A TREATISE

ON

WOODEN TRESTLE BRIDGES

ACCORDING TO THE PRESENT PRACTICE
ON AMERICAN RAILROADS.

BY
WOLCOTT C. FOSTER.

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PREFACE TO SECOND EDITION.

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.

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.

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TECHNICAL TERMS AND NAMES.

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.

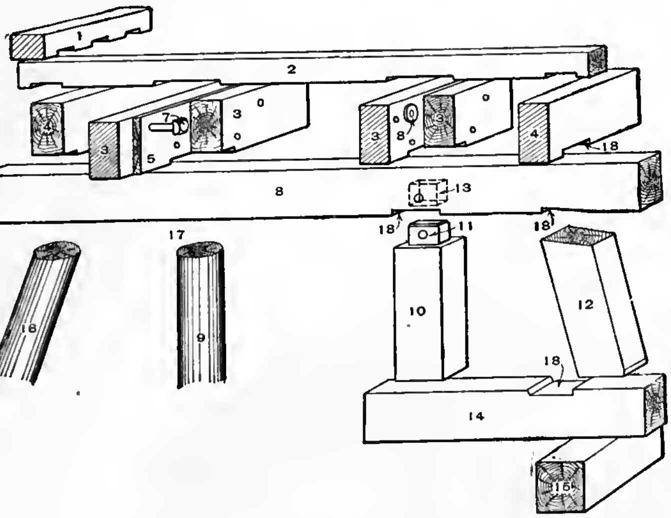
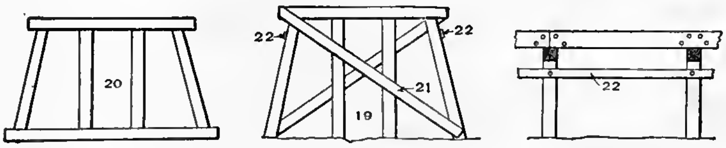


FIG. 1.



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Thimble, see Separator.
Track-stringer, see Stringer.
Waling-strip, see Longitudinal Brace.

ABBREVIATIONS.

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:

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

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 mileage 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′ × 14′, per mile, ...	1,369	1,369	1,369	1,369
Embankment, 14′ × 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 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.

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

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.

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.

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.	Chestnut.	Buttonwood.
White Ash.	Beech.	Red or Norway Pine.
White Cedar.	Scrub Oak.	

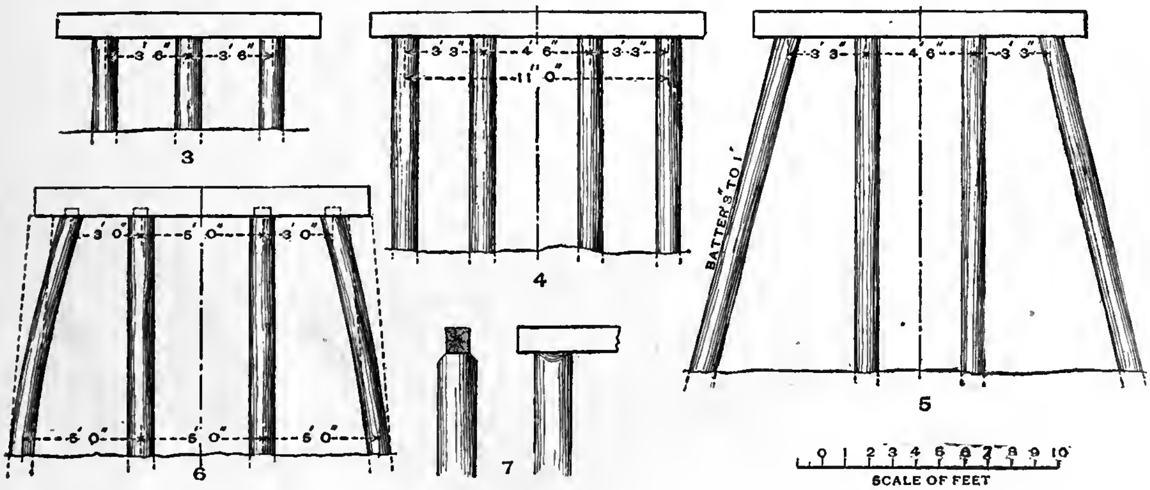
They should be of straight, sound, live heart timber, perfectly free from windshakes, wanes; large, loose, black, or decayed knots; cracks, worm-holes, and all descriptions of decay; and should be stripped of bark. Some engineers prefer the piles to be hewed or sawed square. If piles are squared, they 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° (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 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. 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.

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 2½ 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.	
	c — c.	Distance either side centre-line.	c — c 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.

* I. S. P. Weeks, Chief Engineer C., B. & Q. R. R., west of the Missouri River.

† Outside piles vertical.

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.

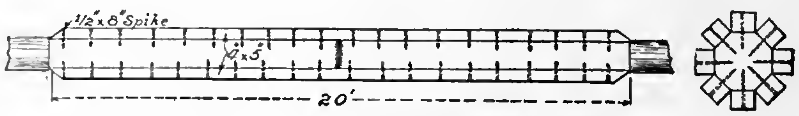


FIG. 8.—PILE-SPLICE, POUGHKEEPSIE BRIDGE.

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 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

FIG. 9.

FIG. 10.

PILE-SPLICES.

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, 12½ 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 8½ 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 6½ 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 4½ inches. A pile 43 feet long received two blows of 2 feet each, and then settled under 2000-lb. hammer 1½ inches in two minutes. Four weeks later it settled but 2¾ inches under a 10-ft. fall and 8½ inches under a 28-ft. fall. These piles bore without failure a load of 13,333 lbs. each.

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* *Eng. News*, vol. xiii. p. 210.
† *Eng. News*, vol. xx. p. 510.
‡ *Eng. News*, May 18, 1893, p. 462.
§ *Eng. News*, Dec. 8, 1892, p. 543.
‖ Discussion of Foster Crowell's paper on "Unfiorm 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.

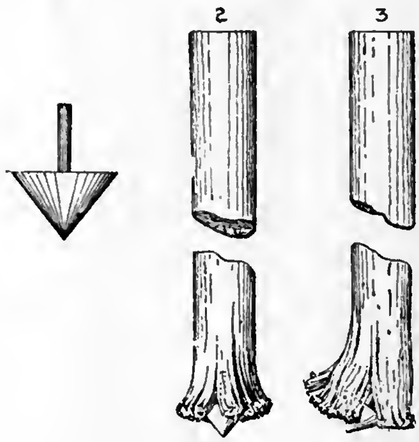


FIG 11*a*.—EFFECT OF SHOES ON PILES.

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. 11*a*. 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.*

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

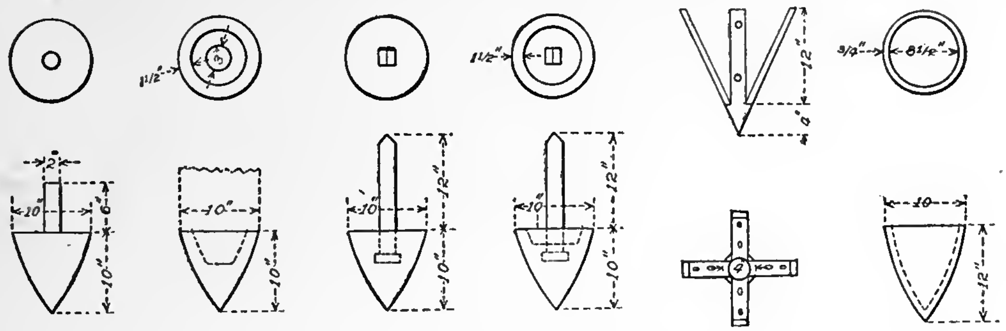


FIG. 12. FIG. 13. FIG. 14. FIG. 15. FIG. 16. FIG. 17.

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. 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.

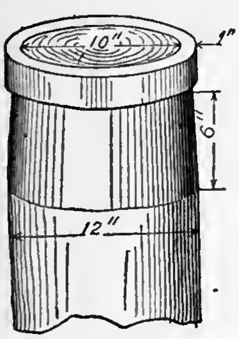


FIG. 18.—RING FOR PILE.

Fig. 18*a* 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. 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.

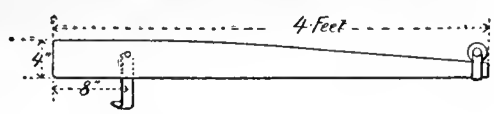


FIG. 18*a*.—RING REMOVER.

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

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

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.

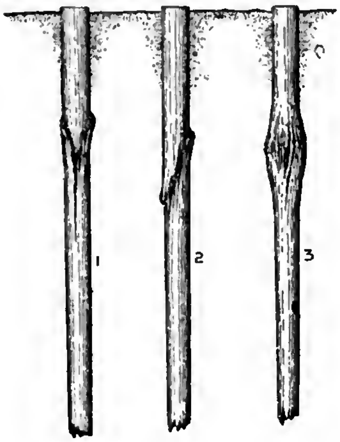


Fig. 18*b*.—Effect of Over-driving Piles.

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.

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

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

In this and the following formulas a factor of safety of 6 has been allowed, and the letters are as follows:

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

† Proc. Amer. Inter. Assoc. Ry. Supts. of B. & B., 1893, pp. 24 and 25.

‡ *Engineering News*, Nov. 17, 1892, p. 469; also in book form, "Piles and Pile Driving."

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 ½ 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 ¼ 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 ½ 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.

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 $2\frac{1}{2}$ 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

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

For piles driven by gunpowder or similar pile-drivers

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

Where the bridge is very long, and hence the number of piles large, it becomes exceedingly important to determine with reasonable accuracy the approximate lengths of the piles and the number of each different length required. To accomplish this end a plan was adopted in the building of the Northern Pacific R.R. Bridge over the St. Louis River at Duluth, Minn., which is said to have proven very satisfactory indeed.* Test-piles were driven every 300 feet along the centre-line, and where any great difference in penetration was noticed an intermediate pile was driven. These piles were driven from a scow, and the distance measured by tying a rope to the last pile driven. The correct position of each pile was finally determined by triangulation. A complete record of the details of the test-piles was kept under the following form: †

Sta.	No. of Pile.	Length.	Dia. of Top.	Diam. of Butt.	Depth of Water.	Dist. Driven.	Elev. Top of Pile.	Elev. Point of Pile.	No. of Blows.	Fall of Hammer.	Wt. of Hammer.	Penetration for each ten consecutive blows.											
												40	50	60	70	80	90	100	110	120	130	140	150
											lbs.												
80+23.7	16	52′	8½″	15½″	9.7′	39.3′	84.8′	32.8′	120	20′	2256			13″	14″	16″	17″	15″	12″	12″			

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

* "Pile-driving," E. H. Beckler, *Eng. News*, vol. xvi., p. 83.

† This form has been very slightly modified by the author.

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.					
Dec. 27.				ft.	ins.	ins.	ft.	ft.	ft.	ft.	ft.	ft.							
114+30	42	1	Wh. P.	40.0	17	14	31.4	8.6	76.2	66.4	9.8	20	85	20	10″ 40	10″ 60	5″ 70	4″ 80	1″ 85
114+30	42	4	Wh. P.	40.0	16	11	33.0	7.0	76.2	64.8	11.3	20	60	20	10″ 30	7″ 40	7″ 50	7″ 60	
Jan. 10. 112+65	53	3	Wh. P.	42.0	15	13	36.0	6.0	74.8	61.8	13.0	18	50			20	11″ 30	11″ 40	9″ 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	19¼	621	$454.43	$0.06969†
1885. Jan. 1 to 5 and 10 to 14. Piles over 45′ long,	5¾	134	5785	23 3/10	1006	212.57	0.0367
Jan. 5 to 10 and 14 to 31,	14½	364	21535	25 1/10	1485	539.61	0.02506
Feb. 1 to 28,	19¾	379	25036	19⅕	1268	747.74	0.0298
March 1 to 5,	3¼	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 record may be taken as a fair average, and under like conditions may be used as a basis to estimate both time and cost. The trestle was a long one across a bay, which was completely frozen over.

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

† Some delay on shore.

The following table, VI (*a*), gives the detail results of some pile-driving done on the Omaha & St. Louis Ry. with one of their combination car pile-driver, derrick, ditcher, scraper, and steam-plough.*

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.

* *Eng. News*, Aug. 16, 1890, p. 140, gives cuts of machine and records of other work.

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.				12 ft.[2]		
Piles per lin. ft. in place,	35c.			25c.		
Round Timber per lin. ft. erected (round-timber trestle)					9c.	
Dimension Timber per M, B. M., erected,	$40				$23	Hemlock, $16.47
Oak,		$30[1]	$30[1]	$25 to $30		
Pine,				$13 to $16		Wh. $26.00
Heart Pine (Va. Pine),		$30[1]	$30[1]			
Cattle-guard Timber per M, B. M., erected,	$30					
Bolts and Nuts per lb.,				5½c.	6c. to 7c.	

[1] Includes iron.

[2] 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 13½c. 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 = $9\frac{1}{11}$ 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.

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.

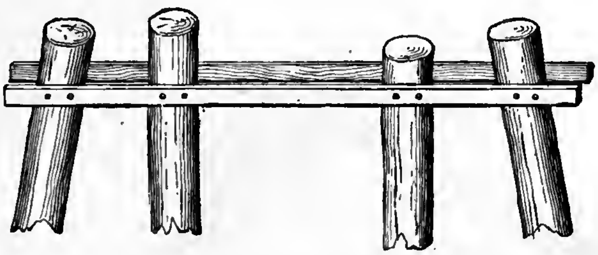


FIG. 19.—MARKING PILES FOR CUTTING OFF.

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.

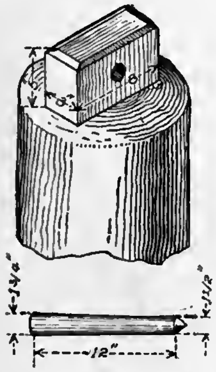


FIG. 20.—PILE TENON AND TREENAIL.

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.

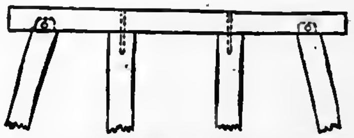


FIG. 21.—FASTENING CAP TO PILES.

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, ⅞-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—

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.

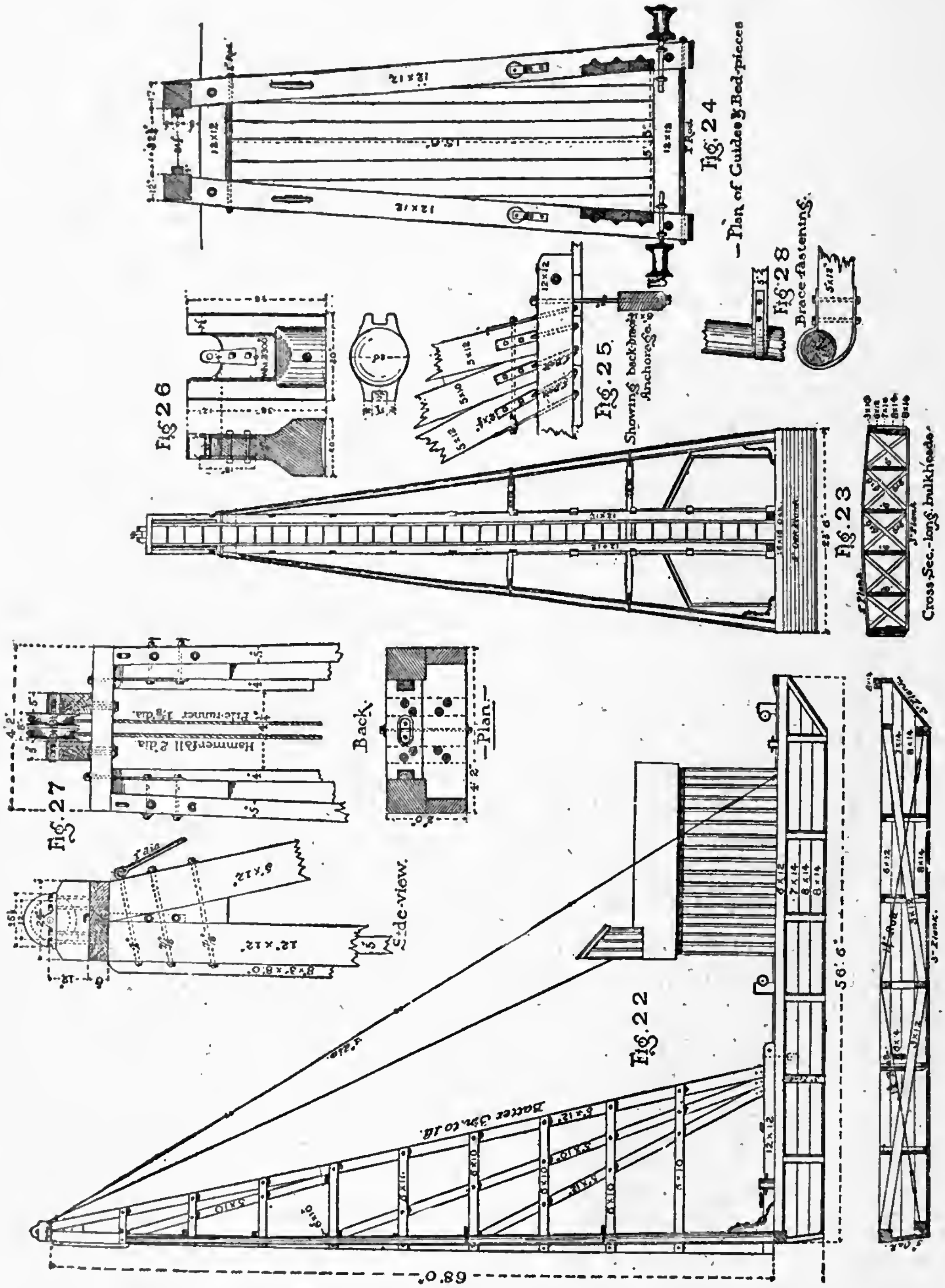
When many piles have to be driven in navigable waters the driver is mounted on a scow.

