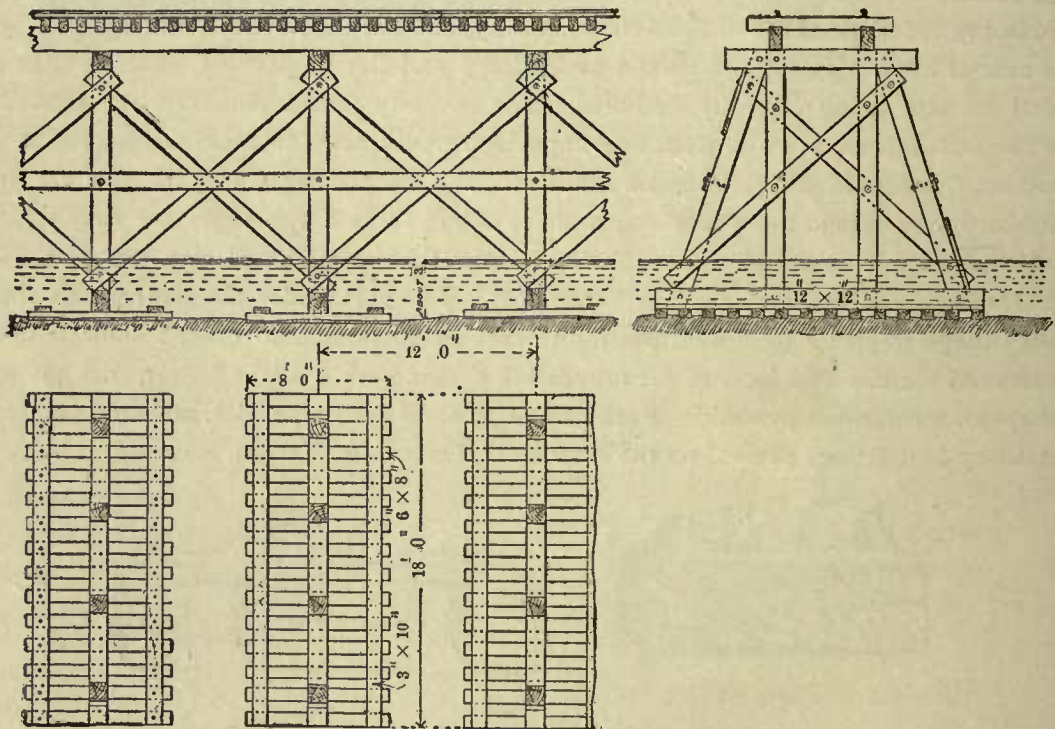


FIG. 40.—GRILLAGE FOUNDATION.

other cases piles or masonry should be employed, depending on circumstances. Some go to the trouble of notching the sub-sill and sill together. This is not necessary, and adds more to the expense of construction than the good derived from it warrants. It is always better to spike or drift-bolt the two together to some extent, though it is not necessary to fasten every sub-sill in this way when there are more than four under the bent. When longitudinal girts are placed immediately above the sill, no fastening at all of the sill to the sub-sill is required.

A grillage was used as a foundation for a trestle on a branch of the New York, New Haven & Hartford Railroad, over Hanover Pond, at Meriden, Conn. The water was still



and shallow, and the bottom soft, treacherous, and of unknown depth. Piles could not be economically used, and hence Mr. J. Devin devised this expedient.

The grillage was made by arranging a number of railroad ties about 15 in. apart, as shown in Fig. 40, and fastening them together by two 3 in. by 10 in. binder-planks spiked to each tie. It was then floated to its place and a framed bent placed upon it, one grating being used for each bent. The weight of the structure sunk the grillages so that they rested on the bottom. The sills were not fastened to them, the bents being kept in place by both sway and longitudinal bracing. It seems as though it might be more advisable ordinarily to fasten the sills to the foundation by a few drift-bolts. This foundation is said to give perfect satisfaction under constant traffic. One grating was put-in-with the binder-planks underneath, but was quickly undermined its whole length either by a slight current or by springs. The trouble was obviated by turning the grating over.\*

On some of the branches from the Cripple Creek extension of the Norfolk & Western Railroad, crib foundations are used for the trestles. These cribs are formed by piling logs on top of each other, notching them where they cross, and then filling up the interior with stones (Fig. 41).

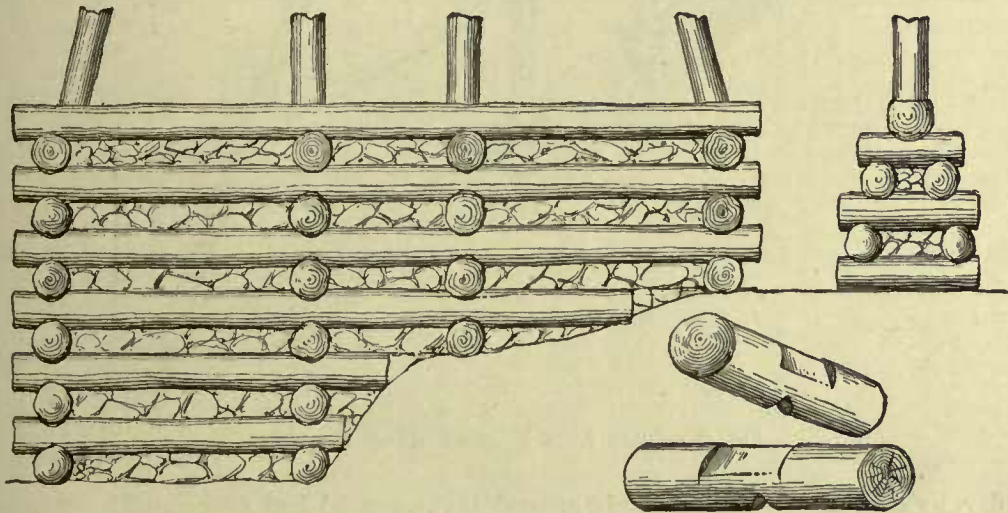


FIG. 41.—CRIB FOUNDATIONS.

They are built pyramidal in form, and are suitable for side-hill work where the slope is not too great, though their use is not by any means limited to this kind of ground, as they form as good a foundation on the level. When on a side-hill the ground beneath them is excavated in steps, and the cribs are built up level so as not to necessitate the breaking of the sill. The logs composing the crib should be at least 10 in. in diameter at the smallest place, and it is better if they are not under a foot.

A novel plan for obtaining a foundation on a side-hill where the surface was of solid rock was adopted on some work by Mr. J. E. Woods, C.E. Holes were cut in the rock where the feet of the posts were to come, and after the posts were placed in them and the bent

\* *Eng. and Build. Rec.*, Dec. 24, 1887.

completed, the remaining spaces were filled with cement (Fig. 42). Of course no sills are required with this form of foundation. The ends of all the posts were tarred before they were placed in the holes.

Where loose rock is plentiful, and cement or lime costly, pretty serviceable foundations may be obtained by filling trenches with it. Sub-sills should be laid on top of these, and the sills rest upon them. This is done in order to distribute the weight over a larger surface.

The life of sub-sills can often be greatly lengthened, and loose rock foundations kept

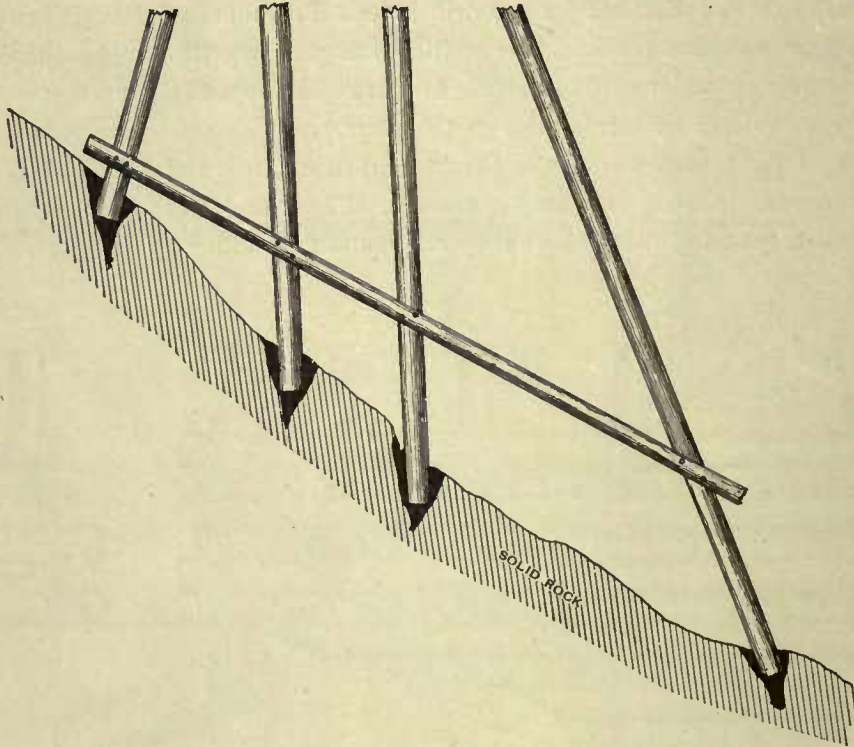


FIG. 42.—SOLID ROCK FOUNDATIONS ON SIDE-HILL.

quite dry, by digging a trench entirely around them, several feet away, and leading off the water that accumulates.

Sills (except when split) should not be of smaller timber than 12 in. square, and should extend from 12 in. to 18 in. beyond the outside of the batter-posts. In very high trestles the sills are usually made up of several pieces. Some examples of these are shown in the cuts of special trestles. When the sills are mortised, a drip-hole  $\frac{1}{2}$  in. in diameter should always be bored with a downward inclination from the bottom of the mortise to the outside of the sill. Figs. 43 and 44 show the method of boring these drips on two roads.\* The object is to keep the water from collecting in the mortises, which would hasten the decay of the sill.

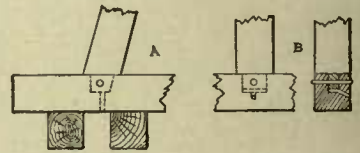


FIG. 43.

FIG. 44.

D RIP-H O L E S.

\* Charleston, Cincinnati & Chicago Railroad; Central Railroad of Georgia, V. H. Kriegshaber, Assistant Engineer.



There are usually four posts to a bent—two vertical or plumb posts, and two batter-posts. As a rule, they are all made of the same size timber,—12 in. × 12 in. Occasionally either all, or else the batter-posts, are made of 9-in. × 12-in. or 10-in. × 12-in. material, and sometimes, in very low trestles, 10-in. × 10-in. is employed.

The large size, 12-in. × 12-in., is rather to be preferred in all cases, it being far more advisable to have an excess of strength in this part than any tendency to weakness. The extra cost for timber does not amount to very much. The plumb-posts should be spaced from 4 ft. to 5 ft. between centres, and the batter posts 11 ft. from centre to centre at the top, immediately under the cap. The inclined posts should have a batter of 3 in. per foot. This give a broad base, and adds considerably to the stiffness of the bent. Other batters are frequently made use of, varying from 2 in. to 4 in. per foot, though 2½ in. and 3 in. are the most common. Table VIII gives the length of the batter-posts for different heights at an inclination of 3 inches per foot.

TABLE VIII.

Length of Batter-posts; Batter 3" per Foot.

Distance between Cap and Sill.		Length of Stick.				Distance between Cap and Sill.		Length of Stick.				Distance between Cap and Sill.		Length of Stick.				Distance between Cap and Sill.		Length of Stick.									
		Shoulder to Shoulder.	Stick with Square Ends.	With two 5" Tenons.				Shoulder to Shoulder.	Stick with Square Ends.	With two 5" Tenons.				Shoulder to Shoulder.	Stick with Square Ends.	With two 5" Tenons.				Shoulder to Shoulder.	Stick with Square Ends.	With two 5" Tenons.							
3	0	3	1	3	4	4	2	13	13	4	13	7	14	5	23	23	8	23	11	24	9	33	34	0	34	3	35	1	
3	6	3	7	3	10	4	8	13	6	13	11	14	2	15	23	6	24	2	24	5	25	3	33	34	6	34	9	35	7
4	4	4	1	4	4	5	2	14	14	5	14	8	15	6	24	24	8	24	11	25	9	34	35	0	35	3	36	1	
4	6	4	7	4	10	5	8	14	6	14	11	15	2	16	24	6	25	3	25	6	26	4	34	6	35	6	36	7	
5	5	5	1	5	4	6	6	15	15	5	15	8	16	6	25	25	9	26	0	26	10	35	36	0	36	3	37	1	
5	6	5	8	5	11	6	9	15	6	15	11	16	2	17	25	6	26	3	26	6	27	4	35	6	36	7	37	8	
6	6	6	2	6	5	7	3	16	16	5	16	8	17	6	26	26	9	27	0	27	10	36	37	1	37	4	38	2	
6	6	6	8	6	11	7	9	16	6	17	0	17	3	18	26	6	27	3	27	6	28	4	36	6	37	7	38	8	
7	7	7	2	7	5	8	3	17	17	6	17	9	18	7	27	27	10	28	1	28	11	37	38	1	38	4	39	2	
7	6	7	8	7	11	8	8	17	6	18	0	18	3	19	27	6	28	4	28	7	29	5	37	6	38	7	39	8	
8	8	8	3	8	6	9	4	18	18	6	18	9	19	7	28	28	10	29	1	29	11	38	39	2	39	5	40	3	
8	6	8	9	8	0	9	10	18	6	19	0	19	3	20	28	6	29	4	29	7	30	5	38	6	39	8	40	9	
9	9	9	3	9	6	10	4	19	19	7	19	10	20	8	29	29	10	30	1	30	11	39	40	3	40	6	41	3	
9	6	9	9	9	10	10	10	19	6	20	1	20	4	21	29	6	30	4	30	7	31	5	39	6	40	8	41	9	
10	10	10	3	10	6	11	4	20	20	7	20	10	21	8	30	30	11	31	2	32	0	40	41	2	41	5	42	3	
10	6	10	9	11	0	11	10	20	6	21	1	21	4	22	30	6	31	5	31	8	32	6	40	6	41	9	42	10	
11	11	11	4	11	7	12	5	21	21	7	21	10	22	8	31	31	11	32	2	33	0	41	42	3	42	6	43	4	
11	6	11	10	12	1	12	11	21	6	22	1	22	4	23	31	6	32	5	32	8	33	6	41	6	42	9	43	10	
12	12	12	4	12	7	13	5	22	22	8	22	11	23	9	32	32	11	33	2	34	0	42	43	3	43	6	44	4	
12	6	12	10	13	1	13	11	22	6	22	2	23	5	24	32	6	33	6	33	9	34	7	42	6	43	9	44	10	

The second columns in the table give the length of the post without tenons, measuring along one of the faces after the ends have been cut off at the proper angle; the third columns, the length of a piece of timber with square ends required to cut the post; and the fourth columns, the length of a piece of timber with square ends required when there is a tenon 5 inches long on each end. The table is used thus: What is the length of timber required for the batter-posts of a bent 21 ft. 6 in. high, the posts being connected to both cap and sill by a 5-inch tenon? Taking the thickness of both cap and sill from the height of the bent in order to find the distance between them, we have 21 ft. 6 in. — 2 ft. = 19 ft. 6 in.

Now looking in the table we find in the fourth column, opposite 19 ft. 6 in., that the length required is 21 ft. 2½ in.

For framing in the field, try-squares, set to the proper angle for cutting the ends of the batter-posts, are very convenient. Fig. 45 shows a form of template for direct use. It consists of a ½-in. board cut to the requisite angle with a 1¼-in. square piece fastened along one edge. It is used in the same manner as an ordinary carpenter's square.

Some designers prefer to have the batter-posts touch the plumb-posts where they meet the cap, as in Fig. 46, while others incline all of the posts (Fig. 47). When all of the posts are

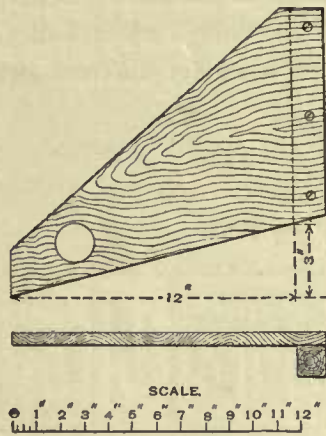


FIG. 45.  
BATTER-POST TEMPLATE.

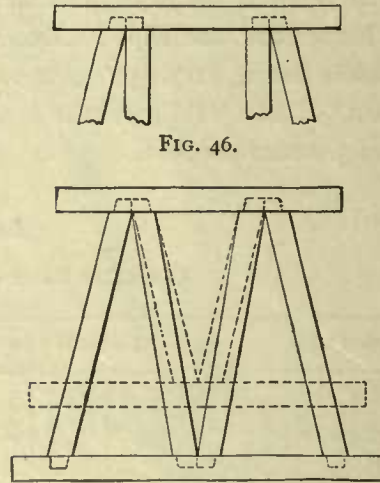


FIG. 46.  
ARRANGEMENT OF POSTS.

inclined, the distance between them at the top is fixed, as is also the batter of the outer posts, while that of the inner ones varies with the height.

It is well to make solid caps of at least 12 in. × 12 in. timber and 14 ft. long. Where the timber is inclined to be weak or brittle, they should be 12 in. wide by 14 in. deep. There are six different ways of joining the sills, posts, and caps together, viz., by

- |                     |            |                       |
|---------------------|------------|-----------------------|
| Mortise and tenon ; | Dowels ;   | Iron-joint plates ;   |
| Drift-bolts ;       | Plasters ; | Split caps and sills. |

A tenon 3 in. thick, 8 in. wide, and 5 in. long is a very good size. The mortise should be a little deeper—say ½ in.—than the length of the tenon. They should be snugly fitted to

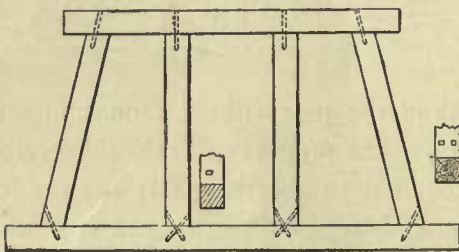


FIG. 48.—ARRANGEMENT OF DRIFT-BOLTS.

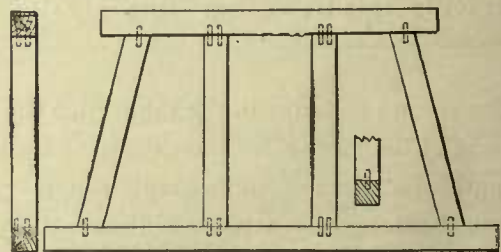


FIG. 49.—ARRANGEMENT OF DOWELS.

each other, and the sides made as smooth as practicable. The same precaution in regard to boring the holes in the tenons, as mentioned when speaking of the tenons on piles, should be



observed here, so that the work may be drawn tightly together. Wooden pins should always be used to hold the parts together.

When drift-bolts are employed, two should be used for fastening each post to the sill, and one for securing it to the cap. A hole very nearly the size of the drift-bolt should be bored through the first stick of timber penetrated, and one somewhat smaller through the balance. The drift-bolts may be arranged as in Fig. 48.

In dowel-joints two dowels should be used in both cap and sill to each post. They should be  $\frac{3}{4}$  in. in diameter, by at least 8 in. long, and arranged as in Fig. 49.

A plaster-joint is one of the most convenient forms for some uses. It is especially advantageous when making repairs, and is made by spiking and bolting a piece of plank 3 in. thick, 12 in. wide, and 3 ft. long to each side of the cap or sill, as the case may be, and to each post. This joint has been adopted by the Delaware and Hudson Canal Co., and is said to be proving very satisfactory. The details are shown in Fig. 50. With this joint all the posts should be notched 1 in. to both sill and cap.

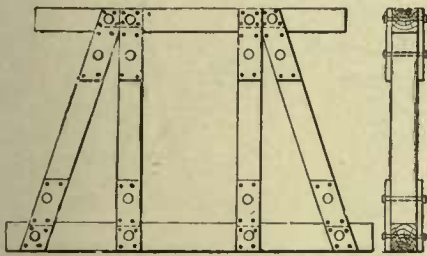


FIG. 50.—PLASTER-JOINTS.

There is a joint in use on the New York, Lake Erie & Western Railroad,\* made with an iron plate bent in a special manner, and which allows of the very easy removal of parts for repairs, while at the same time it is strong and efficient. Fig. 51 shows this joint in all its details.†

Nearly every conceivable combination of the above joints with or without notching is in use. For batter-posts, the notch shown in Fig. 52 is rather better than that in Fig. 53.

The height of the bent is measured from the under side of the sill to the top of the cap.

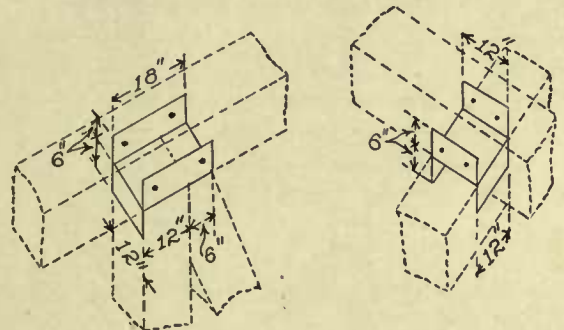


FIG. 51.—IRON JOINT-PLATE, N. Y., L. E. & W. R. R.



FIG. 52. FIG. 53.  
BATTER-POST NOTCHES.

The distance between the cap and sill should not be quoted as its height, as is frequently, though wrongly, done.

Bents should be spaced at such a distance between centres as will use the length of timber easiest to obtain for stringers in the most economical manner. The distance varies from 12 ft. to 16 ft.; spans of 14 ft. and 15 ft. being the most general. Where it is possible, all the bents should be evenly spaced, only employing spans of unequal length where they cannot be avoided. Mr. W. A. McGonagle ‡ of the Duluth & Iron Range R. R. states that the length of span exerts a considerable influence upon the cost of maintenance of pile and framed trestle bridges. He is of the opinion that where very heavy loads are to be provided for it is economical to use a length of span not to exceed twelve feet centres, while for roads with light rolling-stock

\* Also used on the Chicago, Rock Island & Pacific Railroad.

† *Engineering News*, Nov. 5, 1887.

‡ *Proc. Amer. Int. Assoc. Ry. Supts. B. & B.*, 1894, p. 66.



longer spans are preferable. On that road they have a maximum grade of 137 feet per mile descending into the terminal at Two Harbors, and the trains consist of 25 cars, weighing loaded 38 tons per car, drawn by a 12-wheel locomotive of 119 tons, with 69 tons on drivers.

What was said in the chapter on Pile-bents in relation to split caps applies with the same force to framed bents.

Both the sills and caps on the Savannah, Florida & Western Railroad, W. B. W. Howe, Jr., Chief Engineer, are split horizontally, the upper and lower pieces being held together, and kept from sliding, by pins driven into holes bored through them.



## CHAPTER V.

### FLOOR SYSTEM.

**Corbels.**—Corbels are pieces of timber placed lengthwise of the stringers, between them and the caps. They are usually from 4 ft. to 8 ft. long, extending equal distances on either side of the centre of the cap. They are not much in favor, for good reasons. To a certain

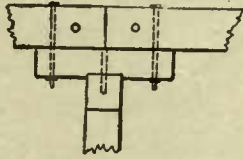
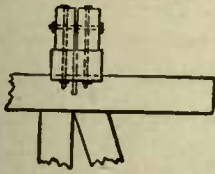


FIG. 54.—DELAWARE & HUDSON CANAL CO.

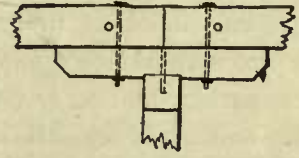
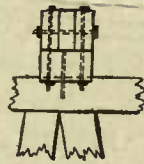


FIG. 55.—CHARLESTON, CINCINNATI & CHICAGO R. R.

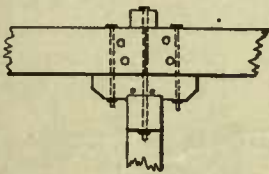
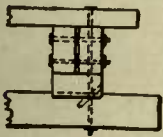


FIG. 56.—LOUISVILLE & NASHVILLE R. R.

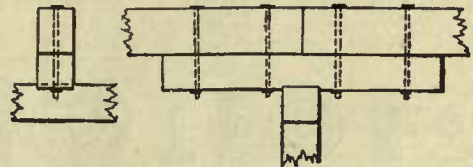


FIG. 57.—SCIOTO VALLEY R. R.

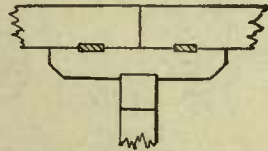


FIG. 58.—OHIO CONNECTING R. R.

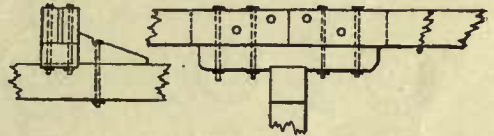


FIG. 59.—NEW YORK, LAKE ERIE & WESTERN R. R.

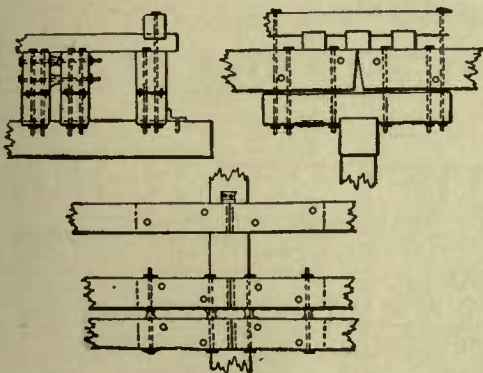


FIG. 60.—CHICAGO & NORTHWESTERN R. R.

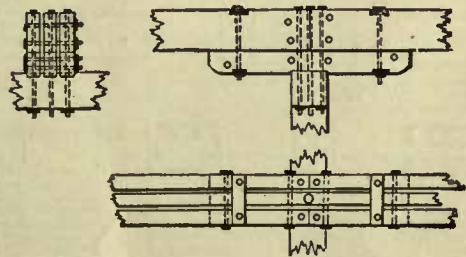


FIG. 61.—NEW YORK, WOODHAVEN & ROCKAWAY R. R.

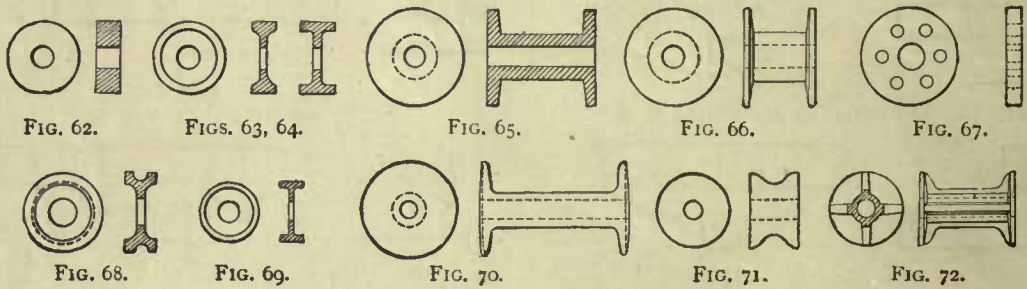
FIGS 54 TO 61.—DETAILS OF CORBELS.

extent they are very useful, but they also have many disadvantages. They give extra support to and consequently strengthen the stringers; but for various reasons, as the stringers should not be made lighter on this account, this does not count for much. They also add stiffness

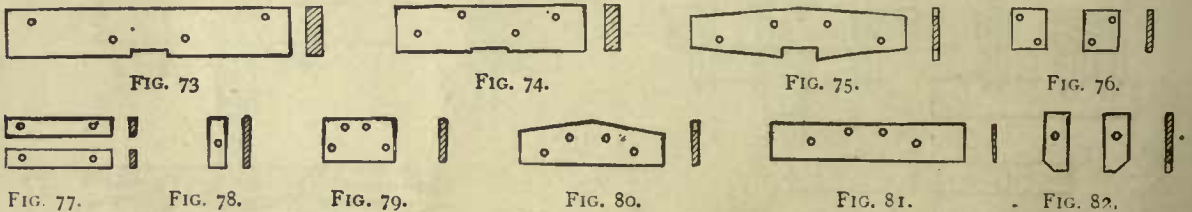
to the stringer-joint, but sufficient stiffness for all intents and purposes may be obtained from a well-designed joint without them. They add to the cost, not only in labor and lumber, but also require the use of a considerably larger amount of iron. They increase the number of joints, and hence the places for the lodgment and beginning of decay. If, however, it is thought desirable to use them, the different ways of fastening the stringers to them, and they in turn to the caps, may be seen in Figs. 54 to 61.

Corbels should be notched down about 1 in. over the cap. A peculiar and rather commendable method of separating the corbels and stringers from each other by cast-iron blocks, as adopted on the Chicago & Northwestern Railroad, is shown in Fig. 60.

**Stringers.**—A stringer should be placed immediately beneath each rail, and in order to guard against defective timber it ought to be "split" or composed of two or more pieces. These pieces should be separated from each other by either cast-iron washers or spools, or wooden packing-blocks, or both. A considerable difference exists in the present practice as to the amount of separation. It varies all the way from nothing to 13 in. From 1½ in. to 2 in. is a very good distance. In Figs. 62 to 72 are shown a number of cast-iron separators, and in Figs. 73 to 82 a number of wooden packing-blocks. Among the latter, those having the general form of Fig. 75 are to be preferred. These are to be placed immediately above the caps. Those packing-blocks which are notched are of course placed so that the cap fits



SCALE  
1 2 3 4 5 6 7 8 9 10 11 12  
FIGS. 62 TO 72.—CAST-IRON SEPARATORS.



SCALE OF FEET  
0 1 2 3 4 5 6 7 8 9 10 11 12  
FIGS. 73 TO 82.—WOODEN PACKING-BLOCKS.

into the notch. Frequently the packing-blocks made of the heavier material are used merely as splice-blocks, they being separated from the stringers by thin cast-iron separators, such as is shown in Fig. 67. Many fasten the stringers together by intermediate bolts placed either at the centre of the span or at regular intervals along it. Separators or packing-blocks are of course required to be placed between the stringers wherever these bolts are located. With good timber and spans of 12 ft. to 14 ft. these intermediate bolts are not necessary, and may be just as well omitted as not.



When it is possible, the stringer-pieces should be long enough to extend over two spans and the joints broken. Various styles of stringer-joints and ways of arranging intermediate bolts are shown in Figs. 83 to 98. The arrangement shown in Fig. 83 is to be greatly pre-

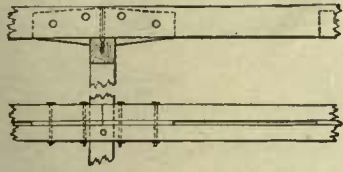


FIG. 83.—PENNSYLVANIA R. R.

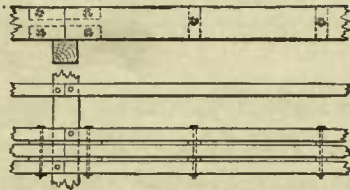


FIG. 84.—WISCONSIN CENTRAL R. R.

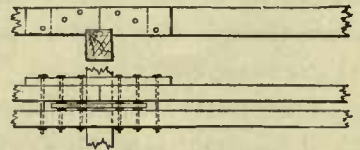


FIG. 85.—N. Y., P. & B. R. R.

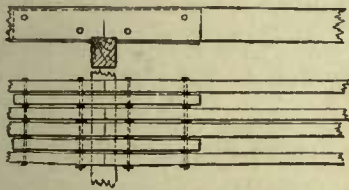


FIG. 86.—B. & M. R. R. IN NEB.

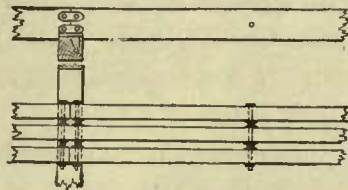


FIG. 87.—A. & P. R. R.

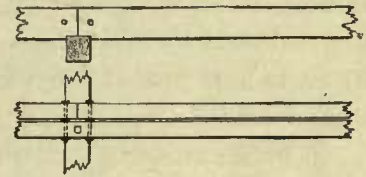


FIG. 88.—GEORGIA PACIFIC RY.

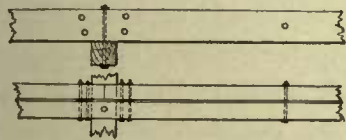


FIG. 89.—C., N. O. & T. P. RY.

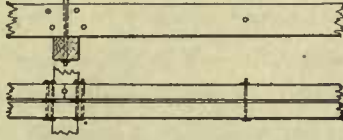


FIG. 90.—CENTRAL R. R. OF GA.

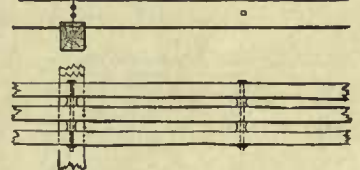


FIG. 91.—GULF, COL. & SANTA FE R.R.

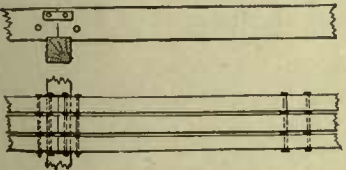


FIG. 92.—D., T. & FT. WORTH R. R.

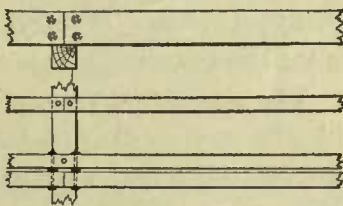


FIG. 93.—CHICAGO & W. MICH. RY.

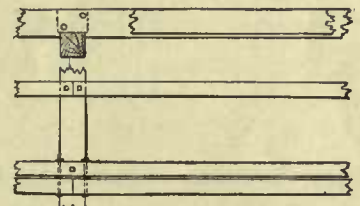


FIG. 94.—CHICAGO & ATLANTIC RY.

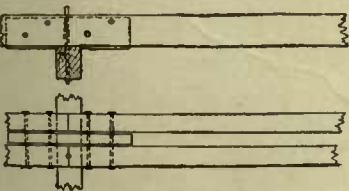


FIG. 95.—B., C. R. & NORTHERN R.R.

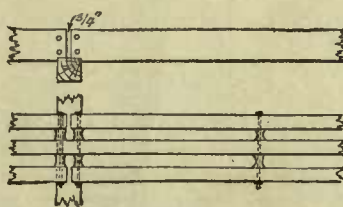


FIG. 96.—SAN F. & N. PACIFIC R. R.

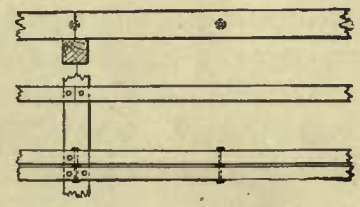


FIG. 97.—ST. P., MIN. & M. RY.

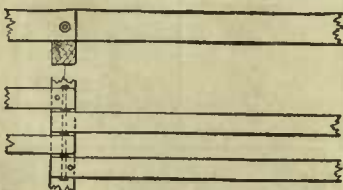


FIG. 98.—OREGON PACIFIC R. R.

FIGS. 83 TO 98.—DETAILS OF STRINGER-JOINTS.

ferred, because, should the support for any reason become weakened, the joint, when it settles as a weight comes upon it, closes at the top and tends to open at the bottom. Now the lower bolts act somewhat as a fulcrum, and the effect will be to tend toward splitting the stringer from these bolts to the nearest end. As this arrangement gives the most material where there is the greatest liability to split, and consequently at the weakest point, it forms the strongest kind of a joint.

Such joints as those shown in Figs. 91, 97, and 98 cannot be condemned too strongly, and are always to be avoided. Those illustrated in Figs. 87, 88, 89, 90, 92, 93, 94, and 96 are also poor on account of the packing-bolts being so close to the end of broken stringer-pieces, and also, in some cases, on account of there being too few of them. That in Fig. 92 would be an excellent joint were the lower bolts placed a foot or so farther apart. The joint shown in Fig. 86 is said by Mr. I. S. P. Weeks, Chief Engineer C., B. & Q. R. R. west of the Missouri River, to have proved very efficient. It has carried an engine over after the bent has been washed out.

The bolts holding the stringer-pieces together, and which are called packing-bolts, should be long enough to extend clear through from face to face of the complete stringer, and allow of placing a cast-iron washer under both nut and head.

When the stringers are not fastened directly to the caps they should be notched over

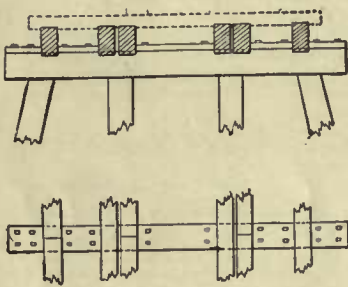


FIG. 99.—STRINGER FASTENING.

them 1 in. A method for holding the stringers in place, and which is becoming quite general, is shown in Fig. 99. It consists of a piece of 3 in.  $\times$  12 in. plank, fastened, outside of each stringer, to the cap by four log-screws or by spikes. The stringers in their turn are kept at the proper distance apart either by a spreader made of the same material or by fastening the ties to them.

The size of the stringer-pieces in cross-section will vary with the span, variety of timber, and weight of the traffic. They should be of sufficient dimensions to prevent any considerable deflection by a passing train. For long spans, or on lines having heavy loads and engines, each stringer should be composed of three pieces; in other cases two are sufficient. The practice of the Pennsylvania Railroad in this respect is given in Table IX.

TABLE IX.

Trestle-stringers, Pennsylvania Railroad Standard.

Dimensions of Stringers.			
Clear Span.	Number of Pieces under each Rail.	Width of each Piece.	Depth of Stringers.
10 ft.	2	8 in.	15 in.
12 "	2	8 "	16 "
14 "	2	10 "	17 "
16 "	3	8 "	17 "

A "jack-stringer," composed of a single piece, should always be placed under either end of the ties, as in Fig. 99. By such an arrangement many advantages are secured. The



principal one is in case of a derailment, when, if the ties give way, the cars are not liable to fall to the ground as they otherwise might. As the ends of the ties are supported, the chances are very much in favor of their not being broken in such a case. Thus the factor of safety is largely increased. These outer stringers should be long enough to extend over two spans, and should always be securely fastened to the caps by a drift-bolt through either end and the centre.

The ends of the stringer-pieces are generally butted together. There are two exceptions to this otherwise universal rule: in the trestles on the San Francisco & North Pacific Railway, Fig. 96, the ends are separated  $\frac{3}{4}$  in., and in those of the Chicago & Northwestern Railroad, Fig. 60, they are bevelled 1 in.

Several roads have adopted the policy of trussing stringers having a span of 14 ft. or over after they become three or four years old. This end is accomplished on the Pontiac, Oxford & Port Austin Railroad, Geo. A. Nettleton, Chief Engineer, by arranging an iron rod and pieces of rail as shown in Fig. 100. While this treatment has a very beneficial effect in some respects, and adds considerably to the strength of the structure, still it seems as though the men in charge of the trestles, as well as the inspectors, would be



FIG. 100.—TRUSSING STRINGERS.

tempted to rely too much upon this extra strength, and allow timber to remain in service which should for safety have been removed long before. The carelessness which would thus tend to be inculcated, would prove very dangerous on the majority of roads.

**Ties.**—Ties may be of 6-in.  $\times$  8-in. timber, sawed, and should have a length of 12 ft. They should be notched over the stringers 1 in., and if outside stringers are used with notched guard-rails they need not be otherwise fastened. In other cases they should be spiked to the stringers. There are many different ways of arranging the spikes. Some fasten every third or fourth tie only, while others spike every tie. It is always better to stagger the spikes or arrange them zigzag, as in Fig. 101. Figs. 101 to 109 show several of the different ways of arranging these fastenings. Opinions as to the spacing of the ties vary. They are placed anywhere from 12 in. to 24 in. from centre to centre. The closer together they are put the better; they should never be spaced with centres over 12 in. apart, leaving 6-in. openings between the ties; 9-in. centres are far better even than 12-in. On the West Shore Railroad small blocks 4 in. thick  $\times$  8 in. square are spiked to the stringers between the ties in such a manner as to act as a cover for the space between the stringer-pieces (Fig. 101). While these blocks serve a good end by preventing "bunching," and in keeping out the rain and moisture, they are hardly advisable because of their interfering with the free circulation of the air between the separate pieces of the stringer, as well as on account of their preventing the penetration of the sunlight into these places.

Often when the ties are not notched, and it is desired to use some other form of fastening than spiking, dowel-pins, made of  $\frac{3}{4}$ -in. iron 5 in. long, may be resorted to. They may be arranged as in Fig. 109.

**Guard-rails.**—Guard-rails serve two principal purposes: first, to keep the train from leaving the bridge in case of a derailment; and second, to aid in keeping the ties in their proper places, and give stiffness to the floor system. They should always be employed, and where an outside stringer is used should be placed immediately above it. They need not be

made of very heavy timber, nor should they be too light; 6 in.  $\times$  8 in., with the narrow face down, is a very good size. The length may vary, using such timber as can be most conveniently obtained; still it is better to have them from 16 ft. to 20 ft. long. Of course greater length is in no wise objectionable, except that it is rather more difficult to obtain, and hence

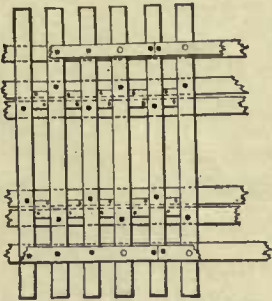


FIG. 101.—N. Y., W. S. & B. R. R.

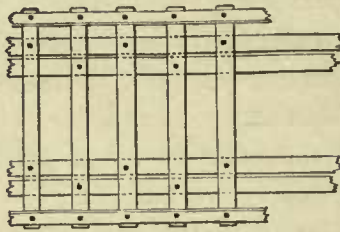


FIG. 102.—PENNSYLVANIA R. R.

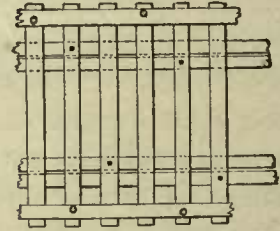


FIG. 103.—TEXAS & PACIFIC RY.

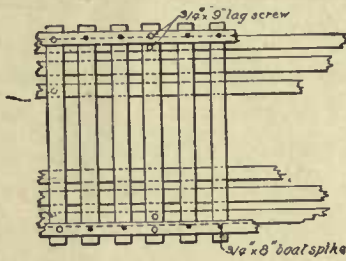


FIG. 104.—T., ST. L. & K. C. R. R.

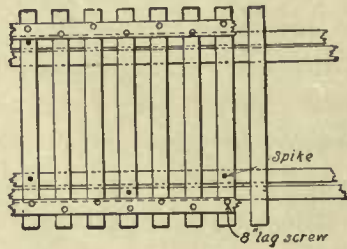


FIG. 105.—K. C., F. S. & M. R. R.

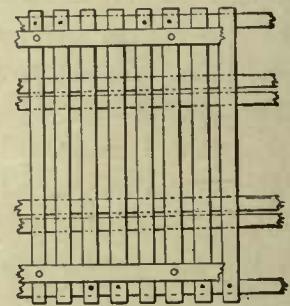


FIG. 106.—ST. P., M. & M. RY.

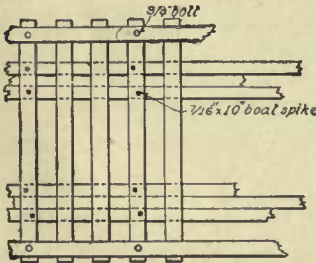


FIG. 107.—C., C. & C. R. R.

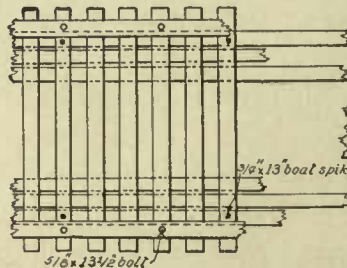


FIG. 108.—M., K. & T. RY.

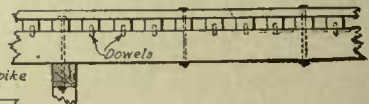


FIG. 109.—L. & N. R. R.

FIGS. 101 TO 109.—FLOOR SYSTEMS.

more costly. There are a number of forms of joints in use for connecting the pieces together. Many of these are shown in Figs. 110 to 115. The ordinary halved joint, Fig. 114, is an excellent one, and fully answers all requirements. The joints should always come immediately over a tie and be broken; i.e., those on opposite sides should be over different ties, no two joints coming over the same tie. A bolt should extend through the joint tie and outside stringer. The guard-rail should always be notched down at least 1 in. over each tie.



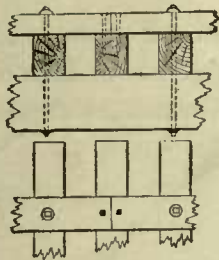


FIG. 110.—N. Y., W. S. & B. R. R.

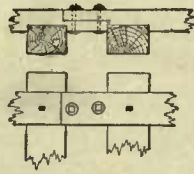


FIG. 111.—PENN. R. R.

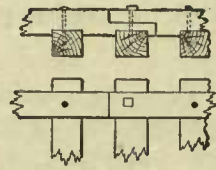


FIG. 112.—T., ST. L. & K. C. R. R.

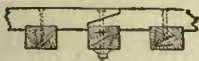


FIG. 113.—C., M. & ST. P. RY.

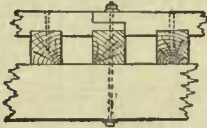


FIG. 114.—R. & D. R. R.

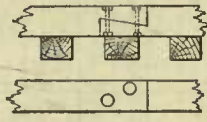


FIG. 115.—N. Y. ELEV. ROADS.

FIGS. 110 TO 115.—GUARD-RAIL JOINTS.

The ends of the guard-rails at either end of the bridge ought to be rounded off or cut at an incline, as in Figs. 116 and 117. Every tie should be fastened to the guard-rail in some way, especially when they are not fastened to the stringers. A bolt should be put through the guard-rail at every fourth or fifth tie, and should extend through the outside stringer. The balance of the ties may be spiked or fastened by lag-screws. Spiking is much cheaper, a  $\frac{1}{2}$ -in.  $\times$  10-in. boat-spike being employed. If lag-screws are used, a  $\frac{5}{8}$ -in.  $\times$  8-in. screw is a very good size. A wrought washer is to be placed under the head of each lag-screw, and a 3-in. to  $3\frac{1}{2}$ -in. cast washer under the head and nut of each bolt. The screw or nut ends of the bolts should be placed up so that they may be more easily inspected and tightened. It is not necessary to countersink the nuts of the bolts or the heads of the lag-screws; in fact it should not be done unless absolutely unavoidable, as the holes form a basis for the lodgment of water, and thus are apt to prove very harmful. At either end of the bridge the guard-rails should extend at least from 20 ft. to 30 ft. on to the embankment, and be flared to such an extent that their extreme ends will be the gauge of the track from the rails. They should be supplemented by bumping-posts (Fig. 118). These, however, will be spoken of later on. It is better, though of course more costly, to face the inside upper corner of the guard-rails with angle-iron. This overcomes to a very large extent the tendency of the wheels to override the guards, by preventing the wheels from cutting into them. Frequently the upper edges of the guard-rails are bevelled. This is bad practice, as it reduces the effective height of the guard, and tends to assist the wheels in overriding them.

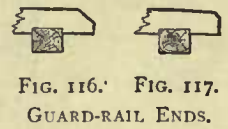


FIG. 116: FIG. 117.  
GUARD-RAIL ENDS.

Inside guard-rails, either of wood or of a second steel rail, placed about  $2\frac{1}{2}$  in. from the rails, are claimed by many to be much more efficient than outside guards. Outside guards, it is said, tend to turn a derailed truck at right angles to the moving train, while inside guards turn it towards the track. It is urged against inside guards that articles such as brake-shoes, etc., are very apt to fall between the guard and the rail, and thus increase the number of derailments. However this may be, there is no doubt that inside guards are very serviceable, but their use is no reason for omitting the use of outside guards, which should always be employed. In regions where it is necessary to use snow ploughs on roads where the pilot comes very close to the rails, inside guards should never rise above the top of the rails.

**Fastening down Floor System.**—There are a number of different methods of fastening the floor system to the bents, some of which have already been described. Drift-bolting the stringers to the caps is the one most generally employed. The drift-bolts should extend a

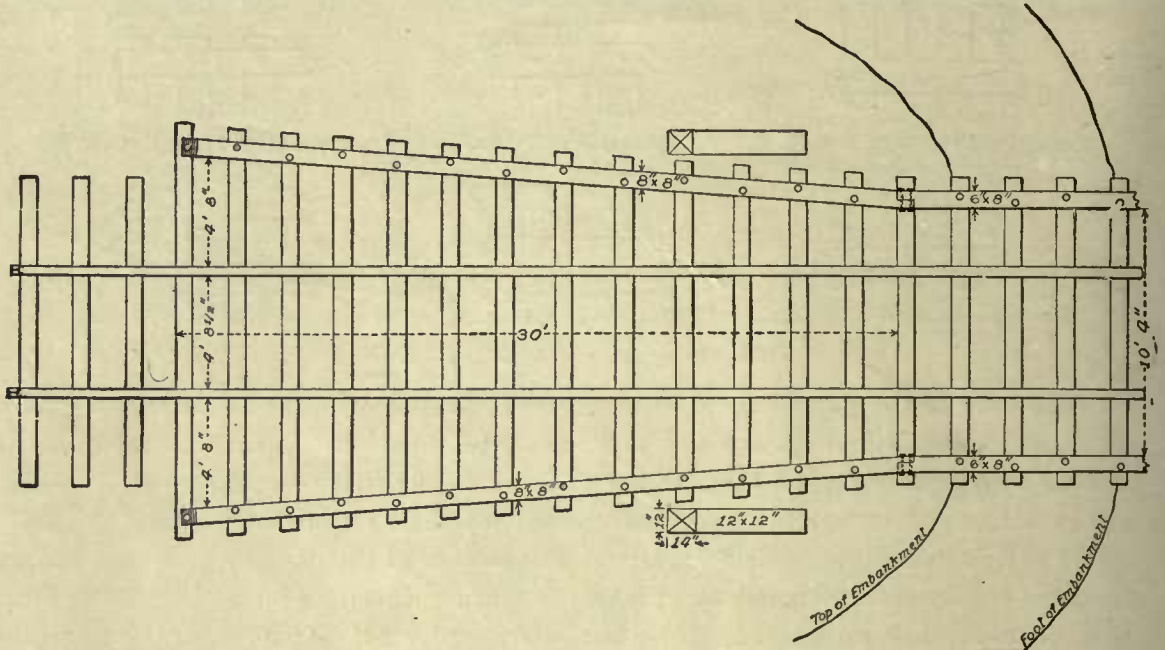


FIG. 118.—EMBANKMENT END OF TRESTLE, SHOWING FLARED GUARD-RAILS AND BUMPING-POSTS.

generous distance into the caps,—say at least 8 in. One drift-bolt through the continuous piece of each compound stringer, per bent, especially if the ties are notched, is amply sufficient (Fig. 119).

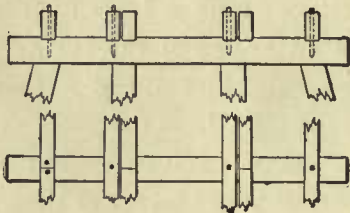


FIG. 119.—DRIFT-BOLTING-DOWN STRINGERS.

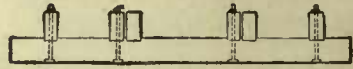


FIG. 120.—BOLTING-DOWN STRINGERS.

Among the other ways is that of using a  $\frac{3}{4}$ -in. bolt with nut in place of a drift-bolt (Fig. 120). This bolt is sometimes made long enough to extend through a tie placed immediately above the cap, in which case it usually passes through the space between the stringer-pieces

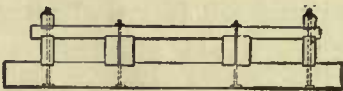


FIG. 121.



FIG. 122.

BOLTING-DOWN STRINGERS.

(Fig. 121). Several roads employ but one bolt, placed on the centre line, as in Fig. 121. Frequently the floor system is not fastened to the bents at all, its weight being depended on to keep it down, and blocks arranged as shown in Fig. 99, and Plates II, III, XXIV, XXVII, etc., Part II, to keep it in place and line. In this case girts, securely fastened to the posts at their upper ends, should always form a part of the structure, no matter how low it may happen to be.



**Rail-spiking.**—The following is an extract from the report of a Committee to the American International Association of Railway Superintendents of Bridges and Buildings (Proceedings, 1893, p. 45) on the subject of "Creeping of Rails in Railway Tracks; Its Effect on Bridges, and Methods to Prevent Injury to the Bridges:

"Our opinion, then, is that no spikes should be driven in the slots of the rail or splices on any bridge to prevent them from creeping, but that they should be spiked to gauge only, and left entirely free to creep or expand or contract as much as they would; neither do we think that any mechanical device or contrivance of any kind whatsoever should be placed at or near the end of any bridge to prevent the rails from creeping, as even if this could be done it would only have a tendency to buckle the rail and cause a derailment of cars. A bridge is not intended to resist any end pressure, such as would be caused by the creeping of rails, and the effect it would have on a bridge would depend to a great extent on how securely the ties were fastened to the stringers. We have known the bents in a pile-trestle to be pushed a foot out of plumb by the creeping of the rails. In this case the ties were securely bolted to the stringers, and the stringers were also bolted to the caps and the rails were spiked to the slots. If the same state of affairs existed on an iron bridge, we can only say that the effects of the creeping rail would make itself visible at the weakest point. It might split the ties and get relief in that way, or it might slide the ties on the stringers; or, if the ties were so securely fastened that they would not slide or split, it might, if the span was not very heavy, pull or push it off the abutment.

"We have thus far stated what should not be done to prevent the creeping of the rails, and endeavored to give some hurried reasons therefor, and now we will say that the way we would recommend for preventing the creeping of rails, would be to spike them securely through the slots into the grade-ties on the bank, and if it was found that that was not sufficient to hold them, we would have as many additional slots cut in the flanges of the rails as might be necessary; and if we found that the rails were running or creeping for a mile or two miles, we would have the additional slots cut in the rails for that entire distance; and if it was found necessary, we would have a slot cut for every tie so that every rail would be securely anchored by itself, which would prevent the tendency for buckling, which would be the case if an arbitrary attempt was made to stop the creeping at any one point; but under no circumstances would we ever allow a spike to be driven in the slot of a rail or splice on a bridge.

"Creeping of rails has been known to crowd or shove a bridge of 154-ft. span three inches endwise in one season, and a case occurred on the L. S. & M. S. Ry. at Goshen, Indiana. The rail was spiked in a slot in the splice at the first tie on the abutment, and said tie was shoved eighteen inches to the west in the space of six months. Rail-creeping in double-track railroads, we think, is much greater, and it usually occurs in the expansion of the rails, working in the direction of the running trains to a very great extent. We have found that at drawbridges it is necessary to hold the rails on the bridge firmly in their places and that all trouble came from the creeping of the rails on either side of the bridge, and that it is necessary at times to take out and cut off a rail that is shoved ahead by expansion of track on one side of a drawbridge. . . ."

## CHAPTER VI.

### BRACING, COMPOUND-TIMBER TRESTLES, HIGH TRESTLES, TRESTLES ON CURVES, AND MISCELLANEOUS TRESTLES.

**Sway-bracing.**—It is seldom that any sway-bracing will be needed for either pile or framed bents under 10 ft. high. For those from 10 ft. to 20 ft. in height a single X of 3-in.  $\times$  10-in. plank is all that is necessary. One plank should be placed on either side of the bent, and extend from the upper corner of the cap across to the lower end of the opposite batter-pile, terminating just above the ground, or to the opposite lower corner of the sill if a framed bent. The braces should be bolted to the cap, to each pile or post, and to the sill by a  $\frac{3}{4}$ -in. bolt, with a cast washer under both head and nut. Often either lag-screws or spikes are used for attaching the braces, but bolts are to be preferred.

For bents over 20 ft. high but not over 40 ft. two X's of sway-bracing should be employed. It is both more convenient and more economical to make the upper X of a constant length, say from 15 to 20 ft., and put the odd lengths in lower one. A horizontal stick on each side of the bent separates the X's. These sticks are also made of 3-in.  $\times$  10-in. plank, and bolted to each post or pile.

Whenever a pile or a cap extends beyond the other so that the sway-braces cannot lie flat, either the larger of the two should be sized down so as to be level with the smaller, or else the smaller should be blocked out to meet the brace. In general, the former method is the better one.

**Counter-posts.**—When framed bents approach a height of 40 ft., they are frequently stiffened by the use of counter-posts rather than sway-bracing, though sometimes by the use of both. The employment of counter-posts requires the dividing of the bent into two stories by means of an intermediate sill. Plates XV, XIX, XXI, XXIII, XXIV, Part II, show several methods of using counters. They are more generally employed in very high work, and for further particulars in regard to them the reader is referred to the section on High Trestles.

**Longitudinal Bracing.**—There is considerable variation in the methods of longitudinal bracing employed, some bracing every bay, others only every third or fourth; some arranging the braces diagonally or latticed, others horizontally, and still others in what might be called a laced form. Examples of all of these forms are shown in Plates XVI, XXIX, XI, Part II. All possible combinations of these, especially of the last two, are employed, as well as many modifications and adaptations. Plate XI illustrates that which may be called the laced form, and is the standard on the Pennsylvania Railroad. The ends of the braces are cut in the form, and the edges of the caps and sills chamfered, as in the detail drawing. Each piece is fastened to both cap and sill by a heavy cut spike. There is but one stick of 8-in.  $\times$  8-in. material to each bay, and it is placed in the centre line of the trestle. When horizontal bracing, such as shown in the side elevation in Plate XXIX, Part II, is used, there should be a stick placed



immediately above the sill on the outside of each post, and one immediately above the horizontal piece of the sway-bracing.

**Lateral Bracing.**—Lateral bracing, such as is illustrated in Plate IX, Part II, adds very greatly to the stiffness of a structure.\* It is made of two 6-in.  $\times$  6-in. timbers placed diagonally across, from cap to cap, immediately beneath the stringers and bolted together at the intersection by a  $\frac{5}{8}$ -in. or  $\frac{3}{4}$ -in. bolt. The timbers are usually slightly notched into the caps, and fastened in place by several heavy spikes. This kind of bracing is coming into quite general use, and is now one of the essentials of many new designs. When used, the longitudinal bracing need not be so extensive. It is said that where lateral bracing is employed the trestle keeps in line much better.

**Compound-timber Trestles.**—There is a style of construction very largely in vogue which may be denominated as above. The members, such as caps, sills, posts, etc., either wholly or partly, are each composed of two or more pieces bolted together instead of being a solid stick. The parts are generally separated from each other to a greater or lesser degree. While the life of the structure may be somewhat shortened in some cases, it is claimed that this disadvantage is more than offset by the ease of repairs, as any part can be replaced with a minimum amount of labor, and without causing the least disturbance in the running of trains or impairing the safety in any way. On account of the smaller size of the timber, much more thoroughly seasoned and better quality material can be obtained. It can also be much more easily inspected. The sticks are generally 6 in.  $\times$  12 in. Several plans of this style of structure are given in Plates XXVII, XXVIII, XXIX, XXX, and XXXII, Part II.

**High Trestles.**—Trestles above 40 ft. in height may be classed as high trestles. Usually they are divided into two or more decks and stories. The height of the decks depends upon several considerations, but is regulated to a certain extent by the length of timber that can be most economically procured. The decks and stories should be of uniform height throughout any one trestle, or at least those upon the same level should be, in order to simplify things as much as possible, and the odd lengths put into the lowest one. It is in the designing of these rather exceptional structures, especially when the extraordinary height of one hundred or more feet is reached, that there is every opportunity for the full employment of a very high grade of constructive skill.

There may be said to be four classes of high trestles :

1st. Those in which the posts are continuous, being made up to the required length by joining single sticks together, end to end, with a butted joint, using splice-blocks or other means.

2d. Those in which the decks, though separate and distinct, are still intimately joined together by means of framing; the sill of one deck acting as the cap of the one beneath.

3d. Those in which the decks are separated entirely by purlins or other means.

4th. Those in which the posts, and frequently other members, are each made up of two or more pieces placed together side by side. In this latter group are included cluster-bent trestles.

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\* Adopted as standard on the Boston & Albany Railroad; the Toledo & Ohio Central Railroad, C. Buxton, Chief Engineer.

Those of the first class are generally erected where good quality long timber of large size may be easily and economically procured. In this group stories are formed by bolting horizontal pieces of timber to the posts, one on either side, at the proper heights. Counter-posts, or what may be called inside batter-posts, are often introduced, a new set being put in at every other story, and continued down to the main sill. This class of trestle is shown very clearly in Part II, Plates XV, XVI, and XVIII. In Plates XV and XVIII the employment of counters is depicted.

Classes 2 and 3 are resorted to when but comparatively short timber can be procured, and for several reasons are, in the writer's judgment, rather to be preferred, especially the third class, to the continuous-post group. The second class hardly needs any enlargement, as the mere defining of it at once describes its peculiarity. The posts are generally connected with sills and caps in this type by mortise and tenon joints. All posts should of course come immediately beneath those in the deck above, and be in the same line with them, forming to all intents and purposes a continuation of them. Illustrations of this type are given in Part II, Plates XIX to XXII.

In the third class the bents of each deck are distinctly separate, being framed entirely by themselves. The lower-deck bents are erected, and then purlins laid along on the caps in such a way as to come directly under the posts of the deck above, the bents of which are of course placed directly over those of the one below. Purlins are laid on the caps of these, and the next deck erected on top of them. This is continued until the necessary height has been attained. The purlins should be firmly fastened to the caps on which they rest either by ordinary bolts or by drift-bolts. The sills should also be secured to the purlins underneath them in the same manner. For illustrations of this construction see Plates XXIII to XXVI. This style offers many advantages for ease of erection, which will be more readily appreciated when that subject is treated of.

The fourth class may be subdivided into two groups, namely, those in which the posts, and sometimes other members, are built up by bolting two or more pieces together, keeping them separated a little from each other (see Part II, Plates XXVII, XXX, XXXI, etc.),—the majority of them might almost be called plank trestles,—and those in which each post is made up of four smaller posts, two of the smaller posts always being continuous over any one story: these are known as cluster-bent trestles. Both of these styles are claimed to have a number of advantages over those built with single sticks of large dimensions. Among them may be mentioned the ability to secure better material, both as respects quality and seasoning, on account of the pieces being smaller; greater economy and ease in the cost of erection; and especially greater facility for making repairs. It is also claimed that they can be much more thoroughly, easily, and certainly inspected. While it is said that their life is hardly as long as that of the others, still the advantages enumerated, it has been stated, greatly offset this disadvantage. Besides they may be kept in a much safer condition.

In all of the different styles the bents should always be thoroughly sway-braced, each story and deck having its own set of braces. There should always be, also, a set of longitudinal braces to each deck. As a rule these are of the horizontal type. It should not be attempted to economize in the amount of timber by reducing either the number or the size of the girts



Scanting the amount of longitudinal bracing is in no case real economy: it is in fact outrageous, tending to great danger to human life. Frequently two adjacent bents every three or four bents apart are connected by diagonal longitudinal braces so as to form, in effect, towers similar to those of iron trestles. While this is an excellent plan, the longitudinal bracing of the intermediate spans should not be left out, as is generally the case; for while the tower construction adds considerably to the stiffness of the structure as a whole, it is no excuse whatever for weakening the remaining parts. To the writer it seems that the best form of high trestle is the cluster-bent type, with every third bay braced diagonally so as to form a tower, and with the intermediate bays braced with horizontal sticks at every deck, a 3 × 10 in. plank being placed on each side of every post.

The plentiful use of counter-posts is also to be recommended. For giving lateral stiffness to the structure, the lateral bracing described on page 69, and illustrated in Part II, Plate IX, is very effective, and should be used whenever possible.

Considerable economy may be effected in trestles of great height by spacing the bents farther apart, say thirty feet, and supporting the floor on a deck truss. Such a construction is shown in Part II, Plates XXXIII and XXXIV.

The floor system for high trestles is of course the same as that for the lower structures, and which was discussed fully in Chapter V.

A far more thorough knowledge of the various practice in the treatment of these structures may be obtained by the careful study of the plates in Part II, than could be imparted by mere descriptive matter, and so the reader is referred to them.

**Trestles on Curves.**—Of course, whenever it is possible, building a trestle on a curve should be avoided. Sometimes, however, this cannot be helped, and then we have to resort to the best means at our command to increase their strength and safety. It is preferable to place the bents on radial lines, especially where the curve is a sharp one. The bracing of all kinds should be heavier and more abundant than where the structure is on a tangent. It is also well to give the batter-posts, especially those on the outside of the curve, as much inclination as possible, a batter of  $3\frac{1}{2}$  in. to 4 in. per foot not being out of the way, so as to increase the breadth of the base, and enable the trestle to better resist the centrifugal force of the train.

Lateral bracing should always be employed on curved trestles, as it tends to save the structure considerably from the racking it otherwise receives from the train.

There are a number of methods in use of elevating the outer rail on bridge structures located on curves.

1. By cutting the piles or posts shorter on one side than on the other, so as to give the cap the proper inclination. Part II, Plate XXXVIII and Fig. 125B.
2. By tapering the tie, as in Part II, Plate XXXVI, and Fig. 123A. Table IXA gives the dimensions of tapered ties for ties 14 ft. long.

The objections to a tapered tie are the weakness of the small end, which renders it dangerous in case of derailment. The large size of timber required to make a tie of proper dimensions, and oak timber (of which bridge-ties are usually made) of sufficient dimensions to cut the larger sizes from, is not found plentifully in many sections of the country. An objection that will probably carry considerable weight with the average railroad manager, especially

on a railroad traversing a mountainous country, is this: The table of tapered ties shows six sizes of ties for six degrees of curvature. This could easily be arranged so that three sizes of

TABLE IXA.\*

## Tapered Ties for Curves.

Degrees.	A.	B.	C.	D.	E.	F.	G.
1	6	6 $\frac{1}{2}$	6 $\frac{2}{3}$	7 $\frac{1}{3}$	7 $\frac{2}{3}$	8	8
2	5	6 $\frac{1}{2}$	6 $\frac{2}{3}$	7 $\frac{1}{3}$	8 $\frac{1}{3}$	9	9
3	4	6 $\frac{1}{2}$	6 $\frac{2}{3}$	8 $\frac{1}{3}$	9 $\frac{1}{3}$	10	10
4	4	7	7 $\frac{1}{3}$	9 $\frac{1}{3}$	11 $\frac{1}{3}$	12	12
5	3	6 $\frac{1}{2}$	7 $\frac{1}{3}$	9 $\frac{1}{3}$	12	12 $\frac{1}{2}$	12 $\frac{1}{2}$
6	3	7 $\frac{1}{3}$	8	10 $\frac{1}{3}$	13 $\frac{1}{3}$	14	14

For sharper curves use elevation-blocks.

ties would answer, but even then to keep on hand a supply of emergency ties would tie up three times the amount of money necessary in case a standard tie was used exclusively. Tapered ties are more expensive than regular sizes, from the fact that in computing the number of feet contained in them the size of the tie at its greatest section is taken and estimated as running its whole length. Millmen are able to govern this feature from the fact that a majority of them cannot saw tapered material.

3. By placing wedge-shaped blocks between the ties and stringer and bolting them to the former, as in Fig. 123.

4. By shimming up the track by wedge-shaped blocks placed on top of the ties and securely spiked to them, as in Fig. 124, and Part II, Plate IX.

5. By a cushion-tie,\* as in Fig. 124A, which consists of a tapered stick about three inches thick at the thin end and of the same width as the tie or floor beam on which it is spiked or bolted. It possesses some merit during its life, which is very short. It is also open to several

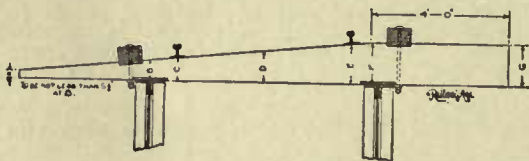


FIG. 123A.—TAPERED TIE.

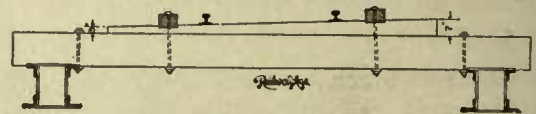


FIG. 124A.—CUSHION TIE.

objections, which all tend to curtail its usefulness. Being very light at the small end, it is soon warped out of shape by the sun. The spikes split it; it forms a horizontal water joint, hastening decay, and in case of derailment it is generally torn to pieces, necessitating a thorough renewal.

6. By placing a bolster or corbel under the stringers on one side and not on the other, or by making the corbel on one side deeper than that on the other, as in Fig. 125A, if corbels are already in the structure.

7. \* By placing a cushion-cap on top of the main cap under the stringers, as in Fig. 124B,

\* Report of a Committee to the Amer. Inter. Assoc. Ry. Supts. B. & B., on "Best Method of Elevating Track for Curves on Bridges." Proceedings 1893, pp. 55 to 61.



tapered to such a degree as to raise the outer rail to the point desired. This cap is generally dapped from 1 inch to 2 inches under the stringers, which is of great assistance to the drift-bolt in holding the stringers in line. The principal objection to this mode is found in the fact that this dap under the stringers holds water, and the joint between the cushion-cap and the main cap also holds water, being horizontal, and is the cause of early decay. For this reason it is not thought well of, and is not used to any great degree.

8. By notching or sizing down one end of the cap, as in Fig. 125. This latter method is in use on the Clinch Valley division of the Norfolk & Western Railroad, and the dimensions given in the figure are for a  $6^\circ$  curve.

9. By tipping the entire bent as in Fig. 125C. As to this method and that shown in Fig. 125B, Mr. G. W. Hinman, Supt. B. & B., L. & N. R. R., has the following to say: \*

After a long experience and trying every method of elevating tracks on bridges, I have adopted these plans. It will be noted that the elevation on Fig. 125B is put in by framing

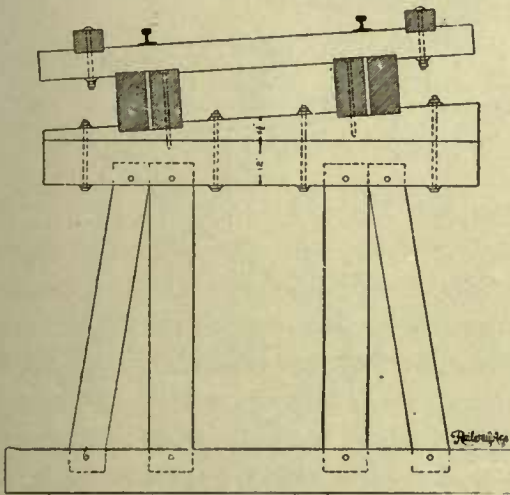


FIG. 124B.—CUSHION CAP.

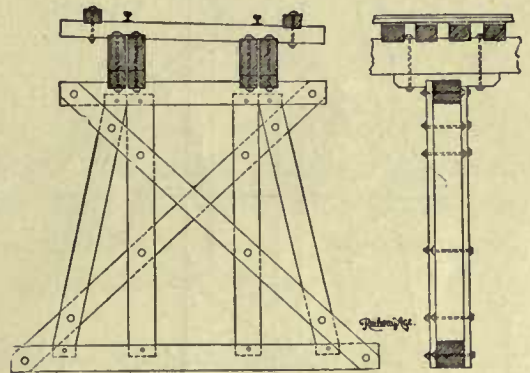


FIG. 125A.—UNEQUAL CORBELS.

the cap on the piles; this leaves all the timber of the different kinds to be framed the same size each. In the frame trestle Fig. 125C the elevation is put in by elevating the bottom sill, thus leaving the several kinds of timber to be framed the same size each. The elevation on the plans is for a six-degree curve, which of course is extreme.

In years past the speed over bridges where curves existed did not exceed twenty-five miles per hour, and of course the elevation was ordinarily put in by using ties sawed tapering. Usually not over three inches of elevation was given at that speed, and so tapering ties answered very well; but at this time, with the fast speed that the railroads are now using, it becomes necessary to put in more elevation. I use one inch for each degree of curve up to six inches. I know of no better way than that shown in the sketches. I have a trestle 800 feet long, 50 feet high, on a grade of 4 feet per 100, with a ten-degree curve on it. I renewed it three years ago and built a trestle on same plan as Fig. 125C, and it has given me very little trouble since. It will be noticed that the trestle-bents stand in a directly perpendicular line

\* Minority Report to the Amer. Inter. Assoc. Ry. Supts. B. & B. on "Best Method of Elevating Track for Curves on Bridges." Proceedings 1893, pp. 61-63.

with the load, which gives the trestle no unnecessary strain. I have a pile-trestle 900 feet long with a four-degree curve on it, built like Fig. 125B, which is six years old and has given me no trouble. I cite these cases to show that elevation put in track according to these sketches works well in practice.

This method is much more convenient than using tapering ties, as any standard tie will go on any elevation. It is a very nice job to put elevation in track with tapering ties. For instance, I have a trestle three miles long, and on it is a three-degree curve 2500 feet long; one inch elevation for each degree of curve elevates the track three inches; and running out sixty feet for each inch of elevation gives you a distance of 2860 feet to use tapering ties. You must have at least four different-sized ties, while if the result had been accomplished by

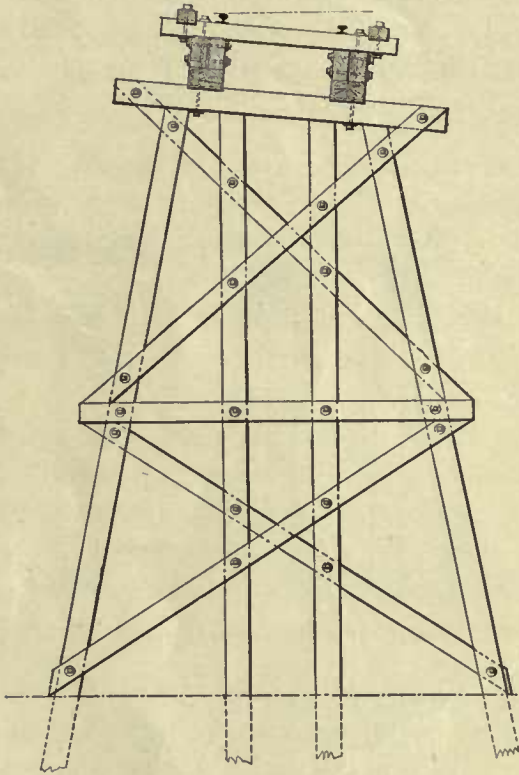


FIG. 125B.—ELEVATION FRAMED IN PILES.

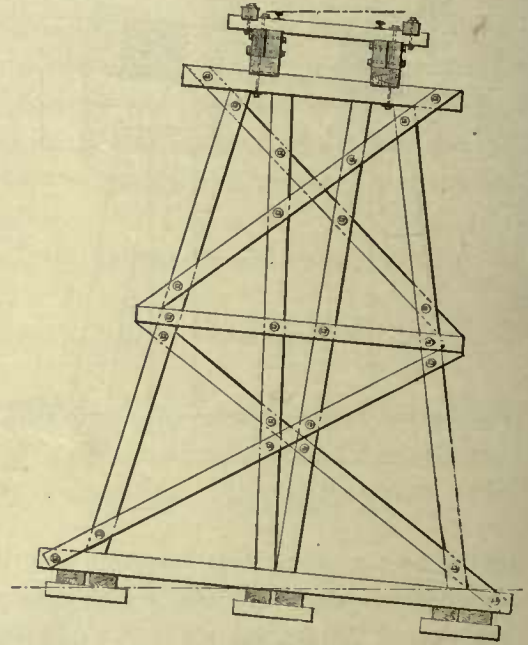


FIG. 125C.—TILTED FRAME TRESTLE.

framing the piles and putting the cap on at the proper elevation the same tie or any standard bridge tie used on the road would fit the place. I will admit that the frame trestle looks rather "cobbled up;" but when you come to look and understand that the elevation rarely is as great as in the sketch, usually about one-half, it is not so "cobbled up" as it looks. On the other hand, if you use tapering ties it will require a tie twenty inches wide to get the required elevation.

It must be borne in mind that we have to use this elevation for the speed that we are now running.

10. \* By placing blocks between a double cap, split horizontally. This method is used on the Savannah, Florida & Western Railway.

\* Discussion on Report cited in foot-note on page 72.



Examples of trestles built on curves are given in Part II, Plates IX, XXXVI and XLV.

**Double-track Trestles.**—Double-track trestles, as a rule, are little else than two single track trestles placed side by side and intimately joined together. The caps and sills should

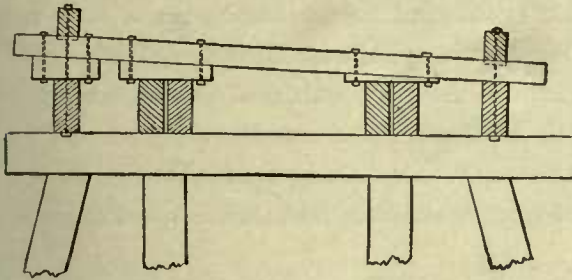


FIG. 123.—BLOCKS UNDER TIE.

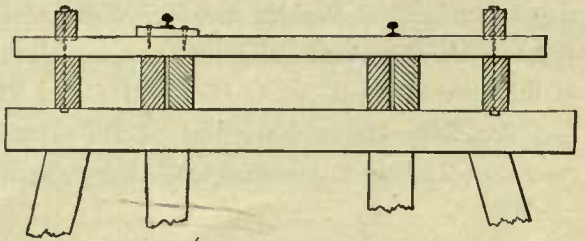


FIG. 124.—BLOCKS ON TIE.

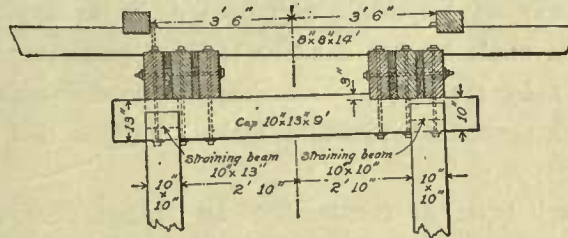


FIG. 125.—NOTCHING CAP.

always be continuous. The two batter-posts or piles which would come in the centre are replaced by a single vertical post or pile, or else entirely omitted, and a heavy guard-rail is bolted to the ties about half-way between the inside rails. An outside or "jack" stringer should always be placed beneath this guard-rail, and secured firmly in place. No scanting of the fastening on account of its interior position should be allowed. Plates IX and XXXV to XXXVII, Part II, show several double track trestles.

**Knee-braced Trestles.**—On unimportant branch lines, where the traffic is light and the trestles high, considerable economy in timber is attained by using the knee-braced type of trestle. In this form every other bent is omitted, making the spans just twice the ordinary length. The stringers are strengthened by placing a short straining-beam beneath them, and running knee-braces from either end of it down against the posts. Many engineers object very strongly indeed to using this form of construction at all. Plate XVI, Part II, shows a form of this type of trestle, which is the standard on the Norfolk & Western Railroad.

**Round-timber Trestles.**—It frequently happens that it is rather difficult to obtain sawed timber, and extensive hewing is both expensive and unnecessary. In this case the trestle is built of round timber. This form of structure is exceedingly cheap, and if well built is very serviceable, though rather rough and unfinished in appearance.

**Trestles with Solid or Ballasted Floors.**—On the line of the Louisville & Nashville Railroad, between Mobile and New Orleans, there are some trestles of very peculiar construction. The floor is made in the form of a trough and filled in with earth. The ties and rails are then laid on top of this filling, the same as on an ordinary embankment. For certain climates and regions this construction has much to recommend it. It is especially adapted to mild southern climates, and is almost absolutely protected against destruction by fire

from cinders dropped by a locomotive. All of the timber should be thoroughly creosoted. Plate VIII, Part II, shows, very clearly, one of these trestles.

Since the foregoing paragraph was written the use of ballasted floor trestles has largely increased. The subject has been pretty thoroughly investigated by the Association of Railway Superintendents of Bridges and Buildings\* and the American Railway Engineering and Maintenance of Way Association.† The plates in Part IV show a number of the later designs of this type of trestle while Plates VIII and VIIIA show some of the earlier designs.

The following is the report of the Committee on Wooden Bridges and Trestles of the American Railway Engineering and Maintenance of Way Association, Bulletin No. 96, February, 1908:

The ballast floor of wooden trestle bridges had its inception in the desire to secure a longer life than that of the common wooden trestle with open deck; to decrease the cost of maintenance; and to obtain on roads bearing a heavy traffic a practically unbroken roadbed at points requiring openings under the track, where either a poor foundation or the difficulty of obtaining materials for a permanent structure makes the first cost of such a structure prohibitive.

There are two general types of construction for ballast floor wooden trestles; one having the stringers separated and covered with plank, to retain the ballast, and the other having the stringers so placed as to form a solid floor that shall carry the ballast directly. The distance from center to center of bents and the number of piles to each bent vary in each type of construction according to the standards of the various roads.

The present standards vary but slightly from those first adopted, the changes being more in detail than in the general designs. Some roads first used the solid floor of packed stringers and later adopted the type with separated stringers. In other cases the changes have consisted either in shortening the distance center to center of bents, or in increasing the cross-section of the stringers, or both.

All the timbers used in the construction of the first ballast floor trestles were treated by the creosote process, the amount of oil injected being in nearly all cases 12 lbs. per cubic foot of timber. The only exception is that of the single ballast-floor wooden structure on the Michigan Central Railroad, with a span of 14 feet, the timbers of which were treated with carbolineum avenarius. This structure was erected in September, 1899, and still has an estimated life of four years (1908).

It has not yet been necessary to renew any of the earliest ballast floor trestles. From the time of their construction the estimated life of these bridges varies from 20 to 25 years, without repairs of any consequence. They first came into use in 1876, more were constructed in 1897, and the greatest number were built from 1901 to 1906. At present all predictions made regarding them are upheld, as no road reports having found

\* Proceedings Association of Railway Superintendents of Bridges and Buildings, 1906, pp. 155 to 215.

† American Railway Engineering and Maintenance of Way Association, Bulletin No. 61, March, 1905, pp. 5 to 7; Bulletin No. 96, Feb., 1908, pp. 12 to 22; and an article in the latter Bulletin on "Open versus Ballast Deck Structures," by A. F. Robinson, pp. 53 to 83.



it necessary to make any repairs of importance to ballast floor bridges, all the timbers of which were treated.

Three plans typical of the two general designs of ballast floor trestles are submitted herewith, those of the Mobile & Ohio Railroad, Plate LIX, and of the Illinois Central Railroad, Plate LVIII, showing the type with separated stringers covered with plank flooring and those of the Atchison, Topeka & Santa Fe System, Plate LVII, showing the type with packed stringers.

The estimated cost per linear foot of trestles similar to the Mobile & Ohio and Illinois Central plans, as constructed by different roads, is as follows:

	Average Height.	Ten Feet High.	Twenty Feet High.	Thirty Feet High.
Frisco, First Plan.....	\$15.00			
Frisco, Present Standard.....	17.70			
L. & N.....	15.00			
I. C. Four pile-bents.....		\$13.50	\$15.50	\$16.60
I. C. Six pile-bents.....		15.20	17.80	19.30
N. C. & St. L.....		16.40	18.00	22.00
E. P. & S. W.....		18.50	20.50	23.00
O. S. L. } U. P. } S. P. }	12.75			
C. R. I. & P.....		22.36	24.74	27.91
M. & O.....	14.00			

For trestles indicated by the plan of the Atchison, Topeka & Santa Fe System, the corresponding cost is as follows:

	Average Height.	Ten Feet High.	Twenty Feet High.	Thirty Feet High.
A. T. & S. F., before 1905.....	\$16.00			
A. T. & S. F., 1905 and after....	18.00			
Southern Ry.....		\$15.00	\$16.60	\$18.30

The Committee is of the opinion that the former type of construction is the better for the following reasons: First, the space between the stringers affords a better means of inspection of the stringers, which becomes increasingly necessary as the trestle nears the end of its life. Second, when repairs, renewals or changes become necessary, they may be made more easily and at less cost.

With the exception of the outside stringers, the stringers should preferably have a length equal to the distance center to center of bents plus the width of the cap. The outside stringers should have a length equal to two spans, and should break joints over the alternate bents.

The Committee is also of the opinion that the ideal ballast for ballast-floor trestles consists of broken stone that will pass through a 2-inch ring; next, in order, clean gravel that will be held on a half-inch screen; and after that, unscreened gravel, chats, and sand ballast. The objections to the last class of ballast are: It holds water, making the track

soft after very heavy rains and during long-continued wet seasons. If the cracks in the floor of the trestle are small it may eventually stop them up, and if the ballast is very fine and the cracks larger, it will sift through the floor.

The bents of the ballast-floor trestles do not drift with the direction of heaviest traffic and no more difficulty has been experienced with track creeping on them than is ordinarily experienced with the track supported by similar ballast on the ordinary roadbed. One road mentioned unusual difficulty with creeping on a very long ballast floor trestle, while another road has had similar trouble with track on an open-deck pile trestle three miles long.

Ballast-floor trestles undoubtedly decrease the danger from fire and will probably never catch fire unless it is communicated to them at their base, where they are as vulnerable to fire as any other wooden trestle.

The merits claimed for the ballast-floor trestle may be summarized thus: Long life, small cost of maintenance, practically continuous roadbed, easier riding track which may be lined and surfaced by section labor, decreased danger from fire, and greater safety in case of derailment.

The claim relating to long life and small cost of maintenance will probably not be sustained unless all of the timbers in the trestle are properly treated with an effective preservative.

The disadvantage of ballast-floor trestles to which attention has been called are the following: Difficulty of obtaining properly treated timber, great cost of first construction, possible and probable excessive cost of maintenance when the structure becomes old, difficulty of careful inspection of the vital parts of the structure, difficulty of making repairs and renewals and their probable excessive cost, and doubt as to the ultimate economy of their use.

In the absence of authoritative information on the final cost of maintenance and of renewals, the Committee cannot make any definite computation on the economic merits or demerits of the ballast-floor trestle.



## CHAPTER VII.

### IRON DETAILS.

**Spikes.**—There are two varieties of spikes used in trestle-building,—cut spikes and boat or ship spikes. Cut spikes (Fig. 126) are fashioned after the same pattern as common nails, and are essentially stamped out of sheet-metal. They should be of good quality and have generous-sized heads. Table X gives the number of cut spikes in a keg of 100 lbs., and also the weight in pounds of a single spike.

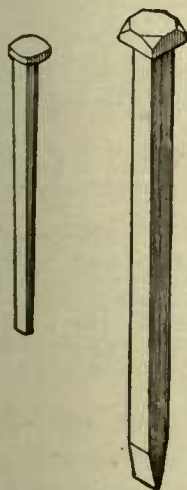


FIG. 126. FIG. 127.  
CUT SPIKE. BOAT-SPIKE.

**TABLE X.**

Cut Spikes.

Length in inches.	No. in Keg, 100 lbs.	Weight of one Spike, lbs.	Length in inches.	No. in Keg, 100 lbs.	Weight of one Spike, lbs.
3	2900	.0344	5½	850	.1176
3½	2100	.0476	6	775	.1293
4	1500	.0667	6½	575	.1739
4½	1150	.0869	7	450	.2222
5	950	.1052	8	375	.2666

Occasionally common nails of the larger sizes have a limited use, and as an aid in estimating, Table XI, giving their size and weight, is appended.

**TABLE XI.**

Size and Weight of Nails.

Name.	Length.	No. in a lb.
10-penny common.	3 inches	60
12 " "	3½ "	44
16 " "	3¾ "	32
20 " "	4 "	24
30 " "	4½ "	18
40 " "	5 "	14
50 " "	5½ "	12
60 " "	6 "	10
8 " fence.	2½ "	50
10 " "	3 "	34
12 " "	3½ "	29

These nails are of the same pattern as the spike shown in Fig. 126, but smaller. Boat-spikes are forged from bars of wrought-iron, and are of the general shape shown in Fig. 127. They have a square section, and are sharpened at the end to a kind of blunt chisel-point. This kind of spike is the one most commonly used in building trestles, and is always the kind to be employed in fastening guard-rails to ties and ties to stringers. Table XII gives the

approximate number of boat-spikes in a keg of 150 lbs. in heavy-faced type, and the weight of a single spike in light-faced type.

TABLE XII.

Number of Boat-spikes in a Keg of 150 lbs. and Weight of a Single Spike.

Thick- ness, Ins.	Length in Inches.														
	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10
¼	1910 .0785	1585 .0946	1326 .1093	1223 .1226	1025 .1463										
⅕	1010 .1485	963 .1557	810 .1851	605 .2479	583 .2572		521 .2879								
⅙			542 .2767	503 .2982	461 .3253	423 .3546	402 .3731	321 .4673							
⅓				340 .4117	312 .4839	298 .5033	280 .5357	261 .5747	240 .625	223 .6726					
⅔							221 .6787	200 .75	190 .7881	180 .8333	170 .8823	160 .9375	150 1.0000	140 1.0714	130 1.1538
⅞											140 1.0714	130 1.1538	120 1.25	110 1.3636	100 1.5000

**Drift-bolts.**—The common form of drift-bolt is but little else than a very long boat-spike, though other shapes are used quite extensively. They should always be long enough to penetrate the last timber desired to be held to a depth sufficient to give a good firm hold. Fig. 128 gives the forms of bolts in general use, the first one being that most commonly employed. Though a drift-bolt without a head is preferable to one with a head if the top of the bolt is to be driven flush with the timber, for the reason that the timbers can be forced apart sufficient to cut the bolt between them, or the bolt may be driven through the timber. They are usually made of iron having a section ¾ in. square or a diameter of ¾ in., and for fastening 12-in. caps to posts or piles are generally 20 in. long. Their weight is about as given in Table XIII.

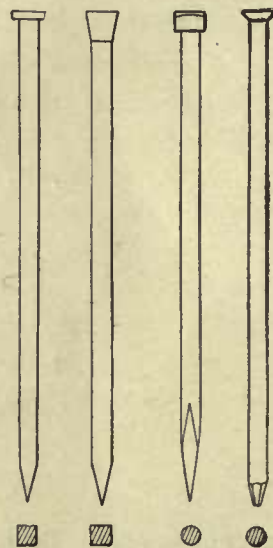


FIG. 128.—DRIFT-BOLTS.

TABLE XIII.

Weight of Drift-bolts.

Length in Inches.	Square Section.		Round Section.	
	¾" Sq.	1" Sq.	¾" Diam.	1" Diam.
	lbs.	lbs.	lbs.	lbs.
18	2.9	5.1	2.3	4.0
20	3.2	5.7	2.5	4.4
22	3.5	6.2	2.8	4.9
24	3.8	6.8	3.0	5.3
26	4.1	7.3	3.3	5.8

The main value of drift-bolts lies in their holding power. Following is a summary of three series of experiments upon this subject : \*

\* *Engineering News*, Feb. 28, 1891.



*U. S. Government Experiments.*—These experiments were made under the direction of General Weitzal by Assistant U. S. Engineers A. Noble and C. P. Gilbert, in 1874-77, and were published by Colonel O. M. Poe in his report to the Chief of Engineers for 1884. This series was very extensive, but the valuable results obtained are robbed of much of their value by the lack (in the original publication) of suitable comparisons and conclusions.

The mean of from 150 to 200 experiments with round and square bolts, both ragged and smooth, in different-sized holes, shows that the resistance after having been driven seven months is 10 per cent greater than the resistance immediately after driving, the different sizes and forms being strikingly uniform. The mean of 150 experiments under various conditions shows that the resistance to being drawn in the direction which it was driven is only 60 per cent of its resistance to being drawn in the opposite direction; that is to say, the resistance to being drawn *through* is only 60 per cent of that to being drawn *back*. The mean of 50 experiments shows that smooth rods have a greater holding power, both to being drawn through, and also to being drawn back, than ragged ones, a "moderate ragging" reducing the resistance a little more than 25 per cent, and an "excessive ragging" reducing the holding power more than 50 per cent.

Concerning the best relation between the diameter of the bolt and that of the hole, one series of 60 experiments, shows that the holding power of a 1-in round rod in a  $\frac{1}{8}$  hole is greater than in either a  $\frac{1}{16}$  or in a  $\frac{3}{16}$  hole, the resistance in the  $\frac{1}{8}$  hole being 98 per cent, in the  $\frac{3}{16}$  90 per cent, of that in the  $\frac{1}{16}$  hole. On the other hand, another series of 35 experiments makes the resistance in a  $\frac{1}{8}$  hole greater than in a  $\frac{1}{16}$  or a  $\frac{1}{4}$ , the first two being practically the same, and the last being only 85 per cent of the first. However, the difference between the two series is not material, considering the nature of the experiments. For a  $\frac{3}{4}$ -in. round bolt, four experiments on each size seem to prove that the holding power in a  $\frac{1}{8}$  hole is about one quarter greater than in a  $\frac{9}{16}$  or an  $\frac{1}{16}$  hole. For a 1-in. square bolt, the holding power in a  $\frac{1}{8}$  hole is only a trifle greater than in a  $\frac{3}{16}$ , and about 20 per cent greater than in a  $\frac{1}{16}$  hole, as deduced from 20 to 40 experiments for each size of hole.

The holding power of a 1-in. square bolt in a  $\frac{1}{8}$  hole was practically the same as for a 1-in. round rod in an  $\frac{1}{16}$ -in. hole. There is 25 per cent more metal in the square drift-bolt, while more labor is required to bore a  $\frac{1}{8}$ -in. hole than an  $\frac{1}{16}$ -in. one; therefore the round drift-bolt is at least 25 per cent more efficient per pound of metal than the square one.

The holding power of a 1-in. round bolt in a  $\frac{1}{8}$ -in. hole in white pine, when drawn back immediately after driving, is a trifle over 10,000 lbs. per linear foot of bolt, a mean of 42 experiments on 7 pieces of timber. Twelve experiments on 3 sticks of Norway pine, under conditions similar to the preceding, gave 9000 lbs. per linear foot of bolt. Experiments upon 4 sticks of nemlock seem to show that the resistance is practically the same as white pine.

One-inch round screw-bolts were screwed into  $\frac{1}{8}$ ,  $\frac{1}{16}$ , and  $\frac{3}{16}$ -in. holes and immediately drawn back, the result being that there was but little difference for the different-sized holes. Half of the bolts had 8 threads to the inch and half had 12, the latter giving a very little the greater resistance. The resistance for the screw-bolts was about 50 per cent more than the maximum resistance of the plain round rods.

The report says: "Two classes of blunt points were used: Long, blunt points, tapered back for a distance of  $1\frac{1}{2}$  to 2 in. and reduced to a round section, on square as well as round

bolts, with a diameter less than that of the hole into which it was driven. They were pointed hot. Short, blunt points were reduced in size at an angle of about  $45^\circ$  by cold hammering, the point of the square bolt remaining square, with rounded corners, the intention being more to remove all cutting edges from the point than to reduce it much in size or change the square sections to round." The experiments were not so arranged as to make it possible to draw any reliable conclusion as to the relative merits of the two forms of points; but if the experiments show anything in this respect, it is that the resistance of bolts having "long, blunt points" is about ten per cent more than those having "short, blunt points."

*Brooklyn Bridge Experiments.*—Experiments made in connection with the construction of the East River Bridge by Mr. F. Collingwood and Colonel Paine, and communicated by the former, gave a holding power of 12,000 lbs. per linear foot of bolt for a 1-in. round rod driven into a  $\frac{1}{8}$ -in. hole in first quality Georgia pine, and a resistance of 15,000 lbs. in a  $\frac{1}{4}$ -in. hole. It was found that in lighter timber containing less pitch the holding power was about 20 per cent less; and in very dense wood, containing more pitch, about 10 per cent more.

*University of Illinois Experiments.*—A third series of experiments was made by Mr. J. B. Tschanner in the testing laboratory of the University of Illinois, and published in full in "No. 4, Selected Papers of the Civil Engineers' Club of the University of Illinois." According to these experiments, the average holding power of a 1-in. round rod driven into a  $\frac{1}{8}$ -in. hole in pine, perpendicular to the grain, is 6000 lbs. per linear foot; and under the same conditions the holding power in oak is 15,600 lbs. per linear foot. The holding power of the bolt driven parallel to the grain is almost exactly half as much as when driven perpendicular to the grain. If the holding power of a 1-in. rod in a  $\frac{1}{8}$ -in. hole be designated as 1, the holding power in a  $\frac{1}{4}$ -in. hole is 1.69; in a  $\frac{3}{8}$ -in. hole, 2.13; and in a  $\frac{1}{2}$ -in. hole, 1.09. The holding power decreases very rapidly as the bolt is withdrawn.

**Dowels.**—In place of drift-bolts with point and head, plain iron bars, either square or round, are frequently resorted to. These are not forged or altered in any way, but are placed in the structure in just the condition that they are sheared from the rods, the only precaution taken being to see that they are straight.

The ties are frequently dowelled to the stringers. Pins made of  $\frac{5}{8}$ -in. round iron cut into pieces 5 in. long, are of a very good size. They weigh 0.4304 lb. each.

One method of fastening the posts, caps, and sills together is by means of dowels,  $\frac{3}{4}$  in. by 8 in., which weigh about one pound each.

The following list gives the weight of one inch of a bar of iron of the various diameters most frequently employed in this kind of work:

1 inch square, . . . . .	0.2806 lb.	$\frac{3}{4}$ inch diam. round, . . . . .	0.1240 lb.
1 " diam. round, . . . . .	0.2204 "	$\frac{5}{8}$ " square, . . . . .	0.1096 "
$\frac{7}{8}$ " square, . . . . .	0.2149 "	$\frac{5}{8}$ " diam. round, . . . . .	0.0860 "
$\frac{7}{8}$ " diam. round, . . . . .	0.1687 "	$\frac{1}{2}$ " square, . . . . .	0.0701 "
$\frac{3}{4}$ " square, . . . . .	0.1579 "	$\frac{1}{2}$ " diam. round, . . . . .	0.0551 "

**Bolts.**—Bolts for holding the stringer-pieces together, fastening on the braces, guard-rails, etc., are made of  $\frac{3}{4}$ -in. round iron. They vary in length of course, according to the use



they are intended for. A head should be forged on one end, and a good, deep, well-formed right-hand thread cut upon the other for an appropriate distance. There are three kinds of heads in use in trestle-building: the round or button head, the flat countersunk head, and the ordinary square head (Fig. 129).

Square nuts with a thickness equal to the diameter of the bolt, and each side to twice the diameter, are the best. The outer top corners of the nuts and square heads should be chamfered. A cast-iron washer, from 3 in. to  $3\frac{1}{2}$  in. in diameter, is to be placed beneath both head and nut of all bolts. The bolts are driven through holes bored in the timber, and which should be  $\frac{1}{16}$  in. less in diameter than the bolts, so as to insure a snug fit.



FIG. 129. BOLTS.

While the weight of the bolt will be somewhat affected by the shape of the head, still the weight given in Table XIV may be used in making up preliminary estimates, as the error will be on the safe side; i.e., too heavy.

TABLE XIV.

Approximate Weight of Bolts in Lbs., with Square Heads and Nuts, including both.

Length under Head in Inches.	Diameter in Inches.				
	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{7}{8}$	1
6	0.59	1.01			
7	0.64	1.10			
8	0.70	1.19			
9	0.75	1.27			
10	0.81	1.36	2.10	3.05	4.23
11	0.86	1.44	2.22	3.22	4.45
12	0.92	1.53	2.35	3.39	4.67
13	0.97	1.62	2.47	3.55	4.89
14	1.03	1.70	2.59	3.72	5.11
15	1.08	1.79	2.72	3.89	5.34
16		1.87	2.84	4.06	5.56
17		1.96	2.97	4.23	5.78
18		2.05	3.09	4.40	6.00
19			3.21	4.57	6.22
20			3.34	4.74	6.44
21			3.46	4.90	6.66
22			3.59	5.07	6.88
23			3.71	5.24	7.10
24			3.83	5.41	7.32

In ordering bolts the term "grip" is sometimes employed, meaning the total thickness of the material to be held together, or, in other words, the distance between the inside faces of the washers.

**Lag-screws.**—A lag-screw (Fig. 130) is little more than a very large wood-screw, with a square head similar to a bolt-head. A hole the full size of the shank should be bored through the first timber, otherwise the screw will not draw the timbers together. For the balance of the distance the hole should be bored much smaller. Under the head of each screw a wrought washer should be placed. The following table gives the details of the proper size of washer to use for different-sized lag-screws:

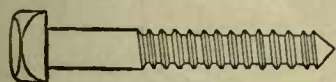


FIG. 130.—LAG-SCREW.

TABLE XV.  
Proper Size of Wrought Washers.

Diam. Lag-screw.	Diam. of Washer.	Diam. of Hole.	Thickness Wire-gauge.	No. in 150 lbs.	Weight of one in lbs.
$\frac{1}{8}$ inch	$1\frac{3}{8}$ inches	$\frac{9}{16}$ inch	No. 12	4500	.0333
$\frac{3}{16}$ "	$1\frac{1}{2}$ "	$\frac{11}{16}$ "	" 10	2500	.06
$\frac{1}{4}$ "	2 "	$\frac{13}{16}$ "	" 10	1600	.0938

Separators, Thimbles, Packing Washers.—These were described when treating of stringers. They are made of cast-iron, which should be of good quality and free from blow-holes. Table XVI gives their dimensions and approximate weight.

TABLE XVI.  
Details of Cast-iron Separators (see Figs. 62 to 72).

Kind.	Dimensions in Inches.						Weight in lbs.
	Diam. of Rims or Ends.	Thickness of Rim.	Breadth of Rim or Ends.	Thickness of Disk or Length of Spool from Outside Face to Outside Face of Ends.	Diam. of Hole.	Diam. of Spool or Smallest Diameter.	
Fig. 62	3	$\frac{3}{8}$	1	$\frac{1}{8}$	$\frac{7}{8}$		1.7
" 63	3	$\frac{3}{8}$	1	$\frac{1}{8}$	$\frac{7}{8}$		1.03
" 64	3	$\frac{3}{8}$	$1\frac{1}{4}$	$\frac{1}{8}$	$\frac{7}{8}$		1.5
" 65	$3\frac{3}{8}$	$\frac{3}{8}$	$1\frac{1}{4}$	$\frac{1}{8}$	$1\frac{1}{4}$	$2\frac{7}{8}$	
" 66	$2\frac{1}{2}$	$\frac{3}{8}$	1	$\frac{3}{16}$	$\frac{7}{8}$		0.6
" 67	4	$\frac{3}{8}$	$\frac{3}{4}$	$4\frac{1}{2}$	$\frac{7}{8}$	2	5.5
" 68	4	$\frac{3}{8}$	$\frac{3}{4}$	3	$\frac{7}{8}$	2	3.25
" 69*	4	$\frac{3}{8}$	$\frac{3}{4}$	6	1		1.7
" 70	4	$\frac{3}{8}$	$\frac{3}{4}$	6	$\frac{7}{8}$	$1\frac{3}{8}$	3.75
" 71	3	$\frac{3}{8}$	2	2	$\frac{7}{8}$	2	2.5
" 72	3	$\frac{3}{8}$	$\frac{1}{4}$	4	$\frac{7}{8}$	$1\frac{1}{4}$	1.75

\* The six smaller holes are  $\frac{5}{8}$ " in diameter.

Washers.—Cast-iron washers are used very extensively. They are always placed under the heads and nuts of all bolts in the structure. Fig. 131 gives a few of the designs in

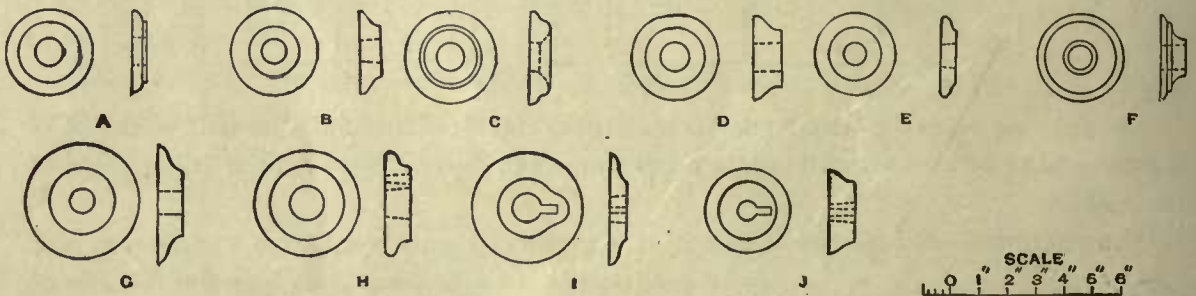


FIG. 131.—CAST-IRON WASHERS.

use, and Table XVII their weight and dimensions. The solid washers are placed under the heads of the bolts, and those having either a slot or second hole in them under the nuts. The purpose of these slots or holes is to enable a nail to be driven in close to the nut after it has been screwed down tight, to serve as a nut-lock.



TABLE XVII.

Details of Cast-iron Washers.

Kind. Fig. 131.	Dimensions in Inches.				Weight in lbs.
	Diam. of Back.	Diam. of Face.	Diam. of Hole.	Thickness.	
A . . . . .	3	2½	1	1	1.25 1.375
B . . . . .	3	1¾	7/8	1	
C . . . . .	3½	2½	1	1	
D . . . . .	3	2	1	1	
E . . . . .	2¾	1¾	7/8	1	
F . . . . .	3	1½	7/8	1	
G . . . . .	4¾	2¾	7/8	1	
H . . . . .	3	2	¾	1	
I . . . . .	4	2	1	1	
J . . . . .	3¾	2½	1 1/16	1	
Similar to B	3½	2	1	1	
" " G	4½	2	1	1	

As wrought-iron washers are used to a greater or lesser extent in this class of work, a table giving the details of the standard washers as now manufactured, is appended.

TABLE XVIII.

Showing the Average Number of Wrought-iron Washers in a Keg of 150 lbs., of each Standard Size, As adopted by "The Association of Bolt and Nut Manufacturers of the U. S."

Diameter.	Size of Hole.	Thickness Wire-gauge.	Size of Bolt.	No. in 150 lbs.
½	¼	No. 18	5/16	80,000
5/8	5/16	" 16	¾	34,285
¾	7/16	" 16	¾	22,000
7/8	¾	" 16	5/8	18,500
1	7/8	" 14	¾	10,550
1¼	¾	" 14	7/16	7,500
1 5/8	9/16	" 12	5/8	4,500
1½	5/8	" 12	9/16	3,850
1¾	11/16	" 10	5/8	2,500
2	13/16	" 10	¾	1,600
2¼	15/16	" 9	7/8	1,300
2½	1 1/16	" 9	1	950
2¾	1½	" 9	1 1/8	700
3	1 5/8	" 9	1 1/4	550
3½	1 7/8	" 9	1 5/8	450

These washers are merely circles stamped from sheet-iron, with a hole punched through the centre of them.

**Nut-locks.**—Special nut-locks are not required in trestle-work. The method of locking by driving a nail close to the side of the nut, through a hole in the washer, as mentioned when treating of cast washers, is as good and cheap a one as could be desired. Nicking the threads of the bolts with a centre-punch, after the nuts have been screwed home, is another very good way.\*

\* This method is used on the Texas & Pacific Railway.



**Rail Chairs.**—On the Lake Shore & Michigan Southern Railway cast-iron rail chairs are used on certain trestles (coal-dumping trestles, etc.) where it is not desirable to use ties. Fig. 131a gives the details of such a chair and shows its use.\*

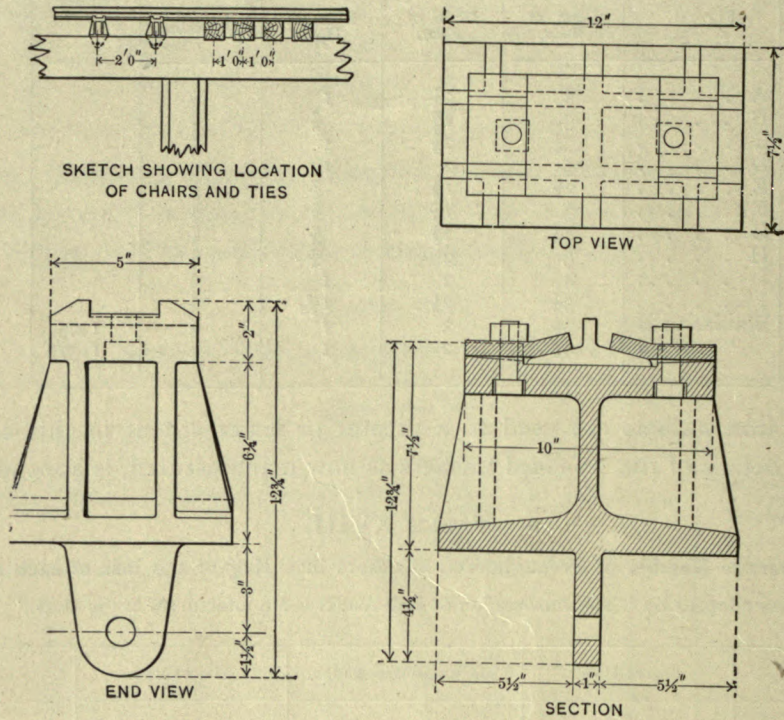


FIG. 131a.—STANDARD CAST RAIL CHAIR FOR CARRYING RAILS WHERE TIES ARE NOT USED, LAKE SHORE & MICHIGAN SOUTHERN RAILWAY.

\* Proceedings American Railway Bridge and Building Association, 1908, p. 168.



## CHAPTER VIII.

### CONNECTION WITH EMBANKMENT—PROTECTION AGAINST ACCIDENTS.

**Connection with Embankment.**—There may be said to be two principal methods of connecting trestles with the embankment, viz., by sills built in the embankment itself, and by a pile-bent placed at its edge.

There are several ways of arranging the bank-sills. Sometimes they are piled up criss-cross, after the same fashion as in building a crib, several layers high. They should be of 12-in.  $\times$  12-in. timber, and at least 10 ft. long, and much better if the crosswise ones are 12 ft., securely fastened together by a drift-bolt wherever they cross each other. It is seldom that more than two sticks are used in each layer; those of the top layer should be at right angles to the center line of the road, and placed quite close together over the center of the crib. Their upper surfaces should be on the same grade level as the caps, so that the stringers will have a good bearing, the stringers being securely drift-bolted to them. After everything is in place earth should be packed in closely both inside and around the crib, and the bank carried out to at least the middle of the first bay. It will frequently be found necessary to protect the end of the bank from being washed away either by a revetment of logs, by sheet-piling, by rip-rap, or by other means.

Rather than arrange the bank-sills crib-fashion, some prefer to lay from two to eight or more pieces of the same size timber close together, on the same level and at right angles to the road. In this case, as before, the stringers should be drift-bolted to the bank-sills.

With whichever arrangement is used, however, the bank should be allowed to stand as long as possible before putting in the bank-sills, so that it will have time to settle.

The preferable way to connect the trestle with the bank is by a bank-bent. This is either a pile-bent of three or four piles, or a light framed bent. In any case the ends of the stringers are usually protected from contact with the earth by a piece of heavy plank nailed across them, called a dump-board. Plate VI, Part II, shows a form of bank-bent. It sometimes happens that it is necessary to plank up behind the bank-bent so as to prevent the embankment spreading beneath the trestle. In this case, if a pile-bent is used, it should be strongly built, and the piles penetrate to a considerable depth, especially if the bent be of any height. It is also well to brace the tops of the piles against the foot of the piles in the next bent, so as to prevent the bank-bent being forced over by the pressure of the embankment behind it. If a frame bent is chosen, it should be strong and heavy, and well braced against its neighbor, both diagonally and by girts acting as struts. If possible, the girts or horizontal bracing should extend clear across the whole structure, be of heavy material, have butted joints and be well fastened, so as to avoid buckling; in other words, they should fulfil all of the requirements for struts.





arranged so as to stop a car, the truck of which has moved half of the gauge or more out of line. This would at least save the bridge, even though it would not prevent an accident. Fig. 118 shows such collision-posts.

In Fig. 132, the details of the Latimer bridge-guard, as used on the Savannah, Florida & Western and the Charleston & Savannah Railways, Mr. B. W. Howe, Jr., Chief Engineer, are given.

A committee report on Pile- and Frame-Trestle Bridges of the American Railway Bridge and Building Association (Proceedings, 1908, p. 164) says, "It would seem to be the best practice to use a metal guard-rail; if no specially designed rail is used, old rails spiked inside the traffic rails, and terminating in an old frog-point in the center of the track against approaching trains may be used. This point should be placed far enough from the end of the bridge so that the rails will not converge too rapidly. On the approach in the direction of traffic the point may be omitted and the rails terminate a short distance from the end of the bridge. On single-track roads there should be a point on each approach." Many roads "use 'T' rails, usually old track rails and somewhat lighter than the traffic rails. These rails are spiked to the ties at a distance varying from 6 to 10 inches on the various roads."

**Refuge-bays.**—On all trestles of any length, say two hundred feet or over, refuge-bays or small railed platforms to receive workmen or track-walkers who may be caught on the bridge by a train should be placed every two or three hundred feet apart. These cost but very little, and are very efficient in insuring greater safety to employees, especially on single-track trestles.

Fig. 133 shows an excellent attachment for this purpose.

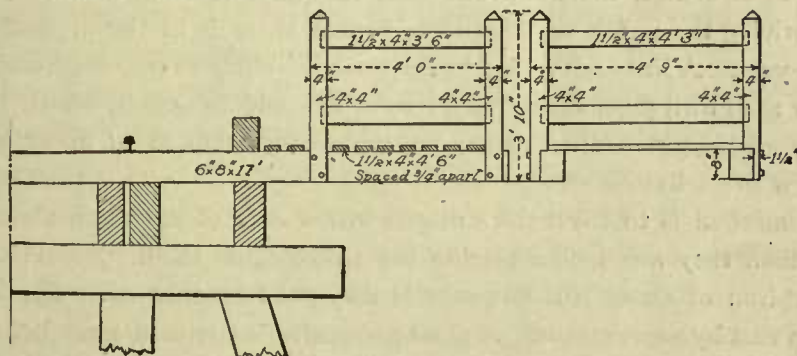


FIG. 133.—REFUGE-BAY.

Every fourth or fifth refuge-bay on trestles over one thousand feet long, especially when on or approached by a curve, should be made large enough to receive the hand-car; and when the section-men or the repair-gang are at work on the bridge they should always be compelled to place the hand-car on the refuge-bay, together with all idle tools, before they begin work.

**Foot-walks.**—Some engineers recommend the laying of foot-walks, composed of three or four rows of 4-inch plank, along the centre of the trestle. This, however, for a number of reasons, does not seem desirable, even though it make the life of the track-walker more enduring. Among the objections may be mentioned:

1st. A tendency to make the track-walkers and others careless in their examination of the structure.

2d. It offers a greater temptation to people to make a highway of the trestle on account of the greater comfort and ease with which it may be crossed, and hence encourages the public to trespass upon the railroad company's property, and that upon the most dangerous places.

3d. It increases, very largely, the area for cinders from the engines to fall upon, and hence makes the risk of fire much greater.

**Fire Protection.**—As long as wooden trestling is used fire will be one of the most troublesome subjects to deal with. There are several devices, which are now employed more or less extensively, to reduce the danger from this source.

The one most extensively used is to place tubs or half-barrels, which are kept full of water, at short intervals along the trestle. They should never be over two hundred feet apart, and should each be supplied with a pail or generous-sized dipper. The pails should never be made of wood, as they are liable to be found in anything but a serviceable condition when most needed. Both "Indurated fibre" and "Granite" or enamelled iron-ware are excellent materials for this purpose. The water in the tubs should never be allowed to become low, and it should be the imperative duty of the track-walker to see that they are kept full. Common kerosene oil-barrels cut in half make very good tubs. On single-track trestles these are placed on one side upon the ends of two ties, which are purposely made longer than the others for this use. On double-track trestles they are placed between the two tracks. As this safeguard is very cheap indeed, there is no reason why every trestle in the country, without exception, should not be so protected. In the colder portions of the country there is, of course, the disadvantage of the water freezing in winter, but this is no reason for depriving the public of what little benefit there is in the apparatus during the balance of the year. A little salt added to the water will help to prevent freezing. Railroad companies, for their own sake, should adopt it, as it would frequently lessen the cost of an accident by furnishing immediate means for the extinguishment of many a fire in its incipiency, after a wreck has occurred.

A second method is to cover the stringers with a strip of sheet-iron about three or four inches wider than they are, before placing the ties, etc., on them. See Plate III, Part II. Common sheet-iron of about No. 27 gauge is very good for this use. The iron should be protected from rust by some means. A good preventive is common tar. Before putting the iron in place it should be warmed, and thoroughly painted all over with the hot tar.

A third kind of fire protection is that illustrated in Plate VIII, Part II, in which the trestle has a solid floor which is covered with earth.

Not only should means be provided to prevent the spread of and to put out fires that have once started from unavoidable or accidental causes, but every precaution possible to prevent them approaching from the outside should also be taken. The right of way to a width of 15 to 20 ft. from either side of the trestle should be kept perfectly clear of all combustible matter of any kind at all times. Not only should this rule be closely observed, but no amount of any moment should be allowed to accumulate outside of this limit. Within it, all weeds and tall grass should be kept closely cut. When construction or repairs are going



on, all chips and small blocks should be raked up in a heap at the close of the day, at a safe distance from the work, and set on fire. If the work is being done by contract, the contractor ought to see that this is done for his own protection. When the trestle is on a line in course of construction, the right of way should be thoroughly cleared, the necessary space grubbed, and the rubbish cleaned up and completely burned before erection is allowed to be begun, or at any rate before the trestle is accepted by the engineer or the contractor estimated for the work done. Any trees off of the right of way which are likely to fall upon and injure the trestle should be felled. It is the railroad company's place to obtain permission to do this, though the contractor may be rightly called upon to do the work for which he may be estimated at the same rate as for clearing.

**Fire-proofing for Timber Trestles.**—The following abstract on the fireproofing of wooden trestles is taken from the report of a committee of the American Railway Bridge and Building Association (Proceedings, 1911) as well as Figs. 133*a*, 133*b*, 133*c*, and 133*d*.

This report deals principally with the methods of preventing fires on timber trestles rather than with the method of extinguishing the fire after it has started. The use of water-barrels and such other things will not be considered here, because they do not make a bridge fireproof; they are only agencies by which the fire may be extinguished if someone gets to the bridge in time. What we want to consider herein is the manner of constructing timber trestles so that they will not ignite.

Most of the fires on bridges are started by sparks or coals from locomotives, although the source of the fire may be entirely foreign to railroad equipment. Not many bridges are destroyed by fire from outside sources, and beyond cleaning away vegetation from the vicinity of the bridge it would hardly pay to fireproof for such causes. Fire dropped from locomotives has burned up many bridges, and almost all such fires can be avoided by the use of a good type of fireproofing.

The question might be raised, "Does it pay to make trestles fireproof?" It is difficult to say just how much loss may result from the burning of a bridge. It will certainly be more than merely the cost of rebuilding the bridge. The greatest loss would be in case of a disastrous train wreck due to a burned bridge. If, however, the fire is discovered before a train may be wrecked, there is the delay to traffic, and the hurried rebuilding of the bridge, which costs considerably more than rebuilding under ordinary conditions.

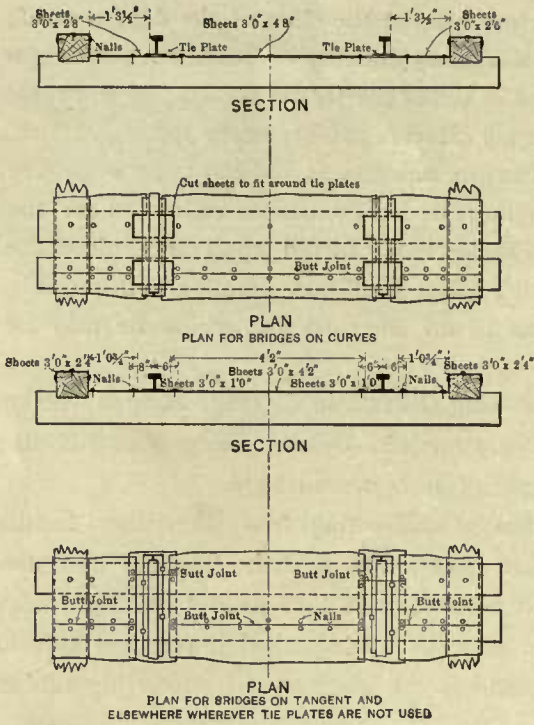
With the primary object of protecting human lives, the Railway Commissioners of Canada require that railroads fireproof their bridges. They have issued a set of regulations, which is given later on, giving several methods which will be accepted by them as sufficient fire protection for timber bridges.

Timber bridges which need fireproofing most are those on high-speed lines and those which may be visible to the engineman for only a short distance. The larger the bridge, the greater the need of fireproofing.

Types of fireproofing used mostly at the present time are as follows:

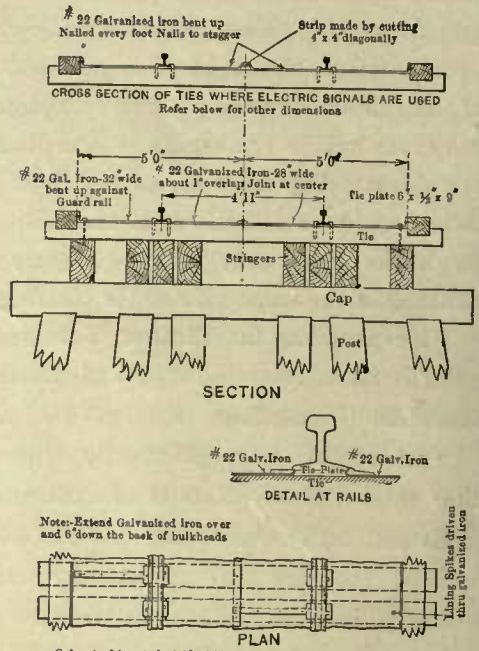
- A. Ballasted-floor pile bridges; about the same amount of ballast being placed under the tie, on the bridge, as on an embankment.

A TREATISE ON WOODEN TRESTLE BRIDGES.



Notes:  
Material #22 Galvanized Iron  
Nails are 7d heavy barbed car nails 2 1/4" long  
#8 Gauge and especially Galvanized

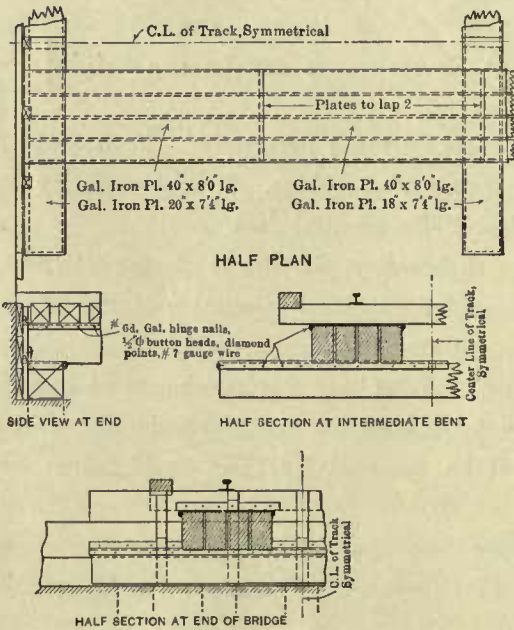
Chicago, Milwaukee & St. Paul Railway.



Note:—Extend Galvanized iron over and 6" down the back of bulkheads

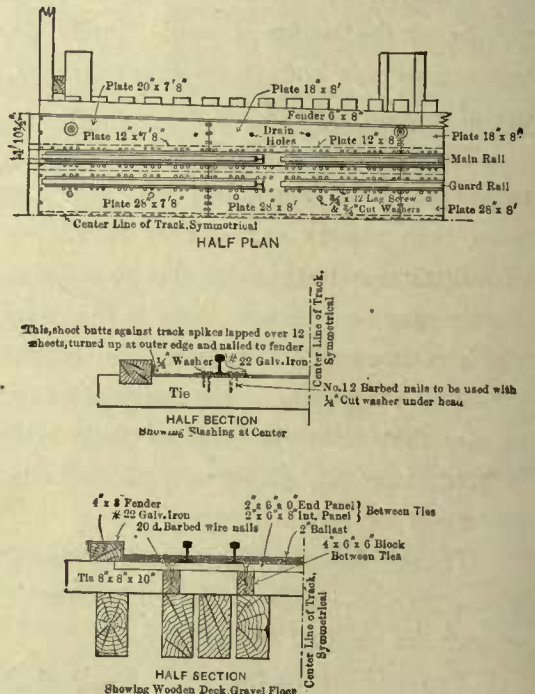
Galvanized iron to be laid with one edge turned up under flange of rail and notched to fit closely around tie plate.  
For bridges on grades or with super-elevation, lap sheets in such a manner as to shed water.

Great Northern Railway.



Notes:—  
Galvanized Iron to be #24 Gauge  
Galvanized American Ingot Iron or an Equivalent

Frisco Lines.



This sheet butts against track spikes lapped over 12" sheets, turned up at outer edge and nailed to fender

No. 12 Barbed nails to be used with 1/4" Cut washer under head

Chicago, Burlington & Quincy Railroad

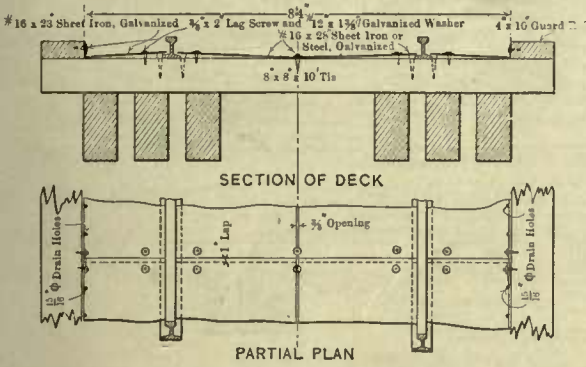
FIG. 133a.—FIRE-PROOFING FOR TIMBER TRESTLES.



B. Metal covering on the ties.

C. Ballast covering from 2 to 4 inches thick on the ties; a wood filler being placed between the ties to support the ballast.

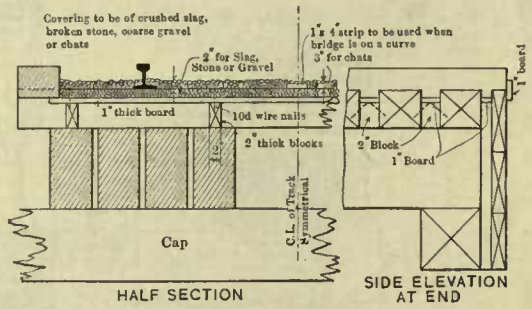
D. Metal covering on the caps and stringers.



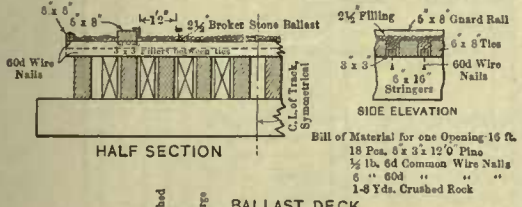
Chicago & Northwestern Railway.



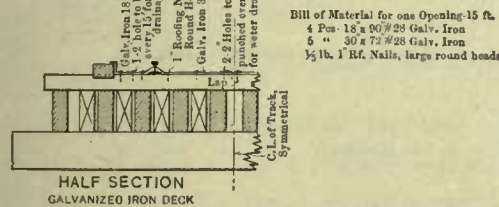
Norfolk & Western Railway.



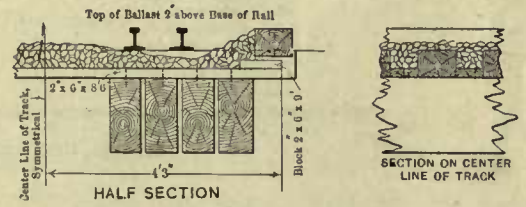
Chicago, Rock Island & Pacific Railway.



Minneapolis, St. Paul & Sault Ste. Marie Railway.



Minneapolis, St. Paul & Sault Ste. Marie Railway.



Atchison, Topeka & Santa Fe Railway.

FIG. 133b.—FIRE-PROOFING FOR TIMBER TRESTLES.

E. Metal covering on the ties with 2 inches of ballast thereon.

F. Ordinary pile bridges built with certain kinds of treated timber.

G. Fire-resisting paints.

H. Pile bridges having I-beam stringers.

The fireproof feature of ballasted-floor timber trestles is not the most important reason for adopting this type of construction, and the details of such bridges cannot properly be considered here, except to say that the ballast serves as a first-class fire protection for the timber. These bridges with treated timber cost about 75 per cent more than the ordinary pile bridges.

The method of entirely covering the ties with metal is favored by many roads. It affords very good protection when the sheets are firmly attached and in good condition. If the

metal used is of a poor quality and light weight, holes will soon develop and if it is not properly fastened it will soon work loose and the ends will curl up. If these things happen the covering is apt to assist ignition rather than prevent it, because the loose ends and holes will catch coals and sparks. There are many different ways of putting on this covering, the

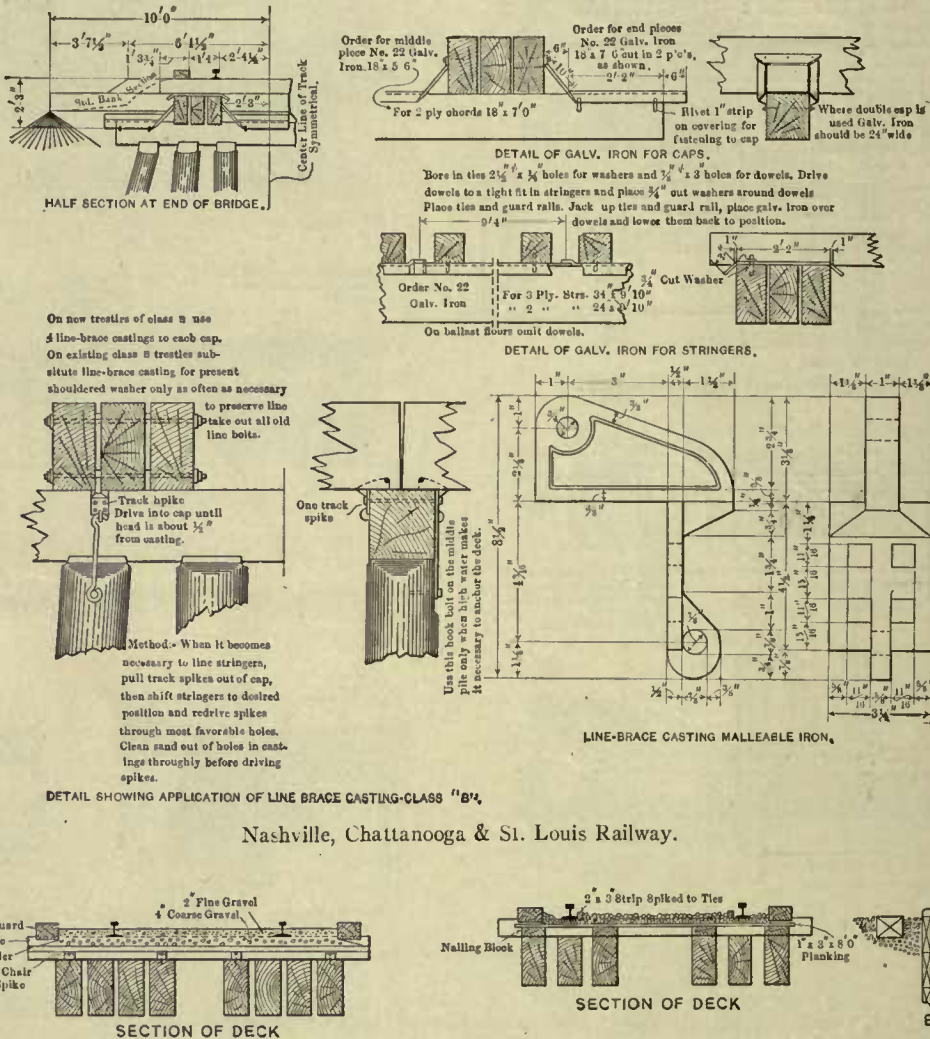


FIG. 133C.—FIRE-PROOFING FOR TIMBER TRESTLES.

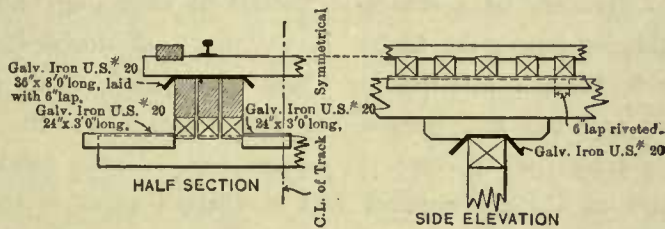
principal difference being the method of attaching the galvanized iron around the track rails. In most cases, No. 22 iron is used. To obtain the best results the metal should be securely fastened and of such a quality and weight that it will last a reasonable length of time. It should last as long as the timber in the bridge. When a good quality of No. 22 galvanized iron is used, this type costs about 75 cents per lineal foot, single-track bridge.

Ballast covering over the entire deck is another type which affords good protection so long as everything is in good condition and no timber is exposed. Gravel ballast is used



in most cases, although stone, slag and clay are also used to a considerable extent. The vibration will cause the ballast to bunch over the more rigid parts of the bridge, leaving some of the ties exposed. A very serious objection is that the ballast holds the moisture, which causes decay in the timber. Clay affords a good protection and can be obtained in almost any locality; it is more stable under vibration than gravel, but it will hold moisture longer than the other materials. The draft of high-speed trains tends to remove the ballast covering from the bridge.

The position of the filler blocks between the ties should be considered. The two extremes are—placing the filler on the stringers and placing it flush with top of ties. Placing the filler directly on the stringers necessitates a large amount of ballast for covering without gaining anything over a smaller amount as regards fireproofing. The decay of the timber is faster, because the contact surface between ballast and timber is larger, and the larger



Notes.—Galvanized iron covers over cap are to fit tight against stringers and to be nailed to cap. In placing galvanized iron on stringers, rivet three of the 8' o'' sheets together and put them in place without riveting the joints between these three sections and adjacent ones, but give them the usual lap of 6'' at these joints. See that vertical bolts through caps are put in as soon as possible after galvanized iron is placed to prevent it from running. Sheets to be riveted together with  $\frac{1}{4}$ '' rivets,  $\frac{1}{2}$ '' long, spaced 3'' single lines.

Louisville & Nashville Railroad.

FIG. 133d.—FIRE-PROOFING FOR TIMBER TRESTLES.

volume of ballast will hold more moisture. If the filler is placed flush with the top of the ties, the gravel rests on an unbroken surface and will readily move about, due to the vibration of the bridge and the draft of trains, which will leave bare spots. Probably the best way is to place the filler so that it will come about 1 inch below the top of the tie and then place 3 inches of ballast on the filler, which would provide 2 inches of ballast above the ties. With gravel ballast such construction costs about 35 cents per lineal foot of single-track bridge. Sometimes galvanized iron is placed over the guard-rail in connection with the ballast covering. This adds about 15 cents per lineal foot to the cost.

Galvanized iron is placed on the tops of caps and stringers by a number of roads, the object being to protect the timber from weather as well as from fire. In this way the ties are left bare, but the more important parts of the bridge are protected. It is not difficult to keep such covering in place. The metal should be of quality and weight sufficient to last as long as the timber. Using a good quality of No. 20 galvanized iron the cost is about 60 cents per lineal foot of single-track bridge.

Sometimes a covering of ballast about 2 inches thick is placed on the metal covering of type B. This partly overcomes some of the objections to this type, in that if some of

the edges of the galvanized sheets work loose or holes develop in the metal the presence of the ballast will prevent fire. The draft caused by trains and the vibration of the bridge will cause the ballast to move about and leave bare spots as in type C. Also, the ballast will retain moisture; but this is not so serious as in type C, because the ballast does not come in contact with the timber; however, the moisture will rust the metal. The use of gravel ballast will increase the cost of type B about 6 cents per lineal foot.

On one road, zinc-treated timber was found to be of value in resisting fire. The trestles are built in the usual way and treated timber used. This type probably adds \$1.50 per lineal foot to the cost of a pile bridge and it would not pay to use it for the one reason of fireproofing, because the cheaper types would afford just as good protection.

Fire-resisting paints are used to a considerable extent in the East and in Canada, with good results in most cases. If a paint exists which makes timber absolutely fireproof its employment would certainly be a first-class method of protecting bridges from fire, provided the paint would not injure the timber in any way. A double-track trestle 136 feet long was painted with Clapp's Fire-resisting Paint—the paint being applied to the top of caps and stringers and top and sides of ties and guard-rails. The cost was 16½ cents per lineal foot, single track, or 1¼ cents per square foot of area painted. The Board of Railway Commissioners of Canada requires that if Clapp's paint is used, one coat must be applied at least every five years.

The use of I-beams for stringers reduces the probability of fire, although this can hardly be called a method of fireproofing timber trestles. Such construction costs about 20 per cent more than ordinary pile bridges.

Inspection and repairs are made more difficult by the use of types A, B, C, D and E, but with types F, G and H, accessibility to the different parts of the bridge is just as easy as for ordinary pile bridges, hence inspection and repairs are not interfered with.

#### CONCLUSIONS.

Most railroads favor the ballasted-floor pile bridge because it has many desirable qualities as well as being fireproof.

The protection of the timber from the weather is probably as much the reason for using type D as the fireproof feature.

Types F and H are used because with them a bridge is more permanent than the ordinary timber trestle, hence does not need so many repairs.

Types B, C, E and G are used solely to protect bridges from fire, and since type E is merely a slight modification of type B there remain only three types used exclusively for fireproofing.

As stated above, with the use of types B and C, inspection and repairs are more difficult to make than ordinarily, and this is quite important on timber structures; also when type C is used a more rigid inspection is necessary and more repairs will be needed than otherwise.

Type G is very simple and does not change the general construction of the bridge in



any way. Another thing in its favor is the comparatively low cost. There is, however, some doubt as to its effectiveness, but a thorough test made under actual working conditions ought to determine whether a fire-resisting paint is practicable to use for fireproofing timber trestles.

The requirements of the Board of Railway Commissioners for Canada, adopted in 1909, are as follows:

1. That every railway company subject to the legislative authority of the Parliament of Canada operating by steam power any railway or railways, any part or parts of which is or are constructed of, or upon, wooden trestles, the whole of which cannot be seen from an approaching train for a distance of at least one thousand feet, do, during the months of May, June, July, August, September and October of each year, provide, place and keep a watchman, track-walker, fire alarm signals, ballast flooring, zinc covering over caps and intersections, or approved fireproof paint, as hereinafter directed, for the purpose of protecting the said trestles from fire; each such company having the option of adopting any of the said foregoing methods of protection.
2. That every such company shall cause to be placed and maintained at every trestle less than thirty feet in length, one barrel of a capacity of at least forty-five gallons, and on trestles of over thirty feet in length a like barrel upon or near each end, with intermediate barrels of the like capacity not more than one hundred and fifty feet apart: Provided however, that pile trestles over streams or other bodies of water need not be furnished with intermediate barrels.
3. That every such company shall cause the said barrels to be kept filled with water.
4. That every such company shall cause all brush and dead grass to be removed from beneath and around every such trestle, and shall cause its right of way crossed by such trestle to be kept free from combustible matter.
5. That, on or in the neighborhood of timber lands, or in localities distant from settlement, every such company shall cause to be provided pails for use at all trestles, and all watchmen and track-walkers shall carry such pails while upon duty at trestles.
6. That where the protection provided is by watchman or track-walker all trestles on main lines shall be inspected at least twice each twenty-four hours, at intervals of not less than eight hours, and once every twenty-four hours on branch lines.
7. That in the event of any such barrel or pail not being in good and efficient condition for holding water every such watchman or track-walker shall forthwith repair or replace the same or if it cannot be done by him, he shall forthwith report such condition to his superior officer. Every such watchman or track-walker shall see that the water barrels are at all times kept filled to within ten inches of the top, or forthwith report same to his superior officer. Every such watchman or track-walker, whenever any such trestle is injured by fire, shall, as soon as possible thereafter, report the same to his superior officer.
8. That the fire alarm signals be equal, in the opinion of an Engineer of the Board, to the Montauk Thermostat.

9. That if fireproof paint is used, one coat thereof, at least equal to the Clapp Fireproof Paint, be applied at least every five years.

10. That the ballast flooring be of gravel and be at least equal to the standard of the flooring adopted by the Great Northern Railway Company, plans of which are on file with the Board under file No. 4966, case 1860. This flooring consists in a complete coating of gravel from beneath the head of the rail to the ties, and extends laterally from outside guard-rail to outside guard-rail.

11. That if zinc or galvanized iron is used, the caps, stringers, and the outside of the batter posts of every such trestle, and, if the company desires, the ties, be covered with a zinc or galvanized iron covering.

12. That every such railway company failing or neglecting to comply with any of the foregoing regulations, shall be subject to a penalty of thirty dollars.

13. That every such watchman or track-walker failing or neglecting to make inspection in accordance with the foregoing regulations, or failing or neglecting to make any of the reports herein required of him, or otherwise defaulting in any of the duties imposed upon him by this order, shall be subject to a penalty of fifteen dollars for each such failure or neglect.

14. That every such railway company shall cause every such watchman or track-walker to be furnished with a copy of this order.

15. That the Order of the Board No. 5103, dated July 30th, 1908, be, and it is hereby rescinded.



## CHAPTER IX.

### FIELD ENGINEERING AND ERECTING.

THERE are several methods of laying out the ground preparatory to erecting a trestle. Of course the exact method of procedure will depend, to a certain extent, upon the surrounding circumstances.

The centre-line should be run in carefully with a transit, and the stakes, which should be well made and stout, driven firmly into ground. A stake should be placed on the centre-line at each bent, and a tack, located by the instrument, driven in.

For a pile-trestle on land the instrument is set up over each centre stake and the proper angle turned off, and stakes driven in on either side at the proper places for the outside piles. The tape is then stretched between the centre and outside stakes, and stakes marking the position of the inside piles driven in. Some prefer, for framed bents especially, to use hubs in place of stakes, and centre a tack on each one. This, however, is an unnecessary refinement. For framed bents it is preferable to place the stakes, which should be driven down pretty close to the surface in this case, a foot ahead of the centre of the bent. A centre stake and one a little distance out on either side is all that is necessary. A mark is made on the sill half-way between the two vertical posts, and when the bent is put in position this mark is placed opposite the centre stake. Care is taken to see that the sill sets back the proper distance from all of the stakes,—6 in. between the stake and the face of the sill in the case mentioned. Of course when a framed bent has a pile-foundation the piles are located in the same manner as for pile-trestles. When the foundation is of masonry the centre-line in both directions is first laid out and then stakes driven in in such a manner that when strings are stretched between them they mark the outline of the top of the masonry. A mark or stake giving the elevation of the top is also given. After the foundation is in, the centre is marked on top of it.

For use on this kind of work a 50-foot tape is much more convenient than a chain. An ordinary linen tape, so thoroughly coated with paint that it will not stretch much, is accurate enough, though some prefer a metallic tape. A steel tape is by no means necessary, as some younger engineers are inclined to think, and is very liable to be broken.

It is exceedingly convenient to have a bench-mark, the elevation of which is somewhere near grade, within one or two hundred feet of either end of the trestle, so that it may be easily seen through the level from the end of the embankment. The elevation of the top of the bent can be given with the instrument while the bent is being put in place, or a bench can be established at the end of the bank, and the foreman can then obtain the elevation with an ordinary carpenter's level and straight-edge, allowance being made by him for the grade. In the latter case the work should always be checked, every day or so, with the Wye level.

After the bents are completed and in place the centre-line is to be marked on each cap by a nail or tack, so that the stringers may be placed in their proper positions. Track centres are

given, of course, in a similar manner as on the grading, after the ties have been placed in position and the structure otherwise completed.

When the trestle is over water and on a tangent there are several ways of lining in the piles. An instrument may be used, but as a rule this is not necessary unless the trestle is very long. A less expensive way is to place very long stakes, standing four or five feet out of the ground, on line with the rows of piles, having two sets of stakes, one fifty or one hundred feet behind the other, and have the foreman line the piles in with these. One edge of the stakes should be on the line, of course, instead of having the line pass through them. The outside stakes should also be driven at the proper batter. As the work progresses these stakes may be replaced by narrow boards nailed to the piles. The results should be checked by the engineer in charge, from time to time.

**Erecting.**—The method used in erection depends upon the location. Where it is permissible the bents are generally framed together while lying upon the ground, with the sill so placed that when the bent is raised it will be in its proper position. They are raised, usually by blocks and a fall, the rope being drawn in by a horse-power or steam hoisting-engine or by a gang of men. As soon as the bents have reached the upright position they are fastened to those already erected by temporary bracing, which should be supplemented by the permanent longitudinal bracing as rapidly as possible, if such is to be used. If not, then the stringers should be placed in position. Stay-ropes should be attached to the bent before it is raised, so that when it reaches its upright position it cannot be pulled over. Of course when the bents are of any considerable height they are liable to considerable racking if erected in this manner. Attaching an additional fall to a couple of timbers lashed to the bent about half-way up, one timber on either side, tends to prevent this to a considerable extent. However, great care must be taken to draw in the ropes of the two falls at the proper rates. It is in this part of the work of building high trestles that the third class of high-trestle structures proves so convenient. The lowest deck is erected and the purlins placed upon it. Then the timbers for the bents of the next deck are put together on a temporary staging formed by placing a flooring on the purlins. These bents are then erected the same as though they were upon the ground, the purlins put on top of them, and the same process carried on as before until the full height is reached. Then there is less liability to injury or loss, while in the course of erection, through the bents falling from lack of temporary bracing, as is too frequently the case.

Another method is to complete the work and lay the track as rapidly as the bents are placed. The bents, in this case, may either all be framed at any convenient place, or on the ground as before, and then brought to and placed in position or raised by a derrick and hoisting machine placed on a flat car. The boom of the derrick should, as a rule, be long enough to reach out so as to place the second bent beyond the completed work in position. The bents for a trestle much over 15 ft. high could not, of course, be conveniently carried any distance.

Sometimes the bents are built in place. This method is absolutely necessary for very high structures, unless they are of the type of class three. The cost is generally greater than with the previous methods. One of the strong arguments advanced for both cluster-bent and compound timber trestles is the economy with which they may be erected by this method.



On account of the smaller size of the timbers they may be handled with much greater ease and rapidity.

#### TOOLS.

The following is a description of the tools used by the carpenters in trestle-building. Most of them will be found absolutely indispensable; the remainder greatly facilitate the work:

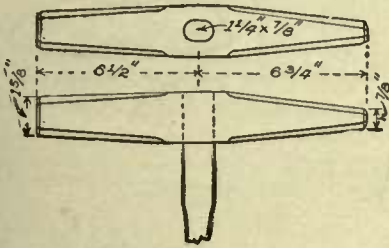


FIG. 134.—SPIKE-MAUL.

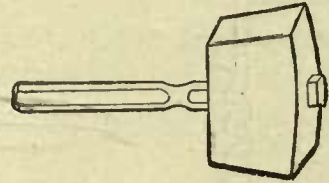


FIG. 135.—MALLET.

**Hammers.**—Practically the only hammers used to any extent are the spike-mauls. Fig. 134 gives the details of a good maul.

**Mallets.**—Mallets are merely wooden hammers. They are used principally to drive the chisels into the wood. Being of wood, they do not, of course, injure the handles of the chisels as steel hammers would. They are made either of a wood called *lignum vitæ* or of hickory. The former is more durable, and also more costly. Fig. 135 shows one form of mallet very commonly used.

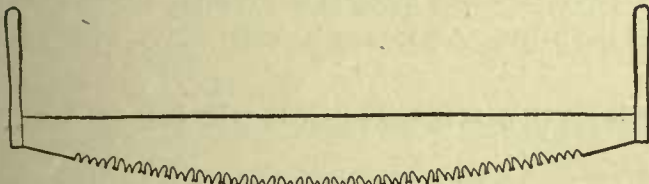


FIG. 136.—CROSS-CUT SAW.

**Saws.**—A cross-cut saw, such as is shown in Fig. 136, about five feet long, is exceedingly useful. If enough work is laid out beforehand, so that two men can be assigned to the saw and be kept constantly employed, great economy will result. If the men have to stop between cuts to lay out the work themselves, more or less time is lost in making the change and hunting for the tools, and it often happens that one man remains entirely idle while the other is preparing the work.

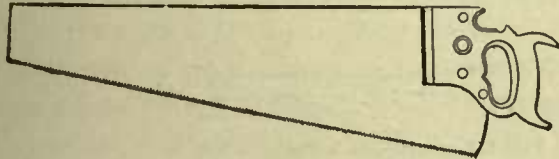


FIG. 137.—HAND-SAW.

Hand cross-cut saws are also required (Fig. 137). These should be of the heavier patterns, and the blade at least two feet long. If the handle is bound with brass and at right angles to the back, so that the saw may be used as a square, it will be found to be very convenient.

These saws are used for the lighter parts of the work, such as notching the ties, guard-rails, ends of stringers, etc.

In addition to these it will be necessary to have some rip-saws. These are used for sawing with the grain of the wood, and are about the same size as hand cross-cut saws, or a little larger. The teeth are larger and differently shaped than those of the cross-cut saw.

**Boring-machines.**—For boring out mortises preparatory to finishing with the chisel, a boring-machine is exceedingly economical and useful.

**Ship Augers.**—For boring holes for bolts, drift-bolts, lag-screws, etc., a ship auger, such as is shown in Fig. 138, is most commonly used. Augers of this style should be long enough to enable a man to use them standing without having to stoop.

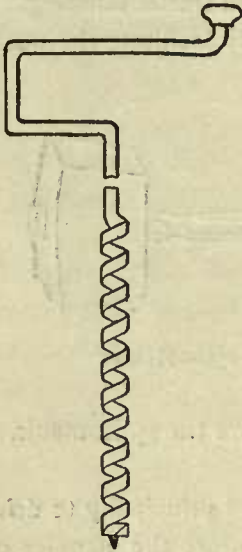
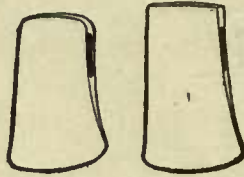


FIG. 138.—SHIP AUGER.



FIGS. 139, 140.—AXES.

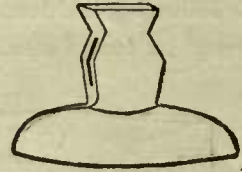


FIG. 141.—BROADAXE.

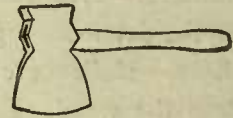


FIG. 142.—HATCHET.

**Axes.**—A common long-handle axe (Figs. 139 and 140) is very useful. They are made of different weights; usually, each man has his own particular liking in this regard. About 4 lbs. is a good weight for the head, exclusive of the helve. A 5-lb. axe is rather heavy, while one weighing only 3 lbs. is rather light.

In addition to the common axe, broadaxes (Fig. 141) and hatchets (Fig. 142) are found convenient.

**Adzes.**—An adze may be defined as an axe with the cutting edge set at right angles to the handle. This tool, which is absolutely necessary to economical and rapid work, is shown in Fig. 143.

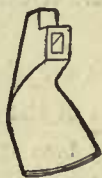


FIG. 143.—ADZE.



FIG. 144.—FRAMING CHISEL.

**Chisels.**—The best form of chisels for this kind of work is the firmer or framing chisel (Fig. 144). The handle should be held in a socket forged on the upper end of the blade, and should have its top end protected by an iron ring. The most convenient widths are  $1\frac{1}{2}$  in. and 2 in.

They are used to cut out mortises, and the notches in the ties, guard-rails, etc. Tanged chisels are of no use, as the work is too heavy for them.

**Squares and Rules.**—The ordinary steel framing square, made of sheet steel about  $\frac{1}{8}$  in. thick, and with one arm about two feet and the other about twelve inches long, in addition to



a batter template, such as is shown in Fig. 45, is all that is required in this line. The arms should be graduated in inches and quarter-inches.

Besides the common two-foot rule, it greatly facilitates matters to have a strip of board about  $\frac{1}{2}$  in. thick by  $2\frac{1}{2}$  in. wide and 10 ft. long, divided into feet and numbered both ways, one set of numbers being in red and the other in black, and separated from each other by a line through the centre of the stick. The first foot of either set should be divided into inches and quarters of an inch.

**Cant-hooks and Lug-hooks.**—Both cant and lug hooks will be found necessary and useful in handling the timber. Fig. 145 shows a cant-hook and Fig. 146 a modification of a

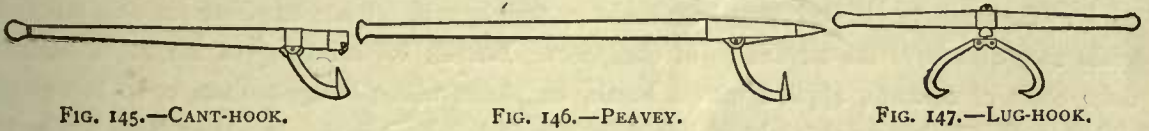


FIG. 145.—CANT-HOOK.

FIG. 146.—PEAVEY.

FIG. 147.—LUG-HOOK.

cant-hook called a peavey. A lug-hook is shown in Fig. 147.

**Log-wheels.**—A pair of log-wheels will be found very useful for carrying the timber from one place to another. They are merely two strongly-built wheels, of a large diameter, with a broad, heavy tire, united by a very strong axle. To the axle is attached a shaft, so that a team of horses or yoke of oxen may be hitched to the wheels. The wheels are backed over one end of a timber to be moved, and the end raised from the ground by means of chains and an arrangement of levers. The rear end of the stick is allowed to drag upon the ground.

**Wrenches.**—For trestle-building, the ordinary monkey-wrench is of little use. As the nuts are all of one or two sizes, the form shown in Fig. 148 is one of the most convenient.

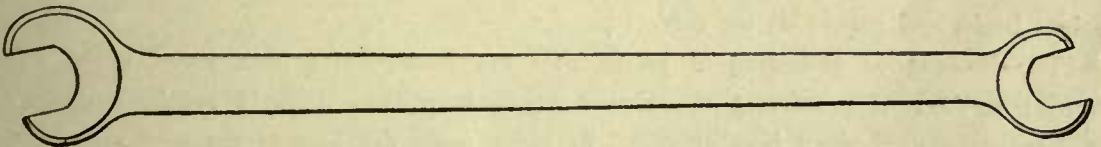


FIG. 148.—WRENCH.

Another form in common use is made upon the same principle as a clock key. This enables the men to tighten up many of the nuts without stooping.

**Hoisting-machines.**—Under the head of ERECTION, hoisting-machines were spoken of as being used to aid in raising the bents and timbers. Whether horse or steam power machines are used will depend on several conditions, among which may be mentioned the extent of the work and the means for the transportation of the machine to the site. A horse-power machine can be much more easily transported, and can be carried over roads over which it would be either impossible to transport a steam machine or prohibitory in cost. Work cannot be prosecuted as rapidly, of course, with a horse-power as with a steam machine.

**Saw-mills.**—It sometimes happens that a very extensive piece of trestling will be needed in a location where there is plenty of timber, but no saw-mills at hand. In this case, if it is deemed necessary to use sawn timber, a portable saw-mill will be found very convenient. These mills are generally arranged so that they can be very conveniently and easily moved from place to place, and may be obtained of various capacities.

## CHAPTER X.

### PRESERVATION OF JOINTS AND STANDARD SPECIFICATIONS.

**Preservation of Joints.**—Wherever two surfaces of timber touch, they should always be painted with some preservative material. White-lead is sometimes used, but is rather costly. Common tar heated very hot, coal-tar, and creosote oil are excellent for this purpose, while they also have the advantage of cheapness. Mr. G. W. Hinman\* of the L. & N. uses three coats of creosote, applied with a brush, on places where bridge-timbers come in contact with wood. He has tried coal-tar, but does not find it beneficial. In many cases where he used coal-tar the timber “burned up.”† On the Lehigh Valley system all joints and places where timber adjoins timber in a frame structure are painted with creosote residuum, applied with a brush. Creosote residuum is a thick tarry matter that remains in creosoting establishments. It is not like tar, owing to the larger amount of boiling it has had. The objectionable features in the coal-tar have been eliminated. It is not as expensive as ordinary creosote. Of course, if all of the timber could be treated with a preservative agent, so much the better; but this is generally too expensive. Creosoted timber is probably as durable as that preserved by any other process. Timber preservation, however, will not be treated of in this work except very briefly. Those who wish to know more about it are referred to the various books and papers on the subject.‡

The housing or protecting of joints from the weather has been found to be a very effective method of preserving the timber at these places. This is usually accomplished by using galvanized sheet iron or zinc. In many cases the tops of the caps and stringers are covered throughout to preserve them. Various methods are shown in detail on pages 93, 95, as well as in some of the Plates in Part II. A fuller discussion of the preservation of timber by this means will be found in Chapter XVI.

**Standard Specifications.**—The degree of care used, and the completeness of the specifications drawn up by different roads, varies between exceedingly wide limits. Some say almost nothing on the subject at all, only, perhaps, devoting one or two lines in the General Specifications to the subject; others draw up a special set entirely devoted to the subject.

The following set of specifications were compiled from the best parts of the best standards in use that could be obtained. The paragraphs having the same headings are alternative paragraphs, any one of which may be used to suit the special conditions of the road.

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\* Proceedings Amer. International Assoc. Ry. Supts., B. & B., 1894, p. 90.

† *Ibid.* W. G. Berg.

‡ Short and interesting articles on this subject appeared in the *Railroad Gazette* of Sept. 5, 1890, and Sept. 19, 1890.



## STANDARD SPECIFICATIONS FOR WOODEN TRESTLES.\*

## CLEARING.

Before commencing work on any structure, the ground must be entirely cleared of logs, brush, and trees for the entire width of the right of way. All material of a combustible nature must be placed in piles at convenient places, and completely burned.

Dangerous trees, liable to fall on the trestle, when outside the right of way, must be felled by the contractor; it being understood that the railroad company is to obtain permission from the land-owner.

Such portion of the right of way, as may be deemed necessary by the engineer, shall be grubbed.

## DRAWINGS.

The drawings are to the scale indicated and marked; but in all cases the figures are to be taken, and in case of omission the engineer in charge is to be referred to for dimensions. Under no circumstances are the drawings to be scaled either by the contractor or by any of his men. The Engineer will be required to mark the dimensions upon the contractor's blue print, and to keep a record of the same in his office.

## DIMENSIONS.

All posts, braces, clamps, stringers, packing-blocks, ties, guard-timbers, sills, and all timber generally, will be of the exact dimensions given and figured upon the plan. Variations from these will only be allowed upon the written consent of the engineer in charge.

## TIMBER.

All timber shall be of good quality and of such kinds as the engineer may direct, free from wind-shakes, waness, black, loose, or unsound knots, worm-holes, and all descriptions of decay. It must be sawed true and out of wind, and full size. Under no circumstances will any timber cut from dead logs be allowed to be placed in any portion of the structure: it must in every case be cut from living trees.

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\* The form used on the Cincinnati, New Orleans & Texas Pacific Ry. and associate roads (Cincinnati Southern Ry., Alabama Great Southern R. R., New Orleans & North-Eastern R. R., Vicksburg & Meridian R. R., Vicksburg, Shreveport & Pacific R. R.), G. B. Nicholson, Chief Engineer, has been very closely followed. The specifications of the following roads have also been drawn from:

Central Railroad & Banking Co. of Georgia, V. H. Kriegshaber, Asst. Engineer.

Ohio Connecting Ry., M. J. Becker, Chief Engineer.

Georgia Pacific Ry. Co., I. Y. Sage, General Superintendent.

Cleveland, Akron & Columbus Ry. Co.

Gulf, Colorado & Santa Fé Ry., B. F. Booker, Asst. Engineer.

St. Paul, Minneapolis & Manitoba Ry. Co., N. D. Miller, Chief Engineer.

Florence R. R., F. Gardner, Chief Engineer.

Brantford, Waterloo & Lake Erie R. R.

Specifications for Standard Pile and Timber Trestle Bridging.—*Engineering News*.

French Broad Valley R. R., H. M. Ramseur, Chief Engineer.

## PILES.

Piles shall be of good live ———

They will be either round or square, as may be required by the engineer.

Round piles must be straight, and have all the bark peeled off. They must have at least twelve (12) inches diameter of heart at the cut-off, when cut to grade to receive the cap. The smaller end must be at least eight inches in diameter.

Square piles must be hewn (or sawed) twelve (12) inches square. Each pile must have at least nine (9) inches of heart wood on each face, from the head of the pile, after being cut to grade, to five feet below the surface of the ground in which the pile is driven.

All piles must be properly pointed. They shall, if required, be shod with cast or wrought iron shoes, made according to the plan furnished by the engineer. In driving they shall be capped with suitable wrought-iron rings, if necessary, to prevent splitting. The actual cost, delivered on the ground, of the necessary shoes and rings will be allowed the contractor.

They must be driven to hard bottom, or until they do not sink more than five inches under the last five (5) blows by a hammer of at least 2000 lbs. weight falling twenty-five (25) feet. A heavier hammer with a shorter fall is preferred.

All piles injured in driving, or driven out of place, shall either be cut off or withdrawn, as the engineer may elect, and another one driven in its stead. The pile thus replaced will not be paid for.

All piles under track-stringers must be accurately spaced and driven vertically, and in each bent the batter-piles will be driven at the angle shown.

Piles shall be measured by the lineal foot after they are driven and cut off, and the price per lineal foot shall be understood to cover the expenses of transportation, driving, cutting off, removing the bark, and all labor and materials required in the performance of the work, but that portion of each pile cut off shall be estimated and paid for by the lineal foot as "Piles cut off."

The contractor must give all facilities in his power to aid the pile-recorder in his duties.

Parts of pile-heads projecting beyond the cap must be adzed off to a slope of 45 degrees.

## FRAMING.

All framing must be done to a close fit, and in a thorough and workmanlike manner. No blocking or shimings of any kind will be allowed in making joints, nor will open joints be accepted.

All joints, ends of posts, piles, etc., and all surfaces of wood on wood shall be thoroughly painted with

hot creosote-oil and covered with a coat of hot asphaltum, hot asphaltum, hot common tar, a good thick coat of pure white-lead ground in and mixed with pure linseed-oil.
---



All bolt and other holes bored in any part of the work must be thoroughly saturated with

* {	hot creosote-oil, hot asphaltum, hot tar, coal-tar, white-lead mixed with linseed-oil.	} And all bolts and drift-bolts before being put in place must be	* {	warmed and coated with hot creosote-oil, warmed and coated with hot asphaltum, warmed and coated with hot tar, coated with coal-tar, coated with white-lead and linseed-oil.
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All bolt-holes for bolts three quarters ( $\frac{3}{4}$ ) of an inch in diameter or over must be bored with an auger one eighth ( $\frac{1}{8}$ ) of an inch smaller in diameter than the bolt, in order to secure a perfectly tight fit of the bolt in the hole. For bolts five eighths ( $\frac{5}{8}$ ) of an inch in diameter or smaller the auger must be one sixteenth ( $\frac{1}{16}$ ) of an inch smaller for the same reason.

#### TRESTLES ON CURVES.

Where any trestle-bridge is built on a curve the blocking for the elevation of the outer rail, or other means for elevating the outer rail, will be as per standard drawings for the same, a copy of which will be furnished from the Chief Engineer's office.

#### CREOSOTED TRESTLES.

All piles used in creosoted trestles must have the bark peeled off, and be pointed, before treatment. None of the sap wood must be hewn from the piles. No notching or cutting of the piles will be allowed after treatment, except the sawing off of the head of the pile to the proper level for the reception of the cap, and the levelling of such part of the head as may project from under the cap.

The heads of all creosoted piles, after the necessary cutting and trimming has been done to receive the cap, must be saturated with hot-creosote oil, and then covered with hot asphaltum before putting the caps in place.

Timber in creosoted trestles must be cut and framed to the proper dimensions before treatment. No cutting or trimming of any kind will be allowed after treatment, except the boring of the necessary bolt-holes.

Hot creosote-oil must be poured into the bolt-holes before the insertion of the bolts, in such a manner that the entire surface of the holes shall receive a coating of creosote-oil.

#### TREATMENT OF CREOSOTED PILES AND TIMBER.

All creosoted timber and piles shall be prepared in accordance with the following process:

The timber and piles, after having been cut and trimmed to the proper length, size, and shape, shall be submitted to a contact steaming inside the injection-cylinders, which shall last from two to three hours, according to the size of the timbers; then to a heat not to exceed 230°, F., in a vacuum of twenty-four (24) inches of mercury, for a period long enough to thoroughly dry the wood. The creosote-oil, heated to a temperature of about 175°, shall then be let in the injection-cylinder and forced into the wood under a pressure of 150 pounds per

\* Alternative methods of treatment.

square inch, until not less than fifteen (15) pounds of oil to the cubic foot of wood has been absorbed.

The oil must contain at least ten (10) per cent of carbohc and cresylic acids, and have at least twelve (12) per cent of naphthaline.

#### IRON.

*Wrought-iron.*—All wrought-iron must be of the best quality of American refined iron, tough, ductile, uniform in quality, and must have a limit of elasticity of not less than twenty six thousand (26,000) pounds per square inch.

All bolts must be perfect in every respect, and have nuts and screws to the full standard sizes due to their diameters. The thickness of the nut shall not be less than the diameter of the bolts and the size of its square not less than twice the diameter of the bolt.

The heads of all bolts shall be  $\left. \begin{array}{l} \text{square} \\ \text{countersunk} \\ \text{round button} \end{array} \right\}$  heads,

$\left\{ \begin{array}{l} \text{with a thickness not less than the diameter of the bolt, and the size of its square not less than} \\ \text{twice the diameter of the bolt.} \end{array} \right.$

$\left\{ \begin{array}{l} \text{with a thickness at the centre of not less than three quarters of the diameter of the bolt, and} \\ \text{an extreme diameter of not less than two and one half times the diameter of the bolt.} \\ \text{countersunk on the under side so as to fit into a cup-washer, with an extreme diameter} \\ \text{of not less than twice the diameter of the bolt.} \end{array} \right.$

*Cast-iron.*—All castings must be from good, tough metal, of a quality capable of bearing a weight of five hundred and fifty (550) pounds, suspended at the centre of a bar one (1) inch square, four and one half ( $4\frac{1}{2}$ ) feet between supports. They must be smooth, well-shaped, free from air-holes, cracks, cinders, and other imperfections.

All iron, before leaving the shop must be thoroughly soaked in boiled linseed-oil.

#### INSPECTION AND ACCEPTANCE.

All materials will be subject to the inspection and acceptance of the Engineer before being used. The Contractor must give all proper facilities for making such inspection thorough.

Any omission to disapprove of the work, by the Engineer, at the time of a monthly or other estimate being made, shall not be construed as an acceptance of any defective work.

#### PROTECTION AGAINST FIRE.

The Contractor must each evening, before quitting work, remove all shavings, borings, and scraps of wood from the deck of the trestle, and from proximity to the bents or piles, and on the completion of the work must take down all staging used in the erection, and burn all shavings, chips, etc., and remove all pieces of timber to a distance sufficient to insure safety from fire.

#### ROADS AND HIGHWAYS.

Commodious passing places for public and private roads shall be kept in good condition by the Contractor, and he shall open and maintain thereafter a good and safe road for passage on horseback along the whole length of his work.



## RUNNING OF TRAINS.\*

The Contractor shall so conduct all his operations as not to impede the running of trains or the operation of the road. He will be responsible to the Railroad Company for all injuries to rolling-stock or damage from wrecks caused by his negligence. The cost of such damage will be retained from his monthly and final estimates.

## RISKS.

The Contractor shall assume all risks from floods, storms, and casualties of every description, except those caused by the Railroad Company, until the final acceptance of the work.

## LABOR AND MATERIAL.

The Contractor must furnish all material and labor incidental to or in any way connected with the manufacture, transportation, erection, and maintenance of the structure until its final acceptance.

Disorderly, quarrelsome, or incompetent men in the employ of the Contractor, or those who persist in doing bad work in disregard of these specifications, must be discharged by the Contractor when requested to do so by the Engineer.

Whenever the Chief Engineer may deem it advisable, he may name the rates and prices to be paid by the Contractors, for such time as he may designate, to the several classes of laborers and mechanics in their employ, and for the hire of horses, mules, teams, etc., and these shall not be exceeded; and having given due notice to the Contractors of his action in regard to these matters, they shall be bound to obey his orders in relation thereto. The Chief Engineer shall not, however, name a rate or price for any class of labor, etc., higher than the maximum rates being paid by the Contractor paying the highest for that class.

## INTOXICATING LIQUORS.

Contractors will not themselves, nor by their agents, give nor sell any intoxicating liquors to their workmen, or any persons at or near the line of the railway, nor allow any to be brought on the works by the laborers or any other person, and will do all in their power to discountenance their use in the vicinity of the work by persons in their employ. A continued disregard for this clause will, if deemed necessary by the Engineer, be considered as a good and sufficient reason for declaring the contract forfeited.

## DAMAGES AND TRESPASS.

Contractors shall be liable for all damages to landholders, arising from loss or injury to crops or cattle, sustained by any cause or thing connected with the works, or through any of their agents or workmen. They will not allow any person in their employ to commit trespass on the premises of persons in the vicinity of the works, and will forthwith, at the request of the Engineer, discharge from their employ any that may be guilty of committing damage in this respect. They will also maintain any fences that may be necessary for the proper protection of any property or crops.

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\* This clause may be inserted when the repairs or renewals are made by contract, or on the double-tracking of a road.

## REMOVAL OF DEFECTIVE WORK.

The Contractors will remove at their own expense any material disapproved by the Engineer; and will remove and rebuild, without extra charge, and within such time as may be fixed by the Engineer, any work appearing to the Engineer, during the progress of the work or after its completion, to be unsoundly or improperly executed, notwithstanding that any certificate may have been issued as due to the execution of the same. The Engineer shall, however, give notice of defective work to the Contractors as soon as he shall become cognizant of the same. On default of the Contractors to replace the work as directed by the Engineer, such work may be done by the Railroad Company at the Contractors' expense.

## DELAYS.

No charge shall be made by the Contractor for hindrances and delay, from any cause, in the progress of any portion of his work; but it may entitle him to an extension of the time allowed for completing the work sufficient to compensate for the detention, to be determined by the Engineer, provided he shall give the Engineer in charge immediate notice, in writing, of the detention.

## EXTRA WORK.

No claim shall be allowed for extra work unless done in pursuance of a written order from the Engineer, and the claim made at the first estimate after the work was executed, unless the Chief Engineer, at his discretion, should direct the claim, or such part of it as he may deem just and equitable, to be allowed.

Unless a price is specified in the contract for the class of work performed, extra work will be paid for at the actual cost of the material remaining in the structure after its completion and the cost of the labor for executing the work, plus fifteen (15) per cent of this total. This fifteen (15) per cent will be understood to include the use of and cost of all tools and temporary structures, staging, etc., and the Contractor's profit, and no extra allowance over and above this will be made.

## INFORMATION AND FORCE ACCOUNTS.

The Contractor will aid the Engineer in every way possible in obtaining information, and freely furnish any which he may possess, by access to his books and accounts, in regard to the cost of work, labor, time, material, force account, and such other items as the Engineer may require for the proper execution of the work, and shall make such reports to him from time to time as he may deem necessary and expedient.

## PROSECUTION OF THE WORK.

The Contractor shall commence his work at such points as the Engineer may direct, and shall conform to his directions as to the order of time in which different parts of the work shall be done, as well as the force required to complete the work at the time specified in the contract. In case the Contractor shall refuse or neglect to obey the orders of the Engineer in the above respects, then the Engineer shall have power to either declare the contract null and void and relet the work, or to hire such force and buy such tools at the Contractor's expense as may be necessary for the proper conduct of the work, as may in his judgment be to the best interests of the Railroad Company.



## CHANGES.

At any time during the execution or before the commencement of the work the Engineer shall be at liberty to make such changes as he may deem necessary, whether the quantities are increased or diminished by such changes, and the Contractor shall be entitled to no claim on account of such changes beyond the actual amount of the work done according to these specifications at the prices stipulated in the contract, unless such work is made more expensive to him, when such rates as may be deemed just and equitable by the Chief Engineer will be allowed him; if, on the other hand, the work is made less expensive, a corresponding deduction may be made.

## QUANTITIES.

It is distinctly understood that the quantities of work estimated are approximate, and the Railroad Company reserves the right of having built only such kinds and quantities, and according to such plans, as the nature or economy of the work may, in the opinion of the Engineer, require.

## ENGINEER.

The term Engineer will be understood to mean the Chief Engineer, or any of his authorized Assistants or Inspectors, and all directions given by them, under his authority, shall be fully and implicitly followed, carried out, and obeyed by the Contractor and his agents and employees.

## PRICE AND PAYMENT.

The prices bid will include the furnishing of materials, tools, scaffolding, watching, and all other items of expense in any way connected with the execution and maintenance of the work, until it is finally accepted and received as completed.

The Contractor will only be paid for the piles, timber, and iron left in the structure after completion. No wastage in any kind of material will be paid for except in the case of piles, when the "piles' cut-off," and which cannot be used on any other part of the Contractor's work, will be paid for at the rate agreed upon. After the material cut off is paid for it is to be considered as the property of the Railroad Company, and is neither to be removed nor used by the Contractor without the consent of the Engineer, and then only upon the repayment of the price which has been paid for it.

The piles and "piles' cut-off" will be paid for by the lineal foot, the former to be driven and in place.

The timber and lumber will be paid for by the thousand feet, board-measure, remaining in and necessary to the completed structure.

The iron will be paid for by the pound actually remaining in the structure after its completion.

The masonry for foundations will be paid for by the cubic yard.

The excavations for foundations will be paid for by the cubic yard.

The retained percentage will not be paid on the cost of any single structure until the final estimate is due on the entire work embraced in the contract.

If the building of the trestle is let with the contracts for grading or under a general contract, then many of these clauses may be omitted, as they are merely general requirements

applicable to all classes of work. Many of the clauses would also be omitted or changed somewhat under the different conditions existing in different sections of the country. The effort has been made, however, to make them as generally applicable and as concise as possible, and all of the clauses inserted have been selected on account of their general excellence and justice to both Contractor and Railroad Company.

A form of proposal is as follows :

## THE RED RIVER RAILROAD COMPANY.

### PROPOSAL FOR BUILDING TRESTLES.

*The undersigned hereby certify that they have personally and carefully examined the location and the plans and specifications for the trestles on the first, second, and third divisions on the line of the Red River Railroad.*

*Having made such examinations, the undersigned hereby propose to the said Red River Railroad Company to furnish all the material and do all the work required for the construction and completion of said first, second, and third division trestles, in accordance with said specifications and plans, and upon the acceptance of this proposal do hereby bind themselves to enter into and execute a contract for the same at the following*

### PRICES:

Material.	Unit.	Approximate quantities. May be more or less.	Rate.
Foundation excavation—Earth, . . . . .	Cubic yard.	25	22
Solid rock, . . . . .	Cubic yard.	15	90
Foundation masonry, . . . . .	Cubic yard.	56	5 00
Round white-pine piles, not creosoted, . . . . .	Lineal foot.	1500	35
" " " " " cut off,	Lineal foot.		06
" " oak " " " " "	Lineal foot.		
" " " " " " cut off,	Lineal foot.		
Etc. etc. etc.			
Square yellow-pine piles, not creosoted, . . . . .	Lineal foot.	1000	35
" " " " " " cut off,	Lineal foot.		08
Etc. etc. etc.			
White-pine timber, not creosoted, erected, . . . . .	M. B. M.	100 M.	30 00
Oak " " " " " " " "	M. B. M.	10 M.	40 00
Etc. etc. etc.			
Round oak piles, creosoted, . . . . .	Lineal foot.	1725	75
" " " " " cut off, . . . . .	Lineal foot.		30
Etc. etc. etc.			
White-pine timber, creosoted, erected, . . . . .	M. B. M.	750 M.	30 00
Etc. etc. etc.			
Wrought-iron, . . . . .	Pound.	10,000	04
Cast-iron, . . . . .	Pound.	1250	02½
.....			
.....			
.....			



*The undersigned further propose to commence work within ten days from date of contract, and to complete the same within sixty days from date of contract.*

*Signed this sixth day of January, 1890.*

*Name of Firm,* SMITH BROS. & COMPANY.

By { GEO. H. SMITH.  
W.M. R. SMITH.  
ED. C. BROWN.

*Post Office address of Contractor :*

97 Great George Street,  
New York City,  
New York.

This form in blank, for filling out, should be printed and bound with the specifications, together with the agreement or contract. Those portions of the form printed in Roman type are left blank for filling in by the bidders, excepting in the table of prices, where only the prices are left blank.

The following specifications have been presented as standard by the Committee on Wooden Bridges and Trestles of the American Railway Engineering and Maintenance of Way Association.

RECOMMENDED SPECIFICATIONS FOR WORKMANSHIP FOR PILE AND TIMBER TRESTLES TO BE BUILT UNDER CONTRACT.\*

SITE.

The trestle to be built under these specifications is located on the line of..... Railroad, at.....County of....., State of.....

GENERAL DESCRIPTION.

The work to be done under these specifications covers the driving, framing and erection of a.....track wooden trestle about.....feet long and an average of..... feet high.

The contractor is to furnish all the necessary labor, tools, machinery, supplies, temporary staging and outfit to build the trestle complete, ready for the rails of track in a workmanlike manner, in strict accordance with the plans and the true intent of these specifications to the satisfaction and acceptance of the engineer of the Railroad Company.

\* Bulletin 71, January, 1906, American Railway Engineering and Maintenance of Way Association.

## GENERAL CLAUSES.

The workmanship to be of the best quality in the several lines of work; all details, fastenings and connections to be of the best method in general use on first-class work.

Holes must be bored for all spikes and drift-bolts for at least two-thirds the length of the spike or drift-bolt to be used; the auger to be the same diameter as the thickness of the spike.

All the timber must be cut at the ends with a saw and not with an axe.

On the completion of the work, all refuse material and rubbish that may have accumulated on top or under and near the trestle, by reason of its construction, shall be removed by the contractor.

The engineer or his authorized agents shall have full power to cause any inferior work to be condemned and taken down or altered at the expense of the contractor. Any material destroyed by the contractor on account of inferior workmanship or carelessness of his men to be replaced by the contractor at his expense.

Figures shown on the plans are to govern in preference to scale measurements; if any discrepancies should arise or irregularities be discovered in the plans, the contractor shall call on the engineer for instructions. These specifications and the plans are intended to cooperate, and, should any question arise as to the proper interpretation of the plans or these specifications, it shall be referred to the engineer for a ruling.

The contractor shall, when required by the engineer, furnish a satisfactory watchman to guard the work.

## DETAIL SPECIFICATIONS.

**Piles.** All piles shall be carefully selected to suit the place and ground where they are to be driven. When required by the engineer, pile-butts shall be provided with iron or steel rings, and the tips with suitable iron or steel shoes; such rings and shoes will be furnished by the Railroad Company. All piles to be driven to a firm bearing, satisfactory to the engineer, or until five blows of a hammer weighing 3000 lbs. falling 15 ft. (or a hammer and a fall producing the same mechanical effect), are required to drive the pile one-half ( $\frac{1}{2}$ ) in. per blow, except in soft bottom, when special instructions will be given.

Batter piles shall be driven to the inclination shown by the plans and shall require but slight bending before framing.

The butts of the piles in a bent to be sawed off to one plane and to be trimmed so as not to leave any horizontal projection outside of the cap.

Piles to be slightly flattened at intersection of braces, to give them a fair bearing.

Piles injured in driving, or driven out of place, shall either be pulled or cut off and replaced by new piles.

**Caps.** Caps shall be sized over the piles or posts to a uniform thickness and even bearing on piles or posts. They shall be drift-bolted to piles or posts.

The side with most sap shall be placed downward.



**Posts.** Posts shall be sawed to the proper length for their position (vertical or batter) to an even bearing on cap and sill. They shall be drift-bolted to cap and doweled or toe-nailed to sill.

**Sills.** Sills shall be sized at the bearing of posts to one plane. They shall be doweled to posts and drift-bolted to sub-sills.

**Sway-braces.** All sway-bracing shall be properly framed and securely bolted to piles or posts, when necessary for pile-bents; filling pieces shall be used between the braces and the piles on account of the variation in size of piles, to obtain a bearing against all piles.

**Longitudinal Braces.** Longitudinal struts and X-braces shall be properly framed and securely bolted to piles or posts.

**Girts.** Girts shall be properly framed and drift-bolted to caps, sub-sills, posts or piles as the plans may require.

**Stringers.** Stringers shall be sized to a uniform height. They shall be laid with alternating joints, provided with packing spools or separators, and the several lines under each rail bolted together. All continuous stringers over cap shall be drift-bolted to cap.

The edges with most sap shall be placed downward.

**Jack Stringers.** Jack stringers, when used, shall be neatly framed on caps and drift-bolted to cap.

**Ties.** Ties shall be notched over the stringers to a close fit, firm-bearing, and uniform top surface. They shall be spaced regularly, cut to even length and a line as called for on the plans.

Every sixth tie shall be spiked at each end to outside stringers, the spikes to be in the same tie in which the guard-bolts occur. When ties are planed to uniform thickness, the rough side shall be placed upward.

**Guard-rails.** Guard-rails shall be neatly notched over every tie, spliced at joints by half and half splice over a tie.

They shall be bolted to every third tie, the bolt to be placed in the same tie for each guard-rail. The splices of guard-rail shall be bolted to the tie underlying the splice.

**Time of Completion.** The work to be completed in all its parts on or before the.....

A.D., 19...

**Payments.** Payments will be made under the usual regulations of the Railroad Company.

#### STANDARD SPECIFICATIONS FOR BRIDGE AND TRESTLE TIMBERS.\*

(To be applied to solid members and not to composite members.)

1. **General Requirements.** Except as noted, all timber shall be cut from sound trees, true and straight, and sawed standard size; shall be square edged, close grained, solid and out of wind; free from defects such as injurious ring shakes and crooked grain, unsound or loose knots, knots in groups, decay, large pitch pockets, or other defects that will materially impair its strength.

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\* Bulletin No. 107, January, 1909, American Railway Engineering and Maintenance of Way Association.

2. **Standard Size of Sawed Timber.** Rough timbers sawed to standard size means that they shall not be over one-fourth ( $\frac{1}{4}$ ) in. scant from the actual size specified. For instance, a 12 in. by 12 in. timber shall measure not less than  $11\frac{3}{4}$  by  $11\frac{3}{4}$  in.

3. **Standard Dressing of Sawed Timber.** Standard dressing means that not more than one-fourth ( $\frac{1}{4}$ ) in. shall be allowed for dressing each surface. For instance, a 12 in. by 12 in. timber after being dressed on four sides shall measure not less than  $11\frac{1}{2}$  in. by  $11\frac{1}{2}$  in.

NO. 1 R.R. GRADE. LONG-LEAF YELLOW PINE AND DOUGLAS FIR.

4. **Stringers.** Long-leaf pine shall show not less than eighty-five (85) per cent heart on the girth anywhere in the length of the piece; provided, however, that if the maximum amount of sap is shown on either narrow face of the stringer, the average depth of sap shall not exceed one-half ( $\frac{1}{2}$ ) in. Douglas fir shall show not less than ninety (90) per cent heart as measured above. Knots greater than  $1\frac{1}{2}$  in. in diameter will not be permitted at any section within 4 in. of the edge of the piece.

5. **Caps and Sills.** Shall show not less than eighty-five (85) per cent heart on each of the four sides, measured across the sides anywhere in the length of the piece; to be free from knots over two and one-half ( $2\frac{1}{2}$ ) in. in diameter.

6. **Posts.** Shall show not less than seventy-five (75) per cent heart on each side of the four sides, measured across the sides anywhere in the length of the piece, and to be free from knots over two and one-half ( $2\frac{1}{2}$ ) in. in diameter.

7. **Longitudinal Struts or Girts.** One face shall show all heart; the other face and two sides shall show not less than eighty-five (85) per cent heart, measured across the face or sides anywhere in the length of the piece, and shall be free from knots one and one-half ( $1\frac{1}{2}$ ) in. in diameter and over.

8. **Longitudinal X-braces, Sash-braces, and Sway-braces.** Shall show four square edges and not less than eighty (80) per cent heart on two faces, and shall be free from knots one and one-half ( $1\frac{1}{2}$ ) in. in diameter.

9. **Ties and Guard-rails.** Shall show one face all heart; the other face and two sides shall show not less than seventy-five (75) per cent heart, measured across the face or side anywhere in the length of the piece; shall be free from knots over two and one-half ( $2\frac{1}{2}$ ) in. in diameter and where surfaced the remaining rough face shall show all heart.

(Since the specifications for structural timber arranged by joint conference do not contain any provisions regarding ties and guard-rails, the preceding paragraph is added by the committee.)

NO. 2 R.R. GRADE. LONG-LEAF AND SHORT-LEAF YELLOW PINE, DOUGLAS FIR, AND WESTERN HEMLOCK.

10. **Stringers.** Shall be square edged, except that it may have one (1) in. wane on one corner. Knots shall not exceed in their largest diameter one-fourth ( $\frac{1}{4}$ ) the width of the face of the stick in which they occur, and shall in no case exceed four (4) in. Ring shakes shall not extend over one-eighth ( $\frac{1}{8}$ ) of the length of the piece.



11. **Caps and Sills.** Shall be square edged with the exception of one (1) in. wane on one corner, or one-half ( $\frac{1}{2}$ ) in. wane on two corners. Knots shall not exceed in their largest diameter one-fourth ( $\frac{1}{4}$ ) of the width of the face of the stick in which they occur, and in no case shall exceed four (4) in. Ring shakes shall not extend over one-eighth ( $\frac{1}{8}$ ) of the length of the piece.

12. **Posts.** Shall be square edged, with the exception of one (1) in. wane on one corner, or one-half ( $\frac{1}{2}$ ) in. wane on two corners. Knots must not exceed, in their largest diameter, one-fourth ( $\frac{1}{4}$ ) of the width of the face of the stick in which they occur, and shall in no case exceed four (4) in. Ring shakes shall not extend over one-eighth ( $\frac{1}{8}$ ) of the length of the piece.

13. **Longitudinal Struts or Girts.** Shall be square edged and sound and shall be free from knots one and one-half ( $1\frac{1}{2}$ ) in. in diameter and over.

14. **Longitudinal Braces (X), Sash-braces, and Sway-braces.** Shall be square edged and sound and shall be free from knots two and one-half ( $2\frac{1}{2}$ ) in. in diameter and over.

#### EXPLANATORY NOTES FOR NO. 1 R. R. GRADE.

These specifications state the maximum limit of sap wood which will be accepted. In practice, with good inspection, the effect of these specifications should be to secure timber the bulk of which is practically all heart. In permanent bridge timber, not protected from decay, sap wood is not only useless in itself, but by furnishing a lodgment for the spores of fungi, it is the cause of starting and promoting the continuance of rot in the heart. Sap wood, especially after decay has set in, is also extremely susceptible to fire, while with precautions ordinarily exercised heart wood is practically immune from this source of danger.

On the other hand, for ordinary commercial purposes sap wood is as valuable as heart. Therefore, if the mill owners understand what is wanted, good heart timber can be obtained for a small advance in price over what is usually furnished, much of which contains in bulk 50 per cent or more of sap wood.

To obtain proper results inspection should be made at the mills, where unsatisfactory timber can be rejected without hardship to the mill owner. Extensive buyers of timber should have inspectors stationed at the mills. To cover the needs of smaller buyers and municipalities, it seems that some of the established inspection companies might maintain an organization of timber inspectors at the mills, which would prove profitable to themselves, satisfactory to the mill owners and of incalculable benefit to those who use the timber.

#### SPECIFICATIONS FOR TIMBER PILES. NO. 1 R. R. GRADE.

1. This grade includes white, burr and post oak, long-leaf pine, Douglas fir, tamarack, Eastern white and red cedar, Western cedar, redwood and cypress.

2. Piles shall be cut from sound trees; shall be close grained and solid, free from defects, such as injurious ring shakes, large and unsound or loose knots, decay or other defects which may materially impair their strength or durability. In Eastern red or white cedar a small amount of heart rot at the butt, which does not materially injure the strength of the pile, will be allowed.

3. All piles must be butt cut above the ground swell and have a uniform taper from butt to tip. Short bends will not be allowed. A line drawn from the center of the butt to the center of the tip shall lie within the body of the pile.

4. Unless otherwise allowed all piles must be cut when sap is down. All piles must be peeled soon after cutting. All knots shall be trimmed close to the body of the pile.

5. For round piles the minimum diameter at the tip shall be nine (9) in. for lengths

not exceeding thirty (30) ft.; eight (8) in. for lengths over thirty (30) ft. but not exceeding fifty (50) ft., and seven (7) in. for lengths over fifty (50) ft. The minimum diameter at one-quarter of the length from the butt shall be twelve (12) in. and the maximum diameter at the butt twenty (20) in.

6. For square piles the minimum width of any side at the tip shall be nine (9) in. for lengths not exceeding thirty (30) ft.; eight (8) in. for lengths over thirty (30) ft., but not exceeding fifty (50) ft., and seven (7) in. for lengths over fifty (50) ft. The minimum width of any side at one-quarter of the length from the butt shall be twelve (12) in.

7. Square piles shall show at least eighty (80) per cent heart on each side at the cross-section of the stick, and all round piles shall show at least ten and one-half ( $10\frac{1}{2}$ ) in. diameter of heart at the butt.

#### NO. 2 R. R. GRADE.

8. This grade includes red and all other oaks not included in No. 1 R.R. grade, sycamore, sweet, black and tupelo gum, maple, elm, hickory, Norway pine, or any sound timber that will stand driving.

9. The requirements for size of tip and butt, taper and lateral curvature are the same as for grade No. 1.

10. Unless otherwise specified piles need not be peeled.

11. No limits are specified as to the diameter or proportion of heart.

12. Piles which meet the requirements of grade No. 1 except the proportion of heart specified will be classed as No. 2.

#### SPECIFICATIONS FOR METALLIC DETAILS USED IN WOODEN BRIDGES AND TRESTLES.\*

##### GENERAL REQUIREMENTS.

(1) **Wrought Iron.** Wrought iron shall be tough, fibrous and uniform in character. It shall be thoroughly welded in rolling and be free from surface defects. When tested in specimens of the form of Fig. A or in full-sized pieces of the same length, it shall show

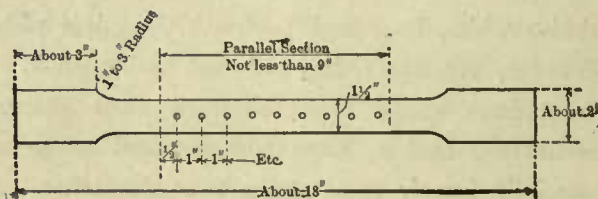


FIG. A.

an ultimate strength of at least 50,000 lbs. per square inch, an elongation of 18 per cent in 8 in., with fracture wholly fibrous. Specimens shall bend cold, with the fiber, through 135 degrees, without sign of fracture, around a pin the diameter of which is not over twice the thickness of the piece tested. When nicked and bent, the fracture shall show at least 90 per cent fibrous.

\* Bulletin 79, Sept. 1906, American Railway Engineering and Maintenance of Way Association, Committee on Wooden Bridges and Trestles.



(2) **Steel.** Steel shall be made by the open-hearth process. It shall contain not over 0.04 per cent phosphorus and not over 0.04 per cent sulphur. When tested in specimens of the form Fig. A or full-sized pieces of same length, it shall have a desired ultimate strength of 50,000 lbs. per square inch; tensile tests of steel showing an ultimate strength within 5000 lbs. per square inch of that desired will be considered satisfactory, except that, if the ultimate strength varies more than 4000 lbs. from that desired, a retest shall be made on the same, which, to be acceptable, shall be within 5000 lbs. of the desired ultimate; it shall have an elongation of  $\frac{1,500,000}{\text{ult. tens. strength}}$  in 8 in.; it shall bend cold without fracture 180 degrees flat. The fracture of tensile test shall be silky.

(3) **Cast Iron.** Cast iron shall be made of tough gray iron, with sulphur not over 0.10 per cent. If tested on the "Arbitration Bar" of the American Society for Testing Materials, which is a round bar  $1\frac{1}{4}$  in. in diameter and 15 in. in length, the transverse test shall be made on a supported length of 12 in. with load at the middle. The minimum breaking load so applied shall be 2900 lbs. with a deflection of at least  $\frac{1}{16}$  in. before rupture.

#### DETAIL SPECIFICATIONS.

(4) **Bolts.** Bolts shall be of wrought iron or steel, made with square heads, standard size, the length of thread to be  $2\frac{1}{2}$  times the diameter of bolt. The nuts shall be made square, standard size, with thread fitting closely the thread of bolt. All threads shall be cut according to U.S. standards.

(5) **Drift-bolts.** Drift-bolts shall be of wrought iron or steel, with or without square head, pointed or without point, as may be called for on the plans.

(6) **Spikes.** Spikes shall be of wrought iron or steel, square or round, as called for on the plans; steel wire spikes, when used for spiking planking, shall not be used in lengths more than 6 in.; if greater lengths are required, wrought or steel spikes shall be used.

(7) **Packing Spools or Separators.** Packing spools or separators shall be of cast iron, made to size and shape called for on plans; the diameter of hole shall be  $\frac{1}{8}$  in. larger than diameter of packing bolts.

(8) **Cast Washers.** Cast washers shall be of cast iron. The diameter shall be not less than  $3\frac{1}{2}$  times the diameter of bolt for which it is used, and its thickness equal to the diameter of bolt; the diameter of hole shall be  $\frac{1}{8}$  in. larger than the diameter of the bolt.

(9) **Wrought Washers.** Wrought washers shall be of wrought iron or steel; the diameter shall be not less than  $2\frac{1}{2}$  times the diameter of bolt for which it is used, and not less than  $\frac{1}{4}$  in. thick. The hole shall be  $\frac{1}{8}$  in. larger than the diameter of the bolt.

(10) **Special Castings.** Special castings shall be made true to pattern, without wind, free from flaws and excessive shrinkage; size and shape to be as called for by the plans.

CHAPTER XI.

BILLS OF MATERIAL, RECORDS, AND MAINTENANCE.

ONE of the most perplexing duties to the young engineer is, perhaps, the making out of proper bills of materials for trestle-work. The following is an example of a properly made out bill of material :

TRESTLE No. 6.

DIVISION No. 2; RESIDENCY No. 4.

BILL OF TIMBER.

No. of Bent.	Number of Pieces.	Name.	Size.	Feet B. M.	Total feet B. M.
1—	Height, 7 feet.				
	2	Cap.	6" x 12" x 14' 0"	168	964
	2	Plumb-posts.	12" x 12" x 8' 0"	192	
	2	Batter-posts.	12" x 12" x 9' 0"	216	
	1	Sill.	12" x 12" x 12' 4"	148	
	8	Blocks—Mud-sills.	12" x 12" x 2' 6"	240	
2—	Height, 13 feet.				
	2	Cap.	6" x 12" x 14' 0"	168	1265
	2	Plumb-posts.	12" x 12" x 12' 0"	288	
	2	Batter-posts.	12" x 12" x 13' 2"	316	
	1	Sill.	12" x 12" x 14' 2"	170	
	2	Sway-braces.	3" x 10" x 16' 6"	83	
	8	Blocks—Mud-sills.	12" x 12" x 2' 6"	240	
3—	Height, 10 feet.				
	2	Cap.	6" x 12" x 14' 0"	168	1088
	2	Plumb-posts.	12" x 12" x 9' 0"	216	
	2	Batter-posts.	12" x 12" x 10' 1"	242	
	1	Sill.	12" x 12" x 12' 8"	152	
	2	Sway-braces.	3" x 10" x 14' 0"	70	
	8	Blocks—Mud-sills.	12" x 12" x 2' 6"	240	
	Floor System and Miscellaneous Parts:				
	8	Bank-sills.	12" x 12" x 12' 0"	1152	7521
	10	Stringers and Jack-stringers.	8" x 16" x 25' 0"	2667	
	4	Stringers.	8" x 16" x 12' 6"	534	
	51	Ties.	6" x 8" x 12' 0"	2448	
	9	Guard-rails.	6" x 8" x 20' 0"	720	
Grand Total, . . . . .					10,838

BILL OF IRON.

No. of Pieces.	Name.	Use.	Size.	Weight.
<i>Wrought Iron.</i>				
24	Drift-bolts.	Stringers to Bank-sills.	$\frac{3}{4}$ " sq. x 24"	
26	Drift-bolts.	Stringers to Caps.	$\frac{3}{4}$ " sq. x 24"	
6	Drift-bolts.	Sills to Mud-sills.	$\frac{3}{4}$ " sq. x 20"	
102	Boat-spikes.	Ties to Stringers.	1" x 12"	
150	Boat-spikes.	Guard-rails to Ties.	$\frac{1}{2}$ " x 12"	
26	Bolts.	Guard-rails to Jack-stringers.	$\frac{3}{4}$ " x 31 $\frac{1}{2}$ "	
12	Bolts.	Caps to Posts.	$\frac{3}{4}$ " x 22"	
16	Bolts.	Sway-bracing.	$\frac{3}{4}$ " x 20"	
32	Bolts.	Packing for Stringers.	$\frac{3}{4}$ " x 22"	
	Total,			
<i>Cast Iron.</i>				
172	Washers.	Under heads and nuts of Bolts.	1" x 3"	
32	Separators.	Between Stringers.	2" x 3"	
	Total,			

Signed,

WILLIAM BOSS, Resident Engineer.

Jan. 25, 1890.



A copy of all such bills as these should be made in a letter-book. In making out the estimates of timber in feet, B. M., the contractor should always be allowed the full size of any stick between the extreme ends of the tenons, and where the ends or tenons are required to be cut on a skew, the full size for the length with square ends required to cut the piece.

The following is the rule for finding the number of feet, B. M., in any stick of timber, or in lumber one inch or over in thickness :

Multiply the breadth and thickness in inches together, and divide by twelve. Multiply this result by the length in feet and fractions of a foot, and the final result will be the number of feet, B. M., in the stick.

Putting this in the form of an algebraic expression, we have

$$\text{Feet B. M.} = \frac{b \times t \times L}{12}$$

$b$  = breadth in inches ;

$t$  = thickness in inches (when one inch or over) ;

$L$  = length in feet and fraction of a foot.

When the lumber is less than one inch in thickness it is always counted as though it were a full inch thick.

It will be found that if such a table as that shown below be made out for bents up to a moderate height, varying by six inches, and blue prints of it sent to the different resident and division engineers, considerable labor and time will be saved, and many annoying, and at times serious, errors avoided.

NORTH AMERICAN RAILROAD COMPANY.

BILL OF TIMBER FOR STANDARD TRESTLES.

PILE.							PILE.								
Height from surface of Ground to top of Cap.		Caps 6" x 12"		Sway-braces 3" x 10"		Feet B. M.	Height from surface of Ground to top of Cap.		Caps 6" x 12"		Sway-braces 3" x 10"		Feet B. M.		
Ft.	Ins.	Pcs.	Length		Pcs.		Length	Ft.	Ins.	Pcs.	Length			Pcs.	Length
			Ft.	Ins.							Ft.	Ins.			
5	0	2	14	0		168	8	0							
5	6	2	14	0		168	8	6							
6	0	2	14	0			9	0							
6	6	2	14	0			9	6							
7	0						10	0	2	14	0	2	16	6	
7	6						10	6					251		
							11	0							





Trestle No.....18..  
 Section No.....  
 Residency No.....

NORFOLK & WESTERN RAILROAD COMPANY.—CONSTRUCTION DEPARTMENT.  
 MASONRY EXHIBIT OF TRESTLE-FOOTINGS.

STATION.	No. of Bent.	ELEVATIONS.						LENGTH OF FOOTING.			Distance between Footings.	Cubic Yards.	Show cross-section of irregular and stepped footings, also skew-bents.		
		Sub-grade.		TOP OF MASONRY.		BOTTOM OF MASONRY.		Left.	Centre.	Right.					
		Sub-grade to top of Masonry.	Left.	Centre.	Right.	Distance from centre.	Left.	Centre.	Right.	Distance from centre.	Left.	Centre.	Right.		

..... Resident Engineer.

This sheet is 13½ in. long by 8½ in. wide, and is ruled horizontally in blue ink, with five lines to the inch.  
 It is indorsed on the back for filing as follows:

NORFOLK & WESTERN RAILROAD.  
 CONSTRUCTION DEPARTMENT.

---

MASONRY EXHIBIT OF TRESTLE-FOOTINGS.

Trestle No.....  
 Section No.....  
 Estimate No.....

..... 18..  
 ..... Contractor.  
 ..... Cubic Yards.

This indorsement is so placed that it will be on the outside when the sheet is folded into four parts across its length so as to make a bundle about 3⅞ in. by 8½ in.



A TREATISE ON WOODEN TRESTLE BRIDGES.

NORFOLK & WESTERN RAILROAD CO.

Timber Estimate No. .... 18.  
 Trestle No. .... Section No. .... Res. .... Contractors.  
 East End of Stringers, Sta. .... West End, Sta. .... Length. .... feet.

STATION.	No. of Bent.	SHOULDER TO SHOULDER.						OVER ALL.					
		Plumb Post.		Outside Batter Post.		Inside Batter Post.		Sill.		Diagonal Bracing.		Longitudinal Bracing.	
		No.	Length.	No.	Length.	No.	Length.	No.	Length.	No.	Length.	No.	Length.
Add Tenons,													
Totals,													

SUMMARY.

No.	Description of Pieces.	Dimensions.		Feet B. M.
		Length.	Sizes.	
	Plumb Posts,			
	Outside Batter Posts,			
	Inside " " "			
	" " "			
	Sills,			
	Caps,			
	Intermediate Caps,			
	" " "			
	Corbels,			
	" "			
	Knee Braces,			
	Straining Beams,			
	" " Caps,			
	Diagonal Bracing,			
	" " "			
	Longitudinal Bracing,			
	" " "			
	Waling Strips,			
	" " "			
	Wall Plates,			
	Stringers,			
	Packing Pieces,			
	" " "			
	Ties,			
	Guard Rails,			
	Mud Blocks,			

.....Engineer.



This sheet is of the same size and indorsed upon the back in the same manner as the foregoing one. The indorsement is as follows:

NORFOLK & WESTERN RAILROAD COMPANY.	<b>TRESTLE ITEM SHEET.</b>	Trestle No. ....	Section No. ....	Estimate No. ....	.....18 Contractor.	..... Ft. B. M.	Total Amount, \$ .....	..... Engineer.
--	----------------------------	------------------	------------------	-------------------	------------------------	--------------------	------------------------	--------------------

Now, if no more than one trestle is put upon any one sheet, the sheets may be bound in their proper order upon the completion of the road, and will then form excellent records for the use of the Maintenance of Way Department. These blanks are, of course, filled out and signed by the Resident Engineer, and their summaries entered upon the "Detail Item Sheet" of the Residency for the corresponding month. These should then be forwarded to the Division Engineer, who compiles the following report from those of the several Residencies under him:

NORFOLK & WESTERN RAILROAD COMPANY.

Estimate No. .... Division. ....  
 .....18 BRIDGE, TRESTLE AND TIMBER ESTIMATE. Contractor.

RES. SEC.	DESIGNATION OF STRUCTURE.	CHARACTER OF STRUCTURE.	IRON BRIDGES.			WOODEN BRIDGES.			TIMBER DELIVERED.		TIMBER FRAMED.	TRESTLE ERECTED.	IRON, BOLTS, ETC.	REMARKS.
			Length Out to Out.			Length Out to Out.			Pine.	Oak.				

TOTAL TO DATE  
 PREVIOUS ESTIMATE NO.  
 CURRENT ESTIMATE.

This sheet is 7 in. by 17 in., and is intended to be folded once each way. One half of the back is ruled for a summary as follows :

SUMMARY.

ITEMS.	PREVIOUS ESTIMATE.	CURRENT ESTIMATE.	TOTAL TO DATE.	RATE.	AMOUNT.
<i>Certified by</i> ..... ..... <i>Engineer.</i>			TOTAL AMOUNT.		

On one half of the remaining half of the back is the following indorsement for filing purposes :

NORFOLK & WESTERN R. R. CO.  <b>BRIDGES, TRESTLE AND TIMBER ESTIMATE.</b>  <i>Estimate No</i> ..... .....18 ..... <i>Contractor.</i>	Dollars.	Cts.
	Total Amount, . . . . .	. . . . .
Retained Percentage, . . . . .	. . . . .	. . . . .
Balance, . . . . .	. . . . .	. . . . .
Former Payments, . . . . .	. . . . .	. . . . .
Amount Due, . . . . .	. . . . .	. . . . .

After the road has been finished and turned over to the operating and maintenance departments, inspections of the trestles, the same as with all the other properties, should be frequently and regularly made. As to the frequency of these special inspections the practice



and opinions vary. A personal inspection of all the structures by the Engineer of Maintenance of Way or of Bridges and Buildings should be made at least once a year at an auspicious season. On the New York, Lake Erie & Western Railroad this inspection is required twice a year. Of course inspections of single structures should be made at any time when the necessities of the case demand them. It is good practice, where there is any considerable amount of trestling and bridging on a division, to have a competent inspector whose sole business is to inspect and oversee repairs to the structures. He should personally and carefully examine every structure under his charge once every month, or two months, as the location of the road may require, and report their condition on proper blanks to the Division Engineer or Division Superintendent. These officers, in their turn, after examining and approving these reports, should forward them to the Engineer of Maintenance of Way, or the Engineer of Bridges and Buildings, as the case may be. Every part of each structure should be carefully and critically examined from all sides, and the inspector should be required under all circumstances to examine trestles, not only from their deck, but also from beneath. Proper facilities should be afforded him for this purpose. In urgent cases he should report by telegraph or letter from the nearest station, as the matter may require. In addition to this the track-walkers should keep a constant watch upon all trestles, and report their condition daily to the inspector. A pad ruled as follows will be found very convenient for the track-walkers to make these reports upon :

NORTH AMERICAN RAILROAD COMPANY.

TRACK-WALKER'S DAILY REPORT ON THE CONDITION OF BRIDGES AND TRESTLES.

NUMBER OF BRIDGE.	TIME.		CONDITION.	
	A.M.	P.M.	A.M.	P.M.
150	10:30	1:40	X	X
151	9:45	3:15	X	X
152				
153				
154				
155				

..... *Track-walker.*  
 .....18....

Six inches wide by seven inches long, with fifty sheets in a pad, is a very good size. It is also advisable to have a cardboard cover which will shut over the face of the pad in the same manner as the cover of a book.

The sheets are folded across for filing, with the following indorsement on one half :

NORTH AMERICAN RAILROAD COMPANY.

TRACK-WALKER'S DAILY REPORT.

BRIDGES AND TRESTLES NOS. 150 TO 155.

.....18....  
 ..... *Track-walker.*

On the other half of the back these instructions are printed:

INSTRUCTIONS TO TRACK-WALKERS:

You will carefully examine each bridge and trestle over which you may pass, and enter their *condition* in the proper column and on the proper line of this blank.

You will also enter the *time* of such examination in the proper column and on the same line.

X in the column headed "Condition" means "all right."

O means injured, or unsafe by *fire, washout*, or other means.

These reports *must* be forwarded every evening to the Inspector of Bridges.

A report must be made out every time a bridge or trestle is passed over, even if three or four times a day.

In case of O, such fact must be *telegraphed at once* from nearest office to the *Inspector of Bridges*, the *Division Engineer*, and the *Division Superintendent*.

A repeated *disregard* of these instructions will be considered a sufficient cause for *discharge*.

An axe or hatchet and a small auger are absolutely indispensable to an inspector for the proper performance of his duty. Frequently the soundness of a piece of timber can be tested by pounding upon it with a hammer, and listening to the sound which the blows make. In case of any question, a hole should be bored into the timber with the auger. This will, of course, settle the matter beyond all doubt. These holes should always be filled up immediately after boring them, either by driving a plug in very tightly or with putty. It is not advisable to bore many holes in one piece of timber, as they greatly weaken it. A better way to arrive at a just conclusion, it seems, is to drive in a long, thin nail, such as a wire-nail. The degree of ease with which the nail penetrates the wood is a very good test of its condition. In pile-trestles on land, where the foot of the piles can be reached, it is very good practice to dig away the ground around them, for a foot or so in depth, once every twelve or eighteen months, in order that the least durable part may be inspected. After the inspection the earth is replaced and properly tamped. This inspection need not be begun until after the pile has been in the ground for several years. The length of time which it is advisable to allow to elapse before beginning it will depend largely upon the kind of timber. Thorough records of all these inspections should be carefully made and preserved. In order to be able to properly and definitely locate any part of any structure beyond the question of a doubt, all of the bridges, trestles, etc., should be numbered consecutively, beginning at one end of road and going toward the other. Then in each trestle the bents should be numbered in the same direction; the stringers, guard-rails and longitudinal bracing should also be numbered from right to left; the ties over each bay should be numbered; and finally, the stories beginning at the top and going to the bottom, should be treated similarly. By this means any one acquainted with the system of the road can take a description of any part from the *Bridge Book*. and locate it upon the ground beyond all question.





Every space opposite a bent should be filled in to show that that part has been examined. If there is no such part, a line should be drawn through the space. The filling in of the report should be done on the ground. After the reports are sent to the Engineer of Maintenance of Way they may be placed in proper order and bound. These reports should be forwarded at regular and stated intervals, and a copy of them kept by the Division Engineer.

They should be on paper about 24 in. long by 12 in. wide, padded in lots of one hundred sheets, in a similar manner to the Daily Reports of Track-walkers. Two or three blotting-sheets should be attached to the front cover, and the filling-in required to be done in ink, a fountain or stylographic pen being useful for this purpose. The instructions and affidavit may either be printed at the bottom or on the back of the sheet, as is found most desirable.