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

* 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. × 16-in. cross-timber at top, and at the stern is an 8-in. × 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. × 6-in. timber. The hull is further braced in the centre by two 3-in. × 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. × 12-in. Y. P. 67 ft. long from out to out, with inside guides of 5 in. × 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. × 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. × 16-in. oak piece on bow, and the after-bolts passing into a cross-timber 6 in. × 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. × $\frac{1}{2}$ 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 $1\frac{5}{8}$ 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. × 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.

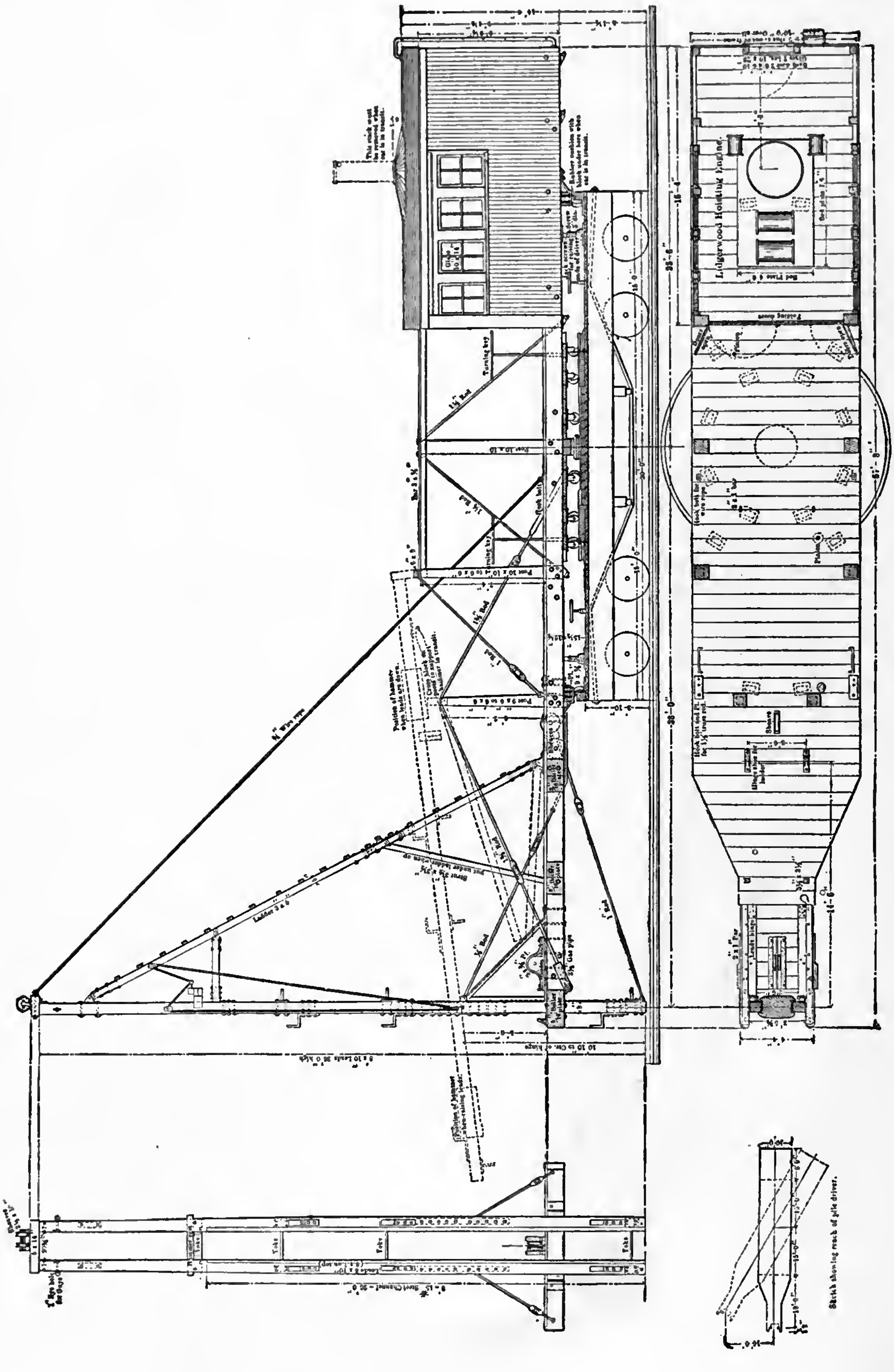


Fig. 29.—Car Pile-driver, Missouri Pacific Railway.

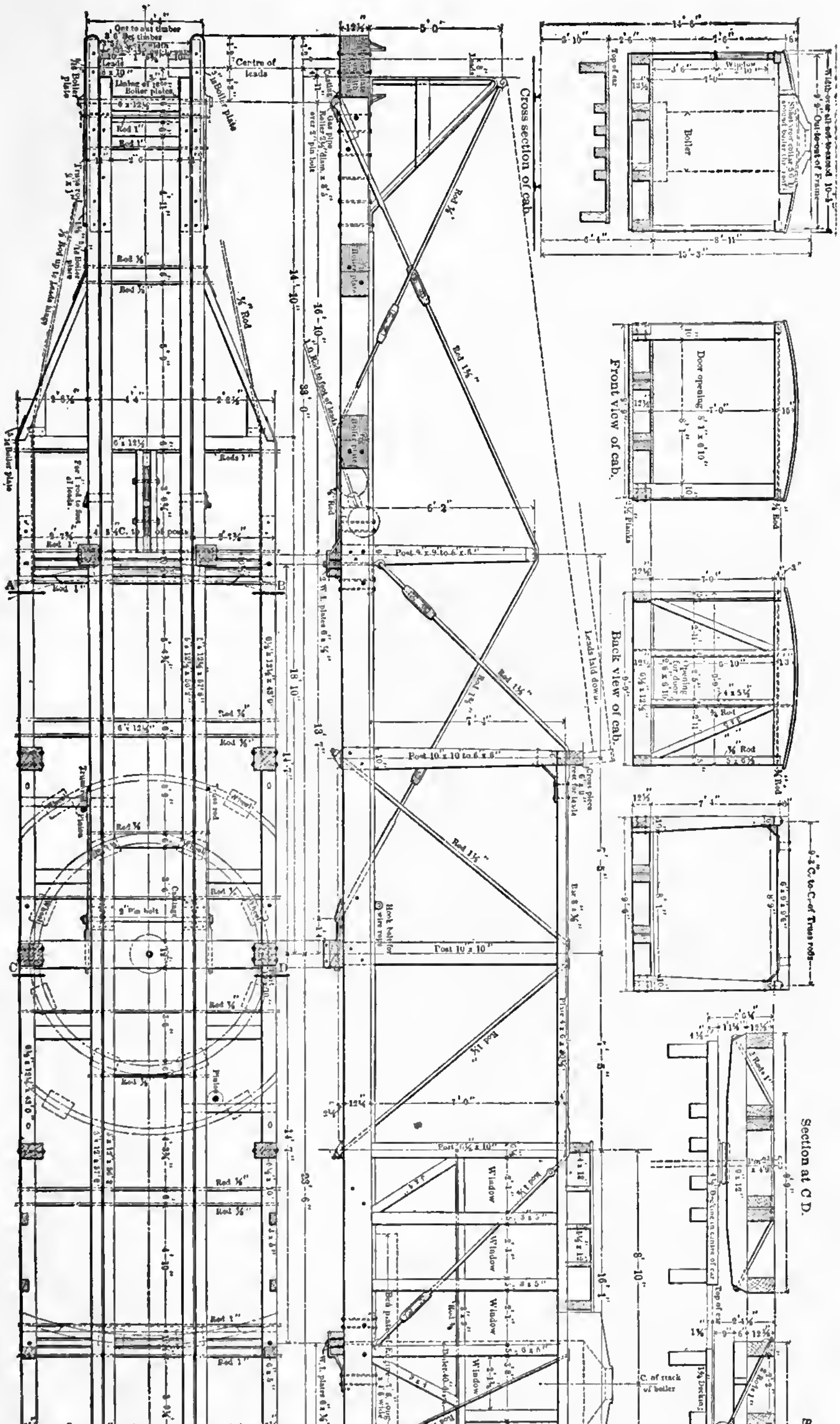


FIG. 30.—CAR PILE-DRIVER, MISSOURI PACIFIC RAILWAY. (FRAMING OF UPPER DECK AND CAB.)

"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. × 12½ in. in thickness. The side-sills are 6⅞ in. × 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 × 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. × ⅞ in. in section intervening between them, the bolster being 6 in. × 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. × ⅝ in. in section is secured to the upper face

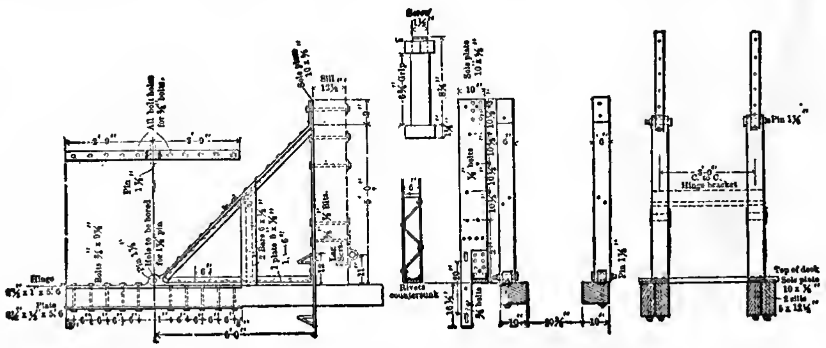


FIG. 31.—CAR PILE-DRIVER, MISSOURI PACIFIC RY. (DETAILS OF LEADS.)

of the longitudinal sills which support the beam. The hinge-frame is secured to this plate, and consists of plates 6 in. × 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."

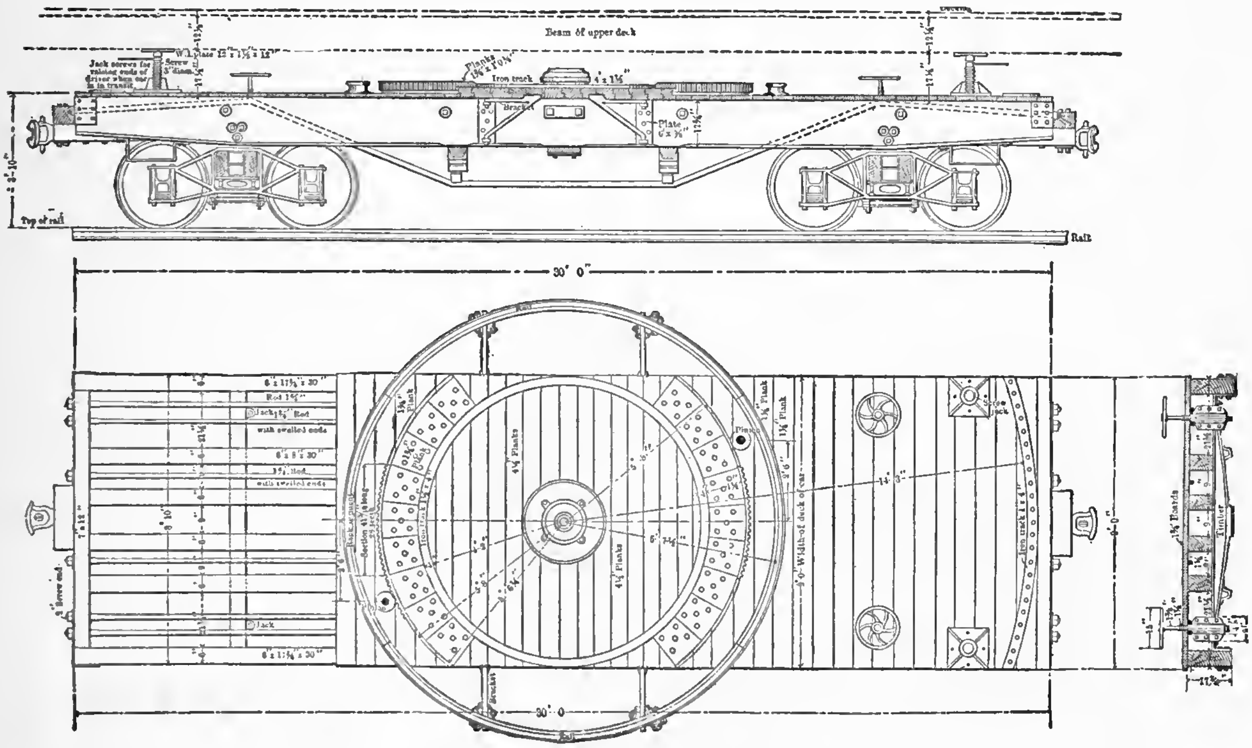


FIG. 32.—CAR PILE-DRIVER, MISSOURI PACIFIC RY. (DETAILS OF CAR.)

"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."

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." *

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

Messrs. Ross & Sanford drove on an average 83 piles, having a penetration of 17 ft., 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.

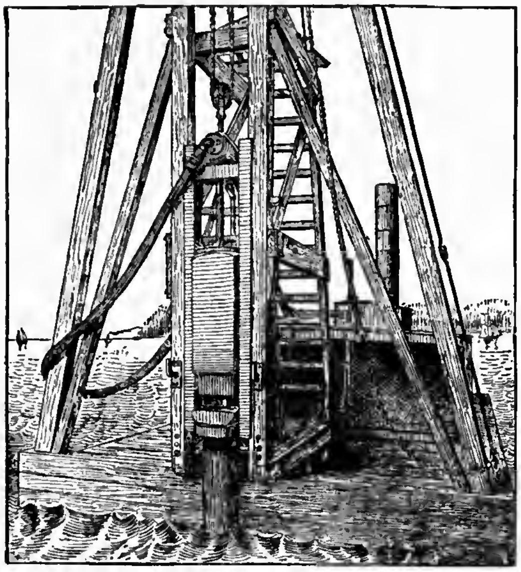


FIG. 33.—STEAM PILE-HAMMER IN OPERATION.

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.

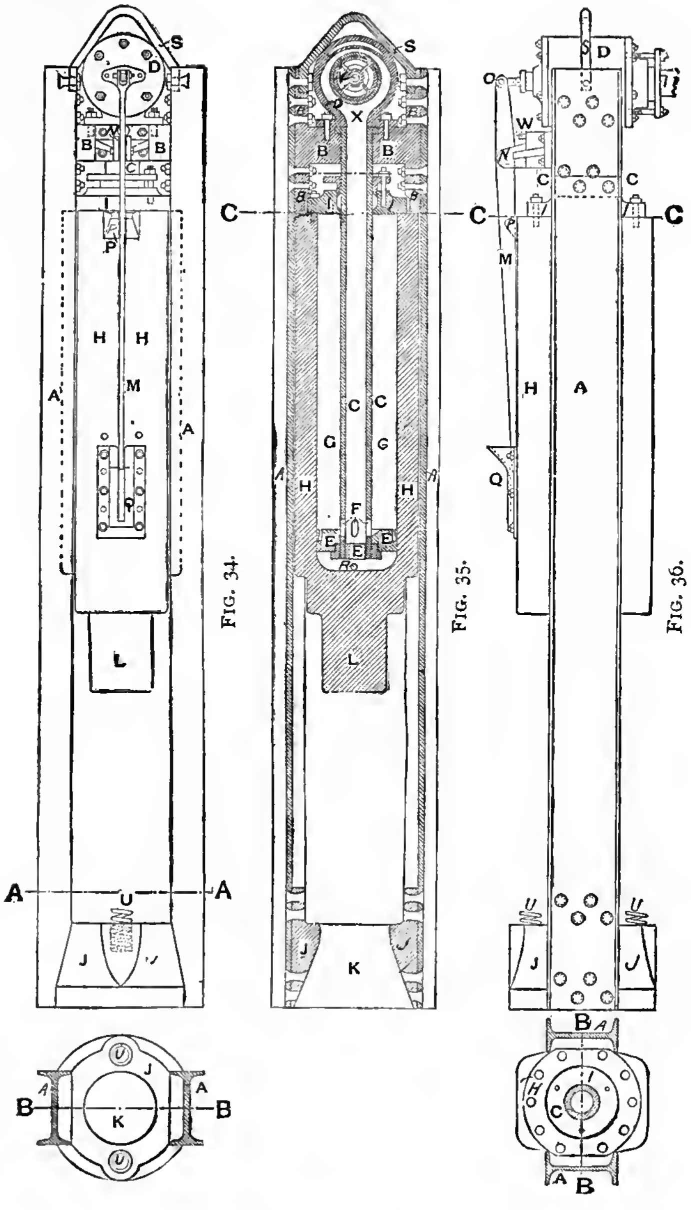
P. Upper trip, which throws the valve-stem in and supplies steam to the cylinder (G).

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

R. Vent for air and condensed water.

S. Bail by which the whole machine is lifted.

T. Connection of steam-hose with steam-chest.



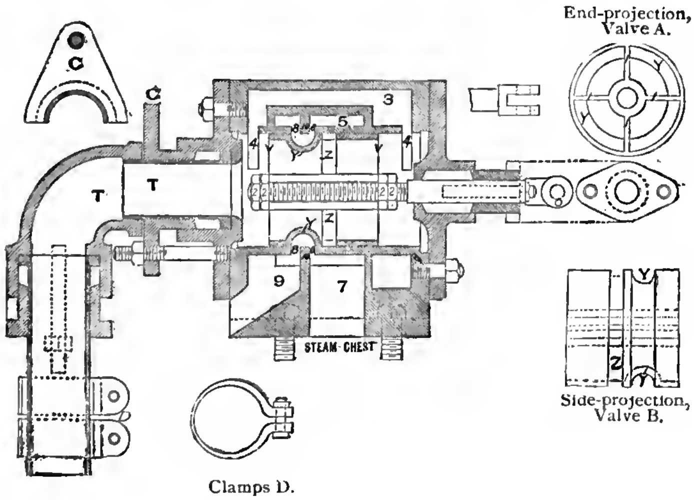


Fig. 37.—Balance-valve.

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

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.

"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.

* Corrected from original.

"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 working 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 (4½ inches) is connected to a Y pipe which has two 2½-in. branches, each having a gate-valve; the two pipes lead upward and connect with two lengths of hose

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

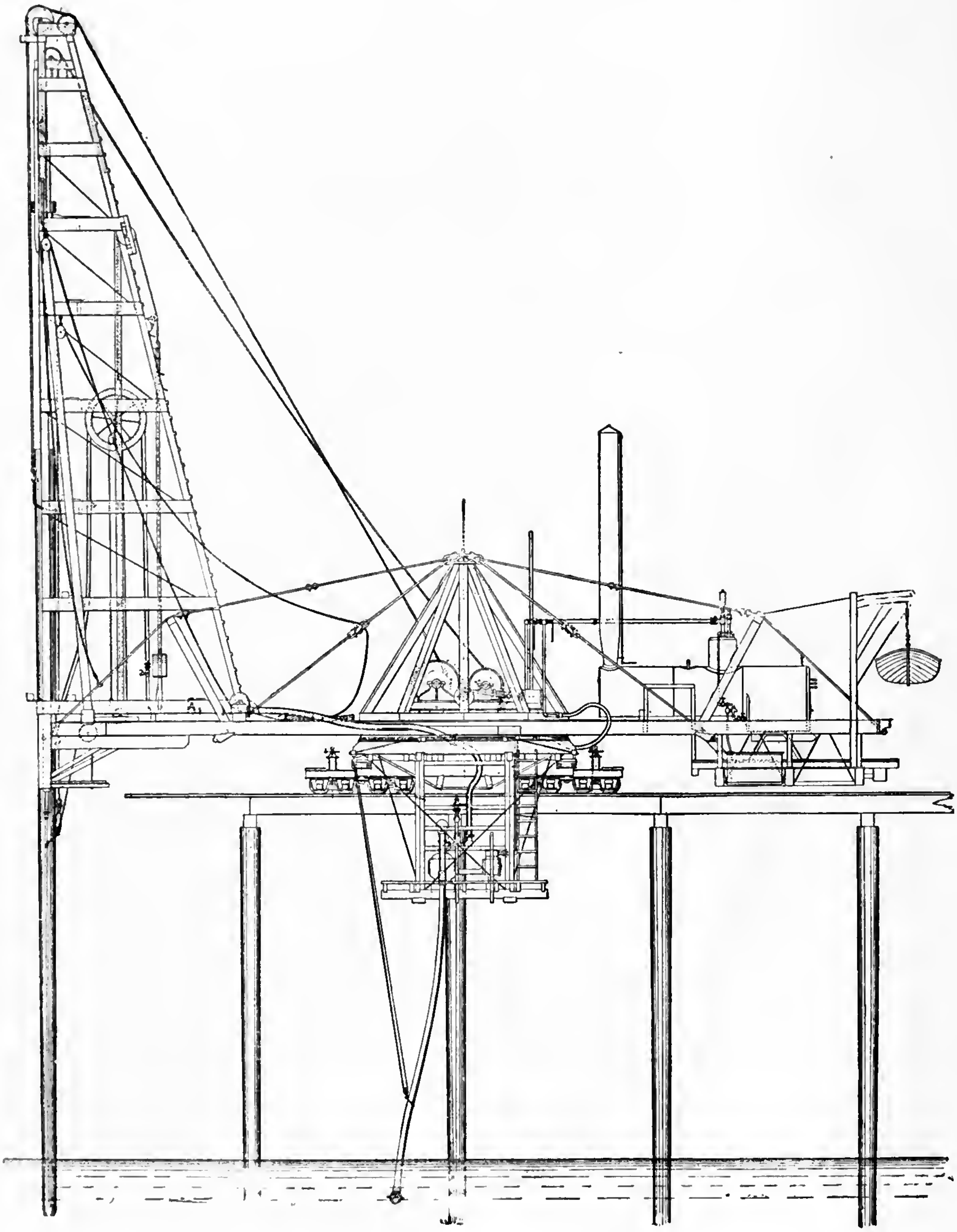


FIG 37A.—WATER-JET PILE-DRIVER.

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

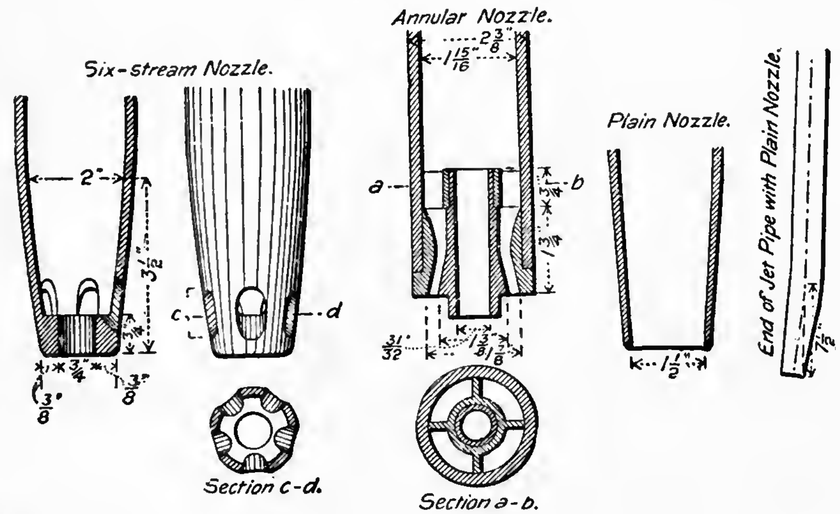


FIG. 37B.—NOZZLES FOR WATER-JET PILE-DRIVER.

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 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 foward 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 $1\frac{1}{2}$-in. plain nozzle, for general service, proved

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

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	$2\frac{1}{2}$	1	$1\frac{1}{4}$
40	$2\frac{1}{2}$	2	$1\frac{1}{8}$
50	$2\frac{1}{2}$	2	1
60	$2\frac{1}{2}$	2	$0\frac{7}{8}$

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.

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

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.

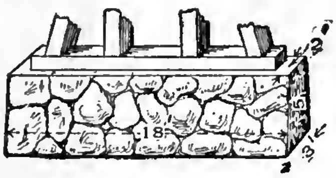


FIG. 38.

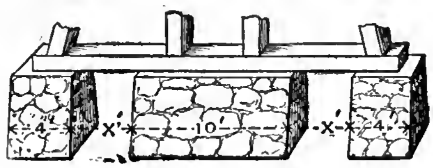


FIG. 39.

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

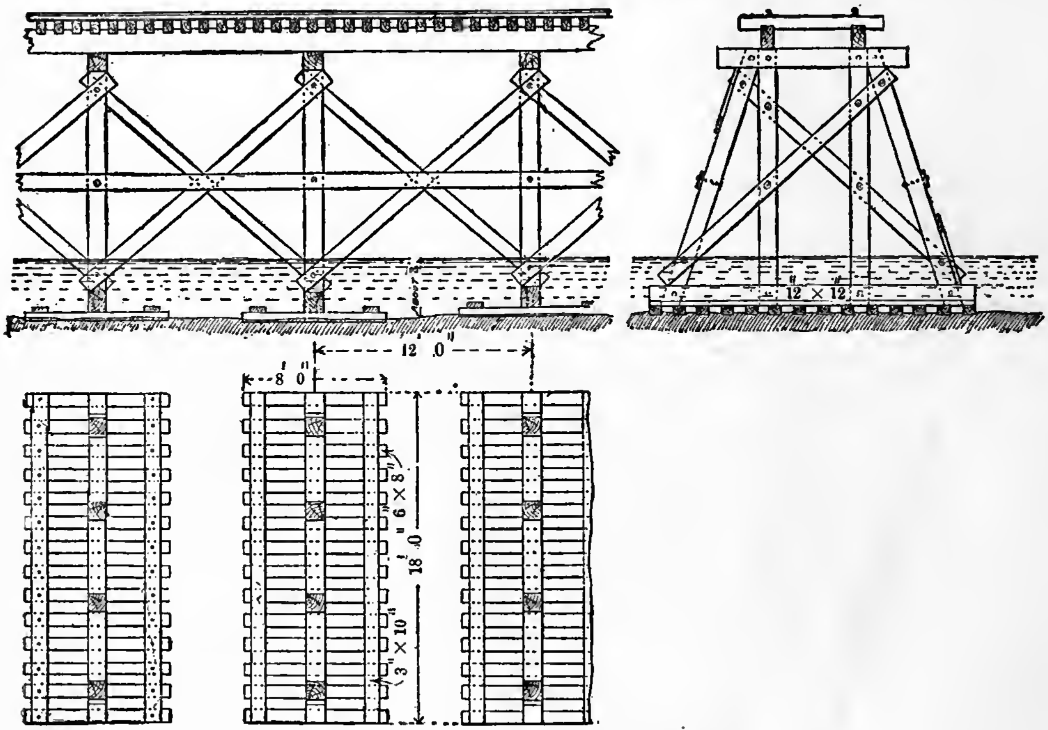


FIG. 40.—GRILLAGE FOUNDATION.

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).

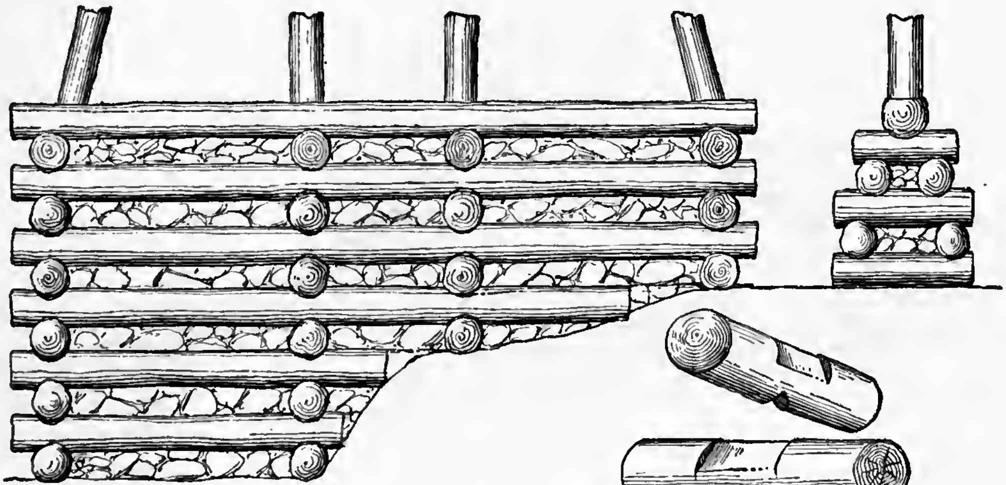


FIG. 41.—CRIB FOUNDATIONS.

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

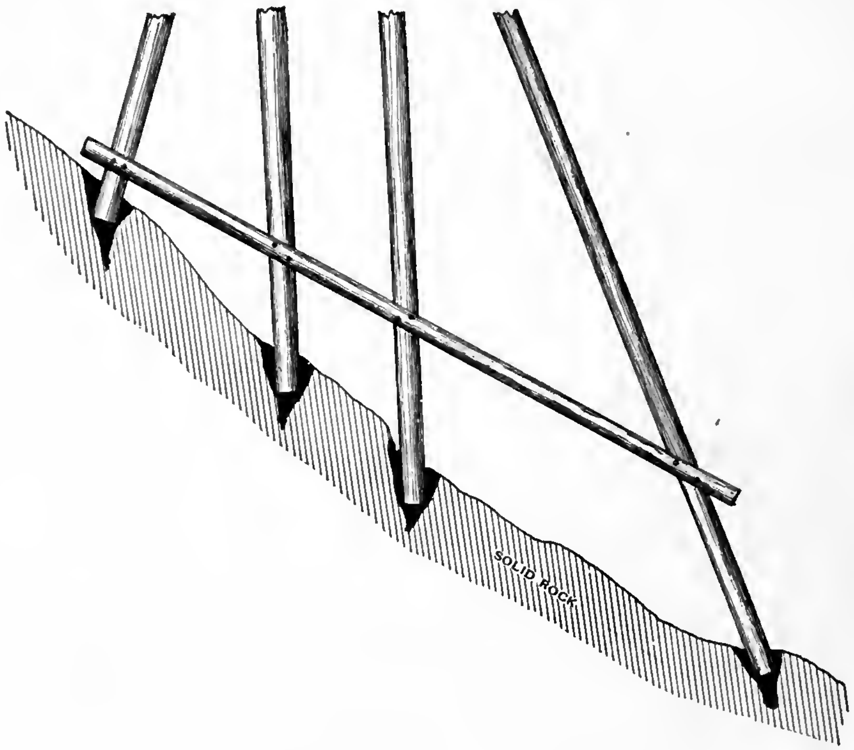


FIG. 42.—SOLID ROCK FOUNDATIONS ON SIDE-HILL.

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 ½ 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.