The following is the order of inspection required upon the Plant system of railways in South Carolina, Georgia, and Florida:\*

Number of bents, piles, sills, legs, caps, corbels, chords, posts, braces, stringers, floor-beams, condition of cross-ties. Do piles in this bridge or trestle settle? If so, state condition of shims, number of feet of standard guard-timber, condition.

Is the opening subject to wash at end, or at bottom?

Total length of bridge. Longitudinal braces every bent, size, condition.

Are abutments protected by rock, revetment timbers, or any other protection? Condition of such protection.

A certificate as to the truth of the inspection is then given by the inspector.

The inspector should have direct charge of all bridge-repair gangs working on his division, and all orders or instructions to the men transmitted through him, and he be held responsible for their proper execution.

The following are the instructions issued by the New York, Lake Erie & Western Railroad, and the Burlington, Cedar Rapids & Northern Railroad, in regard to bridge-work:

#### BRIDGE INSPECTION ON THE ERIE.†

Under the system of inspection and reports now in force on the Erie there are employed 10 inspectors who report directly to their respective Division Roadmasters each month, and every three months the Division Roadmasters make inspections and report to the Division Superintendents. These quarterly reports are forwarded through the General Roadmaster and General Superintendent to the Engineer of Bridges and Buildings, in whose office they are filed. The inspectors have no other duties than those of inspection.

The blank forms for the inspectors' reports are on sheets 20 inches square. The heading of the sheet is as follows:

Form X. 402.

N. Y., L. E. & W. R. R. CO.

REPORT SHOWING CONDITION OF BRIDGES ON THE.....DIVISION, MONTH ENDING.....18....

The sheet is ruled in 17 vertical columns, of which the headings are as follows: Number; Kind of Bridge, Wooden or Iron; *General Conditions of* Masonry, Bed Plates, Rollers and Frames, Pedestals, Main Trusses or Girders, Lateral System, Iron Floor System, Rivets, Hangers, Castings, Paint; Action under Trains; Date of Inspection; Remarks and Recommendations. This is to be signed by the Inspector, and at the foot is further space for remarks. On the back of the sheet are printed the following orders and directions:

#### NEW YORK, LAKE ERIE & WESTERN R. R. CO.

##### GENERAL ORDERS FOR THE INSPECTION OF BRIDGES.

1. Besides the constant and careful examination of all bridges by the regular Inspector, each Roadmaster shall make a personal and thorough inspection of the same once every three months.
2. A regular report of the condition of every bridge shall be made by the Inspector to the Division Roadmaster every month, upon blanks furnished for that purpose.

\* Maj. C. S. Gadsden, *Railroad Gazette*, 1888, p. 652.

† *Railroad Gazette*, July 29, 1887.



3. The quarterly examination made by the Roadmaster shall be reported upon form No. X, 402 A, but must be signed by him and forwarded to the Division Superintendent, who shall in turn transmit it through the proper channels to the Engineer of Bridges and Buildings.

4. The Engineer of Bridges and Buildings will also make a stated personal examination of all bridges twice a year, besides the customary inspection of special cases, as reported from time to time, and upon the request of the General Superintendent.

5. The condition of the different parts of the bridges must be briefly stated under the appropriate heads on the blanks furnished, and in case of need, further information shall be given in the column of "Remarks and Recommendations."

6. Special reports by letter or telegraph, according to the urgency of the case, must be made by the Inspector or Roadmaster wherever any fault or defect is discovered that may, in their judgment, endanger the safety of the bridge.

7. All ordinary repairs, such as tightening loose rivets and renewing wooden floors on iron bridges, or replacing such parts of wooden structures as have become defective by age and are necessary for the safety of the bridge, shall be done without special orders.

8. When, however, alterations, additions, or expensive renewals of any bridge are contemplated and become necessary, they must be reported to the Engineer of Bridges and Buildings, who will then prepare the necessary plans and estimates for approval.

R. H. SOULE, *General Manager.*

#### DIRECTIONS, GIVING THE MOST IMPORTANT POINTS TO BE OBSERVED WHILE INSPECTING BRIDGES.

##### *Masonry.*

1. Each pier and abutment should be carefully looked over, especially those that have already given signs of yielding, either by settling in their foundations or by bulging from the pressure of the embankment they sustain.

2. Examine closely all pedestal stones, looking for cracks or evidence of crushing; they must be maintained level and firmly bedded upon the bridge-seats.

3. Keep the latter clean and free from all rubbish and cinder or coal, especially around the iron bed-plates.

##### *Iron Bridges.*

5. Examine carefully all pedestals, bed-plates, and rollers and their frames. The bed-plates should be perfectly level, the rollers should move freely and their axes should always be kept at a right angle to the line of the bridge. The pedestals should be free from all cracks and flaws, and have a uniform bearing upon all the rollers or upon the bed-plate at the fixed end.

8. In the main trusses look most closely at all the tension members, the rods and bottom chords, especially where they are composed of more than one member. If perfect, they should all be equally strained per square inch in any one panel, and when they are not, when one member is slack and the other tight, the case should be reported at once. The compression members, that is, the posts and top chords, should be straight, without a bend or bulge, and all the joints should bear closely against each other. The counter rods ought never to be allowed to hang loose, but they must not be adjusted while a load is upon the bridge, and they must not be tightened more than just enough to get a good bearing.

6. *All hangers, by which floor-beams or stringers are suspended, must constantly receive the closest attention.* Their bearing around the pins should always be equal and uniform over half the circumference of the latter. If the hangers are made of round or square iron they must be examined with great care in the semi-circle where they are bent around the pins, and where flaws or fracture are most likely to occur, and it is of the utmost importance that the nuts on the ends of such hangers supporting the whole floor of the bridge are never permitted to become loose. A white streak painted across the face of the nut and its bearing will make it easy to detect at once any motion in the nut.

7. *The places where stringers are riveted or otherwise fastened to the floor-beams, and which are generally not easy of access for inspection, on account of the wooden floor over them, must be frequently and thoroughly examined.* Here the rivets are most likely to get loose, and the webs and flanges of the beams and stringers are more liable to fail from shearing or crushing than anywhere else.

8. The lateral systems and sway-bracing must never be neglected when a bridge is inspected. All the rods should be tight but not overstrained, as the struts are liable to be crippled if too much power is used in adjusting the tension members.

9. Cast-iron parts of all bridges, more particularly when in top chords or in joint boxes, must be closely examined. Should any cracks or breaks be discovered the fact must be at once reported. A hole of  $\frac{1}{4}$  in. diameter if drilled at the end of a crack will frequently stop its extending further.

10. Riveted work should frequently be sounded with a hammer to detect loose rivets; and if they cannot be tightened at once their number and location must be reported on the monthly report.

11. No water must be allowed to collect in the interior of any cast or wrought iron parts; drain-holes should be kept open for that purpose, and must be provided if they do not exist.

*Wooden Bridges.*

12. After a wooden bridge or trestle has been in use over three years, a close inspection must be made twice a year as to the condition of the timber, by boring holes in suspicious-looking places, especially near the bridge-seats and at the ends of stringers and braces. The nature of the boring will reveal the fact if the timber is sound or decaying. Whenever splices exist in bottom chords, and principally in long-span bridges where they generally occur in every panel, it is very important to examine them thoroughly and to note if they are pulling apart, which would indicate a weakness or a defective clamp. The braces and counter-braces should always have a square and even bearing upon the angle-blocks, and the sliding away from their true position, if any, would be sure evidence that the bridge needs immediate adjustment.

13. Tubs filled with water and buckets should be kept constantly on hand on every span of all wooden bridges.

*General Conditions.*

14. The action of a bridge under a passing train is the best practical test of its stability, and no inspection shall be completed without having made such observation, and without having carefully noted any undue deflection, swaying or twisting of the bridge as a whole or any part thereof.

15. The Roadmaster should carefully measure with an instrument the absolute deflection and swaying of any bridge reported to him by the Inspector as doubtful, and if the movements are excessive must report the fact at once.

16. The tracks on the bridges as well as on the approaches thereto should always be in good line and surface; they should be firmly bedded on the approaches, so as to avoid any undue shock when a train comes on a bridge at a high rate of speed.

C. W. BUCHHOLZ,

*Engineer of Bridges and Buildings.*

This form is folded, and on the outer fold is the indorsement for filing under the proper division and date.

The form for the report of the quarterly inspection of the Roadmaster is precisely the same, except that the sheet is 20 in. x 25 in., to give room for three columns of remarks. These columns bear the headings, By Roadmaster, By Div. Superintendent, and by Gen'l Roadmaster, and are signed by these officers respectively, and the whole is signed by the General Superintendent when examined, approved, and forwarded by him to the Engineer of Bridges and Buildings.

INSTRUCTIONS TO BRIDGEMEN ON THE BURLINGTON, CEDAR RAPIDS AND NORTHERN  
R. R.; H. F. WHITE, CHIEF ENGINEER.†

INSTRUCTIONS TO BRIDGEMEN.

1. You will be furnished with the bill of material needed for each structure before your men are sent out on the work. You must, as soon as you reach the bridge site, check the material delivered with your bill to see that both agree, and must personally ascertain, as quickly as possible, if the bill of material includes all that will be required. If the requisite amount of material is not delivered, you must notify the Master Builder of the deficiency, that the same may be forwarded promptly. Any material unfit or not proper for the structures will be reported without delay, that another kind may be substituted.

2. You must see before starting for work that you are fully equipped with the necessary tools to do your work. You must bear in mind that you are liable to be called away at any time from work upon which you may be employed, to that of a more pressing nature, and in order that you may be fully prepared for such exigencies must see that you have the facilities at hand for moving from place to place, at short notice, and are provided, as far as practicable, with the necessary tools to do all kinds of bridge work.

3. All bridgemen are expected to be prompt at the depot when it is necessary for them to take trains to reach their work; as far as possible, they will be expected to board near the place where they work. Repeated failures to be in time for trains will be considered good grounds for dismissal; men so left will be docked for time in transit when they take the next train, and receive pay only for time actually at work.

4. All men in the service of the company must report to the head of their department any misconduct or negligence affecting the interests or safety of the road or property, and which may come within their knowledge. The withholding of such information to the detriment of the company's interests will be considered a proof of negligence and indifference to the company's interests.



5. Foremen must actively engage in their work with their men, and see that all the force working under their orders faithfully perform their duties and work full time.

6. Bridgemen will be held responsible for all company tools and material put in their charge. In case of breakage or loss, the company reserves the right to withhold from money now or hereafter due them, a sufficient amount to repair or replace them, as may be thought best by the head of department.

7. You must fill out in full all blanks and forward the same in accordance with instruction given, and must inform yourself about all rules and regulations of the company, and be governed accordingly in the prosecution of your work, and must study and always have a copy of the time-card in force.

Hand-cars must not be left on the track when not in use, but must always be safely cared for.

Signals must always be put out at the proper distance when the roadway is not in good condition for the passage of trains.

8. You must see that your men are not unnecessarily exposed to accidents which will in any way render the company liable for damages.

9. Bridgemen are expected to pay their own board promptly, and in case of failure, the company reserves the right to withhold from money now or hereafter due them a sufficient amount to pay the same, but does not assume any responsibility for board. A repetition of the offence will be considered sufficient cause for dismissal.

10. Tools must not be carried into the ladies' car, and employés of the bridge department must not occupy seats when by so doing passengers are obliged to stand.

11. Any employés not disposed to comply with these instructions are requested to leave the employ of the company at once. The orders will be read to or by each man employed before he commences work. Any failure to have this done will subject the Foreman to discharge from service.

12. Bridgemen, in cases of necessity, will be expected to work on Sunday, at the same rate as paid for work done on the other days of the week.

The following are the methods of inspection pursued on several other roads:

\* On the St. Louis So. W. Ry. a light hand-car propelled by four men is used for transportation by the Superintendent of Bridges and Buildings. The car is equipped for convenience in riding, and carries suitable tools for the inspection as well as tools necessary to make immediate repairs if any structures are found unsafe. The repairs made are such as will carry the trains until the regular bridgemen of the division can reach the structure. A velocipede-car propelled by the inspector was tried, but it was found that the foregoing method was preferable, and that the extra cost was more than offset by the prevention of serious accident by the temporary repairs.

A stop is made at each trestle or bridge, special attention being paid to the smaller openings. All the timbers or piling that appear to be defective are tested by a steel bar  $\frac{1}{4}$  inch in diameter by about 5 feet long. This bar has a ball on one end and a diamond point on the other. The ball end is used for sounding all the timbers and piling that are out of the ground and which are not badly decayed or sap-rotten, and the pointed end for prodding the rotten portions. A brace and small bit is used to bore into places that are most liable to decay and which it is not well to prod with the bar. The earth around sills, subsills, and posts that are buried is removed with pick and shovel, so that those members may be thoroughly examined and tested with the bar.

The notes of the inspection are made in a book which is a copy of the bridge and trestle record, with blank pages sufficient for all notes to be taken. This book contains all the information regarding the trestles and bridges, such as length of panels, number and kind of bents, height of structure, clear span, etc., as well as date when driven and when rebuilt. This information enables the oldest bridges to be inspected the most closely, but under no circumstances are new structures slighted.

After the inspection is completed a copy of the same is sent to each division foreman.

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\* J. S. Berry, Asst. Supt. B. & B. Proc. Amer. Int. Assoc. Ry. Supts. B. & B., 1894, p. 59.

The list mentions all the work to be done on each bridge and the amount of material required. Special remark is made upon bridges that need immediate attention.

Mr. G. J. Bishop,\* General Foreman of Bridges and Buildings of the Chicago, Rock Island & Pacific Ry., uses the following method of inspection for trestles:

Inspect ties and rail-fastenings.

Inspect stringers and see that they have a fair bearing; observe knots, checks, and decays.

Examine caps for breaks and decays; also note bearing of caps on piling.

Examine frame-bents closely—posts usually give way at the bottom.

Examine sills.

When inspecting piles dig away the dirt for about 18 or 20 inches in depth, and if sap rotted remove all decayed parts and note how much sound timber remains.

Inspect superstructure for straw, leaves, grass, and other matter carried there by birds for nests: they largely increase the danger from fire.

In inspecting frame and pile trestles a sketch of each bridge is made in a field-book and each defective part is marked on the sketch. When there is a certain percentage of defective parts that are not safe the structure is marked for rebuilding. All members of a bridge or trestle that have been inspected and that need replacing are marked with certain marks that indicate the time within which they have to be replaced; thus, those members requiring replacing in less than six months with a mark indicating that fact, less than one year with another mark, over one year and less than eighteen months with still another mark.

Mr. Bishop's division is divided into six districts, ranging from 140 to 220 miles in length, with a division foreman over each district, who is held responsible for the good condition of the bridges and structures. The bridges are inspected by the foreman each month while he is working over his district with his men, and if he is not able to get over the entire district he takes a velocipede-car and runs over such part as he has been unable to work over. Mr. Bishop does not consider this method economical and recommends a bridge inspector for all divisions over 500 miles in length, especially where there is much bridging.

Once each year about one-half of the bridges are inspected by the general foreman, and a complete bill of material is made of each structure that needs rebuilding. The district foreman and three men accompany the general foreman on a hand-car, and each bridge is given a very thorough inspection. The repairs necessary are decided upon, and instructions given as to the most economical method of doing the work. This method of inspection costs about nine cents per mile, or one mill per lineal foot of bridge per month.

† On the L. S. & M. S. R. R. an inspection of the bridges is made twice a year by the superintendent of bridges and buildings. He is accompanied by four bridgemen, and the trip is made on a hand-car. The tools used are two crank-augers, four feet six inches long, with twelve-inch pod and a half-inch bore; two octagon steel bars with a sharp diamond point and an oval head three and one-half inches diameter, and shaped similar to the face of a shoemaker's hammer. The division foreman accompanies the party on the inspection trips on their respective divisions. The experience of this road is that men versed in the construc-

\* Proc. Amer. Int. Assoc. Ry. Supts. B. & B., 1894, p. 60.

† G. M. Reid, Proc. Amer. Int. Assoc. Ry. Supts. B. & B., 1894, p. 62.



tion of bridgework are much the best men to aid in inspection ; that is, a man used to driving piles, framing and erecting pile-trestles, makes the best man to assist in the inspection of them. The same may be said of frame-bent work and the men accustomed to erect it.

\* On the Toledo, Peoria & Western Ry. the inspection is made by the Master of Bridges and Buildings. The inspection gang consists of three of the best bridgemen, and the travelling is done on a light hand-car. The tools used are two  $\frac{1}{2}$ -inch octagon steel bars 4 feet long, two shovels, an axe, and a tape-line. A record is kept in an ordinary blank-book of everything that is required to make repairs or renewals. Written orders are given for everything to be done, from the largest job to the smallest. The foreman is instructed to make all necessary repairs in case any small details have been overlooked during the inspection.

† On the B. & O. R. R. there is a bridge inspector for every fifty miles whose sole duty is the inspection of bridges. He makes his reports on blanks furnished for that purpose, giving the number of bridges inspected, their condition, and general remarks. In cases where a bridge needs immediate attention it is his duty to call on the section men, or if a bridge gang is near, to get them to do the work. In cases where the repairs are not urgent the reports go through regular channels to the chief engineer, who preserves them and gives the necessary orders. In addition to this, semi-annual inspections are made by the engineers and supervisors. These inspections are made very thorough and systematic.

It is the practice on some roads to give premiums to the bridge-foreman who puts in his timber at the least cost per thousand feet, board measure. On the Charleston & Savannah Railroad,‡ the practice is as follows :

“General Order 188, paragraph 9, provides for a premium for bridge-foremen.

“At the end of each three months the bridge-foreman who shall have put his timber in at the least cost per thousand feet, B. M., will be rewarded with a premium of fifteen (\$15) dollars. At the same time a premium of ten (\$10) dollars will be given to the bridge-foreman who shall have made the next best showing.

“The conditions of these premiums are as follows :

“(A) Only the actual time devoted to bridge-work will be considered, and fifteen (15) minutes will be allowed for each train passing during working hours.

“(B) All timber put in will be considered.

“(C) The work done must be strictly workmanlike, and in accordance with the standard plans.”

As to the wisdom of adopting this premium system on all roads, it would be difficult to determine. Whether, in many instances, it might not lead to the slighting of work, where it would be difficult or impossible to discover it, is a very serious question.

The tools required in repair-work are much the same as those for building purposes. In addition to those described, a claw-bar, for drawing spikes, drift-bolts, etc., will be necessary. A small hydraulic jack will frequently be found very serviceable.

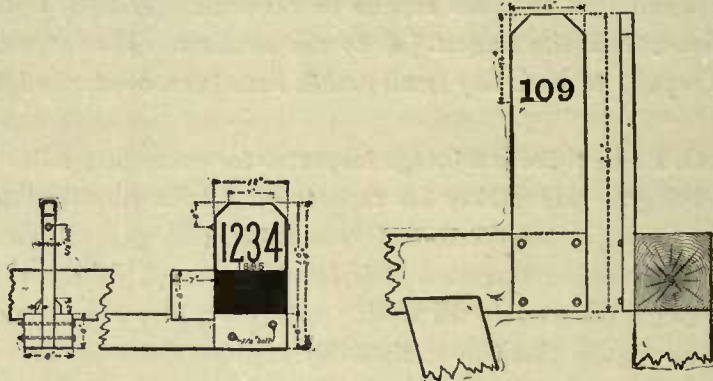
\* J. H. Markley, Proc. Amer. Int. Assoc. Ry. Supts. B. & B., 1894, p. 64.

† Geo. W. Andrews, Proc. Amer. Int. Assoc. Ry. Supts. B. & B., 1894.

‡ Maj. C. S. Gadsden, Supt. Chas. & Sav. R. R., on “Care of Trestles”; *Railroad Gazette*, 1888, p. 652.

For the purpose of designating the bridges and other similar structures, as spoken of in the first part of this chapter, bridge-numbers, as they are called, are used. These are generally made of pieces of 2-in. plank attached to the bridge near one end by  $\frac{5}{8}$ -in. by 4-in. lag-screws with wrought-iron washers. Two forms of bridge-numbers are illustrated in Figs. 149 and 150.

The boards should be planed and painted white with several coats of white-lead, or, better still, zinc-white, ground in good linseed-oil. The figures (Fig. 150) are black, three



FIGS. 149, 150.—BRIDGE-NUMBERS.

inches in height, with the base fourteen inches below the top of the board. The numbers should be placed on the bridges with uniformity, i.e., they should occupy the same relative position on all the structures. For example, the following is the rule for placing them on the Atlantic & Pacific Railroad:

*Position.*—East side of right-hand end of cap on bent, fifteen feet from last or initial end of bridge.

\* On the Duluth & Iron Range R. R. each bridge is furnished with two number boards on which is painted the number of the bridge. The bridges are numbered first with the mile number and then a letter is added to indicate the number of the bridge on that mile; thus, 10 C indicates the third bridge on the tenth mile from Duluth. On branch lines a letter is prefixed to the mile number to indicate the branch; thus, X 5 B indicates the second bridge on the fifth mile on the Western Mesaba branch.

The question of the best method of numbering bridges was investigated by a committee of the American Railway Bridge and Building Association and the following is taken from their report as published in the Proceedings for 1911:

To gather data for making this report a circular letter was sent out to many officials in charge of bridges on the various railroads:

Replies to this inquiry were received from practically everybody to whom it was sent. After going over these replies the following facts seem to stand out:

First. At the present time the number of roads using the mileage system is somewhat, but not greatly, in excess of the number of roads using the consecutive numbering system.

Second. Where changes are made they are from the consecutive numbering system to the mileage numbering system.

\* W. A. McGonagle, Proc. Amer. Int. Assoc. Ry. Supts. B. & B., 1894.



Third. The consensus of opinion seems to be that on a new line where a scientific system can be put in at the start the mileage system is preferable.

Fourth. The mileage system seems to present some difficulties if applied to a large railroad with many main lines and branches.

Fifth. Where the consecutive numbering system is established on an old line of considerable mileage and many branches it seems advisable to retain it. The cost of the change is almost prohibitive. All of the officials on the road know the important bridges by their numbers, so that changes would introduce endless confusion and for a considerable time bridges would be known by either one of two widely varying numbers.

Sixth. It has been urged against the consecutive system of numbering bridges that it gives no indication as to the location of the structures. This is readily overcome by having a proper record of bridges in the office of record, showing the stations and the mileage and indicating the numbers of the bridges in their proper relative position to these stations and mile number-posts. It is the system in use on the Chicago & Northwestern Railway and on practically all other roads of any considerable mileage.

#### SUMMARY.

We do not believe it advisable to recommend any particular system of bridge numbering at this time. The matter has been discussed a good deal, and there are to-day advocates of the consecutive system as well as of the mileage system, although the former are in the minority.

We do not believe the association, as an association, wants to recommend any particular system, nor to go on record as advocating that particular system and that system only.

Mr. D. J. Whittemore, Chief Engineer of the Chicago, Milwaukee & St. Paul systems, says that on his roads\* "everything not covered with earth, except cattle-guards, be the span ten or four hundred feet, is called a bridge. Everything covered with earth is called a culvert. Wherever we are far removed from suitable quarries, we build a wooden culvert in preference to a pile-bridge, if we can get six inches of filling over it. These culverts are built of roughly-squared logs, and are large enough to draw an iron pipe through them of sufficient diameter to take the water. We do this because we believe that we lessen the liability to accident, and that the culvert can be maintained, after decay has begun, much longer than a piled bridge with stringers to carry the track. Had we good quarries along our line, stone would be cheaper [in maintenance and final cost, but not in first cost.—F.]. Many thousands of dollars have been spent by this company in building masonry that, after twenty to twenty-five years, shows such signs of disintegration that we confine masonry work now only to stone that we can procure from certain quarries known to be good."

Mr. Whittemore is an engineer of great experience, skill, and judgment, and there is food for much reflection in these words of his. First, that it is better to use temporary wooden structures, to be afterward renewed, in good stone, rather than to build of the stone of the locality, unless first-class. Second, that a structure covered with earth is much safer

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\* T. C. Clarke, in *Scribner's Magazine* for June, 1888, p. 657.



than an open bridge, which, if short and apparently insignificant, may be, through neglect, a most serious point of danger, as was shown in the dreadful accident of last year \* on the Toledo, Peoria & Western Road in Illinois, where one hundred and fifty persons were killed and wounded, and by the equally avoidable accident on the Florida & Savannah line in March, 1888. Had these little trestles been changed to culverts covered with earth, many valuable lives would not have been lost.

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\* 1887.



## CHAPTER XII.

### TIMBER.

YELLOW PINE—SPECIES—MARKET NAMES—FIELD NAMES—CHARACTERISTICS—ADAPTATIONS—MECHANICAL PROPERTIES—BLED TIMBER—WASHINGTON FIR—OTHER TIMBERS—MECHANICAL CHARACTERISTICS OF TIMBER IN GENERAL—UNIT STRESSES.

**Yellow Pine.**—From an engineering standpoint our knowledge of the properties of our various timbers (American) is not very satisfactory, and there does not exist much reliable published information for general use. While attempts, more or less systematic, have been made from time to time to determine these properties, still our tables are to a large extent unreliable and uncertain, being based mainly upon European timbers, small test-pieces, etc., hence empirical rules and practice prevail very largely in this branch of work. Several years ago Prof. Lanza showed that tests made on small specimens may give results more than twice as high as those made on full-sized sticks. Within the past few years the Forestry Division of the United States Department of Agriculture has undertaken a very exhaustive series of experiments upon and study of our American timbers, using large sticks. Up to the present time only yellow pine has been investigated to an extent sufficient to prove valuable. The results of these investigations have been published in Bulletin No. 8, and the major portion of this chapter is gleaned therefrom. The mechanical tests have been made under the direction of Prof. J. B. Johnson at Washington University, St. Louis, Mo.

The following account of the names and characteristics of the Southern pines will be found useful:\*

There are in the Southern Atlantic and Gulf States ten species of pine which are or can be cut into lumber. Two of these, the white pine (*Pinus Strobus* L.) and the pitch-pine, also called yellow or black pine (*Pinus rigida* Mill.) occur only in small bodies on the Allegheny Mountains from Virginia down to northern Georgia, being rather Northern pines. Three, the Jersey or scrub pine, occasionally also called short-leaf or spruce pine (*Pinus virginiana* Mill.), along the coast to South Carolina; the sand, scrub, or spruce pine [*Pinus clausa* (Engelm.) Sarg.], found in a few localities in Florida; and the pond, also called loblolly or Savannah pine (*Pinus serotina* Mx.) along the coast from North Carolina down to Florida,—occur either so sparingly that they do not cut any figure on the lumber market or do not often produce sizable trees for saw-logs.

There remain, then, five distinctly Southern species which are actually cut for lumber; one of these, the spruce-pine, also called cedar-pine or white pine (*Pinus glabra* Walt.), probably does not reach the market except by accident. But the other four may be found now in all the leading markets of the East.

There exists considerable confusion among architects, builders, engineers, as well as dealers in lumber and lumbermen themselves, as to the identity of these species and their lumber.

The confusion arises mainly from an indiscriminate use of local names and from ignorance as to the differences in characteristics of their lumber as well as the difficulty in describing these. Besides the names used in designating different species, there are names used by lumbermen to designate differences of quality in the same species and, in addition, names used in the markets without good distinction, until it becomes almost impossible to unravel the multiplicity of designations and define their meaning. Architects are apt to specify "Southern pine," not knowing that the greatest range of qualities can be supplied under that name; or refuse to accept "Texas" or "North Carolina pine" for "Georgia pine," although the same pine and quality can be furnished from either State. Dealers handle "long-leaf pine" from Arkansas, where the timber that is understood by that name never grew. Millmen fill their orders for this pine, either overlooking differences or without knowing them.

Names of Southern Lumber Pines in Use.

Botanical Names.	<i>Pinus palustris</i> Miller. Syn. <i>P. australis</i> Michx.	<i>Pinus cubensis</i> Griesebach. Syn. <i>Pinus Tæda</i> var. <i>heterophylla</i> Ell. <i>P. Elliotti</i> Engelm. <i>P. cubensis</i> var. <i>terthrocarpa</i> Wright.	<i>Pinus echinata</i> Miller. Syn. <i>Pinus mitis</i> Michx. <i>Pinus virginiana</i> var. <i>echinata</i> Du Roi. <i>P. Tæda</i> var. <i>variabilis</i> Aiton. <i>P. variabilis</i> Lamb. <i>P. rigida</i> Porcher.	<i>Pinus Tæda</i> Linn. Syn. <i>Pinus Tæda</i> var. <i>tenusifolia</i> Aiton.
Best common names. Local market, and lumbermen's name.	LONG-LEAF PINE: Southern yellow pine. Southern hard pine. Southern heart-pine. Southern pitch-pine. Hard pine (Miss., La.). Heart-pine (N. C. and So. Atlantic). Pitch-pine (Atlantic). Long-leaved yellow pine (Atlantic). Long-leaved pine (Atlantic). Long-leaved pitch-pine (Atlantic). Long-straw pine (Atlantic). North Carolina pitch-pine. Georgia yellow pine. Georgia pine. Georgia heart-pine. Georgia long-leaved pine. Georgia pitch-pine. Florida yellow pine. Florida pine. Florida long-leaved pine. Texas yellow pine. Texas long-leaved pine.	CUBAN PINE: Slash-pine (Ga., Fla.). Swamp-pine (Fla. and Ala.), in part. Bastard-pine (Fla., Ala.). Meadow-pine (Fla., E. Miss.), in part. She pitch-pine (Ga.).	SHORT-LEAF PINE: Yellow pine (N. C., Va.). Short-leaved yellow pine. Short-leaved pine. Virginia yellow pine (in part). North Carolina yellow pine (in part). North Carolina pine (in part). Carolina pine (in part). Slash-pine (N. C., Va.), in part. Old-field pine (Ala., Miss.). Bull-pine (?). Spruce-pine.	LOBLOLLY PINE: Slash-pine (Va., N. C.), in part. Loblolly-pine (Gulf Region). Old-field pine (Gulf Region). Rosemary-pine (N. C., Va.). Short-leaved pine (Va., N. C., S. C.). Bull-pine (Texas and Gulf Region). Virginia pine. Sap-pine (Va., N. C.). Meadow-pine (Fla.). Cornstalk-pine (Va.). Black pine (Va.). Fox-tail pine (Va., Md.). Indian pine (Va., N. C.). Spruce-pine (Va.), in part. Bastard-pine (Va., N. C.). Yellow pine (N. Ala., N. C.). Swamp-pine (Va., N. C.). Long-straw pine (Va., N. C.), in part.

The above table of common names, which have been found applied to the four species furnishing Southern pine lumber, will most readily exhibit the difficulty arising from misapprehension of names. These names are used in the various markets and in various localities in the home of the trees. Where possible the locality in which the name is used has been placed in brackets by the side of the name.

## MARKET NAMES.

The various names under which Southern pine lumber appears in the market are either general or specific: the former being more or less general in application to lumber man-



ufactured in the South, without reference to special localities, the latter referring to special localities from which the lumber is actually or presumably derived. In regard to the latter class of names it is to be regretted, perhaps, that they have been found necessary, the more because through their use not a few misconceptions and difficulties have arisen between consumers, manufacturers, and wholesale dealers, owing to the difficulty in defining what tree species furnish lumber included by such name or names.

The uninitiated may not understand that the various kinds of pine lumber manufactured in different States, although called by a specific name, may, after all, be of the same species and the same in all respects. "Florida long-leaved yellow pine" or "Florida pine" is in no way different from that cut and manufactured in Georgia under the distinctive name of "Georgia long-leaved yellow pine" or "Georgia pine." The question as to any difference of quality dependent upon locality of growth is as yet undecided.

The market names given to the various pines, uncertain as to their precise application in the minds of those that use them, or at least at variance with the conception of other authorities, are the following:

*General.*—Yellow pine, Southern yellow pine, Southern pine, long-leaved yellow pine, long-leaved pine, hard pine, pitch-pine.

*Specific.*—Virginia yellow pine, Virginia pine, North Carolina yellow pine, North Carolina pine, Georgia yellow pine, Georgia pitch-pine, Georgia pine, Georgia long-leaf yellow, Georgia long-leaved pine, Florida yellow pine, Florida pine, Florida long-leaved pine, Texas yellow pine, Texas long-leaved pine.

The names "yellow pine," "Southern pine," seem first of all to be used as generic names, without distinction as to species. In the quotations from Western markets only "yellow pine" and "long-leaved yellow pine," or "long-leaved pine" are distinguished; the first name seemingly being now always used when "short-leaf" is meant, although it is also applied by advertisers from the long-leaf-pine region to their product. In a market report of a leading lumber journal we find that "in the yellow-pine line, long-leaf, short-leaf, and curly pine can be bought," which would show that the attempt to distinguish the two kinds by their proper names is made. Curly pine, however, is in most cases long-leaf pine with a wavy or curly grain, a sort which is also found in the short-leaf species. Loblolly seems not to be quoted in the Western markets.

Formerly, while the long-leaf pine was the only pine reaching the markets, it was commonly known under the name of "yellow pine," but now the supply under this name may be made up of all the species indiscriminately. In Texas and Louisiana "yellow pine" designates the long-leaf species, in Arkansas and Missouri the short-leaf, while there the name "long-leaf" is applied to the "loblolly," which is rarely cut.

In Florida, the Carolinas, and Georgia the name "yellow pine" is also used with less distinctive application. In Florida, besides the Cuban pine, which is never distinguished on the market, loblolly may also appear in the lumber pile. In Georgia and the Carolinas, although locally the name "yellow pine" is most frequently applied to the short-leaf, in the market a mixture of long-leaf, short-leaf, loblolly, and Cuban pine satisfies the name.

In England, where probably nothing but long-leaf pine is handled, the current name is "pitch-pine," and this name is also most commonly used in Georgia and North and South

Carolina, strictly applying to long-leaf pine. In Boston only Southern and hard pine is mentioned without distinction. It is in New York, Philadelphia, Baltimore, and other Atlantic markets that the greatest variety of names is used, with an attempt to distinguish two kinds, the long-leaf and short-leaf, by using the name of the State from which the lumber is supposed to come, but neither the name nor the lumber pile agree always with the species that was to be represented.

“North Carolina pine,” which is supposed to apply specifically to short-leaf, will be found to include in the pile also better qualities of loblolly, sometimes to the amount of 50 per cent. Long-leaf forms only very occasionally a part of the supplies from this section.

“Georgia pine” is meant to designate the long-leaf species, and, like “Florida pine,” does mostly conform to this designation except as noted before under the name of yellow pine.

“Virginia pine” and “Virginia yellow pine” are names hardly known elsewhere than in the markets of Baltimore and Washington, where the bulk of the common building timber consists of it. It applies in the main to the loblolly, with a very small percentage of short-leaf making its way into the pile. While this is mostly coarse-grained, inferior material, selected stuff when well seasoned furnishes good finishing and flooring material.

#### FIELD NAMES.

Field names are those applied to the four Southern pine lumber species in the tree and logs. Such names are usually more or less known to dealers and manufacturers, but, aside from the market names already discussed, are rarely if ever applied to lumber in the market.

Of the three pines, long-leaf, short-leaf, and loblolly, the first alone is perfectly known by lumbermen and woodmen as a distinct “variety” (species). The remaining species, presenting to the lumberman’s eye various forms according to the site producing the timber, are commonly supposed “varieties” or “crosses” more or less related to the long-leaf pine. Specific differences in the lumber, both in appearance and quality, form, however, a sufficient basis of distinction as far as lumber is concerned, although this distinction is not necessarily carried out in putting lumber on the market.

A few of the names in common use are frequently applied by lumbermen to entirely different species from those usually known to botanists by the same name. The perplexity thus arising, upon the supposition that the common names of our botanical text-books are applied to the species by lumbermen, is not inconsiderable, and can doubtless be avoided only by a more careful attention on the part of the people to real specific distinctions.

The confusion in names is such that it is almost impossible to analyze properly the use of these names in the various regions. In the above tabulated account of names a geographical distribution has been given as far as possible. Here only a few of the names are to be discussed.

“Pitch-pine” is the name most commonly applied to the long-leaf in the Atlantic regions, and where it occurs associated with the short-leaf and loblolly the former is called “yellow pine” and the latter is called “short-leaf.” The name “long-leaf or long-leaved pine” is rarely heard in the field, “longstraw” being substituted.

The greatest difference of names and consequent confusion exists in the case of the



loblolly, due no doubt to the great variety of localities which it occupies and consequent variety of habit of growth and quality. "Swamp" and "sap" pine refer to comparatively young growth of the loblolly, coarse-grained, recognized by the rather deep longitudinal ridges of the bark, growing on low ground. "Slash-pine" in Virginia and North Carolina is applied to old well-developed trees of both loblolly and short-leaf; in Florida it is exclusively applied to the Cuban pine. When applied to the loblolly it designates a tree of fine grain, one half to two thirds sap, recognized by the bark being broken into large, broad, smooth plates. This same form is also called "short-leaf pine" in North Carolina.

"Rosemary-pine" is a name peculiar to a growth of loblolly in the swamp region of the Carolinas, representing fully-grown trees, fine-grained, large amount of heart, and excellent quality, now nearly exhausted.

"Loblolly" or "old-field pine," as applied to *Pinus Tæda*, is a name given to the second growth springing up on old fields in North and South Carolinas, while in Alabama and Mississippi, etc., the name "old-field" pine is applied to *Pinus echinata*.

Botanical Diagnosis.

Species.	<i>Pinus palustris</i> Miller.	<i>Pinus cubensis</i> Griseb.	<i>Pinus echinata</i> Miller.	<i>Pinus Tæda</i> Linn.
Leaves ... ..	3 in a bundle, 9 to 12 (exceptionally 14 to 15) inches long.	2 and 3 in a bundle; 7 to 12 (usually 9 to 10) inches long.	2 and 3 in a bundle; 1½ to 4 inches long; commonly 2½ to 4 inches.	3 in a bundle; 5 to 8 inches long.
Cones (open) ..	6 to 9 inches long; 4½ to 5 inches in diameter.	4 to 6½ (usually 4 to 5) inches long; 3 to 4½ inches in diameter.	1½ to 2 inches long; 1½ to 1¾ inches in diameter.	2½ to 4½ inches long; 1½ to 3 inches in diameter.
Scales.....	¾ to 1 inch broad; tips much wrinkled, light chestnut brown, gray with age.	1½ to ¾ inch broad; tips wrinkled; deep russet-brown; shiny.	¾ to 1 (exceptionally about 1) inch broad; tips light yellow-brown.	¾ to 1 inch broad; tips smooth; dull yellow-brown.
Prickles .....	Very short, delicate, incurved.	Very short; straight; declined.	Exceedingly short (¼ inch), delicate, straight, declined.	Short; stout at base.
Buds.....	¾ inch long; ¼ inch in diameter; silver-white.	About ¾ inch long; ¼ inch in diameter; brownish.	¾ to 1 inch long; about ¼ inch in diameter; brownish.	¾ to 1 inch long; ¼ inch in diameter; brownish.

In aspect and habit the long-leaf and Cuban pine somewhat resemble each other. The large silvery-white buds of the long-leaf pine, which constitute its most striking character, and the candelabra-like naked branches with brush-like tufts of foliage at the end readily distinguish it from the Cuban pine, which bears a fuller and denser crown. The dark-green, glossy, and heavy foliage of the latter readily distinguishes this again from the loblolly, where these may appear associated, the latter having sea-green and thinner foliage.

As a rule, the Cuban pine grows taller (up to 110 or 115 feet, with a diameter of 2½ to 3 feet) than the long-leaf, which rarely exceeds 105 feet and 20 to 36 inches in diameter. The Cuban pine forms massive horizontally-spreading limbs, and at maturity a crown with rounded outlines; the long-leaf pine forms a more flattened crown with massive but twisted, gnarled limbs, which are sparingly branched.

The thin bark of the long-leaf (only one quarter to one half inch thick), of uniform reddish-brown color throughout, exfoliates in thin, almost transparent rhombic flakes; the thick bark of the Cuban pine of the same color exfoliates in very thin, broad, purplish flakes.

The short-leaf pine is readily distinguished by the comparatively shorter and more scant appearance of its foliage. Moreover, this species is at once recognized by its characteristically small cones. Its habit is spreading, if compared with the more ascending, compact habit of the loblolly. At maturity the short-leaf has a much shorter bole (85 to 95 feet,

diameter  $1\frac{1}{2}$  to 2 feet) than the loblolly (125 to 150 feet, diameter 4 to 5 feet), with which it is often associated, and a more pyramid-shaped crown.

The reddish bark of the short-leaf in mature trees is broken into long plates, while the loblolly bark appears of grayish color and breaks into broader, larger, and more deeply-fissured plates.

#### CHARACTERISTICS OF THE WOOD.

No more difficult task could be set than to describe on paper the wood of these pines, or to give the distinctive features so that the kinds can be distinguished and recognized by the uninitiated. Only the combined simultaneous impressions upon all the senses permit the expert to make sure of distinguishing these woods, without being able to analyze in detail the characters by which he so distinguishes them. While in many cases there would be no hesitation in referring a given stick to one or the other species, others may be found in which the resemblance to more than one species is so close as to make them hardly distinguishable. The following attempt to diagnose these woods must, therefore, be taken only as an imperfect general guide. So far even microscopic examination has not furnished unfailing signs. Color is so variable that it can hardly serve as a distinguishing feature. The direction of the cut, roughness of surface, exudation of resin, condition of health, width of grain, moisture condition, even the mode of drying, exposure, etc., all have their share in giving color to the wood. Bearing in mind this great complication of color-effects, it will be granted that descriptions of the same, disturbed by peculiarities of each separate observer, will aid but little in identifying the woods.

The sapwood of all the pines looks very nearly alike, and so does the heartwood. The color of the springwood in the sap is a light yellowish with a shade of brown; the summer wood contains more brown, variable with the density of the cells and appearing darker when the bands are more abruptly separated from the spring wood. The heart wood shows a markedly darker color, with a reddish flesh-color tinge added.

It is perhaps easiest to distinguish the wood of the long-leaf and Cuban pines from that of the short-leaf and loblolly. It is also possible to keep apart the long-leaf from the Cuban; but while, in general, the short-leaf and loblolly can be more or less easily distinguished by color or grain, some forms of the latter (rosemary-pine) so nearly resemble the former that no distinguishing feature is apparent.

The most ready means for distinguishing the four seems to be the specific gravity or weight in connection with the grain. The proportion of sap and heart wood will also be an aid in recognizing a log or log-run lumber in the pile. These distinctive features are tabulated on the next page, the figures representing average conditions of merchantable timber and mature trees.

The long-leaf pine, then, is best distinguished by the following four characteristics:

(1) Width of the annual rings, having usually from 18 to 25 rings to the inch, as against 11 to 12 in the short-leaf and loblolly. Fewer rings to the inch would lend countenance to the suspicion that the material is not long-leaf.

(2) Weight, which for partially seasoned wood averages about 48 pounds, being 8 to 12 pounds heavier than short-leaf and loblolly. The lowest specific gravity found by Prof. Johnson was 0.66 or 38 pounds.



(3) Amount of resin, which produces, when the wood is cut across the grain with a sharp knife, a polished and vitreous or horny appearance of the summer wood. This is, however, not a very reliable sign, as other pines react in the same manner. Whether the presence

Diagnostic Features of the Wood.

Name of species.	Long-leaf pine ( <i>Pinus palustris</i> Miller).	Cuban pine ( <i>Pinus cubensis</i> Griseb.).	Short-leaf pine. ( <i>Pinus echinata</i> Miller).	Loblolly pine ( <i>Pinus Teda</i> Linn).
Specific gravity of kiln-dried wood.	Possible range. .58 to .90	.65 to .84 (Sarg.)	.39 to .76	.38 to .61
	Most frequent range. .60 to .70	.....	.50 to .60	.43 to .48
Weight, pounds per cubic foot, kiln dried wood.	Possible range. 44 to 52	38 to 50	36 to 44	31 to 36
	Average. <sup>48</sup>	<sup>47</sup>	<sup>40</sup>	<sup>34</sup>
Character of grain seen in cross-section.	Fine and even; annual rings uniformly narrow throughout; not less than 8 (mostly about 18-25) rings to the inch.	Variable and coarse; rings mostly wide; from 6 to 8 rings to the inch.	Very variable; medium, coarse; rings wide near heart, followed by zone of narrow rings; not less than 4 (mostly about 10) rings to the inch.	Less variable, mostly very coarse; 3 to 12 rings to the inch; generally wider than in short-leaf.
Color, general appearance...	Even dark reddish-yellow to reddish-brown.	Dark straw-color with tinge of flesh-color.	Yellowish red.	Whitish to brownish yellow; the dark bands of summer wood being proportionately narrow.
Sapwood, proportion.....	Very little; rarely over 2 to 3 inches of radius.	Nearly one half of the radius.	Commonly over 4 inches of radius.	Very variable, $\frac{1}{2}$ to $\frac{1}{4}$ of the radius.
Resin.....	Very abundant; tree turning into "light-wood;" pitchy throughout.	Abundant, sometimes yielding more pitch than long-leaf; not turning into "light wood."	Moderately abundant, least pitchy; only near stumps, knots, and limbs.	Abundant; more than short-leaf, less than long-leaf and Cuban.

of large amounts of resin account for the great weight and for superior strength is still an open question.

(4) Thickness of sap-wood, which, at least in the pines now cut for lumber, is rarely over 2 or 3 inches wide, much less than the other pines with which it might be confounded.

SPECIAL ADAPTATIONS OF LONG-LEAF YELLOW PINE.

In regard to the use of this timber, Prof. Johnson makes the following statements:

The long-leaf pine timber is specially fitted to be used as beams, joists, posts, stringers in wooden bridges, and as flooring when quarter-sawed. It is probably the strongest timber in large sizes to be had in the United States. In small selected specimens, other species, as oak and hickory, may exceed it in strength and toughness. Oak timber, when used in large sizes, is apt to be more or less cross-grained, knotty, and season-checked, so that large oak beams and posts will average much lower in strength than the long-leaf pine, which is usually free from these defects. The butt cuts are apt to be wind-shaken, however, which may weaken any large beams coming from the lower part of the tree. In this case the beam would fail by shearing or splitting along this fault with a much smaller load than it would carry without such defect. These wind-shakes are readily seen by the inspector, and sticks containing them are easily excluded, if it is thought worth while to do so. For highway and railway wooden bridges and trestles, for the entire floor system of what is now termed "mill" or "slow-burning" construction, for masts of vessels, for ordinary floors, joists, rafters, roof-trusses, mill-frames, derricks, and bearing-piles; also for agricultural machinery, wagons, carriages, and especially for passenger and freight-cars, in all their parts requiring strength and toughness, the long-leaf pine is peculiarly fitted. Its strength, as compared to that of short-leaf yellow pine and white pine is probably very nearly in direct proportion to their relative weight, so that pound for pound all the pines are probably of about equal

strength. The long-leaf pine is, however, so much heavier than these other varieties that its strength for given sizes is much greater.

A great many tests have now been made on short-leaf and on loblolly pine, both of which may be classed with long-leaf as "Southern yellow pine," and from these tests it appears that both these species are inferior to the long-leaf in strength in about the ratio of their specific gravities. In other words, long-leaf pine (*Pinus palustris*) is about one third stronger and heavier than any other varieties of Southern yellow pine lumber found in the markets. It is altogether likely that a considerable proportion of the tests heretofore made on "Southern yellow pine" have been made on one or both of these weaker varieties.

Table XIX represents the range of value of the various exhibitions of strength of the long-leaf yellow pine (*Pinus palustris*) from Alabama as compiled from Prof. Johnson's report.

TABLE XIX.

Condensed Table of Mechanical Properties of Long-leaf Yellow Pine—*Pinus Palustris*.  
(Ranges reduced to 15% Moisture.)

	Specific Gravity.	Cross-bending Tests.			Crushing Edgewise.	Crushing across Grain.	Tension.	Shearing.	Modulus of Strength at Elastic Limit.
		Strength $f = \frac{3Wl}{2bh^2}$	Modulus of Elasticity.	Relative Elastic Resilience in in.-lbs. per cu. in.	Strength per sq. in.	Strength per sq. in.	Strength per sq. in.	Strength (Mean) per sq. in.	Per sq. in. $f' = \frac{3W_1l}{2bh^2}$
Butt Logs.	0.449-1.039	4,762-16,200	1,118,800-3,117,370	0.23-4.69	4,781-9,850	675-2,094	8,600-31,890	464-1,299	4,930-13,110
Middle "	0.575-0.859	7,640-17,128	1,136,120-2,981,720	1.34-4.21	5,030-9,300	656-1,445	6,330-29,500	539-1,230	5,540-11,790
Top "	0.464-0.907	4,268-15,554	842,000-2,697,460	0.09-4.65	4,587-9,100	584-1,766	4,170-23,280	484-1,156	2,553-11,950

$f$  = modulus of rupture in pounds per square inch.  $W$  = load at centre in pounds.  $l$  = length of beam in inches.  $b$  = breadth of beam in inches.  $h$  = height of beam in inches.

TABLE XX.

Mechanical Properties of Large and Small Beams compared. Mean Results on the Larger Sizes (excluding Beams which failed by Shearing), compared with Mean Results from 4" x 4" Beams from same Log. All Reduced to 15% Moisture.

	Large Beams.			4 inches x 4 inches x 5 (?) feet.		
	Modulus of Rupture per sq. in. $f = \frac{3Wl}{2bh^2}$	Modulus of Strength at Elastic Limit per sq. in. $f' = \frac{3W_1l}{2bh^2}$	Modulus of Elasticity. $E = \frac{Wl^2}{4\Delta bh^3}$	Modulus of Rupture per sq. in. $f = \frac{3Wl}{2bh^2}$	Modulus of Strength at Elastic Limit per sq. in. $f' = \frac{3W_1l}{2bh^2}$	Modulus of Elasticity. $E = \frac{Wl^2}{4\Delta bh^3}$
3 sticks 4 in. x 6 in. x 116 to 160 in.	11,363	9,453	2,330,947	11,202	8,025	1,731,362
17 " 4 in. x 8 in. x 106 to 164 in.	13,130	10,289	2,456,441	11,594	8,715	1,779,911
1 " 6 in. x 12 in. x 136 in.	9,915	8,710	2,105,680	12,326	8,203	1,821,280
2 " 7 in. x 14 in. x 140 in.	10,025	8,505	1,948,400	11,416	8,221	1,790,138
1 " 8 in. x 16 in. x 134 in.	10,705	8,340	203,500	12,473	9,350	1,924,450

Some of the deductions for long-leaf pine may have to be modified upon further study, but at present the more important deductions are as follows:

- (1) With the exception of tensile strength, a reduction of moisture is accompanied by an increase in strength, stiffness, and toughness.
- (2) Variation in strength goes generally hand in hand with variation in specific gravity.
- (3) The strongest timber is found in a region lying between the pith and the sap at about one third of the radius from the pith in the butt log; in the top log the heart portion



seems the strongest. The difference in strength in the same log ranges, however, not over 12 per cent of the average, except in crushing across the grain and shearing, where no relation according to radial situation is apparent.

(4) Regarding the variation of strength with the height in the tree, it was found that for the first 20 to 30 ft. the values remain constant, then occurs a more or less gradual decrease of strength, which finally, at the height of 70 ft., amounts to 20 to 40 per cent of that of the butt log for the various exhibitions of strength.

(5) In shearing and crushing across and parallel with the grain, practically no difference was found.

(6) Large beams appear 10 to 20 per cent weaker than small pieces.

(7) Compression tests seem to furnish the best average statement of value of wood, and if one test only can be made this is the safest.

Investigations into the effect of bleeding the trees for turpentine leave no doubt that bled timber is in no respect inferior to unbled timber. The resinous contents of the heart-wood take no part in the flow of resin induced by the "boxing" or "chipping" of the tree. The drain appears to be entirely from the sap-wood, and as this does not enter into lumber production, being hardly more than two inches on the radius, it may be left out of consideration. The discrimination against bled timber, be it on account of inferior strength or inferior durability, is due to an unwarranted prejudice: see Table XXI.

TABLE XXI.  
Comparative Strength of "Boxed" and "Unboxed" Long-leaf Yellow Pine.

	Specific Gravity.	Per cent of Moisture.	Tensile Strength. Lbs. per sq. in.	Cross Breaking Strength. Lbs. per sq. in.	Modulus of Elasticity. Lbs. per sq. in.	Elastic Resilience. In lbs. per sq. in.	Compressive Strength across Grain. Lbs. per sq. in.	Shearing Strength. Lbs. per sq. in.	Compressive Strength Endwise. Lbs. per sq. in.
"Boxed" timber:									
25 sticks "green".....	0.759	30.91	15,448	8,709	1,566,400	1.73	680	540	4,755
25 sticks "dry".....	0.687	18.91	14,757	11,330	1,644,360	2.71	1,064	648	6,627
Percentage of change.....	-9.5	-39.0	-4.2	+30.1	+4.9	+56.6	56.5	+20.0	+39.4
Percentage of change to reduce to 20 per cent moisture.....	-8.5	-3.5	-3.8	+27.0	+4.4	+51.0	51.0	+18.0	+35.5
Mean of 115 tests.....	0.760	30.9	15,985	8,988	1,623,000	1.83	743	539	5,118
Corrected for 20 per cent moisture.....	0.696	20.0	15,485	11,118	1,694,000	2.76	1,122	636	6,935
"Unboxed" timber:									
Mean 133 tests.....	0.710	20.0	16,429	9,333	1,800,000	1.92	855	652	5,661

From investigations made by the Department it appears—

- (1) That a large proportion of the yellow or long-leaf pine lumber is from bled trees;
- (2) That it is never kept apart or distinguished from the unbled by either millers or dealers;
- (3) That no available criteria exist by which to distinguish the two kinds of lumber after manufacture.

*Washington Fir.*—During March, 1890, A. J. Hart, Mast. Mech. of the C., M. & St. P. Ry. Co., under the direction of Jno. T. Crocker and B. W. Smith of said road, assisted by D. D. Clark, F. M. Haynes, and C. B. Talbot of the N. P. R. R. Co., made the following tests on Washington fir at the mills of the St. Paul & Tacoma Lumber Co. :

TABLE XXII.

## Mechanical Properties of Washington Fir.

Size of Stick.	Length of Span.	Centre Load.	Modulus of Rupture per sq. in. $f = \frac{3Wl}{2bh^2}$ .	Remarks.
Inches.	Ft. In.			
$6\frac{1}{2} \times 15\frac{1}{4}$	18 9	25,284	5,391	
6 × 14	15 9	29,635	7,144	
6 × 14	11 0	39,111	6,585	
6 × 14	15 0	26,794	6,151	Dry stick.
8 × 16	19 0	45,277	7,560	
9 × 16	19 0	25,094	3,724	6 years old.
8 × 16	16 0	39,672	5,591	3 " "
$8\frac{1}{2} \times 16$	15 9	54,722	7,458	
8 × 16	19 0	32,104	5,263	Dry stick.
$9\frac{1}{4} \times 16$	19 0	38,568	5,571	
$8\frac{1}{4} \times 16$	19 0	34,963	5,338	
8 × 14	19 0	16,250	3,544	Cull.

The greatest deflection in any of the sticks was  $3\frac{1}{2}$  inches, the least  $1\frac{1}{2}$  inches.

Timber can be secured in lengths up to 140 ft. and from 20 to 24 in. square. In shorter lengths much larger dimensions can be easily obtained. It weighs when green about 3300 lbs. per M B. M. when rough and about 3000 lbs. per M B. M. when surfaced. The moisture does not dry down to below 10 per cent.\*

*Other Timbers.* †—In a lecture on timbers used for railway purposes, delivered by Mr. Goff at the Railway Institute, Sydney, New South Wales, it was stated that the following timbers shrink in breadth in drying as follows: English oak,  $\frac{1}{12}$ ; Riga fir,  $\frac{1}{32}$ ; Dantzic oak,  $\frac{1}{38}$ ; elm,  $\frac{1}{24}$ ; yellow pine,  $\frac{1}{38}$ ; pitch-pine,  $\frac{1}{40}$ ; kauri,  $\frac{1}{64}$ . In his comparison Mr. Goff took English oak as a stand of measure of the qualities of strength, stiffness, and toughness, and explained that by strength he meant the property which resists fracture or breakage whether as a beam or post; stiffness, the quality of resistance to flexure or bending; and toughness, the power to bend the most before fracture. The following table of comparative qualities of various woods was presented:

TABLE XXIII.

## Comparative Properties of Various Woods.

Variety.	Weight per Cubic Foot. Lbs.	Strength.	Stiffness.	Toughness.
British oak.....	45-58	100	100	100
Baltic Riga oak.....	43-54	108	93	125
American oak.....	37-47	86	114	117
Dantzic oak.....	42-53	107	117	99
Elm.....	35-46	82	78	86
Pine or fir.....	29-42	80	114	58
Poplar.....	33	86	66	112
Mahogany.....	35-53	96	93	99
Tamarac.....	32-40	102	80	130
Walnut.....	50	90	70	110

\* For other tests see "Transverse Strength of Douglas Fir," by Chas. B. Wing, *Eng. News*, March 14, 1895, p. 168.

† *Eng. News*, Aug. 10, 1893, p. 118.



A very valuable report on the "Strength of Bridge and Trestle Timbers" was read before the meeting of the Association of Railway Superintendents of Bridges and Buildings in 1895. The following are the conclusions and recommendations of the committee making this report:

Of all structural materials used for bridges and trestles timber is the most variable as to the properties and strength of different pieces classed as belonging to the same species, hence it is impossible to establish close and reliable limits of strength for each species.

The various names applied to one and the same species in different parts of the country lead to great confusion in classifying or applying results of tests.

Variations in strength are generally directly proportional to the density or weight of timber.

As a rule, a reduction of moisture is accompanied by an increase in strength; in other words, seasoned lumber is stronger than green lumber.

Structures should be, in general, designed for the strength of green or moderately seasoned lumber of average quality, and not for a high grade of well-seasoned material.

Age and use do not destroy the strength of timber, unless decay or season-checking takes place.

Timber, unlike materials of a more homogeneous nature, as iron and steel, has no well-defined limit of elasticity. As a rule, it can be strained very near to the breaking point without serious injury, which accounts for the continuous use of many timber structures with the material strained far beyond the usually accepted safe limits. On the other hand, sudden and frequently inexplicable failures of individual sticks at very low limits are liable to occur.

Knots, even when sound and tight, are one of the most objectionable features of timber, both for beams and struts. The full-size tests of every experimenter have demonstrated not only that beams break at knots, but that invariably timber struts will fail at a knot or owing to the proximity of a knot, by reducing the effective area of the stick and causing curly and cross-grained fibres, thus exploding the old practical view that sound and tight knots are not detrimental to timber in compression.

Excepting in top logs of a tree or very small and young timber, the heart-wood is, as a rule, not as strong as the material farther away from the heart. This becomes more generally apparent, in practice, in large sticks with considerable heart-wood cut from old trees in which the heart has begun to decay or been wind-shaken. Beams cut from such material frequently season-check along middle of beam and fail by longitudinal shearing.

Top logs are not as strong as butt logs, provided the latter have sound timber.

The results of compression tests are more uniform and vary less for one species of timber than any other kind of test; hence, if only one kind of test can be made, it would seem that a compressive test will furnish the most reliable comparative results.

Long timber columns generally fail by lateral deflection or "buckling" when the length exceeds the least cross-sectional dimension of the stick by twenty; in other words, the column is longer than twenty diameters. In practice the unit stress for all columns of over fifteen diameters should be reduced in accordance with the various rules and formulæ established for long columns.

Uneven end-bearings and eccentric loading of columns produce more serious disturbances than is usually assumed.

The tests of full-size, long, compound columns, composed of several sticks bolted and fastened together at intervals, show essentially the same ultimate unit resistance for the compound column as each component stick would have if considered as a column by itself.

More attention should be given in practice to the proper proportioning of bearing areas ; in other words, the compressive bearing resistance of timber with and across grain, especially the latter, owing to the tendency of an excessive crushing stress across grain to indent the timber, thereby destroying the fibre and increasing the liability to speedy decay, especially when exposed to the weather and the continual working produced by moving loads.

After a careful examination of all of the available data, the Committee recommended that the units given in Tables XXIII (a) and (b) be employed in bridge and trestle construction.

TABLE XXIII (a).

Average Ultimate Breaking Unit Stresses in Pounds per Square Inch.

Recommended by the Committee on "Strength of Bridge and Trestle Timbers." Association of Railway Superintendents of Bridges and Buildings, Fifth Annual Convention, New Orleans, October, 1895.

Kind of Timber.	Tension.		Compression.			Transverse.		Shearing.	
	With Grain.	Across Grain.	With Grain.		Across Grain.	Extreme Fibre-stress.	Modulus of Elasticity.	With Grain.	Across Grain.
			End-bearing.	Columns under 15 Diam.					
White oak.....	10,000	2,000	7,000	4,500	2,000	6,000	1,100,000	800	4,000
White pine.....	7,000	500	5,500	3,500	800	4,000	1,000,000	400	2,000
Southern, long-leaf, or Georgia yellow pine.....	12,000	600	8,000	5,000	1,400	7,000	1,700,000	600	5,000
Douglas, Oregon, and Washington fir or pine	12,000	.....	8,000	6,000	1,200	6,500	1,400,000	600	.....
yellow fir... red fir.....			.....	.....	.....	5,000	.....	.....	
Northern or short-leaf yellow pine	9,000	500	6,000	4,000	1,000	6,000	1,200,000	400	4,000
Red pine.....	9,000	500	6,000	4,000	800	5,000	1,200,000	.....	.....
Norway pine.....	8,000	.....	6,000	4,000	800	4,000	1,200,000	.....	.....
Canadian (Ottawa) white pine.....	10,000	.....	.....	5,000	.....	.....	.....	350	.....
Canadian (Ontario) red pine.....	10,000	.....	.....	5,000	.....	5,000	1,400,000	400	.....
Spruce and Eastern fir.....	8,000	500	6,000	4,000	700	4,000	1,200,000	400	3,000
Hemlock.....	6,000	.....	.....	4,000	600	3,500	900,000	350	2,500
Cypress.....	6,000	.....	6,000	4,000	700	5,000	900,000	.....	.....
Cedar.....	8,000	.....	6,000	4,000	700	5,000	700,000	.....	1,500
Chestnut.....	9,000	.....	.....	5,000	900	5,000	1,000,000	600	1,500
California red-wood.....	7,000	.....	.....	4,000	800	4,500	700,000	400	.....
California spruce.....	.....	.....	.....	4,000	.....	5,000	1,200,000	.....	.....

Table XXIIIa gives the average ultimate breaking unit stresses, and Table XXIIIb the safe allowable unit stresses, using the factors of safety recommended, namely :

- Tension, with and across the grain..... 10
- Compression, with the grain..... 5
- Compression, across the grain..... 4
- Transverse extreme fibre stress..... 6
- Transverse modulus of elasticity..... 2
- Shearing, with and across the grain..... 4





In cases where it was not possible to secure results for green timber in large sizes, those for partially air-dry timber are inserted in the table.

It is expected<sup>3</sup> that these unit stresses will be revised at intervals of a few years, whenever new results of timber tests are published, or when the experience of bridge engineers who have adopted them shall indicate that revision is desirable.

TABLE XXIII (c).

Unit Stresses for Structural Timber Expressed in Pounds per Square Inch Recommended by the Committee on Wooden Bridges and Trestles of the American Railway Engineering and Maintenance of Way Association.

Kind of Timber.	Bending.			Shearing.				Compression.						Ratio of Length of Stringer to Depth.
	Extreme Fibre Stress.		Modulus of Elasticity. Average.	Parallel to Grain.		Longitudinal Shear in Beams.		Perpendicular to Grain.		Parallel to Grain.		For Columns Under 15 Diams. Safe Stress.	Formulas for Safe Stress in Long Columns Over 15 Diams.	
	Average Ultimate.	Safe Stress.		Average Ultimate.	Safe Stress.	Average Ultimate.	Safe Stress.	Elastic Limit.	Safe Stress.	Average Ultimate.	Safe Stress.			
Douglas fir . . . . .	6100	1200	1,510,000	690	170	270	110	630	310	3600	1200	900	1200 $\left(1 - \frac{L}{60D}\right)$	10
Long-leaf pine . . . . .	6500	1300	1,610,000	720	180	300	120	520	260	3800	1300	980	1300 $\left(1 - \frac{L}{60D}\right)$	10
Short-leaf pine . . . . .	5600	1100	1,480,000	710	170	330	130	340	170	3400	1100	830	1100 $\left(1 - \frac{L}{60D}\right)$	10
White pine . . . . .	4400	900	1,130,000	400	100	180	70	290	150	3000	1000	750	1000 $\left(1 - \frac{L}{60D}\right)$	10
Spruce . . . . .	4800	1000	1,310,000	600	150	170	70	370	180	3200	1100	830	1100 $\left(1 - \frac{L}{60D}\right)$	
Norway pine . . . . .	4200	800	1,190,000	590	130	250	100	.....	150	*2600	800	600	800 $\left(1 - \frac{L}{60D}\right)$	
Tamarack . . . . .	4600	900	1,220,000	670	170	260	100	.....	220	*3200	1000	750	1000 $\left(1 - \frac{L}{60D}\right)$	
Western hemlock . . . . .	5800	1100	1,480,000	630	160	*270	100	440	220	3500	1200	900	1200 $\left(1 - \frac{L}{60D}\right)$	
Redwood . . . . .	5000	900	800,000	300	80	.....	.....	400	150	3300	900	680	900 $\left(1 - \frac{L}{60D}\right)$	
Bald cypress . . . . .	4800	900	1,150,000	500	120	.....	.....	340	170	3900	1100	830	1100 $\left(1 - \frac{L}{60D}\right)$	
Red cedar . . . . .	4200	800	860,000	.....	.....	.....	.....	470	230	2800	900	680	900 $\left(1 - \frac{L}{60D}\right)$	
White oak . . . . .	5700	1100	1,150,000	840	210	270	110	920	450	3500	1300	980	1300 $\left(1 - \frac{L}{60D}\right)$	12

NOTE.—These unit stresses are for a green condition of timber and are to be used without increasing the live load stresses for impact.

\* Partially air-dry. *L* = length in inches; *D* = least side in inches.

These units are for use in railway bridges in which there will be presumably impact stresses not otherwise provided for. They may be increased 25 per cent for highway bridges, and 50 per cent for buildings or where timber is protected from the weather and not subject to impact. The value of the modulus of elasticity is to be reduced one-half in computing the deflection for a load applied for a long time.

The shipping weights of the different kinds of common lumber used in the United States are given in Table XXIII (d).\* These weights represent a commercial rather than an engineering classification, as they are taken from the reports of the secretaries of the various lumber associations. They are, however, accepted by the trade in place of actual weights. The various classifications are sufficiently explanatory so that no extended reference to them is needed.

\* *Engineering News*, May 5, 1910.



TABLE XXIII (d).

Shipping Weights in Pounds per 1000 Feet B.M.

	Green from Saw.	Shipping Dry.	Well Seasoned.	Kiln Dried.
Ash, black . . . . .	4600	.....	3200	3000
“ , white . . . . .	4600	.....	3800	3300
Basswood . . . . .	4200	2800	2500	2100
Beech . . . . .	5750	.....	4000	
Birch . . . . .	5500	.....	4000	
Buckeye . . . . .	.....	2600		
Butternut . . . . .	4000	2800	2500	
Chestnut . . . . .	5000	3500	2800	2450
Cherry . . . . .	5000	4000		
Cottonwood . . . . .	4600	3100	2800	2400
Cypress . . . . .	5000	3500	2900	
Elm, rock . . . . .	5400	4300	4000	3500
“ , soft . . . . .	4750	3300	3100	2900
Gum . . . . .	5400	3600	3300	3030
“ sap . . . . .	5000	3300	3000	2750
Hemlock, Penna. . . . .	4000	.....	2500	
“ northern . . . . .	4500	3000		
Hickory . . . . .	6000	5000	4500	
Mahogany . . . . .	4500	.....	3500	
Maple, hard . . . . .	5400	4150	3900	3400
“ soft . . . . .	5000	3650	3300	3000
Oak, red . . . . .	5500	4250	4000	3400
“ white . . . . .	5700	4500	4100	3600
Pine, long-leaf . . . . .	4500	3500		
“ white . . . . .	3500	2500	2400	2200
Poplar . . . . .	3900	3000	2800	2400
Poplar bay (Tupelo) . . . . .	4200	.....	3000	
Spruce, Adirondack . . . . .	3300	2700	2300	
“ West Virginia . . . . .	3000	2700	2300	2200
Sycamore . . . . .	4750	3200	3000	
Walnut, black . . . . .	4900	4000	3800	
Douglas fir 37 lbs. per cubic foot.*				

## TIMBERS OF FOREIGN COUNTRIES—CENTRAL AND SOUTH AMERICA.

The following notes on the timbers of Nicaragua and Costa Rica suitable for the purposes of construction were gathered by Mr. J. Francis Le Baron, M. Am. Soc. C. E., during a residence of two years in Nicaragua.†

The trees of Nicaragua, Costa Rica, British and Spanish Honduras, Guatemala, Salvador and the United States of Colombia are all much alike. In the zone of greatest rainfall, the wood often contains so much sap that it cracks and warps on exposure to the sun to an extent that makes it unsuitable for timber. But even these trees, if cut and piled loosely under a shed for six months, or if hewn and then soaked in water for six months, will make good and serviceable timber. The same result will follow girdling when the sap is down.

The termites, or white ants, are very destructive to wood construction in Nicaragua, as they often eat out the entire inside of posts and beams, leaving only a thin outer shell. There are some kinds of native woods, however, that they will not eat.

\* Edward Molum, *Engineering Record*, June 23, 1900, p. 597.

† *Engineering News*, April 28, 1898, p. 266.

In the following notes the relative abundance, hardness and durability are estimated on a scale of 1 to 10, the higher figure being the maximum. The diameter is measured breast high, or above the buttresses, when these occur. The "length" of trunk is that part available for lumber either to or above the first limbs; the "height" is the total height of the tree and branches; the "durability" is that of seasoned timber. The English, Nicaraguan or Spanish, and the Latin names are given when known. Of the 166 varieties of timber noted in the two countries only those are here mentioned which are suitable for timber or cabinet purposes.

Red Cedar; *Cedro colorado*, *Cedrel* or *Cedron*. (*Cedrela odorata*.) This belongs to the same family as the mahogany, and there are 17 varieties, known by special names. It is found on the river banks, with a length of 60 to 80 ft.; diameter, 2 to 3 ft. It floats in water when dry and a relative abundance is 5. It is much used for boards and canoe-making, and is very durable in water.

Male Cedar; *Cedro macho*. Length 80 ft.; diameter 5 ft.; splits hard; floats green, lasts from 10 to 20 years.

Thorny Cedar; *Pochote*, *Cedro Espinado*; (*Pochira bombax?*). Abundance 10; length 60 ft. and more; diameter 9 ft. A good wood, found on the Atlantic side, on the hills and river banks; it is used for boats, boards and posts. Posts of this timber will take root and grow when used in fences. It bears a cotton boll that is used for textile purposes and for mattresses.

Manwood, Iron Wood; *Corteza negro*; *Palo de hierro*; (*Tecoma sideroxylum*.) Abundance 8 in the West, 1 in East; length 16 to 24 ft.; diameter 4 to 9 ins. Hard to cut and split; sinks when green, but floats when dry; grows on the hills and river banks. It is used for bridge and house timber, posts, railway ties, etc. It is tough and very heavy. There are three varieties of this timber. Resembles hornbeam, *Cospinus americana*.

Yellow Manwood; *Corteza amarillo*. Abundance 6 East, 8 West; length 18 ft.; diameter 5 ins. Grows in same localities as above and has the same characteristics and is used for similar purposes. Sinks when dry.

Medlar Tree; *Nispero* or *Itaiba*; (*Hymaenea combaril* L.); (*Mespilus germani*) and (*M. americana*). Abundance 6; length 100 ft.; diameter 5 ft. There are four varieties, known as *N. blanco*, *N. amarillo*, *N. negro* and *N. colorado*. Grows on the hills and river banks; is very strong, hard and heavy; sinks when green. It is used for bridge and house timber; is large and straight; very durable and lasts indefinitely in water. It is a valuable timber, as good as mahogany for some purposes, and bears one of the best fruits of the country. It should be introduced into South Florida. Wood resembles red oak, but is stronger and more durable.

Black Wood; *Madera negro*, *Madre de cacao*; (*Gliricidia maculata*; Kunth.); (*Erythrina umbrosa*): (*E. velutina*). Abundance 1 East, 8 West; length 20 ft.; diameter 3 ft.; height 40 to 50 ft. A fine hardwood for house framing and cabinet work; largely used for ties on the Grenada-Corinto Railway. It is also used for bridges, but is crooked. In the



ground it is said to last for 100 years. It is used as a shade tree in cacao plantations. Wood may be likened to *Lignum vitæ*.

Wild Almond, Break Axe; Almendro, Ibo or Quebrada hacha; (*Terminalia cattapa*). Abundance 8; length 80 ft.; height 125 ft.; diameter 1 to 6 ft.; durability 10; hardness 10. Grows on river bank and hills; sinks green, but floats dry. It could be used for bridge timber, planks, docks, etc. It never splits or rots, except after a long time; it is hard as iron and resists nails. The grain of the wood is intertwined, and it is almost impossible to cut it with an axe. It is probably the same as the Quebrada negro, of the Argentine Republic, "Axemaster" of Belize, and El Rey de los Palos, Paraguay. Wood more nearly resembles Live Oak than any other, but is harder, stronger, more difficult to split and more durable.

Tabcon; Tabacon. Abundance 8 East; length 35 ft.; height 50 ft.; diameter 9 to 14 ins.; durability 8. Grows on high lands; sinks when green; splits very hard; lasts 8 to 10 years in the ground. It is used for house posts, and for tanning.

Mary's Milk Tree; Leche Maria, or Leche cuajo. (*Varriga negro?*) Abundance 7 East; length 18 to 20 ft.; height 50 ft.; diameter 1 to 3 ft.; durability 5. Grows on high lands and in swamps; sinks when green; splits hard. The heart-wood is very good and is used for posts, sills and plates; lasts 5 years under cover.

Red Tree; Arbol colorado, Coloradito. Abundance 3; length 20 ft.; height 40 ft.; diameter 12 to 16 ins. It floats when green; splits hard; is used for girders. Grows on high lands.

Toasted Leaf; Hoja tostada. Abundance 8 East; length 50 ft.; height 80 ft.; diameter 10 to 20 ins. Grows on high and low lands; sinks when green; used for boards, etc.

Marui. Abundance 3; durability 10; length 70 ft.; diameter 2 ft. Grows on high lands; is used for house posts and lasts underground for 10 years.

Chocomico. Abundance 8 East; length 50 ft.; height 115 ft.; diameter 12 to 18 ins. Grows plentifully on high lands; sinks when green; splits hard; is used for girders, and lasts 10 to 15 years.

Matasano; (*Casimiroa edulis*). Abundance 8; durability 5; length 50 ft.; height 80 ft.; diameter 15 to 18 ins. Grows on high lands; sinks when green; splits hard; is used for house posts, and lasts underground 5 to 6 years. It grows wild and is also cultivated, and bears an edible fruit.

Papaya Almendro. Abundance 8 East; durability 10; length 50 ft.; diameter 50 to 60 ins. Grows on high and low lands; sinks when green; splits hard; used for posts and boards, and lasts underground for 20 or 30 years. This is not the pawpaw, or Spanish papaya, which is a soft, valueless wood.

Sapodillo, Naseberry; Sapotillo, Espanel; Sapote, or Limonero rojo; (*Achras sapota* L.). Abundance 6 East; length 12 ft.; diameter 4 ft. Grows on hills on East side and is cultivated on the West. Sinks when green; splits hard; has many limbs; said to be proof against teredo, and furnishes a well-known fruit. Stephens reports finding a door-lintel of

this wood, in perfect preservation, in the ruins of Palenque; he says it must have been placed there before the Spanish Conquest, or over 300 years ago. It is hard and difficult to work, but makes handsome furniture, and is much used for house framing. Wood somewhat resembles elm in texture, but is much harder.

Guava; Guavo; Goyava; six varieties. Abundance 3 East, 8 West; length to first limb 8 ft.; diameter 18 ins. Grows on river banks; has a straight trunk; hardwood; splits hard and is fibrous. Used for cabinet and household work, and the fruit is eaten green in tropics, and from it is made the well-known guava jelly. Wood somewhat resembles beech.

Male Guava; Guavo macho. Abundance 8; length 16 ft.; diameter 3 ft. It resembles the wild Almond, or Ibo, and bears no fruit.

Tamarind; Tamarindo; (*Tamarindus occidentalis*). Abundance 2 East; length 40 ft.; diameter 4 ft.; height 80 to 100 ft. Grows on the hills and in valleys; is a strong, hard, fine wood, used for boat building, wheels and carpenter work. It is cultivated in the interior and fruit is used for medicinal purposes and as material for a cooling drink.

Guayacan; four varieties. (*Lignum vitae*.) Abundance 1; length 18 ft.; diameter 14 ins. Grows on the hills; is hard, straight and fine-grained, very durable; is used for making pulleys, canes, beams and cabinet work. It is exclusively used for ties on the Panama Railway, at a cost of \$1.20 each in Colombian silver. Imperishable under water.

Ebony; Ebano Americano. Three varieties similar to the Guayacan and put to the same uses.

Cotton Tree, White Wood; Ceiba; (*Bombax ceibal*). Abundance 8; length 50 ft.; diameter 6 to 8 ft. Grows on river banks; is straight; wood soft and used for boards and barrels. Grows in U. S.

Gunacaste comun; (*Enterolobium cyclocarpus*). Abundance 1 West; length 50 ft.; diameter 4 ft. Grows on Pacific slope; used for boat-making and for excellent boards. Sometimes grows to enormous dimensions; the large quantity of gum contained would make good varnish. Two varieties.

Acacia; Jenisero; (*Pithecolobium saman*). Abundance 1 East; length 30 to 90 ft.; diameter 9 to 15 ft.; many limbed; and is more plentiful on West side. Is a variety between cedar and mahogany; is an excellent wood for wagon wheels, cabinet work and all manner of construction. It floats dry. Grows on the hills.

Cativo; Cautibo colorado. Length 100 ft.; diameter 5 ft. Floats green or dry; wood soft and red; used for house and bridge timber. The C. blanco is similar to the above; but the wood is white and harder, and somewhat resembles white pine. Both grow on river banks.

Alligato Tree; Lagarto and Lagartillo; two varieties. Grows on Atlantic slope. Abundance 1; length 12 ft.; diameter 18 ins. Floats green; splits hard; wood resembles guava; used for heavy construction.

Coal Wood, or Coyote; Guiliquiste, Guachipelin, Palo do carbon, etc. Abundance 3 West; diameter 4 ft. Floats dry; a very strong yellow wood with many limbs; used for house sills, bridge stringers and railway ties. Very durable in the ground.



Jicaro del Monte, Catabacero; (*Crescentia alota*, or *C. acuminata*). Abundance 6 West; length 12 ft.; diameter 2 ft. A strong wood; floats when dry; used for boat's gunwales.

Junzopote negro. Sunsapote; (*Mangifera domestica*), or *Achras jimenia*. Abundance 8; length 24 ft.; diameter 8 ins. Floats dry; red in color; used for bridge and house timber and railway ties; bears an edible fruit. Grows on hills. It resembles Canveadeaival wood that grows on East slope. Splits hard.

Laurel; (*Laurus nobilis*); 9 varieties. Abundance 2 East, but very plentiful in interior; length 24 ft.; diameter 5 ins. A very good, straight wood; floats dry; used for bridge timber, piles and furniture and carriage making.

Gavilan; Gabilan colorado; (*Mimosa arborea*). Abundance 8; length 16 ft.; diameter 4 ft. A good wood but splits hard; the heart-wood used for ties and general construction; resembles the acacia. Grows in swamps and on river banks.

Black Thorn; Espina negro; E. blanco; E. amarillo. Grows on East side; used in construction and cabinet work; floats dry.

Lead Wood; Palo de plomo. Abundance 4 East; length 80 ft.; diameter 2 to 4 ft. Straight and tall; floats dry. Grows on river banks; wood resembles maple.

Camitos (*Cryosophyllum oliviformis*); five varieties. Abundance 8 East; length 100 ft.; diameter 4 to 5 ft. Wood red; brash and resinous; used for bridge piles. Different from Caimita of U. S. of Colombia, which is hard, close-grained and very heavy. Floats dry.

Strawberry Tree; Madrono negro, M. amarillo. Abundance 8 East; length 16 ft.; diameter 18 ins. A fine-grained wood without fiber, resembling boxwood. Crooked; floats dry; used for railway ties and general construction; good for lathe work.

Guasimo; four varieties. (*Guasuma ulmifolia*.) Abundance 8 East; length 16 ft.; diameter 5 ft. Floats dry; used in carpentry.

Grape Tree; Uva or Huva. Abundance 8 East; length 20 ft.; diameter 14 ins. A good wood, splits hard; sinks dry; used in house building.

Snake Wood; Culebra. Grows on East side; heavy and splits rather easily; floats dry; used in carpentry and cabinet work, and as a dye-wood.

Toledo. Length 18 ft.; diameter 3 ft. Grows on East side; floats green or dry; splits hard; makes good lumber and fine fire wood.

Seven Skins; Siete peles, S. cueros. Abundance 1 East; length 16 ft.; diameter 2 ft. Floats green; cuts like cheese, but splits hard; not used. Grows on river banks.

Match Tree; Foforito. Abundance 1 East; length 12 ft.; diameter 12 ins. Sinks green; wood fibrous and splits hard; resembles sapote in appearance; no uses known. Grows on river banks and islands.

Guapinol, Copinal, Alganobo; (*Hymenaea courbaril*.) (Family Leguminosa.) Abundance 1 East; length 25 ft.; diameter 4 ft. A beautiful, solid and hard wood; used for boards, beams, wheels and cabinet work; color reddish, with very compact fiber. Bears a nutritious fruit and furnishes a gum equal to Ceylon copal.

Red Oak, White Oak; Encina; Roble; (*Quercus robur*; *Tecoma mexicana*); four

varieties. Length 16 ft.; diameter 3 ft.; grows on elevated land in the West. A strong, heavy wood; used for planks, wagons and barrels, and for dyeing and tanning.

Red and White Mangrove; *Mangle colorado* and *M. blanco*. (*Laguncularia racemosa*.) Abundance 6 East and West; length 25 ft.; diameter 20 to 36 ins.; height 30 to 50 ft. Grows in the salt water on both coasts; strong and heavy wood; used for shoe pegs, also for posts, planks and cabinet work, and for shipbuilding and wharves; for the latter purpose it has no equal. The Red Mangrove sometimes grows to a height of 60 to 80 ft.; the white, or light yellow, to 80 ft., and the black Mangrove grows 50 ft. high. The bark is rich in tannin and dye, and is largely exported to Europe. It grows abundantly in Florida. Has medicinal uses.

Quebracho; and *Q. colorado*. Abundance 1, in Chinendega; length 28 ft.; diameter 3 ft. This is a strong, heavy wood; used for posts and cabinet work.

Mahogany; *Caoba*; *Caobano*; *C. Con*; (*Swietenia mahogani*). Grows in Department of Zelaya and near Leon; none in San Juan Valley. Abundance in Zelaya 8; Leon 1; length 25 ft.; diameter 3 ft. Well known in character and use. It costs about \$40 to \$50 per 1000 ft.,<sup>7</sup> B.M., to cut and square mahogany and get it to the seaboard.

Mulberry; *Mora*, *Moran*, (*Rebus ideous* and *Morus tinctoria*); six varieties. Abundance 5 West; none on East; length 20 to 30 ft.; diameter 4 to 6 ft. A heavy, yellow, strong and very fine and durable wood; as good a dye as Brazil wood; used in house building, cabinet work and for railway ties. Bears an edible berry; is cultivated. Grows on the hills and high plains.

Gamvacho. Abundance 2 East; length 24 ft.; diameter 5 ft. Floats dry; is straight and many limbed.

Granadier; *Granadillo*. Abundance 4 West; none East; length 50 ft.; height 80 ft., diameter 6 to 24 ins. Wood hard and takes a fine polish; used for canes and cabinet work.

Ronron; *R. veteado*. Abundance 6 West; length 30 ft.; diameter 4 ft. Used for cabinet and other construction.

Male Brazil Wood; *Brazil Macho*. A heavy wood that makes excellent railway ties.

Nance; *Nanzite colorado*; (*Malpighia puniceifolia*.) Abundance 8 West; length 20 ft.; diameter 2 ft. A heavy, strong wood, used for building; bark useful for tanning and dyeing; bears a small edible fruit.

Cuban Pine; (*Pinus cubensis*). Grows in Zelaya, on Prinzapulka River, in a strip 50 by 20 miles; also in Segovia and on the higher lands up to 2500 ft. elevation; none in San Juan Valley, but the most abundant tree in Florida. Length 40 ft.; diameter 18 to 20 ins.; height 60 to 80 ft. A hard, heavy and durable timber. Floats green and dry. Is the Long-leafed Pine; (*Pinus palustris*); or *Ocote*.

Icaco; (*Chrysobolanus icaco*). Abundance 6 East and West; length 5 ft.; diameter 12 ins. Grows in the sea; bears an edible fruit; brought originally from Senegal. A fine and durable wood; but small and with many limbs.



Papaturo; P. blanco; P. negro. Abundance 5 West; length 16 ft.; diameter 3 ft. Wood soft; crooked; makes a good fence.

Little Cheese Tree; Quisillo. Abundance 10 East and West; length 10 ft.; diameter 12 ins. No known use.

Monkey Tree; Jacote mico, etc.; (*Spondias myrobotanus* L.); five varieties. Grows in San Juan Valley. A very strong yellow wood. Abundance West 7. Floats dry; splits hard. Bark fiber used for matting, baskets, rope, etc. Length 12 ft.; diam. 12 ins.

Copaiba, Camivar; (*Copaifera officinalis*). Abundant in San Juan Valley, and grows to a height of 50 to 60 ft. Wood strong, reddish in color. Much used for inlaid work, being repellant to insects. Used as a dye and in medicine.

Liquid Amber; Liquidambas; (*Liquidambar macrophylla*, etc.). Grows in San Juan Valley and on West Side to a height of 60 ft. The wood has an agreeable odor and is used in making vases, cups, etc., and has the property of preserving organic substances. Its balsam is well known for medicinal purposes and perfumery.

Peruvian Balsam; Balsamo del Salvador, etc. (*Myroxylon pereiral*, etc.). Grows near Salvador and in San Juan Valley. Abundance 4; height 35 to 65 ft. Wood reddish-ochre; compact fiber; suitable for cabinet work; perfumed. The tree is said to live 100 years. Used for medicine and perfumery.

Rubber Tree; Palo de Hule, Cautchu; (*Castilloa elastica*). Abundance 8 East, 2 West; length 30 ft.; height 60 to 65 ft.; diameter 2 to 3 ft. Wood light, soft, and of no use, but each tree yields from 3 to 6 lbs. of rubber sap as a crop, and 100 lbs. of this sap yields 36 lbs. of pure gum.

Milk Tree; Cow Tree; Palo de leche; (*Galactodenidrum utile*). Grows on moist land in the East; length 70 ft.; diameter 40 ins. Floats green; splits hard; wood white and fibrous and not used. It yields an abundant milky sap, which when boiled is used by the natives in their coffee; the wax from it makes excellent candles.

Melon Tree; Calabash, Jicaro, Tigulate, Temante, or Palo de Melon; (*Crescentia cujete*). Plentiful on West side; used for ships' knees and cabinet work; wood durable in ground. The wood resembles the Madrono, and the hard gourd which it bears is much used by the natives for drinking vessels.

Other trees, valuable for structural purposes, fruit, dyes or medicines might be included, did space permit any lengthy description. Among these might be mentioned the following: The Little Coffee Tree, wild, and not bearing the coffee of commerce; the Jovo, Cinnamon, Vegetable Wax and Vegetable Suct trees; the Rosewood, Copal, Logwood, Peruvian Bark, Gutta Percha, Pepper Tree, Dragon's Blood, False Brazil wood, Sandal wood and Bamboo; Cocoanut, Coyol, Royal Palm, Cohune, Pijiballe and other varieties of palms. There are still about 29 other trees valuable for timber, but not so well known, or so common; and in some cases these are, too, useful for their fruit, or for dyes and medicinal products, to be available as lumber.

## NEW SOUTH WALES\*.

In the tenth issue of "The Wealth and Progress of New South Wales," for 1896-7, the Government Statistician, Mr. T. A. Coghlan, presents a brief review of the timber products of the colony, which is here abstracted for the general interest it possesses.

The characteristic of the trees of New South Wales, and of all the Australian colonies, is a dull, evergreen foliage which alters little with the changes of the seasons. The forests are generally open and the trees met with are chiefly species of *Eucalyptus*, *Angophora* and other genera of the order *Myrtaceae*, with the eucalypti predominating. The trees are usually straight and cylindrical in the trunk, with the first branches at a considerable distance from the ground when the tree is full grown. The finest specimens, and those yielding the most valuable timber, are found on ridges and hillsides, usually too rough and stony for cultivation. A list of the best-known varieties of commercially valuable trees is given as follows:

**Flooded Gum** (*Eucalyptus rostrata*). This tree grows, along streams, to a height of 100 ft. Its wood is most useful for heavy work, and for structures liable to attack by white ants.

**Apple-tree** (*Angophora subvelutina*). This tree also grows along the streams; has more spread than the majority of the indigenous trees, and the wood is strong, heavy and durable. The tree is widely distributed over the colony. On the ridges and mountain sides other varieties of trees predominate. The Box reaches a height of 180 ft. and diameter of 6 ft. and its timber is chiefly used for firewood, for which purpose it has no equal. The Bastard Box is supposed to be a cross between the Box and Gray Gum, and is widely distributed; but the quality of the timber varies greatly with the locality. Some varieties are only surpassed among hardwoods by the Ironbark.

**Ironbark** (*Eucalyptus leucoxydon* and *E. paniculata*). A tree of moderate size, usually 60 to 80 ft. high when full grown; though the White Ironbark attains a height of 150 ft. The timber is heavy; remarkable for its great strength, which is nearly twice that of the best oak in fine specimens. The wood is extensively used for wharves, bridges and housework.

**Blue Gum** (*E. globulus*). This is one of the finest of the eucalyptus family. It attains a good height and is sometimes 7 ft. in diameter. The timber is in great demand owing to its comparative lightness and easy working qualities.

**Spotted Gum** (*E. maculata*), grows in the coast districts, on generally poor soil. It attains a height of 100 to 150 ft., but the quality of the wood varies greatly; when good it is considered specially adapted for ship-building.

**Stringy Bark** (*E. eugenioides*), has a peculiar fibrous bark, and grows chiefly on northern table lands. It is large tree, and its wood is of great and general utility. The bark is much used for roofing, and also as a paper-making material.

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\* *Engineering News*, April 28, 1898, p. 268.



The Messmate (*E. obliqua*), also called Stringy Bark, is one of the largest trees in Australia, frequently being over 250 ft. high. The bark is used for roofing and would make excellent paper.

Bloodwood (*E. corymbosa*), is a large tree, growing in the coast districts. The timber is generally used for fencing and for railway ties.

Gray Gum (*E. tereticornis*) grows to a height of 150 ft. and is extensively distributed over the coast districts. The timber is hardly inferior to Ironbark; and some varieties produce a wood of remarkable beauty and great durability.

Tallow-wood (*E. microcorys*) is a very large tree extensively found in the forests north of Sydney. The wood is more easily worked than most of the hardwoods; it has great strength and durability and is employed for floors and building purposes, and for decks of ships.

The Mountain Ash, or White-top (*E. virgata*) is found both on the coast and the hills. The timber is in demand for cooper-work and rough carpentry. The tree grows to a height of about 150 ft.

Turpentine Tree (*Syncarpia laurifolia*) sometimes reaches a height of 200 ft. and diameter of 6 ft. The timber is largely used for piling and other work in sea-water, as it resists the attack of the teredo better than any other wood in the colony.

Red and White Cedar (*Cedrela australis* and *Melia composita*). These trees were once abundant in the northern forests; but few of the full-grown trees are now met with, except on the high ridges. The Red Cedar is a magnificent tree, often attaining a height of 150 ft. and a girth of 30 ft. The timber is very valuable; being light, easily worked, durable, splendidly grained and well adapted for furniture and cabinet-work. The White Cedar is about 80 ft. high and 3 ft. in diameter, and the wood is soft and easily worked, but is deficient in tensile strength and durability.

The Silky Oak (*Grevillea hilliana*, *G. robusta*) grows to a height of about 80 ft. under favorable circumstances, and the wood is very suitable for cabinet-work.

The Tulip Tree (*Harpullia pendula*) is a tall tree, with beautifully marked wood of various shades and susceptible of a high polish.

The Ash, or Pigeonberry Tree, sometimes grows to a height of 130 ft. with a diameter of 5 ft. The timber is light and tough, and in good demand.

The Colonial Pine (*Araucaria cunninghamii*) is one of the finest trees of Australia, sometimes reaching a height of 200 ft. and a diameter of 4 ft. The timber is white in color, easily worked, cheaper than any imported pine, and is largely used.

The Native Beech (*Gmelina leichardtii*), reaches a height of 150 ft. Its timber is in great demand as it neither shrinks nor warps when exposed. In color the wood is white, or silvery, with a fine, close grain.

The specific gravity and resistance to breaking of various timbers of South New Wales is given in a table. In regard to this table, it should be mentioned that the tests were made with picked specimens, so that the results are perhaps considerably higher than would

be obtained in actual practice. The modulus of rupture is eighteen times the load required to break a bar 1 in. square, supported at two points 1 ft. apart and loaded in the middle between the points of support, or

$$S = \frac{3Wl}{2bd^2},$$

when  $W$  = load applied at middle;  $b$  = breadth;  $d$  = depth;  $l$  = length of beam and  $S$  = coefficient of rupture, or breaking stress per square inch:

Timbers of New South Wales.	Specific Gravity.	Resistance to Breaking, or Modulus of Rupture = $S$ , Lbs. per Sq.in.	Timbers of New South Wales.	Specific Gravity.	Resistance to Breaking or Modulus of Rupture = $S$ , Lbs. per Sq. in.
Spotted gum.....	0.995	13,300	Forest mahogany.....	1.156	13,800
Gray gum.....	0.917	13,100	Swamp mahogany.....	1.216	12,100
Flooded gum.....	1.178	14,800	White beech.....	1.008	15,600
Red gum.....	0.995	6,900	Mountain ash.....	1.065	11,500
Woolly butt.....	1.022	12,700	Rosewood.....	1.189	10,600
Black butt.....	1.067	13,700	Pine.....	0.868	8,800
White ironbark.....	1.177	16,900			
Gray ironbark.....	1.182	17,900	Greenheart.....	1.001	22,000
Red ironbark.....	1.224	16,300	Oak, British.....	0.69 to 0.99	11,800
Forest oak.....	1.208	15,500	“ Dantzic.....	.69 to .99	8,700
Turpentine.....	1.109	11,700	“ American.....	.99	10,600
Stringy bark.....	1.141	13,900	Ash, European.....	.753	13,000
Black wood.....	1.129	10,300	Birch, European.....	.711	11,700
Tallow wood.....	1.233	15,260	Beech, European.....	.690	10,500
Australian teak.....	1.006	14,400	Mahogany, Honduras.....	.56	11,500
Mahogany.....	1.201	14,500	Teak, Indian.....	.66 to .88	15,000

The following standard names for structural timber and classifications in railway work have been proposed by the American Railway Engineering and Maintenance of Way Association:

#### STANDARD NAMES FOR STRUCTURAL TIMBERS \*

1. Southern Yellow Pine. Under this heading three classes of timber are used, (a) long-leaf pine, (b) short-leaf pine, (c) loblolly pine.
2. Douglas Fir. The term “Douglas Fir” is to cover the timber known likewise as yellow fir, red fir, Western fir, Washington fir, Oregon or Puget Sound fir or pine, Northwest and West Coast fir.
3. Norway Pine, to cover what is known also as “Red Pine.”
4. Hemlock, to cover Southern or Eastern hemlock; that is, hemlock from all States east of and including Minnesota.
5. Western Hemlock, to cover hemlock from the Pacific Coast.
6. Spruce, to cover Eastern spruce; that is, the spruce timber coming from points east of Minnesota.
7. Western Spruce, to cover spruce timber from the Pacific Coast.

\* Report of Committee on Wooden Bridges and Trestles, American Railway Engineering and Maintenance of Way Association Bulletin 96, February, 1908, p. 50.



8. White Pine, to cover the timber which has hitherto been known as white pine, from Maine, Michigan, Wisconsin and Minnesota.

9. Idaho White Pine, the variety of white pine from Western Montana, Northern Idaho, and Eastern Washington.

10. Western Pine, to cover the timber sold as white pine coming from Arizona, California, New Mexico, Colorado, Oregon and Washington. This is the timber sometimes known as "Western Yellow Pine," or "Ponderosa Pine," or "California White Pine," or "Western White Pine."

11. Western Larch, to cover the species of Larch or Tamarack from the Rocky Mountain and Pacific Coast regions.

12. Tamarack, to cover the timber known as "Tamarack" or "Eastern Tamarack," from the States east of and including Minnesota.

13. Redwood, to include the California wood usually known by that name.

14. Oak. Under this heading three classes of timber are used:

(a) White Oak, to include White Oak, Burr Oak and Post Oak.

(b) Red Oak, to include Red Oak, Scarlet Oak, Black Oak, and all bastard oaks.

(c) Chestnut Oak, to include only Chestnut Oak.

#### CLASSIFICATION OF SOUTHERN YELLOW PINE.

As most of the objections last year related to the subdivision of Southern yellow pine, the following questions were sent to a number of representative inspectors, lumbermen, manufacturers, and engineers:

(1) "In buying long-leaf yellow pine, do you maintain an inspection which shows where the pine is cut which you buy for long-leaf pine? In other words, do you buy long-leaf pine from the appearance of the pine cones?"

(2) "Do you consider that any specimens of short-leaf or loblolly pine are equal to the poorest specimens of sound long-leaf pine in resistance to decay under atmospheric conditions?"

(3) "Do you consider that any specimens of loblolly pine are equal to the poorest specimens of sound short-leaf yellow pine in resistance to decay under atmospheric conditions?"

The most pertinent testimony thus secured is summarized in the following statements: It seems to be generally conceded that when long-leaf yellow pine has all of the bark and most of the sap removed by sawing to merchantable sizes that it cannot always be identified as to species. It can, however, be distinguished always by the cones, straw or leaf, and bark. Many practical inspectors accept as long-leaf pine all yellow pine which is close grained, regardless of its botanical classification. Some of the best buyers, however, maintain an inspection from the time the timber is cut, and thus determine the species.

While trees of the same species differ materially in their rate of growth, and as a rule the strength of the timber is directly proportioned to the closeness of grain, it is claimed that the following gives a fair general comparison:

Long-leaf pine has 16-30 annual rings per inch.

Cuban pine has 10-20 annual rings per inch.

Short-leaf pine has 8-20 annual rings per inch.

Loblolly pine has 3-15 annual rings per inch.

Short-leaf and loblolly pine can resist decay as long as long-leaf only when they are protected from moisture, or are thoroughly preserved by chemical treatment. Some experienced inspectors claim that in durability poor long-leaf pine is better than good short-leaf, and that the poorest short-leaf pine is better than the best loblolly pine. This statement refers to the ordinary atmospheric conditions to which timber is subjected in railroad structures. On the other hand, some claim that close-grained short-leaf pine will outlast coarse-grained long-leaf pine when exposed to the weather.

Practically all of the replies indicate that loblolly pine is less durable than short-leaf pine when thus exposed. True loblolly cannot be air-seasoned in the districts where it grows. It turns "blue" on account of the rapid development of the mycelium of a fungus. Loblolly is used largely for the interior finish of buildings, for which it is well adapted.

While there seems to be some conflict of opinion on what is called loblolly pine, it is stated that in many sections it grows in and adjacent to low places like bay galls and swamps, while short-leaf pine grows in the open dry woods. In other cases loblolly pine exists as second or third growth in areas previously occupied by the stands of the other species of pine.

One inspector describes loblolly pine in characteristic style, as follows: "Always 'honest old loblolly,' a thick, rough bark; open, coarse, soft, pulpy wood; about as much heart as a rabbit, or none at all. Treated by creosoting, that is to say, under pressure, filled and not forced out again, it is given an artificial or second life, better than its first or natural one. This pine takes treatment kindly, cannot help itself. Robbed of its sap, its only form of life, its pores are filled with oil, it enters upon its real existence, which shall be long or short, according to the honesty of the 'creosote man,' who has given it finally what nature denied, a soul."

Loblolly pine is so inferior in durability for railroad bridge and trestle structures, unless chemically treated, that it should be kept in a subdivision by itself.



## CHAPTER XIII.

### THEORETICAL CONSIDERATIONS OF DESIGN.\*

EXTENT OF APPLICATION OF THEORY—STRESSES IN AND DIMENSIONING OF STRINGERS  
—LOADING—USE OF TABLES—TRUSSED STRINGERS—STEEL I-BEAMS AS  
STRINGERS—POSTS—STABILITY—BRACING—FOUNDATIONS.

IT may be stated at the outset that it is customary not to be governed to any great extent by theoretical considerations in the design of wooden trestles. Many railroad companies use a standard bent for trestles of a given height and span without any reference to the strains which are developed in its members during the passage of trains. In fact, with timber so plentiful as it is in this country any effort at great refinement in the design of these structures would be more than offset by the trouble in procuring other than stock sizes, and by the expense of varying the design to suit slightly changed conditions. Then, too, timber undergoes rapid changes in our varying climate and will not bear as great a strain after the lapse of a few years. For these and other reasons it is necessary to be liberal in proportioning the parts of a structure, but it is not necessary to be wasteful, nor to be more liberal in one case than in another. It is for the sake of calling attention to the appropriateness of uniformity and consistency in design, and of pointing out to the builders and users of wooden trestles how to ascertain for themselves whether their design is inside or outside the (so-called) limit of safety, that this chapter has been written.

**Design of Stringers.**—The moving load which passes over a railway bridge or trestle stringer is composed of a series of irregular concentrated loads, and the successive moments which they develop cause rapid and violent changes in the internal forces of the stringer.

The desired condition of equilibrium exists when the moment of all the internal forces is equal to the moment of all the external forces. The moment of the internal forces is equal to  $TR$ , or the allowable fibre-stress,  $T$  (in pounds or tons per square inch), multiplied by the moment of resistance,  $R$ ,† of the shape of the beam. Each shape has a value of  $R$  peculiar to itself. For a rectangular cross-section such as a wooden beam,  $R = \frac{bh^3}{6}$ , where  $b$  is the breadth

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\* The larger portion of this chapter was contributed by Mr. W. W. Crehore, Assoc. M. Am. Soc. C. E.

† This term is more properly the "resistance" than the "moment of resistance," since it is obtained by dividing the moment of inertia of the shape by the greatest distance from the neutral axis to the outside fibre.

NOTE.—The allowable stress units employed in calculating the tables given in this chapter are slightly different in some instances from those given in Tables XXIIIa and XXIIIb, but it has not been thought necessary to recalculate the tables.

and  $h$  the depth, both in inches. The moment of the internal forces of a rectangular beam is, therefore,  $\frac{Tbh^2}{6}$  in inch-tons if  $T$  be given in tons; or if we divide by 12 we have

$$M = \frac{Tbh^2}{72}, \dots \dots \dots (1)$$

the moment in foot-tons. The value of  $T$  is determined by experiment, and is assumed to be constant for a given kind of wood. Since eq. (1) represents the value of the greatest allowable moment of the internal forces of a beam, it follows that the greatest moment of all the external forces which may act upon this beam must be no greater. If the external load were uniform from end to end of the beam, the total external moment would be

$$M = \frac{Wl}{8} = \frac{wl^2}{8} \dots \dots \dots (2)$$

where  $M$  is in foot-tons,  $W$  is the total load in tons,  $w$  is the uniform load per linear foot, and  $l$  is the span in feet. We should then have, combining (1) and (2),

$$W = \frac{Tbh^2}{9l}, \dots \dots \dots (3)$$

and

$$bh^2 = \frac{9Wl}{T}, \dots \dots \dots (4)$$

equations which are useful in determining the allowable uniform load and the size of a rectangular beam, respectively.

When the load is not uniform, but composed of successive concentrated loads, like the wheels of a locomotive, the moment of external forces may be found in a variety of ways. A familiar way is as follows:

1. *A Single Concentrated Load.*—Let  $AB$  (Fig. 151) be a beam resting on two supports, and let it be loaded by a single concentrated load at  $B'$  of magnitude proportional to the line  $PB'$ . Prolong  $AB$  to  $A'$ , making  $A'B'$  equal to the length of the span  $AB$ . Draw  $A'P$ , and finally erect  $AN$  at  $A$  perpendicular to  $AB$  to meet the line  $A'P$ . This line  $NA$  is the proportionate part of the load  $PB'$  which goes to the support  $A$ , and when multiplied by the distance  $AB'$  will give the moment of all the external forces on the beam.

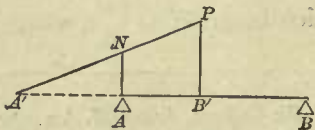


FIG. 151.