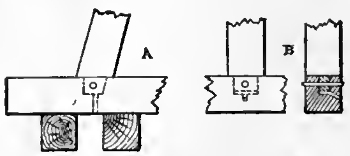


FIG. 43. FIG. 44.

DRIP-HOLES.

* 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. Shoulder to Shoulder.		Stick with Square Ends.		With two 5″ Tenons.	
ft.	in.	ft.	in.	ft.	in.	ft.	in.
3	0	3	1	3	4	4	2
3	6	3	7⅛	3	10⅛	4	8⅛
4		4	1½	4	4½	5	2½
4	6	4	7⅝	4	10⅝	5	8⅝
5		5	1⅞	5	4⅞	6	2⅞
5	6	5	8	5	11	6	9
6		6	2¼	6	5¼	7	3¼
6	6	6	8⅜	6	11⅜	7	9⅜
7		7	2½	7	5½	8	3½
7	6	7	8¾	7	11¾	8	9¾
8		8	3	8	6	9	4
8	6	8	9⅛	9	0⅛	9	10⅛
9		9	3⅜	9	6⅜	10	4⅜
9	6	9	9½	10	0½	10	10½
10		10	3⅝	10	6⅝	11	4⅝
10	6	10	9⅞	11	0⅞	11	10⅞
11		11	4	11	7	12	5
11	6	11	10¼	12	1¼	12	11¼
12		12	4½	12	7½	13	5½
12	6	12	10⅝	13	1⅝	13	11⅝

Distance between Cap and Sill.		Length of Stick. Shoulder to Shoulder.		Stick with Square Ends.		With two 5″ Tenons.	
ft.	in.	ft.	in.	ft.	in.	ft.	in.
13		13	4¾	13	7¾	14	5¾
13	6	13	11	14	2	15	
14		14	5⅛	14	8⅛	15	6⅛
14	6	14	11⅜	15	2⅜	16	0⅜
15		15	5½	15	8½	16	6½
15	6	15	11¾	16	2¾	17	0¾
16		16	5⅞	16	8⅞	17	6⅞
16	6	17	0	17	3	18	1
17		17	6¼	17	9¼	18	7¼
17	6	18	0½	18	3½	19	1½
18		18	6⅝	18	9⅝	19	7⅝
18	6	19	0⅞	19	3⅞	20	1⅞
19		19	7	19	10	20	8
19	6	20	1¼	20	4¼	21	2¼
20		20	7⅜	20	10⅜	21	8⅜
20	6	21	1½	21	4½	22	2½
21		21	7¾	21	10¾	22	8¾
21	6	22	1⅞	22	4⅞	23	2⅞
22		22	8⅛	22	11⅛	23	9⅛
22	6	22	2¼	23	5¼	24	3¼

Distance between Cap and Sill.		Length of Stick. Shoulder to Shoulder.		Stick with Square Ends.		With two 5″ Tenons.	
ft.	in.	ft.	in.	ft.	in.	ft.	in.
23		23	8½	23	11½	24	9½
23	6	24	2⅝	24	5⅝	25	3⅝
24		24	8⅞	24	11⅞	25	9⅞
24	6	25	3	25	6	26	4
25		25	9¼	26	0¼	26	10¼
25	6	26	3⅜	26	6⅜	27	4⅜
26		26	9⅝	27	0⅝	27	10⅝
26	6	27	3¾	27	6¾	28	4¾
27		27	10	28	1	28	11
27	6	28	4⅛	28	7⅛	29	5⅛
28		28	10⅜	29	1⅜	29	11⅜
28	6	29	4½	29	7½	30	5½
29		29	10¾	30	1¾	30	11¾
29	6	30	4⅞	30	7⅞	31	5⅞
30		30	11	31	2	32	0
30	6	31	5¼	31	8¼	32	6¼
31		31	11½	32	2½	33	0½
31	6	32	5⅝	32	8⅝	33	6⅝
32		32	11⅞	33	2⅞	34	0⅞
32	6	33	6	33	9	34	7

Distance between Cap and Sill.		Length of Stick. Shoulder to Shoulder.		Stick with Square Ends.		With two 5″ Tenons.	
ft.	in.	ft.	in.	ft.	in.	ft.	in.
33		34	0¼	34	3¼	35	1¼
33	6	34	6⅜	34	9⅜	35	7⅜
34		35	0½	35	3½	36	1½
34	6	35	6¾	35	9¾	36	7¾
35		36	0⅞	36	3⅞	37	1⅞
35	6	36	7⅛	36	10⅛	37	8⅛
36		37	1¼	37	4¼	38	2¼
36	6	37	7½	37	10½	38	8½
37		38	1⅝	38	4⅝	39	2⅝
37	6	38	7⅞	38	10⅞	39	8⅞
38		39	2	39	5	40	3
38	6	39	8¼	39	11¼	40	9¼
39		40	2⅜	40	5⅜	41	3⅜
39	6	40	8⅝	40	11⅝	41	9⅝
40		41	2¾	41	5¾	42	3¾
40	6	41	9	42	0	42	10
41		42	3⅛	42	6⅛	43	4⅛
41	6	42	9⅜	43	0⅜	43	10⅜
42		43	3½	43	6½	44	4½
42	6	43	9¾	44	0¾	44	10¾

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. 2¼ 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

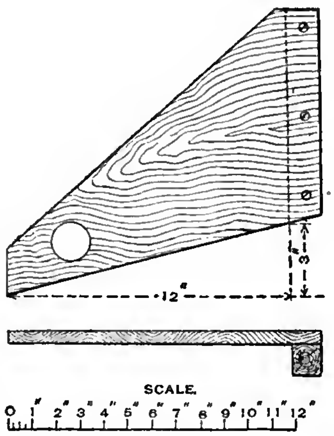


FIG. 45.
BATTER-POST TEMPLATE.

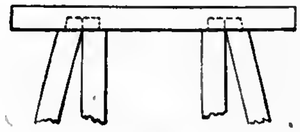


FIG. 46.

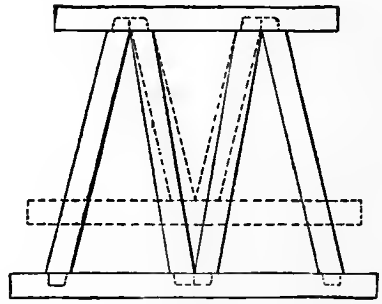


FIG. 47.
ARRANGEMENT OF POSTS.

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

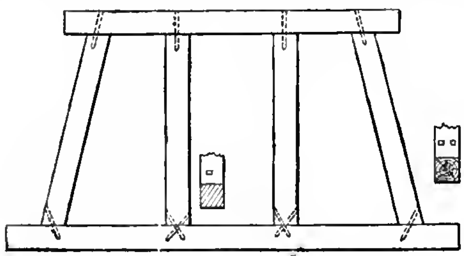


FIG. 48.—ARRANGEMENT OF DRIFT-BOLTS.

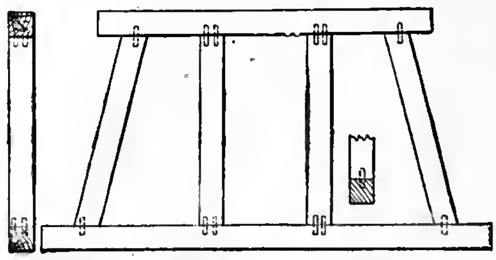


FIG. 49.—ARRANGEMENT OF DOWELS.

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 ¾ 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.

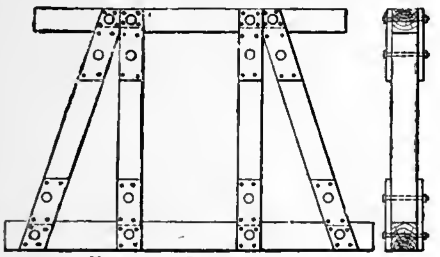


FIG. 50.—PLASTER-JOINTS.

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.†

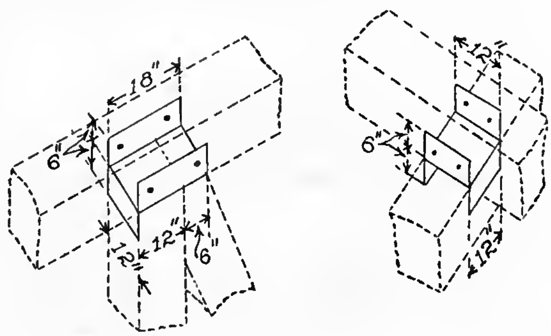


FIG. 51.—IRON JOINT-PLATE, N.Y., L. E. & W. R. R.

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

FIG. 52.

FIG. 53.

BATTER-POST NOTCHES.

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.

That which 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.

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

† *Engineering News*, Nov. 5, 1887.

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

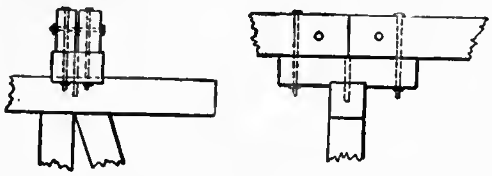


FIG. 54.—DELAWARE & HUDSON CANAL CO.

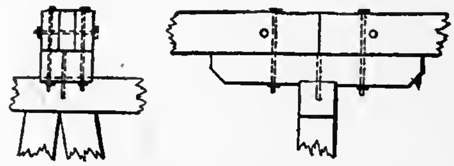


FIG. 55.—CHARLESTON, CINCINNATI & CHICAGO R. R.

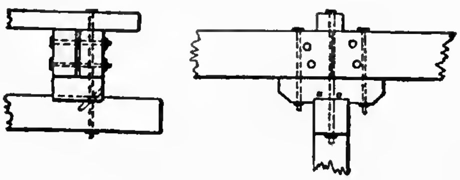


FIG. 56.—LOUISVILLE & NASHVILLE R. R.

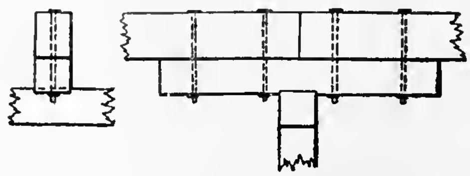


FIG. 57.—SCIOTO VALLEY R. R.

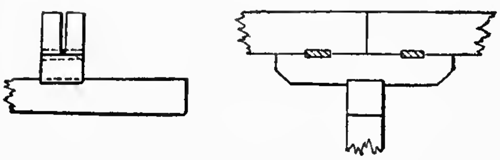


FIG. 58.—OHIO CONNECTING R. R.

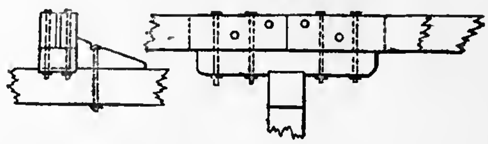


FIG. 59.—NEW YORK, LAKE ERIE & WESTERN R. R.

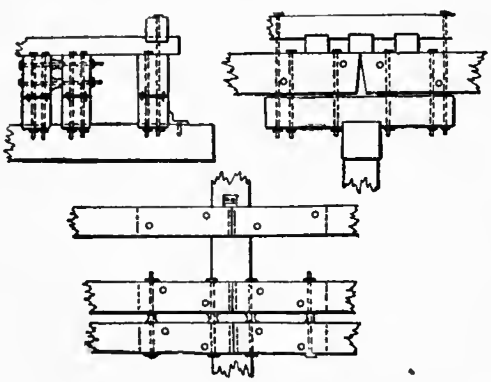


FIG. 60.—CHICAGO & NORTHWESTERN R. R.

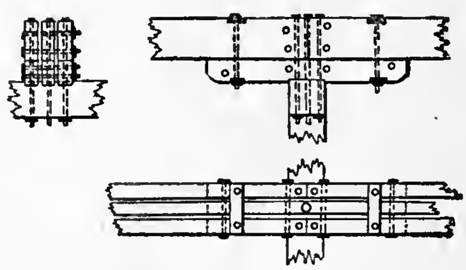


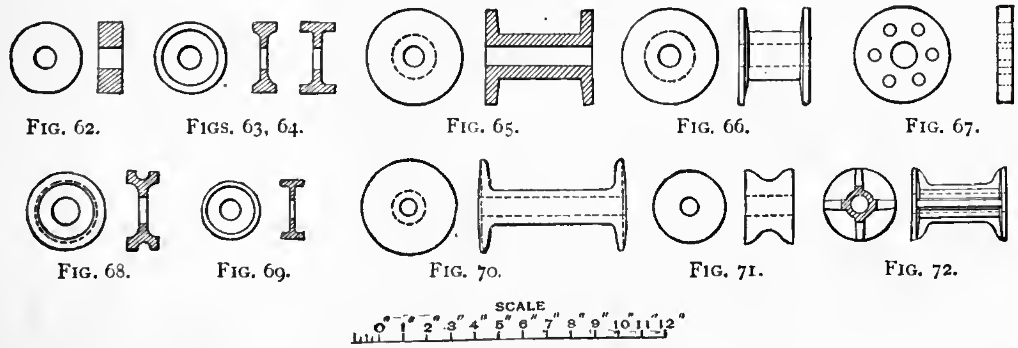
FIG. 61.—NEW YORK, WOODHAVEN & ROCKAWAY R. R.

FIGS 54 TO 61.—DETAILS OF CORBELS.

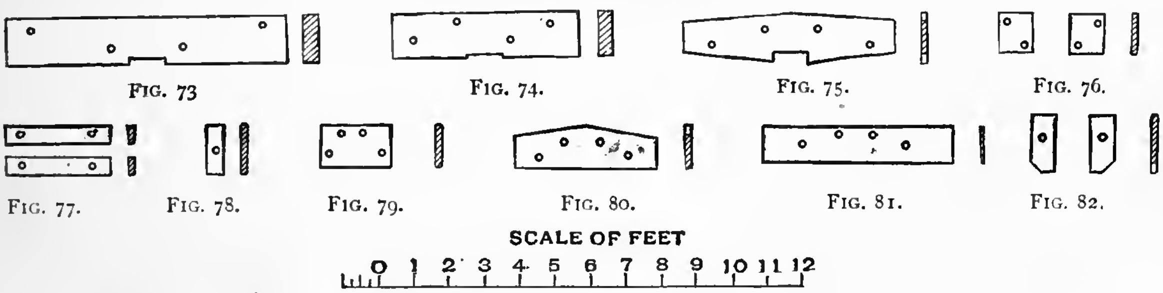
extent they are very useful, but they also have many disadvantages. They give extra support to and consequently strengthen the stringers; but for various reasons, as the stringers should not be made lighter on this account, this does not count for much. They also add stiffness to the stringer-joint,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



FIGS. 62 TO 72.—CAST-IRON SEPARATORS.



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-

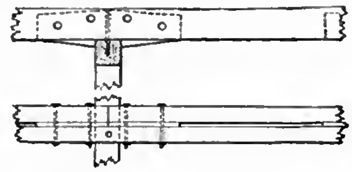


FIG. 83.—PENNSYLVANIA R. R.

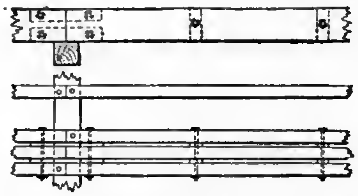


FIG. 84.—WISCONSIN CENTRAL R. R.

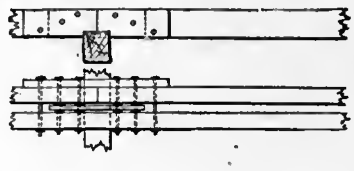


FIG. 85.—N. Y., P. & B. R. R.

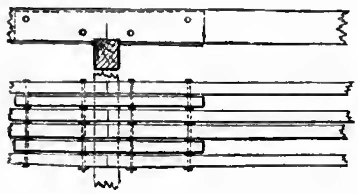


FIG. 86.—B. & M. R. R. IN NEB.

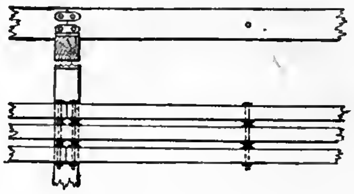


FIG. 87.—A. & P. R. R.

FIG. 88.—GEORGIA PACIFIC RY.

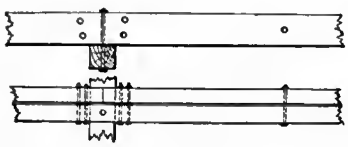


FIG. 89.—C., N. O. & T. P. RY.