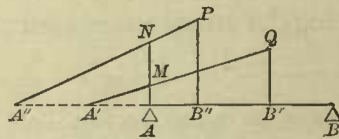


FIG. 152.

2. *More than One Concentrated Load.*—Let  $PB''$  and  $QB'$  (Fig. 152) represent two concentrated loads on the span  $AB$ . Then by the construction already described we find  $NA$



and  $MA$  to be the portions of the loads  $PB''$  and  $QB'$ , respectively, which go to the support  $A$ . The sum of these two portions ( $NA + MA$ ) therefore gives the reaction at  $A$ . The point of greatest moment will be under the load which is nearest the centre, and therefore at  $B'$ . Having multiplied the reaction, which acts upward at  $A$  by the distance to the point of moments,  $AB'$ , we must deduct from this product the negative moment,  $PB'' \times B''B'$ , since it tends to cause rotation in the opposite direction around the point  $B'$ , and hence neutralizes a part of the moment due to the reaction. The result, after deducting all negative moments between the point of moments and the reaction, will be the desired moment of all the external forces. It is apparent that every little change in the position of the loads  $P$  and  $Q$  upon the span will produce a different total moment. There must therefore be some one position where the total moment is the greatest for the given loads.

These maxima stringer moments, the maxima end shears, and the maxima bent loads

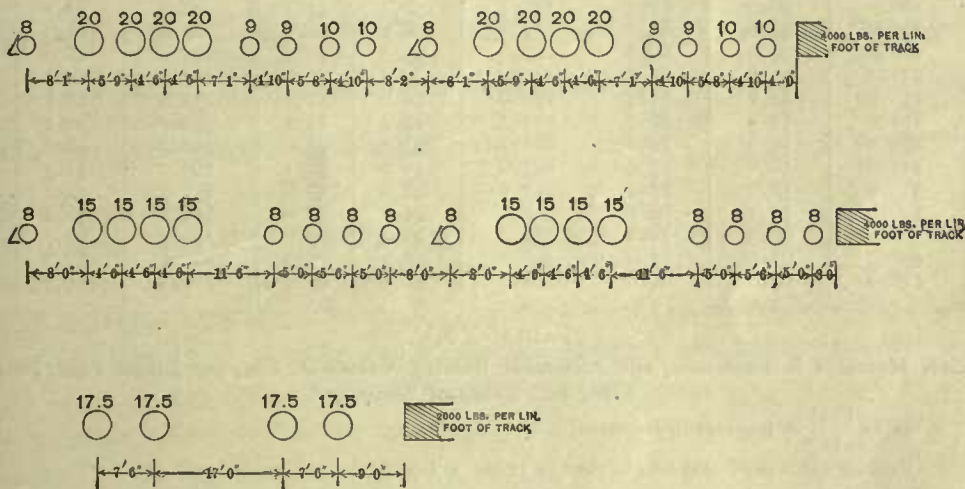


FIG. 153.

have been computed for spans from 8 to 30 feet for three different systems of loading (Fig. 153), viz. :

- (1) Two Lehigh Valley 126-ton consolidated locomotives ;
- (2) Two Pennsylvania Railroad 100-ton consolidated locomotives ;
- (3) Two 35-ton 4-wheel tank locomotives, followed by a uniform load of 1 ton per linear foot.

All wheel loads in Fig. 153 are given in net tons for a single track or thousands of pounds for one rail.

These values are tabulated in Table XXIV, the unit of distance being the foot and the unit of weight being the ton. The moments are given in foot-tons, the end shears and bent loads in tons. All have been figured for one track, and must be divided by 2 to obtain values for one rail. The term "bent load," as employed here, signifies the total maximum load coming on one trestle-bent from both sides, the distance to either adjoining bent being the same, and being called the span.

Table XXV gives safe moments of the internal forces and bearing values per linear foot for different sizes and kinds of timber. The units here employed are the same as in

A TREATISE ON WOODEN TRESTLE BRIDGES.

TABLE XXIV.\*

Maxima Bending Moments, End Shear, and Maxima Panel or Bent Loads for Three Typical Locomotives.  
(All Units in Feet and Tons for Two Rails or Thousands of Pounds for One Rail.)

Span in Feet.	Lehigh Valley 126-ton Consolidated Locomotive.			Pennsylvania Railroad 100-ton Consolidated Locomotive.			35-ton 4-wheel Tank Locomotive.		
	Maximum Moment.	End Shear.	Bent Load.	Maximum Moment.	End Shear.	Bent Load.	Maximum Moment.	End Shear.	Bent Load.
8	41.4	28.8	37.5	31.0	21.6	28.2	35.0	18.7	18.7
9	50.8	30.0	40.0	38.0	22.5	30.0	39.3	20.4	20.4
10	60.0	33.0	41.5	45.1	24.8	33.1	43.7	21.9	21.9
11	75.0	35.4	44.9	56.3	26.6	35.5	48.1	23.1	23.1
12	90.0	37.5	47.9	67.5	28.1	37.5	52.5	24.1	24.8
13	105.0	39.2	50.4	78.8	29.5	39.6	57.6	24.9	25.6
14	120.0	40.6	52.3	90.0	31.1	41.5	65.7	25.6	26.5
15	135.0	42.0	55.0	101.3	33.0	43.4	73.9	26.3	27.5
16	150.0	43.1	57.0	112.5	34.7	44.9	82.0	26.8	28.3
17	165.0	44.6	59.4	125.0	36.2	46.2	90.0	27.3	29.2
18	180.0	46.0	61.5	139.5	37.5	47.5	98.8	27.7	30.0
19	195.0	47.6	64.8	154.0	38.7	48.5	107.0	28.3	30.7
20	211.0	49.3	66.8	169.0	39.8	49.5	115.2	28.7	31.4
21	231.0	50.8	68.7	184.0	40.7	50.8	123.9	29.3	32.2
22	251.0	52.2	70.4	199.0	41.6	52.3	132.0	29.7	33.7
23	271.0	53.9	72.4	213.3	42.4	53.7	142.7	30.2	34.8
24	291.0	55.3	74.2	228.3	43.2	55.0	152.2	30.7	35.8
25	311.0	56.6	75.9	243.0	43.9	56.1	160.2	31.3	37.3
26	333.0	58.0	77.4	257.9	44.8	57.6	172.7	31.7	38.8
27	356.0	59.1	79.1	274.2	45.7	59.0	182.8	32.2	40.3
28	378.0	60.5	81.2	291.2	46.4	60.6	192.2	32.7	41.2
29	400.0	61.9	82.9	308.2	47.1	62.0	201.8	33.2	43.2
30	422.0	63.0	84.8	325.2	47.9	63.2	210.8	33.7	44.5

TABLE XXV.

Maxima Safe Moments in Foot-tons, and Allowable Bearing Values in Tons per Lineal Foot, for Different Sizes and Kinds of Timber.

$$M = \frac{Tbh^3}{72} = \text{moment in foot-tons.}$$

$$\text{Bearing value per lineal foot in tons} = 12 \text{ in.} \times b \times B.$$

$$B = \frac{500}{2000} \text{ for long-leaf yellow pine, } \frac{1000}{2000} \text{ for white oak, } \frac{300}{2000} \text{ for white pine and spruce.}$$

*b* and *h* = breadth and depth in inches.

Size of Timber in Inches.	Georgia Long-leaf Yellow Pine.		White Oak.		White Pine and Spruce.	
	Safe Moment. $T = \frac{1200}{2000}$	Bearing per Lineal Foot.	Safe Moment. $T = \frac{1000}{2000}$	Bearing per Lineal Foot.	Safe Moment. $T = \frac{750}{2000}$	Bearing per Lineal Foot.
8 × 16	17.1	24.0	14.2	48.0	10.7	14.4
7 × 16	14.9	21.0	12.4	42.0	9.33	12.6
6 × 16	12.8	18.0	10.7	36.0	8.00	10.8
12 × 14	19.6	36.0	16.3	72.0	12.2	21.6
7 × 14	11.4	21.0	9.53	42.0	7.15	12.6
6 × 14	9.80	18.0	8.17	36.0	6.13	10.8
12 × 12	14.4	36.0	12.0	72.0	9.00	21.6
10 × 12	12.0	30.0	10.0	60.0	7.50	18.0
8 × 12	9.60	24.0	8.00	48.0	6.00	14.4
6 × 12	7.20	18.0	6.00	36.0	4.50	10.8
10 × 10	8.33	30.0	6.94	60.0	5.21	18.0
8 × 10	6.67	24.0	5.56	48.0	4.17	14.4
6 × 10	5.00	18.0	4.17	36.0	3.12	10.8
5 × 10	4.17	15.0	3.47	30.0	2.60	9.0
4 × 10	3.33	12.0	2.78	24.0	2.08	7.2
8 × 8	4.27	24.0	3.56	48.0	2.67	14.4
6 × 8	3.20	18.0	2.67	36.0	2.00	10.8
4 × 8	2.13	12.0	1.78	24.0	1.33	7.2

\* Copyright, 1894, by W. W. Crehore.



Table XXIV. The values of  $T$ , the allowable fibre-stress per square inch, recommended by Professor Lanza, have been employed here, and are as follows:

For Georgia (long-leaf) yellow pine, 1200 lbs. per square inch;

For white oak, 1000 lbs. per square inch;

For white pine and spruce, 750 lbs. per square inch.

*Example.*—How many and what size stringers of Georgia pine timber should be used under each rail in a trestle to be loaded with Pennsylvania Railroad standard loading, when the distance between bents is 16 feet?

From Table XXIV we see that the Pennsylvania Railroad loading develops a total live moment of 112.5 foot-tons for a 16-foot span. Taking the dead weight of track material at 400 lbs. per foot of track, and the weight of the stringers themselves at 350 lbs. per foot of track,\* we have altogether an additional moment due to dead load of  $\frac{750}{2000}$  times  $\frac{1}{8}$  of the square of

the span (in feet) =  $\frac{750}{2000} \times \frac{1}{8} \times 16^2 = 12.0$  foot-tons (eq. (2)). Adding this 12.0 to 112.5 found above, we have a total live and dead moment of 124.5 foot-tons, or 62.25 foot-tons on each rail. Let us try using 4 sticks under each rail; then  $\left(\frac{62.25}{4} =\right)$  15.56 is the moment to be resisted by each stick.

Referring to Table XXV, we find that the safe moment for a 8-in.  $\times$  16-in. Georgia pine stick is 17.1 foot-tons, which is ample. We may then use four Georgia pine sticks, each 8 in.  $\times$  16 in., under each rail. To save material we might, however, use two sticks 8 in.  $\times$  16 in. and two sticks 7 in.  $\times$  16 in. under each rail, giving a total moment under one rail of  $(2 \times 17.1) + (2 \times 14.9) = 64.0$  foot-tons, as against 62.25 required.

From Table XXIV we find the end shear for a span of 16 ft. under Pennsylvania Railroad loading to be 34.7 tons. Adding to this the end shear due to dead load, which is  $\left(\frac{750}{2000} \times \frac{16}{2} =\right)$  3 tons, we have a total end shear of 37.7 tons, or 18.9 tons for one rail.

Referring to Table XXV, we see that two sticks of 8-in.  $\times$  16-in. Georgia pine and two sticks of 7-in.  $\times$  16-in. Georgia pine have a combined bearing value of  $(2 \times 24) + (2 \times 21) = 90$  tons per linear foot. Dividing the total shear on one stringer, 18.9 tons, by the allowable bearing value per linear foot, 90 tons, we obtain 0.21 feet, or  $2\frac{1}{2}$  in., the length of bearing required. As the cap on the bent is usually a 12-in.  $\times$  12-in. stick, these stringers would in practice have a bearing of 6 in. against  $2\frac{1}{2}$  in. required. It very rarely happens that the stringers selected as possessing the required moment of resistance are not broad enough to furnish the necessary bearing on the bent cap. Instead of redesigning the stringer, this

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\* The assumption of 350 lbs. per foot of track is approximately correct for spans between 14 and 18 feet. Whatever variation there is from this value will affect the result so slightly that it is safe to neglect it. Having selected the stringer to be used, it is, however, an easy matter to compute the weight of it per foot of track by taking the weight of a cubic foot of Georgia pine at 45 lbs., of white oak at 50 lbs., of white pine or spruce at 25 lbs. Knowing the additional weight per foot (in tons), the additional moment (in foot-tons) is always found by multiplying the same by  $\frac{1}{8}$  of the square of the span (in feet).

defect may be remedied by increasing the width of the cap. A careful designer will not overlook this point. "Corbeling" out from the bent to increase the stringer's bearing is not advisable, as heretofore stated (p. 53), because the slightest deflection in the stringer brings all the weight right on the end of the corbel block, and for many other reasons.

Computations are frequently facilitated by the use of diagrams. One for use in computing the strength of wooden stringers was suggested by Mr. P. E. Stevens in *Engineering News*, July 7, 1904, and is given here, Fig. 153a, with the following description of its use as a suggestion. A diagram along similar lines can be constructed to suit different conditions and values.

"The diagram is plotted on ordinary cross-section paper, the vertical distances representing moments and the horizontal distances, in the stringer diagram, representing stresses in the extreme fiber. The large diagram to the right represents the maximum moments produced by various engines on different spans.

"The upper stringer diagram is made on the basis of stringers 16 ins. deep. The radial lines represent stringers of the widths indicated and the coordinates of any point on a line are the bending moment and corresponding stress for 16-in. stringers of the indicated width.

"The smaller diagram below is designed to give stresses on stringers of other depths than 16 in. It is drawn as follows. From a zero line (in this case 1 in. above base of main diagram) point off distances to represent the reciprocals of the squares of various depths. Through each point draw a horizontal line and mark the depth which it represents. Then from the origin in the line of zero draw a system of radial lines.

"The use of the diagram may be illustrated as follows: Given a moment of 1,000,000 in.-lbs. on two stringers  $8 \times 18$  ins., required the fiber stress. Two stringers  $8 \times 18$  ins. equal  $16 \times 18$  inches. On the upper diagram the 16-in.-wide line intersects the line of 1,000,000 in.-lbs. at 1500 lbs. per sq. in., which would be the stress in a stringer  $16 \times 16$  ins. On the lower diagram find 1500 lbs. per sq. in. on the 16-in.-deep line and follow the radial line to its intersection with the 18-in.-deep line, giving the stress of 1200 lbs. per sq. in. as the stress sought.

"Again, given moment of 620,000 in.-lbs., allowable stress of 1100 lbs. per sq. in., depth of stringers 14 ins., required the necessary width. From the lower diagram 14-in. stringers at 1100 lbs. correspond to 16-in. stringers at 840 lbs.; then from the upper diagram the vertical from 840 lbs. intersects the 620,000 in.-lbs., near the radial line, giving 18 ins. as the required width."

**Trussed Stringers.**—A trussed stringer is one which is supported, at one or more points intermediate between the main supports, by bent iron or steel rods which pass under a supporting block or strut, and carry a portion of the total load on the stringer straight to the ends. When the span is unusually long it is found economical from theoretical considerations to truss the stringers, as the span is thereby reduced to  $\frac{1}{2}$  or  $\frac{1}{3}$  of its length, as the case may be, and the cost of the rods and labor is trifling compared to the amount saved in timber.





How far other than theoretical considerations must govern in the determination of whether or not to truss stringers, is a matter to be decided from the special conditions of the case (see p. 57).

In Fig. 154 let the dotted line  $AB$  be about 6 in. shorter than the length of the stringer, and one fourth of the depth of the stringer from the top. At  $C$ , the middle of  $AB$ , draw the perpendicular  $CD$  to  $D$ , the centre of the truss-rods at the bend. Connect the points  $A$  and  $B$  with  $D$ . In determining the size of the parts, begin with the timber itself and proceed as with an untrussed stringer for a single span,  $AC$ , equal to half the actual span. Knowing the depth of stringer, the length of  $CD$  can be easily determined. Next observe the panel or bent load in Table XXIV for the proper loading and span equal to  $AC$ , half the actual span. This load in addition to one half the dead weight of track material and stringer comes over the point  $C$ . Lay off a vertical line  $EF$  (Fig. 155) whose length shall be proportional to the total load upon  $C$  thus found. Bisect  $EF$  at  $G$  and draw a horizontal line of indefinite length.

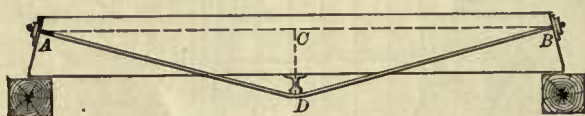


FIG. 154.

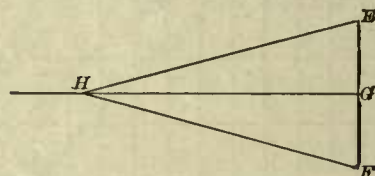


FIG. 155.

Finally from  $E$  draw a line parallel to  $BD$  (Fig. 154) meeting the horizontal line at  $H$ . A line drawn from  $F$  parallel to  $AD$  (Fig. 154) ought to meet the horizontal line at the same point  $H$ . The lengths of these two lines,  $EH$  and  $FH$ , measured in the scale used for laying off  $EF$ , will represent the stresses in  $BD$  and  $AD$  respectively, in pounds or in tons, according as the load on  $C$  was given in pounds or in tons. In like manner the horizontal distance  $GH$  will represent the stress along the line  $AC$  or  $CB$  in the timber, and to this extent the timber must resist compression. This work of resisting compression will seldom if ever determine the size of the timber, however, as its work as a beam is so much greater.

Having found the stress in the truss-rods we may ascertain the necessary size in the usual manner by dividing the total stress by the allowable stress per square inch for the material. The area in square inches thus found may be divided up among two or more rods, as may be convenient. In trussing one stick of timber two rods would be used—one on either side. For two or more sticks one rod might be placed in each of the openings, and if necessary additional ones on either side of the whole bunch. The ends of the stringers are usually beveled off as shown in Fig. 154, and a wrought iron or steel plate  $\frac{1}{2}$  inch or more in thickness (according to the distance between the sticks) is placed on the beveled portion. This plate contains holes for receiving the ends of the rods, and the rods terminate with upset screw ends and nuts as shown. The usual blocking between the rods and the sticks at  $D$  (Fig. 154) is a piece of old rail turned bottom upwards. The deeper the trussing, i.e., the longer the line  $CD$  (Fig. 154) is, the less will be the stress in the rods, as will be plainly seen from Fig. 155; where, in order that the lines  $EH$  and  $FH$  might still be parallel to  $BD$  and  $AD$  respectively, the point  $H$  would be brought nearer to  $G$ , and all lines representing the stresses



would be shorter. If, then, deep trussing is desired, the blocking at  $D$  is preferably made of cast iron, or timber with a cast-iron bearing on the truss-rods. This blocking should be of such a size as will carry the total load which comes upon  $C$ , and for short lengths of 5 feet or less, cast iron may be taken as resisting 6000 lbs. per square inch of cross-section in compression, Georgia pine 1000 lbs., short-leaved yellow pine 825 lbs., white oak 875 lbs., and white pine or spruce 625 lbs. For lengths over 5 feet in the clear these blocks should be proportioned like columns.

In proportioning the sizes of the truss-rods from the stresses, the allowable unit stress per square inch may be taken at 8000 lbs. for iron and at 9600 lbs. for steel, in the absence of specifications requiring some other values to be used.

**Steel Beam Equivalents.**—Table XXVI gives sizes of Georgia-pine stringers, which are equivalent in strength to steel I beams of sizes shown opposite—the values of  $T$  being respectively 1200 lbs. per square inch for Georgia pine and 9600 lbs. per square inch for steel. The moment of the internal forces is also given in the first column, so that a comparison with the sizes and kinds of timber given in Table XXV may be made. In the last column of Table XXVI is given the total breadth of timber required to give the moment. This breadth need not be that of one stick of timber, but is the aggregate breadth of all the sticks which would compose a stringer equivalent in strength to the steel I beam. For example, what steel stringer will carry the same load on the same span as a Georgia-pine stringer composed of 4 sticks each  $8'' \times 16''$ ? Four sticks each each  $8''$  wide give a total width of  $32''$ , and we see from Table XXVI that such a stringer is very nearly equivalent to a  $24''$  I beam 80 lbs. per foot.

Again, what steel stringer will carry the same load on the same span as a Georgia-pine stringer composed of 3 sticks each  $6'' \times 16''$ ? Three sticks each  $6''$  wide give a total width of  $18''$ , and we see from Table XXVI that such a stringer will carry almost as much as a  $15''$  I beam 80 lbs. per foot, which is itself equivalent to a Georgia-pine stringer  $16''$  deep by  $19''.6$  wide.

Again, how many sticks of white pine each  $6'' \times 16''$  must be used to build a stringer equivalent in strength to a  $15''$  I beam 41 lbs. per foot? From Table XXVI the safe moment of a  $15''$  I beam 41 lbs. is 22.6 foot-tons. From Table XXV the safe moment of a white pine stick  $6'' \times 16''$  is 8.00 foot-tons.  $\frac{22.6}{8.0} = 2.825$  or nearly 3—which means that 3 sticks of white pine each  $6'' \times 16''$  will do a little more than the required work, but probably come as close to it as any combination of stock sizes we could make.

The first column of Table XXVI is composed of numbers each equal to the allowable fibre-stress per square inch,  $T$ , multiplied by the particular value of the resistance,  $R$ , for each steel beam given in the second column, and reduced to foot-tons. The last column of the table is made by assuming a depth of beam in each case, and computing the corresponding breadth from the equation

$$bh^2 = \frac{72M}{T},$$

where  $T = \frac{1200}{2000} = .6$  tons,  $M$  takes the successive values given in the first column, and  $b$  and  $h$  are respectively the breadth and depth in inches.

TABLE XXVI.

Comparing Steel I Beams with Georgia Pine Beams.

Safe Moment.	Size of I-Beam.		Size of Georgia Pine Beam.	
	Depth.	Weight per Foot.	Depth.	Breadth.
68.6	24"	80	{ 18"	25".4
			{ 16	32 .2
57.9	20	80	{ 18	21 .4
			{ 16	27 .1
45.8	20	64	16	21 .4
41.8	15	80	16	19 .6
34.4	15	60	16	16 .1
28.2	15	50	14	17 .3
22.6	15	41	14	13 .8
18.8	12	40	12	15 .6
14.8	12	32	12	12 .3
12.9	10	33	12	10 .7
9.8	10	25	{ 12	8 .2
			{ 10	11 .8
7.5	9	21	{ 12	6 .3
			{ 10	9 .0
5.8	8	18	{ 12	4 .8
			{ 8	10 .9
4.3	7	15	{ 12	3 .6
			{ 8	8 .1
3.1	6	13	{ 10	3 .7
			{ 8	5 .8

**Design of Posts.**—In Table XXVII will be found the safe loads (in tons) which may be imposed on posts of various sizes and lengths. The loads here given have been computed from the formula

$$Q = \frac{1000}{1 + \frac{1}{550} \left(\frac{l}{d}\right)^2}, \dots \dots \dots (5)$$

where  $Q$  is the allowable stress in pounds per square inch,  $l$  is the length, and  $d$  is the least dimension—both the latter in the same denomination. The numerator, 1000, gives us a factor of safety of 4, assuming that 4000 lbs. is the elastic limit of the material. The constant, 550, in the denominator is the one in common use for flat-ended wooden pillars. For hinged ends use the formula

$$Q = \frac{1000}{1 + \frac{1}{275} \left(\frac{l}{d}\right)^2}, \dots \dots \dots (6)$$

and for pillars having one flat and one hinged end use the formula

$$Q = \frac{1000}{1 + \frac{1\frac{1}{2}}{550} \left(\frac{l}{d}\right)^2}, \dots \dots \dots (7)$$



Referring to Prof. Johnson's book on the "Theory and Practice of Modern Framed Structures," p. 151, we may use the following values as elastic limits for different material:

- For white pine.....2500 lbs. per sq. incn
- For short-leaf yellow pine.....3300 " " " "
- For long-leaf " " .....4000 " " " "
- For white oak.....3500 " " " "

Having taken one fourth of these values as successive numerators in the right-hand member of formula (5), we obtain appropriate values of *Q* for the different kinds of wood; and it is evident that from Table XXVII, which is computed for long-leaf yellow pine, we may obtain directly the corresponding value of safe load for short-leaf yellow pine by multiplying by  $\frac{3300}{4000}$ , or .825; for white oak by multiplying by  $\frac{3500}{4000}$ , or .875; and for white pine by multiplying by  $\frac{2500}{4000}$ , or .625.

Each value in the table is the product of *Q* times the area of cross-section of the timber in square inches, divided by 2000 to reduce to tons.

TABLE XXVII.\*

Safe Loads, in Tons of 2000 Lbs., for Rectangular Posts of Long-leafed Yellow Pine with Fixed Ends.

$$\text{Allowable load in pounds per square inch} = \frac{1000}{1 + \frac{1}{550} \left(\frac{l}{d}\right)^2}$$

*l* = length in inches, *d* = least dimension in inches.

For short-leafed yellow pine multiply by 0.825.

" white oak " " 0.875.

" white pine and spruce " " 0.625.

Length.	14" X 12".	12" X 12".	12" X 10".	10" X 10".	10" X 8".	8" X 8".
8'	75.26	64.51	51.36	42.80	31.68	25.34
9'	73.25	62.78	49.50	41.25	30.04	24.03
10'	71.06	60.91	47.52	39.60	28.40	22.72
11'	68.88	59.04	45.54	37.95	26.76	21.41
12'	66.53	57.02	43.56	36.30	25.16	20.13
13'	64.26	55.08	41.58	34.65	23.64	18.94
14'	61.91	53.06	39.66	33.05	22.20	17.76
15'	59.64	51.12	37.74	31.45	20.84	16.67
16'	57.29	49.10	35.94	29.95	19.52	15.62
17'	55.10	47.23	34.14	28.45	18.36	14.69
18'	52.84	45.29	32.46	27.05	17.20	13.76
19'	50.74	43.49	30.84	25.70	16.16	12.93
20'	48.64	41.69	29.28	24.40	15.16	12.13
21'	46.62	39.96	27.84	23.20	14.28	11.42
22'	44.69	38.30	26.58	22.15	13.44	10.75
23'	42.84	36.72	25.14	20.95	12.64	10.11
24'	41.00	35.14	23.88	19.90	11.92	9.53
25'	39.31	33.70	22.74	18.95	11.28	9.02
26'	37.72	32.33	21.66	18.05	10.64	8.51
27'	36.12	30.96	20.64	17.20	10.08	8.06
28'	34.61	29.66	19.68	16.40	9.52	7.61
29'	33.18	28.44	18.72	15.60	9.00	7.20
30'	31.84	27.29	17.88	14.90	8.56	6.85
31'	30.58	26.21	17.04	14.20	8.12	6.50
32'	29.32	25.13	16.32	13.60	7.72	6.18
33'	28.22	24.19	15.60	13.00	7.32	5.86
34'	27.05	23.18	14.94	12.45	7.00	5.60
35'	26.04	22.32	14.28	11.90	6.68	5.31

\* Copyright, 1894, by W. W. Crehore.

*Example.*—To find the size of white pine timber to use as posts in a trestle-bent for Lehigh Valley 126-ton engine load, where the bents are 20 feet apart and the posts have an unsupported height of 24 feet.

Referring to Table XXIV we find the bent load, for the Lehigh Valley 126-ton engine, for a 20-foot span to be 66.8 tons. Assuming that the track material weighs 400 lbs. per foot and that the stringers weigh 550 lbs. per foot of span, we have an additional load on the bent of  $\left(\frac{400 + 550}{2000} \times 20 =\right)$  9.5 tons. Adding this to the live load we have a total of 76.3 tons to be carried by the bent. If there are to be four posts in the bent 19.1 tons must be carried by each. Referring to Table XXVII we find that for a length of 24 feet a 12"  $\times$  12" post of white pine will carry  $(.625 \times 35.14 =)$  21.9 tons, which is ample. We must therefore use four posts in this bent, each 12"  $\times$  12" in cross-section. The two outside posts must have a batter sufficient to provide the necessary base; but this fact does not materially diminish their efficiency as posts, provided their ends are firmly imbedded and securely fastened to the cap and base.

Good practice requires that each stick in a composite column should be treated as though it stood alone and unsupported, even though it may be bolted at frequent intervals to its neighbor. The fastenings and bolts are sure to grow loose in time, and it is safer to assume that a composite column cannot act as one stick.

**Stability.**—The following discussion on lateral stability and sway-bracing will deal only with symmetrical bents symmetrically loaded, as these are most frequently met with in practice. If the reader desires a knowledge of the more complicated cases where the two sides of a bent have different batters, or where the trestle supports a double track, he may refer to any standard work on the subject.

Referring to Fig. 156 p.182, let  $a$  be the distance from centre to centre of tops of outside columns in the bent  $ABFE$ , and let  $b$  be the distance from centre to centre of same columns at bottom. Let the height of the bent from centre of base to centre of cap,  $h$ , be divided into two equal panels each equal to  $p$ . First, when there is no train on the trestle, we may have forces,  $G$  and  $H$ , due to the wind acting at the points  $B$  and  $D$  respectively tending to overturn the trestle about the point  $E$  as a fulcrum. To counterbalance this tendency we have the dead weight,  $W$ , of the track, stringers, bent, etc., acting vertically at the centre of gravity of the structure, which in a symmetrical structure is its actual centre. Considering each of these forces separately in its tendency to cause or resist overturning about the fulcrum  $E$ , we find that the perpendicular distance from  $E$  (which is called the point of moments) to the line of direction of the force  $G$  is equal to  $2p$ , and that the perpendicular distance from  $E$  to the line of direction of  $H$  is equal to  $p$ . Similarly the perpendicular distance from  $E$  to the line of direction of  $W$  is  $\frac{b}{2}$ . These perpendicular distances are called the arms of their respective forces. The tendency of any force to cause rotation about a given point depends not only upon the amount of the force but also upon the length of its arm—a well-known mechanical principle. The measure of this tendency is therefore the product of the force by its arm, and is called the moment of the force. The moments of the forces tending to overturn the trestle are

$$2p \times G \quad \text{and} \quad p \times H,$$



while the moment of the one force resisting these forces is

$$\frac{b}{2} \times W.$$

In order that neither of these contrary tendencies may predominate and cause actual rotation,—in other words, in order that there may be equilibrium,—the sum of all the moments of one kind must equal the sum of all the moments of the other kind, and we have

$$\frac{Wb}{2} = 2pG + pH,$$

from which we may derive

$$W = \frac{2p}{b}(2G + H), \dots \dots \dots (8)$$

giving the necessary dead weight to resist overturning; and

$$b = \frac{2p}{W}(2G + H), \dots \dots \dots (9)$$

giving the necessary width of base of the bent.

Second, when there is a live load on the trestle, we have in addition to the wind forces *G* and *H* another wind force, *Z*, acting at a point  $7\frac{1}{2}$  feet above the rail, or about 10 feet above the line of the force *G*. Its arm from point of moments, *E*, is therefore  $2p + 10$ , and its moment is  $Z(2p + 10)$ . We have also to consider an additional vertical load, *L*, the weight of the train. For a single-track trestle this load may be added to *W*, the dead load, as each has the same arm. Our equation of equilibrium then is

$$(W + L)\frac{b}{2} = Z(2p + 10) + 2pG + pH,$$

from which we may derive

$$W + L = \frac{2Z}{b}(2p + 10) + \frac{2p}{b}(2G + H), \dots \dots \dots (10)$$

giving the necessary total weight, both dead and live, to resist overturning; and

$$b = \frac{2Z}{W + L}(2p + 10) + \frac{2p}{W + L}(2G + H), \dots \dots \dots (11)$$

giving the necessary width of base of the bent.

If the bent is on a curve increase the force *Z* by the amount of the centrifugal force likely to be developed. For a speed of 30 miles per hour add for centrifugal force one per cent of the weight of the train for each degree of curvature. For speeds of forty, fifty, and sixty miles per hour add two per cent, three per cent, and four per cent, respectively, for each degree of curvature. By "weight of the train" is here meant the weight of that part of the train which covers the bent in question—that is, which reaches half way to the next bent in either direction.

In determining stability the value to use for  $L$ , the weight of the train, should be such as will give the greatest possible quotient when dividing the amount of surface exposed to the wind by the weight  $L$ . In general, this will be the weight of the lightest train of box cars used. In determining the amount of increase for  $Z$ , however, due to centrifugal force when the train is on a curve, the heaviest train which will ever be run, moving at the greatest velocity allowed for the curve, should be used.

Equations (8), (9), (10), and (11) are all based on the particular assumption that the bent has two panels. Let us suppose the general case of a bent having any number,  $n$ , of panels each equal to  $p$ , then

$$h = np, \dots \dots \dots (12)$$

and it may be easily proved that equations (8), (9), (10), and (11) have the following general forms, respectively,

$$W = \frac{2p}{b}[nG + (n - 1)H + (n - 2)I + \dots n \text{ terms}]; \dots \dots \dots (13)$$

$$b = \frac{2p}{W}[nG + (n - 1)H + (n - 2)I + \dots n \text{ terms}]; \dots \dots \dots (14)$$

$$W + L = \frac{2Z}{b}(h + 10) + \frac{2p}{b}[nG + (n - 1)H + (n - 2)I + \dots n \text{ terms}]; \dots \dots (15)$$

$$b = \frac{2Z}{W + L}(h + 10) + \frac{2p}{W + L}[nG + (n - 1)H + (n - 2)I + \dots n \text{ terms}]. (16)$$

In all these equations  $G$  represents the wind force at the very top of the bent; the other forces,  $H$ ,  $I$ , etc., being in order below  $G$ , the total number including  $G$  being equal to the number of panels, while  $Z$  represents the wind force (or combined wind and centrifugal force if on a curve) on the live load only, acting at the assumed distance of 10 feet above the force  $G$ .

The wind force  $Z$  is usually taken as acting at the centre of a train 10 feet high, and of a length equal to the distance between bents. The bottom of the cars being about  $2\frac{1}{2}$  feet above the rails, this would bring the point of application of this wind force  $7\frac{1}{2}$  feet above the rail. When on a curve the force  $Z$  is made up partly of a centrifugal force, as previously mentioned. The point of application of this force is strictly below the centre line of the cars, but for the sake of simplicity we have kept it at the centre, the error being slight, and on the safe side in determining stability.

The wind forces  $H$ ,  $I$ , etc., are each obtained by multiplying one panel length of the lateral surface of the bent, seen in longitudinal elevation, by 3, and then by the number of pounds per square foot wind pressure. The force  $G$  at the top of the bent consists of the wind pressure upon the upper half of the top panel of the bent multiplied by 3, as seen in longitudinal elevation, together with the pressure on the stringers and track.

*Example.*—What breadth of base,  $b$ , is required in a trestle bent 48 feet high, made in three panels each 16 feet, to carry on single track a train whose minimum weight is 1500 lbs. per foot—the distance between bents being 20 feet?



Assuming the wind force at 50 lbs. to the square foot of exposed surface, we have the force against a train 10 feet high for a distance of 20 feet equal to

$$Z = 10' \times 20' \times 50 \text{ lbs.} = 10,000 \text{ lbs.} = 5 \text{ tons.}$$

Assuming the depth of stringers and guard-rail to be 2 feet, we have the force of wind against the track,

$$2' \times 20' \times 50 \text{ lbs.} = 2000 \text{ lbs.,}$$

to which must be added the wind force on the upper half of the upper panel of the bent, viz., (if the posts be 12''  $\times$  12''):

$$1' \times 8' \times 50 \text{ lbs.} \times 3 = 1200 \text{ lbs.,}$$

as heretofore explained. These two items make the total force

$$G = 3200 \text{ lbs.} = 1.6 \text{ tons.}$$

Continuing on down the bent, we have

$$H = 1' \times 16' \times 50 \text{ lbs.} \times 3 = 2400 \text{ lbs.} = 1.2 \text{ tons.}$$

and

$$I = \text{the same} = 1.2 \text{ tons.}$$

There being only three panels to this bent, we have only these three forces besides the force against the train. Referring now to eq. (16), remembering that  $n = 3$ , that  $h = 48$ , that  $p = 16$ , and that  $L = 1500 \text{ lbs.} \times 20' = 30,000 \text{ lbs.} = 15 \text{ tons}$ ; and assuming the total dead weight,  $W$ , to be 16 tons, we have

$$b = \frac{2 \times 5}{16 + 15}(48 + 10) + \frac{2 \times 16}{16 + 15}[3 \times 1.6 + 2 \times 1.2 + 1 \times 1.2] = 27.38',$$

the width of base required. This gives the inclined posts a batter of 2''.05 to the foot, assuming that they are 11 feet apart at the top.

If in the above example the bent were situated on a 6° degree curve and a speed of 40 miles an hour were to be allowed on it, we should increase the force  $Z$ , as explained, by an amount

$$4000 \text{ lbs.} \times .02 \times 6^\circ \times 20' = 9600 \text{ lbs.} = 4.8 \text{ tons,}$$

the centrifugal force. Here the heaviest train-load (viz., 4000 lbs. per foot) which is likely to pass over the trestle is used. Adding this 4.8 tons to 5 tons, the value previously found for  $Z$ , and solving eq. (16) again, all other values remaining exactly the same, we have

$$b = 45.34 \text{ feet,}$$

the width of base required. This gives the inclined posts a batter of 4''.3 to the foot, if they are 11 feet apart at the top and both are inclined alike. The post on the outer side of a curve is, however, sometimes inclined more than the other.

From this example it will be seen that batters of  $2\frac{1}{2}$  or 3 inches, which are the ones in common use (see p. 55), are on the side of safety, except on some curves where heavy trains are run at great velocities. It is better to have a standard batter, such as 3 inches, which is ample in the majority of cases; but where any doubt exists as to whether or not the standard batter will furnish the necessary base, the formulæ given above should be applied.

It may sometimes occur, in very light trestles with much surface exposed to the wind, that the trestle will require a greater base of bent when unloaded than when loaded. Where such a condition is suspected apply eq. (14) as well as eq. (16), and use the greater of the two values obtained for  $b$ , the base. If, however, it is inconvenient for any reason to increase the size of the base, there are two other ways in which stability may be obtained: first, by increasing the dead weight of the structure  $W$  to an amount indicated by one of the two equations (13) or (15); second, by anchoring the bent to the foundation with sufficient anchorage to take up (in tension) the difference between the actual weight of the structure and the weight  $W$ , as obtained from eq. (13) or (15).

**Sway-bracing.**—It is usual to consider the diagonal sway-bracing as acting in tension, and hence only one set of diagonals will act at a time, depending upon the direction of the wind. If the wind blows from the right, therefore, in the direction of the arrows at  $G, H$ , etc. (Fig. 156) we shall be concerned only with its effect in the diagonals  $AD$  and  $CF$ ; and all that is about to be said concerning these diagonals must be understood to be equally true of the other diagonals  $BC$  and  $DE$  when the wind is blowing from the left.

To find the stresses in the diagonals make a single-line sketch of the bent accurately to some convenient scale. Prolong the two lines representing the inclined posts until they meet, as at  $O$  in Fig. 156. The distance of the point  $O$  above the bent cap  $AB$  may be represented by the letter  $m$ , and its position may be accurately tested by the formula

$$m = \frac{h\bar{a}}{b - a} \dots \dots \dots (17)$$

all of the quantities in the right-hand member being known. Next prolong the diagonals  $AD$  and  $CF$  on the leeward side of the bent, and from  $O$  draw lines respectively perpendicular to each prolonged diagonal. These perpendiculars are the arms of the stresses in their respective diagonals, and their exact lengths must be obtained in some way—preferably by scaling if the sketch has been carefully and accurately made. Methods of obtaining their lengths by trigonometry will readily occur to any one who is familiar with the subject.

The product of the stress in any diagonal by its arm is equal to the sum of the moments of all the horizontal forces above the panel in which the diagonal lies, the point of moments being at  $O$ . This rule applies equally well whether there is a force  $Z$  or not—that is, whether the train is on or off the trestle. In general, whatever be the number,  $n$ , of panels we have, when no train is on,

$$\left. \begin{array}{l} \text{Stress in diagonal of} \\ \text{the bottom panel} \end{array} \right\} = \frac{m(G + H + I + \dots K) + p[H + 2I + \dots (n - 1)K]}{\text{arm for the stress}} \dots (18)$$



and, when a train is on,

$$\left. \begin{array}{l} \text{Stress in} \\ \text{diagonal} \\ \text{of the} \\ \text{bottom} \\ \text{panel} \end{array} \right\} = \frac{(m - 10)Z + m(G + H + I + \dots K) + p[H + 2I \dots (n - 1)K]}{\text{arm for the stress}} \dots (19)$$

$m$  may be found from eq. (17), the forces  $Z, G, H$ , etc., are found in the same way as they were for determining stability, and the arm for the stress may be scaled from a sketch, as explained. If the panel containing the diagonal in question is always considered the bottom panel for the time being, it will be possible to use the above formulæ for every case, observing that  $n$  here means the number of panels, not counting any below the panel in question. For instance, in Fig. 156,

$$\text{the stress in } AD = \frac{(m - 10)Z + mG}{\text{arm}},$$

$n$  being 1, and

$$\text{the stress in } CF = \frac{(m - 10)Z + m(G + H) + pH}{\text{arm}}$$

$n$  being 2.

The maximum stress in each diagonal being known, the size of the stick to be used can be found by dividing the full stress by the allowable unit stress per square inch peculiar to the material used. For the different kinds of timber the following tensile units are recommended by Professor Lanza :

White pine and spruce.....	750 lbs. per square inch.
Long-leaf yellow pine.....	1200 " " " "
White oak.....	1000 " " " "

*Example.*—If the stress in a diagonal of a bent is found to be 4 tons, what size piece of spruce must be used for it? 4 tons = 8000 lbs. and  $\frac{8000}{750} = 10.7$  square inches. A stick 5" × 3", possessing 15 square inches, will give sufficient area and allow enough extra for 2 bolt-holes for  $\frac{3}{4}$ " diameter bolts.

The stress in any diagonal, as  $AD$  (Fig. 156), must be transferred to the other members at  $D$  by bolts, spikes, or some other means of connection. The size and number of these bolts or spikes should be determined from the stress in the diagonal.

It should be borne in mind that, so long as the vertical load (the train) is placed symmetrically on a symmetrical bent, it will not stress the sway-bracing. But if the vertical load is the least bit off the centre, or if one inclined post of the bent slants more than the other, causing the point  $O$  to be off centre (Fig. 156), then there is additional stress in the sway-bracing due to the vertical loads.

The stresses in the horizontal members of the bent may be found by using equations (18) and (19) in the same manner as explained for the diagonals, care being taken to divide

the sum of the moments by the appropriate arm for the stress. For instance, the piece  $AB$  has for its arm the distance  $m$ , and the piece  $CD$  has  $(m + p)$ , and so on. Each horizontal piece must be considered as belonging to the panel below it in order to give  $n$  its proper value in the equations: for instance,  $AB$  and  $AD$  belong to the same panel; so do  $CD$  and  $CF$ . The stresses in these horizontal members are compressive; but they are usually made considerably larger than these wind stresses require them to be, as they serve other purposes, one of which is to stiffen the posts against buckling. In the case of the cap, if the stringers do not bear immediately over a post, or of the base, if the foundations are not placed immediately under a post, there is developed a moment which it requires much additional strength to withstand. On the whole, then, these horizontal members should be made of some standard size, large enough to suit the worst case.

**Sway Stresses in the Inclined Posts.**—Having found the stresses in the diagonals we may proceed as follows to find the wind stresses in the inclined posts, and if necessary increase the size of these posts accordingly beyond the size already found to be required by the vertical loading.

When  $G$  (Fig. 156) is the highest wind force acting,—that is, when there is no train on the

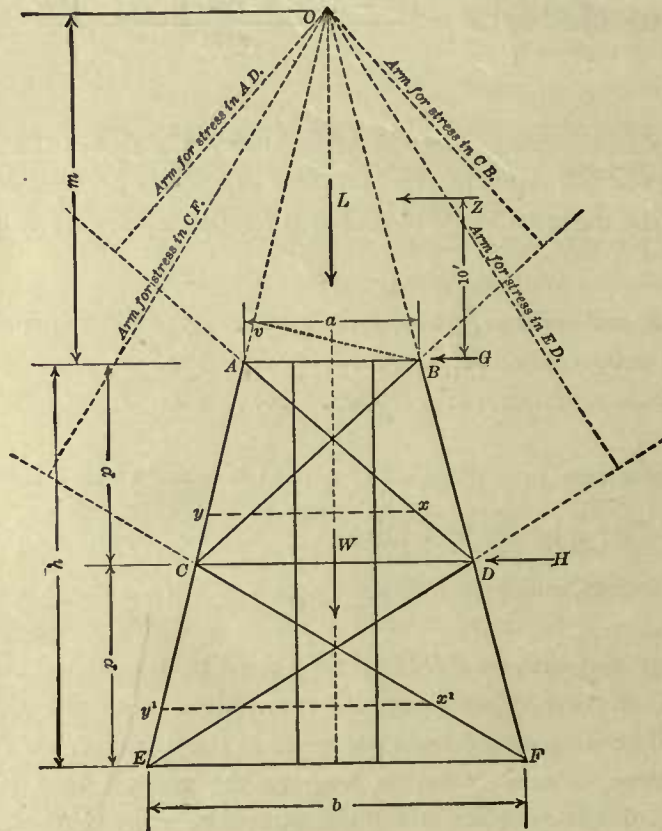


FIG. 156.

trestle,—this force is carried through the bent cap  $AB$  to the point  $A$  and there divides, part going through the diagonal  $AD$  (as tension), and part going into the post  $AC$  (as compression). The manner of finding the tension in  $AD$  has already been shown. Lay off on the line  $AD$  the distance  $Ax$  equal to the stress in  $AD$ , to any convenient scale. From  $x$  draw a hori-



zontal line to meet the post  $AC$  at  $y$ . Then  $Ay$ , measured to the same scale, will equal the stress in  $AC$  due to the wind. Again, lay off  $Cx_1$ , equal to the stress in  $CF$ ; draw the horizontal  $x_1y_1$ , and the distance  $Cy_1$  will represent the additional stress which belongs to the post  $CE$ . In other words, the stress represented by  $Cy_1$ , added to the stress in  $AC$  will give the total stress in the post  $CE$ . And so on, if there were more panels, each post would receive a corresponding stress from the diagonal in its own panel *in addition to the total* wind stress in the post immediately above it.

When the force  $Z$  is acting—that is, when a train is on—draw a line  $Bv$  perpendicular to the line of the inclined post,  $AE$ , produced. Taking  $B$  as a point of moments, the force  $Z$  multiplied by 10 feet and divided by the length of the arm  $Bv$ , measured to the scale of the figure, will give the additional stress in the post due to the force  $Z$ . The total wind stress, therefore, in the post  $AC$ , in the upper panel of the bent, is that derived from the known stress in  $AD$  (with the force  $Z$  acting) by the graphical method described above, increased by the amount  $\frac{10 \times Z}{\text{arm } Bv}$ . And, as before, the post in each succeeding panel below will receive a corresponding stress from the diagonal in its own panel (computed now with the force  $Z$  acting) *in addition to the total* wind stress in the post immediately above it.

The post  $BF$ , on the windward side of a bent, must sustain a tensile stress due to the action of the wind; but as the amount of this stress very seldom exceeds the amount of compressive stress received from the dead load, the resultant is rarely a tensile stress, and when it is may be considered small enough to be neglected. Its amount may be known, if desired, from the stresses in the other side of the bent, compression in  $AC$  being equal in amount to tension in  $DF$ , and so on, each post on the windward side receiving tension equivalent to the amount of compression in the leeward post of the next panel above it.

If desirable, the sizes of the posts, as found from Table XXVII, may now be increased to provide extra security against the contingency of the bent's having to sustain the full load in a very high wind. The stress in the post of the bottom panel is, of course, the greatest. If the posts of all panels are to be of uniform size, we need only figure the bottom post and make those above like it. When found add the stress (in tons) due to the wind forces (and centrifugal if on a curve) to the live and dead vertical loads (in tons) already obtained for the post and hunt in Table XXVII for a new stock size of timber which will carry this new total load.

**Foundations.**—A timber bent should be finished at the bottom with a horizontal sill to secure rigidity and leave nothing but actual vertical pressure on the foundations themselves. Whatever the material of which these foundations are composed, care should be taken to spread it out so that the sill of the bent may have sufficient bearing area through which to transmit its load without being in the slightest degree crushed. The total load to be transmitted consists of the bent-load from the train, the dead weight of track, stringers, bent, etc., and twice the amount of wind stress found in the inclined post of the bottom panel. For, since the wind force may come from either direction, the foundations should be prepared to take it *all* on either side. If the bent is on a curve where trains run fast, an extra load due to centrifugal force will always be transmitted through the inclined post on the outside of the curve. The sum of all these loads will give the total load on the foundations, and dividing this total by the allowable bearing value of the material per unit of area, we obtain the neces-

sary number of square feet or square inches, as the case may be. The bearing value of the softest material (whether it be the sill of the bent or the material in the foundations) should here be used. Values for different kinds of timber are given in the heading of Table XXV.

It is hoped that the foregoing discussion will present to the reader an easy and substantially accurate way of determining what the minimum size of his design should be to perform the required work. The allowable unit stresses have been chosen with factors of safety ranging from 4 to 8 on the ultimate strength of the material, and are based on recent discussions of the subject by competent authorities, permitting the safe use of average timber. The designer must be his own judge as to whether or not the conditions of a particular case require him to make allowance for future decay or any other contingency. Any increase he may make can be made more rationally with some knowledge of the proper proportion of work each member of the structure has to do than without it.

#### FORMULAS FOR ESTIMATING THE QUANTITIES OF MATERIALS IN TIMBER AND PILE TRESTLES.\*

A formula for timber trestles is very useful in computing the approximate cost of a proposed trestle.

The Northern Pacific Railway standard timber trestle consists of bents 13 ft. 9 ins. c. to c. Each bent has four 12 × 12-in. posts, the outside posts having a batter of 3 ins. per ft. and the inside posts a batter of 1 in. per ft. High trestles are built in stories, each story being about 25 ft. The deck consists of six stringers 9 × 18 ins., with 8 × 8-in. cross-ties, 13½ ins. c. to c., and 5 × 8-in. guard-rails.

From a carefully prepared and tabulated bill of material, we have deduced the following formulas:

- (1)  $M = L(220 + 6H)$ , for  $H$  between 0 and 25 ft.
- (2)  $M = L(240 + 8H)$ , for  $H$  between 25 and 50 ft.
- (3)  $M = L(240 + 9H)$ , for  $H$  between 50 and 75 ft.
- (4)  $M = L(240 + 10H)$ , for  $H$  between 75 and 125 ft.

$M$  = ft. B. M. in trestle, including deck.

$L$  = length of trestle in feet.

$H$  = average height in feet from ground to a point 3½ ft. below base of rail.

In order to estimate the average height of a trestle, the more accurate way is to ascertain the profile area in square feet and divide by the length of the trestle in feet. Profile areas may be ascertained by the use of a planimeter, or by dividing the profile area into rhomboids, triangles or other figures easily measured. If it is desired to estimate the amount of timber direct from the profile area, without ascertaining the average height, then proceed as follows:

Let  $A$  = profile area in sq. ft. Then—

$$(5) A = L H.$$

Combining equations (1) and (5) we have:

$$(6) M = 220 L + 6 A, \text{ for heights under 25 ft.}$$

\* *Engineering-Contracting*, Feb. 12, 1908, p. 104.



In like manner equations (2) to (4) can be combined with equation (5).

There are about 35 lbs. of wrought iron and 15 lbs. (or, to be more exact, 12 lbs.) of cast iron per 1000 ft. B. M. of trestle timber in the bents and braces, and nearly double this amount per 1000 ft. B. M. of deck. The deck of the standard Northern Pacific trestle contains 164 ft. B. M. per lin. ft. of trestle, and for each 1000 ft. B. M. there are 40 lbs. wrought iron, 25 lbs. cast iron and 25 lbs. galvanized iron. Therefore the total amount of iron in the deck is 90 lbs. per 1000 ft. B. M. of deck, or 15 lbs. per lin. ft. of trestle. Hence, in estimating the amount of iron in a trestle, first ascertain the total ft. B. M., using equations (1) to (4). Then deduct  $M=164 L$ , the deck timber, and multiply the remainder by 0.05; the product will be the total of pounds of iron in the trestle exclusive of that in the deck. To this add 15 lbs. per lin. ft. for the iron in the deck. Or the total amount of iron in bents, decks, etc., may be arrived at directly by the following formulas, derived from eqs. (1) to (4).

(7)  $W=L(18+0.3 H)$ , for  $H$  between 0 and 25.

(8)  $W=L(18+0.4 H)$ , for  $H$  between 25 and 50.

(9)  $W=L(18+0.45 H)$ , for  $H$  between 50 and 75.

(10)  $W=L(18+0.5 H)$ , for  $H$  between 75 and 125.

From equations (7) to (10) and (1) to (4) we deduce (dividing one equation by the other) the following approximate relations:

Trestle 25 ft. high, 70 lbs. iron per 1000 ft. B. M.

Trestle 50 ft. high, 60 lbs. iron per 1000 ft. B. M.

Trestle 75 ft. high, 56 lbs. iron per 1000 ft. B. M.

Trestle 100 ft. high, 55 lbs. iron per 1000 ft. B. M.

Having ascertained the quantity of timber, the unit price to be used may be arrived at thus:

	Per M.
Timber, f. o. b.....	\$20.00
Freight, 1.8 tons, 200 miles, at $\frac{1}{2}$ ct. ton mile.....	1.80
Iron, 70 lbs., at 3 cts. delivered.....	2.10
Labor framing and erecting.....	10.00
Total in place.....	<u>\$33.90</u>

With bridge carpenters at \$2.50, the labor item should rarely exceed \$10 per 1000 ft. B. M., including, of course, the labor of handling the iron.

The quantity of material in a pile trestle is easily estimated. With four piles to the bent, bents spaced 16 ft. c. to c., and 20 ft. allowed for penetration of each pile and for cut-off at the top, the following formula gives the number of lineal feet of piles per lineal foot of trestle:

$$(11) P = \frac{L(H + 20)}{4}$$

$P$  = total in ft. of piles.

$H$  = average height of trestle in ft. measured from the ground to a point  $3\frac{1}{2}$  ft. below base of rail.

$L$  = length of trestle in ft.

The amount of sawed timber is given by the following formula:

(12)  $M = 185 L$ , for trestles under 15 ft. high.

(13)  $M = 200 L$ , for trestles 15 to 25 ft. high.

$M$  = total number of feet B. M.

The weight of iron is given by—

(14)  $W = 16 L$ , of which 40 per cent is wrought, 30 per cent. cast, and 30 per cent galvanized iron. This is equivalent to about 80 lbs. of iron per 1000 ft. B. M.

The unit cost of the timber in place may be estimated as above, and the cost of the piling may be estimated thus:

	Lin. Ft.
Piles f. o. b. cars.....	\$0.10
Freight, 40 lbs., 400 mi. at $\frac{1}{2}$ ct. ton mile.....	0.04
Labor, etc., driving 35 ft. piles.....	0.07
	<hr/>
Total.....	\$0.21

Each pile should ordinarily be driven for less than \$2.50.

The average height of all the timber and pile trestles on the Northern Pacific and Great Northern Railways in the state of Washington is  $18\frac{1}{2}$  ft. from ground level to base of rail. This average height was computed from the profile areas of the trestles, and is not a rough approximation. Hence  $H = 15$  ft., and substituting in equation (1), we have 310 ft. B. M. per lin. ft. of the average trestle. With timber at \$35 per M (including iron) the cost would be \$10.85 per lin. ft. of timber trestle. For a pile trestle of the same height there would be, according to equations (11) and (12), 9 lin. ft. piles, 185 ft. B. M. timber per lin. ft. of trestle. At 21 cts. per lin. ft. of piles and \$35 per M. of timber (including iron) the cost would be \$8.36 per lin. ft. of pile trestle.

The foregoing prices are merely illustrative of correct methods of estimating the probable cost of trestles. Most railways charge themselves  $\frac{1}{2}$  ct. per ton mile for all freight carried over their own lines, but a contractor might have to pay considerably more for freight.

The timber used for floor beams usually costs a few dollars more per M. than timber for other parts of a trestle. Timber for bridge ties is usually somewhat less expensive than timber for caps, posts, etc. Quotations from dealers will readily enable an engineer to estimate an average price to be assumed for all the timber in a trestle."



## CHAPTER .XIV.

### TEMPORARY TRESTLES AND STRUCTURES—REPAIR GANGS.

TEMPORARY trestles are frequently resorted to for many purposes, among which may be mentioned the sustaining of the track while making large excavations under it, the opening of a road to traffic after a washout, burnout, wreck, etc.

To sustain the track while making large excavations under it, especially where the ground is not too hard, the following method is frequently adopted.

Piles are first driven to a foot or so below the bottom of the proposed excavation or as deep as it is practicable to drive them. A track pile-driver attended by a locomotive is used for this purpose. Unless there is a siding close to the work it is generally advisable to build a short siding to run the pile-driver, engine, and work-cars upon, so that trains may pass. The piles are driven and cut off flush with the rails between trains. If a permanent structure is to be built across the opening, such as an iron bridge spanning an undergrade crossing, the piles should be so located as to be out of the way of the permanent work as far as possible. After the piles are driven trenches are dug across the track to the proper depth, the piles cut off and capped. After the piles are capped the excavations are made for and the stringers put in place, bolted together, and drift-bolted in place, and at the same time the ties are shimmed up and spiked to hold the track in surface and alignment. The excavation is then proceeded with, and several bridgemen are left to watch the structure, put in bracing as it is required, replace broken or shattered piles with temporary posts or strengthen them, and in general to keep the structure safe.

\* In the case of a washout, burnout, or collapse of a bridge the first information necessary is the definite location of the break in the track. In addition to this it is necessary to get as much information as possible, such as the kind of structure which has been washed or burned out, length of the structure, length and depth of opening, characteristics of the stream, as to whether there is likely to be water, mud, or sand to contend with, in order to enable the proper officer to determine what kind and manner of temporary work will best meet the requirements. Much of the necessary data should be on file in the office of the Superintendent of Bridges and Buildings or the corresponding officer.

The conductor's report in case of a wreck in a washout or burnout should be full and complete. The following form is used on the N. Y., L. E. & W. Ry. and some other lines.

	.....Station.....	189..
To.....Supt.	Time sent.....M.	Time received.....M.
Train No.....	Conductor.....	
Engine.....	Engineer.....	

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\* A large part of the following matter is taken from two reports, one by R. M. Peck and one by George J. Bishop, to the Assoc. Ry. Supts. B. & B., Proceedings, 1895.

- A. Time and place of accident. (State also if on main or side track, company or individual siding, at frog or switch, in fill, cut, or on level.).....
- B. What caused it?.....
- C. Were any persons injured, and to what extent? Give name, age, residence, and occupation, and what was done with the persons.....
- D. Which track is obstructed, and which clear?.....
- E. Which track can be opened first, and how soon?.....
- F. What crossing-switches or sidings, east and west of obstruction, can be used to pass trains around?.....
- G. How long will it take to get track clear so trains can pass?.....
- H. Will the derrick-car be required, and which way should it be headed to work to advantage?.....
- I. How much force is wanted to clear the obstruction?.....
- J. Is the track damaged, and to what extent? Have trackmen been notified?.....
- K. Is engine off track or damaged?.....
- L. What position is engine in?.....
- M. What position are cars in?.....
- N. How many cars broken and off track, loaded? (Give numbers, initials, and kind.).....
- O. How many cars broken and off track, empty? (Give numbers, initials, and kind.).....
- P. How many cars and kinds are wanted to transfer freight in?.....
- Q. What does lading of cars consist of? What amount of damage to lading?.....
- R. How many cars next engine?.....
- S. How many behind cars wrecked?.....
- T. How many car-trucks needed? Give numbers of cars under which needed.....
- U. Can passengers be comfortably transferred around wreck?.....
- V. How long will it take to transfer passenger train?.....
- W. What was the speed of the train?.....
- X. What was the state of the weather?.....
- Y. What trains, east or west, are stopped by the obstruction?.....
- Z. Remarks.....

Signature.....

If there are a lot of cars, or an engine and cars, in the washout or burnout, the wrecking outfit will probably be needed to clear away the débris. The wrecking-train consists of an engine, truck-car, tool-cars, and derrick-car. The tool-car provided for this purpose should be large and roomy. Hooks arranged along the sides of the car and at the proper height above



the floor are convenient to hang snatch-blocks, blocks and falls, hauling-lines, etc., on. For other tools racks, boxes, and lockers may be provided. Seats may be provided in this car for the men, and it is well to heat the car in cold or inclement weather. Means should also be provided for feeding the men and cooking their meals.

It is desirable to include the following tools and wrecking devices in the equipment of this car:

Hydraulic jacks. Five, from 10 to 30 tons capacity, as follows: One 10-ton, two 20-ton, and two 30-ton.

Screw-jacks. Twelve: six 12 inches, three 18 inches, and three 24 inches in height.

Manila rope. Two pieces, each 600 feet long by  $2\frac{1}{2}$  inches in diameter; two pieces 600 feet long, 2 inches in diameter; two pieces 125 feet long, 3 inches in diameter, with link spliced into one end of each of them, with hook on other end of one rope, the other to have about 8 feet of best 1-inch crane-chain with ring in one end and hook in the other; the ropes to be properly spliced into the ring of the chain, which must be provided with thimbles to keep the ring from cutting the rope. The hooks on the chains are very useful on account of convenience in making hitches. Six slings of best Manila rope, as follows: Two  $1\frac{1}{2}$  inches, two  $2\frac{1}{2}$  inches, two 3 inches in diameter; one of each size should be 6 feet long, the other one and one-half inch sling 8 feet long, and the remainder 12 feet long.

A  $1\frac{1}{4}$ -inch plow-steel wire rope, which has safe working capacity of about 12 tons, may be used to better advantage than a  $2\frac{1}{2}$ -inch Manila rope. The snatch-blocks, however, will require a larger sheave than for Manila rope, as sheaves for the wire rope should not be less than 22 inches in diameter at bottom of groove. In addition to above line there will also be required enough rope for equipping blocks and falls.

Blocks and falls. Four sets of the following sizes: One for 1-inch line, one for  $1\frac{1}{4}$ -inch, one for  $1\frac{1}{2}$ -inch, and one set for 2-inch line. All blocks to have double sheaves of proper size to fit line. Blocks with steel shells and iron sheaves are generally used for heavy work, such as turning over engines and moving them into a position to be elevated to the level of track.

Blocks. Two iron snatch-blocks for 3-inch Manila rope, two for  $2\frac{1}{2}$ -inch, two for 2-inch, two for  $1\frac{1}{2}$ -inch, and one extra set of double blocks for 2-inch line, one provided with becket.

Chains. Six best charcoal iron crane-chains; three  $\frac{3}{4}$ -inch and three 1-inch; the 1-inch chain to have a ring on one end 4 inches clear diameter, made of  $1\frac{3}{4}$ -inch iron, and the  $\frac{3}{4}$ -inch chain a like ring made of  $1\frac{1}{2}$ -inch iron, each chain to have a hook on the other end. Two of the large chains should be 16 feet long, and the other 12 feet; the  $\frac{3}{4}$ -inch chains should be from 8 to 12 feet long.

Switch-ropes. Two  $1\frac{1}{4}$ -inch plow-steel wire switch-ropes, one 45 feet long, the other 80 feet long, each with a link in one end and hook in the other.

Hooks. Six double hooks made of 2-inch iron.

Links. Six links, from 18 to 30 inches in length, made of  $1\frac{1}{2}$ -inch iron.

Wrenches. The car should be supplied with wrenches of various sizes, including at least twelve monkey-wrenches varying from 12 to 30 inches in length.

Steel bars. Eight steel bars varying in length from 4 to 7 feet; shorter bars to be made of  $1\frac{1}{4}$ , and others of  $1\frac{1}{2}$ -inch octagon steel.

Re-railing frogs. Three pairs of most approved design.





surplus oil removed, and put in their place. There should be a particular location in the car for each of the tools, and each of them placed there, to the end that any of the wrecking-crew may go to the car and pick up any tool at once.

The man in charge of the car should have a complete list of all tools which belong in the car, and should proceed immediately, after the wreck is cleared, to check up his tools, and in case any are missing, report them to the proper superior officer to be replaced.

The derrick-car should be equipped with all necessary lines, blocks, rigging, etc

In case a derrick car is not to be had, other methods may be adopted, one of which is to apply the torch to the wrecked débris, and burn it out. This may be done in extreme cases with good results, but it requires time, and after the-wood is burned the iron is left to be

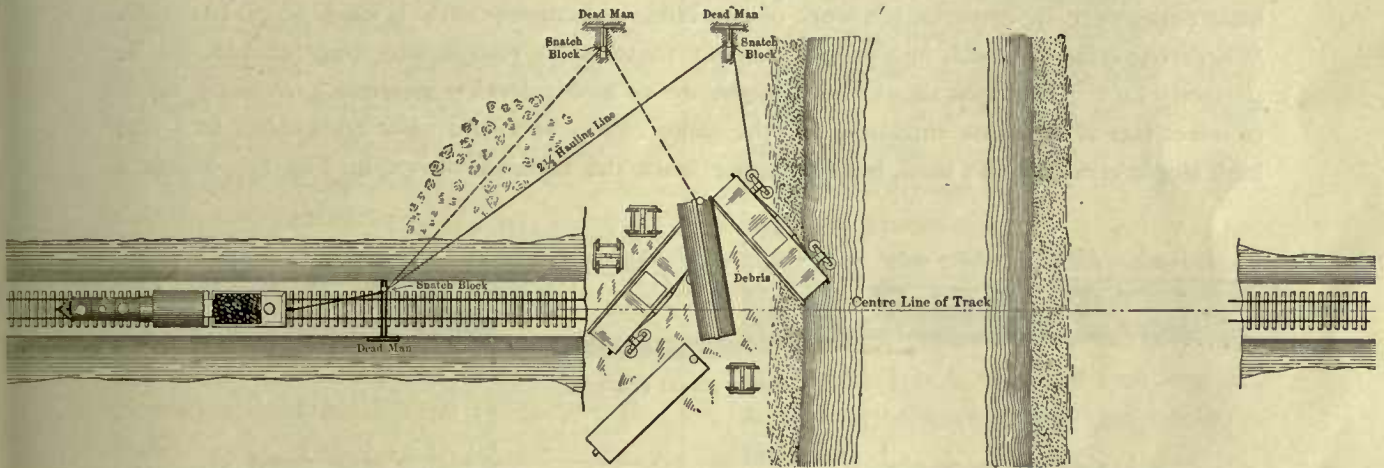


FIG. 158.—SKETCH SHOWING METHOD OF REMOVING DÉBRIS, PREPARATORY TO BRIDGING OPENINGS AT WRECKS OR WASHOUTS.

either picked up with a derrick-car or hauled out of the way with lines and crabs, or locomotive and lines. The quickest method to adopt is to use a locomotive and hauling lines, which is illustrated by Fig. 158. If this method be adopted, the necessary snatch-blocks may be anchored to what are usually termed "dead-men," properly planted in the ground, or anchored to trees if any be found convenient. The anchor usually adopted is the "dead-man," which consists of a piece of timber about 10 by 12 inches by 10 feet in length, set horizontally in a trench about 5 feet deep, and parallel to the centre line of main track, and at a sufficient distance from the wreck to haul out cars, trucks, etc., far enough to clear the site of the temporary work. Commencing at the centre of the trench already dug, dig another at right angles to it, and about 10 feet long, and slope it from the bottom of original trench to surface of ground toward the wreck. Pass a good one-inch chain around the centre of the timber, of sufficient length to lead up to the top of the ground. To this chain attach a snatch-block. Another anchor of the same kind should be placed in the ground near the track, to lead the line in the proper direction so it can be attached to the road-engine, as illustrated in Fig. 158.





The following organization of bridge and pile-driver outfits is recommended by Mr. George J. Bishop, General Foreman of Bridges and Buildings, Chicago, Rock Island & Pacific Railway :

Each bridge gang should have a bunk-car, tool-car, and flat-car.\* On the material-car should be carried one panel of bridge-deck, a large assortment of 1-, 2-, and 3-inch lumber, and staging for cutting off piles for not less than 4 to 6 bents. Under the tool- and material-cars should be boots for carrying tools and supplies. In the tool-car should be carried 6 to 10 panels of bridge-bolts, 50 drift-bolts, and a large assortment of spikes and nails, and the following tools :

- |   |  |
|---|--|
| 1 hand-car.   | 2 track-wrenches.  |
| 1 push-car.   | 4 S wrenches, 2 feet long, for two kinds of                                |
| 1 velocipede-car.   | $\frac{3}{4}$ -inch nuts, jaws $1\frac{5}{16}$ and $1\frac{9}{16}$ inches. |
| 4 timber-dollies.   | 2 1-inch bridge-augers with cranks.  |
| 1 track-dolly.  | 6 $\frac{7}{8}$ -inch bridge-augers with cranks.                           |
| 1 hydraulic jack, 10 tons.                                    | 2 $\frac{5}{8}$ -inch bridge-augers with cranks.                           |
| 4 double-acting telescopic screw-jacks, 14                    | 7 cross-cut saws, 5 feet long, with Climax                                 |
| inches high. Ball's patent.                                   | handles. "V" tooth, $\frac{3}{4}$ of an inch from                          |
| 1 screw-jack, 8 inches high.                                  | point to point.  |
| 2 track-jacks, Barrett No. 1.                                 | 6 8-inch flat mill-files.  |
| 1 medium-size grindstone.                                     | 1 large-size garden-rake.  |
| 1 track-gauge.  | 1 boring-machine with 3 augers : one 1-inch,                               |
| 4 track-chisels.  | one $1\frac{1}{2}$ -inch, and one 2-inch.                                  |
| 2 shackle-bars for $\frac{7}{8}$ -inch bolts.                 | 2 $\frac{5}{8}$ -inch chain-spider, turnbuckle 36 inches                   |
| 3 claw-bars. Verona pattern.                                  | long ; two $\frac{5}{8}$ -inch chains 8 feet long at-                      |
| 6 octagon steel pinch-bars, $1\frac{1}{2}$ in. $\times$ 5 ft. | tached to turnbuckle, with grab-hooks on                                   |
| 4 in.   | the ends.  |
| 5 spike-mauls.  | 1 $\frac{1}{2}$ -inch cable-chain 14 feet long, grab-hook                  |
| 2 8-inch double-face hammers.                                 | on each end.   |
| 2 14-lb double-face hammers.                                  | 6 $\frac{1}{2}$ -inch cable-chains 7 feet long ; grab-hook                 |
| 3 chopping-axes, $4\frac{1}{2}$ lbs. each.                    | on one end, $\frac{3}{4}$ -inch ring, $4\frac{1}{2}$ inches in             |
| 3 clay-picks.   | diameter, at other end.  |
| 12 maul-handles.  | 2 clamp-bolts $1\frac{3}{8}$ inches, 36 inches long,                       |
| 6 sledge-handles.   | threads cut 20 inches, 2 nuts each.  |
| 6 axe-handles.  | 2 clamp-bolts $1\frac{3}{8}$ inches, 44 inches long,                       |
| 6 pick-handles.   | threads cut 20 inches, 2 nuts each.  |
| 1 long-handled shovel.  | 4 cranks to fit nuts on clamp-bolts.                                       |
| 6 short-handled shovels, No. 2.                               | 8 wrought washers $5 \times 5\frac{1}{2}$ inches, $1\frac{1}{2}$ -inch     |
| 2 lumberman's cant-hooks without end,                         | hole.  |
| spike.  | 4 staging-hooks 5 feet long, hooks $8\frac{1}{2}$ and 12                   |
| 2 post-hole diggers. Eureka patent.                           | inches.  |
| 3 chisel-bars, $3\frac{1}{2}$ inches wide, 1 inch thick,      | 3 Select yellow-pine pike-poles 16 feet long,                              |
| and 6 feet long.  | $1\frac{3}{4}$ inches one end, with ferule ; other end                     |
| 2 15-inch monkey-wrenches.                                    | $1\frac{1}{4}$ inches.   |

\* For a very full discussion of the outfit and fitting up of cars furnished by different roads to bridge repair gangs, with many illustrations, see Committee Report Association of Railway Superintendents of Bridges and Buildings, Proceedings, 1901, pp. 156-188; 1902, p. 77.

- |   |   |
|---|---|
| <ul style="list-style-type: none"> <li>2 16-inch select pine poles <math>1\frac{1}{4} \times 1\frac{1}{2}</math> inches, S. 4 S.</li> <li>6 select pine straight-edges 16 feet long, <math>1\frac{1}{4}</math> inches thick, and 10 inches wide full length.</li> <li>2 10-inch double-blocks. Hartz's patent steel.</li> <li>2 8-inch double-blocks. Hartz's patent.</li> <li>1 10-inch snatch-block. Hartz's patent.</li> <li>2 hand-lines 50 feet long, <math>\frac{3}{4}</math>-inch rope.</li> <li>100 feet of <math>1\frac{1}{2}</math>-inch rope.</li> <li>250 feet of 1-inch rope.</li> <li>150 feet of <math>\frac{3}{4}</math>-inch rope.</li> <li>6 lantern-frames.</li> <li>6 white globes.</li> <li>3 red globes.</li> </ul> | <ul style="list-style-type: none"> <li>6 red flags.</li> <li>12 green flags.</li> <li>24 track-torpedoes.</li> <li>4 2-gallon oil-cans, 2 gallons coal-oil, 2 gallons black oil, 2 gallons signal-oil.</li> <li>1 1-quart oiler with short spout.</li> <li>2 water-pails.</li> <li>1 broom.</li> <li>1 water-keg.</li> <li>1 wash-basin.</li> <li>1 dipper.</li> <li>3 torches.</li> <li>1 No. 3 Merrill's saw-set for single-tooth cross-cut saw.</li> <li>1 <math>\frac{5}{8}</math>-inch octagon steel drift 16 inches long.</li> <li>1 <math>\frac{5}{8}</math>-inch octagon steel drift 24 inches long.</li> </ul> |
|---|---|

Pile-driver outfit organized and supplied with tools, etc., as follows :

Train crew :

- Conductor.
- 2 brakemen.
- 1 engineer.
- 1 fireman.

Pile-driver crew :

- 1 foreman.
- 1 engineer and 6 men.
- 1 engine.

- |   |
|---|
| <ul style="list-style-type: none"> <li>1 caboose.</li> <li>1 bunk-car.</li> <li>1 tool-car.</li> <li>1 flat material-car.</li> <li>1 flat-car, 3 feet high and 30 feet long, to go under extension of pile-driver.</li> <li>1 20-foot extension pile-driver.</li> <li>1 pile-driver water-tank with connections for road-engine.</li> </ul> |
|---|

Driver should have solid wrought-iron turntable 10 feet in diameter, and should turn completely around. It should be capable of driving 20 feet ahead of the track and  $26\frac{1}{2}$  feet at right angles from centre of track. It should be fitted to turn by friction, air, or hand. Duplicate parts should be carried for whatever is likely to break or give way; also a complete outfit of tools, as follows :

- |  |  |
|--|--|
| <ul style="list-style-type: none"> <li>2 15-ton hydraulic jacks.</li> <li>4 telescopic, double-acting screw-jacks, 14 inches high.</li> <li>3 track-jacks, Barrett's No. 1.</li> <li>1 grindstone, medium size.</li> <li>2 shackle-bars for <math>\frac{7}{8}</math>-inch bolts.</li> <li>4 claw-bars. Verona pattern.</li> <li>6 octagon steel pinch-bars, <math>1\frac{1}{4}</math> inch <math>\times</math> 5 feet 4 inches.</li> <li>1 track-gauge.</li> </ul> | <ul style="list-style-type: none"> <li>4 spike-mauls.</li> <li>2 8-lb. double-face hammers.</li> <li>2 14-lb. double-face hammers.</li> <li>4 clay-picks.</li> <li>4 chopping-axes, <math>4\frac{1}{2}</math> lbs.</li> <li>12 spike-maul handles.</li> <li>6 sledge-handles.</li> <li>6 clay-pick handles.</li> <li>12 axe-handles.</li> <li>2 long-handled shovels.</li> </ul> |
|--|--|



- 6 short-handled shovels.
- 6 lumberman's patent cant-hooks.
- 2 15-inch monkey-wrenches.
- 4 S wrenches, 2 feet long, for two kinds of  $\frac{3}{4}$ -inch nuts, jaws  $1\frac{5}{8}$  and  $1\frac{9}{8}$  inches.
- 2 track-wrenches.
- 2 1-inch bridge-augers.
- 6  $\frac{7}{8}$ -inch bridge-augers.
- 2  $\frac{5}{8}$ -inch bridge-augers.
- 4 5-foot cross-cut saws, "V" tooth,  $\frac{3}{4}$  inch from point to point, with Climax handles.
- 12 8-inch flat files.
- 2 clamp-bolts  $1\frac{3}{8} \times 36$  inches, threads cut 20 inches, 2 nuts each.
- 2 clamp-bolts  $1\frac{3}{8} \times 40$  inches, threads cut 20 inches, 2 nuts each.
- 2 clamp-bolts  $1\frac{3}{8} \times 44$  inches, threads cut 20 inches, 2 nuts each.
- 6 cranks to fit nuts on clamp-bolts.
- 12 wrought washers  $5 \times 5$  inches,  $\frac{1}{2}$  inch thick, with  $1\frac{1}{2}$ -inch hole.
- 4 pile-clamps  $6'' \times 10'' \times 16'$  pine. S. 4 S.
- 2  $\frac{5}{8}$ -inch chain-spider turnbuckles 36 inches long, with two  $\frac{5}{8}$ -inch chains 8 feet long attached to each turnbuckle, with grab-hook on one end.
- 2 1-inch cable-chains 16 feet long, grab-hook on each end.
- 4  $\frac{3}{4}$ -inch cable-chains 16 feet long, with grab-hook on each end.
- 1  $\frac{3}{4}$ -inch cable-chain 18 feet long, with grab-hook on each end.
- 1  $\frac{5}{8}$ -inch cable-chain 14 feet long, with grab-hook on each end.
- 2  $\frac{5}{8}$ -inch cable-chains 8 feet long, with grab-hook on each end.
- 2  $\frac{5}{8}$ -inch cable-chains 4 feet long, with grab-hook on each end.
- 2 20-inch wooden double blocks with large ring.
- 2 16-inch Hartz's steel double blocks with rings.
- 2 12-inch Hartz's steel double blocks with hooks.
- 2 8-inch Hartz's steel double blocks with hooks.
- 2 12-inch Hartz's steel single blocks with hooks.
- 2 8-inch Hartz's steel single blocks with hooks.
- 4 18-inch Hartz's steel snatch-blocks with rings.
- 2 14-inch Hartz's steel snatch blocks with hooks.
- 2 12-inch Hartz's steel snatch-blocks with hooks.
- 2 10-inch Hartz's steel snatch-blocks with hooks.
- 1 bale of 2-inch Manila rope.
- 1 bale of  $1\frac{1}{2}$ -inch Manila rope.
- 1 bale of  $1\frac{1}{4}$ -inch Manila rope.
- 400 feet of 1-inch Manila rope.
- 400 feet of  $\frac{3}{4}$ -inch Manila rope.
- 24 oak toggle-blocks,  $4 \times 6$  inches  $\times$  4 feet, S. 4 S.
- 2 toggle-irons, top front.
- 2 toggle-irons, bottom front.
- 2 toggle-irons, bottom back.
- 4 pike-poles 16 feet long, large end  $1\frac{3}{4}$  inches with ferule; the other  $1\frac{1}{4}$  inches. Common select yellow pine.
- 10 18-inch poles  $1\frac{1}{4} \times 2$  S. 4 S. Second clear pine.
- 12 straight-edges 16 feet long,  $1\frac{1}{4}$  inches thick, 10 inches wide, full length. Second clear pine.
- 6 pile-rings, 12 inches inside diameter.
- 10 pile-rings, 14 inches inside diameter.
- 16 pile-rings, 16 inches inside diameter.
- 20 pile-rings, 16 inches inside diameter.
- 25 pile-rings, 18 inches inside diameter.
- 4 staging-hooks 5 feet long, hooks  $8\frac{1}{2}$  and 12 inches.
- 2 kegs of 10-inch boat-spikes.
- 2 kegs of track-spikes.
- 2 kegs special track-bolts with loose nuts.
- 2 kegs 60-penny nails.
- 1 keg 30-penny nails.

- |  |   |
|--|---|
| 1 keg 10-penny nails.  | 12 red flags.   |
| 2 steel rails $4\frac{1}{4}$ inches high, 20 feet long.                        | 12 green flags.                                       |
| 2 steel rails $4\frac{1}{4}$ inches high, 10 feet long.                        | 2 water-kegs.   |
| 1 marlinpin.   | 2 dippers.  |
| 1 car-coupling 20 feet long.   | 2 wash-basins.  |
| 6 lantern frames.  | 24 track-torpedoes.                                   |
| 6 white globes.  | 12 fuses.   |
| 3 red globes.  | 1 No. 3 Merrill cross-cut saw-set.                    |
| 6 torches.   | 1 octagon steel drift $\frac{5}{8} \times 24$ inches. |
| 1 locomotive headlight.  | 1 octagon steel drift $\frac{5}{8} \times 16$ inches. |
| 1 Lucigen lamp with hand-compressor and fifty feet of hose, 1000 candle-power. |   |

## List of tools for pile-driver engine :

- |  |   |
|--|---|
| 1 $1\frac{3}{4}$ -lb. hammer.  | 12 gauge-glasses.                                     |
| 1 $1\frac{1}{4}$ ball-pein hammer.   | 12 lubricator-glasses.                                |
| 1 15-inch Stillson wrench.   | 24 hand-hole gaskets.                                 |
| 1 15-inch monkey-wrench.   | 2 1-quart oilers.                                     |
| 1 10-inch monkey-wrench.   | 1 tallow-pot.   |
| 1 small steel wrench for eccentric bolts $\frac{5}{8}$ -inch and $\frac{3}{4}$ -inch jaws. | 15 lbs. tallow.                                       |
| 1 small steel S wrench, $\frac{3}{4}$ - and 1-inch jaws.                                   | 5 gallons coal-oil in can.                            |
| 1 cold-chisel $\frac{3}{4} \times 8$ inches.   | 3 gallons black oil in can.                           |
| 1 cold-chisel 1 $\times 8$ inches.   | 3 gallons engine-oil in can.                          |
| 1 pair pipe-tongs, $\frac{3}{8}$ - to 1-inch pipe.   | 3 gallons signal-oil in can.                          |
| 1 pair pipe-tongs, 1- to 2-inch pipe.  | 1 coal-pick.  |
| 1 key-punch.   | 1 ash-hoe.  |
| 1 packer-ratchet.  | 1 fire-hook.  |
| 4 drills, $\frac{1}{2}$ , $\frac{5}{8}$ , $\frac{3}{4}$ , and $\frac{7}{8}$ inch.          | 1 scoop-shovel.                                       |
| 1 half round file, 16-inch.  | 100 feet of 1-inch steam-hose.                        |
| 1 flat-mill bastard-file, 16-inch.   | $\frac{1}{2}$ dozen 3-inch hose-clamps.               |
| 3 lbs. sheet lead.   | $\frac{1}{2}$ dozen $1\frac{1}{4}$ -inch hose-clamps. |
| 3 lbs. sheet rubber $\frac{1}{8}$ inch thick.  | 200 feet bell-cord.                                   |
| 3 lbs. sheet rubber $\frac{1}{4}$ inch thick.  | 12 pinion-keys.                                       |
| 2 lbs. asbestos packing, $\frac{5}{8}$ inch round.   | 1 steel key-drift 16 inches long.                     |
| 1 ball candle-wicking, $\frac{1}{4}$ pound.  | 5 lbs. waste.   |

"In making repairs across streams where water is from 10 to 30 feet in depth, the following organization is recommended: First, unload enough material to start work; second, start a gang of men framing ties and one end of stringers and sizing both ends, sizing the end not framed back 30 inches; third, start pile-driver to driving; fourth, have foreman and ten men in front. By the time the pile-driver has a bent of piles driven the foreman has his staging up and height marked on the piles, and at the last blow of the pile-driver hammer the straight-edge is put on and two men to each pile start sawing them



off. While the men are sawing off the piling the driver has run back for a cap. When the piles are sawed off the pile-driver lowers the cap to position and starts for stringers for one side. The stringers are lowered to position and the driver goes back for the other side. While the pile-driver is gone men place stringers and finish drift-bolting the cap. The other stringers are then lowered to position and the pile-driver starts for a panel of bridge-ties. As soon as bridge-ties are lowered the driver goes back for two 30-foot rails. These are placed on the ties and the driver goes for a pile. It is necessary to use two rails 20 feet long and two of 10 feet for temporary work. Thirty-foot rails do not always work to good advantage on 14- and 16-foot spans; they are either too short or too long, as the rails should project over the bridge. While it is gone the track is spiked, bolted, gauged, and lined up. At this point there is generally a few minutes' delay of driver waiting for men to get through. Then the driver starts driving the next bent. While driving this two of the men in front are sawing off the ends of the stringers, getting ready for the next panel, and two of the men are detailed to bore and bolt up the stringers, so as to keep everything safe, and so it goes until the gap is crossed. Of the ten men that work in front of the pile-driver each man has his part to look after. While the pile-driver is driving the next bent, one man should see that angle-bars, track-bolts, drift-bolts, and tools are ready for the next bent. Two men are sawing off stringers, five men putting up ledger-boards and staging, putting on sway-braces and bolting up same. The other two men are back boring and bolting up the chord. They should have turnbuckles to pull bents square with the track and to pull the piles into place. All caps are bored out on the dump for sway brace-bolts, and the gang there should do all the unloading, framing of material, and piling same after being framed, for the pile-driver to pick up. A foreman and nine men can do this and keep materials prepared for a day and a night gang. One man should be detailed from this gang to file cross-cut saws for the pile-driver and the two bridge gangs. There is no reason why, with proper management, they cannot drive and complete six to ten panels of bridgework every ten hours, and at night three to five panels of permanent work. As the night gang have to do all the changing and coaling-up on their own time, there will necessarily be considerable loss of time to them and slower work on account of the darkness. If night-work is done it will be necessary to have an extra engine-tank for water for pile-driver and locomotive. The locomotive should be arranged to take water from the pile-driver tank to avoid running for water from 7 A.M. to 7 P.M., or from 7 P.M. to 7 A.M.

"In temporary work, where only three piles are driven to the bent, better results can be secured and fewer men are required."

"In case water is deep it may be found convenient to employ the use of pontoons, which can be readily built of old pieces of pine or cypress timber, such as 7 × 15 inches or 8 × 16 inches, stringers 16 to 20 feet long, packed side by side, from 5 to 8 feet wide, with plank deck spiked crosswise on it after it is placed in the water. Such pontoons can be built to carry three to four men, can be anchored at any point required in the stream, and moved to the various positions with pike-poles. These pontoons are often found to be very serviceable, as men on them can guide piles to proper location, spike sway-braces to the piles immediately above the water, as well as greatly assist in handling the bracing."

Where frame bents can be used riprap stone is frequently of assistance in securing a

foundation. It is placed where the bents are to be located and levelled off. The sills are then put on top of it. Bents placed on foundations of this kind often remain in place several months without showing any signs of settlement. Where frame bents, such as are represented in Fig. 160, can be set without liability of settling, they can be constructed very much

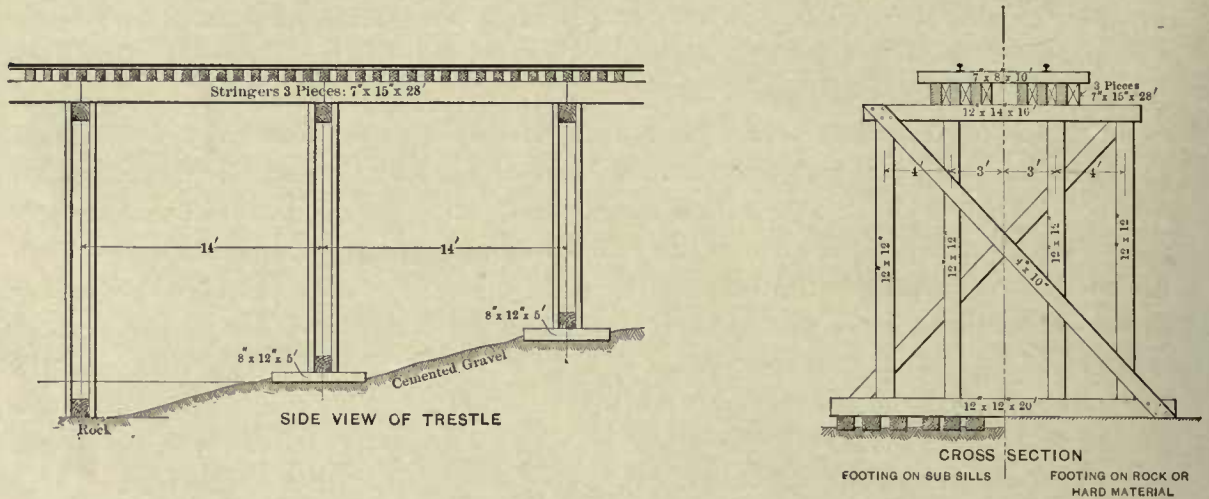


FIG. 160.—SKETCH OF FRAME TRESTLE FOR BRIDGING WASHOUT.

cheaper than any other kind, and put in place much quicker than piles. They require to be well braced, however.

There is another method of using frame bents where the bottom of the stream is comparatively solid, and particularly where a rock bottom is found; this is to use  $12 \times 12$ -inch posts, placed separately, and of such length as will meet the requirements of an uneven or irregular bottom. The bents can be framed together by securing the exact height where each post is to be located. The posts are cut off to the required length, placed the proper distance apart, and the cap drift-bolted on, after which a  $4'' \times 10''$  plank is spiked horizontally across the posts at a distance from the bottom which will bring the plank level with the water-surface when the bent is raised in place. A sway-brace running from the top of this plank to one end of the cap is then spiked on. The bent is then raised in place and a horizontal plank and sway-brace are spiked on the opposite side. This is not a quick process, but it can be adopted where other methods cannot be used to advantage. In case such a bent should settle to one side, two more braces are added and the levelling-up done on the cap.

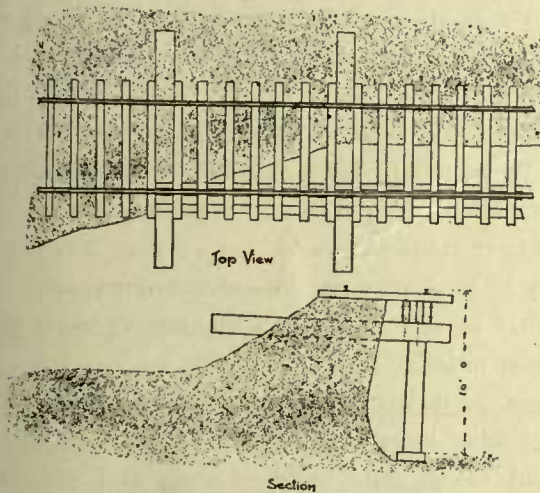
If frame bents are used, means for raising them must be provided. A single mast or gin-pole with four guy-lines and one set of blocks and falls can be used to good advantage. The mast should be located near the centre line of the track, and of the proper height for the work, two of the guy-lines anchored near the track, the other two on the other side of the washout. The guy-lines should be of the best plough-steel wire rope,  $\frac{3}{4}$  of an inch in diameter, two of them 225 feet, the other two 200 feet long. Before raising the mast the upper fall-block should be hooked in the ring provided near the top of the mast and the hook securely lashed with marlin to prevent it from being unhooked. After the mast is properly guyed into position, and the end of fall-line fastened to the crab, which has been properly located and anchored, fasten a  $1\frac{1}{4}$ -inch line, having a double bow-line in the centre to hook the lower fall-



block into, to each end of cap of bent, and raise bent to a perpendicular position, adjust properly, brace longitudinally, after which other bents can be raised without changing location of mast; and this process continued until all bents are raised.

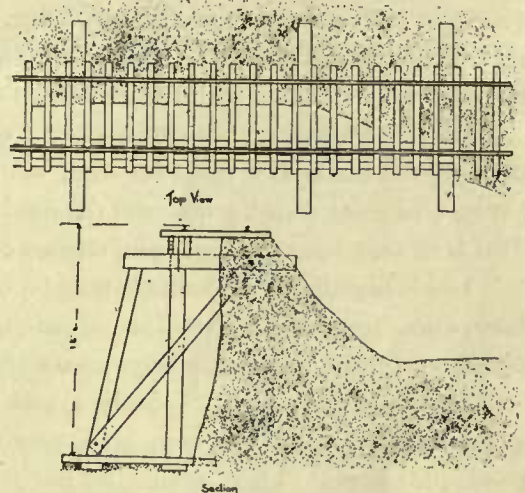
In constructing temporary trestles the stringers are usually placed on the caps without packing them together as in permanent work; hence great care should be taken to see that the stringers do not move endwise and pass off the cap at one end, otherwise a serious accident may follow, especially if the temporary work is left in place for any length of time.

Where embankments are side-washed the following methods are usually preferable to cutting down the embankment or building a shoofly, as previously described. If the washout is not over 10 feet deep, a single sill  $6'' \times 16'' \times 10'$  is laid parallel with the track and a plumb-post set on it. A cap is then projected through the embankment with one end resting on the post. Stringers are placed under the outside rail. The stringers carry the track on one side and the embankment on the other, as shown in Fig. 161. Where the washout is of a greater



METHOD OF REPAIRING WASHOUT.

FIG. 161.



METHOD OF REPAIRING WASHOUT.

FIG. 162.

depth than 10 feet the method shown in Fig. 162 can be followed up to reasonable depths. By putting in this trestlework the track is up to grade, regular trains can be run, and the embankment filled out by work-train or steam-shovel. If a steam-shovel and side-plough are used, only a few section men will be required to handle the dirt.

Burnouts are treated in a general way similar to washouts; but, as a rule, there is no water to contend with, and driving can be started at one end and frame bents at the other.

Rapid repairs of washouts depend, to a great extent, on the number of men and conveniences for doing the work.

There should be boarding-trains at all large washouts, or other arrangements made for the men to get their meals regularly. This should be looked after by the head of the bridge and building or roadway department, or by some one detailed by him.

The superintendent, supervisor, or general foreman of bridges and buildings should be a thorough mechanic, competent not only to instruct, but to do in detail any work he has in charge, and he should have a thorough experience in repairing washouts and burnouts.

There should be material-yards located at division and junction points where there are large bodies of men and where there are likely to be plenty of cars, so material can be loaded rapidly. The amount of bridge material that is carried in stock at these places should be governed by the number of lineal feet of bridges on that division of road which is subject to washouts and burnouts. There should be one principal material-yard, and that should be located at some prominent division point nearest to the point where material is received, at which there should always be kept on hand a large supply of all kinds of bridge material. At the smaller yards there should be kept from five to fifteen panels of substructure and some old bridge material, such as stringers, 12 × 12 inches, and bridge-ties, and also from five to fifteen panels of standard bridge hardware.

During heavy storms section foremen should patrol their tracks and, as a rule, discover washouts. If discovered by a section foreman, he should notify the chief dispatcher and roadmaster. The chief dispatcher or roadmaster should notify the bridge foreman and also superintendent of bridges and buildings and the head of his department of break, giving details in full to the best of his knowledge. If only a small break, it can be repaired by the roadmaster and his men. If it is a bridge of few panels, or a small fill, it can be repaired by the bridge foreman with the assistance of the section men.

All roadmasters at division points where material is located should have blue-prints showing the material it takes for from one to thirty panels of bridge-deck, and should also have a blue-print showing material required for framed bents from 8 feet up to 50 feet in height. This is to save long messages and chance of mistakes in transmitting.

In extraordinary washouts it may be necessary to have material loaded at from three to five points, for usually there is not enough carried at one point, and in most cases it is necessary to call on the roadway department to assist in loading.

The superintendent of bridges and buildings, in selecting foremen, should make it a point to employ the best men possible, men who have had experience and display good judgment. They should be good all-round bridge and building men, and should be competent to do all classes of work in their department. They should be furnished with a complete list of plans of pile and trestle bridges, and should have blue-prints showing bill of material for from one to thirty panels of bridge-deck complete. They should also have a bill of material for framed bents from 8 feet up to 50 feet in height, showing sway-braces and longitudinal and sash girts, and they should have the same for pile-bents. They should have a blue-print for framing bents, showing length of sills and distance between mortises and length of plumb- and batter-posts, so it will not be necessary for them to do any figuring in case of a rush. The superintendent should see that his foremen understand thoroughly how to make repairs with the material they have on hand, as the telegraph-wires often go down and they cannot get instructions. The line may be washed out at a number of places, and the superintendent of bridges and buildings unable to get around on account of being busy at other points, when the foremen should understand that they are to act without instructions and use their own judgment.

The following is a list of tools which should be furnished an ordinary repair or maintenance gang of eight bridge men doing general repair and construction work on iron



bridges and wooden trestles as recommended by a committee of the Association of Railway Superintendents of Bridges and Buildings (Proceedings, 1900).

- |   |   |
|---|---|
| 6 steel timber bars.  | 4 8-inch single-screw jacks.                        |
| 2 track claw bars.  | 4 4-ft. 6-inch cross-cut saws.                      |
| 1 shackle bar.  | 1 6-ft. cross-cut saw.                              |
| 4 spud bars.  | 4 handsaws, 6 teeth to the inch.                    |
| 4 steel erecting bars.  | 4 track spike mauls.                                |
| 1 long spud bar.  | 4 8-lb. double-face spike mauls.                    |
| 4 standing timber trucks.                                       | 2 12-lb. double-face sledges.                       |
| 4 running timber trucks.  | 1 40-lb. double-face sledge.                        |
| 2 running timber trucks to be used on rail only.                | 2 sets single- and double-sheave blocks for         |
| 1 low rail truck.   | 1 $\frac{3}{4}$ -in. rope.                          |
| 1 hand car.   | 2 sets single- and double-sheave blocks for         |
| 1 push or truck car.  | 1 $\frac{1}{4}$ -in. rope.                          |
| 1 tool box 3 ft. $\times$ 4 ft. $\times$ 6 ft. 6 in.            | 2 sets single- and double-sheave blocks for         |
| 1 tool box 18 in. $\times$ 24 in. $\times$ 6 ft. 6 inches.      | 1-in. rope.   |
| 1 lantern box for 10 lanterns. One one-half                     | 2 sets single- and double-sheave blocks for         |
| gallon oil can, and 3 lbs. waste.                               | $\frac{3}{4}$ -in. rope.                            |
| 6 white lanterns.   | 400 ft. 1-in. rope.                                 |
| 2 red lanterns.   | 400 ft. $\frac{3}{4}$ -in. rope.                    |
| 2 green lanterns.   | 4 100 ft. each 1-in. hand lines.                    |
| 4 extra white globes.   | 2 50 ft. each 1-in. hand lines.                     |
| 2 extra red globes.   | 2 75 ft. each $\frac{3}{4}$ -in. hand lines.        |
| 1 key wrench 5 ft. 6 ins. long, heavy.                          | 2 100 ft. each $\frac{1}{2}$ -in. braided lines.    |
| 1 key wrench 3 ft. 6 ins. long.                                 | 4 long-handled dolly bars, various shapes as        |
| 6 S wrenches to fit standard nuts.                              | required for riveting.                              |
| 2 track wrenches.   | 2 short-handled dolly bars, various shapes as       |
| 2 12-inch monkey wrenches.                                      | required for riveting.                              |
| 2 16-inch monkey wrenches.                                      | 4 8-in. long-handled double-faced rivet ham-        |
| 2 socket-wheel wrenches for standard nuts,                      | mers.   |
| wheel 20 ins. diameter.   | 2 pairs rivet tongs.                                |
| 6 1-inch chains 12 ft. long, with hooks and links.              | 2 pairs blacksmith tongs.                           |
| 6 $\frac{3}{4}$ -inch chains 12 ft. long, with hooks and links. | 24 barrel drifts for standard rivets.               |
| 6 $\frac{3}{4}$ -inch chains 8 ft. long, with hooks and links.  | 24 handled backing-out drifts.                      |
| 4 $\frac{3}{4}$ -inch chains 5 feet long, with hooks and links. | 2 $\frac{3}{4}$ -inch $\times$ 20-in. steel drifts. |
| 4 30-ton hydraulic jacks.                                       | 2 $\frac{5}{8}$ -in. $\times$ 20-in. steel drifts.  |
| 2 10-ton hydraulic jacks.                                       | 12 rivet snaps for different size rivets.           |
| 4 ball-ratchet screw jacks (double screw).                      | 6 track chisels.                                    |
| 2 Barrett track jacks.  | 2 shear chisels.                                    |
| 4 pull jacks, right and left thread.                            | 2 No. 10 Buffalo portable forges.                   |



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| 1 grindstone.  | 2 squirt cans.                                 |
| 1 track gauge.   | 1 12-ft. ladder.                               |
| 6 chopping axes.   | 1 16-ft. ladder.                               |
| 4 hand axes.   | 1 24-ft. ladder.                               |
| 6 clay picks.  | 1 dozen 8-in. flat bastard fine-cut files.     |
| 6 maul handles.  | 1 dozen 5-in. paper saw files.                 |
| 4 axe handles.   | 1 16-ft. straightedge.                         |
| 6 track shovels.   | 1 12-ft. straightedge.                         |
| 3 long-handled shovels.                                      | 1 track level.                                 |
| 6 cant-hooks.  | 1 75-ft. tape line.                            |
| 6 carrying hooks.  | 2 heavy steel chisels for cutting drift-bolts. |
| 6 $\frac{13}{16}$ ship augers.                               | 2 spike pullers, O'Laughlin's patent.          |
| 2 2-in. augers.  | 2 ratchet drills and an assortment of drills.  |
| 2 $1\frac{1}{2}$ -in. augers.                                | 6 cold chisels.                                |
| 1 boring machine.  | 6 hand-chipping chisels.                       |
| 6 16-ft. pike-poles.   | 6 cape chisels.                                |
| 4 $1 \times 2 \times 16$ ft. poles graduated in ft. and ins. | 1 iron vise.                                   |
| 2 $1 \times 2 \times 12$ ft. poles graduated in ft. and ins. | 1 small anvil.                                 |
| 24 8-in. diameter $\times$ 24 ins. long turned wood rollers. | 2 No. 3 brack chain pipe wrenches.             |
| 12 6-in. diameter $\times$ 24 ins. turned wood rollers.      | 2 pairs rail tongs.                            |
| 2 water-pails.   | 1 windlass.                                    |
| 2 dippers.   | 4 good snatch-blocks.                          |
| 4 red flags.   | 2 good crabs for derrick.                      |
| 2 green flags.   | 4 bridge clamps.                               |
| 2 white flags.   | 1 pair heavy stone hooks.                      |
| 1 5-gallon oil can.  | 1 pair timber grab-hooks.                      |
| 2 1-gallon oil cans.   | 2 tool cars.                                   |
| 1 filler.  | 1 flat car.                                    |
| 1 funnel.  | 2 doz. torpedoes.                              |



## CHAPTER XV.

### RENEWAL AND REPLACING OF TRESTLES.

THE selection of timber materially affects the cost of maintenance, and the life of pile and framed trestles. As far as possible native timber should be selected and the proper season for cutting it determined. Finally the proper locations for different kinds of timber in the structure should be investigated. For instance, in certain localities Norway pine makes an excellent post, but a very poor sill, cap, or stringer, while white pine answers the latter purposes very well.

The life of timber used in railroad structures varies with the section of the country and the local conditions. Table XVIII gives the experience of a number of railroad companies in this country.

When the time arrives for the renewal of pile-trestles the records of driving as outlined in Chapter II will be found of great value. It is an easy matter to make out from them a bill of piling that is correct. In case such records are not available an outside pile in each bent can be driven without much disturbance of the existing structure, and thus the required length be ascertained. The pile-driving can then be completed by removing a few track-ties. As rapidly as the piles are driven they are cut off level with the top of the ties. The floor is then raised by shimming between the stringers and old caps, the piles cut off to the proper elevation, and new caps slipped in and drift-bolted on. The sway-braces are then put on and the floor shifted ahead span by span until it rests on the new work. In the mean time any stringers are renewed that may require it, and after they are firmly fastened the ties and guard-rails may be replaced. This work may all be done without delaying a regular train, provided there is a spur-track near by.

As rapidly as the finances of a road will permit it is advisable to replace wooden structures, as far as possible, with those of a more permanent character, such as iron and masonry bridges, and embankments either with or without permanent culverts. The kind of structure will depend entirely upon the local conditions. After a road is in operation these structures can usually be built for far less than they could have been at the time of the original construction of the road.\* The experience on the Lake Erie & Western has been that where iron pipe culverts, stone arches, and boxes can be used, and the depth does not exceed 15 feet, the cost of permanent work is but little more than that of renewing wooden trestles, and seldom exceeds twice the cost, including the cost of filling openings with earth. For larger openings, where plate girders and masonry are necessary, the cost is little more than twice, and seldom exceeds three times, the cost of renewing wooden structures. The average life of wooden structures on this road is nine years.