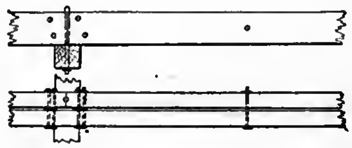


FIG. 90.—CENTRAL R. R. OF GA.

FIG. 91.—GULF, COL. & SANTA FE R.R

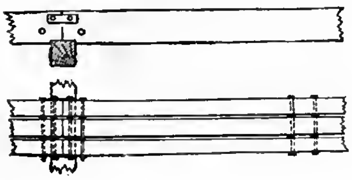


FIG. 92.—D., T. & FT. WORTH R. R.

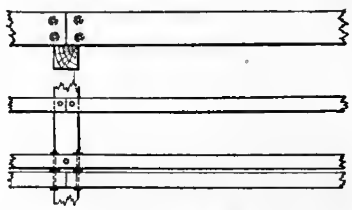


FIG. 93.—CHICAGO & W. MICH. RY.

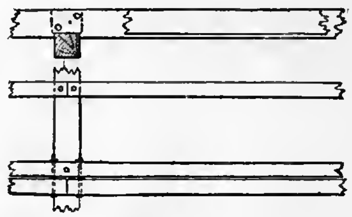


FIG. 94.—CHICAGO & ATLANTIC RY.

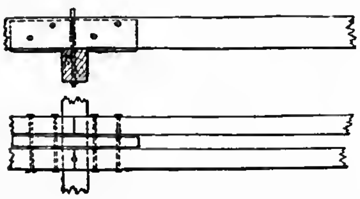


FIG. 95.—B., C. R. & NORTHERN R.R.

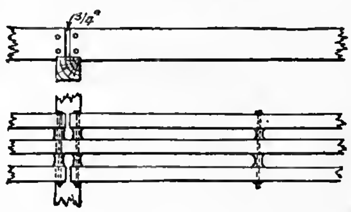


FIG. 96.—SAN F. & N. PACIFIC R. R.

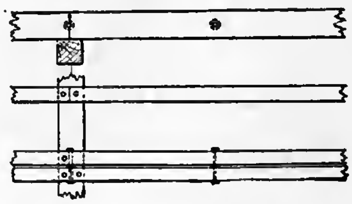


FIG. 97.—ST. P., MIN. & M. RY.

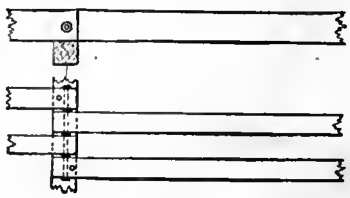


FIG. 98.—OREGON PACIFIC R. R.

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 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. × 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.

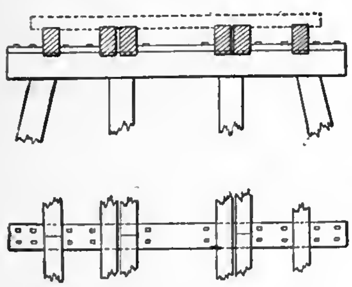


Fig. 99.—Stringer Fastening.

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 ¾ 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 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.

FIG. 100.—TRUSSING STRINGERS.

Ties.—Ties may be of 6-in. × 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 × 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 ¾-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. × 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

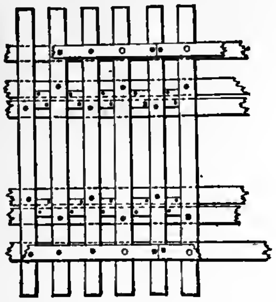


FIG. 101.—N. Y., W. S. & B. R. R.

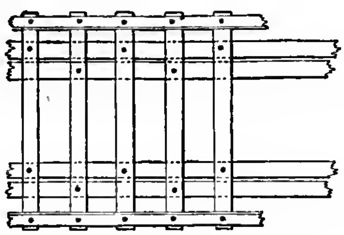


FIG. 102.—PENNSYLVANIA R. R.

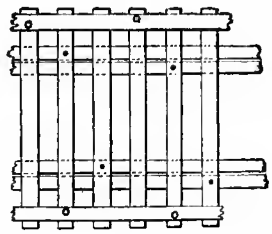


FIG. 103.—TEXAS & PACIFIC RY.

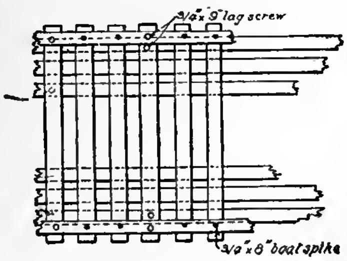


FIG. 104.—T., ST. L. & K. C. R. R.

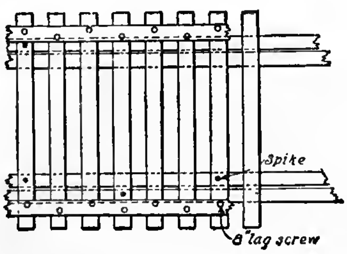


FIG. 105.—K. C., F. S. & M. R. R.

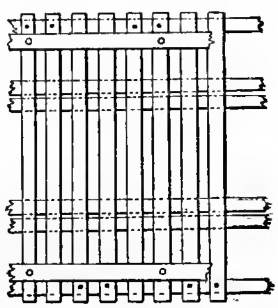


FIG. 106.—ST. P., M. & M. RY.

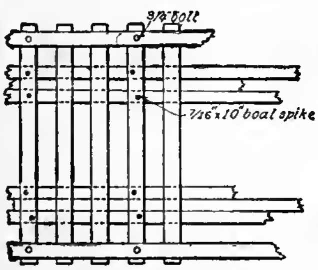


FIG. 107.—C., C. & C. R. R.

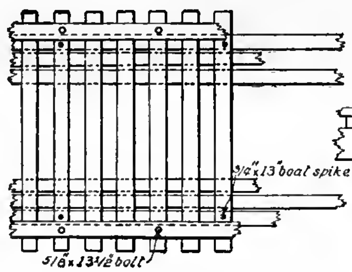


FIG. 108.—M., K. & T. RY.

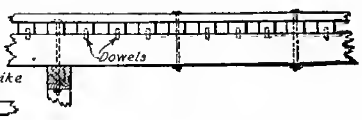


FIG. 109.—L. & N. R. R.

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.

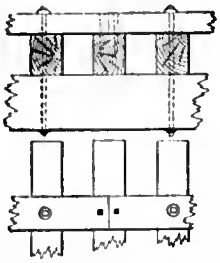


FIG. 110.—N. Y., W. S. & B. R. R.

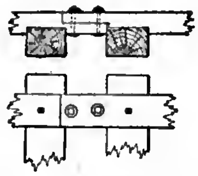


FIG. 111.—PENN. R. R.

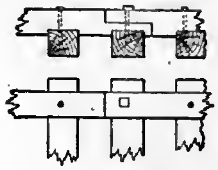


FIG. 112.—T., ST. L. & K. C. R. R

FIG. 113.—C., M. & ST. P. RY.

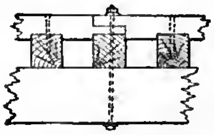


FIG. 114.—R. & D. R. R.

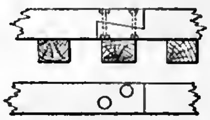


FIG. 115.—N. Y. ELEV. ROADS.

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 ½-in. × 10-in. boat-spike being employed. If lag-screws are used, a ⅝-in. × 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 3½-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.

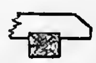


FIG. 116.

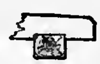


FIG. 117.

GUARD-RAIL ENDS.

Inside guard-rails, either of wood or of a second steel rail, placed about 2½ 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

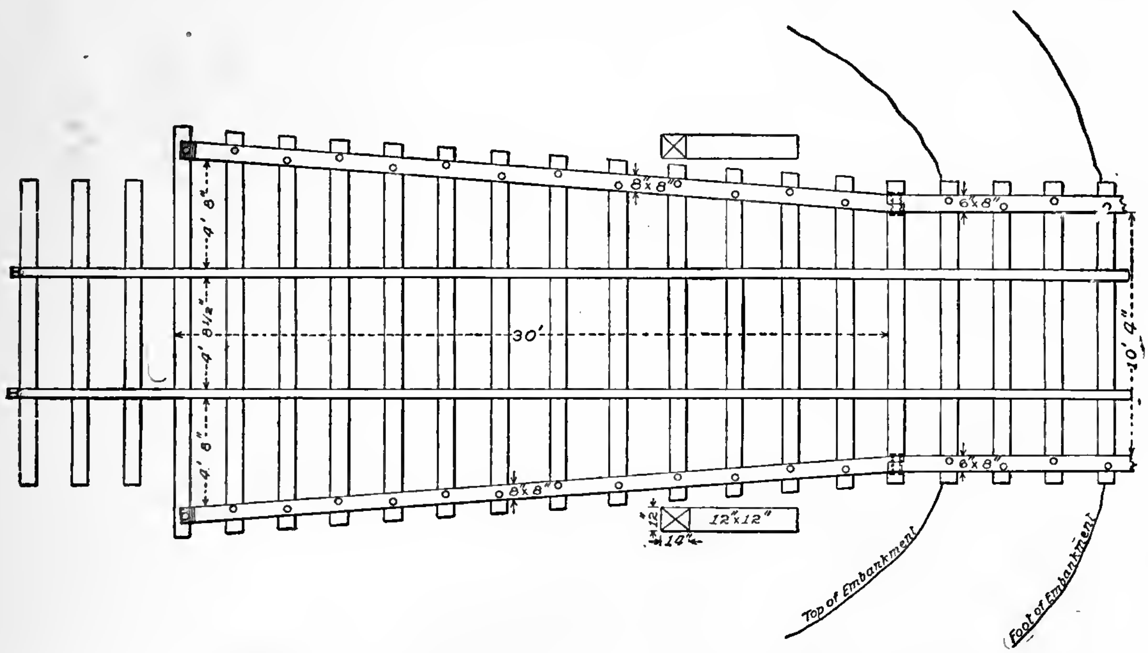


FIG. 118.—EMBANKMENT END OF TRESTLE, SHOWING FLARED GUARD-RAILS AND BUMPING-POSTS.

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).

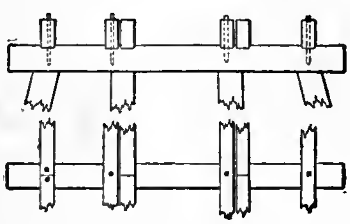


FIG. 119.—DRIFT-BOLTING-DOWN STRINGERS.

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

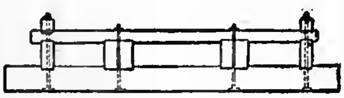


FIG. 121.

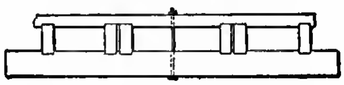


FIG. 122.

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. × 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. × 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. × 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. × 6-in. timbers placed diagonally across, from cap to cap, immediately beneath the stringers and bolted together at the intersection by a ⅝-in. or ¾-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. × 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 40, 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	$6\frac{3}{4}$	$6\frac{7}{8}$	$7\frac{3}{8}$	$7\frac{7}{8}$	8	8
2	5	$6\frac{1}{2}$	$6\frac{3}{4}$	$7\frac{3}{4}$	$8\frac{3}{4}$	9	9
3	4	$6\frac{1}{4}$	$6\frac{3}{4}$	$8\frac{1}{4}$	$9\frac{3}{4}$	10	10
4	4	7	$7\frac{5}{8}$	$9\frac{5}{8}$	$11\frac{5}{8}$	12	12
5	3	$6\frac{1}{2}$	$7\frac{1}{4}$	$9\frac{5}{8}$	12	$12\frac{1}{2}$	$12\frac{1}{2}$
6	3	$7\frac{1}{8}$	8	$10\frac{1}{4}$	$13\frac{1}{2}$	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 shiming 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

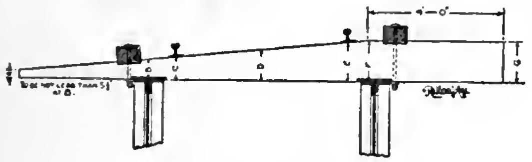


FIG. 123A.—TAPERED TIE.

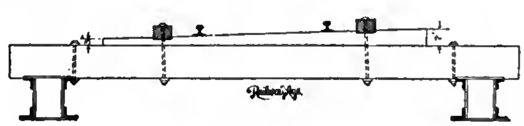


FIG. 124A.—CUSHION TIE.

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° 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

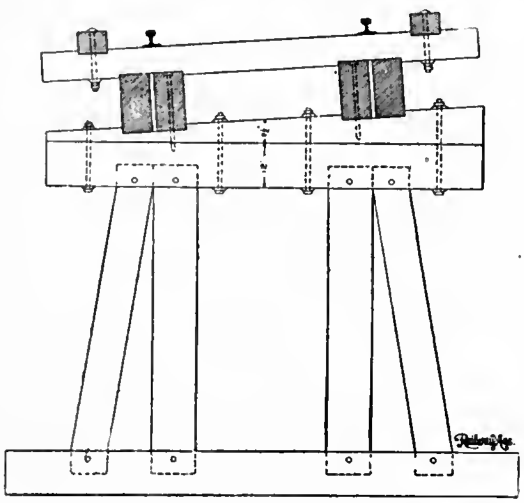


FIG. 124B.—CUSHION CAP.

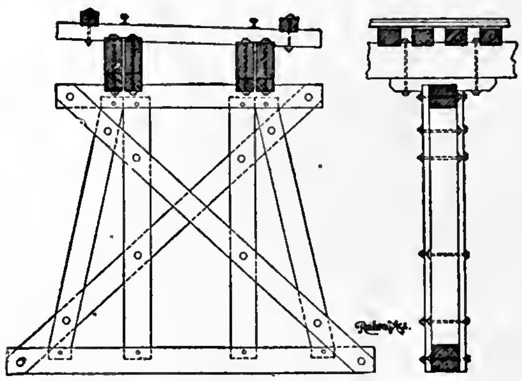


FIG. 125A.—UNEQUAL CORBELS.

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

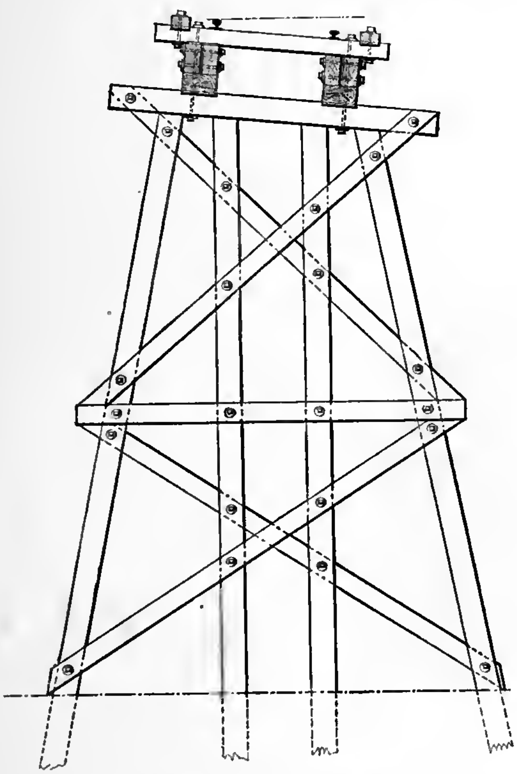


FIG. 125B.—ELEVATION FRAMED IN PILES.

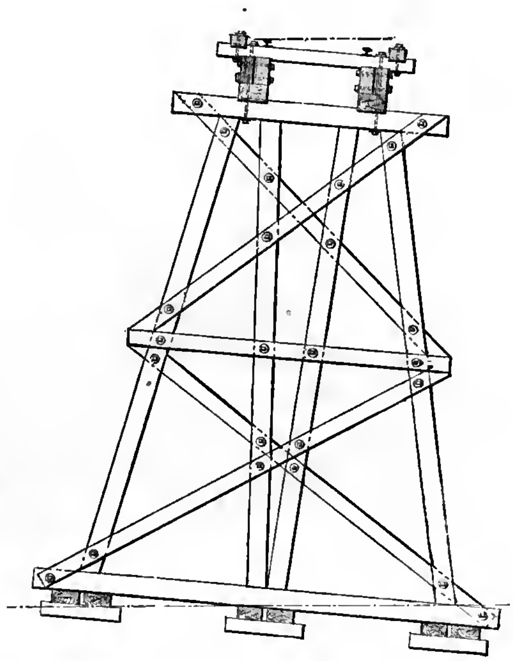


FIG 125C.—TILTED FRAME TRESTLE.