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\* Review of report by Mr. W. F. Gotra, *Eng. News*, August 6, 1896, p. 96.

TABLE XXVIII.\*

Bridge Timber. Average Life in Years.

Kind of Timber.	Exposed to Weather.			Protected from Weather.			State.	Railroad.	Authority.
	Stringer.	Trestle.	Truss.	Stringer.	Trestle.	Truss.			
Long-leaf Southern pine	12-14	15-20	15-20	Indefinitely	.....	Indefinitely	Me., N. H., Vt., Mass.	Boston & Maine	J. P. Snow
"	10-12	12-15	12-24	Practically as lasting as iron	.....	.....	Massachusetts	Boston & Maine	C. P. Austin
"	Good for about 15 years.	18	15	40-50	40-50	40-50	New Hampshire	Boston & Maine	B. Y. Pickering
"	8	9	16-17	.....	.....	.....	Rhode Island	N. Y., N. H. & H.	I. B. Sheldon
"	.....	8	.....	.....	.....	.....	Alabama	Southern	R. W. Hutchings
"	.....	8	.....	.....	.....	.....	Miss. and La.	N. O. & N. E.	T. H. Kelleher
"	.....	8	.....	.....	.....	.....	S. Dak., Minn.	C. & N. O., Dak. Div.	A. W. Merrick
"	.....	.....	.....	.....	.....	.....	Illinois	St. Louis, P. and N.	F. G. Jonah
"	.....	.....	.....	.....	.....	.....	Ill., Ind., Ohio, Mass.	T., St. L. and K. C.	A. Shane
White pine.....	10-12	10	10	Indefinitely	.....	Indefinitely	Colorado	Colorado & Southern	A. Zimmerman
"	.....	.....	.....	.....	.....	.....	Me., N. H., Vt.	Boston & Maine	J. P. Snow
"	.....	.....	.....	.....	.....	.....	Massachusetts	Boston & Maine	C. P. Austin
"	.....	.....	.....	.....	.....	.....	New Hampshire	Boston & Maine	B. Y. Pickering
"	.....	.....	.....	.....	.....	.....	Missouri	C. M. & St. P., Sup. Div.	W. E. Smith
"	.....	.....	.....	.....	.....	.....	Ohio, Ind., Ill.	T., St. L. & K. C.	A. Shane
"	.....	.....	.....	.....	.....	.....	Illinois	Chicago & East Ill.	Aaron S. Markley
"	.....	.....	.....	.....	.....	.....	Wisconsin	Chicago & N. W.	A. Montzheimer
"	.....	.....	.....	.....	.....	.....	S. Dak., Minn.	Chicago & N. W.	A. W. Merrick
"	.....	.....	.....	.....	.....	.....	Minnesota	Duluth & Iron Range	W. A. McGonagle
Eastern pine.....	10	10	10	.....	.....	.....	Wyoming	Union Pacific	A. H. King
Colorado pine.....	10	8-15	12	.....	.....	.....	Colorado	Denver & Rio Grande	C. S. Thompson
Norway pine.....	10	.....	.....	.....	.....	.....	Wisconsin	C. M. & St. P.	W. E. Smith
"	.....	.....	.....	.....	.....	.....	Minn.	Duluth & Iron Range	W. A. McGonagle
Spruce.....	6-7	.....	8	.....	.....	.....	Me., N. H., Vt., Mass.	Boston & Maine	J. P. Snow
"	.....	.....	8-10	.....	.....	.....	Massachusetts	Boston & Maine	C. P. Austin
Oregon fir.....	16	5-7	10	.....	.....	.....	Wyoming	Union Pacific	A. H. King
"	18	14	18-20	.....	.....	.....	Colorado	Denver & Rio Grande	C. S. Thompson
Fir.....	12	.....	.....	.....	.....	.....	Minnesota	Duluth & Iron Range	W. A. McGonagle
White oak.....	.....	.....	.....	.....	.....	.....	Ohio, Ind., Ill.	T., St. L. & K. C.	A. Shane
"	.....	.....	.....	.....	.....	.....	Illinois	Chicago & East Ill.	Aaron S. Markley
"	18	.....	.....	.....	.....	.....	Wyoming	Union Pacific	A. H. King
Red cypress.....	12	.....	.....	.....	.....	.....	Alabama	Southern	R. W. Hutchings

\* Report of B. W. Guppy, Proc. Assoc. Ry. Supts. B. & B., 1899. For some notes on the life of piling, see Chapter II.



From the financial standpoint only, assuming the interest at 5% on the investment for permanent improvements, the life of wooden structures at nine years, and average cost of same at \$9.90 per foot, it is easily seen that it would be profitable to spend \$3 for permanent work rather than to spend \$1 for renewal of wooden structures. But aside from this, what is saved by the reduction of openings in the track, thereby eliminating danger by fires, wrecks, and accidents, is incalculable.

If the ground upon which a trestle is built is firm, little trouble need be feared from filling it in; but if the bottom is soft, or is underlaid by a soft or slippery layer, then much difficulty is frequently experienced in keeping the track in passable condition. Care has also to be exercised lest the ground swell or raise up at places more or less distant from where the work is being done and cause damage to other property. With a bad bottom and sloping rock-surface beneath it, the embankment replacing a portion of one trestle on the Canadian Pacific Ry. sank eight times in about two years, settling each time from a few feet to 18 feet. In other cases on the Canadian Pacific Ry. difficulty from the settling of embankments replacing trestles was overcome by filling the sunken portion of the embankment with sawdust instead of earth, and covering the top of the sawdust with about one foot of gravel. Sawdust shrinks less than earth, the bank yields less under a passing train than the trestle, and it has less spring to it than a muck bank built over a swamp of the same character.

\* In no case should such work be commenced until careful investigation has been made as to the conditions to be met, or the result may be a loss of money, time, and material, or the wrecking of a structure and a costly interruption to traffic. In the case of a long structure, especially if the longitudinal bracing is deficient, as is too often the case, it is not safe to fill in from the ends or from one end, as the pressure may result in the injury or collapse of the trestle, but the filling must be carried on uniformly along the length of the trestle, thus maintaining a practically horizontal surface for the fill and preventing the straining of the structure. Again, if the earth or gravel is to be ploughed off the cars in the usual way, the strength of the trestle is an important consideration in regard to the resistance to the racking strains, and to the lateral strains if a side-plough is used, especially if the material is stiff and the cars are chained to the track. A plough being hauled over a car and suddenly striking a boulder or other obstruction may throw very severe strains upon a trestle. This is more particularly the case where the trestle is on a curve. The strains due to ploughing off the material may be considerably reduced by using a "rapid unloader," with a steam winding engine on the front car.† On the Lake Erie & Western R. R. the cost of filling embankments with a steam-shovel and unloader to replace trestles is from 12 to 14 cents per cubic yard. This includes wages of train crew and laborers, fuel, oil, waste, and repairs.

On this work there are many dangers to the laborers if hand-shovelling or hand dump-cars are employed, there being the constant liability of a man falling from or being knocked off the structure. This is especially the case when hand dump-cars are used on high trestles, the floors being usually narrow, and the men likely to stumble, get dizzy, or be struck by the moving body of a car. In order to provide against these dangers on the Canadian Pacific Ry., an investigation was made into the question of fitting dump-cars with mechanism oper-

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\* *Eng. News*, November 28, 1895, p. 361.

† For description of rapid unloader see *Eng. News*, October 6, 1892.

ated from the engine, either by steam (as in car-heating) or by air (as in train-brakes). At that time (1891), however, no such device was in practical use, but an apparatus was designed by the company's officers (on the basis of an unapplied United States patent) by which the cars were dumped by compressed air. Trains of twenty cars operated in this way were put in service in 1892 with satisfactory results, and these are said to have been the first railway dump-cars so operated. Since that time, however, two or three systems of dumping cars by compressed air have been introduced and used to some extent in this country. The principle consists in attaching to the bottom of the pivoted body of the car the piston-rod of a cylinder, connected by a train-pipe and hose-couplings with the air-reservoir on the engine.\*

A very effective and economical method of filling where water is obtainable under considerable head is that of washing earth into place from the hillside above the trestle, using a water-jet from a "monitor" in the same way as in placer mining. This method has been employed on the Canadian Pacific Ry. and Northern Pacific R. R.

† The accompanying cuts represent the filling in of a trestle at Mountain Creek, B. C., on the Canadian Pacific Ry., the trestle being 1611 feet long, with a height of 145 feet over the creek. Water is brought down by a steel pipe-line and thrown against the hillside in powerful jets, as in hydraulic mining. This is illustrated in Fig 163, which shows the end of



FIG. 163.

the trestle, with the pipe-line, the water-jet, and the great excavation which has been made. In the centre is the flume which carries the stream of water and débris to the site of the bank. Fig. 164 shows the end of the flume and the two partly completed banks, with the stream of water and débris falling from the flume upon the bank on the far side of the trestle. The end of the flume is shifted as desired to level up and distribute the material.

\* For description of similar cars see *Eng. News*, September 14, 1893 and June 27, 1895.

† *Eng. News*, Oct. 12, 1899. P. A. Peterson, Chf. Eng. C. P. Ry.



The bank looks as if it were covered with riprap, but this appearance is due to the rows of old ties which are laid along the top of the slope, forming shallow dams to retain the water in a pool, and so insure settlement of the finer material which it brings down. They also prevent the water from flowing away with such force as to cut the face of the slope. Brush of spruce, pine, or cedar is sometimes used for this purpose, when it can be obtained more readily than old ties.

The trestle was originally built with two timber-truss deck-spans at the centre, supported on timber trestle-towers with masonry pedestals. A single steel deck-span on steel towers has since been erected, as shown in Fig. 164 (which also shows the old abandoned centre

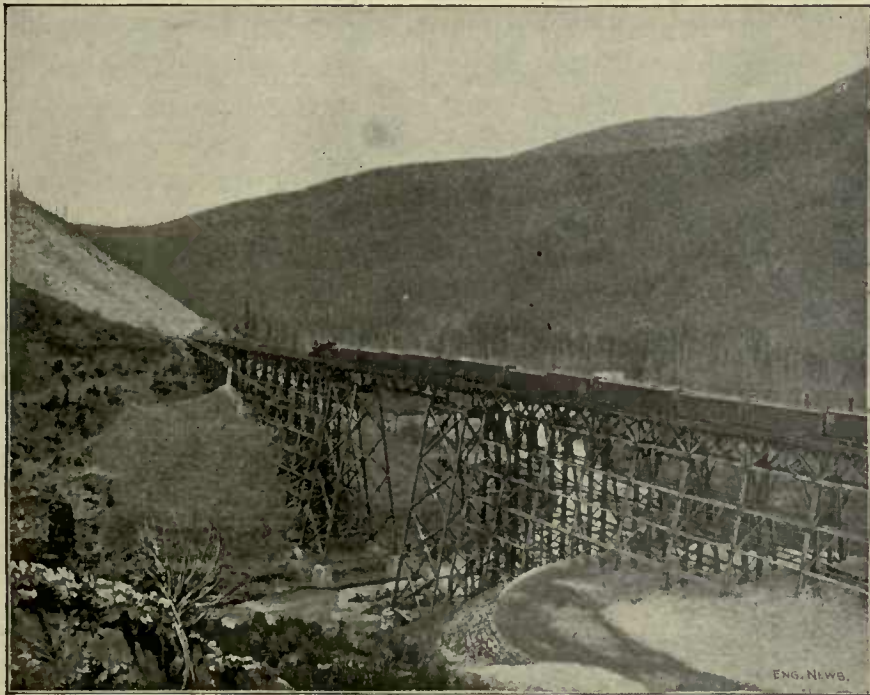


FIG. 164.

pier). It is proposed to put in two additional spans on each side of the centre span. The piers for these will be built on the hydraulic-filled bank, which is said to be more compact than any natural earth foundation, and which can, therefore, be built upon with entire safety.

The same general practice is pursued on the Northern Pacific Ry., and Mr. E. H. McHenry, Chief Engineer, describes it as follows:

\* The water is diverted from the most convenient mountain stream, and carried alongside the mountain, parallel with the line of track, and usually about 200 feet above the same where it is taken for use in the hydraulic "monitor" or "giant" employed in this work. The jet used is from 3 to 4 inches diameter, depending upon the amount of water available. The material is carried to the trestle in ordinary rectangular box-flumes, and the discharge outlet is varied from time to time to meet the requirements. There is nothing special in the

\* *Eng. News*, Oct. 12, 1899. P. A. Peterson, Chf. Eng. C. P. Ry.

process, apart from the building of the levee, or dam, around the edge of the bank. This is constructed of alternate layers of earth and straw or hay. The tough marsh-hay is found the best for this purpose. The material is spaded from the inside and the hay is distributed by a man walking along the dike and shaking the same down loosely. The next layer of material compacts it thoroughly. While this may appear to be quite pervious, it is in fact very quickly puddled by the action of the water.

The embankment is constructed to within three or four feet of its finished elevation, and the fill is then completed by work-trains. The banks are remarkably solid, and no subsidence has ever been observed other than that arising in some cases from the compression of the original soil on which it rests. The hay or straw on the levee has the incidental advantage of protecting the newly made bank, not only during the first year, but subsequently, as the seeds germinate and form a sod. The cost of the process varies with the local conditions, as may be imagined, and ranges from  $1\frac{1}{2}$  cents per cubic yard to 20 or 25 cents. The average cost of several million cubic yards does not exceed 6 cents per cubic yard. The system has been peculiarly satisfactory in that the track is not occupied by work-trains. While the process is cheap, it is somewhat slow, the average daily result of a small working crew of five men and one hydraulic nozzle being between 500 and 1500 cubic yards, but where water is abundant a number of crews can be worked simultaneously.

The timberwork of the trestle itself remains in place in the bank, but the floor system (consisting of the ties and stringers) is taken out. On the Canadian Pacific Ry. the practice is to fill up to the level of the tops of the ties in the autumn of one year, and then in the spring of the next year, after the frost is out of the ground, the ties and stringers are removed, and those that are sound are used in repairing old trestles.

The conclusions of a Committee of the Association of Railway Superintendents of Bridges and Buildings (Proceedings, 1904, pp. 112-127) as to the best method of caring for trestles while being filled are as follows:

“1st. That in high fills of timber trestles, breakages of horizontal timbers are unavoidable, as they are not supported except at bearings, and points where posts are *not* in direct contact with sills and caps are also subject to the same conditions, and will also give way under added tons of filling material, so that under a heavy fill it is safe to assume that the posts and portions of longitudinal timbers, with the actual bearings of caps and sills in this vertical line of posts, are the only timbers not distorted and rendered worthless by the weight and settling of material in the fill, therefore it should be borne in mind that the vertical timbers and, more strictly speaking, the plumb posts, are the only supporting timbers unaffected by the pressure of the fills, as batter posts are affected in proportion to their inclination from a vertical line, and to insure stability in the structure during filling the best practice is to cut off all horizontal timbers when filling reaches a height so that they can be eliminated, as they would then be of no value in sustaining a vertical position of the bents, which (if filling is carried up evenly) would be insured by the filling mattee all around the bent, and their use would only tend to throw the sill of next bent above from its natural bearing. These timbers need not be removed until dirt in the fill reaches



them, when the necessity for their use no longer exists and their presence in their natural position would be a serious detriment to the structure, as it would be, in the fill.

2d. As we have considered in the foregoing the importance of keeping intact the natural position of vertical timbers, we find that the precaution of getting supporting posts in vertical line before filling is a necessary one, and more especially in the heavier fills, as the fills of trestles (say 20 feet in height or less, single deck) is much simpler and the trestle, sufficiently rigid for practical purpose of carrying trains, is all right for resisting any pressure that could be exerted against it in filling, and a pile bent has the advantage of having no surface exposed to a vertical pressure, which would be the reverse where frame bents are used supported by blocking, which bearing surface would be increased where ground is yielding and tendency to settle would be increased accordingly.

3d. It is generally recommended, and your committee concurs in the opinion, that the best results are obtained by carrying up the filling level, and in this way preventing the slipping of the filling, which would result in a lateral pressure and consequent displacing of bents or breaking of vertical timbers, and should such manner of filling for any reason not be practical or expedient, the trestle would be kept in better position by taking off sway-braces which would tend to obstruct the natural settlement of the filling, and the least resistance presented by the structure to the natural movement of the filling material will give best results in maintaining same during the filling period.

We find the *general* practice is to remove bridge ties, stringers, and guard-rail, leaving in the caps to rot out in the fill. Since learning that this is the *usual* practice the chairman of this committee has not had the opportunity of advising with other members as to whether it should be recommended as the *best* practice. The stand might be taken that it is immaterial whether the caps are released or not; that it takes time to remove them when time is an object to make the change between trains, etc. His individual method has always been to remove the caps; they are worth saving in this country and are easily removed, and his opinion is that a firmer and better job results from the removal of the caps while it is torn up and ground is loose, and it is then permanently finished up.

The best time for removal of these timbers is when frost is out of the ground, and change should be made also when dirt is dry and not in a rainy season. This of course is plain to any one having had charge of track maintenance, and if a general, absolute rule is to be laid down, the best time is during summer months and not so close to the freezing, up season as to have any great amount of settlement occur. After that time, however in low fills where the settling is slight, we believe there are points of advantage in getting timbers out, as they can catch fire and cause possible trouble. If they break, there is no chance to detect it until it could be observed in surface of track, and it is our experience that such a filled-in bridge is not as easy to hold in surface and line as when track is on the dump. We have many calls for old timber, and a little old timber, we find, is an important factor in securing authority for needed structures along the line. A careful section



foreman would not allow a trifling settlement where the bridge was to go unsurfaced if he had some cinders or gravel handy to lift it up with.

It is found that where practicable it is an economical plan to grade in as much by team and scraper from below as can be conveniently reached, and such filling is pretty well packed as it is made, and this appears to be the usual practice, but in high fills it is of course necessary to fill in the greater bulk of it from the top."



## CHAPTER XVI.

### THE PRESERVATION OF TRESTLE TIMBERS BY MECHANICAL AND CHEMICAL MEANS.

It has long been known that if timber can be effectively protected from the weather it will last indefinitely. To do this with the timber used in trestles is a problem which has been receiving much attention in recent years. In 1911, Mr. Hunter McDonald read a paper before the Engineering Association of the South describing a method that he uses for accomplishing this end and the results of his experience, extending over many years. The following is an abstract of this paper as published in the *Railway Age Gazette*, June 16, 1911:

“ In 1893 the writer had charge of the renewal of a number of combination spans which had been in service about twenty years. The main and second braces and top chords were of yellow pine, and since their original construction all had been carefully covered with weatherboarding on the sides and tin on the tops, the latter carefully fastened to sheathing, with air space beneath, and soldered. All of the timber upon removal was found to be sound, and was used again for trestle stringers.

The value of such protection had been previously observed, and in 1887 the plan of protecting intermediate sills on double-deck trestles with sheets of galvanized iron was adopted. The sheets extended about three inches over the sides and six inches over the ends, and the posts of the upper section were held in place by allowing the drift-bolts, passing through the cap into the posts below, to extend about six inches above the cap, through the galvanized iron protection and into the feet of the upper section posts. In a number of instances the top caps were similarly protected about the same time.

The intermediate caps were found to be sound in 1906 when the trestles were filled. The top caps, although the housing had not been well maintained and the stringers rested directly on the galvanized iron, with drift-bolts through it, did not require renewal until 1908.

About 1900 the writer had occasion to notice a large pile of stringers which had been removed from the trestles on the Cincinnati Southern Railroad. These stringers were put in place about 1879, and had been protected with galvanized iron according to the designs of Mr. G. Bouscaren, chief engineer. The ties rested directly on the stringers, holes being made at frequent intervals in the galvanized iron in order to confine the ties to position. Col. G. B. Nicholson, chief engineer of the Cincinnati Southern Railroad, was present with the writer at the time these stringers were examined and told him that the galvanized iron had not been carefully removed as it rusted out, nor had any great effort been made to keep it from creeping or leaking. Trestles which were still covered were examined, and

many leaks found in the iron and many sheets found out of position. The condition of the stringers removed showed remarkable preservation, rot occurring only in local spots—around bolt holes—and at points where the protection had been improperly maintained. This examination convinced the writer that, whether the galvanized iron was properly maintained or not, the results obtained fully justified its use, and since 1900 stringers and caps when renewed on the lines under his charge have been so protected.

At that time the standard trestle consisted of two  $8 \times 16$  stringers on each side, packed one inch apart, each pair being spaced six feet apart on the inside. The chords were confined to the caps by what were called "stag-bolts"—that is, drift-bolts driven slantingly through their sides into the caps. The ties were 8 in.  $\times$  9 in.  $\times$  10 ft., and each was doweled to the chord by  $\frac{3}{4}$ -in.  $\times$  5-in. dowels, two dowels to each tie passing into alternate members of the chord on each side. Holes were bored into the tie and the dowels driven in to a tight fit, the corresponding holes in the stringers being a loose fit. The guard-rail was directly over the outside member of the chord. Two bolts to each span on each side passed through guard-rail, tie, and stringer.

The galvanized iron was applied to the caps in the manner already described, and that on the stringers by jacking up the ties, the dowels following them, inserting the iron under them and lowering them again. The weight of the ties caused the dowels to perforate the sheet iron and settle snugly to place after a slight blow with a hammer. It was supposed that the dowels and guard-rail bolts would confine the iron permanently to position, but subsequent observation showed that the iron at many points crept, always outward, no matter whether on sharply elevated trestles or not. The creeping was very slow, and slots were torn in the iron by every dowel and bolt. Careful observations were made with a view of determining the cause of this creeping, but so far the exact cause has not been ascertained. No doubt it is due to different causes at different points. There are many trestles on which no creeping occurs, others where isolated sheets are found to creep, and others where nearly all the sheets creep. It is believed to be generally due to imperfect bearing of the ties on the stringers, longitudinal vibration of the structure, and vertical movement of stringers on the cap or caps on the piles. The problem of remedying this, and also the leaking of water through the dowel and bolt-holes, has been continuously studied, with the result that the method of housing hereafter described has been adopted and has been found to be almost entirely successful, both as to leaking and creeping.

To dispense with the drift-bolts through the stringers into the caps, which are not only destructive to the timber, but cause much expense in adjustment for line and surface, a malleable casting, called a "line-brace casting," has been devised. Its form and method of application are shown in Fig. 133 c. <sup>p<sup>aa</sup></sup>

The line-brace casting serves as a packing ring, and also as an anchor for the chord to the cap. The chord members are packed only one inch apart to prevent the nesting of sparrows between them.

The four holes in the bottom part of the casting admit of fine adjustment and shimming where necessary, new wood into which to drive the anchoring spike being always available.



This device has been found after long test to be entirely effective, even where heavy floods have overtopped the trestle and deposited driftwood against and under it.

The covering of the cap, instead of being continuous over the entire length as formerly, is made in three pieces, flaps being turned up on the sides of the chords under the overhanging sheet-metal chord cover. These covers are fastened to the cap by nailing through strips of galvanized iron riveted to the underside of each cover piece at four points. This arrangement permits direct bearing of the stringers on the caps and ready removal of sheets for the purpose of adjustment. In place of two, the plans show three stringers on each side, which is now the standard on lines of heavy traffic. The addition of the third member to each chord was begun in 1905, and the iron applied in 1900 was found in many cases to be rusted out. The timber underneath the iron was found in as good condition as when covered in all cases where protection had been placed over new timber; but where timber had already been in place a few years before being covered the rotting begun in the open was found to continue under the cover. Upon removal of the covering all chord members beginning to show decay are marked with white paint on the under side and all defective coverings replaced.

In the present plan the dowels are driven to a tight fit into the stringer instead of the tie, thus perforating the sheet iron upward instead of downward. Before driving the dowels the holes are filled with creosote, which is allowed to soak in. It was found necessary, in order to secure perfectly cut holes in the iron, to cut the upper end of the dowel in a lathe instead of by shearing.

After many experiments to determine the best way to prevent leaking through the dowel-holes, it was found that this leaking was generally due to the churning of the ties and to capillarity, and that shearing the dowels was sufficient.

The plan now in use is to bore, with an extension bit, a recess in the bottom of the tie concentric with the dowel hole  $\frac{1}{4}$  in. deep and 2 in. in diameter. Before putting the sheet iron on the stringers cut washers  $1\frac{1}{2}$  in. in diameter are dropped over each dowel in the stringer. When the sheet iron is settled home by the weigh of the ties, the washer forces it up into the recess in the tie, secures a better hold on the iron to prevent creeping, and to a great extent destroys capillarity by creating an open space instead of tight contact around the hole in the iron. The water must be forced up an incline in order to enter the hole.

The sheets of iron are connected to each other by bending and lapping and riveting at one point on each side of the joint where it overhangs the stringer. The sheets are ordered in such lengths as to bring the joints between instead of under the tie. This method has been found almost universally effective to prevent creeping, and has reduced the leaking very greatly. No remedy has been found for leaks around the guard-rail bolts, but all holes in the stringers are carefully plugged at the bottom after framing and filled with creosote, which is allowed to soak in.

It is still found necessary occasionally to stop creeping by bending the iron downward on the inside of the chord, nailing it to the stringer and flaring the lower edge of the iron

to keep the drip off the sides. Small squares of galvanized iron or washers are used when this plan is resorted to in order to keep the nail-heads from pulling through the iron.

The method of covering the caps has proved entirely satisfactory; gum and red-oak caps in use five years show no signs of decay. No caps put on since 1900 and properly covered have required renewal. Caps next to the bulkhead and those subject to frequent overflow on low trestles are of creosoted pine, as housing does not prevent decay in these.

When the use of sheet iron on the stringers was begun in 1900, no attempt was made to secure metal of great durability. Failure of many sheets appeared in about three years at points where switching was done or much sand used. Under ordinary road traffic it lasted about five years, and on branch lines of light traffic even longer. No failures of the metal on the caps due to rust have yet occurred. Later an effort was made to secure greater durability, and after considerable investigation it was decided to use a charcoal iron made by an Eastern mill, the galvanizing upon which was found to be much heavier than on the ordinary galvanized (steel) iron purchased on the market. The difficulty with this iron was found to be that it would not stand short bending, the cracking causing leaks.

Attention having been called to the remarkable purity and claims for consequent durability of certain sheet metals manufactured by a new refining process, investigation was made of their qualities, and the results seemed to warrant the adoption of one of them, which took place in 1908.

Ballasted floors on trestles are meeting with much favorable consideration at present on account of the low cost of maintenance and decreased danger from fires, but it has not been heretofore considered advisable to use this plan without treating piles, caps and chords. On account of the success attained in the preservation of chords by housing, a plan for ballasted floor has been adopted on the lines of which the writer has charge. The creosoted flooring on top of the stringers is confined to place by lag-screws passing upward through a casting which also engages the packing bolts passing through the upper part of the chord. By this method all perforation of the chord covering is avoided. The chord covering can be renewed when required by jacking up the flooring from the caps below, and at the same time the members of the chord can be inspected on top. The cap covering is the same as for the open deck. This plan is much cheaper than one consisting of a larger number of creosoted stringers with planks spiked on top of them, and has the advantage of immediate conversion of present open-deck trestles to ballasted floors and admits of more ready inspection. It is believed to be able to take care of derailed equipment as successfully as any other plan. Driving spikes into creosoted timber penetrates the outer surface and admits moisture to the untreated interior, and will no doubt hasten the decay of the timber.

It requires seven and one-third square feet of the galvanized iron to cover caps and stringers for every lineal foot of trestle with twelve-foot spans. The best quality of iron will cost about .042 cent per square foot, or .308 cent per lineal foot of bridge. The labor cost for open decks, including the boring of recesses in the ties, is about .087 cent per lineal foot of bridge, making the total cost of covering per lineal foot of bridge about .395 cent.



If the stringers and caps of open-deck trestles were creosoted instead of covered, the extra cost for treatment would be about \$10 per thousand, B.M., or 75 cents per foot of bridge. To secure the full benefit of treatment, the framing should be done in advance, which is often quite difficult, in view of the varying span lengths, and cutting has often to be resorted to. If not done in advance, decay is likely to set in. Assuming that creosoted stringers will last twenty years, and that the galvanized iron on untreated stringers will last only five years, it would seem the best policy to use the creosoted timber. On the other hand, the creosoted timbers should be protected against fire, and a covering which will answer this purpose will also protect the timber from decay.

For ballasted deck trestles the protection from fire is afforded by the ballast, and for all new work there seems no doubt but that the best plan is to use creosoted stringers and caps. However, for present conditions, where all stringers are already in place and sound, it seems most economical to cover the present stringers and to continue to renew the covering until new stringers are required. All patching should be done with creosoted stringers. Just what effect the placing of the creosoted timber on top of the galvanizing covering is likely to have on the durability of the latter is a matter for future determination. It is also a question whether black iron painted with two coats of red lead applied immediately after mixing would not be more economical than the galvanized iron for the open-deck trestle.

Many mechanical means have been suggested and put into use more or less extensively for protecting piles driven in salt water from attack and destruction by marine worms, such as the teredo. Among them may be mentioned the driving of the submerged portion of the pile above the ground full of small nails; the covering of this portion of the pile with a ribblon of sheet metal (copper) wound spirally around the pile with edges touching and nailed to the pile; the coating of the pile with a thin layer of cement mortar or concrete; the surrounding of this portion of the pile with concrete-pipe sections and filling between the pipe and pile with sand or with cement mortar, generally the former. Fig. 165 shows the method of protecting the piles by a split concrete pipe filled in with sand as used on the Charlotte Harbor & Northern Railway.\* Some of the timbers growing in tropical and semi-tropical countries and used for piling in those countries are naturally proof against attacks by marine creatures and will last indefinitely. Practically all timbers, if they can be protected against the destructive attack of marine life, will last indefinitely if kept continually submerged in either fresh or salt water. Those portions which are alternately wet and then exposed to the air are subject to decay and destruction from other causes than the teredo and similar creatures.

For the protection of timber exposed either to the attack of marine creatures or to the weather many processes have been devised, depending upon the use of chemicals or the production of chemical changes. Some of these processes when properly carried out and selected with due consideration of the local conditions and uses have proven very successful.

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\* *Engineering-Contracting* Feb. 12, 1908.

It is not the intention to go into this subject very extensively and the following abstract from a committee report of the Association of Railway Superintendents of Bridges and Buildings (Proceedings, 1904) will give a brief idea of this matter as applied to railway work. For a more thorough study of the subject the reader is referred to special works upon it and to the bibliography in Part III of this book.

The subject of preservation of timber has been so largely discussed in connection with the tie question that in writing of preservative processes as applied to wood from the stand-

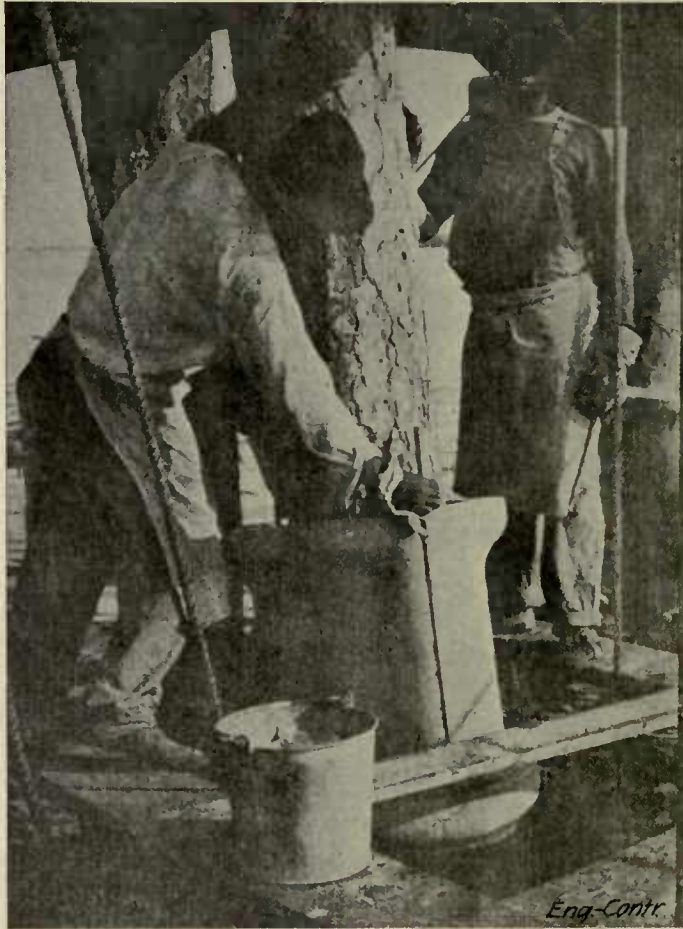


FIG. 165.—VIEW SHOWING METHOD OF APPLYING PIPE TO PILES.

point of the structural engineer your committee has not hoped to do any original work, but has tried to select from the numerous existing works on the subject those salient features which will present to the members of this Association who have little time for individual research an outline of the main principles underlying the various processes.

The necessity for using preservative processes at all will depend upon various conditions—principal of which are:

- (1) First cost of lumber.
- (2) Kind of structure in which it is to be used.



(3) Cost and ease of rebuilding structure when original materials have changed their nature by decay or wear, so as to be no longer suitable for the use for which originally intended.

To illustrate: If a building is to be erected, which, due to conditions, will be removed in a number of years less than the life of untreated timber, it would plainly be uneconomical—in fact, folly—to employ treated timber. If, on the other hand, a permanent structure is to be built, especially of the variety to rebuild which would cause considerable disturbance to traffic, in addition to the labor cost involved, the economy of using timber treated by one of the many processes is then evident.

In view of the fast-failing source of timber supply, the use of timber treated with the object of preserving its life will become more necessary every year. It is hardly to be expected, however, that the railroads, who are the largest users of timber in the country, will view the matter from the standpoint of a national necessity so long as the price of lumber remains at present prices, as will be stated more in detail later. Of the miles of timber trestle on the various large railroad systems in this country but a relatively few structures are built of preserved timber. One member has well stated that preservative processes undoubtedly have not been used more generally on account of the uncertainty and ignorance concerning them.

In order to approach this subject intelligently, a knowledge of the structure of wood in general, and conditions favoring decay of same, will be of value.

Wood is composed of a series of tubes, the chemical composition of which in general is cellulose—these tubes being united in a direction parallel with the axis of the tree. When these cells are first formed they are filled with what is known as protoplasm, which deposits on the walls of the cells, thickening them, until the matured wood cells are formed. The size and distribution of these cells varies for the different kinds of wood. As the tree grows new cells are added next to the bark. The cells nearer the center of the tree gradually lose their original contents of protoplasm, and become filled with gums and resins.

The decay of timber is caused principally by fungi, but also by bacteria and insects. The fungi are a low order of plants composed of thread-like structure called *hyphæ*, which collectively form the *mycelium*. The *mycelium* has its origin from a spore or microscopic seed, which germinates, and sends out a single thread, or *hypha*, which soon branches and multiplies, filling the cells of the wood. For sustenance they depend upon the starches, sugars, and oils contained in the cells. In the process of obtaining their food the chemical compounds of the wood are changed, and there is left behind the substance known as rotted wood. The fruit of the fungi are best known in the form of toadstools or mushrooms, that are found on timber in the forests.

The three conditions necessary for the growth of *mycelium*—in other words, decay of timber—are air, moisture, warmth. Without one of these decay is impossible. Timber submerged in water may be destroyed by marine animals, but will never decay. Timber exposed to a constant low temperature, or kept perfectly dry, will never decay.

*Note.*—A full description and reproductions of photographs relative to this matter may

be found in Bulletin No. 14, by Hermann Von Schrenk, United States Department of Agriculture.

With the above general properties of wood understood, it will now be in order to give

#### AN OUTLINE OF PRESERVATIVE PROCESSES.

These are:

- (a) Creosoting, or treatment with dead oil of coal tar, often called the Bethell Process.
- (b) Burnettizing. (Chloride of Zinc.)
- (c) Kyanizing. (Bi-chloride of Mercury.)
- (d) Wellhouse. (Chloride of Zinc, with Glue and Tannin.)
- (e) Allardyce. (Chloride of Zinc with Dead Oil of Coal Tar.)
- (f) Boucherizing, or Margaryizing. (Sulphate of Copper used, but name applied primarily to method.)
- (g) Thilmany. (Copper Sulphate and Zinc Sulphate, with after treatment of Barium Chloride.)
- (h) Hasselmann. (Sulphate of Copper, Iron, and Aluminum.)
- (i) Creo-resinate. (Creosote, Resin, Formaldehyde, followed by milk of lime.)
- (j) Hagen Method. (Chloride of Zinc and Gypsum.)
- (k) Woodiline and Carbolineum Avenarius.
- (l) Vulcanizing.

Within the limits of this paper it will not be possible to give full details for the above processes. Their general characteristics are as follows:

##### (a) *Creosoting.*

The dead oil of coal tar used in this process is a product of the distillation of coal tar, a by-product from the manufacture of illuminating gas. It contains a considerable amount of carboic acid. The chemical compounds contained, which have an important bearing upon its preservative properties, are given in Table XXVIII (page 219).

Of these the naphthalene compounds, which are the most abundant, are of great value as antiseptics. Naphthalene proper melts at 79° C., and vaporizes at 212 to 220° C. Its specific gravity at boiling-point is 0.9778. It is insoluble in cold water, and but slightly soluble in hot water, and for average temperature may be termed non-volatile. Dead oil weighs about 8.8 pounds per gallon. When used as a preservative it undoubtedly coats the cells of the wood fiber. If sufficient quantity is used it undoubtedly entirely fills the pores of the wood, providing the sap has been removed. This condition of filling the pores of the wood cells is valuable in any preservative process where insoluble material is used, inasmuch as water, one of the agents necessary to decay, is thus excluded.

Preservative processes in general consist of three stages: Seasoning, removal of sap and moisture, application of the preservative to all of the wood cells. Seasoning may be accomplished artificially. At the present time, however, when orders for lumber must of necessity be filled direct from the forest, a process of steaming is almost entirely used. In steaming the fresh timber is placed in a closed cylinder, to which live steam is admitted and held



TABLE XXVIII.

Name.	Symbol.	Fuses.	Vaporizes.
HYDROCARBON COMPOUNDS, ACIDS.			
Naphthalene.....	C <sub>10</sub> H <sub>8</sub>	79°	218°
Naphthalene, di-hyd.....	C <sub>10</sub> H <sub>10</sub>	Liquid	200
“ a-methyl.....	C <sub>11</sub> H <sub>10</sub>	“	242
“ b-methyl.....	C <sub>11</sub> H <sub>10</sub>	32.5°	242
“ di-methyl.....	C <sub>11</sub> H <sub>12</sub>	Liquid	262
“ tetrahyd.....	C <sub>10</sub> H <sub>12</sub>	“	190
Anthracene di-hyd.....	C <sub>14</sub> H <sub>12</sub>	106°	305
“ hexahyd.....	C <sub>14</sub> H <sub>16</sub>	63	290
Phenanthrene.....	C <sub>14</sub> H <sub>10</sub>	100	340
Fluoranthrene.....	C <sub>16</sub> H <sub>10</sub>	109	360
Retene.....	C <sub>18</sub> H <sub>18</sub>	99	350
NITROGENIZED COMPOUNDS, BASES.			
Pyridine.....	C <sub>5</sub> H <sub>5</sub> N	Liquid	116.7
Picoline.....	C <sub>6</sub> H <sub>7</sub> N	“	135
Lutidine.....	C <sub>7</sub> H <sub>9</sub> N	“	152
Collidine.....	C <sub>8</sub> H <sub>11</sub> N	“	170
Coridine.....	C <sub>10</sub> H <sub>15</sub> N	“	211
Rubidine.....	C <sub>11</sub> H <sub>17</sub> N	“	230
Viridine.....	C <sub>12</sub> H <sub>19</sub> N	“	251
QUINOLINE SERIES.			
Leucoline.....	C <sub>9</sub> H <sub>7</sub> N	Liquid	240
Isquinoline.....	C <sub>9</sub> H <sub>7</sub> N	18°	236
Quinaldine.....	C <sub>10</sub> H <sub>9</sub> N	Liquid	243
Indoline.....	C <sub>10</sub> H <sub>9</sub> N	“	252
Cryptidine.....	C <sub>11</sub> H <sub>11</sub> N	“	274
Acridine.....	C <sub>13</sub> H <sub>9</sub> N	111°	360

under pressure for several hours. This results in liquefying the sap and solidifying the albumen. The water contained in the wood cells is transformed into steam, and is driven off. The temperature of the steam depends upon the pressure, and should not vary more than between the limits of 200 to 250° F. After the steaming has continued for a proper length of time the air contained in the cylinder is exhausted, and a partial vacuum maintained for a short interval of time, during which the moisture and liquids formed by the steam are expelled from the interior of the timber. The cylinder is then filled with the dead oil at a temperature of about 175° F., the pressure in the tank being raised to 80 to 100 pounds per square inch, and maintained until the pores of the wood have absorbed the necessary amount of oil.

The method of procedure is essentially the same for the various processes of creosoting, with the exception of that known as the Rueping process, in which the oil is driven into the wood by pressure after the cells have been previously filled with air under high pressure. When the air pressure is removed the cells are partially emptied of their oil contents. In brief, the fiber of the wood cells is merely coated with the preservative.

(b) *Burnettizing.*

In this process the impregnating fluid is zinc chloride, which is applied in the form of a solution in water, similar to method for creosoting. After treatment the wood must be thoroughly dried, in order that the salt contained in the solution may be deposited in the fiber of the wood. If the wood is afterward exposed to the action of water, the salt is

leached out, leaving the cells unprotected eventually. To overcome this possibility a concentrated solution has been proposed, but this is impracticable, as injurious to the fiber of the wood, rendering it brittle. The process has been extensively used in tie preservation, but from the two properties above mentioned is not desirable for the treatment of structural timber. It will be of interest to state that this process has been abandoned by nearly all the European railroads.

(c) *Kyanizing.*

In this process the seasoned timber is steeped or soaked in a solution of bichloride of mercury (better known as corrosive sublimate, the strongest antiseptic of metallic salts). This solution coagulates albumen, is very poisonous, and attacks iron, hence is unsuited for structural purposes where iron is used to fasten the members of a structure together. On account of its corrosive properties, tanks containing it must be constructed of stone, wood, or other substance not affected by it. Instances can be cited where structures built of Kyanized timber have existed from twenty-five to thirty-five years without decay.

(d) *Wellhouse.*

In this process zinc chloride is used, to which has been added a small percentage of glue. After the timber has been treated under pressure, the solution is drawn off and a solution of tannin added. The latter combines with the glue to form a plug, of a leathery water-proof substance, thus excluding damp and retaining the salt.

(e) *Allardyce.*

In this process the timber is first treated with an injection of a solution of zinc chloride. This is followed with a second injection of dead oil, for the purpose of closing the pores of the wood and preventing the escape of the zinc salts.

(f) *Boucherizing, or Margaryizing.*

In this process the antiseptic solution was applied under hydrostatic pressure to the end of the timber to be treated, so that the solution should be forced through the pores of the wood. The salt mainly used was sulphate of copper, so that the name has of late been applied to the use of that chemical rather than as originally to the method of injecting it. This process is objectionable from a structural standpoint, as the salt attacks iron brought in contact with it, due to the sulphuric acid which is formed.

(g) *Thilmany.*

In this process the timber was first impregnated with a solution of sulphate of copper, and then with a solution of barium chloride. It was supposed that a chemical combination would be formed, depositing sulphate of barium and copper chloride in the pores of the wood. Results of this process have been unsatisfactory.

(h) *Hasselmann.*

In this method timber is boiled in a solution of copper, iron, and aluminum sulphate, to which a small amount of kainit is added. The latter is a salt consisting of potassium and magnesium sulphates and magnesium chloride. It is supposed that the boiling produces a chemical reaction between the fiber of the wood and the salts used. Statistics relative to this process are not abundant. Where used in Germany it seems to promise good results.



*(i) Creo-resinate.*

In this process the timber is first subjected to a temperature of 200° F., with the object of evaporating moisture contained in the cells. The temperature is increased gradually to about 300° F., and the pressure increased to 80 pounds per square inch. The temperature and pressure are then both gradually reduced. At a temperature of about 200° F., and a vacuum of 26 inches, a solution of dead oil, melted resin, and formaldehyde is injected. The timber is then placed in another cylinder, and solution of milk of lime applied, at a temperature of about 150° F., and a pressure of 200 pounds per square inch. The efficacy of this process is undoubtedly largely due to the preliminary heating of the timber. Statistics relative to this process are as yet meagre.

*(j) Hagen Method.*

In this process a solution of chloride of zinc and gypsum is used. The efficiency of the gypsum in sealing the pores of the wood when it has crystallized is doubtful.

*(k) Woodiline and Carbolineum Avenarius.*

These substances contain creosote as the main ingredient. They are applied by brushing or soaking the timber with the material. In many cases the use of these substances may be warranted as hindering the decay of timber. They cannot replace the more thorough methods of impregnation and sterilization. The specifications of one important railroad require that when two wood surfaces are joined they shall be treated with a material of this variety.

*(l) Vulcanizing.*

This process consists in subjecting timber to the action of air which has been heated to a temperature of 500° F. The air is heated by passing it over coils, through which live steam is circulated. It is supposed that the heat coagulates the albumen, expels the water from the wood cells, kills the organisms which may exist therein, and seals the cells by transforming the sap into preservative compounds, which are prevented from escaping by the pressure at which the heated air is supplied. This method has been used by the elevated railway systems of several cities, with good results. The cost of this process is about the same as for creosoting, and as it possesses only in part the many excellent features of the latter process, creosoting is to be recommended in preference to vulcanizing.

## RECOMMENDATIONS.

To sum up: Mr. Hermann Von Schrenk\* has well expressed the conditions to which the ideal preservative should conform:

- (1) It must be poisonous to bacterial and other destroying agents.
- (2) It must be capable of easy injection, and when once in the wood it ought to stay there.
- (3) It must penetrate all parts of a piece of timber.
- (4) It must be cheap.

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\* Bulletin No. 14, U. S. Department of Agriculture.

The above qualifications immediately exclude from the list of ideal preservatives those processes which employ salts soluble in water, and fix one's attention on the creosoting method, which is without doubt the most universal and best method to date. The dead oil is antiseptic, thus preventing the formation of hyphæ. It is insoluble. It fills the wood cells, thus excluding all moisture. Timber treated by it is proof against the attacks of limnorea and the teredo. The argument against it, that is, first cost, is largely offset by its many other good qualities, and the extremely long life of timber treated by it. As the use of this method of preservation becomes more extended the cost of same will be greatly reduced, undoubtedly to a point at which timber treated by it will become available for purposes where higher cost now makes it prohibitive. For ordinary purposes for which timber is used it is recommended that an average amount of creosote of 12 pounds per cubic foot of timber treated be used (for piles and submerged work this quantity should be increased; in water in which the teredo abounds 22 pounds per cubic foot of timber should be used), that for the steaming process a temperature not varying more than between the limits of 200 to 250° F., and for the amount of steaming necessary that one hour for each inch of minimum depth of stick be used. Lower temperature than 200° will not produce the necessary effect in the interior of the wood cells. Greater temperature than 250° would be injurious to the wood fiber.

It is also the opinion of this committee that too much stress cannot be laid upon the matter of proper seasoning of the timber before treatment. The best argument in favor of seasoning is the result obtained in European countries, where timber is cut from six months to one year before it is used.

Much valuable work is being done and important investigations are being made and statistics compiled by committees of the American Railway Engineering and Maintenance of Way Association. In Bulletin 107, January, 1909, the following proposed standard specifications for creosote oil appear:

#### STANDARD SPECIFICATIONS FOR COAL-TAR CREOSOTE.\*

The oil used shall be the best obtainable grade of coal-tar creosote; that is, it must be a pure product of coal-tar distillation and must be free from admixture of oils, other tars or substances foreign to pure coal-tar; it must be completely liquid at thirty-eight (38) degrees centigrade, and must be free from suspended matter; the specific gravity of the oil at thirty-eight (38) degrees centigrade must be at least 1.03. When distilled according to the common method, that is, using an eight (8) ounce retort, asbestos covered, with standard thermometers, bulb one-half ( $\frac{1}{2}$ ) inch above the surface of the oil, the creosote, calculated on the basis of the dry oil, shall give no distillate below two hundred (200) degrees centigrade, not more than five (5) per cent below two hundred and ten (210) degrees centigrade, not more than twenty-five (25) per cent below two hundred and thirty-five (235) degrees

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\* Report of Committee on Wood Preservation, American Railway Engineering and Maintenance of Way Association, Bulletin 107, January, 1909, pp. 79, 80.



centigrade, and the residue above three hundred and fifty-five (355) degrees centigrade, if it exceeds five (5) per cent in quantity, must be soft. The oil shall not contain more than three (3) per cent water.

In the same Bulletin (p. 90) the committee states its conclusions as follows:

(1) Coal-tar creosote and zinc chloride are efficient preservatives when properly applied and when used under proper conditions.

(2) It is necessary to keep better records than have been kept so far in order to form proper conclusions as to the merit of different methods and processes.

(3) Preserved wood may be destroyed by mechanical action long before it is decayed.

(4) The specification as given for coal-tar creosote is good practice and should be adopted.

(5) There should be a standard temperature at which coal-tar creosote is measured. The temperature of 100° Fahrenheit as given in the report is recommended.

(6) It is essential that timber should be properly grouped in order that a successful treatment may be obtained. The species, proportion of heartwood and sapwood, condition of the timber with respect to its moisture content, and the wood structure, will in general determine this grouping.

(7) It is desirable to air-season timber in order to prepare it for treatment. Most woods can be best treated after being air-seasoned.

## CHAPTER XVII.

### CONCRETE TRESTLES.

WITH the wearing out of wooden trestles and the increasing cost and scarcity of timber suitable for their replacement the ingenuity of railroad officials has been taxed to find suitable means or structures to take their place. In many cases fills can and have been made. In some cases iron or steel structures have been resorted to. However, there are numerous locations where local conditions make either one of these methods so expensive as to be prohibitive, or other causes require either the renewal of the timber trestle in a somewhat more permanent form than in the past, as by the use of treated timber or their renewal by a similar structure built of durable material, such as concrete. In the past few years a number of roads have used concrete trestles in replacing wooden ones which have required renewal. Among such roads may be mentioned\* the Chicago, Milwaukee & St. Paul, which has 83 (1910) reinforced concrete trestles aggregating 8359 lin. ft.; the Northern Pacific Lines in Montana; the Chicago Rock Island & Pacific Railroad; the Wabash Railroad; the Cleveland, Cincinnati, Chicago & St. Louis Railway; and the Chicago, Burlington & Quincy, which was one of the first to adopt this kind of trestle and which has built approximately 20,000 lin. ft. (1910). The Great Northern Railroad and the Chicago Great Western Railroad have (1910) adopted standard plans for concrete trestles, and the Delaware, Lackawanna & Western has used reinforced concrete for coal trestles. The Philadelphia & Reading Railroad has built coal trestles at manufacturing plants with concrete piers supporting wooden floors. The Chicago, Indiana & Southern Railway and other railways and manufacturing companies have recently built trestles wholly or partly of reinforced concrete.

There are several types of such structures in use: Those having thin piers of concrete supporting wooden floors, those having thin piers of concrete supported on concrete piles or otherwise with concrete floors of slab or girder construction, and those having bents of concrete piles carrying concrete caps supporting concrete floors of slab construction. Section V of Part II gives a number of designs used on different roads.

Mr. C. H. Cartledge, Bridge Engineer of the Chicago, Burlington & Quincy Railway, read a very valuable paper on the subject of concrete trestles in 1910 before the Western Society of Engineers, the major portion of which is here reproduced from the journal of that society for October, 1910.

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\* Bulletin 130, December, 1910, American Railway Engineering and Maintenance of Way Association, Report of Committee on Masonry.





great length, there being neither ice nor drift to catch upon supports placed closely together. For bridges having the characteristics described, many of them of lengths from one hundred to a thousand feet or more, the writer has devised a construction which seems well fitted to replace the timber or wooden pile trestle bridge. As the wooden pile bridge is the cheapest wooden construction possible, it occurred to the writer, when considering how best such structures might be made permanent, to design a reinforced concrete construction, following the main features of the timber trestle.

An investigation of the reasons for the great economy of such a construction as the pile trestle shows that it is largely due to the small amount of work necessary to be done in the field. There are no cofferdams, foundation pits, or falseworks to be built. Very



FIG. 167.—FIRST CONCRETE TRESTLE. CHICAGO, BURLINGTON & QUINCY RAILWAY.

little raw material has to be unloaded and cared for. The members comprising both the substructure and superstructure are taken out and put in place, often largely by machinery and with a minimum of disturbance of the track and delay to traffic. It was evident that if a construction of permanent materials, having the characteristics mentioned, could be devised, the result would be what was wanted.

A structure embodying these features was built and tested, and with the experience gained, a standard plan was drawn up, which is shown in Fig. 166.

It should be emphasized that this construction is suited only for shallow openings, and it is the writer's practice to limit the height of concrete pile trestles to 16 ft. from ground line to base of rail. For greater heights it is his practice to substitute thin piers for the pile bents, although at considerably increased cost.

In Fig. 167 is shown a view of the first trestle built, and experience in its construction led to the design of Fig. 168, which is in accordance with the standard plan of Fig. 166.

The construction of these bridges in any great length requires some little organization,



and the **more** thorough this is the less will be the unit cost and the better the construction.

In the bridges so far built, concrete piles of two kinds have been used—one being moulded in horizontal forms and the other made by *rolling* in a machine, under the Chenoweth patents. The moulded piles were used in the first of these bridges. They were 16 ins. square at the butt, had a 4-in. chamfer at each corner, a taper of 4 ins. in 30 ft. on each face, and were pointed at the tip. The reinforcement consisted of four  $\frac{3}{4}$ -in. square corrugated bars, hooped with No. 12 gauge steel wire, wound at close pitch near the butt and point, and at 3-in. pitch over the greater part of the length of the pile. The reinforcement was assembled on a mandrel and the spiral hooping wound around it by turning

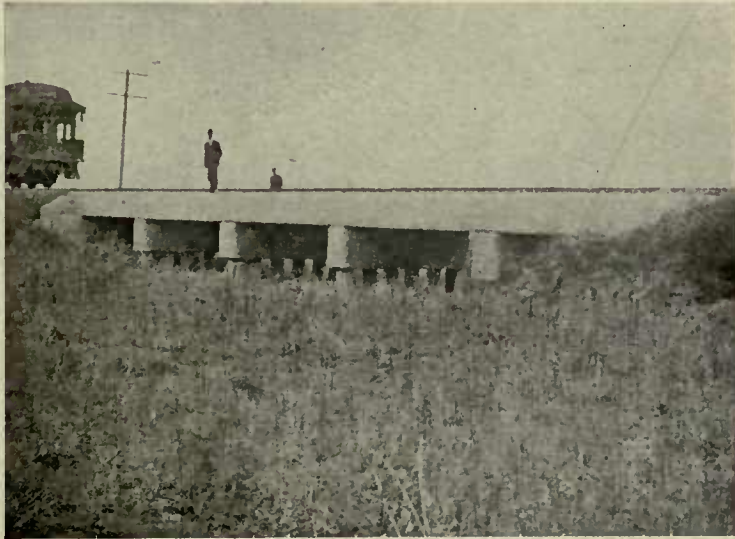


FIG. 168.—SECOND CONCRETE TRESTLE.

the mandrel. After the hooping was in place it was tied at frequent intervals with No. 16 soft wire, and the complete reinforcement was then withdrawn from the mandrel.

The forms were of wood, unlined and made so that the sides could be removed as soon as the concrete was firm; the pile was left on the bottom boards until hard enough to stand handling. The reinforcement was hung in the forms by wires depending from the cross braces and concrete, composed of one part of cement to four and one-half parts of gravel, mixed to a slushy consistency, poured in. The gravel was generally screened so that all the sand and pebbles  $\frac{1}{2}$ -in. in diameter or less were retained and used, the coarser aggregate being rejected. The piles were allowed to harden at least thirty days before being shipped. This seems to be about the least time which can be allowed, as attempts to ship and drive piles of less age have not been successful. More extended seasoning is often easily obtained and is to be preferred.

The *rolled* piles are made in the machine shown in Fig. 169. This machine consists essentially of a movable platform, a shaft or mandrel, and means for moving and turning the piles together with rolls for holding them in line during fabrication. The illustrations,

Figs. 169, 170 and 171, show the process quite plainly. Fig. 172 shows the whole plant with some completed piles in the seasoning yard, where the piles are sprinkled frequently to assist the hardening of the concrete.

A somewhat incomplete comparison of the first year's costs of rolled and moulded piling

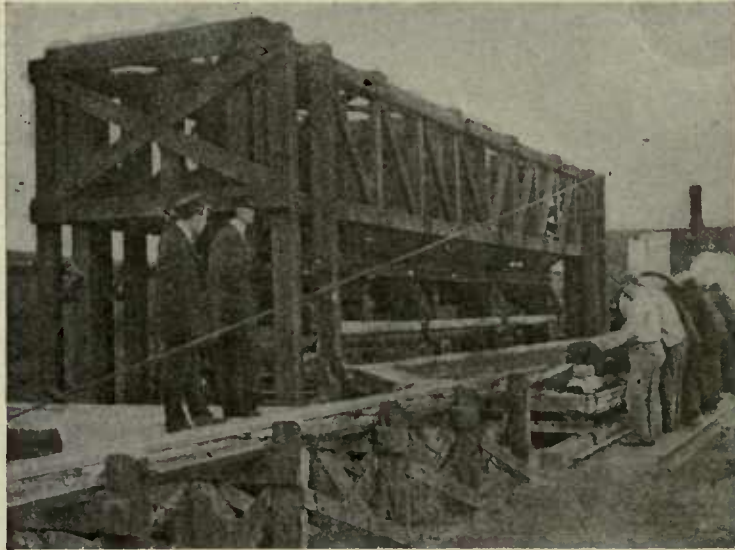


FIG. 169.—MANUFACTURE OF ROLLED CONCRETE PILES.

indicates that there is little difference in the cost of the two kinds. As the cost of making reinforcement for the moulded piling was one of the principal items, it was decided to

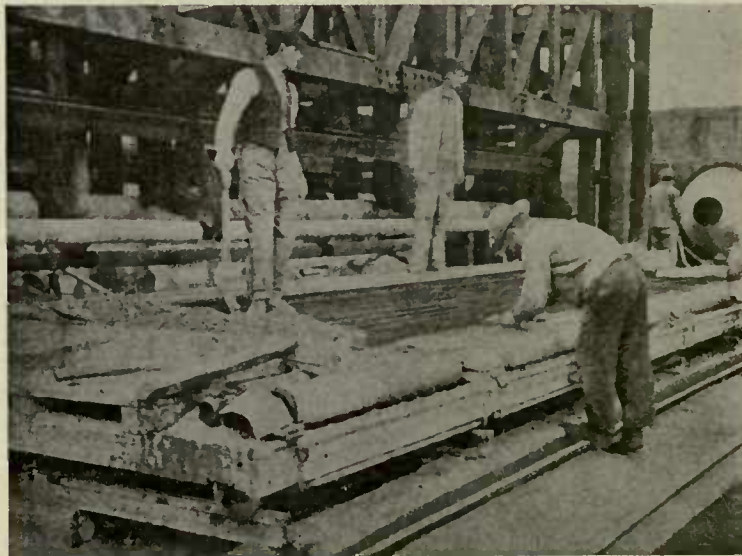


FIG. 170.—ROLLED CONCRETE PILING BEING MADE.

experiment with moulded piling made without taper, the idea being to use a wire fabric, as reinforcement, which could be simply folded into a square and wired together at the lap,



thus avoiding considerable labor. The cost of forms is also much reduced if they are not tapered. An efficient plant was designed and is shown in Fig. 173. On each side of each form a rail is placed. A pair of trucks has a short piece of track spiked to it at right angles to the track on which it runs, the level of the latter being such that a car can run

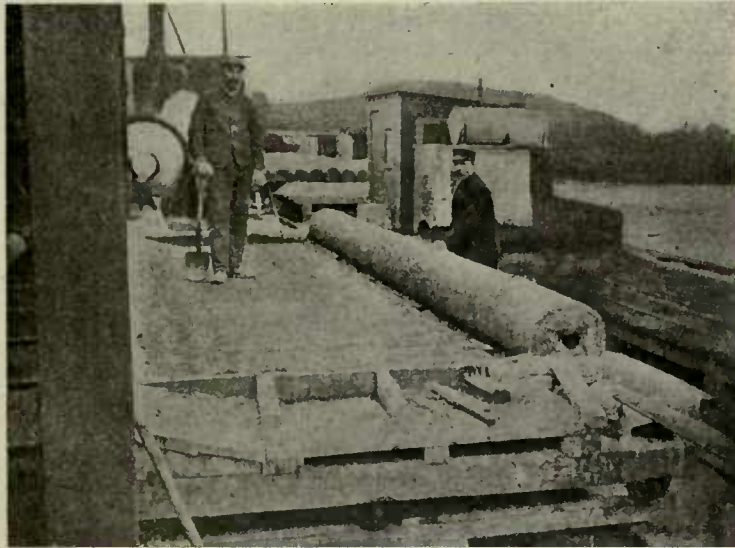


FIG. 171.—ROLLED CONCRETE PILE NEARLY COMPLETED.

off the upper track directly on to the rails between the forms. The car on the trucks is a hopper-bottom dump car and carries a half yard of concrete, Fig. 174. In operation the



FIG. 172.—GENERAL VIEW OF PLANT FOR CONCRETE PILES.

mixer is placed high enough to dump into this hopper car standing on the trucks. This two-storied car is pushed over to the form and the dump car run off and dumped directly into the form. In spite of the economy of this arrangement no great difference in the cost has resulted, partly because of the difficulty of handling the square piles. On the whole, in the absence of definite comparative tests, the writer is inclined to favor the rolled pile. Tests to determine the

relative strength of the two kinds will be made, however, for both compression and bending. It is probable that each form of pile will be found to have its own place and use.

As yet, no soil has been encountered in which wooden piles could be driven and in

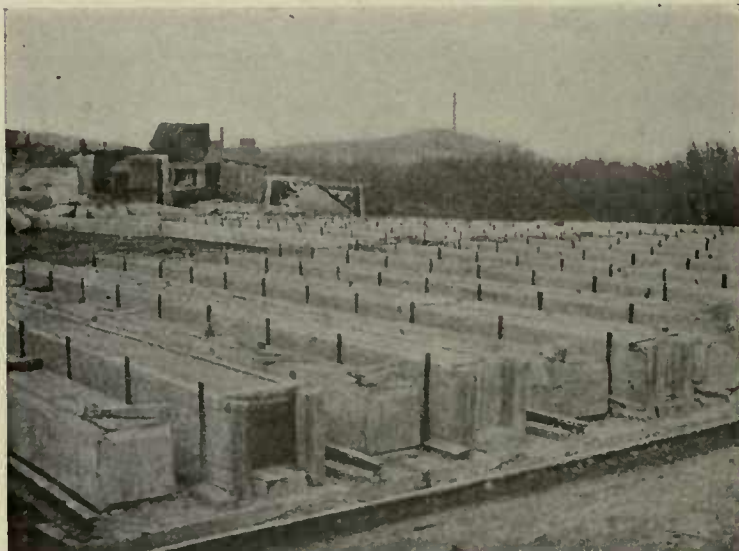


FIG. 173.—SQUARE MOULDED CONCRETE PILES.

which it has not been possible to drive the concrete piles. In some soils it is expedient to employ a jet; in others, an ordinary drop hammer, a steam hammer, or a combination

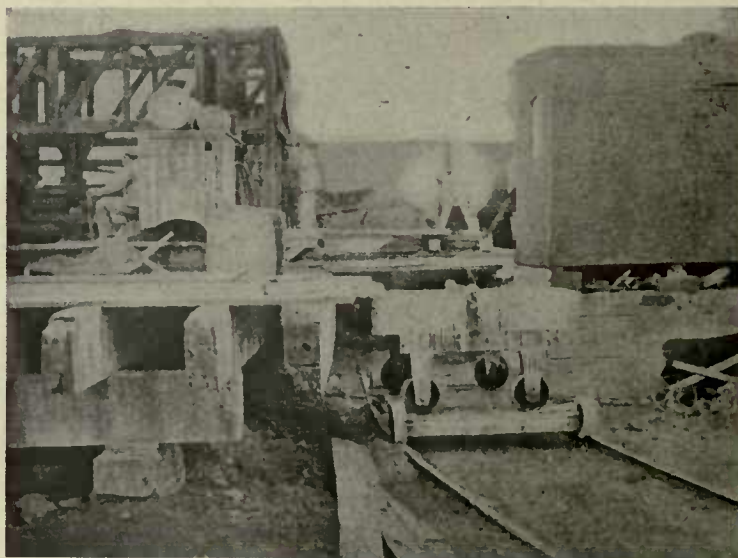


FIG. 174.—HOPPER CAR FOR MOULDED PILES.

of the jet with one or the other forms of hammer. It is necessary to lift the drop hammer somewhat more slowly for the concrete pile than for the wooden pile, in order not to set the driver into vibration. A cushion of some elastic material must be placed between the hammer and the pile, and with this precaution very little damage to the head of the pile



results, even after long-continued driving. As a matter of fact, it is surprising how much punishment a well-seasoned pile will stand. When it is necessary to drive the pile below the leads, as is generally the case, the follower is placed on top of the cushion. As the loads on these piles are great it is necessary to drive them to refusal, so that accurate knowledge of the required length is necessary. In case it is found that the piles so driven do not reach the elevation called for on the plans, the depth of the cap is increased accordingly. If it is found impossible or impractical to drive the piles to the depth anticipated, they can be cut off without difficulty. The cut need not be a smooth one, as the casting of the cap will take care of all irregularities of the head of the pile. Should settlement occur in a finished bent, the strength of the cap is important, so that the loads may be equalized and even settlement result. Experience has shown that the design of Fig. 166 provides sufficient strength. Slight

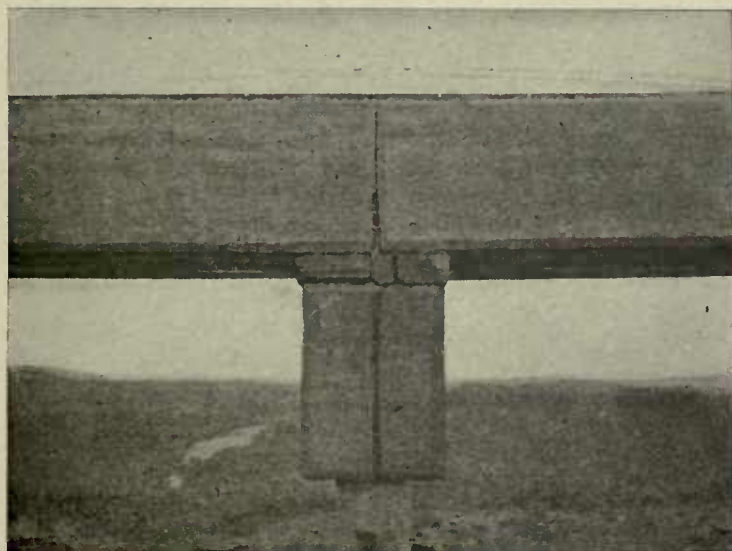


FIG. 175.—CONCRETE GIRDER, LEVELED UP AFTER SETTLEMENT.

settlement has taken place in two bridges but without causing cracks or damage. As the settlement was doubtless due to the fact that the piles had not been driven to refusal, a mass of concrete was placed about each settled bent, extending from just below the ground line to about 3 ft. below; the slabs were jacked up to grade and a layer of concrete was placed between them and the caps. This is shown in Fig. 175.

The manufacture of the floor slabs is best accomplished in a convenient yard, where advantage can be taken of economical methods. Such a plant is shown in the illustrations, Figs. 176 and 177, and in Fig. 178 are shown some of the slabs. It is necessary to provide a firm, unyielding bed. The sides and ends of the forms are removable, and as one span consists of two slabs, a temporary partition is placed in each form to be removed after a half span has been completed. A layer of paper is placed against the slab and the remaining half is cast. Drainage holes are also cast along the dividing line.

By referring again to Fig. 166 it will be seen that U bolts or stirrups are set in the

upper part of the slab to permit of its being easily handled. These are set at an angle so that there may be a direct pull when attached to a chain, thus obviating the necessity for a toggle-beam when lifting and placing the slabs.

After the slabs have remained in the forms for from two to four weeks, they are lifted

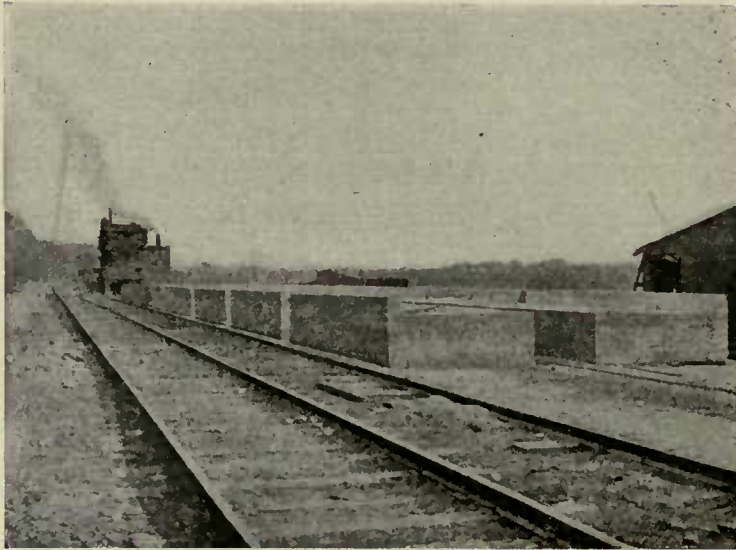


FIG. 176.—FLOOR SLABS IN YARD.



FIG. 177.—PLANT FOR FLOOR SLABS.

by means of a locomotive crane and piled to one side until hard enough for service, the minimum time for seasoning being three months. When seasoned they are readily erected by the same locomotive crane, a mortar joint being placed between the bottom of the slab and the cap.



After being erected the slabs are painted on top with a waterproofing compound, and the joints over the caps are filled with a mastic of tar or asphalt and sand. It is better to fill these joints with such material than to allow them to fill with sand, as the former will admit of the slight expansion necessary. Thus far, the best material for waterproofing with which experiments have been made on work under the direction of the writer, has been found to be a paint made of coal tar, Portland cement and kerosene, after a formula published in an engineering periodical a few years ago. This compound not only covers the surface, but sinks into and bonds with it, so that two or three coats are sometimes required. It is put on with paint brushes, in the same way as ordinary paint is applied.

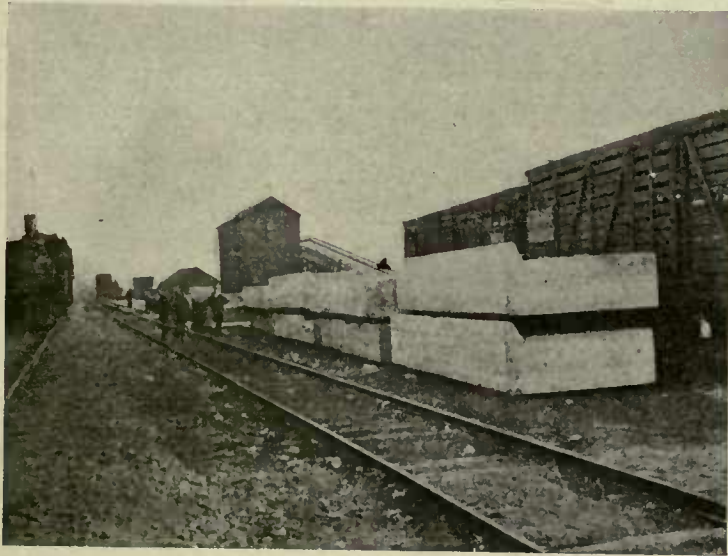


FIG. 178.—CONCRETE SLABS BEING SEASONED.

Another valuable attribute is its ability to adhere to moist or even wet concrete. Still another, and not its least recommendation, is its very low cost.

It is evident that in a pile trestle the piling must be capable of transmitting the lateral and longitudinal stresses to the ground, so that considerable bending strength is required.

The double bents are designed to take up such longitudinal stresses as might be apt to place undue bending on the piling. As a matter of fact the stiffness and weight of the floor are such that it is somewhat questionable whether the double bents are necessary. It seems well to put them in, however, as an extra precaution.

As to cost, it is difficult to generalize, as conditions of traffic, length of structure, etc., have a very important bearing. With men experienced in this work, several bridges of lengths of from 80 to 250 ft. have been built at a total cost of from \$20 to \$26 per lineal foot, and on lines carrying heavy traffic, while in one or two short bridges of two or three spans, the cost has been as high as \$45 per foot. For the purpose of estimating, a cost of \$30 per lineal foot plus a constant of \$300 will be ample for the design shown.

For bridges having a height above the ground line greater than 16 ft., a plan involving the use of thin piers is preferable. Photographs of several such structures are shown in

Figs. 179 and 180. The piers are heavily reinforced and are generally founded upon wooden piles cut off 5 or 6 ft. below the ground line. Because of the greater cost of these piers, it is generally economical to make the spans longer than 16 ft., spans of 18 to 25 ft. being

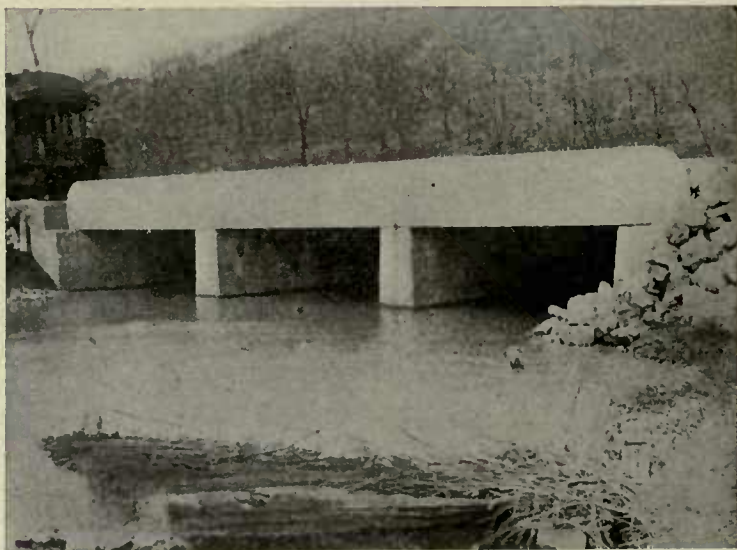


FIG. 179.—THROUGH GIRDER, CONCRETE TRESTLE ON PIERS.

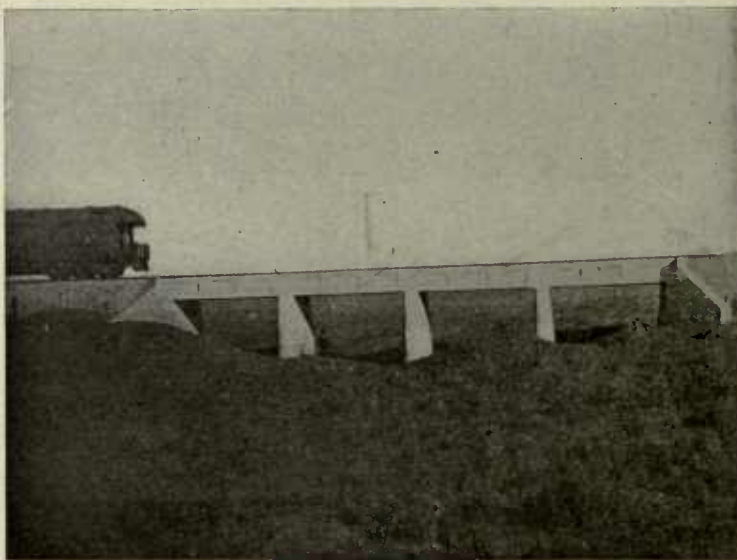


FIG. 180.—CONCRETE TRESTLE ON PIERS OVER 16 FT. HIGH.

common. A great number of such bridges have been built and have so far developed no defects. When the spans are as long as 25 ft., however, it is impracticable to build the slabs in a plant away from the bridge, because of their great weight. In general, it has been found best to build them on false work adjoining their final position and to jack them into position.



The writer wishes to lay especial stress upon the necessity for the use of the best materials and the most skillful labor on such work. Not only should the cement be tested, but also the sand to be used, unless its properties have already been thoroughly established. If the work of making piling or slabs is to be done by contract it should be done by experienced men, under proper specifications and under rigid inspection during every step of the process. If the work is done by company forces, the foreman must be one worthy of confidence, willing to obey instructions to the letter, and intelligent enough to realize the necessity for refinement of the work. The comparative novelty of reinforced concrete, and especially of such designs, makes necessary a most efficient organization for the work, and the placing of all possible safeguards to insure its integrity. Such organization and safeguards have been in effect in the case of steel construction for so long that they have become matters of course, and when reinforced concrete is carried on with similar care and scrupulous watchfulness, no fear need be felt as to its value as a material of construction. Without these, it is needless to say, it is dangerous.

It is possible, under some specifications, to design short-span steel bridges on concrete supports which will be as cheap as the designs described herein, but not, the writer believes, of equal strength to the bridges shown in these designs. Further, if the obvious advantages of ballasted, non-corrodible, fireproof bridges are considered, it will be seen that there is a preponderance of good qualities on the side of the reinforced concrete construction.

Some tests made on full-size rolled concrete piles similar to those described by Mr. Cartlidge were made by Prof. A. N. Talbot at the University of Illinois with the following results:\*

TABLE XXIX.

Compression Tests of Rolled Concrete Piles.

Spec.	Length, ft., in.	Equivalent Diameter, in.	Area sq. in.	Maximum Applied Load, lb.	Average Unit Stress, lb. per sq. in.	Age at Test, Months.	Remarks.
1	24 4	14.4	163	280,000	1720	4	Failed along a diagonal plane about 8 ft. from top. Many wires broken and long rods buckled at and near point of failure.
10	24 3	14.1	156	264,000	1690	4½	Failed by shattering at top and bottom.
10A	19 9	14.1	156	401,000	2570	12	This is No. 10 with injured ends cut off. Failed along a diagonal plane about 3 ft. from top.
9	20 7	15.0	177	231,000	1300	4	Shattered at top.
9A	19 3	15.0	177	350,000	1980	12	This is No. 9 with injured top cut off. Failed by shattering at bottom (original end).
2	20 5	15.3	184	260,000	1410	4	Failed at top by bulging and splitting; wires broken at end.
7	20 3	14.4	163	271,000	1660	4	Failed by shattering and splitting at top.
7A	17 0	14.4	163	319,000	1960	4	This is No. 7 with about 3 ft. cut from top. Failed by shattering at bottom.
7B	14 0	14.4	163	356,000	2180	4½	This is No. 7A with about 3 ft. cut from bottom. Failed by splitting near top.
4	20 0	15.0	177	214,000	1210	4½	Failed by shattering and splitting at bottom.
5	16 6	15.0	177	257,000	1450	4	Failed by bulging and splitting at bottom; long cracks extending 18 in. high.
8	16 6	14.8	172	176,000	1020	4	Shattered at bottom.
3	16 0	14.1	156	279,000	1790	4½	Top shattered.

\* Journal Western Society of Engineers, October, 1910, p. 558.



These tests show that such piles are ample for any load that would come upon them, especially as a large part of the pile is buried in and surrounded by earth and the head is encased in the concrete cap.

The use of concrete for building the entire structure, especially where the form of construction is an imitation of the pile trestle, is so recent that the final results of experience cannot be given at the present time. Sufficient time has not elapsed in which to gather much data under actual practical use and conditions, though the present outlook on the whole seems to point favorably to the continued use of this material.



## PART II.

### STANDARD TRESTLE PLANS.

NOTE.—As the quantity of much of the material in a trestle varies with the height and of all of it with the length, it was considered better to merely give a list of dimensions of the different parts rather than a bill of material for some special height and length in the descriptions of the following examples of construction.



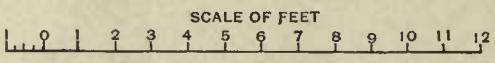
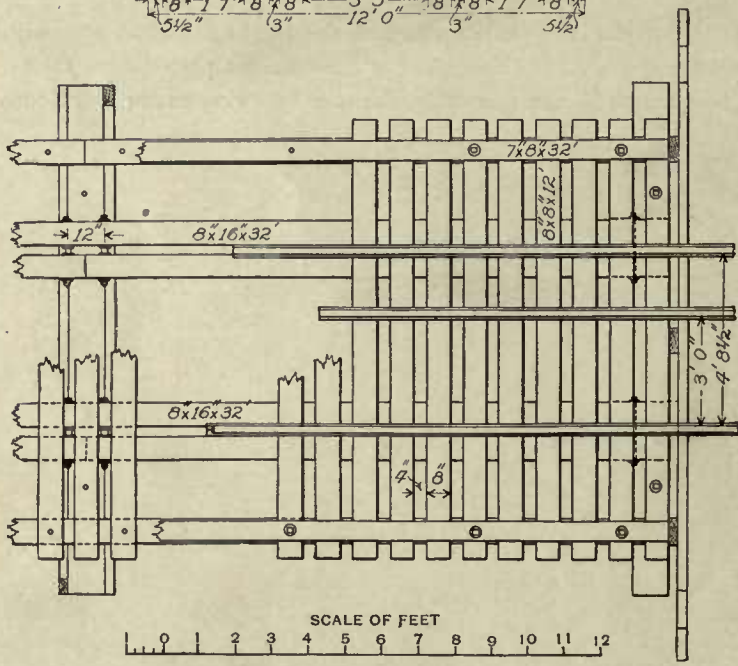
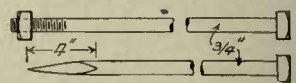
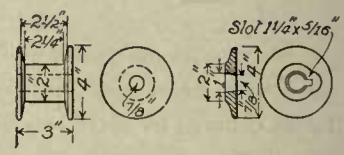
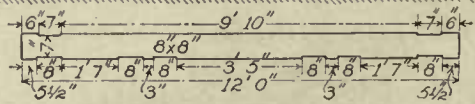
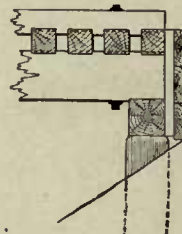
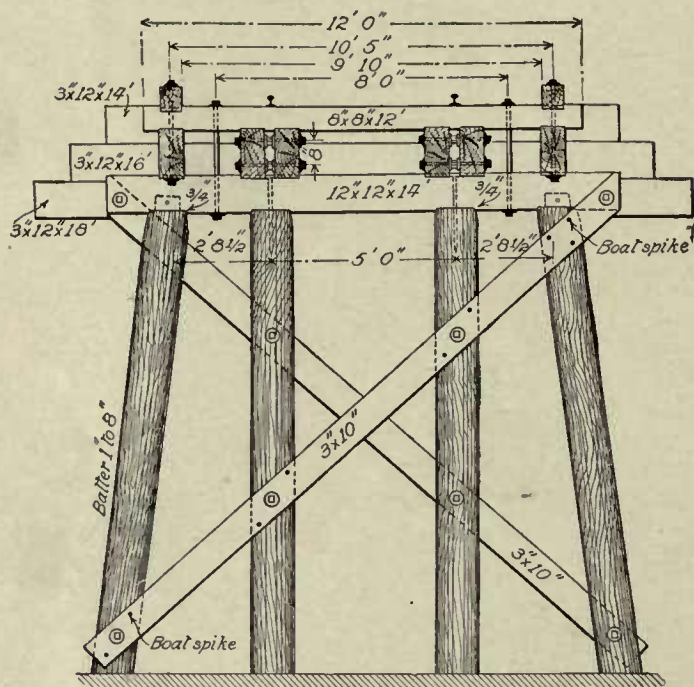


PLATE I.—STANDARD PILE-TRESTLE, DENVER & RIO GRANDE RAILROAD.



## PART II.

### STANDARD TRESTLE PLANS.

#### SECTION I.

#### PILE TRESTLES.

STANDARD PILE-TRESTLE, DENVER & RIO GRANDE RAILROAD.—PLATE I.

##### *Dimensions of Timber.*

- Floor-System : Guard-rails, 7 in.  $\times$  8 in.  $\times$  32 ft., notched 1 in.  
Ties, 8 in.  $\times$  8 in.  $\times$  12 ft., notched  $\frac{1}{2}$  in. for both guard-rails and stringers  
as shown in detail.  
Track-stringers, 8 in.  $\times$  16 in.  $\times$  32 ft., notched  $\frac{3}{4}$  in. over caps.  
Jack-stringers, 8 in.  $\times$  16 in.  $\times$  32 ft., notched  $\frac{3}{4}$  in. over caps.  
Bent : Cap, 12 in.  $\times$  12 in.  $\times$  14 ft., notched  $\frac{3}{4}$  in. over piles.  
Sway-braces, 3 in.  $\times$  10 in.  
Piles, 14 in. diameter at top.  
Bank-bent : Dump-boards, 3 in.  $\times$  12 in.  $\times$  14 ft. ; 3 in.  $\times$  12 in.  $\times$  16 ft. ; 3 in.  $\times$  12 in.  
 $\times$  18 ft.  
Battens, 3 in.  $\times$  10 in.  $\times$  3 ft.

##### *Dimensions of Iron Details.*

- Bolts :  $\frac{3}{4}$  in.  $\times$  33 in. ; guard-rail to ties and jack-stringers.  
 $\frac{3}{4}$  in.  $\times$  38 in. ; ties to caps.  
 $\frac{3}{4}$  in.  $\times$  22 in. ; stringer-joints ; packing-bolts.  
 $\frac{3}{4}$  in.  $\times$  18 in. ; sway-braces to posts.  
Drift-bolts :  $\frac{3}{4}$  in.  $\times$  22 in. ; caps to piles.  
Boat-spikes :  $\frac{1}{2}$  in.  $\times$  8 in. ; sway-braces to posts.  
Cast washers :  $\frac{5}{8}$  in.  $\times$  4 in. ; under heads and nuts of  $\frac{3}{4}$ -in. bolts.  
Cast separators : 3 in.  $\times$  4 in. ; between stringer-pieces for  $\frac{3}{4}$ -in. bolts.

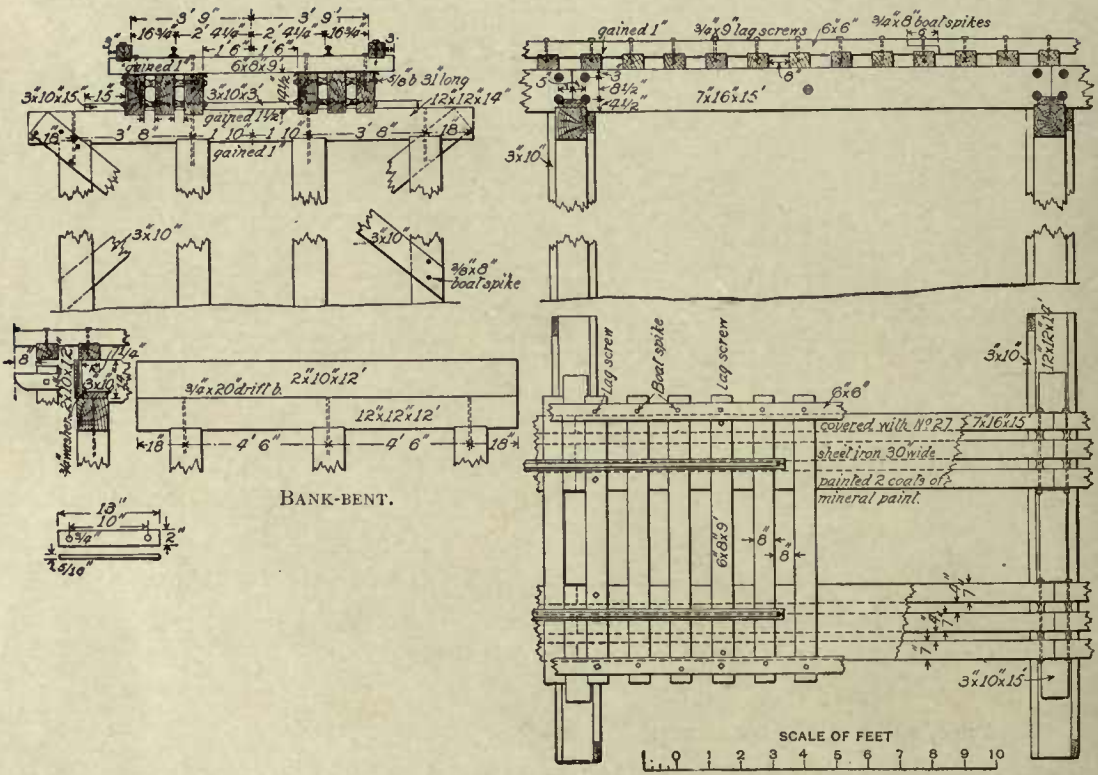


PLATE II.—STANDARD PILE-TRESTLE, TOLEDO, ST. LOUIS & KANSAS CITY RAILROAD.



## STANDARD PILE-TRESTLE, TOLEDO, ST. LOUIS &amp; KANSAS CITY RAILROAD.—PLATE II.

*Dimensions of Timber.*

- Floor-system:** Guard-rails, 6 in.  $\times$  6 in., notched 1 in. over ties.  
 Ties, 6 in.  $\times$  8 in.  $\times$  9 ft.  
 Stringers, 7 in.  $\times$  16 in.  $\times$  15 ft., notched  $1\frac{1}{2}$  in. over caps.  
 Brace-blocks, 3 in.  $\times$  10 in.  $\times$  15 in.; 3 in.  $\times$  10 in.  $\times$  3 ft.
- Bents:** Caps, 12 in.  $\times$  12 in.  $\times$  14 ft., notched 1 in. over piles.  
 Sway-braces, 3 in.  $\times$  10 in.  
 Piles, 4.
- Bank-bent:** Dump-board, 2 in.  $\times$  10 in.  $\times$  12 ft.  
 Cap, 12 in.  $\times$  12 in.  $\times$  12 ft.  
 Piles, 3.

*Dimensions of Iron Details.*

- Bolts:**  $\frac{5}{8}$  in.  $\times$  31 in.; stringer-joints, packing-bolts.
- Lag-screws:**  $\frac{3}{4}$  in.  $\times$  9 in.;  $\left\{ \begin{array}{l} \text{guard-rails to ties.} \\ \text{ties to stringers.} \end{array} \right.$
- Boat-spike:**  $\frac{3}{8}$  in.  $\times$  8 in.;  $\left\{ \begin{array}{l} \text{guard-rails to ties.} \\ \text{sway-braces to posts.} \end{array} \right.$
- Drift-bolts:**  $\frac{3}{4}$  in.  $\times$  20 in.; caps to piles.
- Wrought strap:** 13 in.  $\times$  2 in.  $\times$   $\frac{5}{16}$  in.; stringer-joints.
- Cast separators:** 4 in. thick; between stringers.
- Cast washers:** Under head and nut of each bolt.
- Sheet-iron:** No. 27, 30 in. wide; to cover stringers.



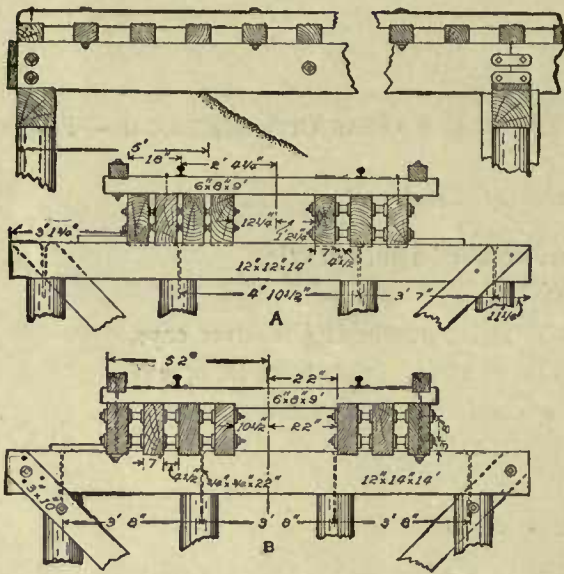


FIG. 1.—DETAILS OF FLOOR-SYSTEMS.

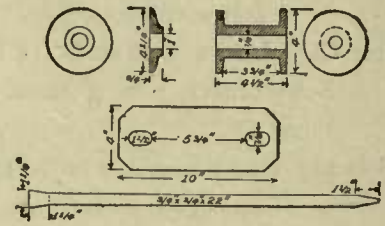
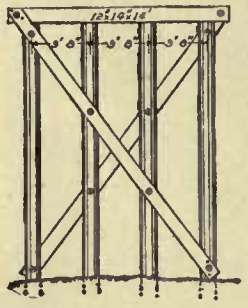
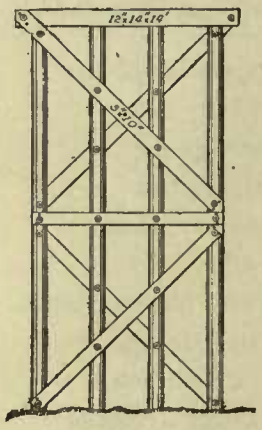


FIG. 3.—IRON DETAILS.

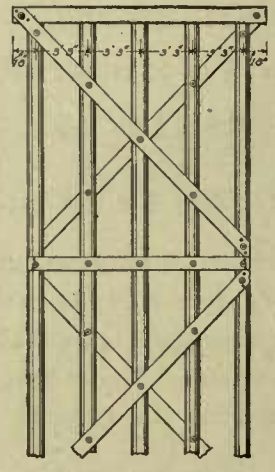


A, UP TO 18 FT. HIGH.



B, 19 TO 26 FT. HIGH.

FIG. 2.—PILE-BENTS.



C, 27 TO 32 FT. HIGH.

PLATE III.—STANDARD PILE-TRESTLES, ATLANTIC & PACIFIC RAILROAD.



## STANDARD PILE-TRESTLE, ATLANTIC &amp; PACIFIC RAILROAD.—PLATE III.

(See also Plate XXXI.)

*Dimensions of Timbers.*

Floor-systems—Fig. 1, A: Guard-rails, 6 in.  $\times$  6 in.  $\times$  16 feet.  
 Ties, 6 in.  $\times$  8 in.  $\times$  9 ft.  
 Stringers, 7 in.  $\times$  16 in.  $\times$  15 ft.  
 Brace-blocks, 2 in.  $\times$  10 in.  $\times$  18 in.

Fig. 1, B: same as above.

Bents: Caps, 12 in.  $\times$  14 in.  $\times$  14 ft.  
 All sway-braces, 3 in.  $\times$  10 in.  
 Piles, 12 in. diameter.

*Dimensions of Iron Details.*

Floor-system—Fig. 1, B; Four-piece stringer:

Bolts,  $\frac{3}{4}$  in.  $\times$  46 in.; stringer-joints.  
 Packing-bolts,  $\frac{3}{4}$  in.  $\times$  30 in.; guard-rails to stringers.  
 Splice-plates:  $4\frac{3}{8}$  in.  $\times$  4 in.  $\times$  10 in.; stringer-joints.  
 Cast separators: 4 in.  $\times$   $4\frac{1}{2}$  in.; between stringer-pieces;  $\frac{3}{4}$ -in. bolts.  
 Cast washers:  $\frac{3}{4}$  in.  $\times$   $4\frac{1}{4}$  in.; under head and nut of each bolt.  
 Spikes: Boat,  $\frac{5}{8}$  in.  $\times$   $\frac{5}{8}$  in.  $\times$  7 in.;  
 Cut 20-penny.

Three-piece stringer: Bolts,  $\frac{3}{4}$  in.;  $\times$  34 in.; stringer-joints; packing-bolts.

$\frac{3}{4}$  in.  $\times$  30 in.; guard-rails to stringers.  
 Splice-plates, as above.  
 Cast separators, as above.  
 Cast washers, as above.  
 Spikes: Boat, as above. Cut, as above.

Bents: Bolts,  $\frac{3}{4}$  in.  $\times$  20 in.; sway-braces to piles.

Drift-bolts:  $\frac{3}{4}$  in.  $\times$   $\frac{3}{4}$  in.  $\times$  22 in.; caps to piles.

Boat-spikes:  $\frac{5}{8}$  in.  $\times$   $\frac{5}{8}$  in.  $\times$  7 in.; sway-braces to piles.

Cast washers:  $\frac{3}{4}$  in.  $\times$   $4\frac{1}{4}$  in.; under head and nut of each bolt.





STANDARD PILE-TRESTLE, CHICAGO & WEST MICHIGAN RAILWAY.—PLATE IV

(See also Plate X.)

*Dimensions of Timbers.*

- Floor-system: Guard-rails, 8 in. × 10 in., notched 2 in. over ties.  
 Ties, 6 in. × 8 in. × 12 ft., notched  $\frac{1}{2}$  in. over stringers.  
 Stringers, 6 in. × 16 in. × 24 ft.
- Bent: Cap, 12 in. × 12 in. × 14 ft.  
 Sway-braces, 3 in. × 12 in.  
 Piles, 12 in. diameter.
- Bank-bent: Dump-plank, 3 in. × 12 in. × 16 ft.

*Dimensions of Iron Details.*

- Bolts:  $\frac{3}{4}$  in. × 32 in.; guard-rails to stringers.  
 $\frac{3}{4}$  in. × 16 $\frac{1}{2}$  in.; stringer-joints; packing-bolts.  
 $\frac{3}{4}$  in. × 18 in.; sway-braces to piles.
- Drift-bolts:  $\frac{3}{4}$  in. × 24 in.; stringers to caps.
- Boat-spikes:  $\frac{3}{8}$  in. × 7 in.; sway-braces to piles.
- Cast washers:  $\frac{3}{4}$  in. × in. 3 $\frac{1}{2}$  in.; under head and nut of each bolt.

Other dimensions as per following table:

BOLT.	A	B	C	D	E	F	G	WEIGHT.
$\frac{5}{8}$ "— $\frac{3}{4}$ "	$\frac{3}{4}$ "	$\frac{7}{8}$ "	1"	3 $\frac{1}{2}$ "	2"	$\frac{1}{2}$ "	$\frac{5}{8}$ "	1 $\frac{1}{4}$ lbs.
$\frac{7}{8}$ "—1"	1"	1 $\frac{1}{8}$ "	1 $\frac{1}{4}$ "	5"	2 $\frac{1}{2}$ "	$\frac{5}{8}$ "	$\frac{1}{2}$ "	
1 $\frac{1}{8}$ "—1 $\frac{1}{4}$ "	1 $\frac{1}{4}$ "	1 $\frac{3}{8}$ "	1 $\frac{3}{8}$ "	6"	3"	$\frac{3}{4}$ "	1 $\frac{1}{8}$ "	
1 $\frac{3}{8}$ "—1 $\frac{1}{2}$ "	1 $\frac{1}{2}$ "	1 $\frac{5}{8}$ "	1 $\frac{3}{4}$ "	7 $\frac{1}{4}$ "	3 $\frac{1}{2}$ "	$\frac{7}{8}$ "	1 $\frac{1}{2}$ "	
1 $\frac{5}{8}$ "—1 $\frac{3}{4}$ "	1 $\frac{3}{4}$ "	1 $\frac{7}{8}$ "	2"	8 $\frac{1}{2}$ "	4 $\frac{1}{2}$ "	1"	$\frac{1}{2}$ "	
1 $\frac{7}{8}$ "—2"	2"	2 $\frac{1}{8}$ "	2 $\frac{1}{4}$ "	9 $\frac{1}{2}$ "	5"	1 $\frac{1}{8}$ "	$\frac{3}{4}$ "	

- Cast separators: 3 in. × 2 in. thick; between stringer-pieces.  
 These trestles are built with spans of 12 ft., 14 ft., and 16 ft.

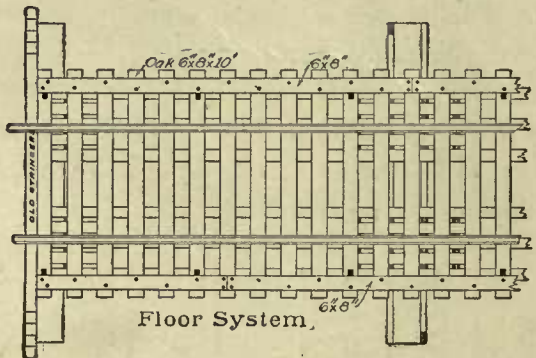
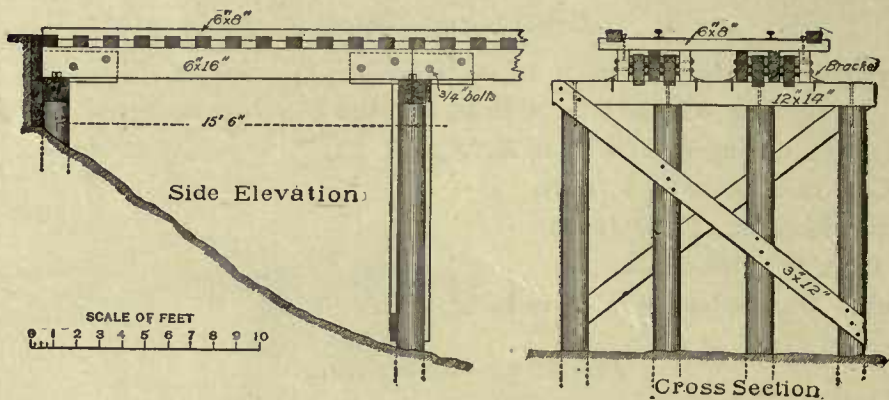


PLATE V.—STANDARD PILE-TRESTLE, MINNEAPOLIS & ST. LOUIS RAILWAY.



STANDARD PILE-TRESTLE, MINNEAPOLIS & ST. LOUIS RAILWAY.—PLATE V.

(See also Plate XXII.)

*Dimensions of Timbers.*

Floor-system : Guard-rail, 6 in.  $\times$  8 in., notched 2 in. over ties.

Ties, 6 in.  $\times$  8 in.  $\times$  10 ft., white oak.

Stringers, 6 in.  $\times$  16 in.  $\times$  15 ft. 6 in.

Packing-block, 6 in.  $\times$  16 in.  $\times$  5 ft. 4 in., notched 2 in. over caps.

Bent : Cap, 12 in.  $\times$  14 in.  $\times$  14 ft., laid flat.

Sway-braces, 3 in.  $\times$  12 in.

Piles, not less than 11 in. diameter.

Bank-bent : Dump-plank, old stringers.

*Dimensions of Iron Details.*

Bolts :  $\frac{3}{4}$  in.  $\times$  41 in.; stringer-joints; packing-bolts.

Lag-screws : Stringer-brackets to caps.

Spikes : Boat,  $\frac{1}{2}$  in.  $\times$  8 in.; guard-rails to ties.

Drift-bolts :  $\frac{5}{8}$  in.  $\times$  12 in.; ties to stringers.

$\frac{7}{8}$  in.  $\times$  22 in.; caps to piles.

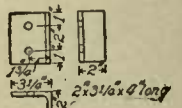
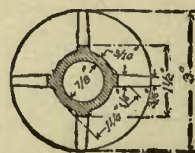
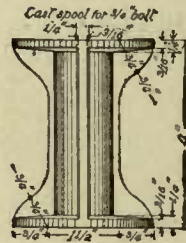
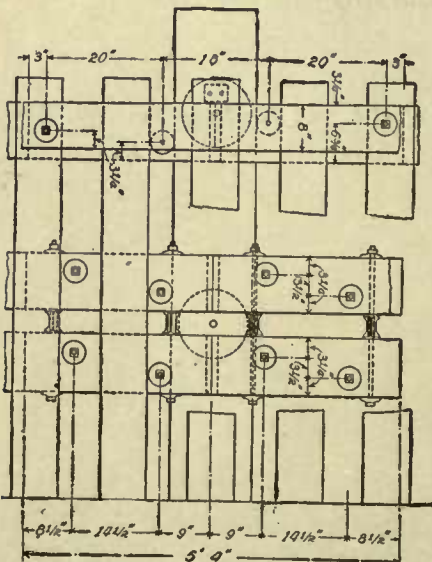
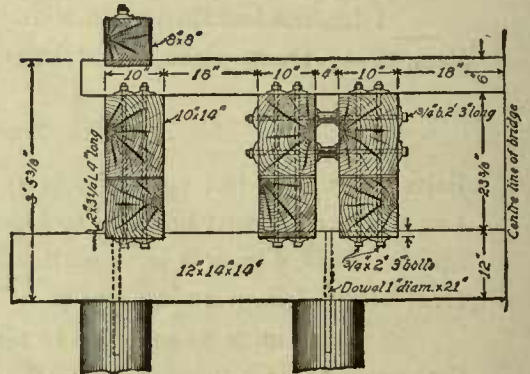
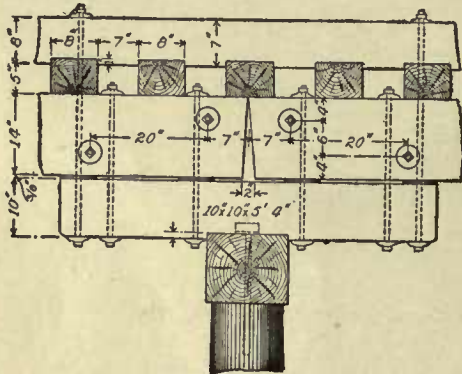
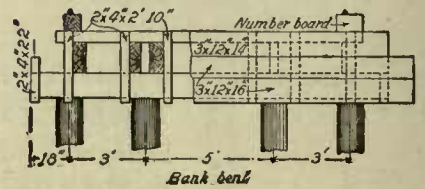
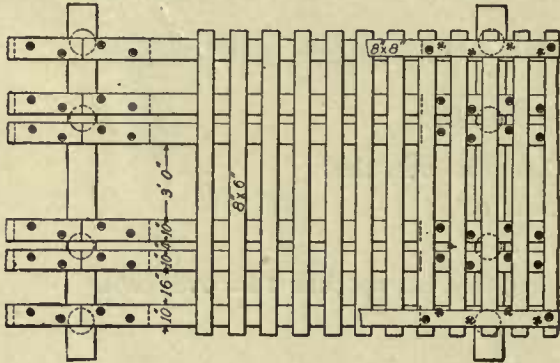
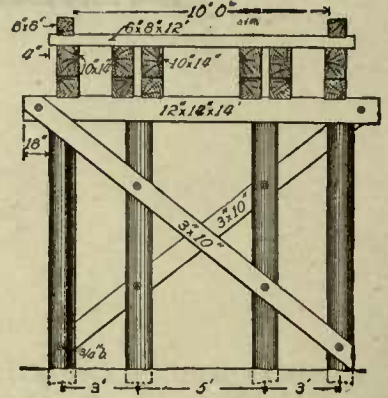
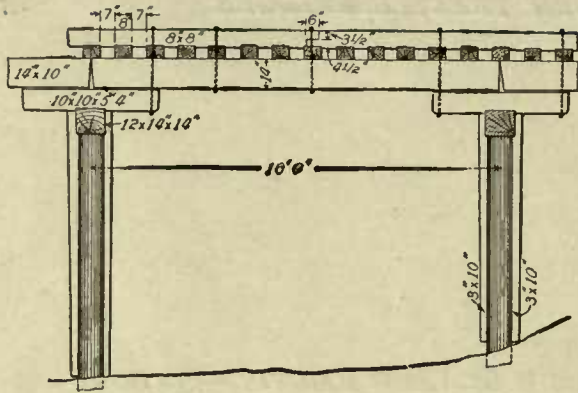
Cast separators : 2 in. wide; between packing-blocks and stringers.

Cast washers : Under head and nut of each bolt.

Cast brackets : Stringers to caps.

For arguments in favor of and description of this trestle, see *Railroad Gazette*, April 17, 1891.





Cast-iron Spool.

Corbel-stringer Separator.

Angle-lug.

DETAILS OF STRINGER-JOINT.

PLATE VI.—STANDARD PILE-TRESTLE, CHICAGO & NORTHWESTERN RAILWAY.

IRON DETAILS.



## STANDARD PILE-TRESTLE, CHICAGO &amp; NORTHWESTERN RAILWAY.—PLATE VI.

*Dimensions of Timbers.*

**Floor-system :** Guard-rails, 8 in.  $\times$  8 in.  $\times$  16 ft., notched 1 in. over ties.

Ties, 6 in.  $\times$  8 in.  $\times$  12 ft., white oak.

Track-stringers, 10 in.  $\times$  14 in.  $\times$  16 ft.

Jack-stringers: 10 in.  $\times$  14 in.  $\times$  16 ft.

Corbels, 10 in.  $\times$  10 in.  $\times$  5 ft. 4 in., notched 1 in. over cap, and used only on bridges of two spans or over.

**Beats :** Cap, 12 in.  $\times$  14 in.  $\times$  14 ft.

Sway-braces, 3 in.  $\times$  10 in.

Piles, 12 in. diameter.

**Bank-bent :** Dump-plank,  $\left\{ \begin{array}{l} 3 \text{ in.} \times 10 \text{ in.} \times 16 \text{ ft.;} \\ 3 \text{ in.} \times 12 \text{ in.} \times 14 \text{ ft.;} \\ 3 \text{ in.} \times 12 \text{ in.} \times 16 \text{ ft.} \end{array} \right.$

Battens,  $\left\{ \begin{array}{l} 2 \text{ in.} \times 4 \text{ in.} \times 34 \text{ in.;} \\ 2 \text{ in.} \times 4 \text{ in.} \times 22 \text{ in.} \end{array} \right.$

Number-boards:  $1\frac{1}{2}$  in.  $\times$  8 in.  $\times$  12 in.

*Dimensions of Iron Details.*

**Bolts :**  $\frac{3}{4}$  in.  $\times$  2 ft. 3 in.; stringer-joints; packing-bolts; also stringers to corbels.

$\frac{3}{4}$  in.  $\times$  2 ft.  $5\frac{1}{4}$  in.; guard-rails to stringers.

$\frac{3}{4}$  in.  $\times$  3 ft.  $4\frac{1}{2}$  in.; guard-rails to corbels.

$\frac{3}{4}$  in.  $\times$   $19\frac{1}{2}$  in.; sway-braces to caps and piles.

**Dowels :** 1 in.  $\times$  21 in.; caps to piles.

**Spikes :** Boat,  $\frac{5}{16}$  in.  $\times$  5 in.

Cut 30-penny.

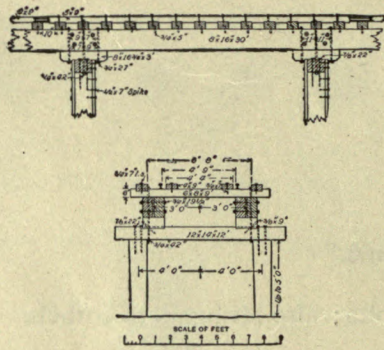
**Cast separators :** 3 in.  $\times$  4 in.; as per detail drawing; between stringer-pieces.

6 in.  $\times$  10 in.; as per detail drawing; between stringers and corbels.

**Cast washers :** Under head and nut of each bolt.

**Angle-iron lugs :** 2 in.  $\times$   $3\frac{1}{2}$  in. L  $\times$  4 in. long; hold stringers in place.





FIGS. 1, 2.—FOR HEIGHTS OF 5 FT. OR UNDER.

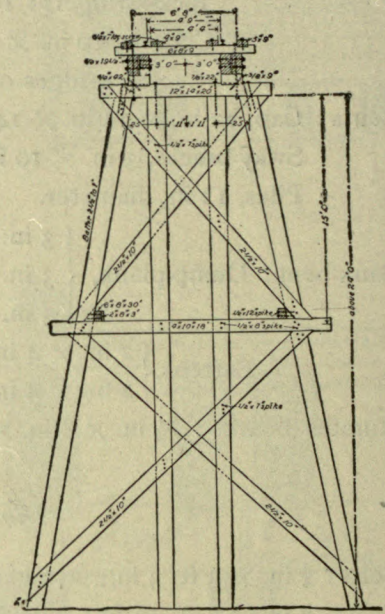


FIG. 3.—FOR HEIGHTS ABOVE 24 FT.

PLATE VII.—STANDARD PILE-TRESTLE, LOUISVILLE & NASHVILLE RAILROAD.



## STANDARD PILE-TRESTLE, LOUISVILLE &amp; NASHVILLE RAILROAD.—PLATE VII.

(See also Plates VIII and XVII.)

*Dimensions of Timbers.*

Floor System: Guard-rails, outside, 5 in.  $\times$  9 in., notched 1 in. over ties.  
inside, 4 in.  $\times$  9 in., not notched.

Ties, 6 in.  $\times$  8 in.  $\times$  9 ft.

Stringers, 8 in.  $\times$  16 in.  $\times$  30 ft.

Corbels, 8 in.  $\times$  16 $\frac{3}{4}$  in.  $\times$  3 ft., notched 1 in. over caps.

Bents: Caps, 12 in.  $\times$  14 in.  $\times$  12 feet.

Sway-braces, diagonal, 2 $\frac{1}{2}$  in.  $\times$  10 in.

horizontal, 4 in.  $\times$  10 in.

Piles, 12 in. diameter.

Girts: 6 in.  $\times$  8 in.  $\times$  30 ft.

Splice-blocks: 2 in  $\times$  8 in.  $\times$  3 ft.

*Dimensions of Iron Details.*

Bolts:  $\frac{3}{4}$  in.  $\times$  27 in.; stringers to corbels.

$\frac{3}{4}$  in.  $\times$  19 $\frac{1}{2}$  in.; stringer-joints; packing-bolts.

$\frac{3}{4}$  in.  $\times$  42 in.; floor-system to caps.

Drift-bolts:  $\frac{7}{8}$  in.  $\times$  22 in.; caps to piles.

Dowels:  $\frac{3}{4}$  in.  $\times$  5 in.; ties to stringers.

Spikes:  $\frac{3}{8}$  in.  $\times$  9 in.; corbels to caps.

$\frac{1}{2}$  in.  $\times$  8 in.; horizontal sway-braces to piles.

$\frac{1}{2}$  in.  $\times$  7 in.; diagonal sway-braces to piles.

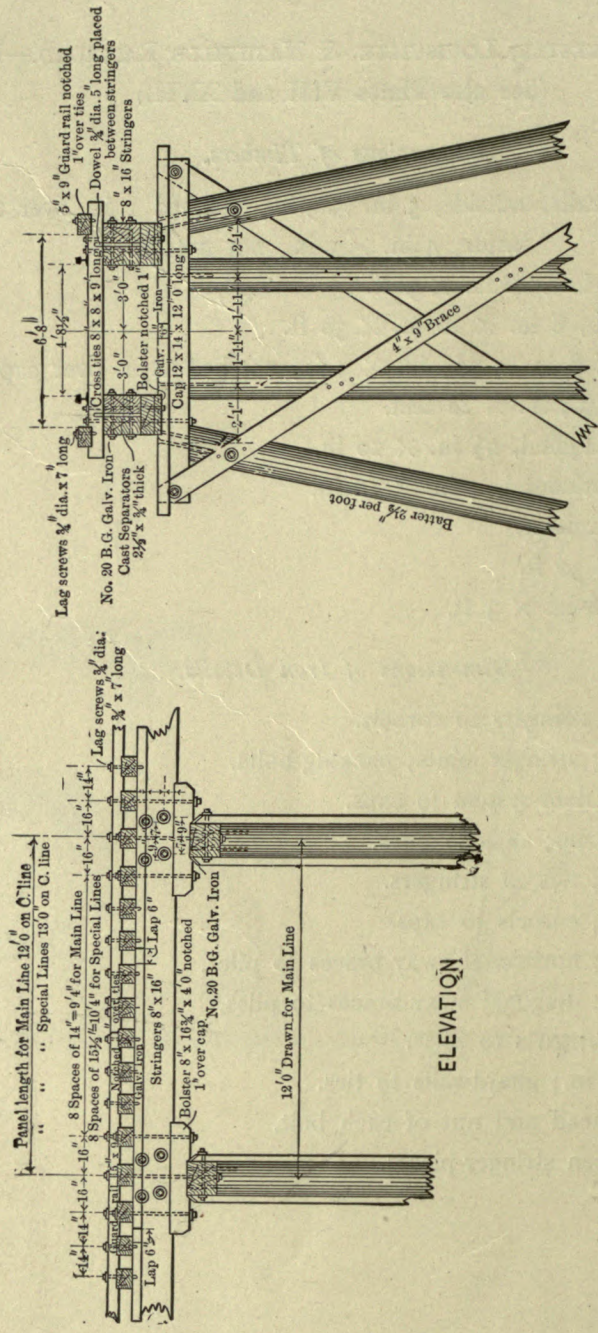
$\frac{1}{2}$  in.  $\times$  12 in.; girts to piles.

Lag-screws:  $\frac{3}{4}$  in.  $\times$  7 in.; guard-rails to ties.

Cast washers: Under head and nut of each bolt.

Cast separators: Between stringer-pieces.





SECTION

ELEVATION

PLATE VIIA.—PILE TRESTLE (1906). LOUISVILLE & NASHVILLE RAILROAD.



## LOUISVILLE &amp; NASHVILLE RAILROAD.—PLATE VIIA.

The recent standard plans of the Louisville & Nashville Railroad for pile-trestles with open floors are as shown in Plate VIIA according to the Proceedings of the Association of Railway Superintendents of Bridges and Buildings, 1906. For earlier trestles of this road see Plates VII, VIII and XVII. For more recent trestles with ballasted floor see Plate LXIII.

*Dimensions of Timbers.*

Floor System: Guard Rails, 5 in.  $\times$  9 in.  
 Ties, 8 in.  $\times$  8 in.  $\times$  9 ft.  
 Stringers, 8 in.  $\times$  16 in.  
 Bolsters, 8 in.  $\times$  16 $\frac{3}{4}$  in.  $\times$  4 ft.  
 Bents: Caps, 12 in.  $\times$  14 in.  $\times$  12 ft.  
 Braces, 4 in.  $\times$  9 in.

*Dimensions of Iron Details.*

Lag Screws:  $\frac{3}{4}$  in.  $\times$  7 in.; guard-rails to ties.  
 Dowels:  $\frac{3}{4}$  in.  $\times$  5 in.; inserted in ties and extending down between stringers.  
 Bolts: through ties, stringers, bolsters and caps.  
 Through stringers at joints.  
 Through ties, stringers and bolsters.  
 Through bracing.

Drift-bolts: Caps to piles.

Cast Separators: Between stringers 2 $\frac{1}{2}$  in. diameter  $\times$   $\frac{3}{4}$  in. thick.

Stringers covered with No. 20 B. G. Galvanized Iron lapped 6 in. at ends of sheets.

Caps covered with No. 20 B. G. Galvanized Iron lapped 6 in. at ends of sheets.

*Note:*—All piles to be straight and not less than 10 in. at small end.

Where cedar piles are used they must be peeled clean of all bark and painted with creosote oil 3 ft. above the ground and 2 ft. below.

Mop the inside face and tops of stringers before putting on the galvanized iron.

Tops of caps and all other inaccessible surfaces to be mopped with creosote oil at the time of placing the timber. The cross-ties, guard-rails, bolsters, cross-bracing and bottom of piles 3 ft. above and 2 ft. below the ground to be mopped with creosote oil after the following summer so that the timber will have a good chance to season.



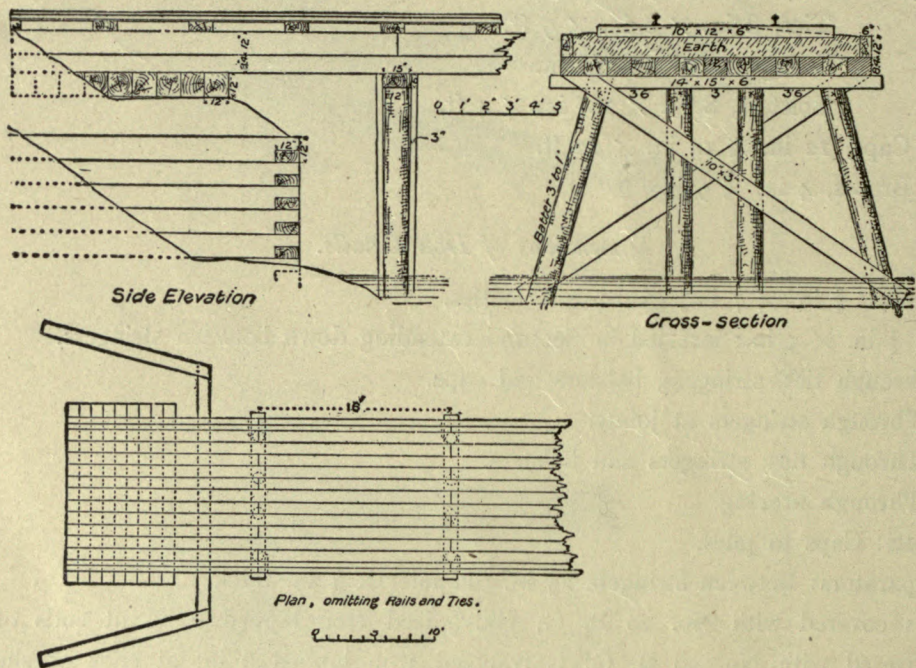


PLATE VIII.—PILE-TRESTLE WITH EARTH ROADBED, LOUISVILLE & NASHVILLE RAILROAD



PILE-TRESTLE WITH EARTH ROADBED, LOUISVILLE & NASHVILLE RAILROAD.—  
PLATE VIII. (See also Plates VII and XVII.)

*Dimensions of Timbers.*

Ties, 6 in.  $\times$  12 in.  $\times$  10 ft.

Side-timbers, 6 in.  $\times$  12 in.  $\times$  32 ft.

Floor-timbers, 8½ in.  $\times$  12 in.  $\times$  32 ft.

Caps, 6 in.  $\times$  15 in.  $\times$  14 ft.

Sway-bracing, 3 in.  $\times$  10 in.

Piles, 12 in. diameter.

Revetment-timbers, 12 in.  $\times$  12 in.

All timber creosoted yellow pine, spiked together. No bolts or mortise and tenon joints used.—*Eng. News*, Oct. 29, 1887.



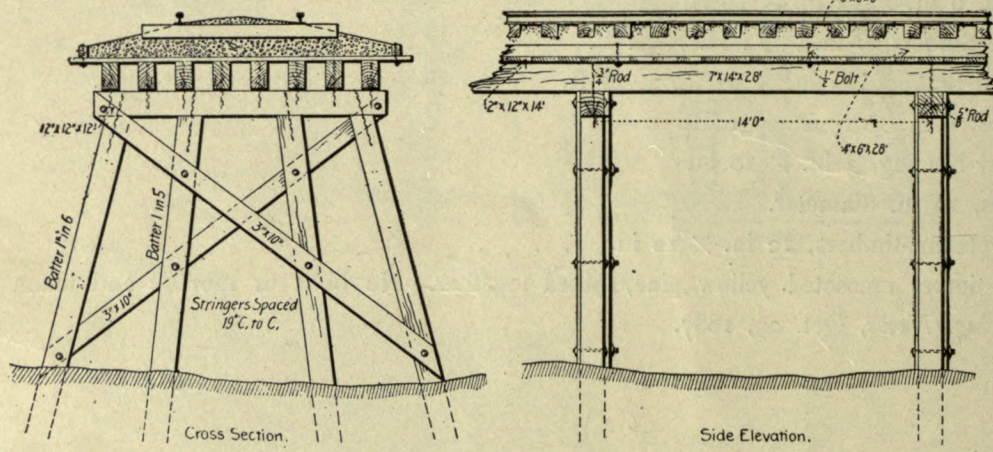


PLATE VIIIa.—TRESTLE WITH BALLASTED FLOOR, HOUSTON & TEXAS CENTRAL R. R.



STANDARD BALLASTED FLOOR-TRESTLE, HOUSTON & TEXAS CENTRAL RAILROAD.—  
PLATE VIII A.

*Dimensions of Timbers.*

Ties, 6 in.  $\times$  8 in.  $\times$  8 ft.

Flooring, 2 in.  $\times$  12 in.  $\times$  14 ft.

Side timbers, 4 in.  $\times$  6 in.  $\times$  28 ft.

Stringers (eight lines), 7 in.  $\times$  14 in.  $\times$  28 ft.

Caps, 12 in.  $\times$  12 in.  $\times$  12 ft.

Sway-bracing, 3 in.  $\times$  10 in.

Depth of ballast, 10 in. under ties.

All timber creosoted.

Average cost \$8.50 per linear foot.

—*Eng. News*, April 4, 1895, p. 228.



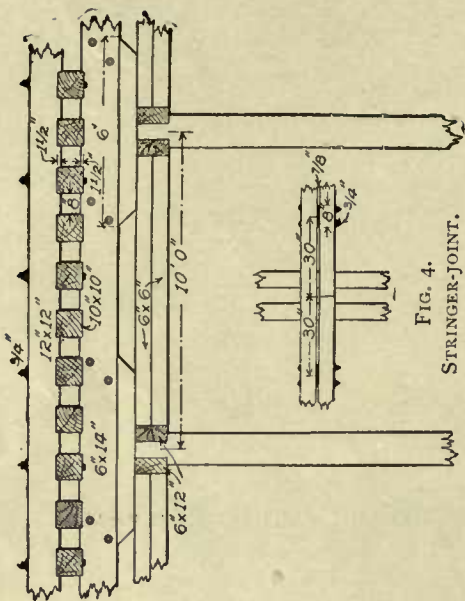


FIG. 4.  
STRINGER-JOINT.

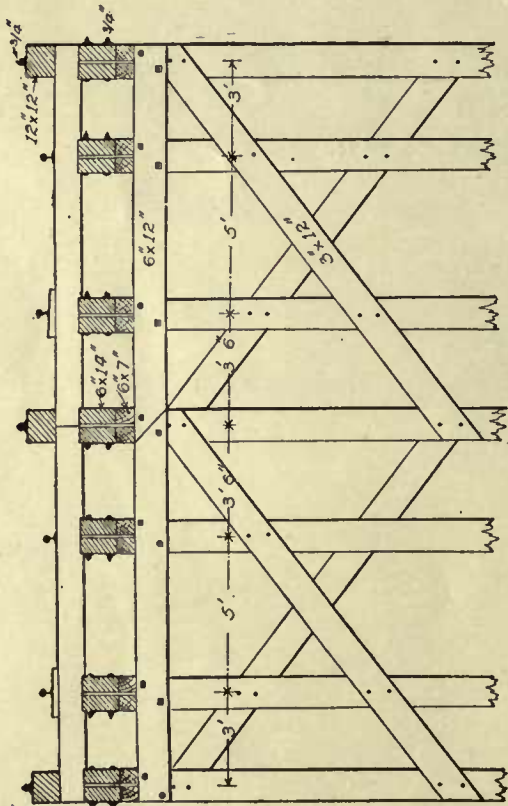


FIG. 1.—CROSS-SECTION.

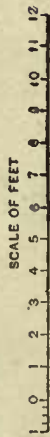


FIG. 2.—SIDE ELEVATION.

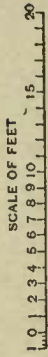
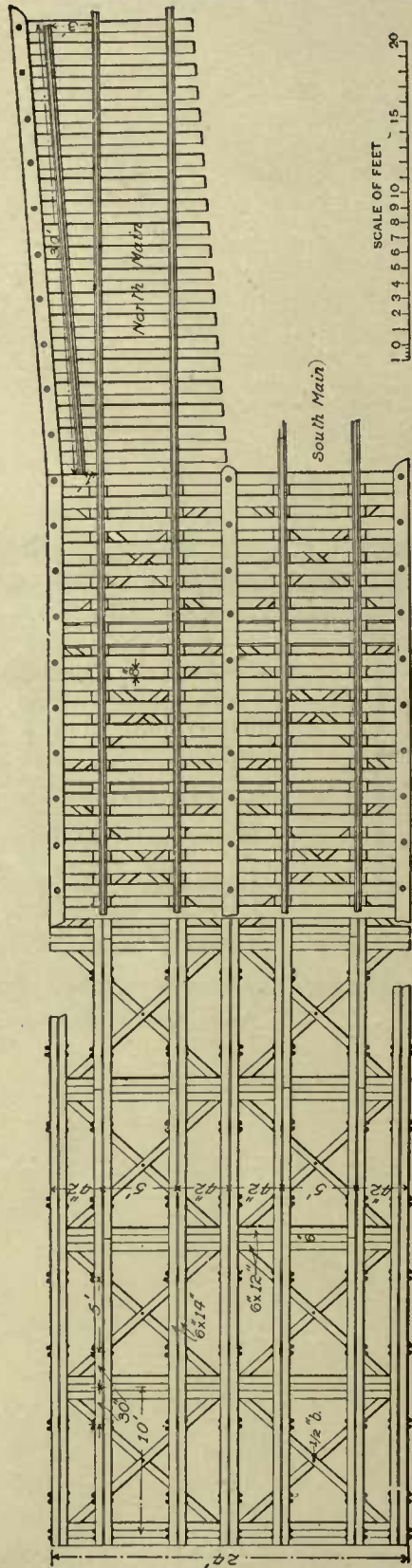


FIG. 3.—PLAN.



STANDARD PILE-TRESTLE, BOSTON & ALBANY RAILROAD.—PLATE IX.

*Dimensions of Timbers.*

- Floor-system : Guard-rails, 12 in.  $\times$  12 in., notched  $1\frac{1}{2}$  in. over ties.  
Ties, 10 in.  $\times$  10 in.  $\times$  12 ft., notched  $1\frac{1}{2}$  in. over stringers.  
Stringers, 6 in.  $\times$  14 in.  $\times$  30 ft.  
Corbels, 6 in.  $\times$  7 in.  $\times$  6 ft.
- Bents : Caps, 6 in.  $\times$  12 in.  $\times$  12 ft. 6 in.  
Sway-braces, 3 in.  $\times$  12 in.  
Piles, 12 in. diameter.
- Lateral braces : 6 in.  $\times$  6 in.

*Dimensions of Iron Details.*

- Bolts :  $\frac{3}{4}$  in.  $\times$   $23\frac{1}{2}$  in. ; guard-rails to ties.  
 $\frac{3}{4}$  in.  $\times$  16 in. ; stringer-joints ; packing-bolts.  
 $\frac{3}{4}$  in.  $\times$  21 in. ; caps to piles.  
 $\frac{1}{2}$  in.  $\times$   $13\frac{1}{2}$  in. ; lateral brace intersections.

Spikes.

Cast separators.

Cast washers.



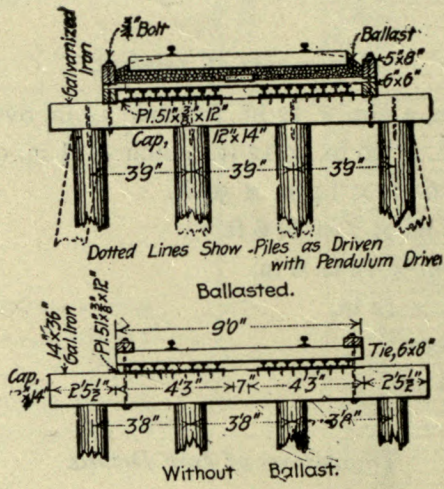


PLATE IXA.—RAIL FLOOR, ATCHISON, TOPEKA & SANTA FÉ RAILWAY.



ATCHISON, TOPEKA & SANTA FE RAILWAY.—TRESTLE OR BRIDGE WITH RAIL FLOOR.—  
PLATE IXA.

(See also Plate LVII.)

*Ballasted.*

Side Timbers: Timber 5 in.  $\times$  8 in. and 6 in.  $\times$  6 in.

Ties: 6 in.  $\times$  8 in.

Caps: 12 in.  $\times$  14 in.

Flooring.

Piles.

*Iron.*

Drift-bolts.

Bolts through side timbers and caps  $\frac{3}{4}$  in.

Stringers, old rails.

Bearing plates between rail stringers and caps 51 in.  $\times$   $\frac{3}{8}$  in.  $\times$  12 in.

Galvanized-iron covering for caps 14 in. wide.

Cast-iron washers for bolts.—*Engineering News*, May 28, 1903.



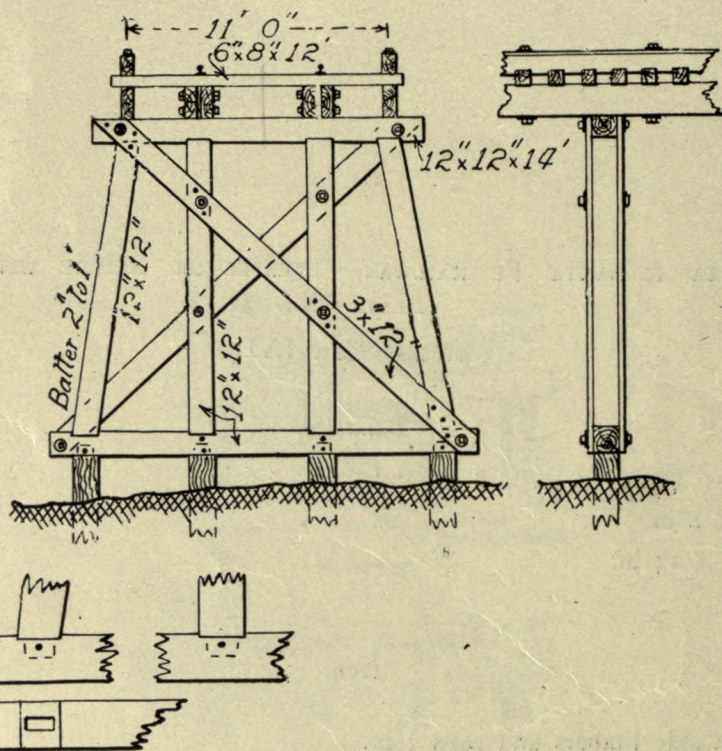


PLATE X.—STANDARD FRAMED TRESTLE, CHICAGO & WEST MICHIGAN RAILWAY.



SECTION II.

FRAMED TRESTLES.

STANDARD FRAMED TRESTLE, CHICAGO & WEST MICHIGAN RAILWAY.—PLATE X.

(See also Plate IV.)

*Dimensions of Timbers.*

Floor-system: Guard-rails, 8 in.  $\times$  10 in., notched 2 in. over ties.

Ties, 6 in.  $\times$  8 in.  $\times$  12 ft., notched  $\frac{1}{2}$  in. over stringers.

Stringers, 8 in.  $\times$  16 in.  $\times$  32 ft.

Bent: Cap, 12 in.  $\times$  12 in.  $\times$  14 ft.

Plumb-posts, 12 in.  $\times$  12 in.

Batter-posts, 12 in.  $\times$  12 in.; batter, 2 in. to 1 ft.

Sill, 12 in.  $\times$  12 in.

Sway-braces, 3 in.  $\times$  12 in.

Sub-sills, 12 in.  $\times$  12 in.  $\times$  6 ft

*Dimensions of Iron Details*

Same as for Plate IV.



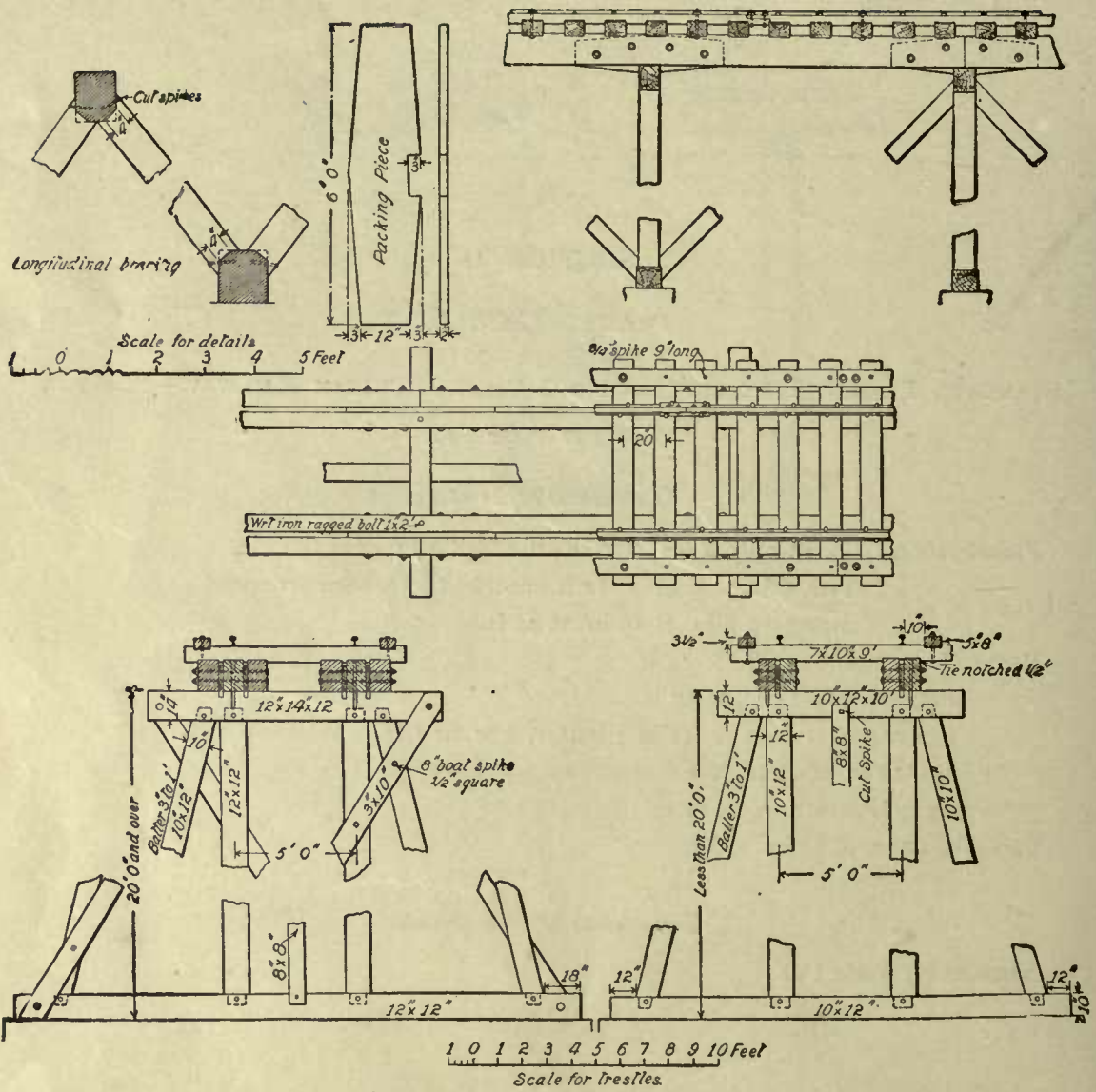


PLATE XI.—STANDARD FRAMED TRESTLES, PENNSYLVANIA RAILROAD.



STANDARD FRAMED TRESTLE, PENNSYLVANIA RAILROAD.—PLATE XI.

*Dimensions of Timbers.*

Floor-system: Guard-rails, 5 in. × 8 in., notched 1 in. over ties.

Ties, 7 in. × 10 in. × 9 ft., notched  $\frac{1}{2}$  in. to receive guard-rails, and  $\frac{1}{2}$  in. over stringers.

Stringers :

Clear Span.	Number of Pieces under each Rail.	Width of each Piece.	Depth of Stringers.
10 ft.	2	8 in.	15 in.
12 "	2	8 "	16 "
14 "	2	10 "	17 "
16 "	3	8 "	17 "

Packing-blocks, 2 in. × 18 × 6 ft.

Bents under 20 ft. : Cap, 10 in. × 12 in. × 10 ft.

Plumb-posts, 10 in. × 12 in.

Batter-posts, 10 in. × 10 in.; batter, 3 in. to 1 ft.

Sill, 10 in. × 12 in.

Bents 20 ft. and over: Cap, 12 in. × 14 in. × 12 ft.

Plumb-posts, 12 in. × 12 in.

Batter-posts, 10 in. × 12 in., batter 3 in. to 1 ft.

Sill, 12 in. × 12 in.

Sway-bracing, 3 in. × 10 in.

Bracing: Longitudinal, 8 in. × 8 in.

Treenails: Locust, 1 in. diameter.

*Dimensions of Iron Details.*

Bolts:  $\frac{3}{4}$  in. × —; guard-rails to ties.

$\frac{3}{4}$  in. × —; guard-rail joints.

$\frac{3}{4}$  in. × —; stringer-joints; packing-bolts.

All of above bolts have  $2\frac{1}{2}$ -in. flat heads, with  $2\frac{1}{2}$ -in. wrought washer under nuts.

✓  $\frac{3}{4}$  in. × —; sway-bracing to caps and sills; 3-in. wrought-iron washers used.

Drift-bolts (ragged): 1 in. × 24 in.; stringers to caps.

Spikes: Boat,  $\frac{3}{4}$  in. × 9 in.; guard-rails to ties.

$\frac{1}{2}$  in. × 8 in.; sway-braces to posts.

Cut  $\frac{1}{2}$  in. × 8 in., longitudinal braces to caps and sills.

Wrought washers:  $2\frac{1}{2}$  in. square for  $\frac{3}{4}$ -in. bolt.

3 in. round for  $\frac{3}{4}$ -in. bolt.

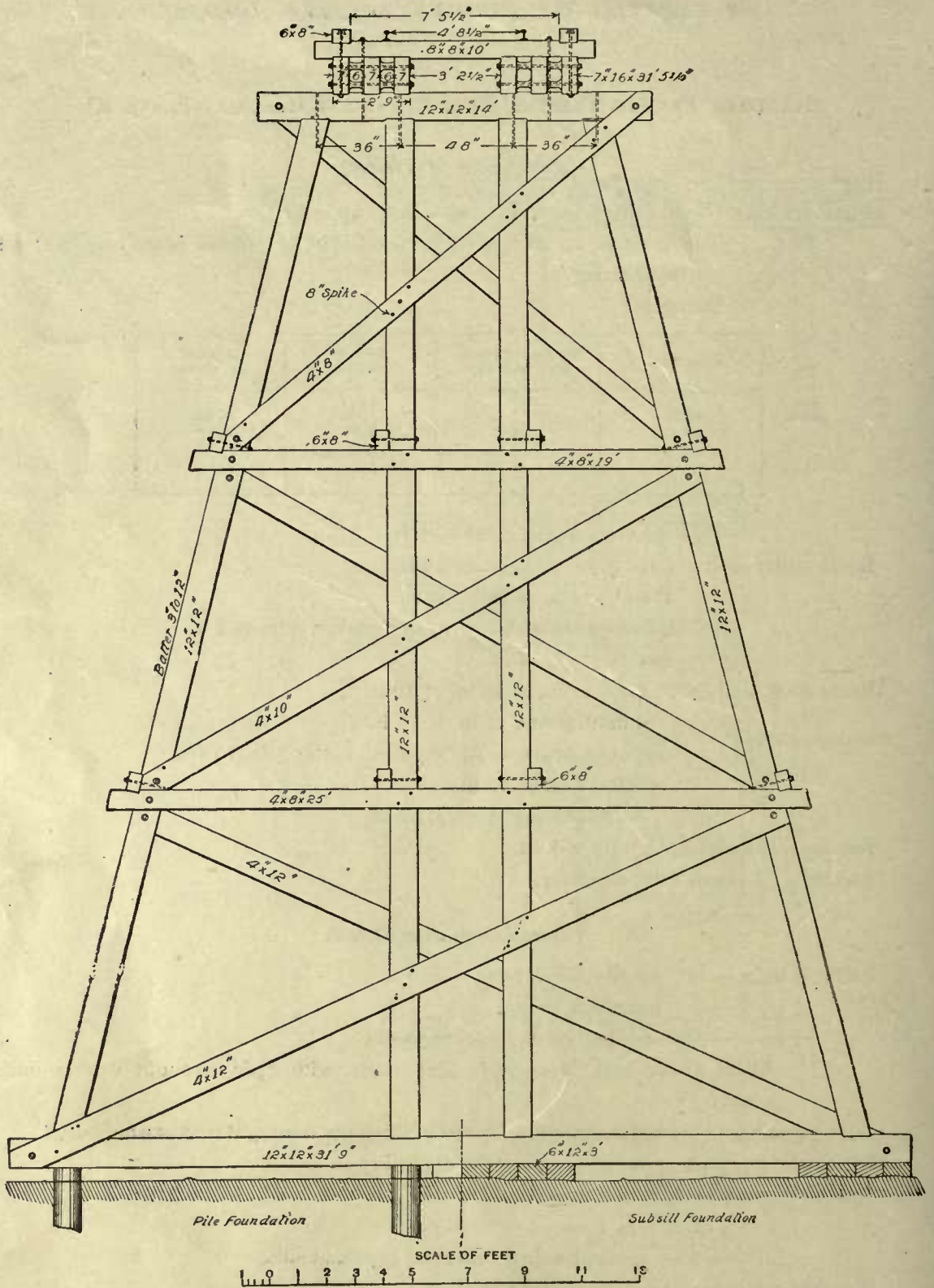
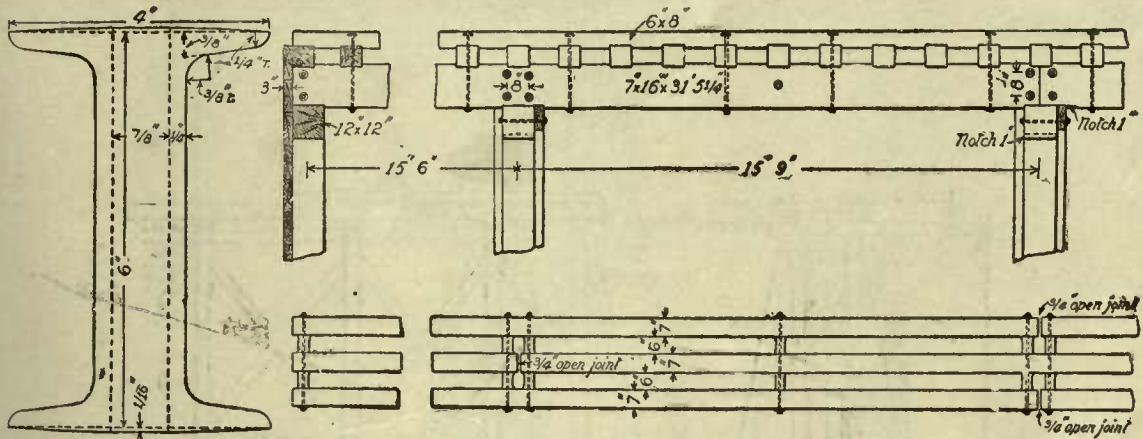


PLATE XII.—STANDARD FRAMED TRESTLE, SAN FRANCISCO & NORTH PACIFIC RAILROAD.





DETAILS OF FLOOR-SYSTEM.

PLATE XIII.—STANDARD FRAMED TRESTLE, SAN FRANCISCO & NORTH PACIFIC RAILROAD.

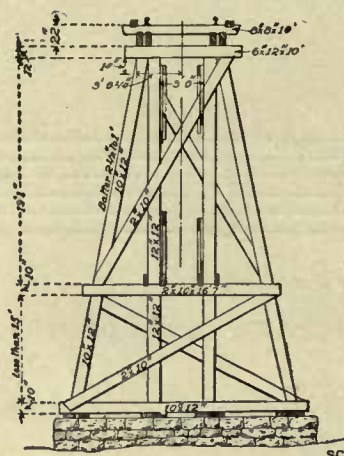
STANDARD FRAMED TRESTLE, SAN FRANCISCO & NORTH PACIFIC RAILROAD.—  
PLATES XII AND XIII.

*Dimensions of Timbers.*

- Floor-system : Guard-rails, 6 in. × 8 in., notched over ties.  
 Ties, 8 in. × 8 in. × 10 ft., notched over stringers.  
 Stringers, 7 in. × 16 in. × 31 ft. 5 1/4 in., notched 1 in. over caps.  
 Bents : Caps, 12 in. × 12 in. × 14 ft.  
 Plumb-posts, 12 in. × 12 in. .  
 Batter-posts, 12 in. × 12 in. ; batter, 3 in. to 1 ft.  
 Sill, 12 in. × 12 in.  
 Sway-braces : Horizontal, 4 in. × 8 in.  
 Diagonal, 4 in. × 8 in., 4 in. × 10 in., 4 in. × 12 in.  
 Longitudinal bracing : Girts, 6 in. × 8 in.  
 Sub-sills : 6 in. × 12 in. × 3 ft.  
 Bank-bent : Dump-boards, 3 in. × 12 in. × 14 ft.

*Dimensions of Iron Details.*

- Bolts : 3/4 in. × 37 in. ; floor-system to cap.  
 5/8 in. × 36 in. ; stringer joints ; packing bolts.  
 5/8 in. × 28 1/2 in. ; guard-rails to ties and stringers.  
 5/8 in. × 21 1/2 in. ; horizontal sway-braces to posts.  
 5/8 in. × 18 1/2 in. ; longitudinal braces to posts.  
 5/8 in. × 17 1/2 in. ; diagonal sway-braces to posts, etc.  
 Drift-bolts : —×— ; cap to posts.  
 —×— ; sill to piles.  
 Spikes : 8 in. ; sway-braces to posts, etc.  
 Cast separators : 4 in. × 6 in. thick ; between stringer-pieces.  
 Cast washers for 5/8-in. and 3/4-in. bolts.



SCALE OF FEET  
1 0 1 2 3 4 5 6 7 8 9 10 15 20

FIG. 1.—CROSS-SECTION.

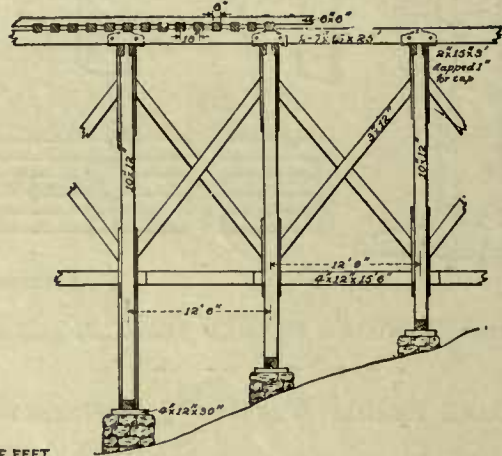


FIG. 2.—ELEVATION.

GENERAL PLAN SINGLE-DECK TRESTLES.

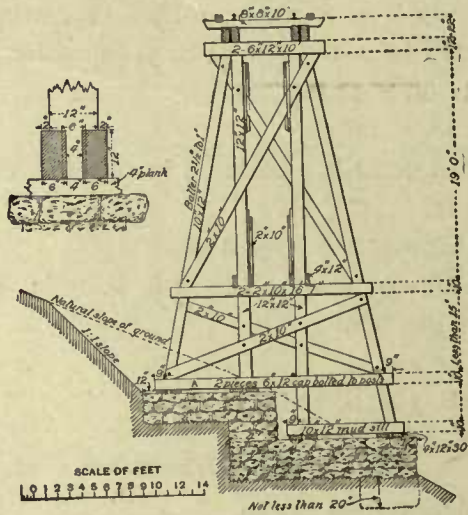


FIG. 3.—PLAN FOR BREAKING SILLS AND STEPPING FOOTINGS ON STEEP SLOPES.  
 PLATE XIV.—STANDARD TRESTLES, NORFOLK & WESTERN RAILROAD.





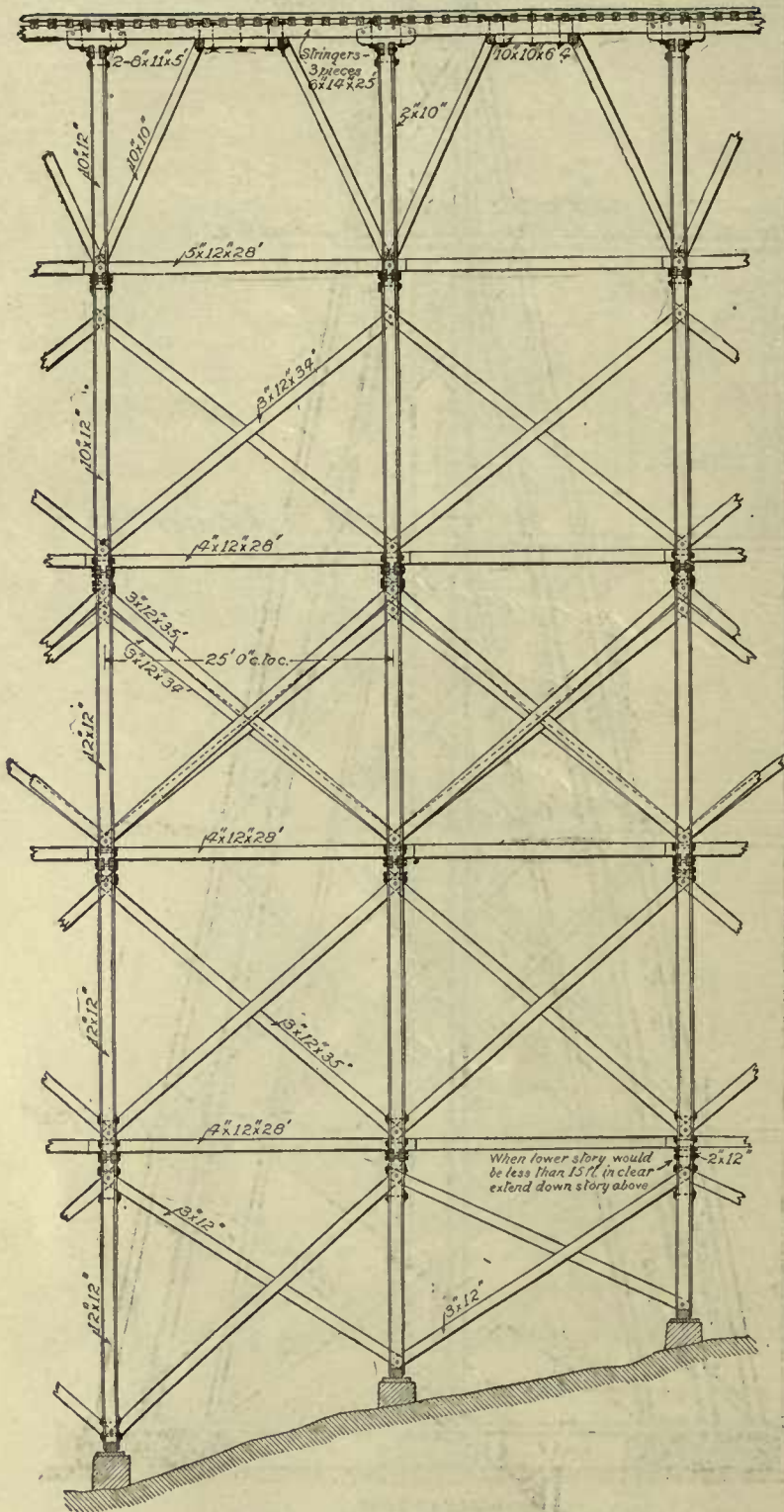


FIG. 5.—ELEVATION HIGH OR MULTIPLE STORY TRESTLE.

PLATE XVI.—STANDARD TRESTLE, NORFOLK & WESTERN RAILROAD.



STANDARD FRAMED TRESTLE, NORFOLK & WESTERN RAILROAD.--  
PLATES XIV, XV, AND XVI.

PLATE XIV.

*Dimensions of Timbers.*

- Floor-system : Guard-rails, 6 in.  $\times$  8 in., notched.  
                   Ties, 8 in.  $\times$  8 in.  $\times$  10 ft., notched.  
                   Stringers, 7 in.  $\times$  15 in.  $\times$  25 ft.  
                   Packing-blocks, 2 in.  $\times$  15 in.  $\times$  3 ft., notched 1 in. over cap.
- Bent : Cap, 6 in.  $\times$  12 in.  $\times$  10 ft.  
           Plumb-posts, 12 in.  $\times$  12 in.  
           Batter-posts, 10 in.  $\times$  12 in. ; batter,  $2\frac{1}{2}$  in. to 1 ft.  
           Sill, 10 in.  $\times$  12 in.  
           Sway-bracing : Diagonal, 2 in.  $\times$  10 in.  
                           Horizontal, 2 in.  $\times$  10 in.
- Longitudinal bracing : Horizontal, 4 in.  $\times$  12 in.  $\times$  15 ft. 6 in.  
                           Diagonal, 3 in.  $\times$  12 in.
- Sub-sills : 4 in.  $\times$  12 in.  $\times$  2 ft. 6 in.

PLATES XV AND XVI.

- Floor-system : Guard-rails, 6 in.  $\times$  8 in.  
                   Ties, 8 in.  $\times$  8 in.  $\times$  14 ft.  
                   Stringers, 6 in.  $\times$  14 in.  $\times$  25 ft.  
                   Packing-blocks, 2 in.  $\times$  14 in.  $\times$  5 ft.  
                   Corbels, 8 in.  $\times$  11 in.  $\times$  5 ft.
- Bent : Cap, 6 in.  $\times$  12 in.  $\times$  10 ft.  
           Plumb-posts, 12 in.  $\times$  12 in.  
           Outside batter-posts, 10 in.  $\times$  12 in., and 12 in.  $\times$  12 in.  
           Inside batter posts, 8 in.  $\times$  12 in., and 10 in.  $\times$  12 in.  
           Sway-braces, 2 in.  $\times$  10 in.  
           Intermediate caps, 6 in.  $\times$  12 in.  
           Sill, 10 in.  $\times$  12 in.
- Longitudinal bracing : Horizontal, 4 in.  $\times$  12 in.  $\times$  28 ft.  
                           Diagonal, 3 in.  $\times$  12 in.
- Knee-braces : Straining-beam, 10 in.  $\times$  10 in.  $\times$  9 ft.  
                   Top chord, 10 in.  $\times$  10 in.  $\times$  6 ft. 4 in.  
                   Bottom chord, 5 in.  $\times$  12 in.  $\times$  28 ft.  
                   Diagonals, 10 in.  $\times$  10 in.
- For method of elevating rails on curves, see Part I, Fig. 125.

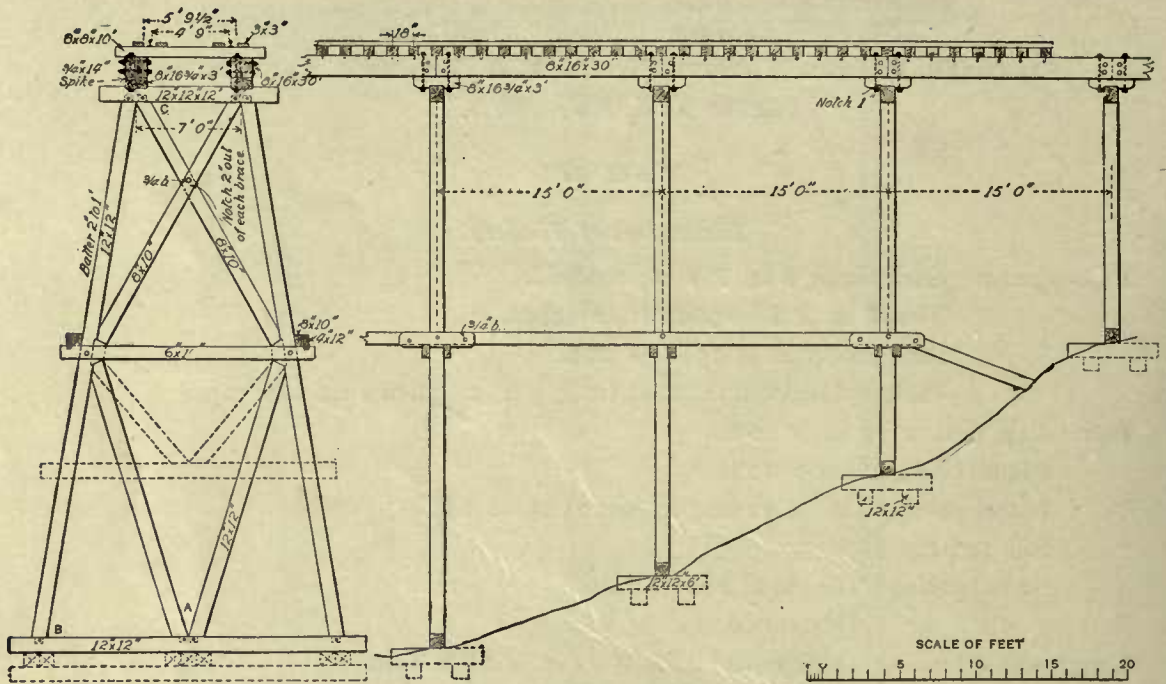


FIG. 1.—GENERAL PLANS.

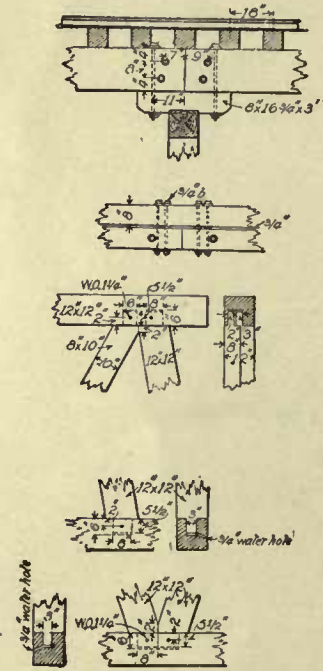


FIG. 2.—DETAILS OF STRINGER AND POST JOINTS.

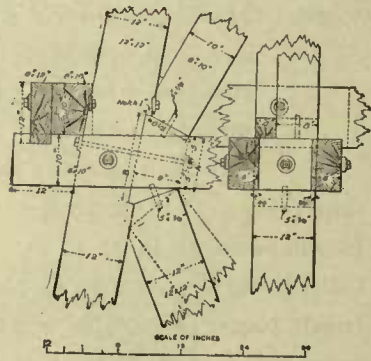


FIG. 3.—DETAIL OF JOINT OF DIAGONAL POSTS.



## STANDARD FRAMED TRESTLE, LOUISVILLE &amp; NASHVILLE RAILROAD.—PLATE XVII.

(See also Plates VII and VIII.)

*Dimensions of Timbers.*Floor-system: Guard-rails, 3 in.  $\times$  9 in.Ties, 8 in.  $\times$  8 in.  $\times$  10 ft.Stringers, 8 in.  $\times$  16 in.  $\times$  30 ft.Corbels, 8 in.  $\times$  16 $\frac{3}{4}$  in.  $\times$  3 ft.Bent: Cap, 12 in.  $\times$  12 in.  $\times$  12 ft.Batter-posts, 12 in.  $\times$  12 in.Diagonal posts, 8 in.  $\times$  10 in., notched 2 in. each at intersection.Intermediate cap, 6 in.  $\times$  10 in.Sill, 12 in.  $\times$  12 in.Longitudinal braces: Horizontal, 8 in.  $\times$  10 in.  $\times$  30 ft.Splice-block, 4 in.  $\times$  12 in.Sub-sills: 12 in.  $\times$  12 in.  $\times$  6 ft.*Dimensions of Iron Details.*Bolts:  $\frac{3}{4}$  in.  $\times$  27 in.; stringers to corbels and intermediate cap to posts. $\frac{3}{4}$  in.  $\times$  20 in.; stringer-joints; packing-bolts. $\frac{3}{4}$  in.  $\times$  15 in.; splice-block to girts. $\frac{3}{4}$  in.  $\times$  23 in.; angle-block to posts.Spikes:  $\frac{3}{4}$  in.  $\times$  14 in.; corbels to caps.Dowels:  $\frac{7}{8}$  in.  $\times$  5 in.; diagonal posts to angle-blocks.

Cast washers: Under head and nut of each bolt.

Cast separators:  $\frac{3}{4}$  in.  $\times$  —; between stringer-pieces.



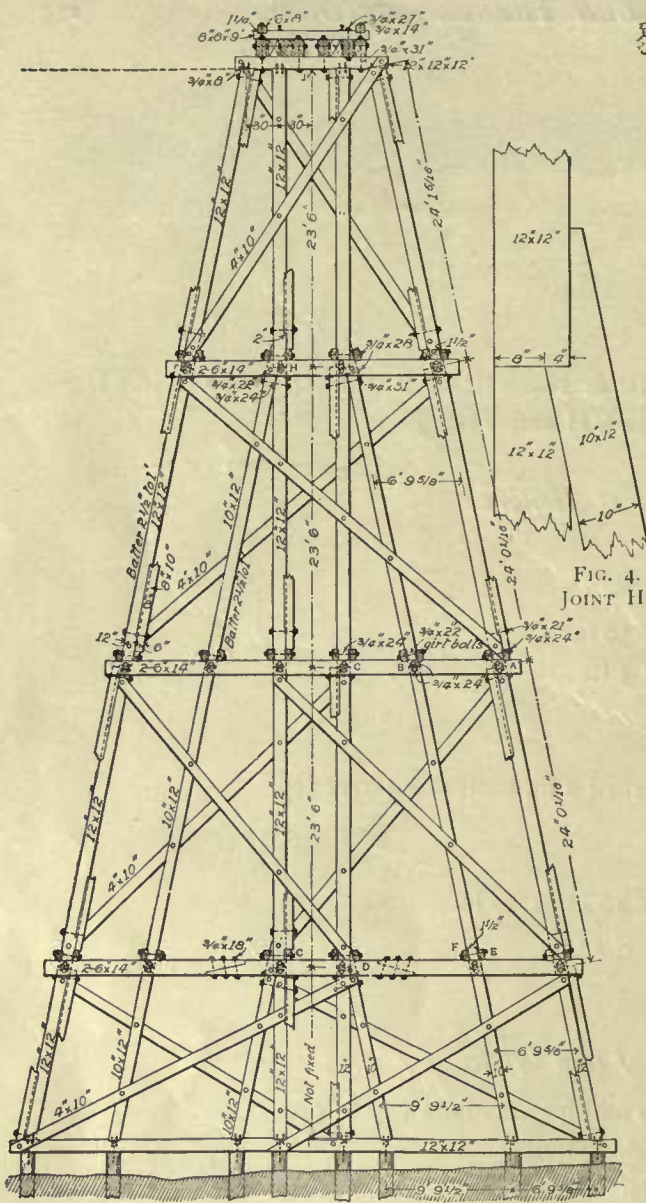


FIG. 1.—CROSS-SECTION.

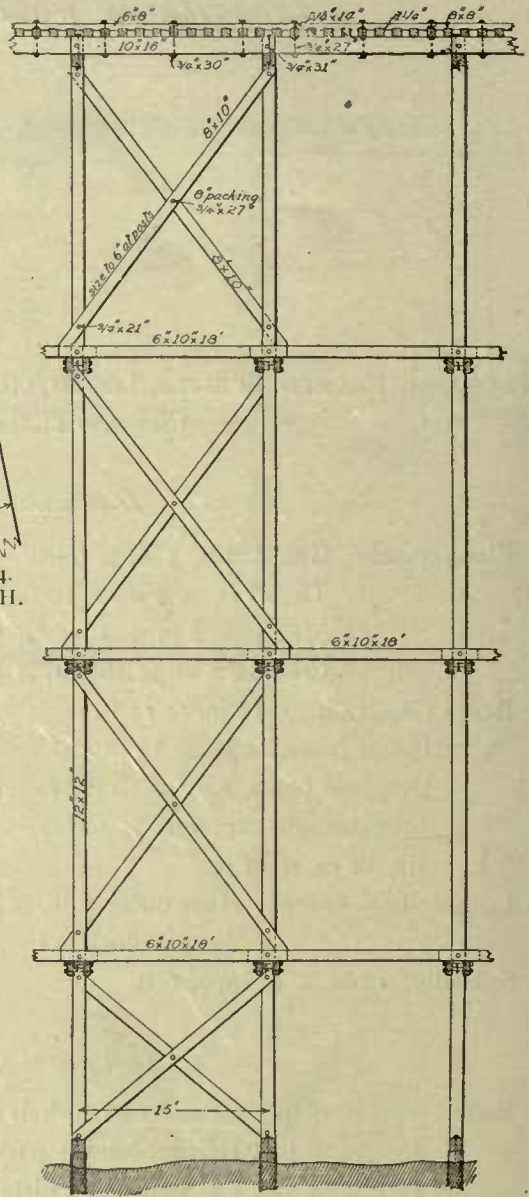


FIG. 2.—ELEVATION.

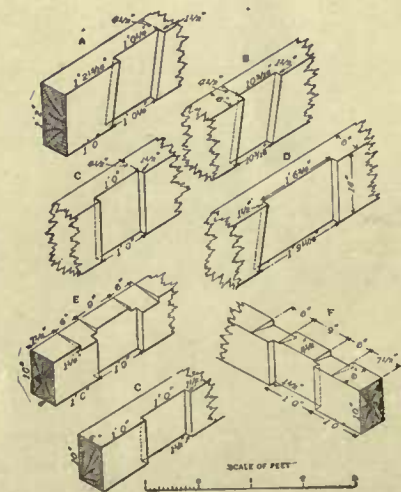


FIG. 5.—DETAILS OF WALLS AND GIRTS.

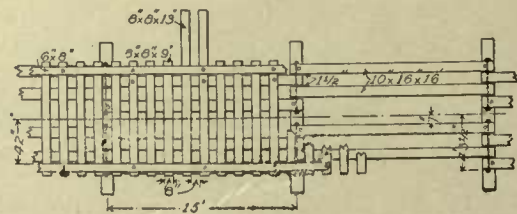


FIG. 3.—FLOOR-SYSTEM.

PLATE XVIII.—STANDARD FRAMED TRESTLE,  
OREGON PACIFIC RAILROAD.



STANDARD FRAMED TRESTLE, OREGON PACIFIC RAILROAD.—PLATE XVIII.

*Dimensions of Timbers.*

- Floor-system: Guard-rails, 6 in. × 8 in., notched  $1\frac{1}{4}$  in.  
 Ties, 8 in. × 8 in. × 9 ft., not notched; and two ties 13 ft. long for every fourth span projecting on alternate sides.  
 Stringers, 10 in. × 16 in. × 16 ft., not notched.
- Bent: Caps, 12 in. × 12 in. × 12 ft.  
 Plumb-posts, 12 in. × 12 in., in 23 ft. 6 in. lengths.  
 Outside batter-posts, 12 in. × 12 in., in 24 ft.  $0\frac{1}{16}$  in.\* lengths.  
 Counter-posts or inside batter-posts, 10 in. × 12 in., in 24 ft.  $0\frac{1}{16}$ \* in. lengths.  
 Intermediate caps or horizontal sway-bracing, 6 in. × 14 in.  
 Diagonal sway-bracing, 4 in. × 10 in.  
 Sill, 12 in. × 12 in.
- Longitudinal bracing: Girts, 6 in. × 10 in. × 18 ft., notched  $1\frac{1}{2}$  in.  
 Diagonals, 8 in. × 10 in., sized to 6 in. at posts.  
 Packing-pieces, 8 in. thick at intersection of diagonals.

*Dimensions of Iron Details.*

- Bolts:  $\frac{3}{4}$  in. × 14 in.; guard-rails to ties.  
 $\frac{3}{4}$  in. × 30 in.; through guard-rails, ties, and outside stringers.  
 $\frac{3}{4}$  in. × 27 in.; ties to stringers.  
 $\frac{3}{4}$  in. × 31 in.; stringers to caps.  
 $\frac{3}{4}$  in. × 48 in.; stringer-joints; packing-bolts.  
 $\frac{3}{4}$  in. × 18 in.; diagonal sway-braces to posts.  
 $\frac{3}{4}$  in. × 28 in.;  
 $\frac{3}{4}$  in. × 22 in.;  
 $\frac{3}{4}$  in. × 24 in.;  
 $\frac{3}{4}$  in. × 31 in.; } bolt at joint H and its companion joint.  
 $\frac{3}{4}$  in. × 24 in.; intermediate caps to posts.  
 $\frac{3}{4}$  in. × 18 in.; sill-joint bolts.  
 $\frac{3}{4}$  in. × 22 in.;  
 $\frac{3}{4}$  in. × 24 in.; } girt-bolts.  
 $\frac{3}{4}$  in. × 21 in.; diagonal longitudinal braces to posts.  
 $\frac{3}{4}$  in. × 27 in.; intersection of above.
- Dowels:  $\frac{3}{4}$  in. × 8 in.; cap and sill to posts; post-joints.  
 Drift-bolts: — × —  
 Cast washers: Under heads and nuts of each bolt.  
 Cast separators:  $1\frac{1}{2}$  in. × —; between stringer-pieces.

\* So in original blue print, but rather too close to work to in this size timber.



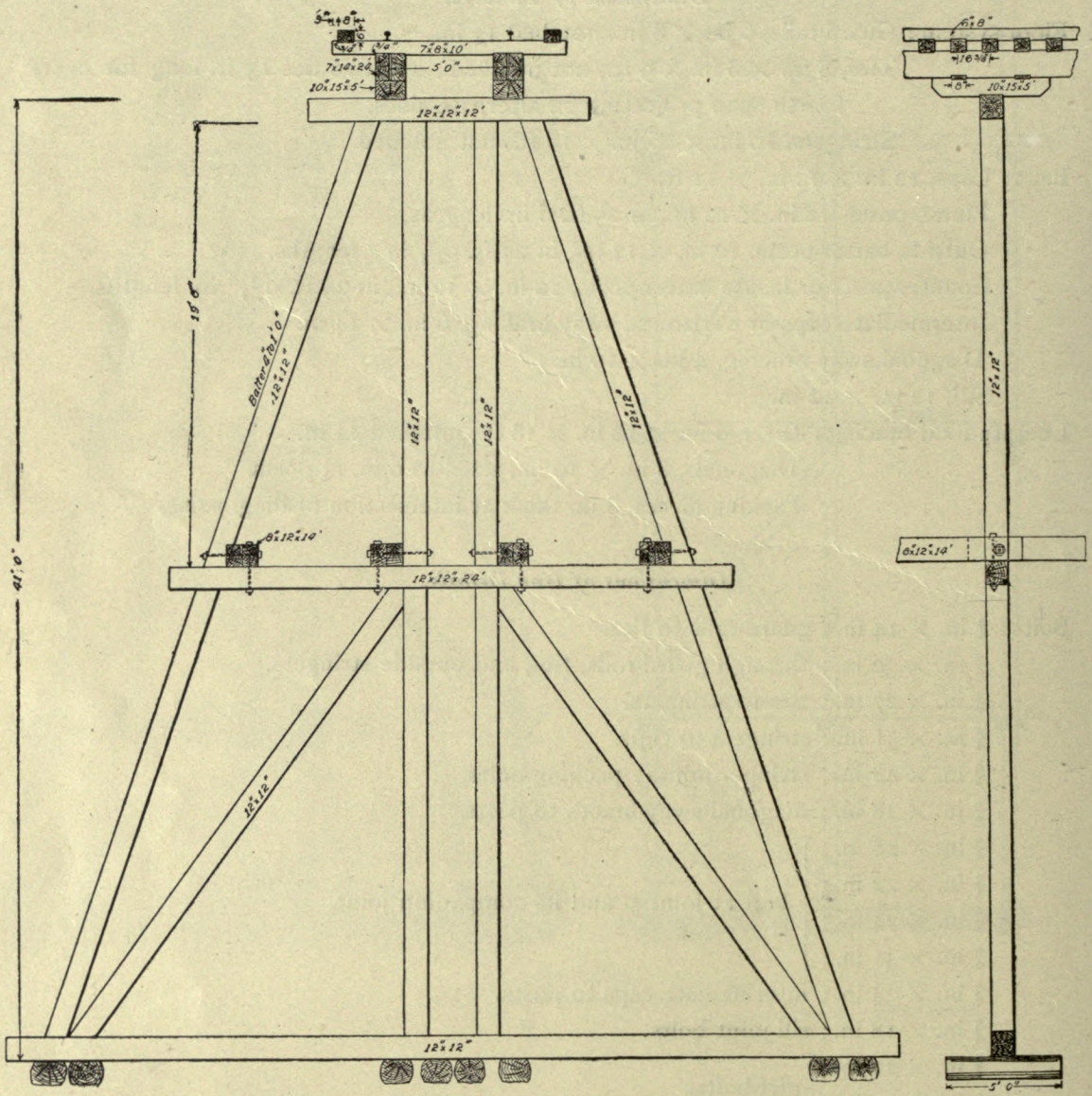


PLATE XIX.—FRAMED TRESTLE, OHIO CONNECTING RAILWAY.



FRAMED TRESTLE, OHIO CONNECTING RAILWAY,—PLATE XIX.

*Dimensions of Timbers.*

Floor-system: Guard-rails, 6 in.  $\times$  8 in., notched  $\frac{3}{4}$  in. over ties.

Ties, 7 in.  $\times$  8 in.  $\times$  10 ft., notched  $\frac{3}{4}$  in. over stringers.

Stringers, 7 in.  $\times$  14 in.  $\times$  24 ft.

Corbels, 10 in.  $\times$  15 in.  $\times$  5 ft., notched over caps.

Bents: Caps, 12 in.  $\times$  12 in.  $\times$  12 ft.

Plumb-posts, 12 in.  $\times$  12 in.

Batter-posts, 12 in.  $\times$  12 in.

Counter-posts, 12 in.  $\times$  12 in.

Intermediate caps, 12 in.  $\times$  12 in.

Sills, 12 in.  $\times$  12 in.

Longitudinal braces, 8 in.  $\times$  12 in.  $\times$  14 ft.



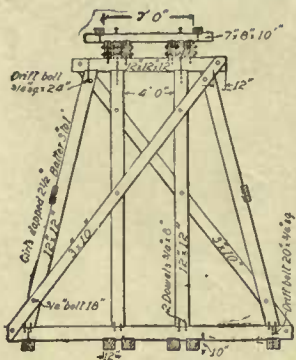


FIG. 1.—CROSS-SECTION.

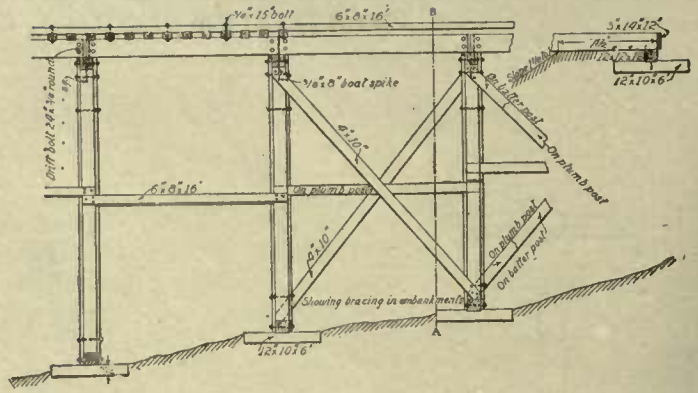


FIG. 2.—ELEVATION.

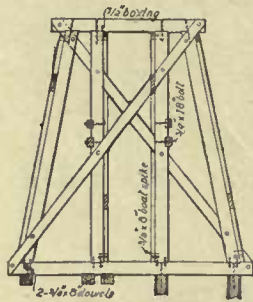


FIG. 4.—SECTION A B, SHOWING BRACING IN EMBANKMENT.



FIG. 5.—PACKING-WASHER.

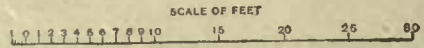
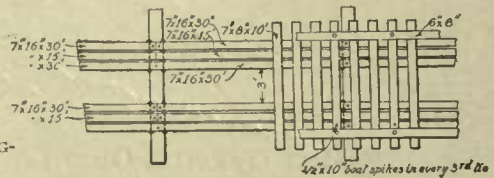


FIG. 3.—PLAN.

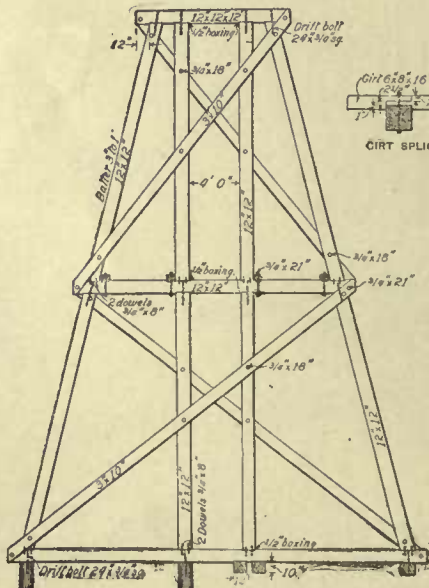
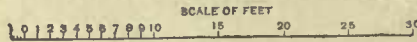


FIG. 6.—DOUBLE-DECK TRESTLE.

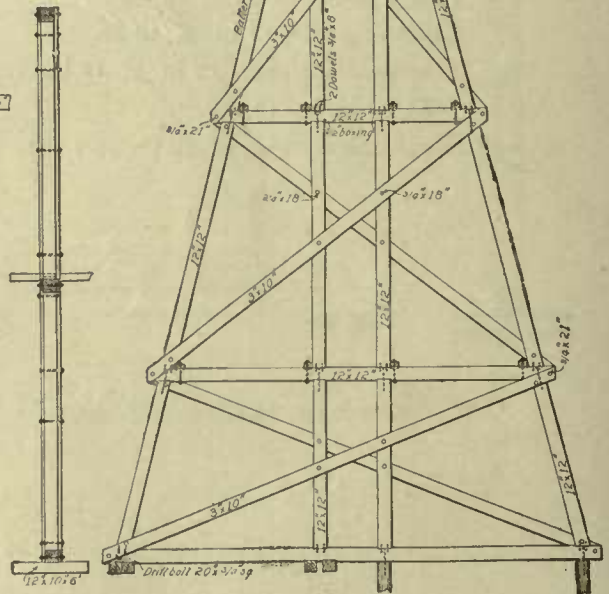


FIG. 7.—TRIPLE-DECK TRESTLE.

PLATE XX.—PRESENT STANDARD TRESTLE, CHARLESTON, CINCINNATI & CHICAGO RAILROAD.



STANDARD FRAMED TRESTLE, CHARLESTON, CINCINNATI & CHICAGO RAILROAD.—  
PLATES XX AND XXI.

PLATE XX.

*Dimensions of Timbers*

- Floor-system: Guard-rails, 6 in. × 8 in. × 16 ft.  
                   Ties, 7 in. × 8 in. × 10 ft.  
                   Stringers, 7 in. × 16 in. × 30 ft. and 15 ft.
- Bent: Cap, 12 in. × 12 in. × 12 ft.  
       Plumb-posts, 12 in. × 12 in.  
       Batter-posts, 12 in. × 12 in.  
       Sway-bracing, 3 in. × 10 in.  
       Intermediate cap, 12 in. × 12 in.  
       Sill, 12 in. × 12 in.
- Longitudinal bracing: Horizontal, 6 in. × 8 in. × 16 ft.  
                           Diagonal, 4 in. × 10 in.
- Sub-sills, 10 in. × 12 in. × 6 ft.

*Dimensions of Iron Details.*

- Bolts:  $\frac{3}{4}$  in. × 15 in.; guard-rails to ties.  
        $\frac{3}{4}$  in. × 18 in.; sway-braces to posts.  
        $\frac{3}{4}$  in. × 28 in.; stringer-joints; packing-bolts
- Drift-bolts:  $\frac{3}{4}$  in. ×  $\frac{3}{4}$  in. × 20 in.; sills to sub-sills.  
                $\frac{3}{4}$  in. ×  $\frac{3}{4}$  in. × 24 in.; stringers to caps; caps to posts
- Dowels:  $\frac{3}{4}$  in. × 8 in.; posts to sills.
- Spikes, boat:  $\frac{5}{8}$  in. × 8 in.; girts to posts.  
                $\frac{1}{2}$  in. × 10 in.; ties to stringers.
- Cast separators: 2 in. × 3 in.; between stringer-pieces.
- Cast washers: — × 3 in.; under head and nut of each bolt.

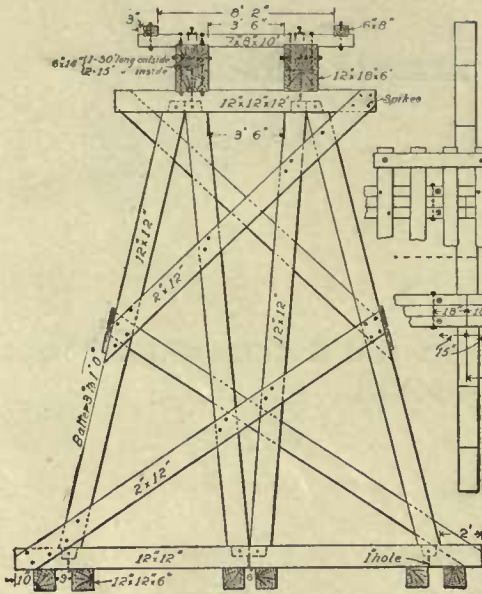


FIG. 1.—CROSS-SECTION.

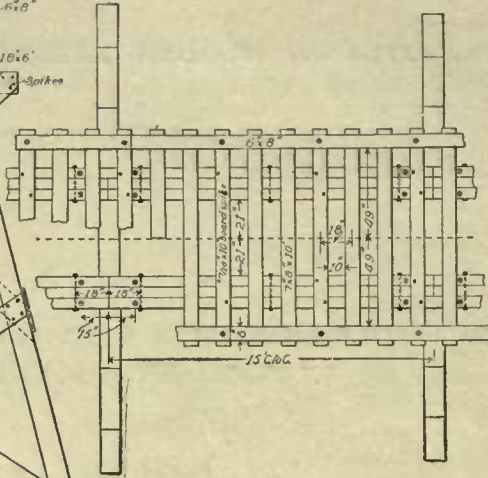


FIG. 3.—PLAN.  
SINGLE-DECK TRESTLE.

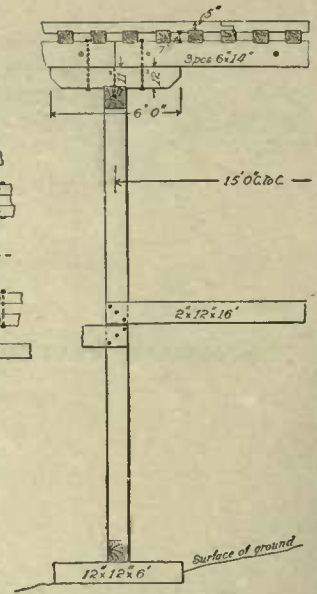


FIG. 2.—ELEVATION.

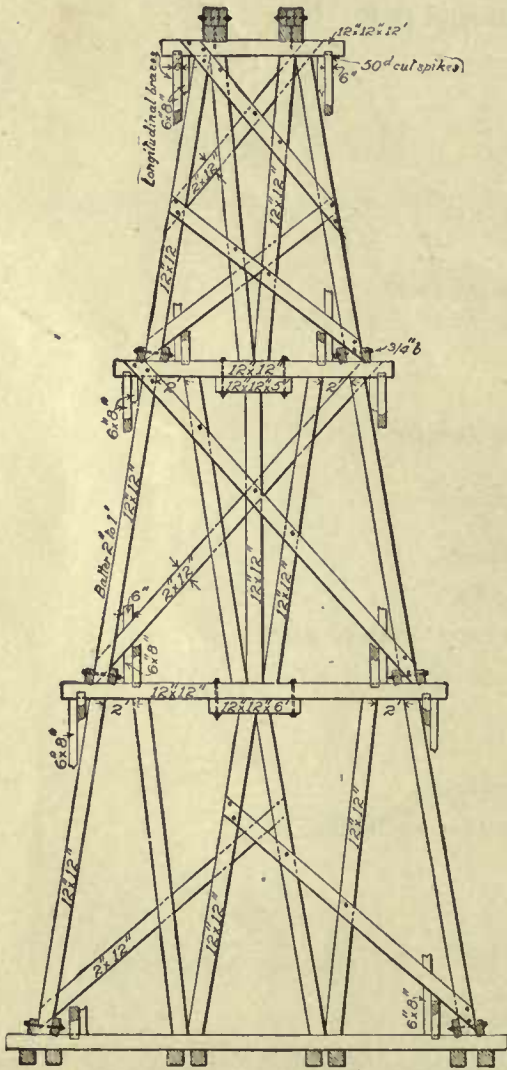


FIG. 4.—CROSS-SECTION.

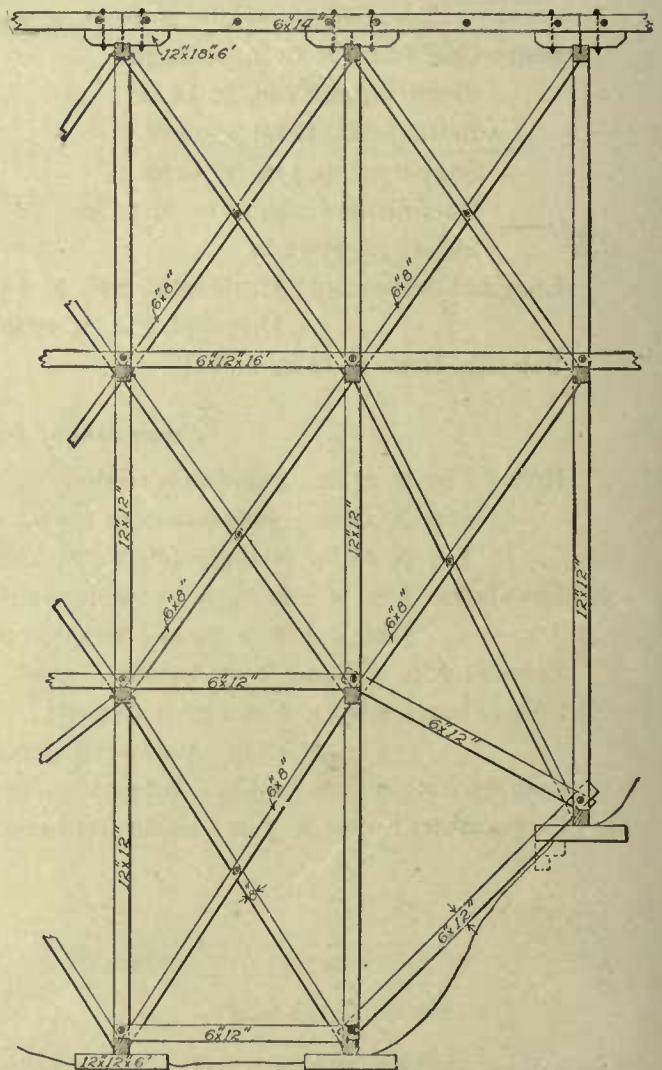


FIG. 5.—ELEVATION.

SCALE OF FEET  
0 1 2 3 4 5 10 15 20 25

TRIPLE-DECK TRESTLE.



## PLATE XXI.

*Dimensions of Timbers.*

- Floor-system: Guard-rails, 6 in.  $\times$  8 in.  
 Ties, 7 in.  $\times$  8 in.  $\times$  10 ft.  
 Stringers, 6 in.  $\times$  14 in.  $\times$  30 ft. and 15 ft.  
 Corbels, 12 in.  $\times$  18 in.  $\times$  6 ft.
- Bent: Cap, 12 in.  $\times$  12 in.  $\times$  12 ft.  
 Posts, 12 in.  $\times$  12 in.  
 Intermediate caps, 12 in.  $\times$  12 in.  
 Sway-braces, 2 in.  $\times$  12 in.  
 Sill, 12 in.  $\times$  12 in.
- Longitudinal braces: Horizontal, 6 in.  $\times$  12 in.  $\times$  16 ft.  
 Diagonal, 6 in.  $\times$  8 in.
- Sub-sills, 12 in.  $\times$  12 in.  $\times$  6 ft.

*Dimensions of Iron Details.*

- Bolts:  $\frac{3}{4}$  in.  $\times$  15 in.; guard-rails to ties.  
 $\frac{3}{4}$  in.  $\times$  19 in.; stringers to corbels.  
 $\frac{3}{4}$  in.  $\times$  21 in.; stringer-joints; packing-bolts.  
 $\frac{3}{4}$  in.  $\times$  27 in.; longitudinal braces to posts, and post-caps to intermediate caps.  
 —  $\times$  15 in.; intersection of diagonal longitudinal braces.
- Drift-bolts:  $\frac{3}{4}$  in.  $\times$   $\frac{3}{4}$  in.  $\times$  18 in.; corbels to cap.
- Spikes: Boat,  $\frac{7}{16}$  in.  $\times$  10 in.; ties to stringers.  
 Cut 50-penny; bracing to posts.
- Cast washers: Under head and nut of each bolt.







## HIGH FRAMED TRESTLES, MINNEAPOLIS &amp; ST. LOUIS RAILWAY.—PLATE XXII.

(See also Plate V.)

*Dimensions of Timbers.*

- Floor-system: Guard-rails, 6 in.  $\times$  8 in.  
 Ties, 6 in.  $\times$  8 in.  $\times$  10 ft.  
 Stringers, 8 in.  $\times$  14 in.  $\times$  30 ft.
- Bent: Cap, 12 in.  $\times$  12 in.  $\times$  14 ft.  
 Plumb-posts, 12 in.  $\times$  12 in.  
 Batter-posts, 12 in.  $\times$  12 in.  
 Sway-bracing: Horizontal, 3 in.  $\times$  12 in.  
 Diagonal, 3 in.  $\times$  12 in.  
 Intermediate cap, 12 in.  $\times$  12 in.  
 Sill, 12 in.  $\times$  12 in.  
 Sill-splice, 12 in.  $\times$  12 in.
- Longitudinal braces: Horizontal, 3 in.  $\times$  12 in.  
 Diagonal, 3 in.  $\times$  12 in.

*Dimensions of Iron Details.*

- Bolts:  $\frac{3}{4}$  in.  $\times$  —; stringer-joints; packing-bolts.  
 —  $\times$  —; braces to posts.
- Lag-screws: —  $\times$  —; stringer-brackets to caps.
- Spikes, boat:  $\frac{1}{2}$  in.  $\times$  8 in.; guard-rails to ties.
- Drift-bolts:  $\frac{5}{8}$  in.  $\times$  12 in.; ties to stringers.
- Cast separators: Between stringer-pieces.
- Cast washers: Under head and nut of each bolt.
- Cast brackets: Stringers to caps.
- Cast pile-caps: }  
 Cast post-caps: } As per details.  
 Cast post foot-blocks: }
- For complete description, etc., of this trestle see *Railroad Gazette*, April 17, 1891.







STANDARD FRAMED TRESTLE, GEORGIA PACIFIC RAILWAY.—PLATE XXIII.

*Dimensions of Timbers.*

Floor-system : Guard-rails, 8 in.  $\times$  8 in.

Ties, 8 in.  $\times$  10 in.  $\times$  9 ft.

Stringers, 8 in.  $\times$  16 in.

Bent : Cap, 12 in.  $\times$  12 in.  $\times$  11 ft.

Plumb-posts, 12 in.  $\times$  12 in.

Batter-posts, 12 in.  $\times$  12 in., and 10 in.  $\times$  12 in.

Vertical counter-posts, 10 in.  $\times$  12 in.

Intermediate caps and sills, 12 in.  $\times$  12 in.

Compound sills and caps, 4 $\frac{1}{4}$  in.  $\times$  12 in., and 2 $\frac{1}{2}$  in.  $\times$  12 in.

Longitudinal bracing : Horizontal, 4 in.  $\times$  10 in.  $\times$  16 ft. 4 in., and 7 in.  $\times$  10 in.  $\times$  16 ft.

Diagonal, 3 in.  $\times$  10 in.

Sub-sills, 12 in.  $\times$  12 in.







STANDARD FRAMED TRESTLES, OREGON & WASHINGTON TERRITORY RAILROAD.—

PLATE XXIV.

*Dimensions of Timbers.*

Floor-system: Guard-rails, 10 in. × 12 in., and 5 in. × 8 in.

Ties, 6 in. × 8 in. × 16 ft.

Track-stringers, 9 in. × 16 in. × 32 ft.

Jack-stringers, 7 in. × 16 in. × 32 ft.

Spreaders, 3 in. × 12 in.

Bent: Cap, 12 in. × 14 in. × 16 ft.

Plumb-posts, 12 in. × 12 in.

Batter-posts, 12 in. × 12 in.

Intermediate caps and sills, 12 in. × 14 in.

Sway-bracing: Horizontal, 4 in. × 10 in.

Diagonal, 4 in. × 10 in.

Main sill, 12 in. × 14 in.

Longitudinal bracing: Horizontal, 6 in. × 10 in.

Diagonal, 6 in. × 10 in.

Purlins, 12 in. × 12 in. × 18 ft.

*Dimensions of Iron Details.*

Bolts:  $\frac{3}{4}$  in. × 50 $\frac{1}{2}$  in.; floor-system to caps.

$\frac{3}{4}$  in. × 41 in.; sills to caps of different decks.

$\frac{3}{4}$  in. × 37 in.; outside guard-rails to jack-stringers.

$\frac{3}{4}$  in. × 27 in.; } longitudinal bracing.

$\frac{3}{4}$  in. × 24 $\frac{3}{4}$  in.; }

$\frac{3}{4}$  in. × 23 in.; sway-brace splice, sill-splice, horizontal sway-bracing to posts

$\frac{3}{4}$  in. × 22 in.; stringer-joints; packing-bolts.

$\frac{3}{4}$  in. × 19 in.; sway-braces to posts.

$\frac{5}{8}$  in. × 11 in.; inside guard-rails to ties.

Drift-bolts:  $\frac{3}{4}$  in. × 24 in.; sill to piles.

Dowels: 1 in. × 6 in.; posts to caps and sills.

Spikes: Cut 60 penny; spreaders and brace-blocks to caps.

Boat,  $\frac{1}{2}$  in. × 9 in.; sway-braces to posts.

Cast washers: Under head and nut of each bolt.



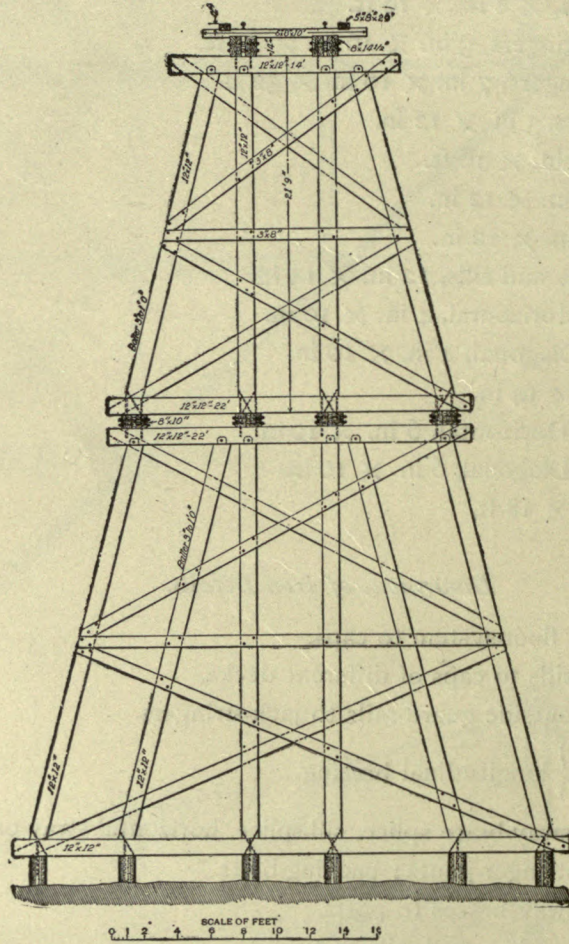


PLATE XXV.—STANDARD FRAMED TRESTLE, FORT WORTH & DENVER CITY RAILWAY.



STANDARD FRAMED TRESTLE, FORT WORTH & DENVER CITY RAILWAY

PLATE XXV.

*Dimensions of Timbers.*

Floor-system: Guard-rails, 5 in.  $\times$  8 in.  $\times$  29 ft.

Ties, 6 in.  $\times$  8 in.  $\times$  10 ft.

Stringers, 8 in.  $\times$  14 $\frac{1}{2}$  in.

Bent: Cap, 12 in.  $\times$  12 in.  $\times$  14 ft.

Plumb-posts, 12 in.  $\times$  12 in.

Batter-posts, 12 in.  $\times$  12 in.

Intermediate cap and sill, 12 in.  $\times$  12 in.

Sway-bracing: Horizontal, 3 in.  $\times$  8 in.

Diagonal, 3 in.  $\times$  8 in.

Main sill, 12 in.  $\times$  12 in.







STANDARD FRAMED TRESTLE, RICHMOND & DANVILLE RAILROAD.—PLATE XXVI.

*Dimensions of Timbers.*

- Floor-system : Guard-rails, 8 in.  $\times$  8 in.  
 Ties, 8 in.  $\times$  8 in.  $\times$  10 ft.  
 Stringers, 7 in.  $\times$  14 in.  
 Spreader, 2 in.  $\times$  4 in.  $\times$  3 ft. 9 in.
- Bent: Cap, 12 in.  $\times$  12 in.  $\times$  12 ft.  
 Plumb-posts, 12 in.  $\times$  12 in.  
 Batter-posts, 10 in.  $\times$  12 in.  
 Counter-posts, 10 in.  $\times$  12 in.  
 Intermediate sills and caps, 12 in.  $\times$  12 in.  
 Sway-braces, 3 in.  $\times$  10 in.  
 Main sill, 12 in.  $\times$  12 in.
- Purlins, 10 in.  $\times$  12 in.  $\times$  27 ft.  
 Sub-sills, 10 in.  $\times$  12 in.  
 Longitudinal braces, 3 in.  $\times$  10 in.

*Dimensions of Iron Details.*

- Bolts: —  $\times$  — ; guard-rails to jack-stringers.  
 $\frac{5}{8}$  in.  $\times$  — ; stringer-joints ; packing-bolts.  
 —  $\times$  36 in. ; floor-system to caps.  
 $\frac{7}{8}$  in.  $\times$  — ; longitudinal bracing to posts.
- Spikes: —  $\times$  7 in. ; sway-braces to posts, etc.  
 — ; spreaders to ties.
- Cast washers: Under head and nut of each bolt



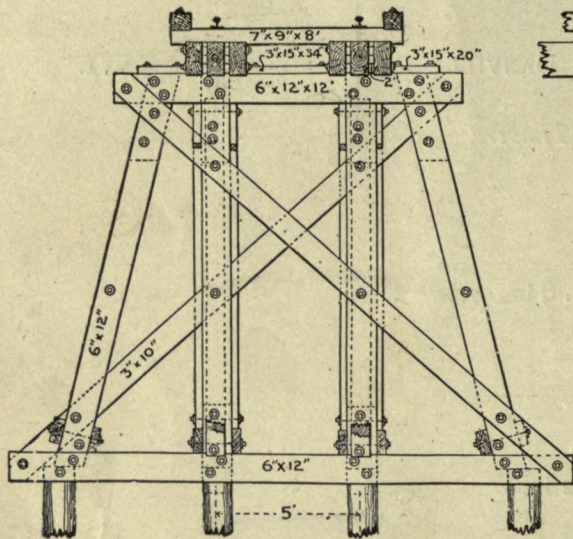


FIG. 1.—CROSS-SECTION.

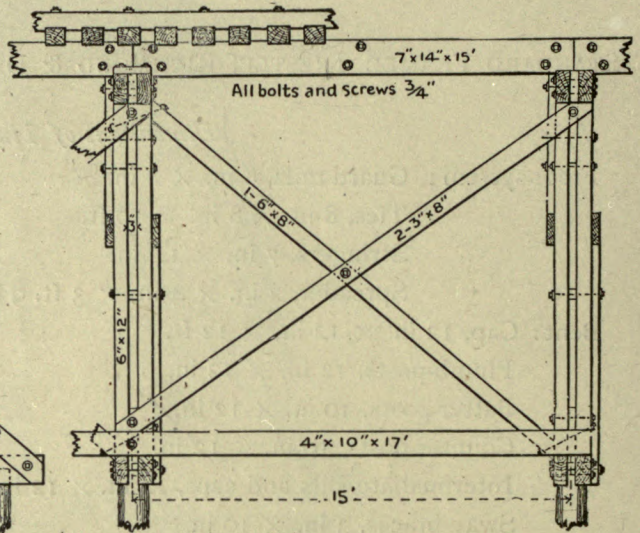


FIG. 2.—ELEVATION.

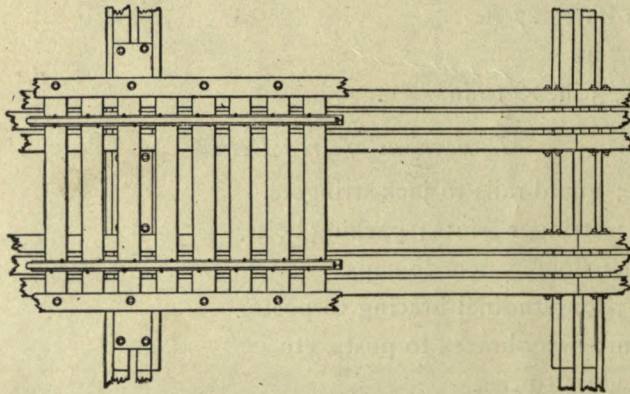


FIG. 3.—PLAN.

PLATE XXVII.—STANDARD FRAMED TRESTLE, CLEVELAND & CANTON RAILROAD.



## STANDARD FRAMED TRESTLE, CLEVELAND &amp; CANTON RAILROAD.—PLATE XXVII.

*Dimensions of Timbers.*

Floor-system: Guard-rails, 8 in.  $\times$  8 in., notched 1 in. over ties.

Ties, 7 in.  $\times$  9 in.  $\times$  8 ft., notched 1 in. over stringers.

Stringers, 7 in.  $\times$  14 in.  $\times$  15 ft., notched 1 in. over caps.

Brace-blocks,  $\left\{ \begin{array}{l} 3 \text{ in.} \times 15 \text{ in.} \times 20 \text{ in.} \\ 3 \text{ in.} \times 15 \text{ in.} \times 34 \text{ in.} \end{array} \right.$

Bents: Caps, 6 in.  $\times$  12 in.  $\times$  12 ft.

All posts, 6 in.  $\times$  12 in.

Sills, 6 in.  $\times$  12 in.

Sway-braces, 3 in.  $\times$  10 in.

Tenon-blocks, 3 in.  $\times$  12 in.  $\times$  3 ft.

Longitudinal braces: Girts, 4 in.  $\times$  10 in.  $\times$  17 ft.

Diagonals,  $\left\{ \begin{array}{l} 6 \text{ in.} \times 8 \text{ in.} \\ 3 \text{ in.} \times 8 \text{ in.} \end{array} \right.$

*Dimensions of Iron Details.*

Bolts:  $\frac{3}{4}$  in.  $\times$  18 in.; post, sill, and cap; packing-bolts.

$\frac{3}{4}$  in.  $\times$  28 in.; stringer-joints; packing-bolts.

$\frac{3}{4}$  in.  $\times$  21 in.; sway-braces to posts.

$\frac{3}{4}$  in.  $\times$  —; diagonal longitudinal braces to posts.

$\frac{3}{4}$  in.  $\times$  17 in.; diagonal longitudinal braces to posts; intersection of diagonals.

Lag-screws:  $\frac{3}{4}$  in.  $\times$  —,  $\left\{ \begin{array}{l} \text{guard-rails to ties.} \\ \text{brace-blocks to caps.} \end{array} \right.$







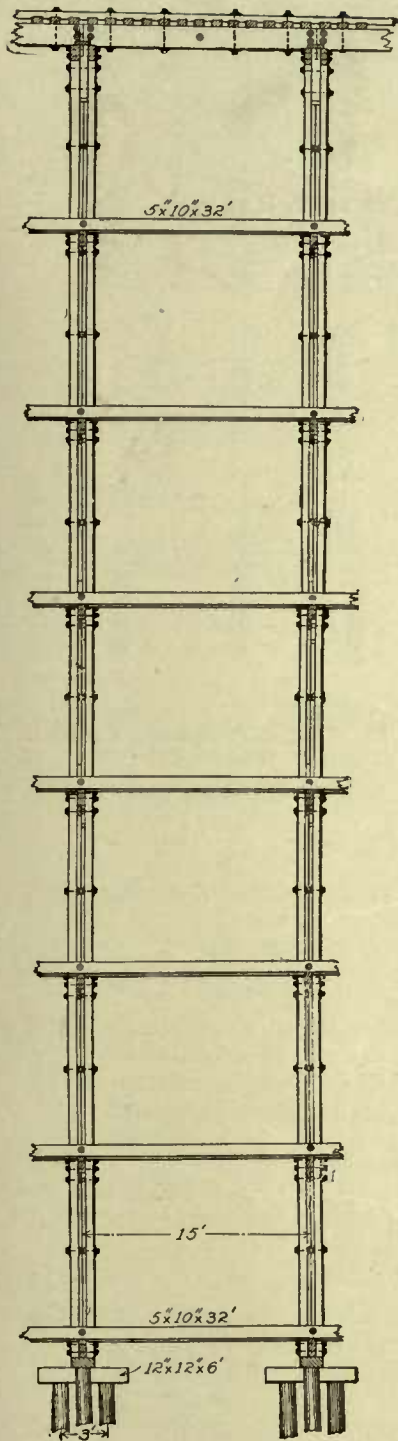


FIG. 2. —ELEVATION.

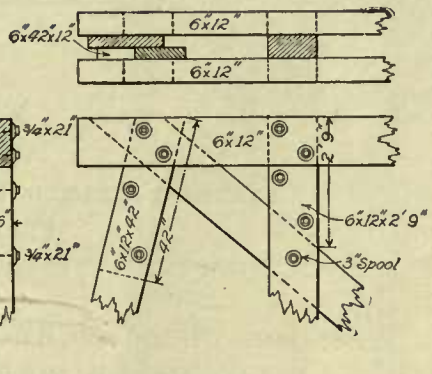


FIG. 3.—CAP AND POST JOINT.

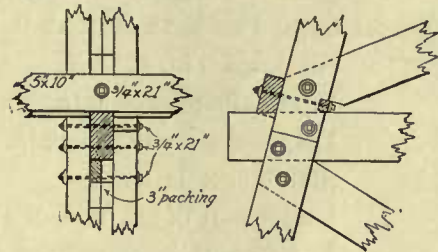


FIG. 4.—POST-SPLICE.