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 55, p. 76.

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

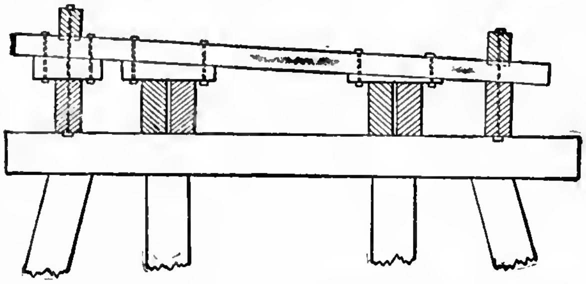


FIG. 123.—BLOCKS UNDER TIE.

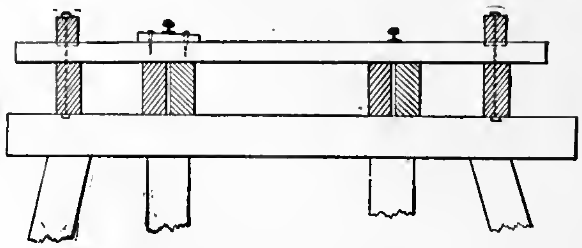


FIG. 124.—BLOCKS ON TIE.

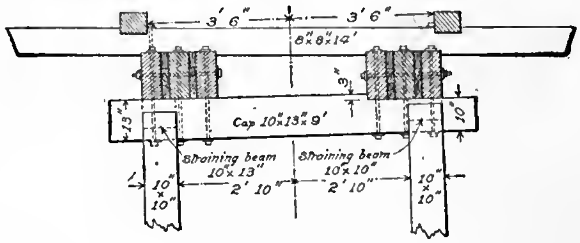


FIG. 125.—NOTCHING CAP.

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 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.

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. CUT SPIKE.

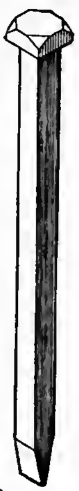


FIG. 127. BOAT-SPIKE.

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 " "	3¼ "	44
16 " "	3½ "	32
20 " "	4 "	24
30 " "	4½ "	18
40 " "	5 "	14
50 " "	5½ "	12
60 " "	6 "	10
8 " fence.	2½ "	50
10 " "	3 "	34
12 " "	3¼ "	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.

Thickness, 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										
5/16	**1010** .1485	**963** .1557	**810** .1851	**605** .2479	**583** .2572		**521** .2879								
7/16			**542** .2767	**503** .2982	**461** .3253	**423** .3546	**402** .3731	**321** .4673							
½					**340** .4117	**312** .4839	**298** .5033	**280** .5357	**261** .5747	**240** .625	**223** .6726				
9/16							**221** .6787	**200** .75	**190** .7881	**180** .8333	**170** .8823	**160** .9375	**150** 1.0000	**140** 1.0714	**130** 1.1538
⅝											**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. 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.

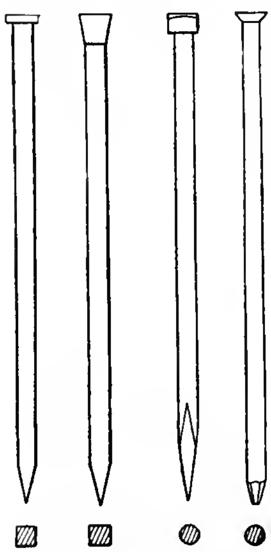


FIG. 128.—DRIFT-BOLTS.

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 $\frac{11}{16}$ hole is greater than in either a $\frac{12}{16}$ or in a $\frac{13}{16}$ hole, the resistance in the $\frac{12}{16}$ hole being 98 per cent, in the $\frac{13}{16}$ 90 per cent, of that in the $\frac{11}{16}$ hole. On the other hand, another series of 35 experiments makes the resistance in a $\frac{12}{16}$ hole greater than in a $\frac{13}{16}$ or a $\frac{14}{16}$, 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 $\frac{10}{16}$ hole is about one quarter greater than in a $\frac{9}{16}$ or an $\frac{11}{16}$ hole. For a 1-in. square bolt, the holding power in a $\frac{14}{16}$ hole is only a trifle greater than in a $\frac{13}{16}$, and about 20 per cent greater than in a $\frac{15}{16}$ hole, as deduced from 20 to 40 experiments for each size of hole.

The holding power of a 1-in. square bolt in a $\frac{14}{16}$ hole was practically the same as for a 1-in. round rod in an $\frac{11}{16}$-in. hole. There is 25 per cent more metal in the square drift-bolt, while more labor is required to bore a $\frac{14}{16}$-in. hole than an $\frac{11}{16}$-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 $\frac{12}{16}$-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 hemlock seem to show that the resistance is practically the same as white pine.

One-inch round screw-bolts were screwed into $\frac{13}{16}$, $\frac{14}{16}$, and $\frac{15}{16}$-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° 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 15/16-in. hole in first quality Georgia pine, and a resistance of 15,000 lbs. in a 14/16-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. Tscharner 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 15/16-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 15/16-in. hole be designated as 1, the holding power in a 14/16-in. hole is 1.69; in a 13/16-in. hole, 2.13; and in a 12/16-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 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, 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.	3/4 inch	diam. round,	0.1240 lb.
1 "	diam. round,	0.2204 "	5/8 "	square,	0.1096 "
7/8 "	square,	0.2149 "	5/8 "	diam. round,	0.0860 "
7/8 "	diam. round,	0.1687 "	1/2 "	square,	0.0701 "
3/4 "	square,	0.1579 "	1/2 "	diam. round,	0.0551 "

Bolts.—Bolts for holding the stringer-pieces together, fastening on the braces, guard-rails, etc., are made of 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).

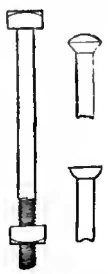


FIG. 129. BOLTS.

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 3½ 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.

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.				
	½	⅝	¾	⅞	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:

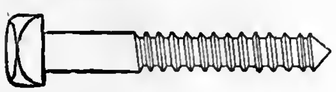


FIG. 130.—LAG-SCREW.

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.
$\frac{1}{2}$ inch	$1\frac{3}{8}$ inches	$\frac{9}{16}$ inch	No. 12	4500	.0333
$\frac{5}{8}$ "	$1\frac{3}{4}$ "	$\frac{11}{16}$ "	" 10	2500	.06
$\frac{3}{4}$ "	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		1		$\frac{7}{8}$		1.7
" 63	3	$\frac{3}{8}$	1	$\frac{1}{4}$	$\frac{7}{8}$		1.03
" 64	3	$\frac{3}{8}$	$1\frac{1}{2}$	$\frac{3}{8}$	$\frac{7}{8}$		1.5
" 65	$3\frac{3}{16}$	$\frac{1}{2}$	$1\frac{1}{4}$	$\frac{1}{4}$	$1\frac{1}{4}$	$2\frac{7}{16}$	
" 66	$2\frac{1}{2}$	$\frac{1}{4}$	1	$\frac{3}{16}$	$\frac{3}{4}$		0.6
" 67	4		$\frac{3}{8}$	$4\frac{1}{2}$	$\frac{7}{8}$	2	5.5
" 68	4		$\frac{1}{4}$	3	$\frac{7}{8}$	2	3.25
" 69*	4		$\frac{5}{8}$		1		1.7
" 70	4		$\frac{3}{8}$	6	$\frac{7}{8}$	$1\frac{3}{8}$	3.75
" 71	3		2	2	$\frac{7}{8}$	2	2.5
" 72	3		$\frac{1}{4}$	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

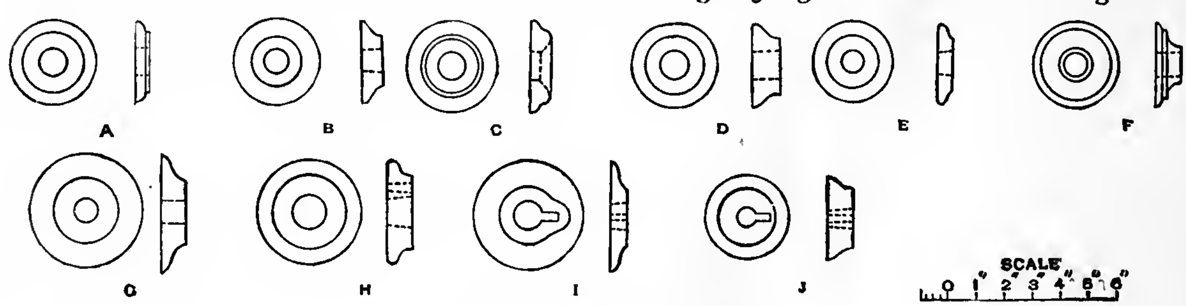


Fig. 131.—Cast-iron Washers.

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	2 1/4	1	1/2	
B	3	1 3/4	7/8	3/4	
C	3 1/4	2 1/4	1	3/4	
D	3	2	1	1	
E	2 3/4	1 3/4	7/8	1/2	
F	3	1 1/8	7/8	3/4	
G	4 3/8	2 3/8	7/8	7/8	
H	3	2	3/4	3/4	
I	4	2	1	5/8	
J	3 7/8	2 1/2	1 3/16	3/4	
Similar to B	3 1/2	2	1	3/4	1.25
" " G	4 1/4	2	1	3/4	1.375

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.
1/2	1/4	No. 18	3/16	80.000
5/8	5/16	" 16	1/4	34.285
3/4	5/16	" 16	1/4	22.000
7/8	3/8	" 16	5/16	18.500
1	7/16	" 14	3/8	10.550
1 1/4	1/2	" 14	7/16	7.500
1 3/8	9/16	" 12	1/2	4.500
1 1/2	5/8	" 12	9/16	3.850
1 3/4	11/16	" 10	5/8	2.500
2	13/16	" 10	3/4	1.600
2 1/4	15/16	" 9	7/8	1.300
2 1/2	1 1/16	" 9	1	950
2 3/4	1 1/4	" 9	1 1/8	700
3	1 3/8	" 9	1 1/4	550
3 1/2	1 1/2	" 9	1 3/8	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.

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. × 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 centre line of the road, and placed quite close together over the centre 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 framed 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.

Rerailing Guards.—All extensive and all high trestles should be protected by a rerailing guard, and it would be far better if *all* the trestles were, without regard to their size.

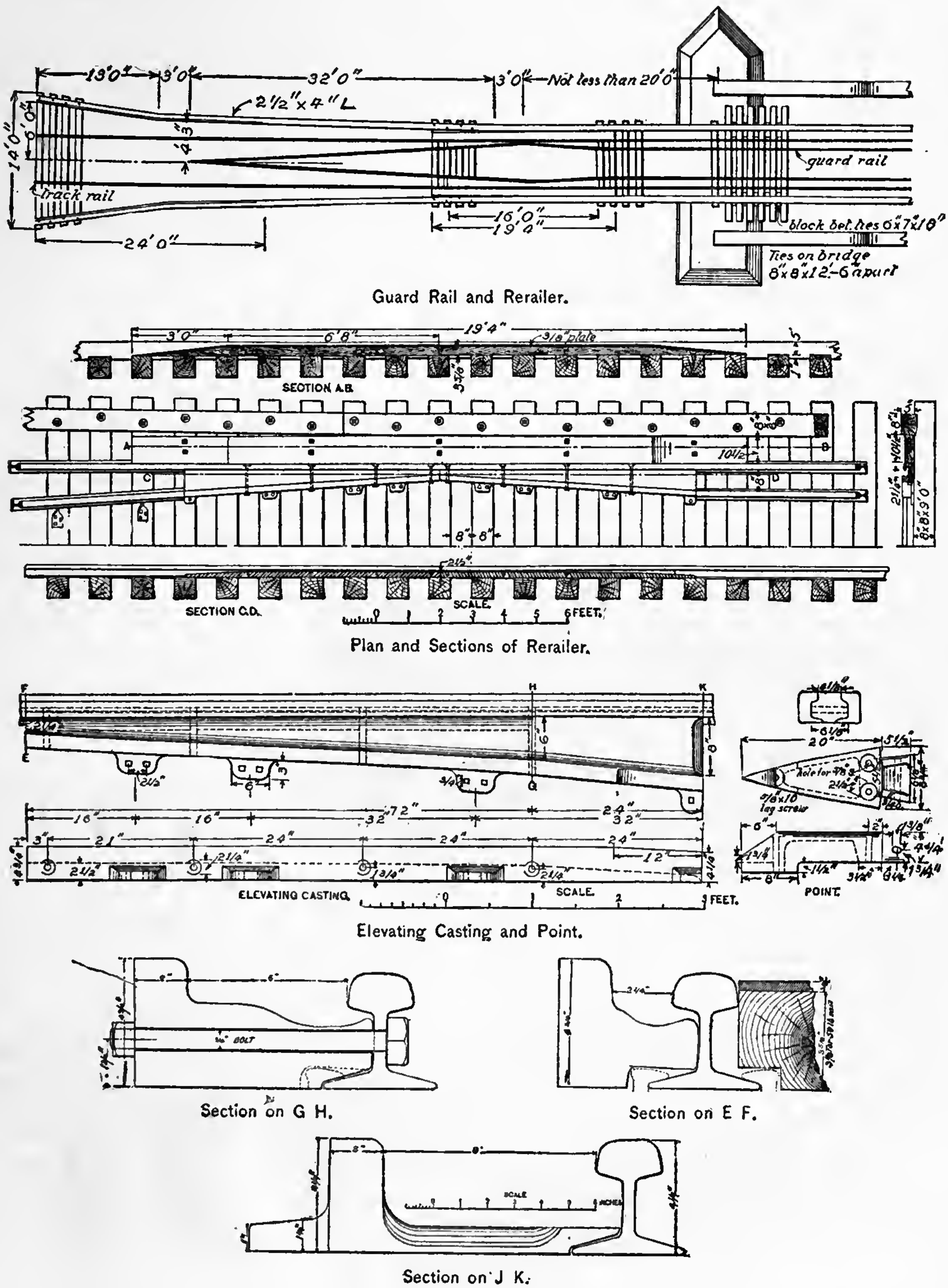


Fig. 132.—Latimer Bridge-Guard.

If this cannot be done, then collision-posts at least should be erected to guard them. Even where rerailing guards are used it is an excellent plan to supplement them by collision-posts 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.

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.

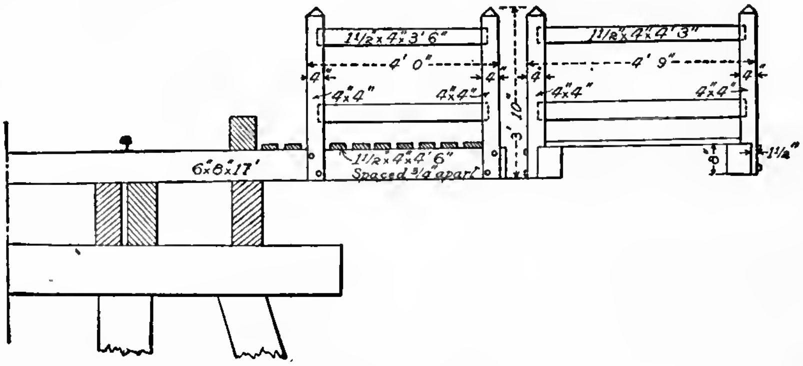


FIG. 133.—REFUGE-BAY.

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 endurable. 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. 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.

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 car 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:

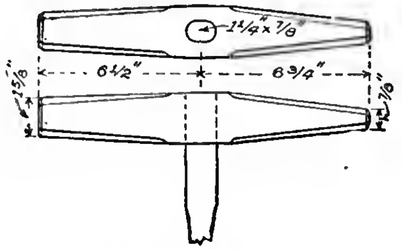


FIG. 134.—SPIKE-MAUL.

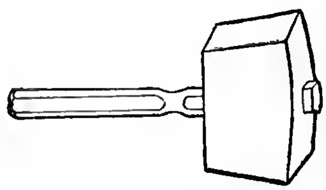


FIG. 135.—MALLET.

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.