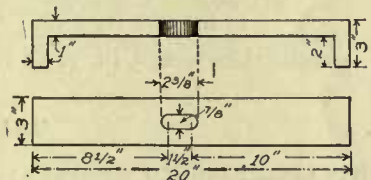


FIG. 5.—STRAP.

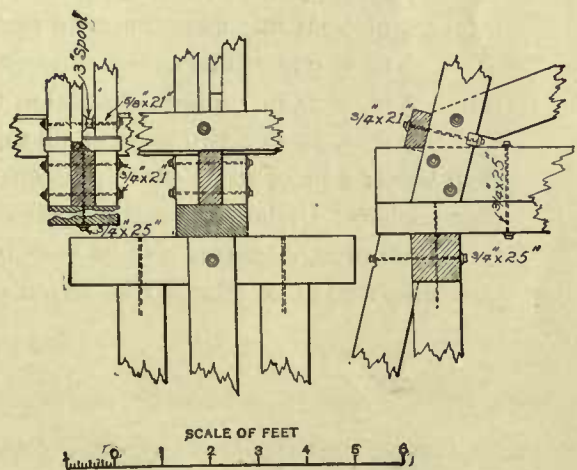


FIG. 6.—SILL AND POST JOINT DETAILS.

PLATE XXIX.—STANDARD TRESTLE, CALIFORNIA CENTRAL RAILWAY.



STANDARD FRAMED TRESTLE, CALIFORNIA CENTRAL RAILWAY.  
PLATES XXVIII AND XXIX.

*Dimensions of Timbers.*

- Floor-system: Guard-rails, 6 in.  $\times$  8 in., notched.  
Ties, 6 in.  $\times$  8 in.  $\times$  9 ft., notched.  
Stringers, 8 in.  $\times$  16 in.  $\times$  30 ft.
- Bents: Caps, 6 in.  $\times$  12 in.  $\times$  14 ft.  
All posts, 6 in.  $\times$  12 in.  
Intermediate caps, 6 in.  $\times$  12 in.  
Diagonal sway-braces, 3 in.  $\times$  12 in.  
Sill, 6 in.  $\times$  14 in.  
Under part of sill, 8 in.  $\times$  18 in.  
Pile-caps, 12 in.  $\times$  12 in.  $\times$  6 ft.  
Packing-blocks between posts and cap-pieces, 6 in.  $\times$  12 in.  $\times$  42 in., and 6 in.  $\times$  12 in.  $\times$  2 ft. 9 in.
- Longitudinal braces, 5 in.  $\times$  10 in.  $\times$  32 ft.

*Dimensions of Iron Details.*

- Bolts: Guard-rails to stringers.  
Stringer-joints; packing-bolts.  
 $\frac{5}{8}$  in.  $\times$  21 in.; sway-braces to posts.  
 $\frac{5}{8}$  in.  $\times$  9 in.; intersection of sway-braces.  
 $\frac{3}{4}$  in.  $\times$  21 in.; intermediate caps to posts; girts to posts.  
 $\frac{3}{4}$  in.  $\times$  25 in.; two parts of sill together; brace-pile to pile-caps.
- Drift-bolts:  $\frac{3}{4}$  in.  $\times$  20 in. sill to pile-caps; caps to piles.
- Cast washers: Under head and nut of each bolt.
- Cast separators or spools: 3 in.  $\times$  — and 6 in.  $\times$  —.
- Cast strap: 20 in.  $\times$  3 in.  $\times$  1 in. as per detail; girts to posts.



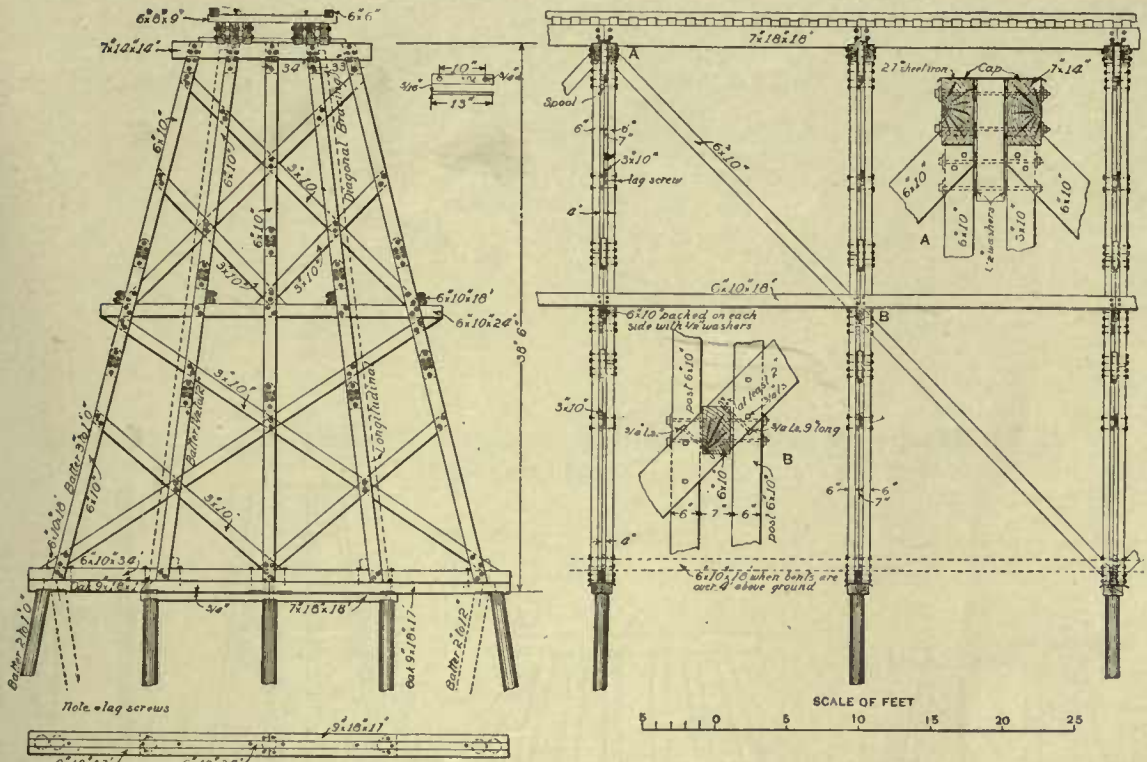


PLATE XXX.—STANDARD FRAMED TRESTLE, TOLEDO, ST. LOUIS & KANSAS CITY RAILROAD.  
STANDARD FRAMED TRESTLE, TOLEDO, ST. LOUIS & KANSAS CITY RAILROAD.  
PLATE XXX.

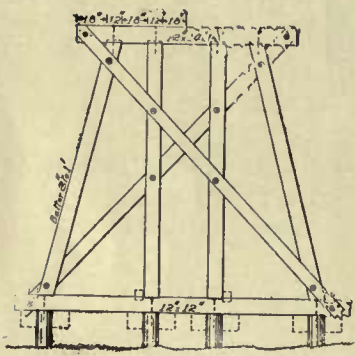
*Dimensions of Timbers.*

- Floor-system : Guard-rails, 6 in. x 6 in. x 18 ft.
- Ties, 6 in. x 8 in. x 9 ft.
- Stringers, 7 in. x 18 in. x 18 ft.
- Spreader, 3 in. x 12 in. x 3 ft.
- Brace-blocks, 3 in. x 12 in. x 15 in.

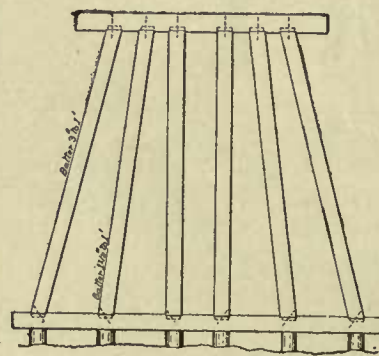
- Bent : Cap, 7 in. x 14 in. x 14 ft.
- Plumb-post, 6 in. x 10 in.
- Inclined posts, 6 in. x 10 in.
- Splice-blocks, 6 in. x 10 in. x 2 ft.
- Sway-bracing : Horizontal, 6 in. x 10 in.
- Diagonal, 3 in. x 10 in.
- Sill, 6 in. x 10 in., 9 in. x 18 in., and 7 in. x 18 in.
- Longitudinal bracing : Horizontal, 6 in. x 10 in. x 18 ft.
- Diagonal, 6 in. x 10 in.

*Dimensions of Iron Details.*

- Bolts :  $\frac{5}{8}$  in. x 31 in. ; stringer-joints ; packing-bolts.
- $\frac{3}{4}$  in. x 23 in. ; cap-pieces together.
- $\frac{3}{4}$  in. x 21 in. ; post-splices, sway-brace intersections, posts to tenon-blocks, posts to sill
- Lag-screws :  $\frac{3}{4}$  in. x 9 in. ; sway-braces to posts, longitudinal braces to posts, etc. ; spreader and brace blocks to cap.
- $\frac{3}{4}$  in. x 14 in. ; sill-pieces together.
- Drift-bolts :  $\frac{3}{4}$  in. x  $\frac{3}{4}$  in. x 20 in. ; sill to piles.
- Cast-separators : 4 in. thick } for  $\frac{5}{8}$ -in. bolts.
- $\frac{1}{2}$  in. " }
- Cast-washers : Under head and nut of each bolt.
- Splice-plates :  $\frac{5}{16}$  in. x 2 in. x 13 in. ; stringer-joints.
- Sheet-iron : No. 27, 30 in. x 36 ft. ; covering stringers.
- No. 27, 24 in. x 14 ft. ; covering caps.
- No. 27, — x 34 ft. ; covering sill.
- Also, sheet-iron to cover all places where fire can lodge.



A



B

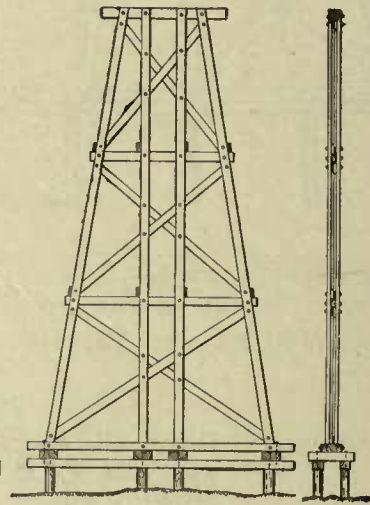


FIG. 2.—40 TO 90 FT. HIGH.

FIG. 1.—FRAMED BENTS.  
 PLATE XXXI.—STANDARD FRAMED TRESTLES, ATLANTIC & PACIFIC RAILROAD.



STANDARD FRAMED TRESTLE, ATLANTIC & PACIFIC RAILROAD.—PLATE XXXI.  
(See also Plate III.)

*Dimensions of Timbers.*

Floor-system: See Plate III.

Bent—Fig. 1: Cap, 12 in. × 14 in. × 14 ft.

Plumb-posts, 12 in. × 12 in.

Batter-posts, 12 in. × 12 in.

Sway-braces, 3 in. × 10 in.

Sill, 12 in. × 12 in.

Fig. 2: Cap, 12 in. × 14 in.

Plumb-posts, 6 in. × 12 in.

Batter-posts, 6 in. × 12 in.

Intermediate caps, 6 in. × 12 in.

Sway-braces, 3 in. × 10 in.

Sill, 8 in. × 12 in., and 12 in. × 12 in.

Sub-sills, 12 in. × 12 in.

Pile-caps, 12 in. × 14 in.

*Dimensions of Iron Details.*

See Plate III.



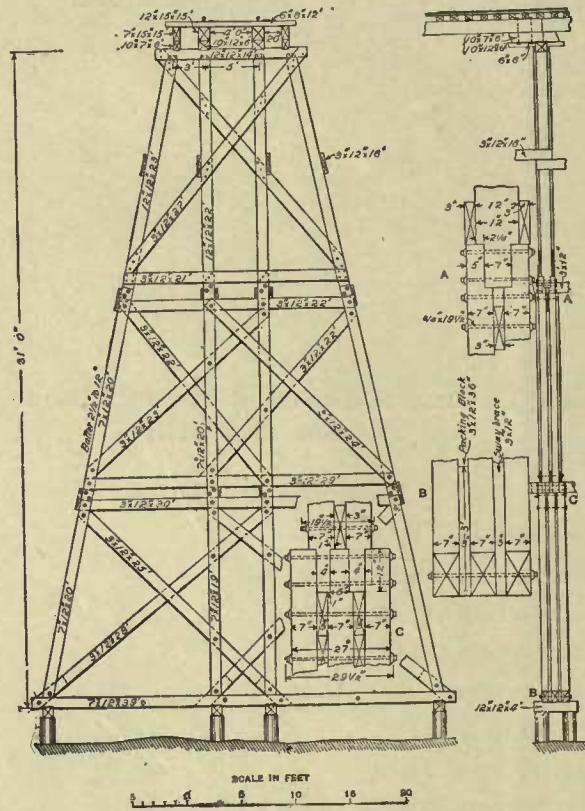


FIG. 1.—DOUBLE AND TRIPLE DECK FRAMED TRESTLE.

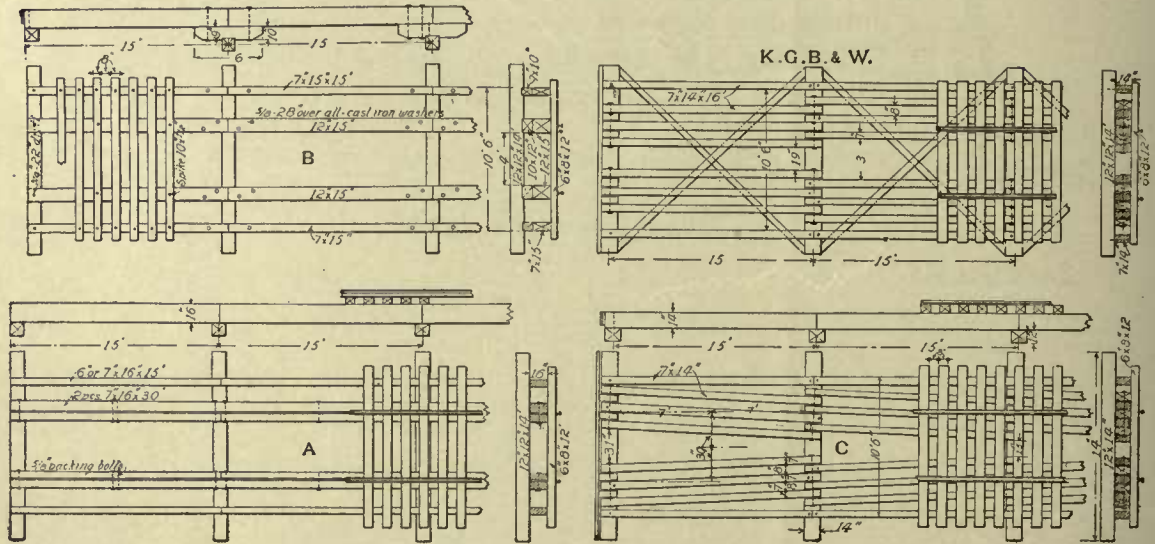


FIG. 2.—FLOOR-SYSTEMS OF TRESTLE-BRIDGES.



## STANDARD FRAMED TRESTLE, MILWAUKEE &amp; NORTHERN RAILROAD.—PLATE XXXII.

*Dimensions of Timbers.*

- Floor-systems—A: Ties, 6 in.  $\times$  8 in.  $\times$  12 ft.  
 Track-stringers, 7 in.  $\times$  16 in.  $\times$  30 ft.  
 Jack-stringers, 6 in. or 7 in.  $\times$  16 in.  $\times$  15 ft.
- B: Ties, 6 in.  $\times$  8 in.  $\times$  12 ft.  
 Track-stringers, 12 in.  $\times$  15 in.  $\times$  15 ft.  
 Jack stringers, 7 in.  $\times$  15 in.  $\times$  15 ft.  
 Track-stringer corbels, 10 in.  $\times$  12 in.  $\times$  6 ft.  
 Jack-stringer corbels, 7 in.  $\times$  10 in.  $\times$  6 ft.
- C: Ties, 6 in.  $\times$  8 in.  $\times$  12 ft.  
 Track-stringers, 7 in.  $\times$  14 in.  $\times$  16 ft.  
 Jack-stringers, 7 in.  $\times$  14 in.  $\times$  15 ft.
- K., G. B. & W. R. R. :  
 Ties, 6 in.  $\times$  8 in.  $\times$  12 ft.  
 Track-stringers, 7 in.  $\times$  14 in.  $\times$  16 ft.  
 Jack-stringers, 7 in.  $\times$  14 in.  $\times$  16 ft.
- Bent : Cap, 12 in.  $\times$  12 in.  $\times$  14 ft.  
 Plumb-posts, 12 in.  $\times$  12 in., and 7 in.  $\times$  12 in.  
 Batter-posts, 12 in.  $\times$  12 in., and 7 in.  $\times$  12 in.  
 Intermediate caps and sills, 3 in.  $\times$  12 in.  
 Sway-braces, 3 in.  $\times$  12 in.  
 Main sill, 7 in.  $\times$  12 in.  
 Packing-blocks, 3 in.  $\times$  12 in.  $\times$  3 ft.
- Pile-caps : 12 in.  $\times$  12 in.  $\times$  4 ft.  
 Longitudinal braces : 3 in.  $\times$  12 in.  $\times$  16 ft.

*Dimensions of Iron Details.*

- Bolts :  $\frac{3}{4}$  in.  $\times$  19 $\frac{1}{2}$  in.  
 $\frac{3}{4}$  in.  $\times$  22 $\frac{1}{2}$  in.  
 $\frac{3}{4}$  in.  $\times$  29 $\frac{1}{2}$  in.
- Spikes : —  $\times$  —.



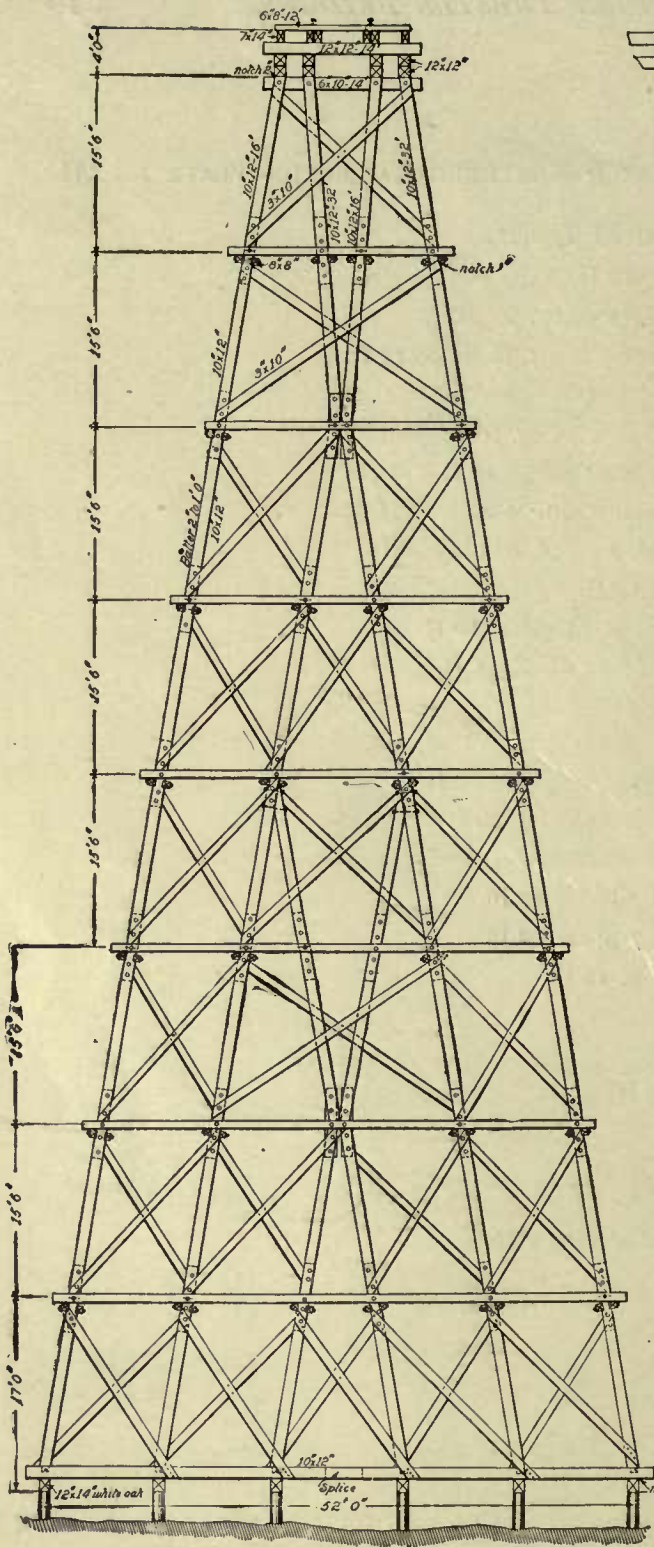


FIG. 1.—CROSS-SECTION.

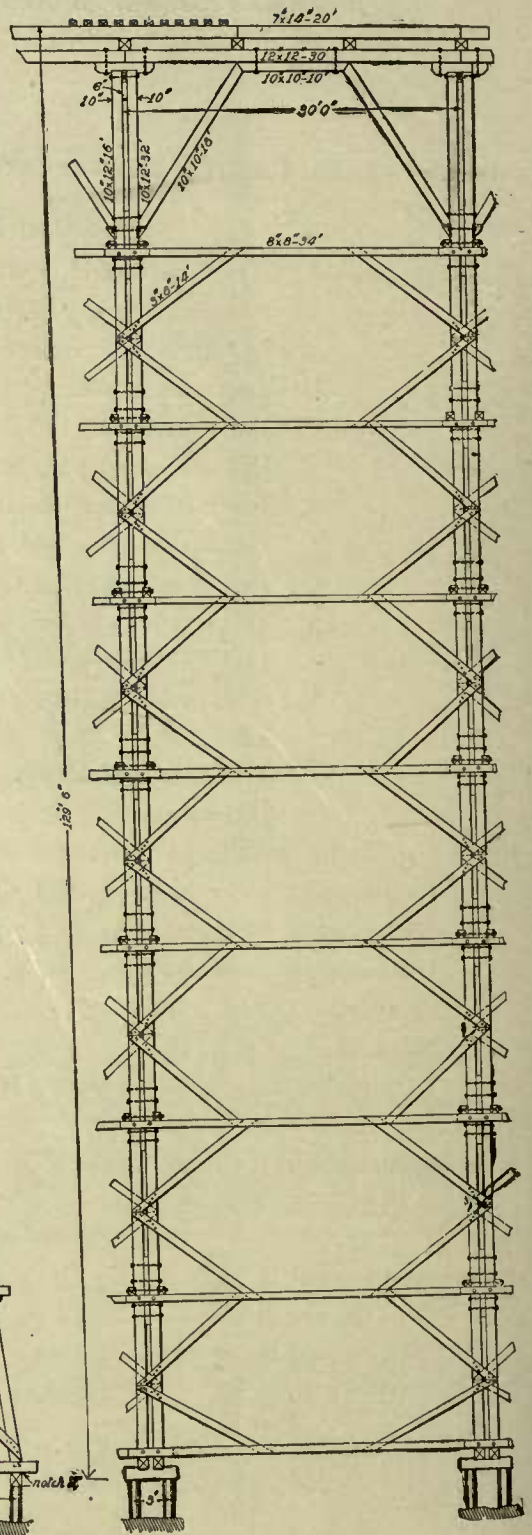
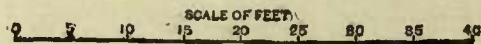


FIG. 2.—ELEVATION.





FRAMED TRESTLES, ST. PAUL, MINNEAPOLIS & MANITOBA RAILROAD.—  
PLATES XXXIII AND XXXIV.

*Dimensions of Timbers.*

FIGS. 1 AND 2.

- Floor-system : Ties, 6 in.  $\times$  8 in.  $\times$  12 ft.  
 Track-stringers, 7 in.  $\times$  14 in.  $\times$  20 ft.  
 Jack-stringers, 7 in.  $\times$  14 in.  $\times$  20 ft.  
 Floor-beams, 12 in.  $\times$  12 in.  $\times$  14 ft.  
 Sub-stringers, 12 in.  $\times$  12 in.  $\times$  30 ft.  
 Corbels, 12 in.  $\times$  12 in.  $\times$  5 ft.
- Bent : Cap, 6 in.  $\times$  10 in.  $\times$  14 ft.  
 Posts, 10 in.  $\times$  12 in.  
 Sway-bracing : Horizontal, 8 in.  $\times$  8 in.  
                   Diagonal, 3 in.  $\times$  10 in.  
 Splice-blocks, 6 in.  $\times$  12 in.  $\times$  6 ft.  
 Sill, 10 in.  $\times$  12 in.
- Pile-caps, 12 in.  $\times$  14 in.
- Knee-braces : Top cord, 10 in.  $\times$  10 in.  $\times$  10 ft.  
                   Diagonals, 10 in.  $\times$  10 in.  $\times$  18 ft.
- Longitudinal braces : Horizontal, 8 in.  $\times$  8 in.  $\times$  34 ft.  
                   Brackets, 3 in.  $\times$  8 in.  $\times$  14 ft.



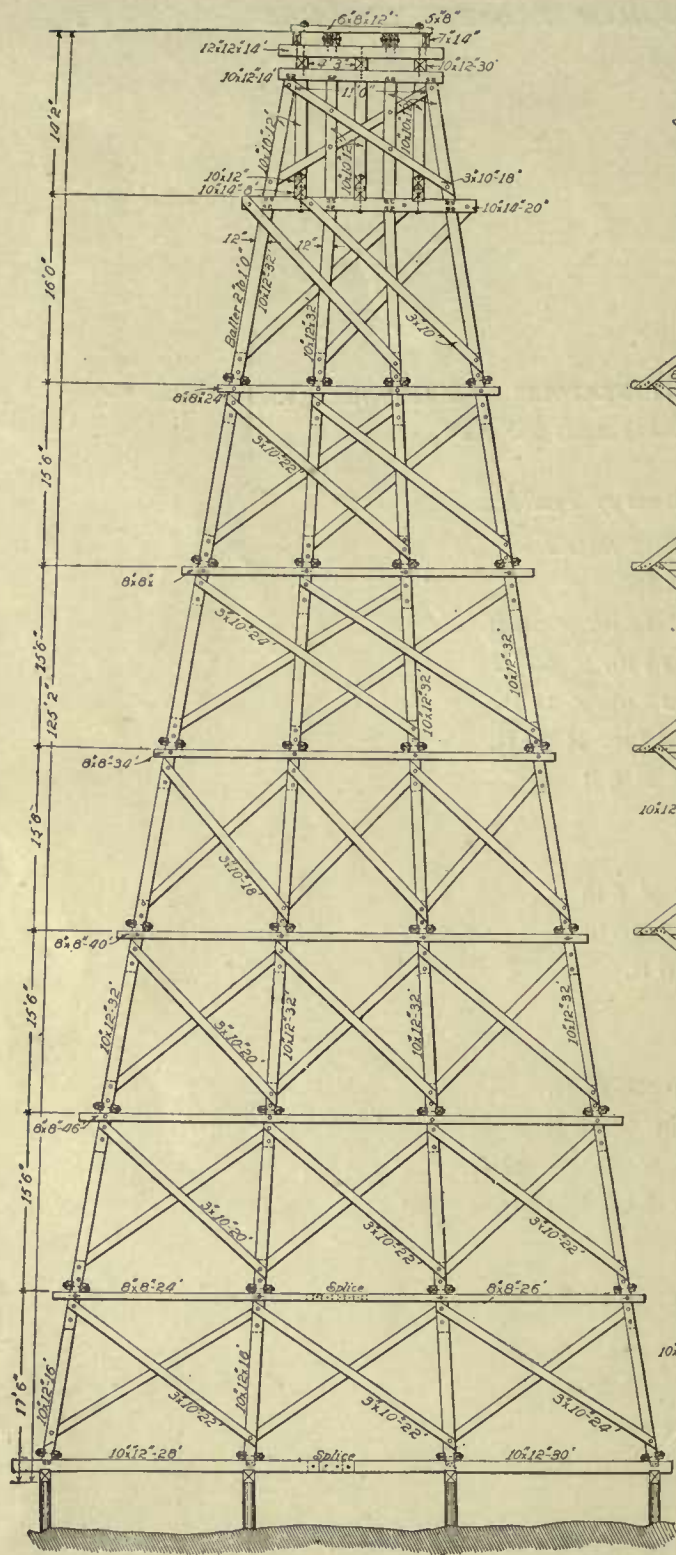


FIG. 3.—CROSS-SECTION.

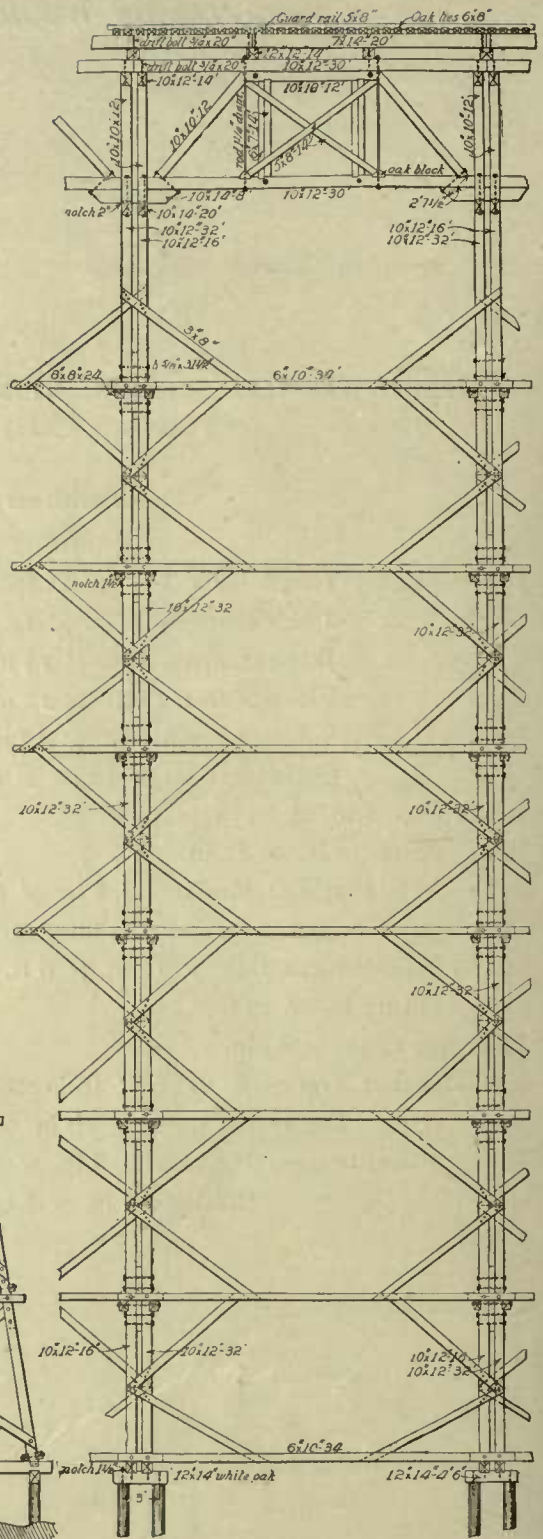
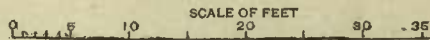


FIG. 4.—ELEVATION.





## FIGS. 3 AND 4.

- Floor-system: Guard-rails, 5 in.  $\times$  8 in.  
 Ties, 6 in.  $\times$  8 in.  $\times$  12 ft.  
 Track-stringers, 7 in.  $\times$  14 in.  $\times$  20 ft.  
 Jack-stringers, 7 in.  $\times$  14 in.  $\times$  20 ft.  
 Floor-beams, 12 in.  $\times$  12 in.  $\times$  14 ft.  
 Sub-stringers, 10 in.  $\times$  12 in.  $\times$  30 ft.
- Bent: Upper cap, 10 in.  $\times$  12 in.  $\times$  14 ft.  
 Lower cap, 10 in.  $\times$  14 in.  $\times$  20 ft.  
 Upper posts, 10 in.  $\times$  10 in.  
 Main posts, 10 in.  $\times$  12 in.  
 Sway-bracing: Horizontal, 8 in.  $\times$  8 in.  
                   Diagonal, 3 in.  $\times$  10 in.  
 Splice-blocks, 6 in.  $\times$  12 in.  $\times$  6 ft.  
 Sill, 10 in.  $\times$  12 in.  
 Sway-brace splice-block, 6 in.  $\times$  8 in.  $\times$  5 ft.  
 Sill splice-block, 6 in.  $\times$  12 in.  $\times$  4 ft.
- Pile-caps, 12 in.  $\times$  14 in.  $\times$  4 ft. 6 in.
- Longitudinal bracing: Horizontal, 6 in.  $\times$  10 in.  $\times$  34 ft.  
                           Brackets, 3 in.  $\times$  8 in.
- Floor trusses: Upper chord, 10 in.  $\times$  10 in.  $\times$  12 ft.  
 Lower chord, 10 in.  $\times$  12 in.  $\times$  30 ft.  
 End-posts, 10 in.  $\times$  10 in.  $\times$  12 ft.  
 Diagonals, 5 in.  $\times$  8 in.  $\times$  14 ft.  
 Lateral braces, 6 in.  $\times$  7 in.  $\times$  14 ft.  
 Foot-blocks: Corbels, 10 in.  $\times$  14 in.  $\times$  8 ft.

*Dimensions of Iron Details.*

- Bolts:  $\frac{5}{8}$  in.  $\times$  12 $\frac{1}{2}$  in.; guard-rails to ties:  
        $\frac{5}{8}$  in.  $\times$  17 $\frac{1}{2}$  in.; stringer-joints; packing-bolts.  
        $\frac{5}{8}$  in.  $\times$  27 $\frac{1}{2}$  in.; longitudinal braces to posts.  
        $\frac{5}{8}$  in.  $\times$  28 $\frac{1}{2}$  in.; post-joints.  
        $\frac{5}{8}$  in.  $\times$  31 $\frac{1}{2}$  in.; diagonal sway-braces to posts.  
        $\frac{5}{8}$  in.  $\times$  41 $\frac{1}{2}$  in.; horizontal sway-braces to posts.
- Drift-bolts:  $\frac{3}{4}$  in.  $\times$  20 in.; stringers to floor-beams; floor-beams to sub-stringers; sub-stringers to caps; main sill to pile-caps; pile-caps to piles.
- Spikes: Boat,  $\frac{1}{2}$  in.  $\times$  10 in.; ties to stringers.  
        $\frac{3}{8}$  in.  $\times$  7 in.; sway-bracing to posts; bracket-braces to posts; and longitudinal bracing.
- Iron in trusses: Rods, 1 $\frac{1}{4}$  in.  $\times$  11 ft. 4 in.; between upper and lower chords.  
                   Tie-rods, —  $\times$  —; three trusses together.
- Bolts: —  $\times$  —; intersection of panel diagonals.  
       —  $\times$  2 ft. 11 in.; end-posts to lower chords.  
       —  $\times$  3 ft. 5 $\frac{1}{2}$  in.; lower chords and corbels to caps.

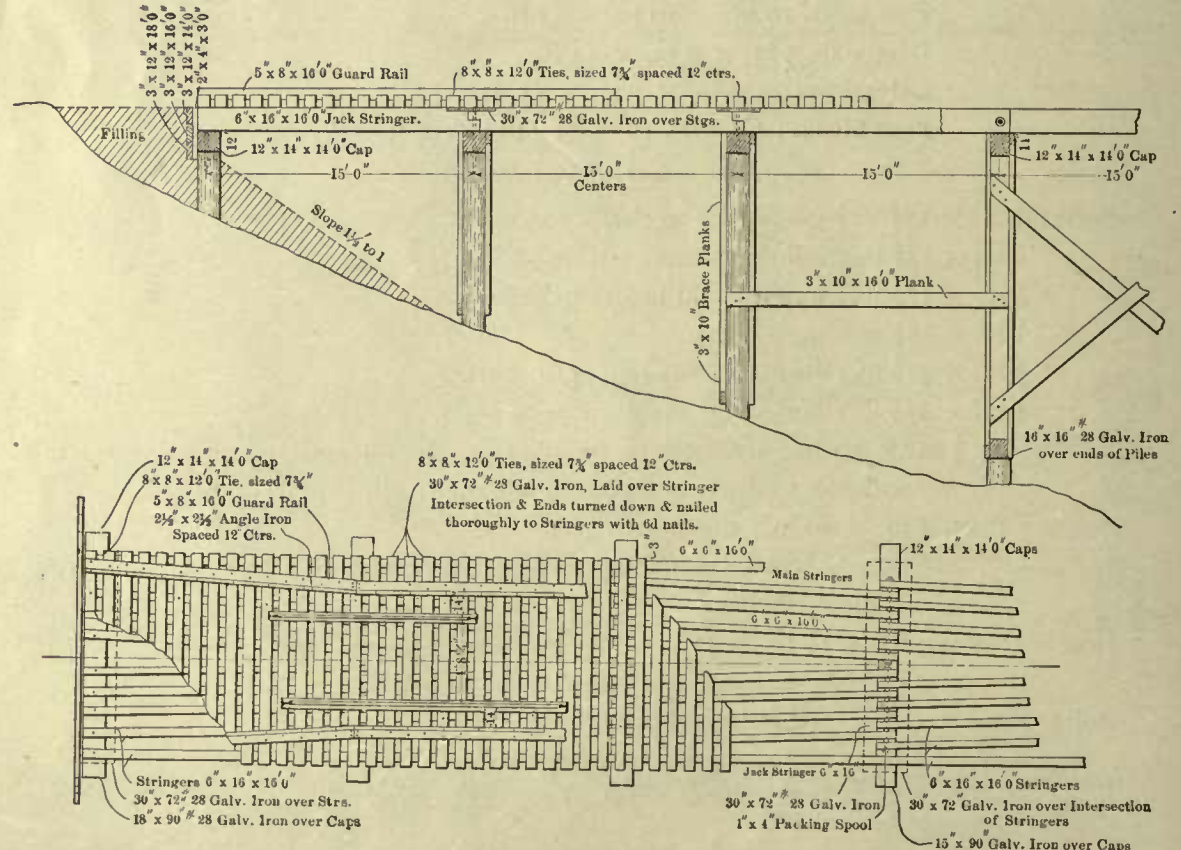
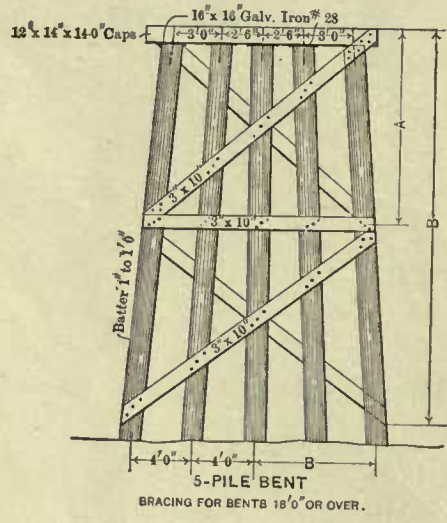
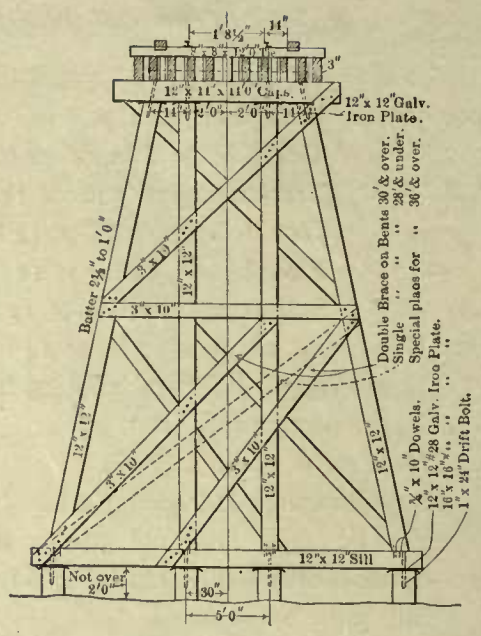
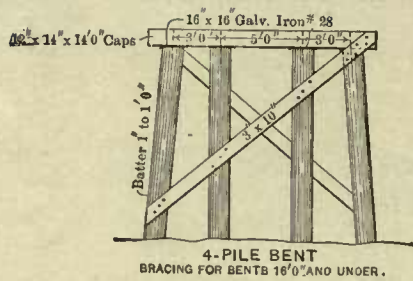


PLATE XXXIVA.—STANDARD TRESTLES, MINNEAPOLIS, ST. PAUL & SAULT STE. MARIE RAILWAY.



## MINNEAPOLIS, ST. PAUL &amp; SAULT STE. MARIE RAILWAY.—PLATE XXXIVA.

For ballasted floor used on this road see Fig. 3, Plate LXII.

## BILL OF MATERIALS.

*Dimensions of Timbers.*

- Pile-bents: Caps, 12 in.  $\times$  14 in.  $\times$  14 feet.  
 Sway-braces, 3 in.  $\times$  10 in.  
 Floor-system—Guard-rails, 5 in.  $\times$  8 in.  $\times$  16 ft.  
 Ties, 8 in.  $\times$  8 in.  $\times$  12 ft.  
 Jack-stringers, 6 in.  $\times$  16 in.  $\times$  16 ft.  
 Main-stringers, 6 in.  $\times$  16 in.  $\times$  16 ft.  
 Framed bents: Caps, 12 in.  $\times$  14 in.  $\times$  14 ft.  
 Plumb and batter posts, 12 in.  $\times$  12 in.  
 Sills, 12 in.  $\times$  12 in.  
 All bracing, 3 in.  $\times$  10 in.

*Dimensions of Iron Details.*

- Galvanized-iron covers for tops of piles: 16 in.  $\times$  16 in.  $\times$  No. 28.  
 Galvanized-iron covers over stringer joints, 30 in.  $\times$  72 in.  $\times$  No. 28.  
 Galvanized-iron covers for ends of framed posts, 12 in.  $\times$  12 in.  $\times$  No. 28.  
 Galvanized-iron covers over caps, 18 in.  $\times$  90 in.  $\times$  No. 28 and  
 15 in.  $\times$  90 in.  $\times$  No. 28.  
 Angle-iron protection for inside top corner of guard-rails, 2½ in.  $\times$  2½ in.  
 Drift-bolts: 1 in.  $\times$  24 in.  
 Dowels: ¾ in.  $\times$  10 in.  
 Packing-spools: 1 in.  $\times$  4 in.

—Proceedings Association Railway Superintendents of Bridges and Buildings, 1906.





DOUBLE-TRACK FRAMED TRESTLE, NEW YORK, WOODHAVEN & ROCKAWAY RAILROAD.—  
 PLATE XXXV.

*Dimensions of Timbers.*

Floor-system : Guard-rails, 8 in.  $\times$  6 in.  
 Ties, 6 in.  $\times$  8 in.  $\times$  21 ft.  
 Stringers, 5 in.  $\times$  14 in.  $\times$  32 ft. 6 in.  
 Corbels, 5 in.  $\times$  8 in.  $\times$  5 ft. 9 in.  
 Beams: Cap, 12 in.  $\times$  12 in.  $\times$  24 ft.  
 Plumb-posts, 12 in.  $\times$  12 in.  
 Batter-posts, 12 in.  $\times$  12 in.  
 Sway-braces, 3 in.  $\times$  10 in.  
 Sill, 12 in.  $\times$  12 in.  
 Sub-sills,

*Dimensions of Iron Details.*

Bolts:  $\frac{5}{8}$  in.  $\times$  13 in. ; guard-rails to ties.  
 $\frac{5}{8}$  in.  $\times$  — in. ; stringer-joints ; packing-bolts.  
 $\frac{3}{4}$  in.  $\times$  — in. ; stringers to corbels.  
 $\frac{5}{4}$  in.  $\times$  — ; } stringers to caps.  
 1 in.  $\times$  — ; }  
 Plates:  $\frac{1}{2}$  in.  $\times$  3 in.  $\times$  17 in. ; corbel-bolts.  
 Spikes : Ties to stringers.  
 Cast-washers : 1 in.  $\times$  3 in. ; under head and nut of each bolt.







FRAMED TRESTLES, NEW YORK, PROVIDENCE & BOSTON RAILROAD.—  
PLATE XXXVI.

FIGS. 1 AND 2: WINTHROP'S COVE TRESTLE, ON  $8^{\circ} 15'$  CURVE AND 0.714 GRADE.

FIG. 3: THAMES RIVER BRIDGE APPROACH.

*Dimensions of Timbers.*

- Floor-system: Guard-rails, 8 in.  $\times$  8 in.  
 Tics, 8 in.  $\times$  11 in.  $\times$  22 ft.  
 Stringers, 8 in.  $\times$  14 in.  $\times$  24 ft.  
 Splice-blocks,  $\left\{ \begin{array}{l} 2 \text{ in.} \times 14 \text{ in.} \times 4 \text{ ft.} \\ 4 \text{ in.} \times 14 \text{ in.} \times 6 \text{ ft.} \end{array} \right.$   
 Bent: Cap, 12 in.  $\times$  14 in.  $\times$  23 ft.  
 Plumb-posts, 12 in.  $\times$  12 in.  
 Batter-posts, 12 in.  $\times$  12 in.  
 Sway-braces, 4 in.  $\times$  12 in.  
 Sill, 12 in.  $\times$  14 in.  
 Longitudinal braces, 4 in.  $\times$  12 in.  $\times$  25 ft.  
 Purlins, 12 in.  $\times$  14 in.  
 Purlin splice-blocks, 4 in.  $\times$  14 in.  $\times$  6 ft.  
 Foundation: Pile-cap, 12 in.  $\times$  14 in.  
 Piles, 12 in. diameter.  
 Brace-piles, 12 in. diameter.  
 Knee-braces: Upper chord, 10 in.  $\times$  10 in.  $\times$  5 ft.  
 Straining-beams, 10 in.  $\times$  10 in.  $\times$  21 ft.  
 Diagonals, 6 in.  $\times$  14 in.  
 Splice-block, 12 in.  $\times$  14 in.  $\times$  4 ft.

*Dimensions of Iron Details.*

- Bolts:  $\frac{3}{4}$  in.  $\times$   $15\frac{1}{2}$  in.; }  
 $\frac{3}{4}$  in.  $\times$   $19\frac{1}{2}$  in.; } guard-rails to ties.  
 $\frac{3}{4}$  in.  $\times$   $18\frac{1}{4}$  in. sway-braces to posts, etc.  
 $\frac{3}{4}$  in.  $\times$  22 in.; purlin splice.  
 $\frac{3}{4}$  in.  $\times$   $26\frac{1}{2}$  in.; upper chord to stringers.  
 $\frac{3}{4}$  in.  $\times$  16 in.; foot of knee-brace to prevent splitting.  
 $\frac{7}{8}$  in.  $\times$   $27\frac{1}{4}$  in.; knee-braces to purlins, to packing-blocks, to posts.  
 1 in.  $\times$  18 in.; longitudinal braces to posts.  
 1 in.  $\times$   $22\frac{1}{2}$  in.; } stringer-joints; packing-bolts.  
 1 in.  $\times$   $26\frac{1}{2}$  in.; }  
 $1\frac{1}{8}$  in.  $\times$  34 in.; batter and sway-brace piles to piles.  
 Drift-bolts:  $\frac{3}{4}$  in.  $\times$   $\frac{3}{4}$  in.  $\times$  21 in.; stringers to caps.  
 1 in.  $\times$  18 in.; sills to posts.  
 1 in.  $\times$  20 in.; cap to posts; pile-cap to piles.  
 Spikes: —  $\times$  —; ties to stringers.  
 $\frac{5}{8}$  in.  $\times$  12 in.; purlins to pile-caps.  
 $\frac{3}{4}$  in.  $\times$  16 in.; sills to purlins.  
 Washers, wrought:  $\frac{3}{4}$ -in. bolts; guard-rail bolts.  
 4 in.  $\times$  4 in.  $\times$   $\frac{3}{8}$  in.; sway-brace bolts.  
 4 in.  $\times$  4 in.  $\times$   $\frac{1}{2}$  in.; longitudinal brace-bolts.  
 4 in.  $\times$  4 in.  $\times$   $\frac{5}{8}$  in.; sway-brace, pile, etc., bolts.  
 3 in.  $\times$   $\frac{3}{8}$  in.; purlin splice-bolts.  
 $3\frac{1}{2}$  in.  $\times$   $\frac{1}{2}$  in.; stringer-bolts.  
 Cast separators:  $3\frac{1}{2}$  in.  $\times$  1 in.; between splice-blocks and stringers.  
 $3\frac{1}{2}$  in.  $\times$  4 in.; between stringers, where there are no splice blocks.





## DEEP-WATER FRAMED TRESTLE, INTERCOLONIAL RAILWAY.—PLATE XXXVII.

As the structure illustrated in Plate XXXVII is exceptional, and had to fulfil unusual requirements, it was thought best to reprint the full description of the work, as given in the *Railroad Gazette* of April 9, 1886.

It was designed to carry a short branch-line of minor importance across a narrow strait (the Narrows) in Halifax Harbor. The water being from 65 to 80 feet deep, some peculiar features of design and methods of construction were naturally required.

The branch as constructed (the Dartmouth Branch) is about 5 miles long. To avoid the trestle it would have been necessary to begin the branch at a point 9 miles or at one 14 miles distant, which would have made it seven or 12 miles long, and required a special train service in operating it.

Richmond yard being on the shore of the narrow passage between Halifax Harbor and Bedford Basin, at the most favorable point for bridging it, the structure shown was built instead, permitting the branch to leave the yard inside the semaphore, thus enabling the shunting-engines to do the business on it without in any way interfering with the traffic of the main line.

The Narrows are about 1500 ft. wide, and from 65 to 80 ft. deep in the channel where the line crosses for a distance of 650 ft. The mean rise and fall of the tide is 6 ft., causing a current through the Narrows of about  $1\frac{1}{2}$  miles an hour. At spring-tide, with a strong wind, this is sometimes increased to three miles an hour.

The bottom is generally compact gravel, mixed with stones and bowlders. In no place could a bar be driven more than 3 ft.; below that depth was apparently ledge-rock.

In severe winters ice forms in Bedford Basin, but owing to the extreme narrowness of the outlet into the harbor, it is held in the basin until decayed by the spring weather. The bridge has a total length of 2050 ft., of which 1204 ft. is on piling, 650 ft. trestling in the channel, and the remaining 196 ft. is a steel swing-bridge.

The piling, where in deep water, was well stiffened transversely by brace-piles, which were driven plumb and afterwards drawn over to a considerable angle, when they were fitted to the capping and bolted. The pivot pier for the swing-bridge is of masonry, and has a passage for vessels on each side of 85 ft. in the clear.

From the top of the pier to 2 ft. below low-water it is laid in cement, and is circular in form, with a diameter of 20 ft. Thence to the bottom, about 33 ft., it is built square, with a batter of 1 in 12, and is laid without mortar. Large stones only were permitted to be used in the square portion of the work, and were required to be full bedded throughout and closely fitted. Each course was carefully dressed and put together in the quarry upon a level platform; the stones were then marked with white paint at all connections with their fellows, and carefully numbered.

The courses were then forwarded to the site of the pier, where they were lowered from a lighter, each stone in its proper order, and received by a diver, who, standing on the course last laid, placed them in position, using lines, straight-edge, and spirit-level to insure all possible accuracy. A complete course was frequently laid in a day by the one diver employed, for with the footings once properly levelled he had but little to do to keep the work in good order. Before putting in the foundation courses the sloping bottom was properly benched by the diver, and frequent testings as the work proceeded showed that perfect line and level was being kept.

No accident or difficulty of any kind occurred in the construction of the pier, the work being carried on as smoothly and regularly as if in the open air; the steam winch of the lighter working with quickness and precision as the diver signalled his directions.

The time occupied in building the pier was 70 days, the same diver being employed throughout. The cost per cubic yard was \$23.

The trestling across the channel consisted of timber bents, framed as shown on the accompanying drawings. The bents were placed 25 ft. apart between centres, and rested on a ballasted timber crib, which had previously been lowered in place. The bents were floated to the site and drawn down to their seat on the cribs by the methods shown in the cuts and described hereafter. The work of putting down the trestling was commenced on the west side of the channel August 8, 1884, and on the east side October 4, 1884. In all 25 bents were put down, in depths generally from 70 to 80 ft. The two sides were connected November 20,

1884. When the level portion of the channel was reached three bents were sometimes put down in a week. One diver, with occasionally an assistant, worked on each side of the channel. In addition to the travelling derrick shown, a lighter was provided for each side, having a steam-winch for lowering ballast, etc., and a steam-pump for the diver.

The correct centring at each bent was given by a theodolite placed at the outer end of the piling, and at slack-water lining in the rope holding the hammer of the floating pile-driver, which had been brought approximately into position, with the hammer raised about one foot from the bottom. When correctly lined the diver was signalled, and a bolt driven into the ground at the centre of the hammer.

It is not anticipated that there will be any trouble from worms, as the strength of the current and the large amount of fresh water discharged into the basin render their presence in the Narrows improbable. The wharves in the harbor also show that the nearer the Narrows are approached the less destructive are the worms. It is therefore hoped that the bents below low-water will but rarely require to be renewed, and they have been constructed of sawn hemlock, a cheap and sufficiently good material where secure from decay. The upper or supplementary bents were constructed of white pine, as more durable, and are so connected with the lower bents that, though erected as a whole, they can be easily separated and renewed.

The work of preparing the bottom for the crib foundation of the bent was as follows: Six flattened timbers 10 ft. long and weighted were lowered to the bottom. These were bedded by the diver, and were brought to a uniform level by means of a long straight-edge with spirit-level attached. Where the slope or character of the ground demanded, additional timbers were placed under these bed logs to bring them to the required height, the whole being filled in and about with stone. In fairly level ground the six logs could be bedded by one diver in 1½ days. In the worst cases, where the slope of the bottom was 1 in 2½ longitudinally and 1 in 5 transversely, it took the same diver six days to bed them properly.

The crib for each boat was next launched from the ways on which it was constructed, and floated out, and the lines from the winch on the travelling derrick attached to the chain at each end, by hooking on the iron swivel-blocks as shown.

The crib was supported until about nine tons of ballast had been thrown on, when it was lowered to its place on the bed-logs. When near the bottom the diver signalled any slight alteration required in its position, and the correction was made by side lines. The time occupied in lowering the cribs and finally adjusting them was about 1½ hours.

In difficult bottom the diver then proceeded to the next foundation, leaving an assistant to place the remainder of the ballast on the crib. This took about 1¼ days to do properly.

The bent, which, like the crib, was built on ways on the shore, was next launched and towed to the site, and the lines from the travelling derrick, which passed through the blocks at the ends of the crib, were attached to the sill of the bent. About 10 tons of ballast were next placed in the lockers near the bottom, and the engine was started, drawing the bent gradually downward till, led by the blocks, it rested in its proper place on the crib. It was readily adjusted vertical by a line to the cap, and was then secured by bolting on temporary stays from the end of the bridge. The diver then permanently secured the bent to the crib in the manner shown, by lifting the galvanized-iron fastenings into place, fitting on the cover-blocks and screwing home the nuts. The fastenings were so arranged that they could be thrown back out of the way until the bent was finally settled in place.

The time occupied in towing out, hauling down, and adjusting a bent, together with the complete fitting and securing of the fastenings, was in general about 1½ days; of this the actual hauling down occupied but a small portion.

The permanent stringers were next placed and sleepers, the rails for the derricks laid, and the derrick run out for the next crib.

The average cost of the trestling per bent completed ready for the rails was as follows:

11 M. ft. B. M., hemlock, . . . . .	@ \$6.47	\$71.17
9 M. ft. B. M., pine, . . . . .	@ 16.00	144.00
12 knees, . . . . .	@ 3.50	42.00
500 lbs. ordinary iron, . . . . .	@ .04½	22.50
1800 lbs. galvanized iron, . . . . .	@ .08	144.00
Crib—material and work, . . . . .	@ 60.00	60.00
Framing, 20 M. ft. B. M., . . . . .	@ 10.00	200.00
Stone ballast, 66 tons, . . . . .	@ .40	26.40
Diving work, . . . . .	@ 108.00	108.00
Incidentals, . . . . .		31.93
Total, . . . . .		<u>\$850.00</u>



The bents number 25, making the total cost of the trestling \$21,250, or at the rate of nearly \$33 per lineal foot.

No accident of any kind occurred in putting down the trestle-bents or foundations, everything working smoothly throughout. All iron to be exposed to the action of salt water was galvanized. The crib foundations, from their position, and from being covered with stone, may be considered secure from the action of worms or other destroying agencies. Should a bent at any time require to be removed, it can be easily released from the crib and a new one substituted. In the deepest water the divers worked skilfully and without difficulty, and by coming to the surface for a few minutes every 1½ hours, were enabled to do good work throughout the entire day. All levelling and lining under water was accurately done, as proved when the bents were drawn down to their place. The divers were paid \$150 per month each, with board; the assistant-divers about half that amount.

Steam-pumps were used for supplying air, in preference to those worked by hand, the increased regularity of stroke being of importance in deep water.

The current at the bottom, while not so rapid as at the surface, was more changeable, sometimes almost entirely ceasing and then suddenly recommencing, as though restrained temporarily by eddies or cross-currents. The divers, however, were rarely prevented by the current from working satisfactorily. Very severe gales occurred during the construction of the bridge and after its completion. No movement or working was at all perceptible during their continuance.

The bridge has now been completed and in operation nearly a year. Trains preceded by two locomotives crossing at 15 miles an hour have failed to produce the slightest motion or settlement in any part of the structure.

The work was planned and carried through under the direction of Mr. P. S. Archibald, Chief Engineer of the Intercolonial Railway.

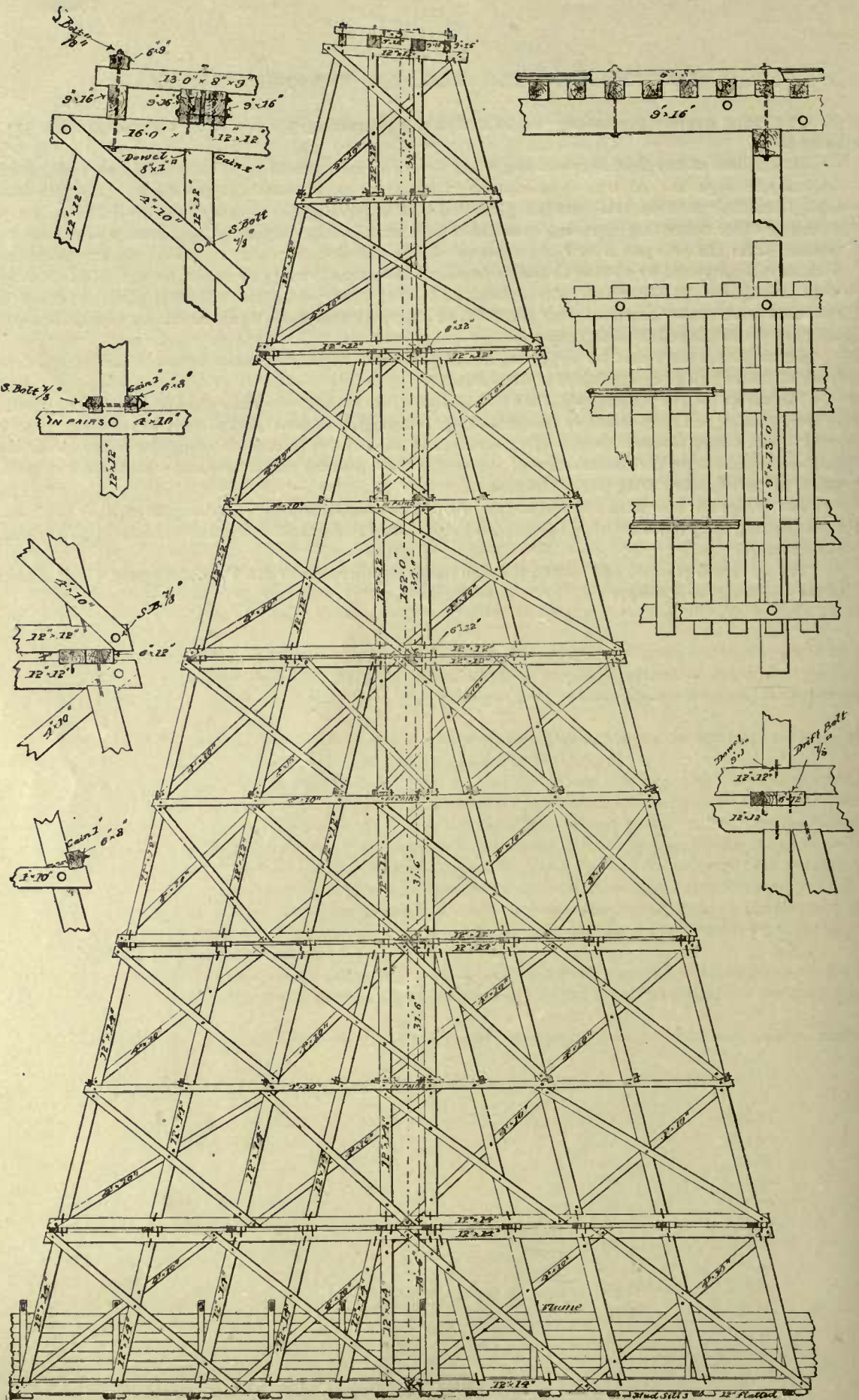


PLATE XXXVIII.—STANDARD FRAMED TRESTLE, ESQUIMALT & NANAIMO RAILWAY.



## STANDARD FRAMED TRESTLE, ESQUIMALT AND NANAIMO RAILWAY.—PLAT. XXXVIII.

*Dimensions of Timbers.*

Floor-system: Guard-rails, 6 in.  $\times$  9 in.

Ties, 8 in.  $\times$  9 in.  $\times$  13 ft.

Stringers, 9 in.  $\times$  16 in.

Bents: Caps, 12 in.  $\times$  12 in.  $\times$  16 ft.

Plumb-posts, 12 in.  $\times$  12 in., and 12 in.  $\times$  14 in.

Batter-posts, 12 in.  $\times$  12 in., and 12 in.  $\times$  14 in.

Counter-posts, 12 in.  $\times$  12 in., and 12 in.  $\times$  14 in.

Sill, 12 in.  $\times$  14 in.

Intermediate caps and sills, 12 in.  $\times$  12 in., and 12 in.  $\times$  14 in.

Sway-braces, 4 in.  $\times$  10 in.

Longitudinal braces, 6 in.  $\times$  8 in.

Purlins, 6 in.  $\times$  12 in.

Sub-sills, 12 in. round, flatted.

The trestle illustrated is built on a  $10^\circ$  curve. Mr. Joseph Hunter is the Chief Engineer of the road. For further description, see *Railroad Gazette*, February 6, 1891, p. 89. In the reduction of the drawing of this trestle the figures become so small that the reader is referred to the enlarged details for the dimensions which are also given above.



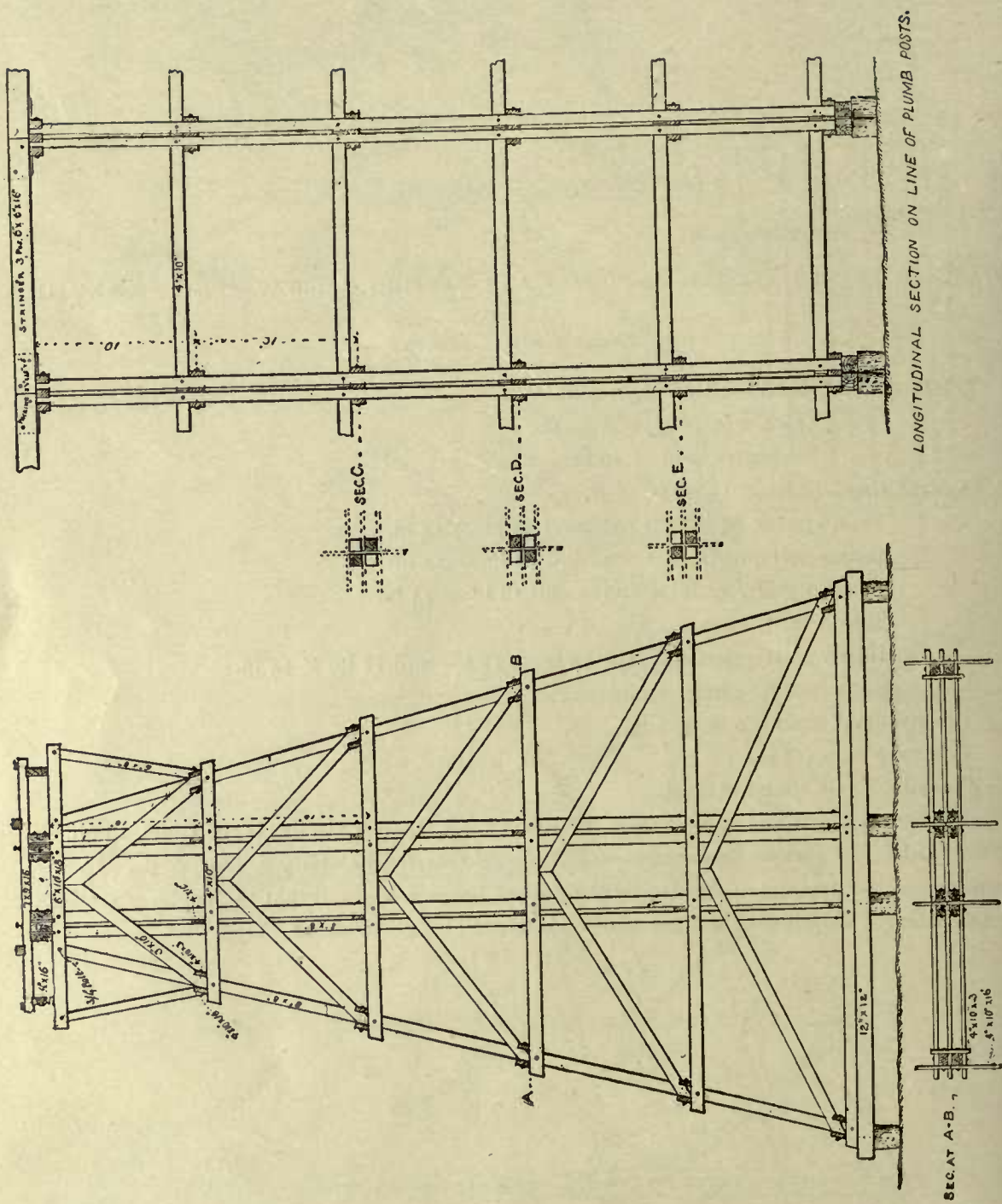


PLATE XXXIX.—CLUSTER-BENT TRETTLE, CLEVELAND, LORAIN & WHEELING RAILWAY.



CLUSTER-BENT TRESTLE, CLEVELAND, LORAIN & WHEELING RAILWAY.\*  
PLATE XXXIX.

There is an objection to the method of sway-bracing this trestle; otherwise the design is good. The floor is rather wider than usual, and consequently is not so economical in timber as some other designs.

*Dimensions of Timbers.*

Floor-system : Ties, 7 in.  $\times$  9 in.  $\times$  16 ft.  
Track-stringers, 6 in.  $\times$  16 in.  $\times$  16 ft.  
Jack-stringers, 6 in.  $\times$  16 in.  $\times$  16 ft.  
Packing-block, 2½ in.  $\times$  18 in.  $\times$  5 ft.  
Guard-rails.  
Outside guard-strips, 4 in.  $\times$  6 in.

Bent: Cap.  
Posts, 8 in.  $\times$  8 in.  
Sway-bracing : Horizontal, 4 in.  $\times$  10 in.  
Diagonal, 3 in.  $\times$  10 in.  
Sill, 12 in.  $\times$  12 in.  
Knee-braces, 6 in.  $\times$  8 in.

Longitudinal braces : Horizontal, 4 in.  $\times$  10 in.  $\times$  16 ft.

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\* *Engineering News*, Dec. 31, 1887.







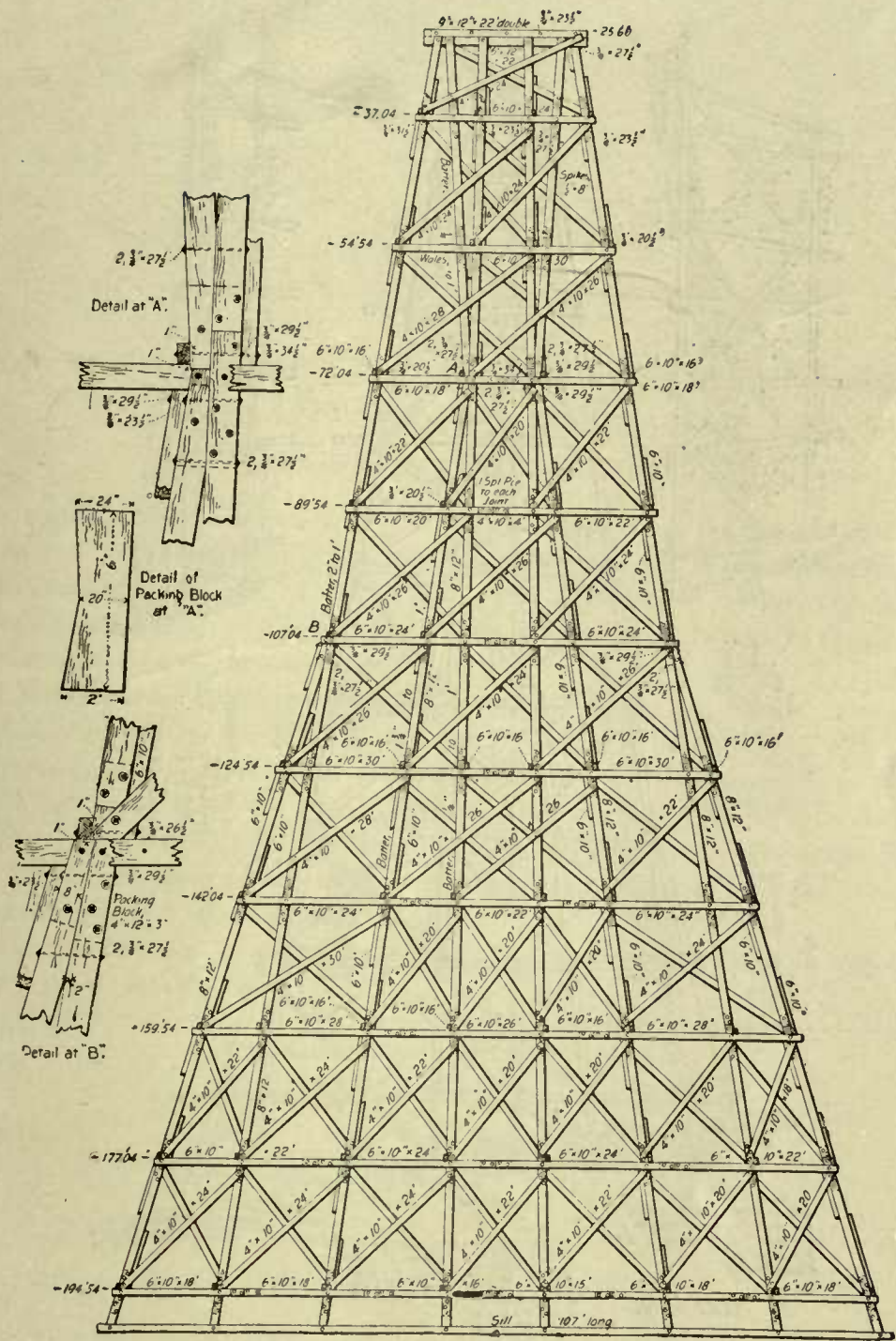


PLATE XLI.—TOWER-BENT ST. PAUL, MINNEAPOLIS & MANITOBA RAILROAD.

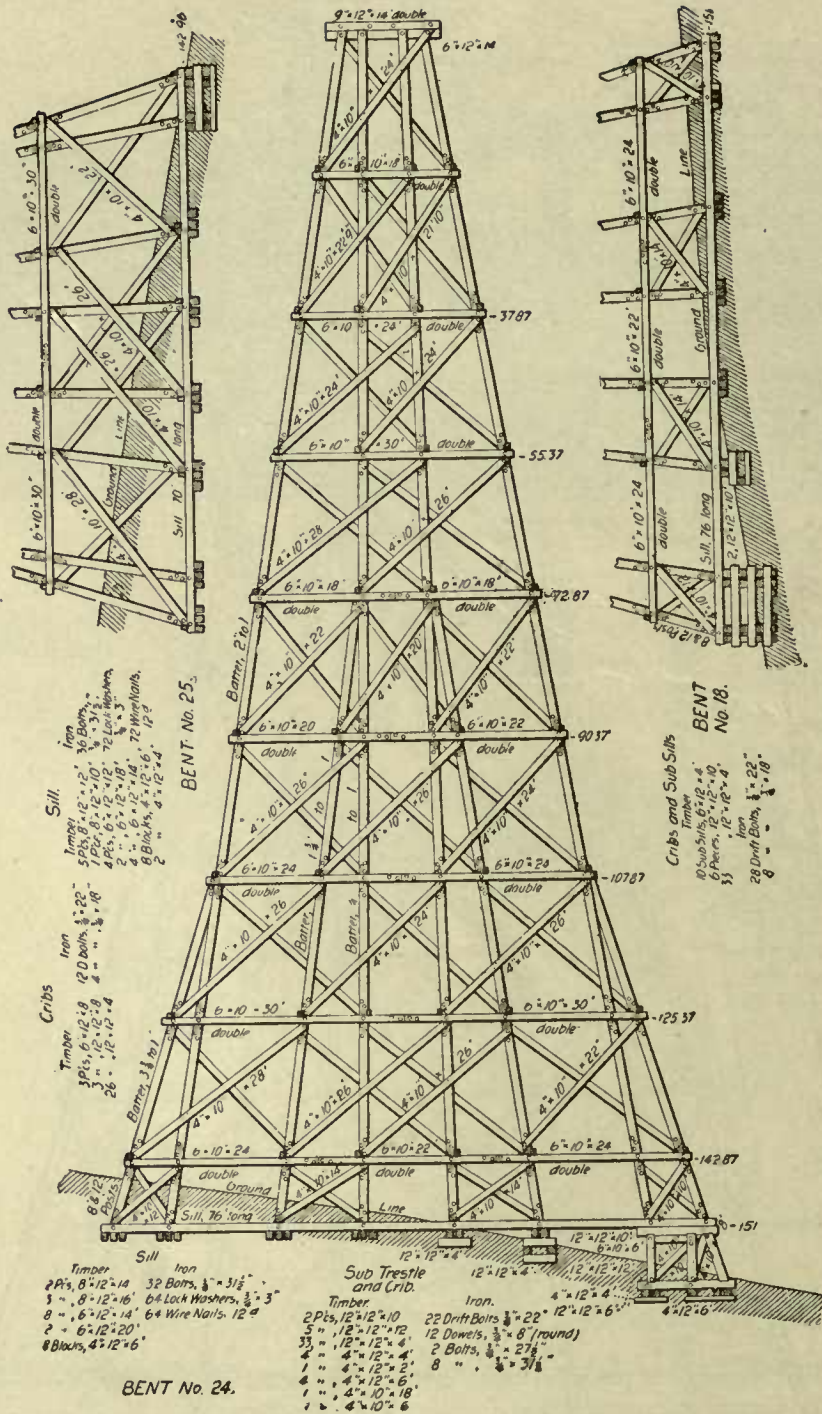


PLATE XLII.—SIDE BENT, ST. PAUL, MINNEAPOLIS & MANITOBA RAILROAD.



TWO MEDICINE BRIDGE, ST. PAUL, MINNEAPOLIS & MANITOBA RAILROAD.  
PLATES XL, XLI, XLII.\*

(See also Plates XXXIII, XXXIV.)

The accompanying cuts give a general view and details of the great Two Medicine Bridge on the Pacific extension of the St. Paul, Minneapolis & Manitoba Railroad; Mr. E. H. Beckler, Chief Engineer. This structure, which ranks among the very highest timber trestles ever erected, is 751 ft. long and 211 ft. from rail to water. It consists of one span of 120 ft., four spans of 40 ft., and all the rest of 16 ft.

The posts are made continuous from the foundation to the cap, packed at every story with a plank 4 in.  $\times$  12 in.  $\times$  6 ft. The stories are made  $17\frac{1}{2}$  ft. in height.

The arrangement of short spans alternating with two trestle-bents as shown in Fig. 1, Plate XL, was found to be the most economical plan where the height exceeded 100 ft. For heights under 100 ft., trestle-bents with 16-ft. spans are used. The foundations are cribs, solid rock and stone piers, and for the lighter bents piling or mudsills. The bridge contains about 750 M ft. B. M. of timber.

In Fig. 1 an error has been made by the artist in showing, but one bent in the left-hand bridge pier where there should be two.

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\* *Engineering News*, March 19, 1892, p. 268.

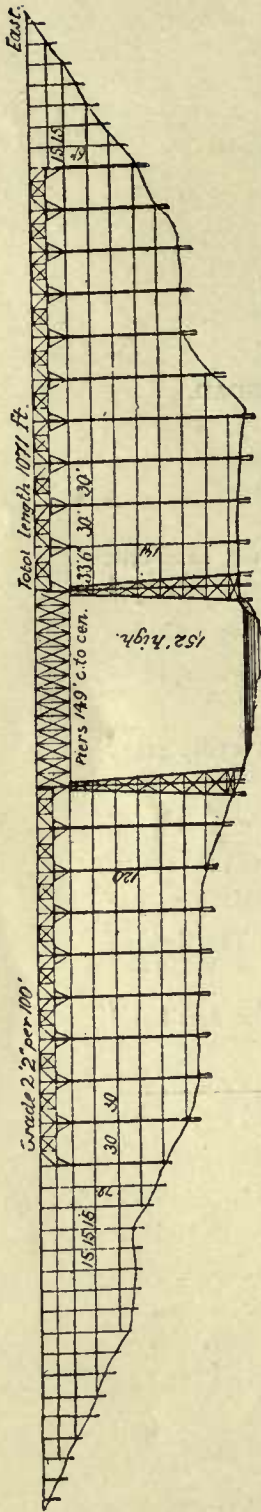


PLATE XLIII.—MOUNTAIN CREEK BRIDGE, CANADIAN PACIFIC RAILROAD.

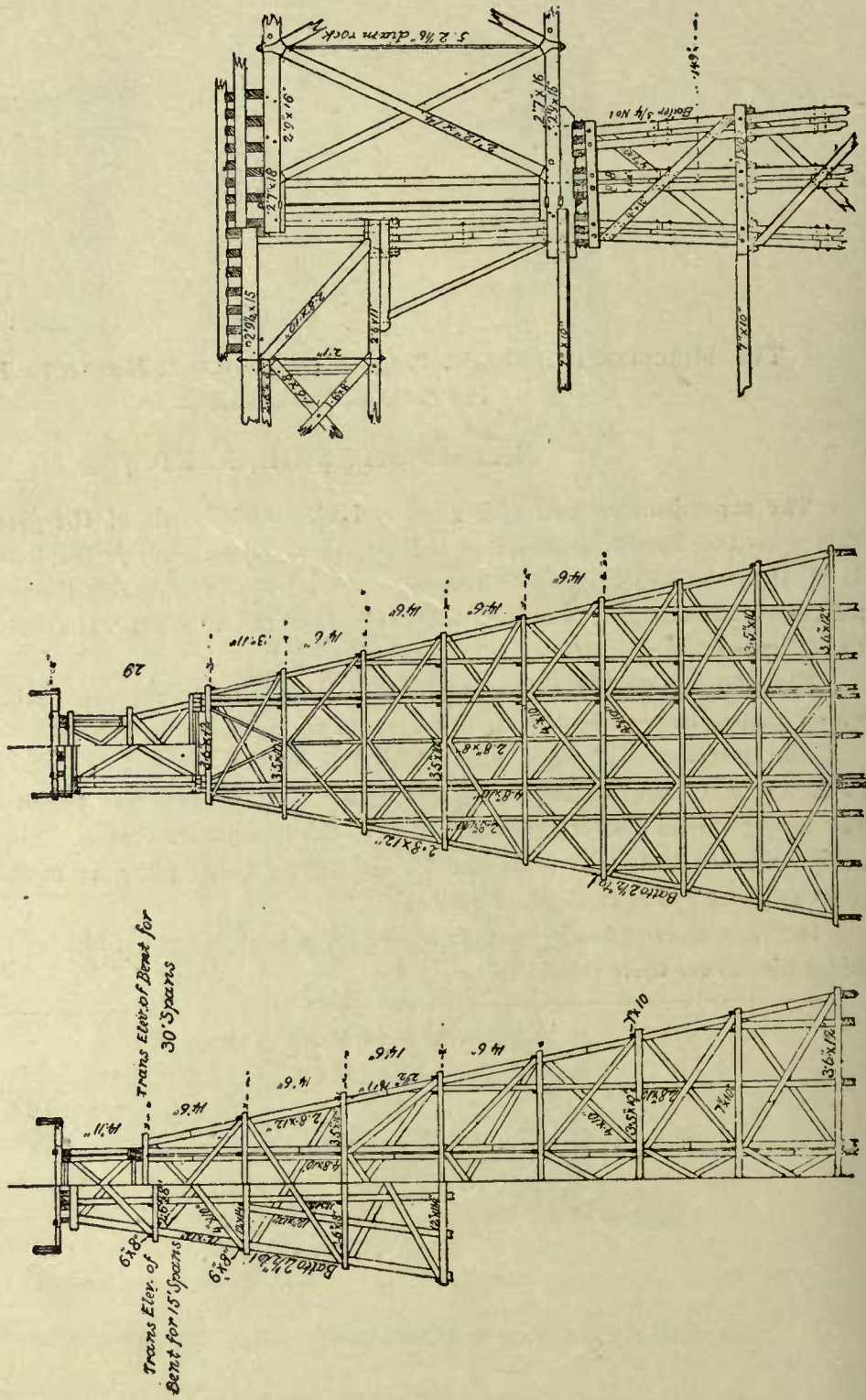


FIG. 1.

FIG. 2.

PLATE XLIV.—MOUNTAIN CREEK BRIDGE, CANADIAN PACIFIC RAILROAD.



## MOUNTAIN CREEK BRIDGE, CANADIAN PACIFIC RAILWAY.\*—PLATES XLIII, XLIV.

BY W. A. DOANE, C.E.

This large structure, a general description of which is here given, is located on the eastern slope of the Selkirk range of the Rocky Mountains. From the summit of the range just mentioned the line of railway descends with a maximum grade of 116 ft. per mile for a distance of 17 miles, crossing in its course several deep ravines and narrow valleys, requiring bridges and trestles of more than ordinary size, this one being more than 14 miles from the summit. On account of the great cost and difficulty of teaming ahead from the end of track, and in view of the fact that no suitable stone could be found within a reasonable distance, it was decided to build the whole structure, foundations included, so far as possible, of wood, timber being very abundant and good—mostly spruce and Douglas fir.

Plate XLIII is a skeleton elevation, showing general style and spans, which are as follows: Sixteen 15-foot spans at the west and seven at the east end, 345 ft.; seventeen 30-foot spans, 510 ft.; two 33-ft. 6-in. spans, 67 ft.; and one span 149 ft.; all centre to centre, making a total length of 1071 ft. The 15-ft. spans at the west end are on a ten-degree curve (grade reduced to 1.9 ft. per 100 ft.), all others on tangent. Piles driven from 6 to 12 ft. in firm earth, with occasional boulders, form the supports for trestle-bents and piers throughout, the total number required being 596. These were cut off not more than 5 ft. above surface of ground to receive the short caps and the sills, the latter being carried horizontally across as in Fig. 2, although in many places the transverse slope of the ground required from 2 to 8 ft. cutting, which was trenched out before the piles were driven.

Half of Fig. 1 shows trestle-bent for the 15-ft. spans; ties are 8 in.  $\times$  8 in., spaced 8 in. apart in clear, every fourth one projecting 4 ft. to support walk and railing; every alternate span has two 9-in.  $\times$  15 in. stringers under each rail; intermediate spans  $\frac{3}{8}$  in.  $\times$  15 in. overlapping joints; in addition, a line of 9-in.  $\times$  15-in. pieces under each guard-rail. The figure shows size and number of posts, etc.; top of piles to base of rail varies from 20 to 79 ft.; the sills, caps, posts, etc., for these spans were hewn.

Half of Fig. 1 shows trestle-bent for 30 ft. spans, an extra price being paid to contractors for timber more than 30 ft. in length; the decks were made 14 ft. 6 in. high, so that posts (all reach two decks) would not exceed that; half the joints in centre groups of posts are at cross walls, others are in centres of decks; rails are laid on 8-in.  $\times$  12-in. ties, spaced, etc., as in the 15-ft. spans; being supported by two double lines of 9½-in.  $\times$  15-in. stringers, packed and carried continuously directly over the 30-ft. trusses; top of piles to base of rail varies from 69 to 141 ft. Each of the two piers is formed of three bents (Fig. 2), very similar to those of the 30-ft. spans, joined by bracing-wales, etc., as shown; top of piles to base of rail at one pier is 143 ft., the other 140 ft. 6¼ in.; screw-bolts and washers are used throughout to pack posts at both cross and longitudinal wales, at all joints, etc., and ½-in.  $\times$  9-in. wrought spike for all 4-in.  $\times$  10-in. braces. The piers carry an ordinary Howe-truss span, built some-

\* *Engineering News*, Sept. 26, 1885.

what heavier than usual; false work was carried up for this, consisting of six bents with pile foundations, each having four 8-in.  $\times$  8-in. posts in 29-ft. lengths, with 8-in.  $\times$  10-in. sills and cap-sills, each set well braced both ways, and with longitudinals 14 ft. 6 in. apart vertically.

A portable sawmill was erected as near the site of the bridge as possible, and began running January 26, 1885, averaging 20 M per day; at the same time contractors began clearing off the heavy timber and underbrush for camps, offices, and framing grounds; the right of way having been already cleared, three pile-drivers were started January 26 and February 10th. Framing was begun January 31st and raising on February 16th, with a force of 60 carpenters at the latter date, which was gradually increased to 100 as the work progressed.

Except for the 149-ft. span, the iron was teamed in from end of track, a distance of eight miles; for that, the timber was sawn and framed at another mill twenty-one miles east, being delivered with the iron by train; when the track had reached the bridge, April 20th.

April 1st a strike occurred, and work was suspended for a week. April 28th a train crossed the bridge for the first time, and little remained to be done but lay the footway and put up the railing. It will be seen by the general design that a large force of men could be employed and work to good advantage; all framing was done from patterns, and the different pieces put together only when raised to their places, the raising being done by a 10 H.P. engine and three hoists, the gin-poles being lashed to the posts and raised from time to time as required.

The bridge is designed to safely carry a Baldwin consolidation locomotive, having 116,000 lbs. on 21-ft. wheel-base, followed by maximum weight of tender and train, with a wind-pressure of 300 lbs. per lineal foot for train, and thirty pounds per square foot on twice the projected area of side.

While the arrangement of posts, etc., in the style of bent adopted is far from being above criticism, yet the pressure is well distributed over the foundations, and framing and raising were simply and quickly done.

The cost was somewhat increased by adverse circumstances, the snow being fully five feet in depth, which had to be removed by shovelling; high prices of labor and material, etc. Wm. McKenzie & Co. were the contractors; R. Balfour in charge of framing and erecting, and it is but just to add that no accidents occurred.

James Ross, C.E., is Manager of Construction and Chief Engineer of the Mountain Division C. P. R. The writer has charge of the designing and draughting office. Below is given the cost to the company of the finished structure.

Clearing right of way, extra width for fire protection.....	\$1,525 00
Clearing snow.....	1,472 00
Excavation for foundations, riprapp, etc.....	6,754 00
Piling.....	4,200 00
One 149-ft. span, 88,066 B. M. at \$55.00 per M (contract).....	4,843 63
One 930-ft. span, 146,997 B. M. at \$40.00 per M (contract).....	5,879 88
Trestle-bents, piers, etc., 854,889 B. M. at \$40.00 per M (contract).....	34,195 56
False work 149-ft. span, 50,000 B. M. at \$16.00 per M (contract)....	8 00 00
One 149-ft. span, 29,342 lbs. cast iron at 4 cts., including freight.....	1,173 68



One 149-ft. span, 38,264 lbs. wrought iron at 4½ cts., including freight.....	1,721 88
One 930-ft. span, 22,629 lbs. wrought iron at 4½ cts., including freight.....	1,018 30
One 930-ft. span, 3,192 lbs. wrought iron at 4 cts, including freight.....	127 68
Trestle-bents, piers, etc., including extra spike for staging, etc., 50,111 lbs. wrought iron at 5½ cts., including freight.....	2,756 10
Trestle-bents, 19,137 lbs. cast iron at 3 cts., including freight.....	574 11
Iron teamed 8 miles, 47½ tons at \$6.00.....	285 00
	<hr/>
Total.....	\$67,326 82

It cost the contractors \$750 to clear off the snow and timber for two framing grounds—one 150 ft. × 300 ft., and one 200 ft. × 400 ft.; and for clearing away and erecting buildings for the men, for offices, etc., \$2000.



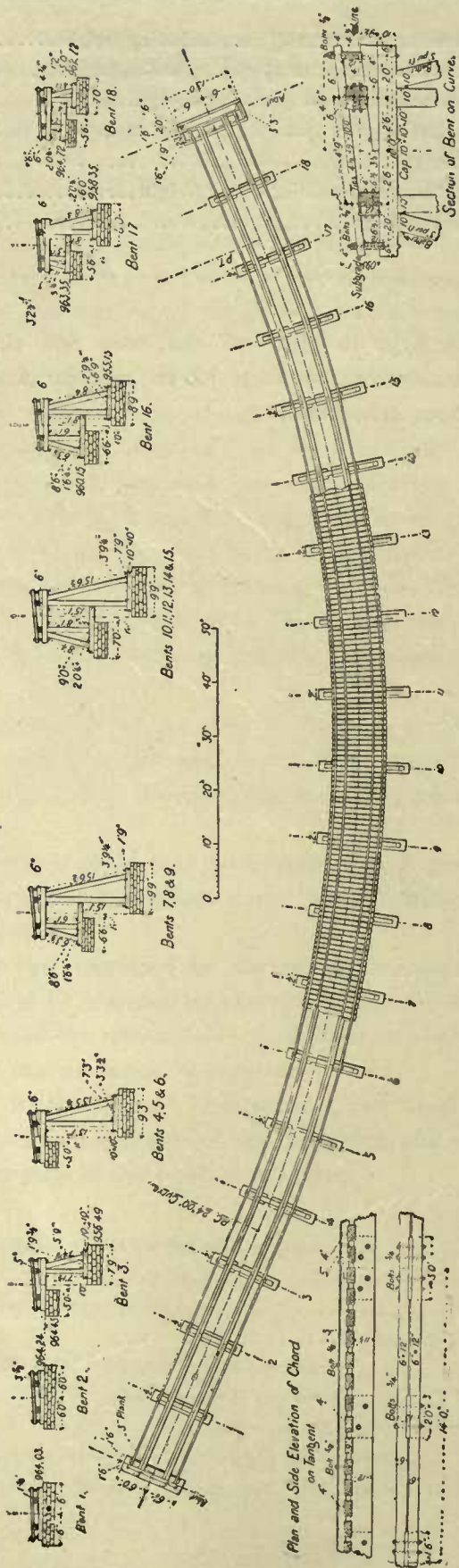


PLATE XLV.—TRESTLE ON 24° CURVE.



## FRAMED TRESTLE, H. C. FRICK COKE CO.—PLATE XLV.

Plate XLV shows the details of a trestle built on a  $24^\circ$  curve for the H. C. Frick Coke Co. at Scottsdale, Pa., Mr. J. H. Paddock, Chief Engineer. The trestle is built on a steep hillside which necessitates the breaking of the sills and making the posts of the same bent of different lengths. It is used by a light engine (10 tons) hauling trains to the coke ovens.

*Dimensions of Timbers.*

- Floor-system : Ties,  $4\frac{1}{2}$  in.  $\times$  9 in.  $\times$  10 ft.  
Track-stringers, 6 in.  $\times$  12 in.  $\times$  28 ft.  
Jack-stringers, 4 in.  $\times$  12 in.  $\times$  28 feet.  
Packing-blocks, 2 in.  $\times$  12 in.  $\times$  3 ft.  
Separating-blocks, 2 in.  $\times$  12 in.  $\times$  2 ft.  
Guard-rails, 4 in.  $\times$  5 in.
- Bent : Cap, 10 in.  $\times$  in.  $\times$  10 ft.  
Posts, 10 in.  $\times$  10 in.  
Sill, 10 in.  $\times$  10 in.







PHILADELPHIA & READING RAILWAY: STANDARD WOODEN COAL TRESTLE.—PLATE XLVA.

On incline trestle approaches, on tangents as well as curves, sawed ties of standard dimensions (7 in. × 9 in. × 8 ft. 6 in.) spaced 22 in. between centers, must be used. Every fourth tie shall be spiked to the stringers and 6 in. × 8 in. guard-rails, placed with their outer edges flush with the ends of the ties and fastened thereto, shall be used on these approaches. On curves and tangents, off the approaches, the floor arrangement shall be as shown.

LENGTH OF FOUNDATIONS FOR DIFFERENT HEIGHTS OF TRESTLE.

SIZES OF Y.P. STRINGERS PER RAIL FOR DIFFERENT SPANS.

	6' 0"	8' 0"	10' 0"	12' 0"	14' 0"	16' 0"	18' 0"	20' 0"	10 and 11 ft. span one 12"×16" 12-ft. span two 8"×16" 13-ft. span two 9"×16" 14-ft. span two 10"×16" 15 and 16 ft. span two 12"×16"
C	12' 0"	12' 0"	13' 0"	14' 0"	15' 0"	16' 0"	17' 0"	18' 0"	
D	9' 0"	9' 0"	9' 6"	10' 0"	12' 6"	15' 0"	17' 6"	20' 0"	

Width of foundations (2 ft.) is for hard compact bottom. For soft soils the width of foundation must be increased as directed by the Engineer.

Location of stairs, number of partitions between bins and whether concrete or wooden floor shall be used, to be determined by local requirements.

When two stringers are used under each rail they shall be of such lengths as to cover two bents, with joints staggered, so that one piece shall be continuous over each pier.

All adzing or sizing of ties made necessary by irregularities in timber shall be done on the under surface of ties. Where trestle is on a curve tie plates shall be used under rails.

Sometimes all-concrete bents are substituted for wooden bents.







### SECTION III.

#### ELECTRIC-RAILROAD TRESTLES.

THE principles governing the design and construction of trestles for electric railroads are similar to those governing the design and construction of trestles for steam-railroads. The trestles are usually lighter on account of the loads being lighter. Where overhead trolleys are used provision must be made for supporting the wires. It is also well to provide walks and railings, or at least railings, on each side of a trestle for safety when open cars are operated.



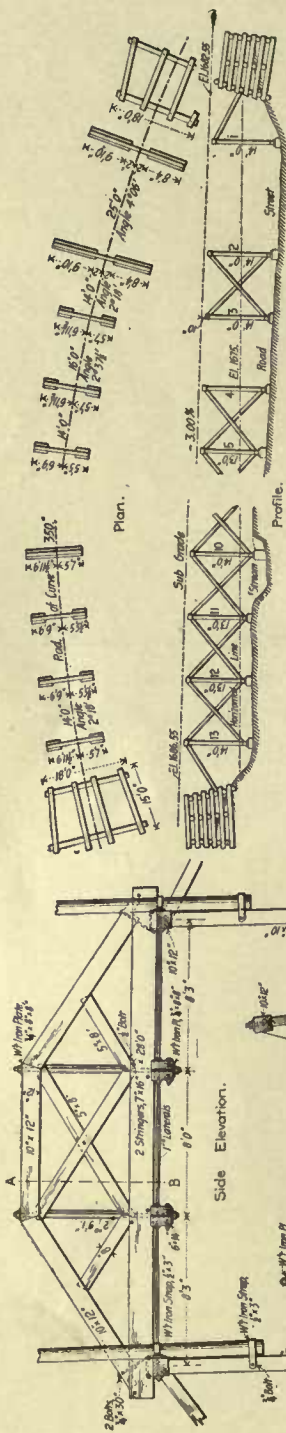


FIG. 1. GENERAL PLAN AND PROFILE.

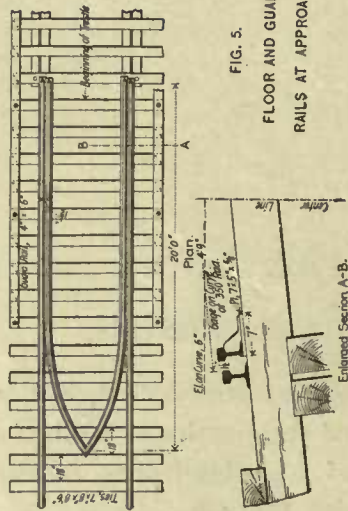


FIG. 5. FLOOR AND GUARD RAILS AT APPROACH.

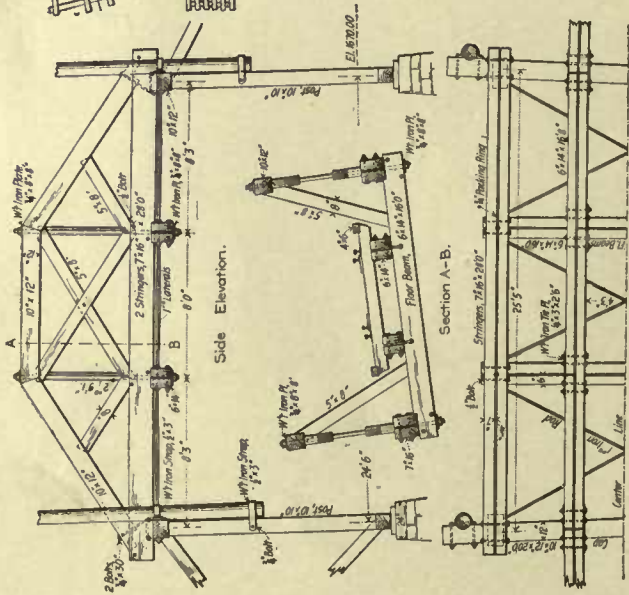


FIG. 2. DETAILS OF WOODEN TRUSS SPAN OVER STREET.

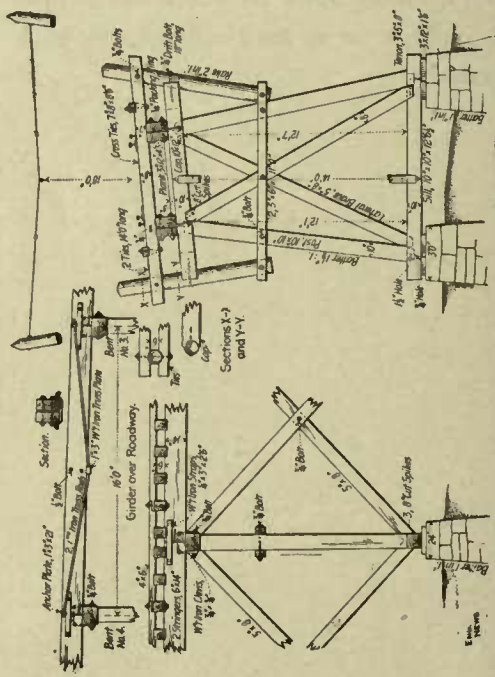


FIG. 4. DETAILS OF BENTS AND GIRDER OVER ROAD.

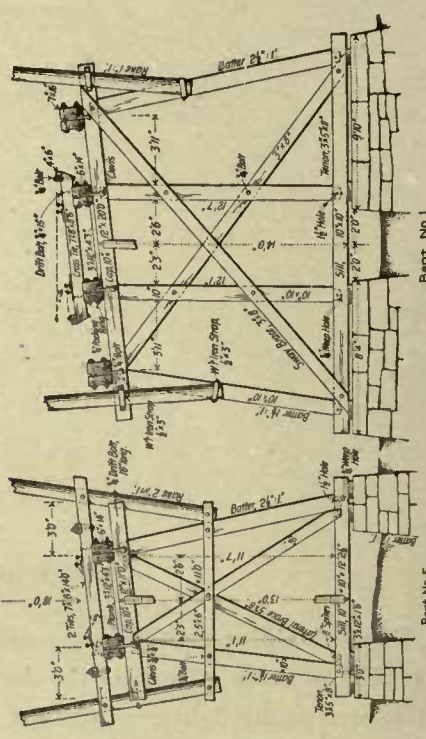
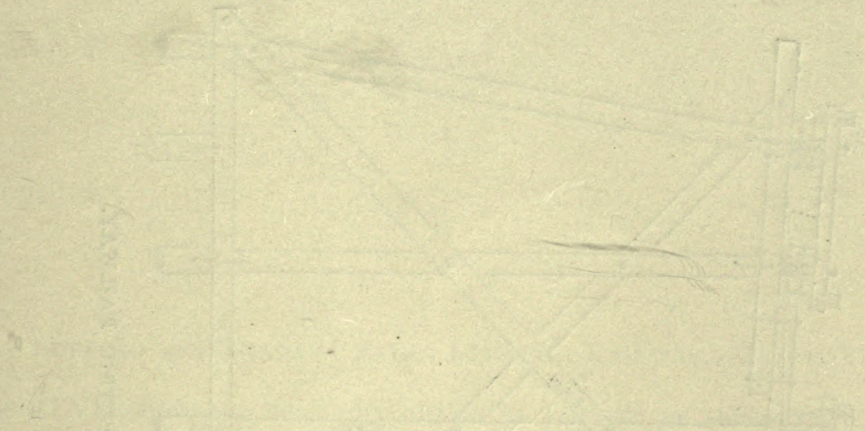


FIG. 3. DETAILS OF BENTS 1 AND 5.

PLATE XLVI.—FRAMED TRESTLE, LEHIGH TRACTION CO.



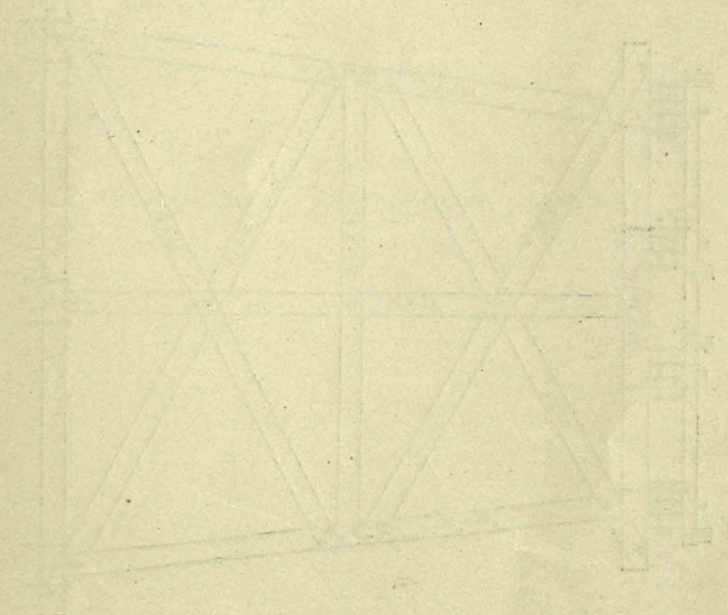


\* FRAMED TRESTLE, LEHIGH TRACTION CO.—PLATE XLVI.

Plate XLVI shows a trestle on a 350-foot radius curve ( $16^{\circ} 26'$ ) and a 3% grade built for the Lehigh Traction Co. 28,000 feet B. M. of yellow pine was used in this trestle, and the costs were as follows: Timber f.o.b. Drifton, Pa., \$19 per 1000 feet B. M.; erection, \$11.25 per 1000 feet B. M.; iron,  $2\frac{1}{4}$  cents per pound; masonry laid in cement mortar, \$3 per cubic yard.

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\* *Eng. News*, April 16, 1896.









## \* BUFFALO AND NIAGARA FALLS ELECTRIC RAILWAY.—PLATE XLVII.

Plate XLVII shows the bent construction of a trestle on this electric railway. The straight trestle is on a grade of 5.3%. A portion of the trestle is on a curve of 90 feet radius. The wires are supported on iron posts held in brackets on the ties and connected overhead with cross-struts of gas-pipe, with diagonal pipe-braces.

*Dimensions of Timbers.*

Floor system: Guard-rails, 6" × 8".

Ties, 6" × 8".

Stringers, ?.

Bent: Cap, 10" × 12" and 12" × 12".

Posts, 10" × 12".

Sway-braces, 3" × 10".

Sills, 10" × 12".

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\* The *Street Railway Journal*, October, 1895, p. 626.



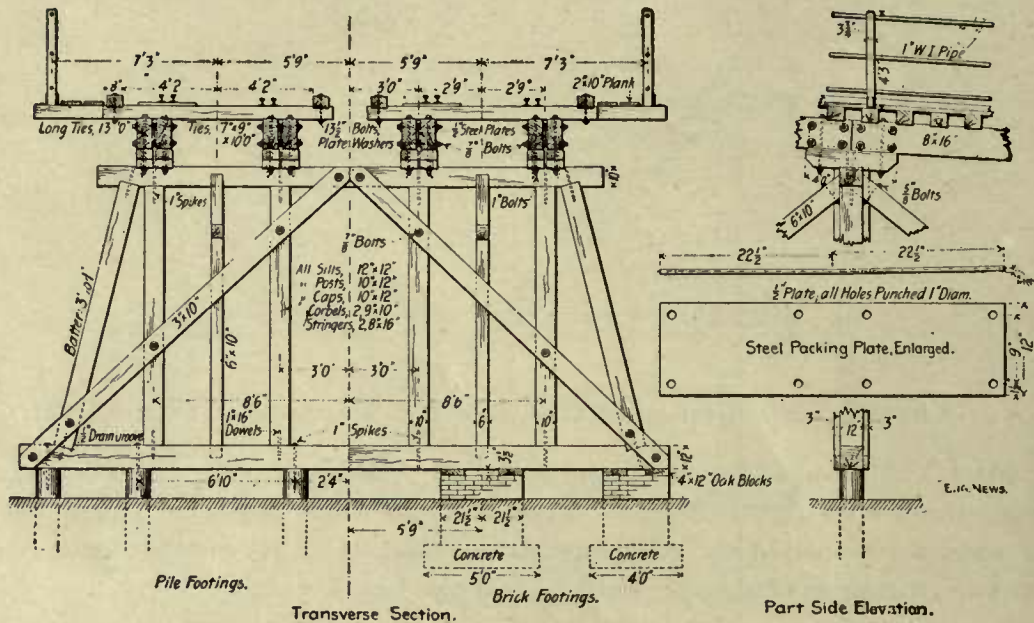


PLATE XLVIII.—ATLANTIC HIGHLANDS, RED BANK & LONG BRANCH ELECTRIC RAILWAY.

ATLANTIC HIGHLANDS, RED BANK & LONG BRANCH ELECTRIC RAILWAY.—PLATE XLVIII.

A portion of this trestle is on a grade of 5.8 % and a 6° curve. In place of a wooden packing block between the stringers  $\frac{1}{2}$ -in. iron plates 25 in.  $\times$  12 in. are used. Cast-iron washers were placed on either side of the iron plate to allow air to circulate between the plate and the stringers. At intermediate points "spacers" composed of 12 in.  $\times$  12 in.  $\times$   $\frac{1}{2}$  in. iron plates with cast washers were used.

*Dimensions.*

Floor-system: Guard-rails, 6 in.  $\times$  8 in.

Ties, 7 in.  $\times$  9 in.  $\times$  10 ft.

Stringers, 8 in.  $\times$  16 in.

Corbels, 9 in.  $\times$  10 in.

Bent: Cap, 10 in.  $\times$  12 in.

Posts, 10 in.  $\times$  12 in.

Sway-braces, 3 in.  $\times$  10 in.

Sill, 12 in.  $\times$  12 in.

Longitudinal braces, 6 in.  $\times$  10 in.—*Engineering News*, Jan. 13, 1898.





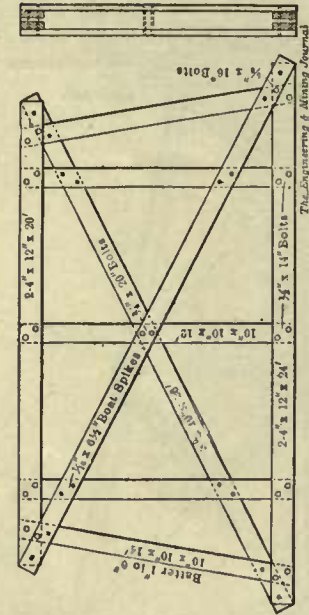


FIG. 2. METHOD OF FRAMING A STRONG SELF-CONTAINED FIVE-POST BENT

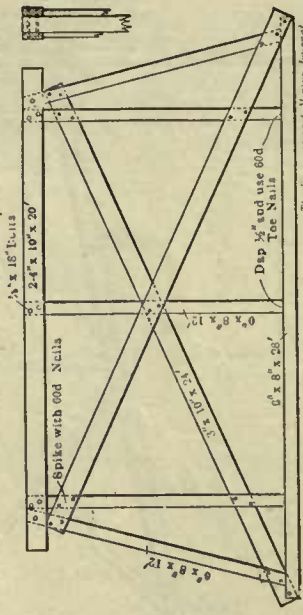


FIG. 5. A STYLE OF BENT BUILT OF LIGHT MATERIAL AND ADAPTED FOR ORDINARY TIPPLES

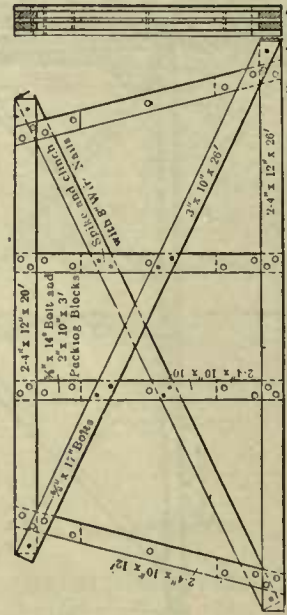


FIG. 7. A TYPE OF BENT WHERE THE ENGINEER CAN USE UP LIGHT MATERIAL IN A COMPOSITE CONSTRUCTION

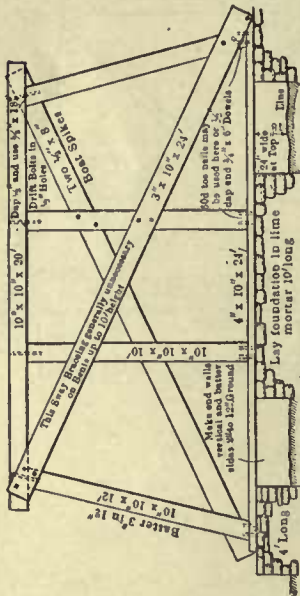


FIG. 1. SHOWING A POPULAR BUT SIMPLE AND RIGID TYPE OF BENT

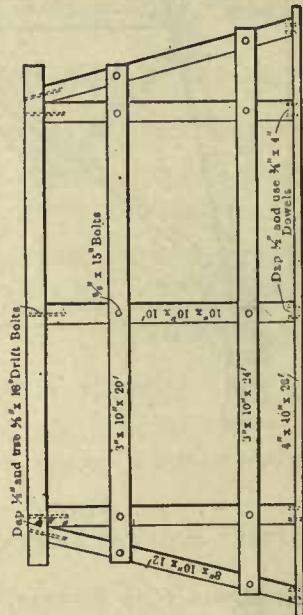


FIG. 4. MODIFIED FORM OF BENT SHOWN IN FIG. 1, AND BEST ADAPTED FOR A TRESTLE

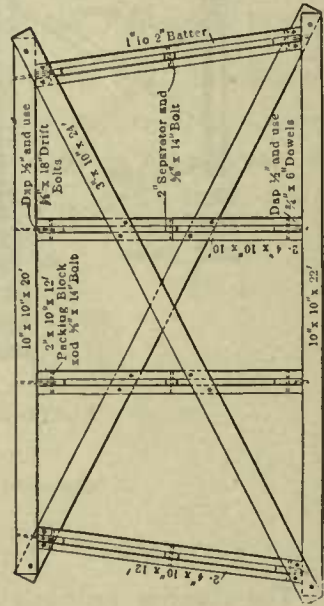


FIG. 6. SHOWING A TYPE OF COMPOSITE FRAMING LARGELY USED IN TIPPLE CONSTRUCTION









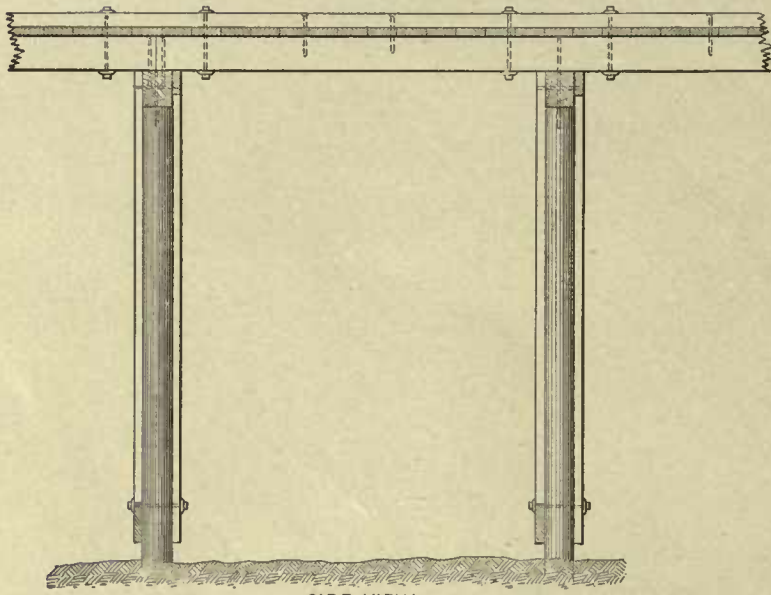


SECTION IV.

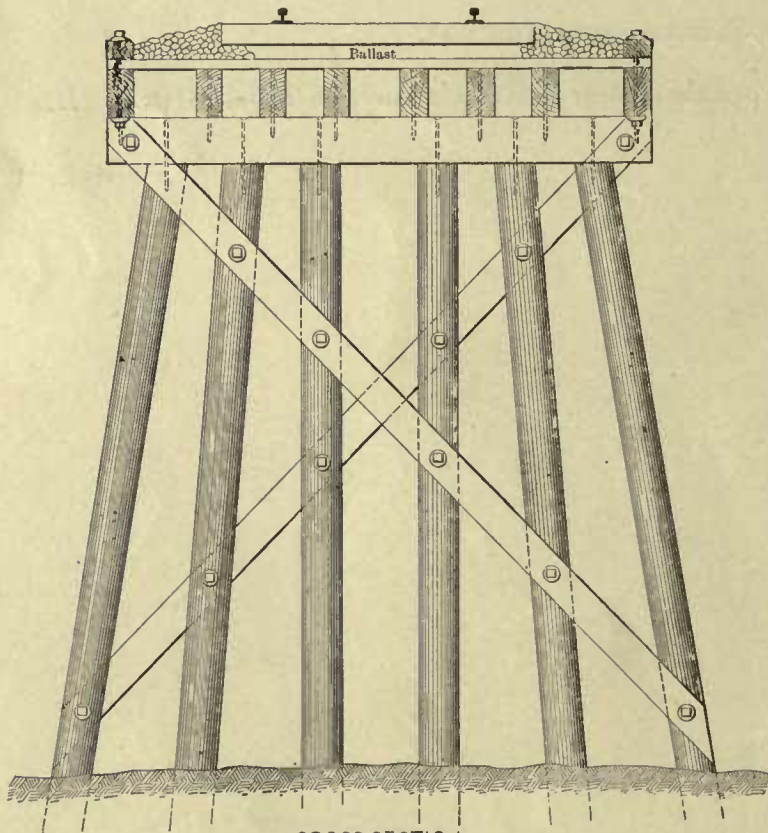
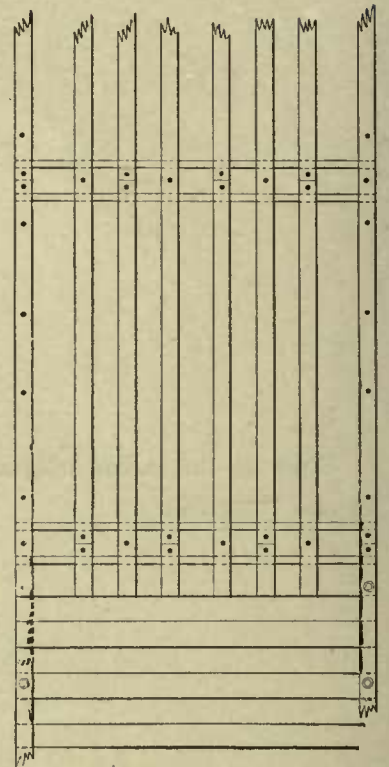
BALLASTED FLOOR TRESTLES.

SOME of the earlier designs of ballasted floor trestles are shown in Plates VIII and VIII A.  
See also Plate IX A.





SIDE VIEW.



CROSS-SECTION.

PLATE LII.—BALLASTED FLOOR TRESTLE.

Plan Suggested by Committee on Wooden Bridges and Trestles, American Railway Engineering and Maintenance of Way Association, Bulletin 61.



PLAN FOR BALLASTED FLOOR-TRESTLE.—PLATE LII.

Plate LII shows the plan for a ballasted floor-trestle as suggested by the Committee on Wooden Bridges and Trestles of the American Railway Engineering and Maintenance of Way Association in Bulletin No. 61, March, 1905, and of which they say:

A plan for a ballasted deck-trestle is submitted without dimensions. Local conditions and varying unit-stresses will determine many of the sizes and details, but your Committee believes that the type shown is best, keeping in mind the fact that repairs must be made in time. Treated timber is to be used throughout.















UNION PACIFIC RAILROAD.—PLATES LIII, LIV, LV AND LVI.

From Bulletin 96, February, 1908, American Railway Engineering and Maintenance of Way Association.

PLATE LIII.

Bill of Material.

Order for one span bridge—above caps.				Order for each additional span—above caps.			
TIMBER.				TIMBER.			
Pcs.	Size.	Length.	Description.	Pcs.	Size.	Length.	Description.
See table below			Stringers	See table below			Stringers
1	8×14"	28'	Guard-rail	1	8×14"	28'	Guard-rail
18	4×10"	14'	Cresoted floor plank	17	4×10"	14'	Cresoted floor plank
	8×16"	.....	Bulkhead, use old stringers				
	3×5"	.....	" strips, use old braces				
	3×5"	.....	" blocks, use old braces				
			IRON				IRON.
4	¾" dia.	51"	Anchor-bolt with 1 nut, weight, 6.68 lbs.	2	¾" dia.	51"	Anchor-bolt with 1 nut, weight 6.68 lbs. each
2	"	37"	Guard-rail bolt with 1 nut, weight 4.96 lbs. each	2	"	37"	Guard-rail bolt with 1 nut, weight 4.96 lbs. each
4	"	10½"	Stay-brace bolt with 1 nut, weight 171. lbs. each	4	"	10½"	Stay-brace bolt with 1 nut, weight 4.71 lbs. each
20	7/8" dia.	24"	Drift-bolts wt. 4.00 lbs. each	15	7/8" dia.	24"	Drift-bolts, weight 4.00 lbs. each
4	.....	.....	Cast stay-braces pat. No. L 568	4	.....	.....	Cast stay-braces, pat. No. L 568
4	14×4×1"	8"	Cast fillers pat. No. L 566	2	14×4×1"	8"	Cast fillers, pat. No. L 566
2	4×2×1"	8"	Cast fillers pat. No. L 567	2	4×2×1"	8"	Cast fillers, pat. No. L 567
8	5/16"	4½"	Wrought spikes, wt. 0.14 lb. each	12	.....	.....	Cast washers, pat. No. L 551 weight 2/3 lb. each
80	1/2"	12"	Boat spikes for bulkhead, weight 5/8 lb. each	8	5/16"	4½"	Wrought spikes, wt. 0.14 lb. each
16	.....	.....	Cast washers No. L 551, weight 2/3 lb. each	25 lbs.	60d	.....	Wire nails for floor
30 lbs.	60d	.....	Wire nails for floor and strips	1 lb.	20d	.....	Common iron nails for washers
1 lb.	20d	.....	Common iron nails for washers				STRINGERS.
							Order according to No. of spans, as follows:
				10	8×16"	13'	For one span
				10	8×16"	26'	For two spans
				10	8×16"	13'	For three spans
				10	8×16"	26'	
				5	8×16"	26'	For each additional span above 3

NOTE.—All ¾" bolts will have square heads and nuts with thread 3" long.



PLATE LIV.

Bill of Material.

For 1 span, without sidewalk, above cap.					For 1 span, with sidewalk, above cap, order in addition to above:				
No.	Size.	Length.	Description.	No.	No.	Size.	Length.	Description.	No.
12	8×17"	.....	Stringers—see table below	2	3	1½×6"	16' 0"	Railing	3
2	6×8"	16' 0"	Guard-rail	2	3	4×6"	6' 6"	Posts	3
22	4×10"	15' 0"	Creosoted floor plank	22	6	5/8" dia.	12½"	Bolts, wt. ea. 1.33 lbs.	4
			Bulkhead, old stringers		6	"	14½"	Bolts, wt. ea. 1.50 lbs.	4
			" strips, old braces		24	"	.....	Cast washers, Pat. No. M.	16
			" blocks, old braces					W. 2	
4	¾" dia.	44½"	Anchor-bolts, wt. ea. 5.87lb.	2	2	¾" dia.	50½"	Bolts in place of 2 ¾×44½"	1
2	"	32¾"	Guard-rail bolt, weight ea. 4.43 lbs.	2	1	"	38¾"	Bolts in place of 1 ¾×32¾"	1
			Stay-brace bolt, weight ea. 1.54 lbs.	6	2	10×12×1"	6	C.I. stay-brace in place 2 10×9×6×1"	1
6	"	9"	C.I. stay-braces	4	1	lb.	20d	Wire nails for railing	1lb.
6	10×9×1"	6"	C.I. separators	4					
6	3×1×1"	6"	Drift-bolts, wt. ea. 3.08 lbs.	12					
24	¾" dia.	25"	Wrot. spikes, wt. ea. 0.14lb.	8					
11	5/16"	4½"	Boat spikes for bulkhead, 5/8 lb.						
30	1/2"	12"	Cast washers, Pat. No. M. W. 3	14					
18	1/4"	.....	Wire nails for floor & strips 45 lb.	45					
45	lbs.	60d	Wire nails for washers 1 lb.	1					

For each additional span order.

NOTE.—For frame trestle order anchor-bolts ¾"×46½".

NOTE.—For frame trestle order anchor-bolts ¾"×52½".

STRINGERS.

For one span order, 12 8"×17"×15' 0"  
 For two span order, 12 8"×17"×30' 0"  
 For three span order, { 12 8"×17"×15' 0"  
 12 8"×17"×30' 0"  
 For each additional span, 6 8"×17"×30' 0"

All bolts will have 3-inch thread, square head and one square nut.

PLATE LVI.

Bill of Material.

For 1 span, without sidewalk, above cap.					For 1 span, with sidewalk, above cap, order additional material:				
No.	Size.	Length.	Description.	No.	No.	Size.	Length.	Description.	No.
22	8×17"	.....	Stringers—see Table	2	3	1½×6"	16' 0"	Railing	3
2	6×8"	16' 0"	Guard-rail	2	3	4×6"	6' 6"	Posts	3
22	4×10"	28'	Creosoted floor plank	22	6	5/8" dia.	12½"	Bolts, wt. ea., 1.33 lbs.	4
			Bulkhead old stringers		6	"	14½"	Bolts, wt. ea., 1.50 lbs.	4
			" strips, old braces		24	"	.....	Cast washers, Pat. No. M.	16
			" blocks, old braces					W. 2	
4	¾" dia.	44½"	Anchor bolts, wt. ea. 5.87lbs.	2	2	¾" dia.	50½"	Bolts in place of 2 ¾×44½"	1
2	"	32¾"	Guard-rail bolts, wt. ea. 4.43 lbs.	2	1	"	38¾"	Bolts in place of 1 ¾×32¾"	1
			Stay-brace bolts, wt. ea. 1.54 lbs.	6	2	10×12×1"	6"	C.I. stay-brace in place 2 10×9×6×1"	1
6	"	9"	C.I. stay-braces	4	1	lb.	20d	Wire nails for railing	1lb.
6	10×9×1"	6"	C.I. separators	4					
6	3×1×1"	6"	Drift-bolts, wt. ea. 3.08 lbs.	12					
44	¾" dia.	25"	Wrot. spikes, " 0.14 lb.	8					
12	5/16" dia.	4½"	Boat spikes for bulkhead, 5/8 lb.						
80	1/2" dia.	12"	Cast washers, Pat. No. M. W. 3	14					
18	¾" dia.	.....	Wire nails for floor & strips 90 lbs.	90					
90	lbs.	60d	Wire nails for washers 1 lb.	1					

For each additional span order.

NOTE.—For frame trestle order anchor-bolts ¾"×46½".

NOTE.—For frame trestle order anchor-bolts ¾"×52½".

STRINGERS.

For one span order 22 8"×17"×15' 0"  
 For two span order 22 8"×17"×30' 0"  
 For three span order { 22 8"×17"×15' 0"  
 22 8"×17"×30' 0"  
 For each additional span 11 8"×17"×30' 0"

All bolts will have 3-inch thread, square head, and one square nut.





ATCHISON, TOPEKA & SANTA FÉ RAILWAY.—PLATE LVII.

From Bulletin 96, American Railway Engineering and Maintenance of Way Association  
and 1906 Proceedings Association of Railway Superintendents of Bridges and Buildings.  
For Ballasted Floor Trestle of this Railway with stringers of old rails, see Plate IXA.

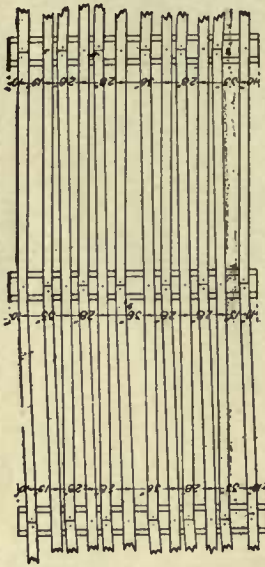




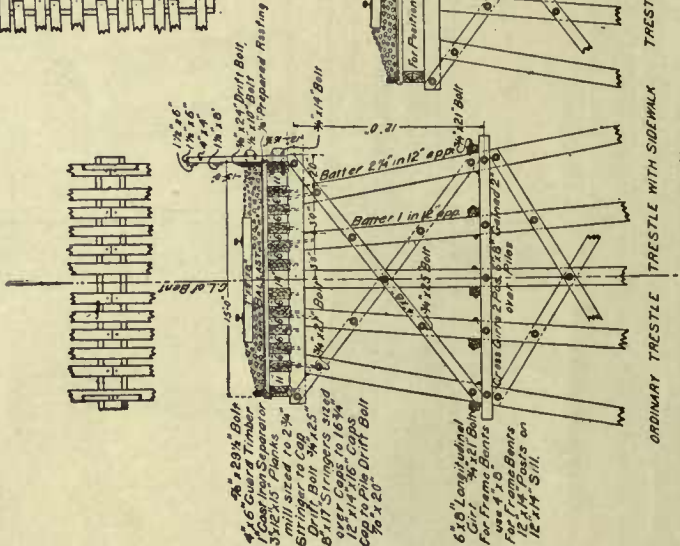




**GENERAL INSTRUCTIONS.**  
 For trestles more than one story in height longitudinal girts to occur at regular intervals of 12 ft measured from top of cap and at every 6th center to center of cap and at the surface to top of cap longitudinal girts to be omitted.  
 For heights less than 7 ft from ground surface piles and caps to be omitted. All other material untreated pine  
 Prepared roofing to be laid with 3/4 in lap joints parallel to the center line of the trestle to have a coat of hot asphalt applied between laps and nailed with 4x4x16 2x4 in spout, lengthwise, sheet 24 in  
 Roofing to be reinforced with extra asphalt coat 1 lb per sq ft to make 2 in thick and before laying temporary concrete to ballasting, spread a 1 in coat of coarse sand or pea gravel to prevent blocking striking to or injuring asphalt coating.  
 Floor planking will be spiked with 6 in spikes, two at each end, and one at each end spaced 20 in to center line of track and spaced 20 in that outside stringers will be 30 ft long. Spikes of ballast under outer rail the depth of ballast under inner rail remaining constant. Outside stringers to be drilled with 10 caps at every joint inside stringers 30 ft long when driftball at all joints.



ARRANGEMENT OF STRINGERS FOR CURVED TRACK

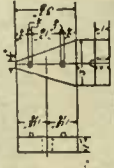


3/4 x 2 1/2 Bolt  
 4 x 16 Guard Timber  
 1 Coat Hot Separator  
 3/4 x 12 x 10 Planks  
 5/8 x 12 x 10 Stringers  
 5/8 x 12 x 10 Cap  
 8 x 17 Stringers sized over caps to 16 1/4  
 12 x 16 x 16 Caps  
 6 x 12 Bolt  
 7/8 x 20 Bolt  
 6 x 10 longitudinal Girt  
 3/4 x 12 Bolt  
 For Frame Braces use 4 x 6  
 For Frame Braces use 4 x 6 on 1/2 x 14 Sill

Cast iron separator between guard timber and ready asphalt roofing

**COMMON STANDARD SINGLE TRACK BALLASTED DECK TRESTLE 15'-0" WIDE**

SCALE 1/8" = 1'-0" A.C.S. ADAPTED FROM U.S. G.S.



ORDINARY TRESTLE WITH SIDEWALK TRESTLE WITH SIDEWALK

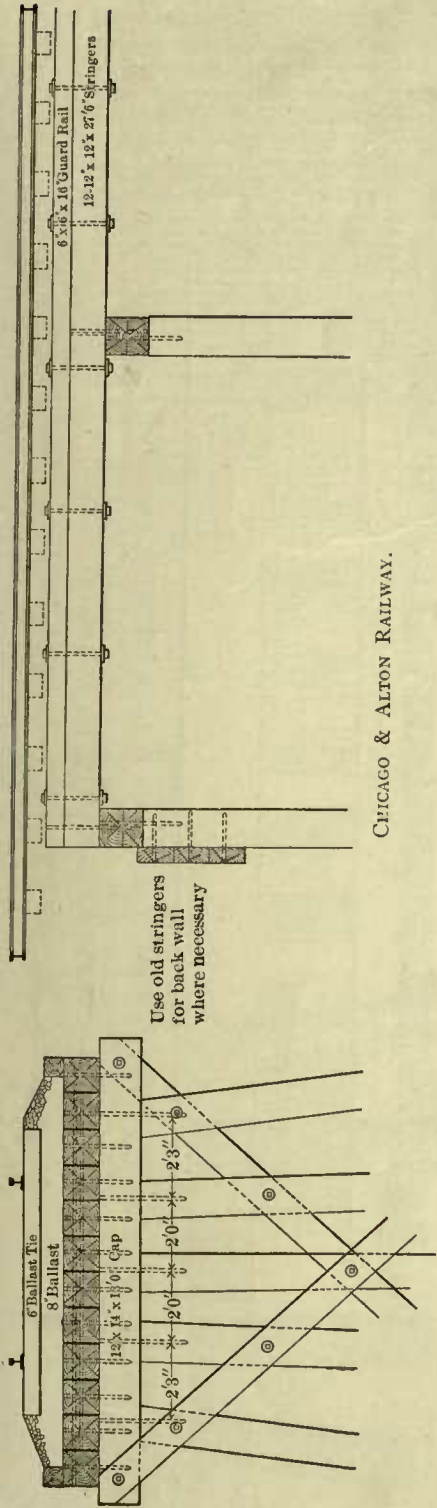
TRESTLE ON CURVE

ORDINARY TRESTLE WITH SIDEWALK

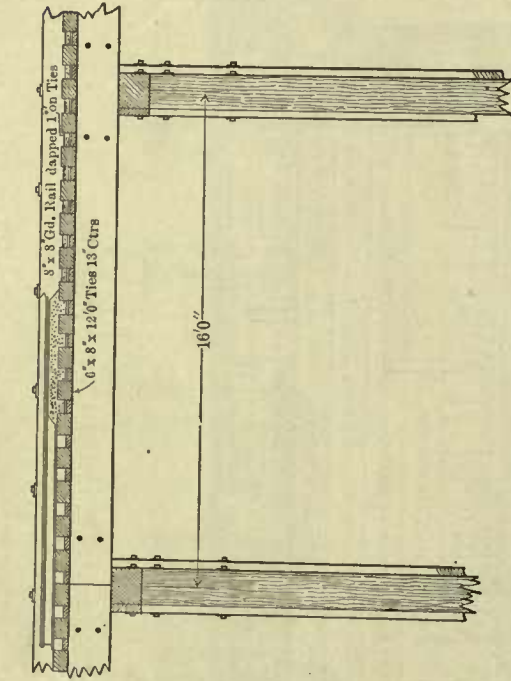
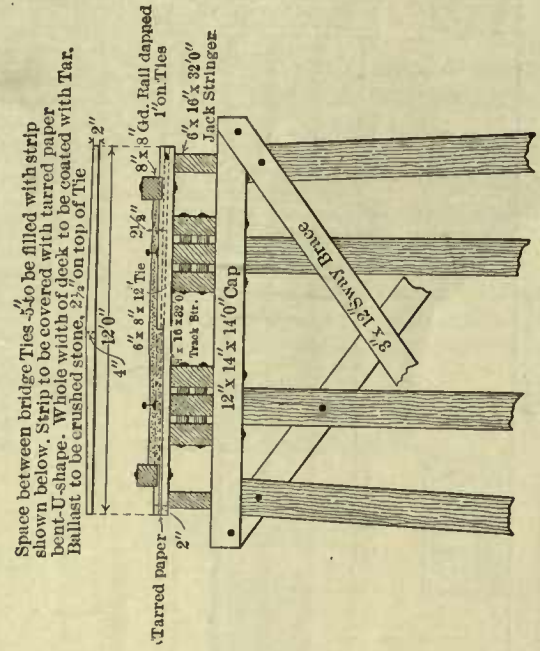
The center line of piles prolonged should meet at a common point about 26 above base of rail.

PLATE LX.—SUGGESTED BALLASTED FLOOR TRESTLE.  
 Bulletin 96, American Railway Engineering and Maintenance of Way Association.





CHICAGO & ALTON RAILWAY.



WISCONSIN CENTRAL RAILWAY.

PLATE LXI.—BALLASTED FLOOR TRESTLES.

Proceedings of the Association of Railway Superintendents of Bridges and Buildings, 1906.





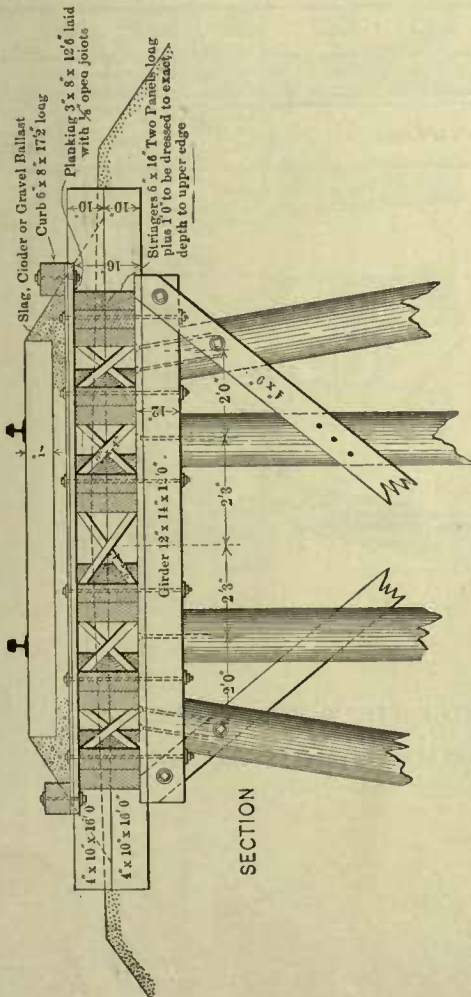
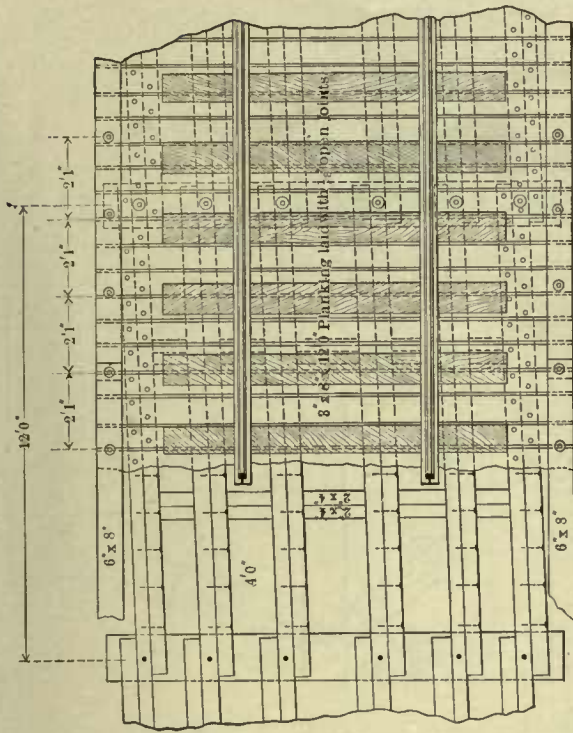
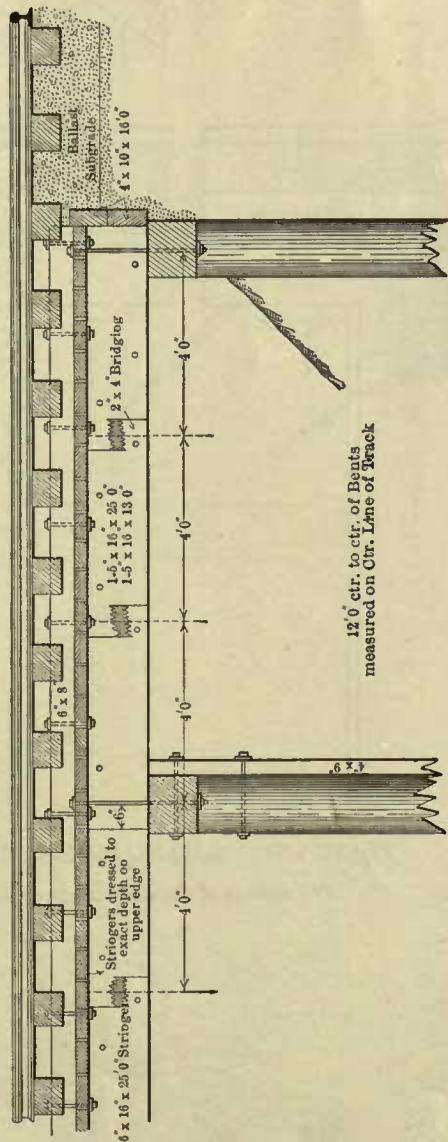


PLATE LXIII.—BALLASTED FLOOR TRESTLE, LOUISVILLE & NASHVILLE RAILROAD.

(See also Plate VIIA. For earlier trestles on the Louisville & Nashville Railroad see Plates VII, VIII, XVII.)

Timber is creosoted.

These figures are from the Proceedings of the Association of Railway Superintendents of Bridges and Buildings, 1906.



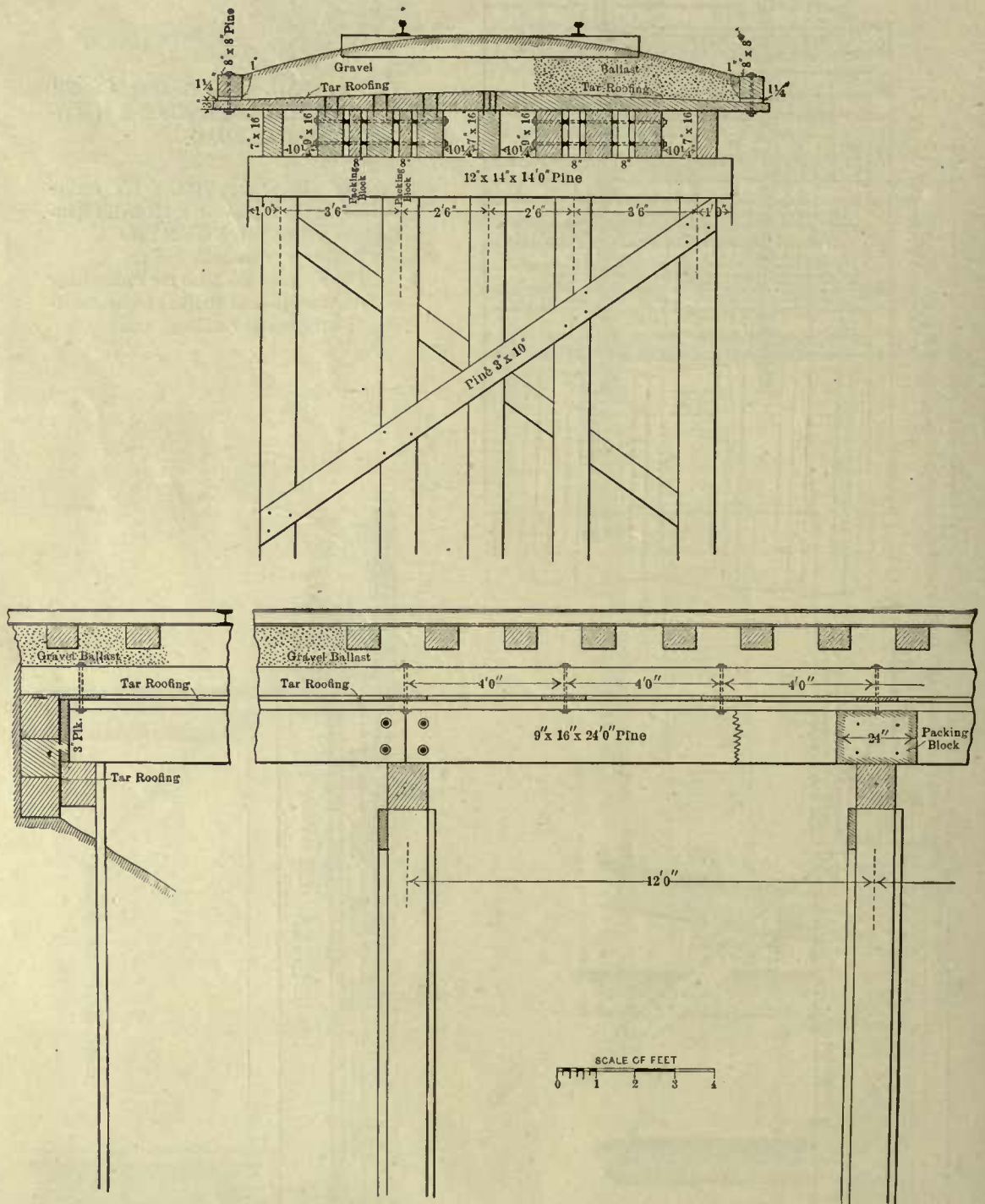


PLATE LXIV.—BALLASTED FLOOR TRESTLE, GRAND RAPIDS & INDIANA RAILWAY.

Proceedings of the Association of Railway Superintendents of Bridges and Buildings, 1906.



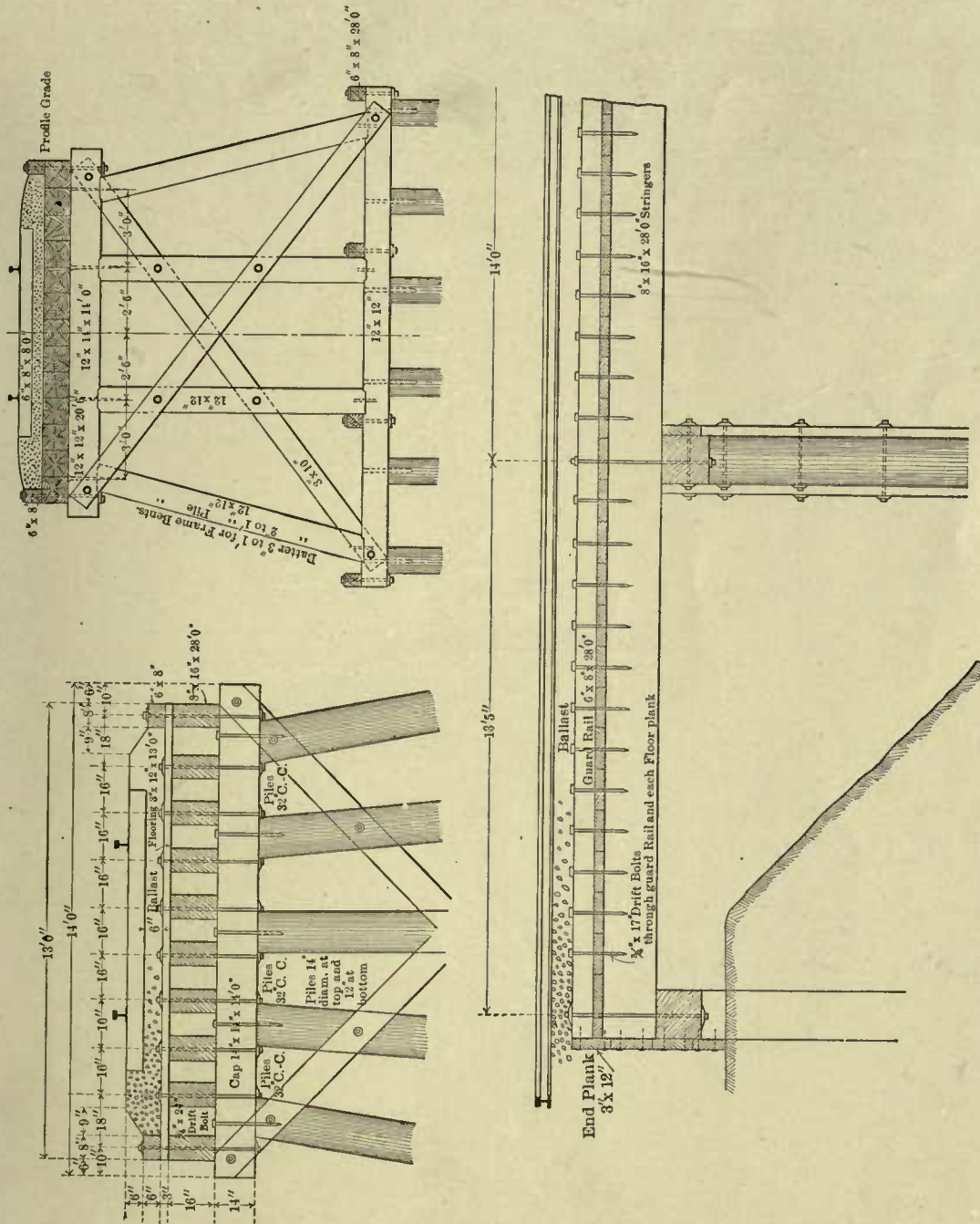


PLATE LXV.—BALLASTED FLOOR TRESTLE, EL PASO & SOUTHWESTERN RAILWAY.

Proceedings of the Association of Railway Superintendents of Bridges and Buildings, 1906.

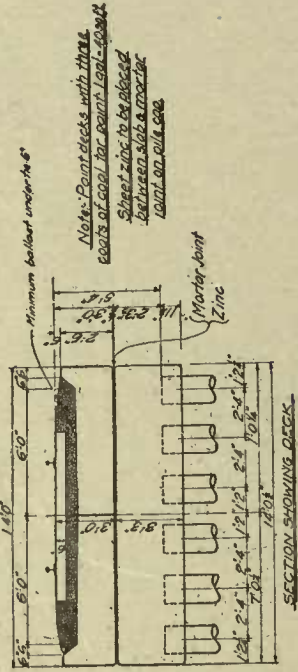
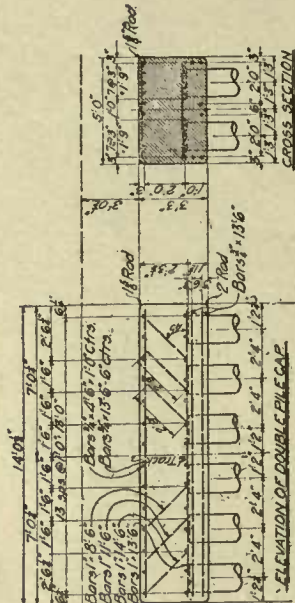
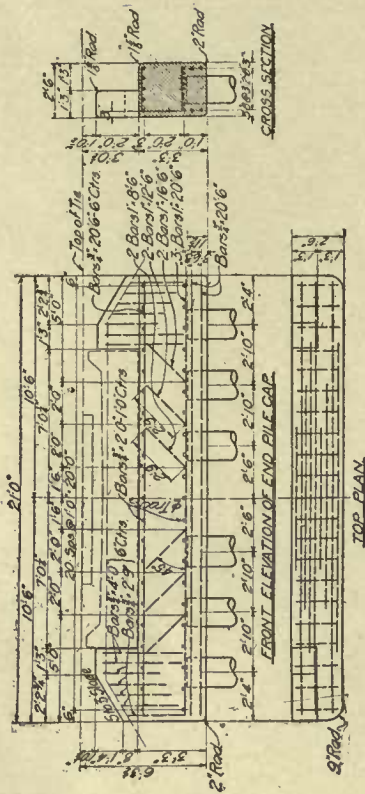






SECTION V.  
CONCRETE TRESTLES.





Notes: Paint decks with three coats of coal tar paint. Lay out sheet zinc to be placed between slabs & mortar.

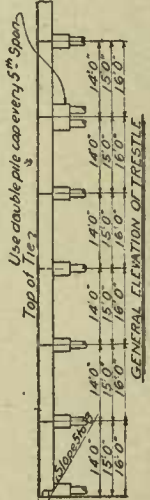
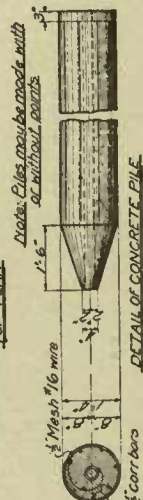
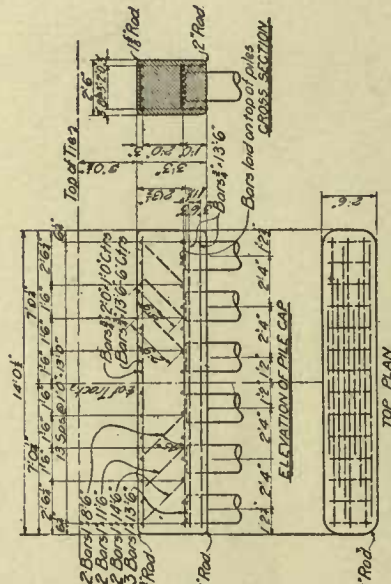
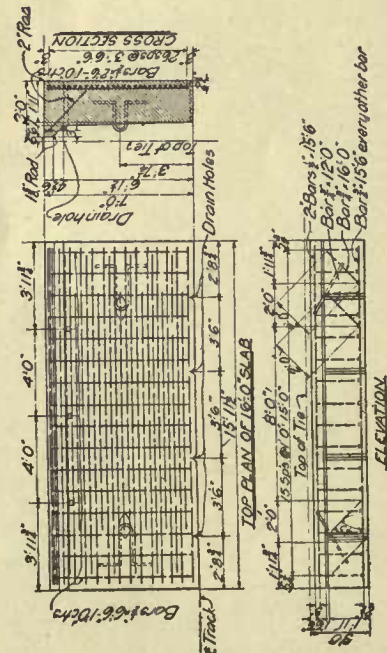


PLATE LXVI.—STANDARD CONCRETE TRESTLE, CHICAGO, BURLINGTON & QUINCY RAILROAD.

Bulletin 130, American Railway Engineering and Maintenance of Way Association.





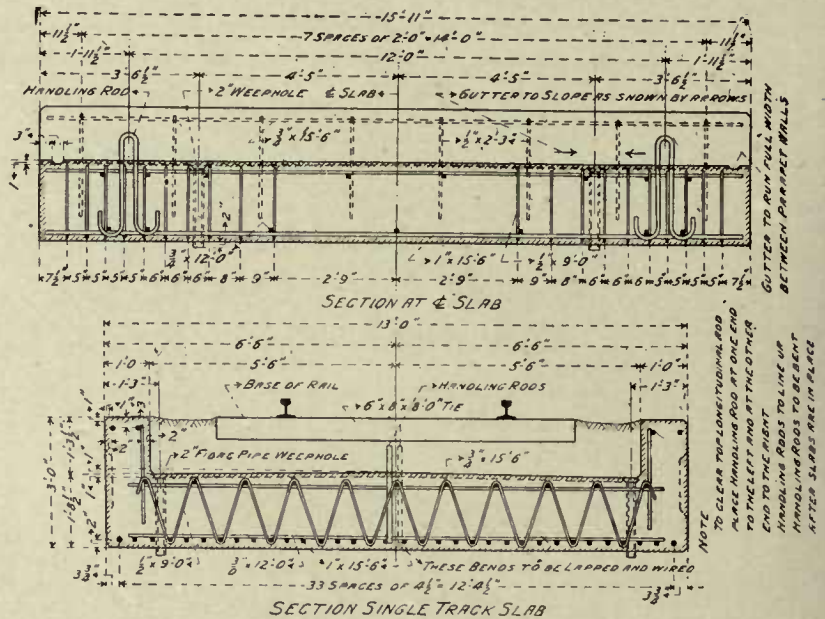
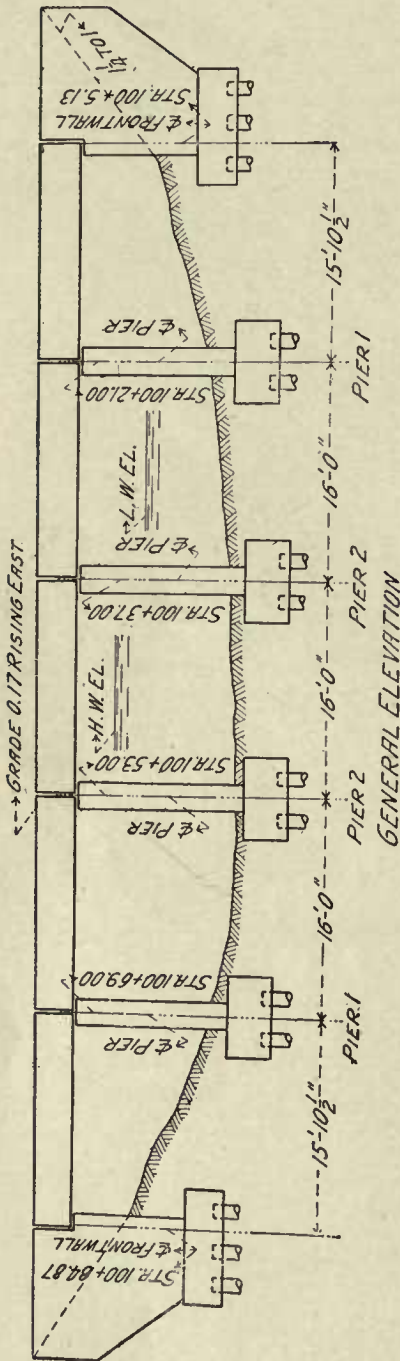


PLATE LXVIII.—STANDARD CONCRETE TRESTLE, CHICAGO, MILWAUKEE & ST. PAUL RAILWAY.

Bulletin 130, American Railway Engineering and Maintenance of Way Association.











## A RAILWAY TRESTLE WITH BENTS OF REINFORCED CONCRETE.—PLATE LXX.

By Wm. A. Allen,\* Assoc. M. Am. Soc. C. E.

A piece of trestle work built last fall at Perth Amboy, N. J., differs from the ordinary trestle in having its supporting bents made of concrete, reinforced with steel rods. The trestle in question runs over coal and ore stock piles, and is a comparatively low structure. The concrete bents form solid dividing walls between the different spans, and thereby make it more convenient to separate the different lots of ores and coals than if ordinary timber or steel bents were used. The abrasion of the bents by the ore is an important consideration favoring the concrete bent. The construction used is novel, and it seems to have points of merit for many cases of trestle work, especially as some materials have a decided corrosive action on iron and steel and also hasten the decay of wood.

A good view of a portion of the completed trestle is shown in the accompanying Fig. 1; a nearer view of one of the bents is given in Fig. 2. The concrete bents are simple cross-walls resting on foundation piles and carried up to the under side of the stringers. Cast-iron boxes are fastened to the top of the wall by anchor bolts set in the concrete, and the ends of the wooden stringers are notched to fit into these boxes. The track-work above the stringers is arranged in the ordinary way, with cross-ties, guard-stringers and a foot-walk.

The details of the trestle are given in the drawing, Fig. 3. The structure is 1277 ft. long between the extreme bents, bents being placed 12 ft. apart on centers, and rises at each end on a 3% grade from a low approach embankment to a normal height of 9 ft. 2 ins. to top of rail, corresponding to a height of 6 ft. 9½ ins. to top of bents. The stringers are each a double timber of two 8×16 in. yellow pine sticks spaced one inch apart by cast-iron separators. The cast-iron boxes in which the ends of the stringers rest, shown in Fig. 4, are anchored by 1-in. bolts set in the concrete of the bents. These boxes have the object of protecting the ends of the stringers from the weather. The stringers are anchored at both ends of the trestle, and owing to this fact, to the imbedded rods, and to the stability and weight of the concrete bents, no longitudinal bracing between bents was necessary.

The bents themselves are concrete walls 12 ins. thick at the top and 16 ins. at the ground level. The top of the wall is sloped both ways to shed water, except where the boxes rest on it. At the ground level each bent spreads out to form a footing 24 ins. thick, which rests over four 13-in. piles driven about 25 feet through marshy and made ground to firm soil; the piles were cut off one foot below ground level, and the concrete footing formed over and around them. Steel reinforcing rods were imbedded in the concrete of the bents in both vertical and horizontal directions; these rods are Ransome cold-twisted rods of ¾-in. square steel. As will be seen from the drawing, the vertical rods are arranged in two vertical planes 8 inches apart in the direction of the thickness of the wall, and are set 18 inches apart in each row, being staggered in the two rows. The object of the rods is to provide against tension in the concrete due to longitudinal traction of braked trains.

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\* Superintendent of Construction, American Smelting & Refining Co., Perth Amboy plant, Maurer, N. J.



The bents were built in forms made of  $\frac{7}{8}$ -in. dressed lumber, stiffened by brace pieces and bolted across at the ends. The inside faces of the forms were well soaped. The forms were allowed to remain in position about 48 hours. The concrete used in the bents was composed of 1 part Giant Portland cement, 2 parts sand and 4 parts broken slag from a lead blast furnace. It was allowed to set one month before the trestle was put into use, but in the meantime the superstructure had been placed. The ends of the stringers where they rest in the cast-iron boxes were well coated with "sludge," a tarry residue of fuel oil, and this with the protection afforded by the boxes is thought to insure the arrest of decay.

The trestle was designed by and built under the supervision of the writer in September and October of the past year.

The trestle was put into use November 17, 1902, the concrete having been finished on October 17. The structure has been used continuously since then by heavy trains of loaded ore cars, and no cracks of any kind have appeared in the concrete. The cost of the concrete bents was about the same as that of equivalent wooden bents, including braces and mud sills.

—*Engineering News*, March 12, 1903.





COAL TRESTLE, DELAWARE, LACKAWANNA & WESTERN RAILROAD.—PLATE LXXI.

In connection with the new power house which the Delaware, Lackawanna & Western has now nearly completed as a part of its Hoboken terminal station, a concrete coaling trestle and ash-handling plant have been built. The power house is south of the station tracks and a little beyond the center end of the train shed of the new terminal station. The purpose of the trestle is to form an approach by which loaded coal cars may be taken to the level of the second floor of the power house, whence coal is dumped to the space in front of the boilers. The trestle also serves as the support, on one side, of a steel structure which carries the trolley track of the conveyor for handling ashes from the boiler room. The rest of the structure is entirely of reinforced concrete.

As shown in the accompanying photographs, the trestle lies alongside of and parallel to a two-story coach house and material building just beyond the power house, on the ground floor of which the boilers are located. The power house is three stories high. Between the trestle and the building is the ash-car track, over which, for 130 ft., extends the trolley and its supporting structure. The trestle proper is 226 ft. 3 in. long, consisting of 18 bents on piers spaced 12 ft. center to center. The inner abutment is the wall of the power house and the outer abutment is the end of an approach 112 ft. 4 in. long. The surface of the whole structure, trestle and approach, is on a 4% grade up to the last three bents toward the power house. Here a vertical curve is introduced between the incline and the level within the power house, into which the tracks are carried through an arched entrance on the level of the second floor. The approach is filled in between retaining walls tied together near the abutment by old rails 15 ft. long extending from one wall to the other and fastened in each wall by an 18-in. rod passing through the end of the rail and embedded in the concrete. Four of these rails are used, spaced 10 ft. apart. The walls are necessary because of the limited ground space, the tracks on each side being too near to let the fill take its material slope. From out to, out the structure is 16 ft. wide, about one-half this width being occupied by a walk on each side. These are protected by railings of iron pipe.





The bents vary in height from that of No. 1, next the approach abutment, which is 11.32 ft. high, to No. 18, nearest to the power house, which is 19 ft. All are on piles on account of the nature of the soil, which is largely made ground. Footings are 4 ft. 9 ins. wide and in length vary from 11 ft. 9½ ins., at bent No. 1, to 13 ft. 1 in. at bent No. 18. The thickness is 3 ft., of which 1 ft. is filling between the tops of the piles. Each pier 19 ft. wide and 18 in. thick at the top with a batter of 1 inch per foot in cross section of the trestle and ½ inch per foot in longitudinal section. On these are concrete stringers, 13 in. × 27 in., in which are embedded ¾-in. bolts, 12 in. long, to which are secured the clamps which hold the rails in place. Ordinarily, in structures of this kind metal plates are put between the concrete stringer and the base of the rail. In this case, the plate was dispensed with and the indications are that this construction will prove satisfactory. The anchor bolts, however, project far enough above the stringer to allow for plates, should they subsequently be found desirable. Between the stringers and on each side of them open spaces, 3 ft. 5 in. wide, respectively, have been left, partly to separate the stringers which carry heavy loads from the floor structure which is of lighter construction, and partly to facilitate the dumping of material along the incline for any reason. This arrangement has already been made use of in connection with the handling of construction materials for the power house.

The piers are reinforced by ¾-in. square rods placed vertically in two rows 3 in. from the outside of the pier, spaced 5 in. apart underneath the stringers, and 8 or 9 in. apart outside of and between the stringers, by similar rods are laid horizontally, spaced 18 in. apart. The stringers are reinforced by three 1¼-in. square rods laid with centers 3 in. from the bottom of the stringer. Over each bearing point the upper part of the stringer is reinforced by four rods, each 1½ in. square and 8 ft. 4 in. long, and on these upper rods an inverted rail, extending the width of the structure, rests at each bent. On each side of this rail, abutting against the flange and web, are two 1¼ in. square rods, extending to the lower reinforcement at an angle of about 35 degrees with it.

In the construction of the sidewalks, a novel method was used. The cross rails above referred to are the principal means of support. These rails, as stated, extend to the outer edge of the sidewalk. At intervals of 6 ins., clips of the form shown in one of the drawings are attached to and hang from the head, and through openings in each leg of the clip are passed the rods which form the horizontal reinforcement of the sidewalk. As shown in the cross-section, the sidewalk on the outside away from the power house has no other support than that just described; on the opposite side, a bracket 8 in. thick, tied to the pier by reinforcing rods, is formed to serve as a support opposite each bent. This bracket is solely for the purpose of giving additional support to the columns on which the cross-beams of the ash handling plant are carried. The other extremities of these beams are supported in the wall of the power house extension.

The trestle was designed and built by the engineering department of the Delaware, Lackawanna & Western, Lincoln Bush, Chief Engineer, and George T. Hand, Assistant Engineer.—*Railroad Gazette*, March 8, 1908.





## COST OF CONSTRUCTING A CONCRETE TRESTLE NEAR EASTON, PA.—PLATE LXXII.

This reinforced concrete trestle was constructed near Easton, Pa., by Mr. M. P. McGrath, general contractor, of that place. The contractor or his engineer, Mr. J. F. Mooney, supervised the work so that while one man was employed nominally as a foreman and received \$2.75 per day, he worked like the other laborers; generally he was charged to placing or finishing. The costs given are actual costs except for the form lumber, which had been used before and the cost of which was approximated.

*Coal Trestle.*—The trestle was designed as a coal trestle and was constructed as shown by Plate LXXII except that the bents instead of being made solid, were built with a 4 × 8 ft. opening in each to permit the coal to flow more readily. There were 8 bents and two abutments and the trestle was 114 ft. long. It was designed to carry the rails directly on the girders without cross-ties, so that the girder reinforcement was made quite heavy, as is clearly shown by the drawings. It will also be seen that the rails had their bases partly embedded in the girders and were fastened by chairs. The chairs were of cast-iron and were held by bolts extending down into the girder and secured under the lower reinforcement bar. The chairs were spaced 2 ft. apart, those of one rail being staggered with those of the other rail. This construction gave excellent results in operation and saved some 6 ins. in height over the ordinary cross-tie construction. The remaining structural details and dimensions of the trestle are clearly shown by Plate LXXII.

The wages paid on this trestle were as follows:

Laborers, per 10-hour day.....	\$1.50
Blacksmiths, per 10-hour day.....	2.00
Engineman, per 10-hour day.....	1.70
Carpenter, per 10-hour day.....	3.00
Foreman, per 10-hour day.....	2.75

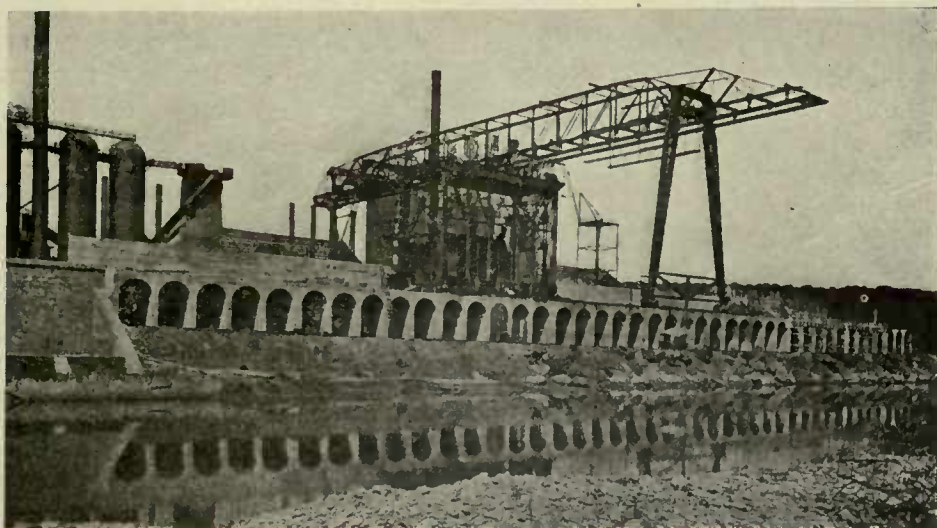
The location of the trestle being almost flush against a railway embankment and it being necessary to locate the stock piles some 150 ft. from the mixer, made the cost of wheeling the materials high. The mixer was set up at the center point of the trestle and discharged into barrows which were hoisted by a pole and yard arm. The pole was provided with a yard and had three-quarters swing. A rope passing over a pulley at the end of the yard arm was provided at one end with a three-line sling provided with a hook to attach to the wheel and two rings to slip over the handles. This rope hoisted the barrows to the top of the trestle by means of a horse hitched to the free end. The concrete used for the reinforced girders was a 1-2-4 mixture, the other parts of the trestle were made of 1-3-6 concrete in which were embedded stones ranging from the size of a man's head to the size of a half-barrel; these rubble stones were thrown into the forms in 1¼-ft. layers. The total amount of concrete in this trestle was 116 cubic yards and its cost was as follows:



Materials:	Per cubic yard.
1.069 bbls. cement at \$1.24.....	\$1.325
0.631 ton sand at 70 cents.....	0.442
1.11 tons stone at \$1.25.....	1.387
131½ lbs. steel at 2 cts.....	2.630
Lumber (\$112.63 charged up).....	0.971
	<hr/>
Total materials.....	\$6.755
Labor and supplies:	
Making and erecting forms.....	\$1.210
Handling sand.....	0.180
Handling stone.....	0.175
Mixing concrete.....	0.184
Placing concrete.....	0.300
Finishing concrete.....	0.103
Miscellaneous.....	0.246
	<hr/>
Total labor.....	\$2.398
Total labor and materials.....	\$9.153

In the item miscellaneous were included blacksmith's work on reinforcement, handling cement, coal, oil, etc. As will be noticed the cost of reinforcement is distributed over the whole structure, 116 cubic yards of concrete; to be strictly accurate, the total 15,250 lbs. of reinforcing metal should be divided into the volume of concrete in the girders which, figured from the drawings, was approximately 24 cubic yards. This gives the great weight of 635 lbs. of reinforcement per cubic yard of concrete.—*Engineering-Contracting*, Feb. 5, 1908.





A HEAVY REINFORCED-CONCRETE TRESTLE.—PLATE LXXIII.

The Youngstown Sheet & Tube Company, of Youngstown, Ohio, has completed recently a large extension to its plant on the Mahoning River, in that city. Two blast furnaces are included in the extension, and provisions have been made in the plans for the ultimate construction of two more of them. These furnaces are placed in a row parallel to the river, and back far enough to provide space for an ore-storage yard along the latter. Ore is delivered to this yard in standard-gauge cars, from which it is unloaded by a Hulett traveling-car dumper. A traveling bridge that spans the yard picks up the ore dumped from the cars and places it as desired in storage piles, or delivers it directly, or by means of a transfer car, to a row of distributing bins along the furnaces. The car dumper and the shear legs of the traveling bridge are carried by a reinforced-concrete trestle 35 ft. 2 ins. wide and 19.5 ft. high above the floor of the yard, which has a present length of 765 ft.; when the additional furnaces are built this trestle will be extended to serve the yard required in connection with them. One side of the trestle also has a retaining wall, 30.5 ft. high, to hold in place ore stored in the yard.

The conditions were such that short-span reinforced-concrete arches, carrying a reinforced-concrete floor, were found to be the most economical design for the long, high structure required to carry the very heavy concentrated loads produced by the car unloader and the shear legs of the traveling bridge. The wheel loads on the trucks of the car dumper and the shear legs of the bridge are shown in one of the accompanying diagrams. The center line of the car dumper had to be placed slightly to the yard side of the axis of the trestle, and travels on two pairs of rails spaced as shown in the cross-section of the latter. The pair of rails on the inside of the trestle carry two four-wheel driver trucks of the dumper, and on each of these trucks, spaced 52 ft. apart on centers, a load of 224,800 lbs. may occur. The other pair of rails for the unloader, placed toward the outer

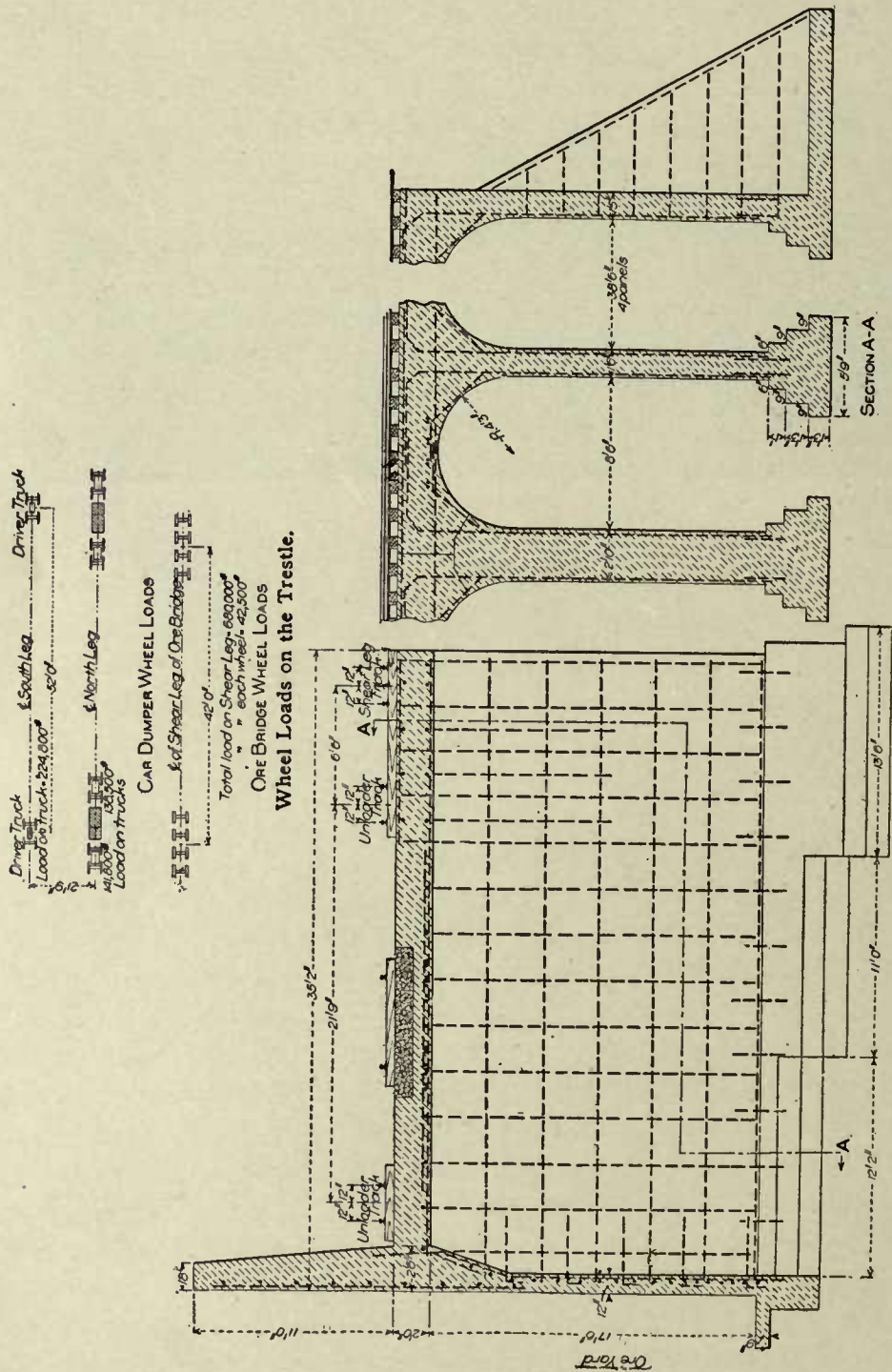


PLATE LXXIII.—REINFORCED CONCRETE TRESTLE, YOUNGSTOWN SHEET AND TUBE COMPANY.



side of the trestle, carry two pairs of four-wheel trucks, one truck of each pair being an idler and the other for driving. The load on each of the idler trucks is 141,800 lbs., while a 138,500-lb. load may be brought on each of the driver trucks. Between the two pairs of rails for the unloader is also a standard-gauge track on which the ore cars are brought to and taken away from the latter. This track is, therefore, designed for a load produced by a continuous train of 100,000-lb. ore cars.

The shear legs of the bridge are each carried on a four-wheel truck, operating on a pair of rails at the extreme outer side of the trestle. These trucks are 42 ft. apart on centers, and together may be required to carry a load of 680,000 lbs. In addition to the concentrated loads on the various tracks, the arrangement of the latter is such that a great weight is brought on the outer end of the cross-section of the trestle.

The details of the design of the trestle are shown in one of the accompanying drawings. The arches of the structure are semi-circular, having a span at the springing line of 8.5 ft. and a rise of 4.25 ft. These arches are carried by bench walls 13.25 ft. high above the footings. The trestle is in sections comprised of five arches, every fifth bench wall being 2 ft. 10 in. thick, while the remaining walls are 1.5 ft. thick. The footings of the walls are increased in depth from the inner to the outer side of the cross-section, as shown in the drawing, to provide for the difference in loading on the two sides. The walls have a plane of reinforcement near both faces consisting of horizontal and vertical bars. The vertical bars in these planes are  $\frac{3}{4}$  in. in diameter, and are spaced 2.5 ft. apart on centers from the inner side of the structure to within 13 ft. of the outer side, and thence 1.25 ft. apart, on account of the increased load in that portion of the section. The horizontal reinforcement consists of  $\frac{3}{8}$ -in. bars, spaced 3 ft. apart on centers, to take up any unequal stresses due to settlement or temperature changes.

The arches carry a floor having a minimum thickness of 2 ft. at their crowns. The vertical bars in the walls extend up into this floor, in which they are bent over to distribute the stresses and to cause the parts of the structure to act together. Each alternate bar is bent over the adjacent haunch of the arch and continued across to the crown of the latter. The other bars are carried up toward the top of the floor slab and then bent over the arch to lap with the corresponding bars from the other side of the span. A horizontal plane of reinforcement is placed in the floor 3 in. from the crown of the arches, and for the entire width of the structure. Under the tracks toward the outer side of the section, a second horizontal plane of reinforcement is also placed 3 in. from the upper surface of the floor slab.

The wall along the inside of the trestle, which forms the limit of the ore yard, is simply a 12-in. reinforced concrete slab to the springing line of the arches. Up to this height it was most economical to design it as a beam built to withstand horizontal pressure, since the span between the bench walls of the arches is only 8.5 ft. Above the springing line of the arches the width of the wall is increased to 2.5 ft. at the floor line, because the wall acts somewhat as a support for the latter and so receives shearing stresses. The upper 11 ft. of the wall above the floor of the trestle was designed as a cantilevered

reinforced concrete retaining wall, with its front face in line with the edge of the footing formed by the floor.

The floor has an expansion joint over each of the heavy piers at the junction between the sections comprised of five panels. These joints are made so the floor is entirely separated from the corresponding pier at each of them, on the lines shown in the drawing. They are also continuous through the vertical wall on the inside of the trestle, thus dividing the latter into 50-ft. sections to permit movement of the floor due to any cause.

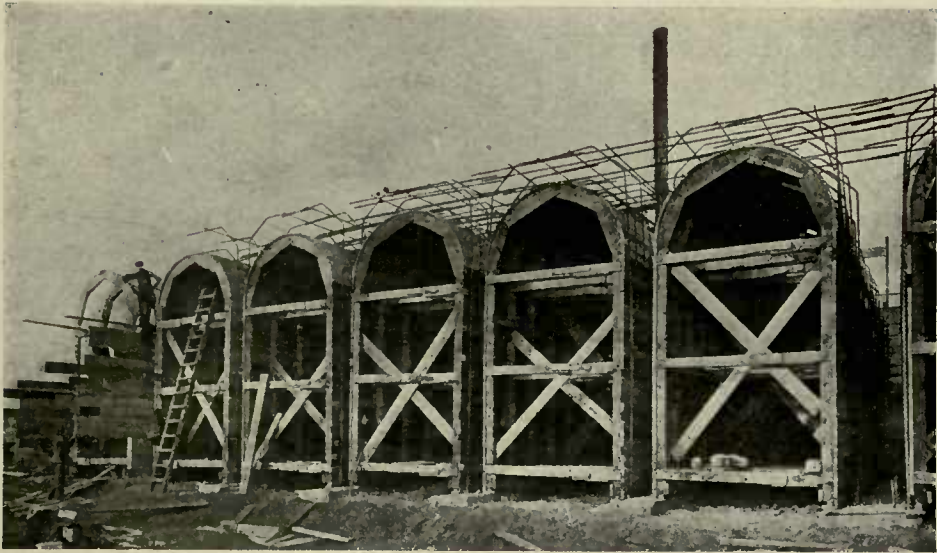
In the construction of the trestle the footings for the 42 arches included were all completed first. Vertical reinforcing bars were set to extend 1.5 ft. from the tops of these footings to insure the bonding of the bench walls of the arches to them later. The structure was then completed continuously from one end to the other, the forms being made in sections so they could be taken down and used repeatedly.

The forms for the bench walls of the arches were built up to the springing lines of the latter in sections one-third the width of the structure. These forms were made in 2-in. tongue and grooved plank, nailed to 2 × 8-in. studding, spaced 2.5 ft. apart on centers. Attached horizontally to the bottom of the studding on the outside of the form was a 2-in. plank that served as a block on which to slide the sections into place. The forms were braced together and held accurately in line by three rows of struts between the studding on the opposite sides of the openings, one row at the base, the second halfway up and the third just below the springing line of the arch. The wall forms could thus be assembled to the proper spacing and maintained in place without wires or other anchorage through the concrete.

The forms for each arch were built in three sections, corresponding to the sections of those for the walls. Each section of them was also divided longitudinally at the crown into two parts to facilitate handling. Ribs for the arch forms were cut to the circle of the arch intrados and spaced to come on the studding of the wall forms. These ribs were framed so a rigid joint could be made between the two parts of them when fastened together at the top by a single bolt. At the springing lines they were attached to the studding by a cleat which held them firmly in place.

Forms for ten panels of the structure, including those for the wall along the ore yard, were first built. The steel reinforcement for all of these panels was then erected in place and wired together. After the concrete for these ten panels had been poured, the forms for the first panel completed were taken down, carried ahead and erected again by means of a locomotive crane traveling on a track laid on the ground. Following this procedure, the remaining nine forms were removed and taken forward to be used again. In no case were the forms stripped in less than 48 hours, and they were generally allowed to remain in place considerably longer. The one set of ten forms was used in building the entire 42 panels, and was in good enough condition at the end of the work to have seen much more service. After the forms had been stripped, each time their surfaces were cleaned carefully and wetted to prevent the concrete adhering to them. The locomotive crane was found to be particularly well adapted to moving the sections in which the forms were built. It could



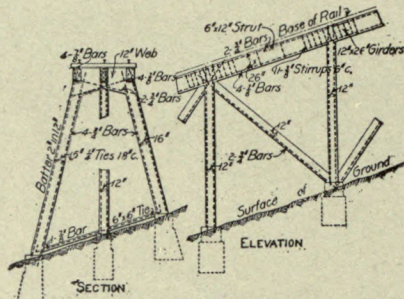


pick up one of these sections, move ahead and set it in place very quickly with only a few laborers being required.

The concrete was made in the proportions of 1 part Portland cement, 2 parts river sand and 4 parts broken stone. A portable motor-driven Smith mixer, hauled along as the work progressed, was used on the yard side of the wall. The materials were delivered to storage piles in wagons, and thence to a charging platform at the mixer in wheelbarrows. The mixer discharged directly into a pit, from which it was taken by a clam-shell bucket, and handled to place in this bucket by the same locomotive crane used in moving the forms. This method of delivering the concrete was found to be the most satisfactory one applicable to the conditions presented. The crane could take the concrete from the mixer as fast as it was produced and deliver it practically into place in the forms for the bench walls, arches and floor. A wet mixture was employed, so little shoveling or rehandling had to be done after the concrete was discharged from the clam-shell. When the high forms for the retaining wall of the trestle were erected, the locomotive crane also had sufficient reach to deposit the concrete directly into these forms. The space available on the river side of the wall was too limited to permit the location of the mixer on that side, and even if it could have been placed there, the upper part of the retaining wall on the opposite side could not have been reached from that position.

The wall was designed by the General Fireproofing Company, of Youngstown, Ohio, which company also furnished the reinforcing material required. The construction work was carried on under the supervision of that company by the regular forces of the Youngstown Sheet and Tube Company.—*Engineering Record*, April 3, 1909.





Dimensions of Bent:



PLATE LXXIV.—CONCRETE TRESTLE, OTIS ELEVATING RAILWAY.



## CONCRETE TRESTLE, OTIS ELEVATING RAILWAY.—PLATE LXXIV.

A 3-foot gauge double-track railway up Catskill Mountain, N. Y., has two outside rails and one center rail, with a turnout half way up the mountain, and runs up the northern slope of a ravine on a  $33\frac{1}{3}\%$  grade. Two open passenger cars, one at either end of a double steel cable, are operated in such a way that when the cable is all on the north track one car is at Otis Junction, at El. 500 feet, and the other at Otis Summit, at El. 2500 feet, and on the next trip, the cars being reversed, the cable is all on the south track, but when each car is half-way up, on the turnout, all the track below is clear and all above has the cable on each track, resting on pulleys supported on the ties. When freight is to be carried a trailer is coupled to each of the passenger cars, or the regular narrow-gauge box freight cars of the Catskill Mountain Railway, which ends at Otis Junction, are coupled on instead.

About 100 yards above the turnout there existed a yellow-pine structure 286½ feet long, averaging about 20 feet in height and supporting ties about 10 feet long. It was known as the middle trestle, and over it the cable is always on one track or the other and part of the time on both tracks. At the upper end of this trestle, and near its center, cliffs about 15 feet high drop down vertically and at the lower end an abutment 12 feet high had been built of stone masonry. Opposite each of these points there are level patches of ground, but under the remaining parts of the trestle the surface slopes at an angle of about 30° to the south and east, and has a little earth and loose rock strewn over it.

The bedrock is North River bluestone, and crops out almost everywhere along the north side of the trestle.

The wooden trestle consisted of seventeen bents of 10-inch square yellow-pine timber, with caps 10 feet long, sills about 12 feet, two plumb and two batter posts, each with sway and sash braces. Six corbel blocks, 6 × 13 inches by 3 feet, were spiked to the caps in pairs at the center and outer ends of each bent, being gained out on the under side to a point upon the  $33\frac{1}{3}\%$  grade and supported six 6 × 13 inch stringers, 17 and 34 feet long, to which were bolted the ties, surmounted by 6 × 8 inch guard-rails and the track.

The wooden trestle having been in use 16 years, it was decided to replace it by a permanent embankment of stone, laid up on stepped-out foundations to prevent its sliding on the steep slope. The nearest available place to get the stone for this purpose was at a cut some distance above, where blasting would have been necessary and the cable of the road could not be used, but would have to be protected. The plans showed a width of 12½ feet at the top, with a batter of 1 to 2, the estimated quantity of rock fill being 3400 cubic yards.

Alternative plans were also prepared for a trestle of reinforced concrete having the same number and spacing of bents as the old trestle. The plans called for two posts, 12 × 16 inches each, having a batter of 1½ inches to the foot outward, with 12 × 12-inch diagonal braces on the center line of the trestle, meeting alternately at the top and bottom of the bents. Three girders 12 × 26 inches by 16-foot span were spaced nearly under the rails of the track, tied by a 6 × 12-inch strut at the center of the span in their top surface and at each bent by a 12-inch web about 3 feet 6 inches deep, thus tying the batter posts and

strut bases together with concrete. The whole volume of reinforced concrete was estimated at 125 cubic yards.

The writer proposed to do the rock fill for \$4250, or at the rate of \$1.25 for 3400 cubic yards, or, as an alternative, to build the reinforced concrete trestle for the sum of \$4000, being at the rate of \$32 per cubic yard for 125 cubic yards. The bid of \$4000 was accepted on Sept. 16, 1908, and the writer notified to order materials so that they might be transported up the mountain before Oct. 17, when the inclined railway was to close operation. Mr. Asher Atkinson, Assoc. M. Am. Soc. C. E., of New York, prepared the plans and specifications, let the contract, and the construction was performed by the writer under the direct supervision of his representative, A. N. Whitlock.

All materials, apparatus and tools had to be on the site before Oct. 17, as before stated, and no work could be done toward dismantling the old structure until then. As there was no local planing mill, the spruce form lumber, 14 M feet, was shipped from Watertown, N. Y., the order was given Sept. 22 and it arrived on the job Oct. 15; 200 bbls. of Alsen's cement were ordered Oct. 12 and arrived on the job Oct. 16; 22,835 lbs. round corrugated bars ordered through H. C. Miller & Co., of New York, and shipped from Youngstown on Sept. 26, arrived Oct. 10, and 125 cubic yards of sand and gravel mixed were hauled from a local bank about 2 miles to foot of incline between Sept. 29 and Oct. 8. All materials, apparatus and tools were hauled from the foot of the incline to the job on the cars of the Otis Ry., the writer's men handling them.

While waiting for the materials to arrive and the road to close down, excavation was begun on the footings, stone for the concrete was broken, a pipe line 1000 feet long was laid to a waterfall, a cement house and a shanty in which to fabricate the steel were built.

In excavating for the footings it developed that there were alternate strata of slate rock and earth, with boulders in about half of them, so that to get a good foundation on bedrock it was necessary to go from 4 to 10 feet below the ground, the surface of which was so steep that it was very difficult to work on them. Slides and caving caused a much larger quantity of material to be handled than that represented by the holes excavated.

The position of the new footings was determined by measuring off intervals of 17 feet on the center rail of track, starting 3 feet ahead of the first old footing, then plumbing down and squaring off from the center line and carrying the excavation out laterally a little farther than the batter of  $1\frac{1}{2}$  inches to the foot called for, and down to bedrock. These excavations were then walled up in pyramidal form on a batter of 2 inches to the foot outward to within 2 feet of the ground surface, there narrowing to a section  $30 \times 30$  inches, on top of which a wooden box 30 inches square and 24 inches high was set up. Every bent had two such forms for the batter post footings, and every alternate bent had in addition a third for the diagonal bracing struts to meet on. Then footings were concreted with a mixture of 1 : 3 : 6, the stone being broken by hand to  $1\frac{1}{2}$  inch size and the wooden top forms being shifted ahead as the work progressed, the stone-breaking, mixing board, etc., being likewise shifted ahead. Half of the lumber was stored at the lower end of the trestle and half at the middle; half of the sand at the middle and half at the upper end; half of the steel at the lower end and half at upper end, and all cement at the middle.



Five mixing boards were established along the trestle, and stone was broken successively at each as it was needed for the concrete. The water pipe which ran alongside was shortened as the work progressed. The sand and gravel were separated by screening and sent to the mixing boards through temporary chutes, the superstructure concrete being one part cement, two parts sand, two parts  $\frac{3}{4}$ -inch gravel and two parts  $\frac{3}{4}$ -inch stone.

Work was begun with a force of ten men, working 9 hours, of whom one was a foreman drawing \$4 a day, one carpenter at \$2.50, one steel bender at \$2.25, and seven laborers at \$1.75 each. When the road closed down the force was doubled, eight more laborers being added at \$1.75 and two carpenters at \$2 and \$3.25, respectively, these latter working for a bonus.

Concreting the footings began on Oct. 18, and dismantling the old trestle at the same time, with some men fabricating steel, some building forms, some breaking stone, and some excavating the upper footings.

The pulleys were first removed from under the cable, and the latter supported by a 2×4-inch plank spiked to the old trestle bents, on which were also preserved the line and the grade. The guard-rails and track-rails were next removed, then the cross-ties and four inner stringers were unbolted and lowered by ropes to the ground and piled so as to form mixing boards. The remaining outside stringers were then shifted out to the ends of the bent caps, leaving a clear space in the center 8 feet 6 inches by 26 inches deep. In some places the tops of these stringers were 2 inches above grade and in other places 2 inches below, otherwise they represented approximately the level for the new work and allowed a clearance of 3 inches for the outside girder form of the new work. Next 2×6-inch spruce floor timbers for the girder forms were hung at 3-foot intervals on a grade 27 $\frac{1}{4}$  inches below by 2×4-inch battens spiked to the outside of the old stringers. The old bent caps were then gained out for each new girder to the grade of the floor timber, and a 1 $\frac{1}{4}$ ×12-inch by 16-foot bottom board for each of the three new girder forms nailed in place. These girder forms were then built up to a depth of 26 inches of 1 $\frac{1}{4}$ ×9-inch spruce matched boards, 1 $\frac{1}{4}$ ×4-inch pieces being used for the battens every 36 inches. These sides were braced internally at 3-foot intervals by tablets taken from the footing forms and placed like cross-partitions between the girder forms; the outer sides were braced by wedging against the 2×4-inch hangers and old supporting stringers, the tops of the latter being held from gaping outward by 1 $\frac{1}{4}$ ×4-inch strips nailed across the top over the floor timbers. The three floor timbers at the center of each span were then further supported from below by struts composed of old ties and braces from the dismantled structure.

The forms for the batter posts and bracing struts were made up in trough form, leaving the outer and upper side open, then set in place on the foundation, and the tops sawed to fit the bottom of the girder forms. The webs were then built between their tops, uniting the whole with the girders. The post and strut forms were then properly braced and supported, the reinforcing steel put in place, a section of the fourth side put in place, and the whole securely clamped together by  $\frac{3}{4}$ ×26-inch bolts passing tangent to two sides and drawing 2 × 4-inch yokes against the remaining two sides.

The reinforcement having been placed in the girders, the concrete was then poured in

and carefully rammed and spaded, and the third side built up and clamped directly ahead of the concreting so as to permit the most careful placing of the latter without chance of displacing the reinforcement. These posts were concreted together up to the level of the girders for two bents usually. Owing to the 30% surface, the tops of the girders had to be boarded over continuously as the concreting progressed to keep it from running out, and a section of 1-inch pipe had to be left in place every 4 feet in the outer girders through which to bolt the track to the new structure. When concreting stopped for the day bulkheads in the form of saddles were placed in the web at a bent, these bulkheads being removed the next day, allowing the concrete of each girder on the succeeding day to begin half-way in the web of the preceding bent.

Each batter post was reinforced by a rack composed of  $\frac{3}{4}$ -inch rods wired to dowels in the footing or let into holes drilled in bedrock, extending up through the girder above it nearly to the top surface and bound together every 18 inches by a rectangular hoop of  $\frac{1}{4}$ -inch corrugated bar, previously bent to the right form and securely wired together. These racks were made up as needed, and when set in place inside the forms had about 1 inch of clearance around them and had to be constantly watched by the man ramming the concrete to keep them centered. Each strut brace had a  $\frac{3}{4}$ -inch rod within 1 inch of each of its two lower corners wired to the footing dowels and passing up through the central girder nearly to the surface and requiring great care in placing the concrete to maintain them in place.

Each girder had two  $\frac{7}{8}$ -inch bars suspended from the cross-batters on top of the forms by wire, so that they lay  $1\frac{1}{2}$  inches below the upper surface continuously, and two intermediate 8-foot bars over each web for continuity. At 6-inch intervals eleven stirrups were hung on them at the bent webs and two more were hung near the center of span, so that they lay in V-shape normal to the axis of each girder and 1 inch distant from its bottom and sides. Four  $\frac{7}{8}$ -inch bottom bars were then hung or laid in these stirrups, the length being 34 feet; two were made to break joints at each bent. When these bars were all in place and securely wired, two  $\frac{3}{4}$ -inch bars were sprung into the cross-struts at the center of span and four more in each of the webs and wired in place, whereupon the girders were ready for concreting.

The congestion of steel at the webs made it difficult to place the concrete and properly ram it at and near the webs and particularly to place and remove bulkheads and clean out the forms before going ahead with the concreting. It was also hard to place the concrete in the top of the bracing struts. The best results in placing the concrete were attained with a very wet mix, poured so that the water would flow up the forms ahead and be followed by a grout which ran all around and between the reinforcement, leaving the stone and gravel to be rammed down into it at last.

The mixing was done by hand, the gang being divided so that one batch was being prepared while the other was being deposited. The sand and gravel were sent to the board by a chute, the stone broken at the edge of the board as used, and the cement carried to the board, each man taking a bag as he came to work and after lunch. Inclined runways of plank were shifted from bent to bent for the posts and others built from the mixing board to the top of structure and planks laid along the sides of the girder forms in such manner that the employees



could return to the board without interfering with the loaded pails. Owing to the steepness of the ground and of the grade on the finished work, there was unusual danger of accidents and need of constant vigilance to prevent bad results from careless work, and this is the reason why only so many men were employed and in such a manner.

Because of the unexpected depth of thirteen of the footings, a  $\frac{7}{8}$ -inch steel bar encased in 6 inches of concrete was placed as a tie between the batter post feet wherever the latter did not reach directly to bedrock. This and 37 cubic yards of extra concrete not indicated on the plans and a corresponding quantity of excavation not originally called for delayed the completion of the work, which was to have been finished on Dec. 1, so that it took until Dec. 12 to complete it. The weather was unusually favorable, being dry and warm until Nov. 3, from which time on there were light squalls of snow, succeeded by mild weather till Dec. 1, when it became so cold that the aggregates had to be heated. An old section of steel smokestack, 4 feet in diameter and 12 feet long, was filled with fire and sand and gravel piled over it, the water being heated in pails over a fire.

The 14 M of form lumber sufficed to complete about half the forms, and thereafter the forms first concreted, having been filled ten days, were stripped, and the lumber used as the form work progressed. When the clamps were removed the post forms came off in four pieces in good shape to be set up again at once, but the girder and web forms had to be taken apart and rebuilt.

The top boards and tie strips were first pried off the top of the girders, the hangers and floor timber next removed, then the old stringers pried off and lowered with ropes, all the girder batters then knocked off, and the form boards taken off separately from both the outside and inside of girders, webs, and struts. The bottom boards to the girders and diagonal strut braces were left in place two weeks longer, with props under them, and then the old bent caps were sawed in two and the bent timber unbolted and dismembered, releasing the bottom boards, which were then removed, leaving the concrete completely stripped.

There was very little pointing necessary, except on the posts, which was done from a ladder, after which the exterior surfaces were given a wash of cement, alum and lye, rubbed in with a cement brick to waterproof the structure and remove board marks. The cable was blocked up on the concrete webs, the ties and guard-rails bolted on, the pulleys rehung and track laid back in place by the Otis Railway Company, replacing track not coming under the contract.

The amount of work done under this contract was as follows: Excavation called for 87 cubic yards earth, and extra excavation, uncalled for, 63 cubic yards boulders, making a total of 150 cubic yards; dismantling and piling 34 M feet yellow pine structure; 37 cubic yards concreting (1 : 3 : 6) in extra footings; 125 cubic yards concreting called for (1 : 2 : 4), reinforced; 13 tie rods for batter post feet; cleaning up and removal of debris; total cost, \$4332.14; contract price, \$4000; extras, \$677.75; total \$4677.75; profit on contract, \$345.61.

Daily records were kept showing kind of weather, temperature, amount of each kind of work done, with proportion of pay roll spent in doing it and the unit cost noted down for the immediate purpose of more economically planning the next day's work. A distribution

statement showed the cost of both labor and material, charged up against each item of work performed during the week and the unit costs computed for each. A comparison was made between weekly average and daily rates, and the conditions prevailing on those days showing the most economic rates were then planned for the succeeding week's work.

Separate records were kept for the items applying to the general contract, the costs on extra work being kept apart. Finally all the costs were referred to the quantity of work done under them in the form of unit prices per cubic yard and the percentage which each represented to the whole.

Cost of 125 Cubic Yards Reinforced Concrete as Indicated on Plans.

	Per Yard.	Total.	Percentage.
Aggregates: Cement, \$2.31; sand, \$1.73; gravel, \$0.33; stone, \$2; water, \$0.35.....	\$6.72	\$840.50	23.0
Form material: Lumber, bolts, and nails.....	4.75	593.88	16.3
General expenses: Investigation, laying out, superintendence, insurance, etc.....	4.45	556.93	15.2
Steel reinforcement: Bars, wire, etc.....	3.77	472.13	12.4
Form labor: Erecting and working 28,000 ft. lumber.....	3.58	446.28	12.2
Concreting labor: Mixing and placing.....	1.94	242.60	6.6
Steel reinforcement labor: Fabricating, \$0.37½; placing, \$0.74.....	1.11½	139.50	3.8
Dismantling old trestle: Track, \$0.65; bents, \$0.35.....	1.00	124.75	3.4
Pointing and waterproofing: Pointing, \$0.37; waterproofing, \$0.60.....	0.97	120.80	3.3
Excavation, 87 cu. yds.....	0.56	69.75	1.9
Cleaning up at completion: Grading and piling lumber.....	0.40	50.00	1.4
125 cu. yds. reinforced concrete.....	\$29.25	\$3657.12	100.0
Contract price.....	32.00	4000.00	
Net profit.....	\$2.75	\$342.88	

Cost of Extra Footings, 37 Cubic Yards, Averaging 1.2 Yards in a Place.

	Per Yard.	Total.	Percentage.
Excavation, 63 yds. rock, at \$2.80.....	\$4.91	\$181.70	36.3
Aggregates: Cement, \$1.94; sand, \$0.97; stone, \$1.01.....	3.92	145.76	29.2
Forms, material.....	1.20	42.40	8.5
Forms, labor.....	1.44	55.15	11.0
Concreting, labor.....	2.07	76.50	15.0
37 yds. concrete.....	\$13.50	\$501.51	100.0

Thirteen Extra Tie Rods, ¾-inch Steel in 6×6-inch Concrete, 1½ Cubic Yards Concrete.

	Per Yard.	Total.	Percentage.
Excavation.....	\$6.01	\$9.10	12.7
Bending and placing steel rods.....	7.80	11.65	16.3
Form labor.....	8.35	12.50	17.5
Form material.....	8.30	12.44	17.4
Reinforcement (steel bars).....	5.10	7.68	10.8
Concreting labor.....	5.00	7.50	10.5
Aggregates: Cement, \$2.70; sand, \$1.35; stone, \$3.....	7.00	10.50	14.8
1½ yds. concrete.....	\$47.50	\$71.37	100.0

Although the total unit cost of \$29.25 per cubic yard for the 125 cubic yards of reinforced concrete in the trestle would at first seem high, the statement shows that it is the result of an



unusual number of component items, some of which are too often left out in such statements. Moreover, a good deal of the work was done on overtime at double the daily rates, in order to finish before cold weather. The magnitude of these items individually does not seem excessive, considering the difficult position of the work, and by comparing the succeeding statements for the extra concrete in footings and for the tie rods, it may be seen that the distribution of the concrete, whether in mass underground or in slender reinforced members, is what determines the cost per yard.

Only \$65 was allowed on these tie rods. The contractor was allowed 10% profit on the actual cost of the extras.—C. C. Mitchell, *Engineering Record*, Feb. 20, 1909.



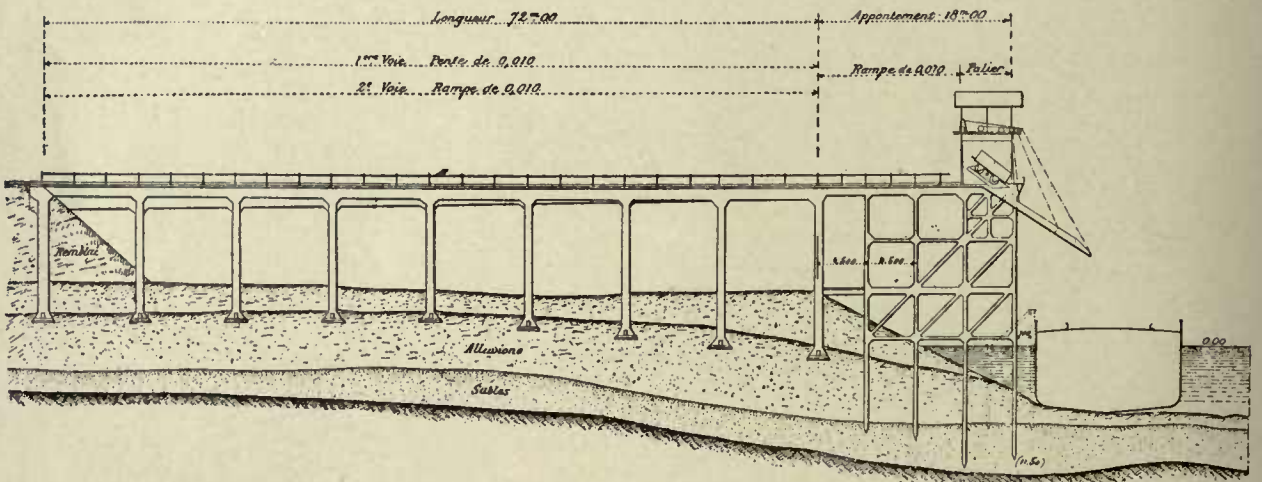
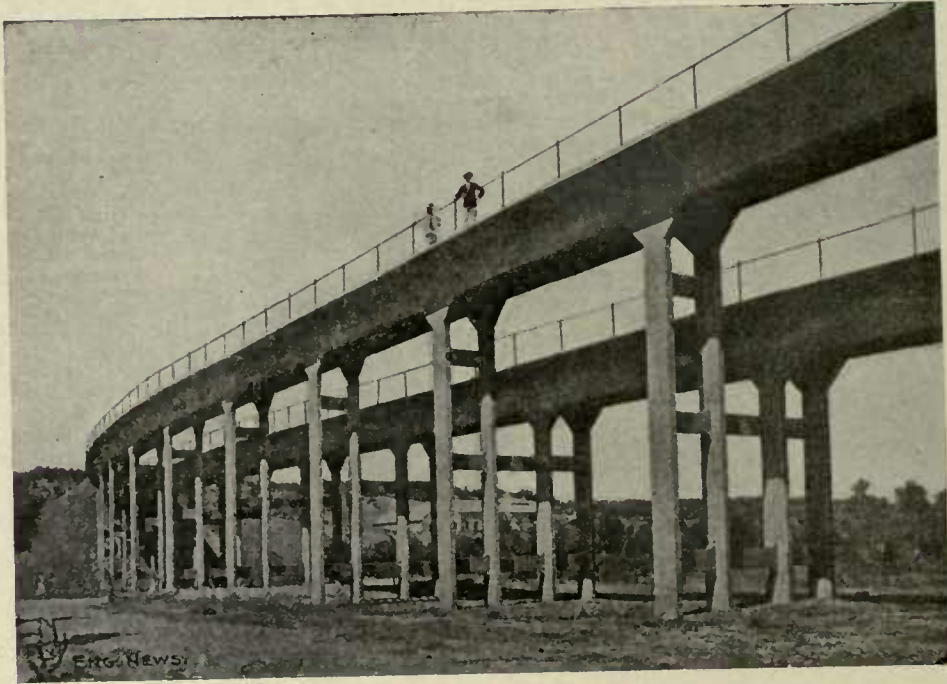


FIG. 1.—VIADUCT AND ORE-LOADING PIER OF REINFORCED CONCRETE CONSTRUCTION.





REINFORCED CONCRETE TRESTLEWORK VIADUCT FOR A SPANISH MINERAL RAILWAY.  
PLATES LXXV, LXXVI.

Two trestlework viaducts of reinforced concrete, with an aggregate length of 207 m. (679 ft.) and a height of between 30 and 40 ft., have been constructed on the railway line from the Cala iron mines to the Guadalquivir River, near Seville, Spain. The purpose of the railway is to take ore from the mines some 97 kilometers (60 miles) to ore vessels navigating the river, and the viaducts with an intervening embankment carry the line across the broad flood channel of the stream to a loading pier on the edge of deep water in the normal channel. From this point to the Atlantic Ocean, 95 kilometers (59 miles), and thence abroad, the ore is taken in vessels.

Of the two viaducts the longer is inshore and has a total length of 117 m. (371 ft.); a view of this structure is given by the accompanying picture. From the end of this viaduct an embankment 86.5 m. (284 ft.) extends to the inshore end of the second viaduct, shown in side elevation by Fig. 1, and which terminates in the loading pier. The scheme of handling cars to and from the loading platform involves two tracks; a locomotive pushing a train of ore cars ahead advances to the loading pier on one track, where the cars are tipped and discharged one at a time and sent back on the second track by gravity to a point back of the inshore viaduct, where they are again assembled into trains.

The two viaducts are substantially alike in construction; each consists of two parallel single-track structures, as indicated by Fig. 1, and more clearly by the cross-section, Fig. 2, of the longer viaduct. The bents, which are spaced 9 m. (29.52 ft.) apart on centers, are each composed of four posts,  $0.67 \times 0.23$  m. in section. Each longitudinal line of posts carries a girder 1.2 m. deep and 0.23 m. thick (3.94 ft.  $\times$  0.75 ft.), and the two girders on each track carry a slab, whose outer edges bracket over the girders to form sidewalks. The reinforcement of the girders is shown by Fig. 3. The bracing connecting the bent posts transversely is shown with its reinforcement by Figs. 2 and 3. Fig. 2 also shows the footing for the bent posts; this consists of a slab 20 cm. (5 ins.) thick, 1.75 m. (5.74 ft.) wide and 7 m. (23 ft.) long, stiffened by a rib or girder between posts. A footing of plain concrete 30 cm. (7.62 ins.) thick supports the reinforced slab. With the maximum possible loading this footing brings a pressure of 2,362 lbs. per sq. ft. on the soil.

The actual train loads for which the viaducts are designed are made up as follows: A locomotive of 48 metric tons (36 tons on coupled axles 2.85 m. apart and 12 tons on a bogie with axles 1.6 m. apart) and 20 cars carrying 20 tons each on axles 1.6 m. apart.

The loading pier is shown in sectional plan by Fig. 4, and in side elevation by Fig. 1. The main supporting members are 14 columns, which form continuations of 14 reinforced concrete piles constructed as shown by Fig. 5. These columns are braced together by two platforms, one at track level and the other at ground level, and by horizontal struts at two intermediate levels as shown. The struts are  $32 \times 32$  cm. (12.6  $\times$  12.6 ins.), and the girders carrying the platform slabs are of the same dimensions. The diagonal bracing is used



only in the two lines of columns between which the ore chute is placed; the diagonals are of the same cross-section as the struts.

The completed viaduct was subjected to elaborate tests, under which it exhibited very little deflection or vibration. The preceding description has been compiled from an article in *Le Génie Civil* of Dec. 23, 1905, by Mr. Juan-Manuel de Zafra, Under Director of Works, Port of Seville, Spain.--*Engineering News*, May 17, 1906.







### PART III.

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THE following references to articles on trestles and related subjects of interest in the design, construction, and maintenance of trestle bridges, while not exhaustive, is believed to be very complete. It covers the field of engineering periodicals and the transactions of many societies and clubs, but does not attempt to cover books or standard works on engineering and railway matters.







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