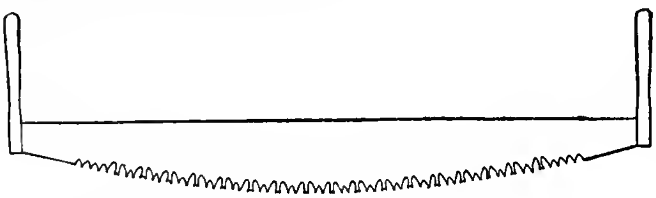


FIG. 136.—CROSS-CUT SAW.

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.

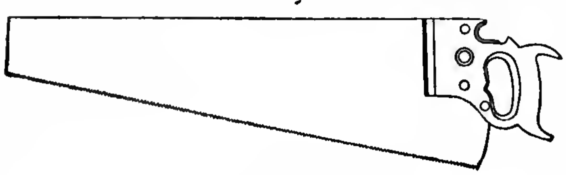


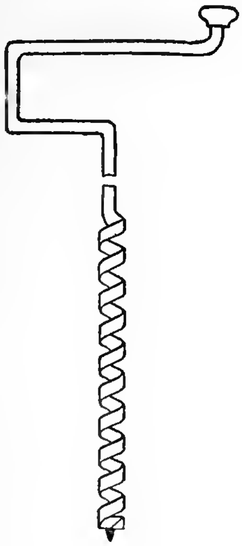
FIG. 137.—HAND-SAW.

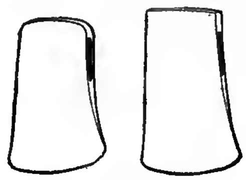
Hand cross-cut saws are also required (Fig. 137). These should be of the heavier patterns, and the blade at least two feet long. If the handle is bound with brass and at right angles to the back, so that the saw may be used as a square, it will be found to be very convenient. These saws are used for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





FIGS. 139, 140.—AXES.

FIG. 141.—BROADAXE.

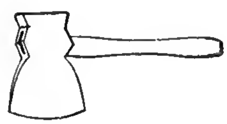


FIG. 138.—SHIP AUGER.

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 ½ in. thick by 2½ 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

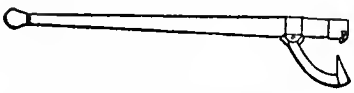


FIG. 145.—CANT-HOOK.

FIG. 146.—PEAVEY.

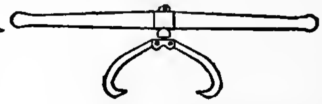


FIG. 147.—LUG-HOOK.

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.

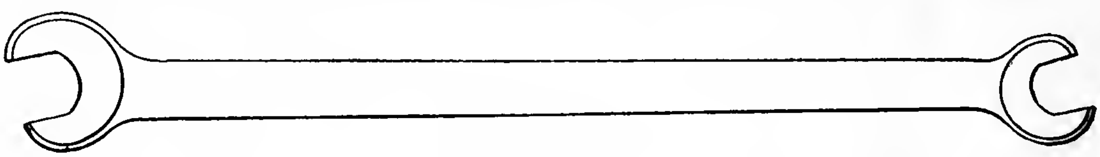


FIG. 148.—WRENCH.

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. 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. This subject of timber preservation, however, will not be treated of in this work. Those who may wish to know more about the subject are referred to the various books and papers on the subject.*

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.

STANDARD SPECIFICATIONS FOR WOODEN TRESTLES.†

CLEARING.

Before commmencing 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.

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

† 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. Co., 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,—*Eng. News.*
French Broad Valley R. R., H. M. Ramseur, Chief Engineer.

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, wanes, 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.

PILES.

Piles shall be of good live ———

They will be either round of 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.

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.

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* **Alternative methods of treatment.**

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 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 carbolic 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 { square / countersunk / round button } heads,

{ with a thickness not less than the diameter of the bolt, and the size of its square not less than twice the diameter of the bolt.
with a thickness at the centre of not less than three quarters of the diameter of the bolt, and an extreme diameter of not less than two and one half times the diameter of the bolt.
countersunk on the under side so as to fit into a cup-washer, with an extreme diameter of not less than twice the diameter of the bolt.

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 (4½) 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.

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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.

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.

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.
WM. 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.

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, [illegible] feet.					
	2	Cap.	6″ × 12″ × 14′ 0″	168	
	2	Plumb-posts.	12″ × 12″ × 8′ 0″	192	
	2	Batter-posts.	12″ × 12″ × 9′ 0	216	
	1	Sill.	12″ × 12″ × 12′ 4″	148	
	8	Blocks—Mud-sills.	12″ × 12″ × 2′ 6″	240	964
2—Height, 13 feet.					
	2	Cap.	6″ × 12″ × 14′ 0″	168	
	2	Plumb-posts.	12″ × 12″ × 12′ 0″	288	
	2	Batter-posts.	12″ × 12″ × 13′ 2″	316	
	1	Sill.	12″ × 12″ × 14′ 2″	170	
	2	Sway-braces.	3″ × 10″ × 16′ 6″	83	
	8	Blocks—Mud-sills.	12″ × 12″ × 2′ 6″	240	1265
3—Height, 10 feet.					
	2	Cap.	6″ × 12″ × 14′ 0″	168	
	2	Plumb-posts.	12″ × 12″ × 9′ 0″	216	
	2	Batter-posts.	12″ × 12″ × 10′ 1″	242	
	1	Sill.	12″ × 12″ × 12′ 8″	152	
	2	Sway-braces.	3″ × 10″ × 14′ 0″	70	
	8	Blocks—Mud-sills.	12″ × 12″ × 2′ 6″	240	1088
Floor System and Miscellaneous Parts:					
	8	Bank-sills.	12″ × 12″ × 12′ 0″	1152	
	10	Stringers and Jack-stringers.	8″ × 16″ × 25′ 0″	2667	
	4	Stringers.	8″ × 16″ × 12′ 6″	534	
	51	Ties.	6″ × 8″ × 12′ 0″	2448	
	9	Guard-rails.	6″ × 8″ × 20′ 0″	720	7521
Grand Total, ...					10,838

BILL OF IRON.

No. of Pieces.	Name.	Use.	Size.	Weight.
		Wrought Iron.		
24	Drift-bolts.	Stringers to Bank-sills.	¾″ sq. × 24″	
26	Drift-bolts.	Stringers to Caps.	¾″ sq. × 24″	
6	Drift-bolts.	Sills to Mud-sills.	¾″ sq. × 20″	
102	Boat-spikes.	Ties to Stringers.	½″ × 12″	
150	Boat-spikes.	Guard-rails to Ties.	½″ × 12″	
26	Bolts.	Guard-rails to Jack-stringers.	¾″ × 31½″	
12	Bolts.	Caps to Posts.	¾″ × 22″	
16	Bolts.	Sway-bracing.	¾″ × 20″	
32	Bolts.	Packing for Stringers.	¾″ × 22″	
Total,				
		Cast Iron.		
172	Washers.	Under heads and nuts of Bolts.	1″ × 3″	
32	Separators.	Between Stringers.	2″ × 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″ × 12″		Sway-braces 3″ × 10″		Intermediate Caps 3″ × 10″		Feet B. M.		Height from surface of Ground to top of Cap.		Caps 6″ × 12		Sway-braces 3″ × 10″		Intermediate Caps. 3″ × 10″		Feet B. M.
Ft.	Ins.	Pcs.	Length Ft. Ins.	Pcs.	Length Ft. Ins.	Pcs.	Length Ft. Ins.			Ft.	Ins.	Pcs.	Length Ft. Ins.	Pcs.	Length Ft. Ins.	Pcs.	Length 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			251	
7	6									10	6								
										11	0								

FRAMED.

Height from bottom of Sill to top of Cap.		Caps 6″ × 12″			Plumb-posts 12″ × 12″			Batter-posts 12″ × 12″			Sill 12″ × 12″			Sway-braces 3″ × 10″			Intermediate Caps 3″ × 10″			Mud-sills 12″ × 12″			Feet B. M.
Ft.	Ins.	Pcs.	Length. Ft.	Length. Ins.	Pcs.	Length. Ft.	Length. Ins.	Pcs.	Length. Ft.	Length. Ins.	Pcs.	Length. Ft.	Length. Ins.	Pcs.	Length. Ft.	Length. Ins.	Pcs.	Length. Ft.	Length. Ins.	Pcs.	Length. Ft.	Length. Ins.	
5	0	2	14	0	2	4	6	2	4	6	1	16	0							8	2	6	816
5	6																						
6	0																						
6	6																						
7	0																						
7	6																						
8	0																						
8	6																						
9	0																						
9	6																						
10	0																						
10	6																						
11	0																						

General.—Each trestle will require:

8 Bank-sills 12 in. × 12 in. × 12 ft................	1152 ft. B. M.
4 Dump-boards 4 in. × 8 in. × 11 ft. 4 in..........	121 " " "
Stringer-pieces 8 in. × 16 in. × 25 ft., contain each.	267 " " "
Ties 6 in. × 8 in. × 12 ft. " " ...	48 " " "
Guard-rails 6 in. × 8 in. × 20 ft. " " ...	80 " " "

Many other devices for furnishing aid in making out bills of material have been invented, and are used to a greater or lesser extent in the various offices throughout the country. One of the most notable of those which have come to the Author's notice, and of which the originator is not known, is that of drawing a bent to a large scale,—say three-quarters of an inch to the foot, on paper that will not vary much with changes in the atmosphere. The sills for heights varying by regular amounts—six inches is very good—are then drawn in. When the length of any part, for any height of bent, is needed, it can readily be scaled directly from the drawing.

Construction records in detail are, of course, made out each month for all of the trestle-work built since the previous estimate was taken up. The thoroughness and completeness of these records vary considerably on different roads.

Following are some forms of construction records as kept on the Norfolk & Western Railroad. These records are very complete, and are to be recommended.

Trestle No........ ....18..

Section No........ ....*Contractor.*

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.	Sub-grade to top of Masonry.	Ground.			Top of Masonry.				Bottom of Masonry.									
				Left.	Centre.	Right.	Left.	Centre.	Right.	Distance from centre.	Left.	Centre.	Right.	Distance from centre.	Left.	Centre.	Right.			

.... *Resident Engineer.*

This sheet is $13\frac{1}{2}$ in. long by $8\frac{1}{2}$ 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 $3\frac{3}{8}$ in. by $8\frac{1}{2}$ in.

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. Length.	Dimensions. Sizes.	Feet B. M.
	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.

TRESTLE ITEM SHEET.

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.
Certified by.................................... ....*Engineer.*			TOTAL AMOUNT.		

On one half of the remaining half of the back is the following indorsement for filing purposes:

NORFOLK & WESTERN R. R. CO. BRIDGES, TRESTLE AND TIMBER ESTIMATE. *Estimate No*.............................. ....18 ....*Contractor.*		
	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.

A heading suitable for the inspector's reports and records is as follows:

NORTH AMERICAN RAILROAD COMPANY.

MAINTENANCE OF WAY DEPARTMENT.

Bridges No. — to No. —

TRESTLE INSPECTION.

Bridge Number.	Date, 18–	Number of Bent.	Class.	Piles.				Foundation.		Story.	Sill and Intermediate Cap.	Posts.				Cap.	Stringers.						Ties.							Guard-rails.		Sway-braces.		Longitudinal Bracing.				Iron.	Condition of Fire Protection.	Remarks.
				1	2	3	4	Class.	Condition.			1	2	3	4		1	2	3	4	5	6	1 / 8	2 / 9	3 / 10	4 / 11	5 / 12	6 / 13	7 / 14	1	2	1	2	1	2	3	4			

Symbols.—O.K. = good for more than one year.
D = dangerous, and must be removed at once.
6 = must be removed within six months.
S = must be removed within one year.
X = replaced since last report.

I hereby certify that I personally made the above examinations and reports on the dates named, and that they are true and correct in every particular, to the best of my knowledge and belief. (Signed)

—— ——, *Inspector*.

———— 18—

Examined and approved,

—— ——, *Division Engineer*.

—— ——, *Division Superintendent*.

———— 18—

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 semicircle 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 ¼ 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. × 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.

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† *Railroad Gazette*, Sept. 21, 1883.

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.

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."

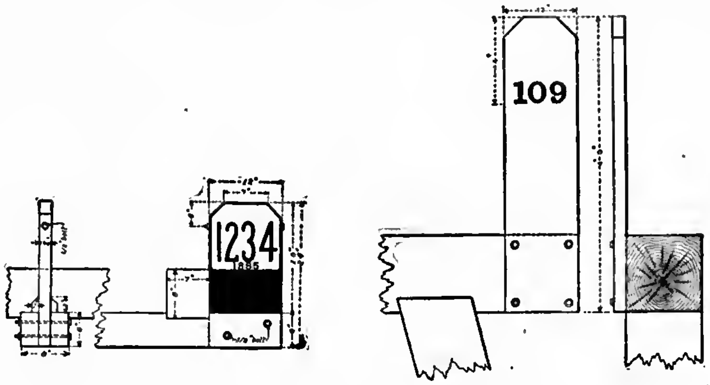
As to the wisdom of adopting this premium system on all roads, it would be difficult to determine. Whether, in many instances, it might not lead to the slighting of work, where it would be difficult or impossible to discover it, is a very serious question.

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.

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.

* Maj. C. S. Gadsden, Supt. Chas. & Sav. R.R., on "Care of Trestles;" *Railroad Gazette*, 1888, p. 652.

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.

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 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.

* T. C. Clarke, in *Scribner's Magazine* for June, 1888, p. 657. † 1887.

CHAPTER XII.

TIMBER.

YELLOW PINE — SPECIES — MARKET NAMES — FIELD NAMES — CHARACTERISTICS — ADAPTATIONS—MECHANICAL PROPERTIES—BLED TIMBER—WASHINGTON FIR—OTHER TIMBERS.

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.

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* Bulletin No. 8, Forestry Division U. S. Depart. Agriculture.

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.	*Pinus palustris* Miller. Syn. *P. australis* Michx.	*Pinus cubensis* Griesebach. Syn *Pinus Tæda* var. *heterophylla* Ell. *P. Elliotii* Engelm. *P. cubensis* var. *terthrocarpa* Wright.	*Pinus echinata* Miller. Syn. *Pinus mitis* Michx. *Pinus virginiana* var. *echinata* Du Roi. *P. Tæda* var. *variabilis* Aiton. *P. variabilis* Lamb. *P. rigida* Porcher.	*Pinus Tæda* Linn. Syn. *Pinus Tæda* var. *tenuifolia* 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 (No. 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 manufactured 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 know 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.	*Pinus palustris* Miller.	*Pinus cubensis* Griseb.	*Pinus echinata* Miller.	*Pinus Tæda* 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; $1\frac{5}{8}$ to 4 inches long; commonly $2\frac{1}{2}$ to 4 inches.	3 in a bundle; 5 to 8 inches long.
Cones (open) ..	6 to 9 inches long; $4\frac{1}{2}$ to 5 inches in diameter.	4 to $6\frac{1}{2}$ (usually 4 to 5) inches long; 3 to $4\frac{3}{4}$ inches in diameter.	$1\frac{1}{2}$ to 2 inches long; $1\frac{1}{2}$ to $1\frac{3}{4}$ inches in diameter.	$2\frac{1}{2}$ to $4\frac{1}{2}$ inches long; $1\frac{3}{4}$ to 3 inches in diameter.
Scales..........	$\frac{5}{8}$ to 1 inch broad; tips much wrinkled, light chestnut brown, gray with age.	$\frac{11}{16}$ to $\frac{7}{8}$ inch broad; tips wrinkled; deep russet-brown; shiny.	$\frac{5}{16}$ to $\frac{3}{8}$ (exceptionally about $\frac{1}{2}$) inch broad; tips light yellow-brown.	$\frac{3}{8}$ to $\frac{3}{4}$ inch broad; tips smooth; dull yellow-brown.
Prickles	Very short, delicate, incurved.	Very short; straight; declined.	Exceedingly short ($\frac{1}{10}$ inch), delicate, straight, declined.	Short; stout at base.
Buds.....	$\frac{3}{4}$ inch long; $\frac{1}{2}$ inch in diameter; silver-white.	About $\frac{1}{2}$ inch long; $\frac{1}{4}$ inch in diameter; brownish.	$\frac{3}{8}$ to $\frac{1}{2}$ inch long; about $\frac{1}{8}$ inch in diameter; brownish.	$\frac{1}{2}$ tn $\frac{3}{4}$ inch long; $\frac{1}{4}$ 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 $2\frac{1}{2}$ 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 (*Pinus palustris* Miller).	Cuban pine (*Pinus cubensis* Griseb.).	Short-leaf pine. (*Pinus echinata* Miller).	Loblolly pine (*Pinus Tæda* 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	48	47	40	34
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, $\frac{1}{3}$ 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 Endwise.	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 "	0.484–0.907	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" × 4" Beams from same Log. All Reduced to 15% Moisture.

	Large Beams.			4 inches × 4 inches × 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. $E = \frac{Wl^3}{4\Delta bh^3}$.	Modulus of Rupture per sq. in. $f = \frac{3Wl}{2bh^2}$.	Modulus of Strength at Elastic Limit per sq. in. $f' = \frac{3W'l}{2bh^2}$.	Modulus of Elasticity. $E = \frac{Wl^3}{4\Delta bh^3}$.
3 sticks 4 in. × 6 in. × 116 to 160 in.	11,363	9,453	2,330,947	11,202	8,025	1,731,362
17 " 4 in. × 8 in. × 106 to 164 in.	13,130	10,289	2,456,441	11,594	8,715	1,779,911
1 " 6 in. × 12 in. × 136 in.	9,915	8,710	2,105,680	12,326	8,203	1,821,280
2 " 7 in. × 14 in. × 140 in.	10,025	8,505	1,948,400	11,416	8,221	1,790,138
1 " 8 in. × 16 in. × 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	162,300	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.			
$6\frac{1}{8} \times 15\frac{3}{4}$	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 " "
$8\frac{1}{8} \times 16$	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	
$8\frac{3}{4} \times 16$	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

* *Engineering News*, Aug. 10, 1893, p. 118.

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, $R = \frac{bh^2}{6}$, where b is the breadth 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

$$M = \frac{Tbh^2}{72}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

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*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.

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

$$M = \frac{Wl}{8} = \frac{wl^2}{8} \quad \ldots \ldots \ldots \ldots \quad (2)$$

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),

$$W = \frac{Tbh^2}{9l}, \quad \ldots \ldots \ldots \ldots \quad (3)$$

and

$$bh^2 = \frac{9Wl}{T}, \quad \ldots \ldots \ldots \ldots \quad (4)$$

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.

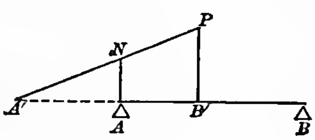

FIG. 151.

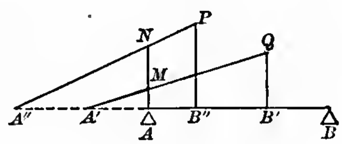

FIG. 152.

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

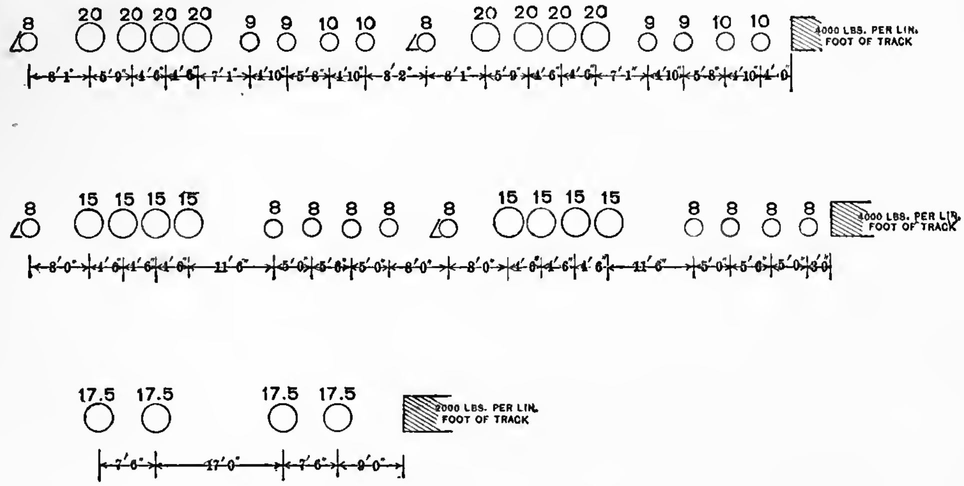

FIG. 153.

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 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

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.

$M = \frac{Tbh^2}{72}$ = moment in foot-tons.

Bearing value per lineal foot in tons = 12 in. $\times b \times B$.

$B = \frac{500}{2000}$ for long-leaf yellow pine, $\frac{1000}{2000}$ for white oak, $\frac{300}{2000}$ 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

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. × 16-in. Georgia pine stick is 17.1 foot-tons, which is ample. We may then use four Georgia pine sticks, each 8 in. × 16 in., under each rail. To save material we might, however, use two sticks 8 in. × 16 in. and two sticks 7 in. × 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. × 16-in. Georgia pine and two sticks of 7-in. × 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 2½ in., the length of bearing required. As the cap on the bent is usually a 12-in. × 12-in. stick, these stringers would in practice have a bearing of 6 in. against 2½ 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 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. 42), because the slightest deflection in the stringer brings all the weight right on the end of the corbel block, and for many other reasons.

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 ½ or ⅓ 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.

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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 ⅛ of the square of the span (in feet).

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. 46.)

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.

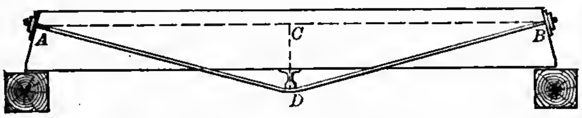


FIG. 154.

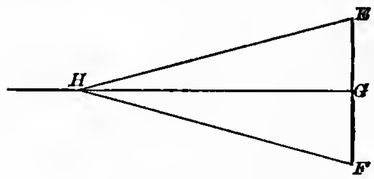


FIG. 155.

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-leafed 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″ × 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″ × 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″ × 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″ × 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″ × 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.

	Size of I Beam.		Size of Georgia Pine Beam.	
Safe Moment.	Depth.	Weight per Foot.	Depth.	Breadth.
68.6	24″	80	18″ 16	25″.4 32 .2
57.9	20	80	18 16	21 .4 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 10	8 .2 11 .8
7.5	9	21	12 10	6 .3 9 .0
5.8	8	18	12 8	4 .8 10 .9
4.3	7	15	12 8	3 .6 8 .1
3.1	6	13	10 8	3 .7 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

$$Q = \frac{1000}{1 + \frac{1}{550}\left(\frac{l}{d}\right)^2}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

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

$$Q = \frac{1000}{1 + \frac{1}{275}\left(\frac{l}{d}\right)^2}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

and for pillars having one flat and one hinged end use the formula

$$Q = \frac{1000}{1 + \frac{1\frac{1}{2}}{550}\left(\frac{l}{d}\right)^2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

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. inch
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″ × 12″.	12′ × 12″.	12″ × 10″.	10″ × 10″.	10″ × 8″.	8″ × 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

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″ × 12″ post of white pine will carry (.625 × 35.14 =) 21.9 tons, which is ample. We must therefore use four posts in this bent, each 12″ × 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. 124, 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

$$W = \frac{2p}{b}(2G + H), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

giving the necessary dead weight to resist overturning; and

$$b = \frac{2p}{W}(2G + H), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

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

$$W + L = \frac{2Z}{b}(2p + 10) + \frac{2p}{b}(2G + H), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

giving the necessary total weight, both dead and live, to resist overturning; and

$$b = \frac{2Z}{W + L}(2p + 10) + \frac{2p}{W + L}(2G + H), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

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

$$h = np, \qquad (12)$$

and it may be easily proved that equations (8), (9), (10), and (11) have the following general forms, respectively,

$$W = \frac{2p}{b}[nG + (n-1)H + (n-2)I + \ldots n \text{ terms}]; \qquad (13)$$

$$b = \frac{2p}{W}[nG + (n-1)H + (n-2)I + \ldots n \text{ terms}]; \qquad (14)$$

$$W + L = \frac{2Z}{b}(h + 10) + \frac{2p}{b}[nG + (n-1)H + (n-2)I + \ldots n \text{ terms}]; \qquad (15)$$

$$b = \frac{2Z}{W+L}(h + 10) + \frac{2p}{W+L}[nG + (n-1)H + (n-2)I + \ldots n \text{ terms}]. \qquad (16)$$

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 $L = 1500 \text{ lbs.} \times 20' = 30{,}000 \text{ lbs.} = 15$ 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. 39), 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

$$m = \frac{ha}{b-a} \quad \ldots \ldots \ldots \ldots \quad (17)$$

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 rules 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,

$$\left.\begin{array}{r}\text{Stress in diagonal of}\\ \text{the bottom panel}\end{array}\right\} = \frac{m(G+H+I+\ldots K)+p[H+2I+\ldots(n-1)K]}{\text{arm for the stress}} \quad . \; . \quad (18)$$

and, when a train is on,

$$\left.\begin{array}{c}\text{Stress in}\\ \text{diagonal}\\ \text{of the}\\ \text{bottom}\\ \text{panel}\end{array}\right\} = \frac{(m - 10)Z + m(G + H + I + \ldots K) + p[H + 2I \ldots (n - 1)K]}{\text{arm for the stress}} \quad . \quad . \quad (19)$$

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 ¾″ 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 enongh 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

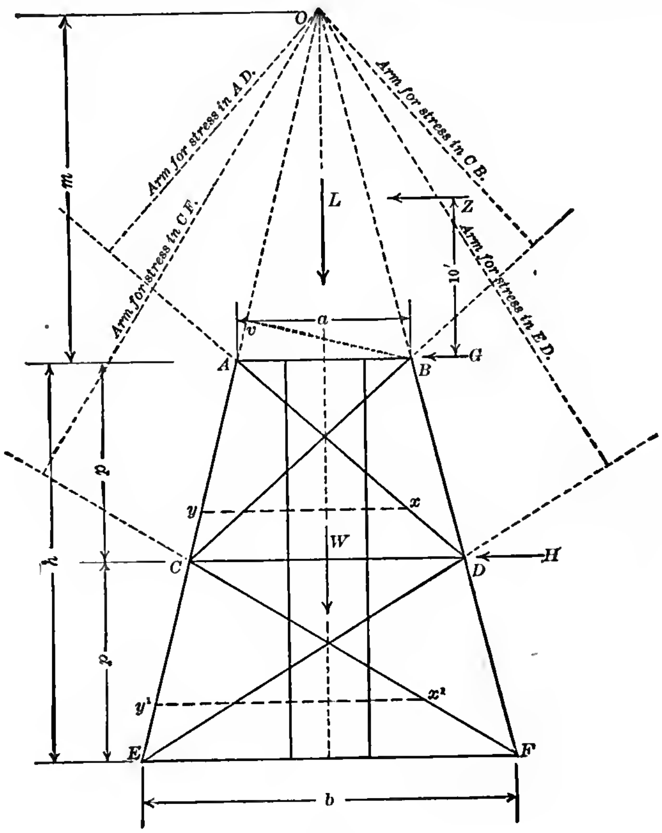


FIG. 156.

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 slighest 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 necessary 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.

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.

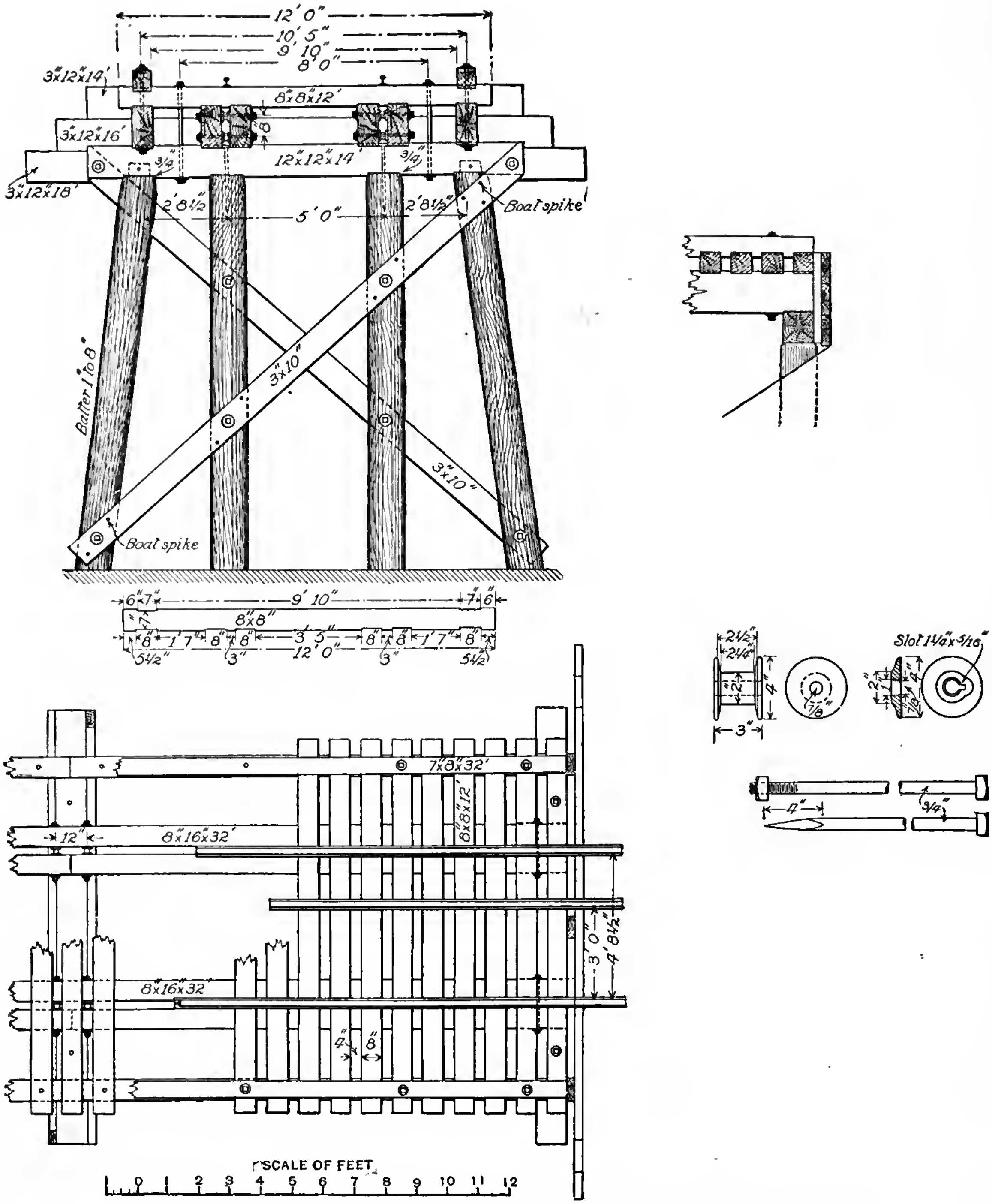


PLATE I.—STANDARD PILE-TRESTLE, DENVER & RIO GRANDE RAILROAD.

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. × 8 in. × 32 ft., notched 1 in.
Ties, 8 in. × 8 in. × 12 ft., notched ½ in. for both guard-rails and stringers, as shown in detail.
Track-stringers, 8 in. × 16 in. × 32 ft., notched ¾ in. over caps.
Jack-stringers, 8 in. × 16 in. × 32 ft., notched ¾ in. over caps.

Bent: Cap, 12 in. × 12 in. × 14 ft., notched ¾ in. over piles.
Sway-braces, 3 in. × 10 in.
Piles, 14 in. diameter at top.

Bank-bent: Dump-boards, 3 in. × 12 in. × 14 ft.; 3 in. × 12 in. × 16 ft.; 3 in. × 12 in × 18 ft.
Battens, 3 in. × 10 in. × 3 ft.

Dimensions of Iron Details.

Bolts: ¾ in. × 33 in.; guard-rail to ties and jack-stringers.
¾ in. × 38 in.; ties to caps.
¾ in. × 22 in.; stringer-joints; packing-bolts.
¾ in. × 18 in.; sway-braces to posts.

Drift-bolts: ¾ in. × 22 in.; caps to piles.

Boat-spikes: ½ in. × 8 in.; sway-braces to posts.

Cast washers: ⅝ in. × 4 in.; under heads and nuts of ¾-in. bolts.

Cast separators: 3 in. × 4 in.; between stringer-pieces for ¾-in. bolts.

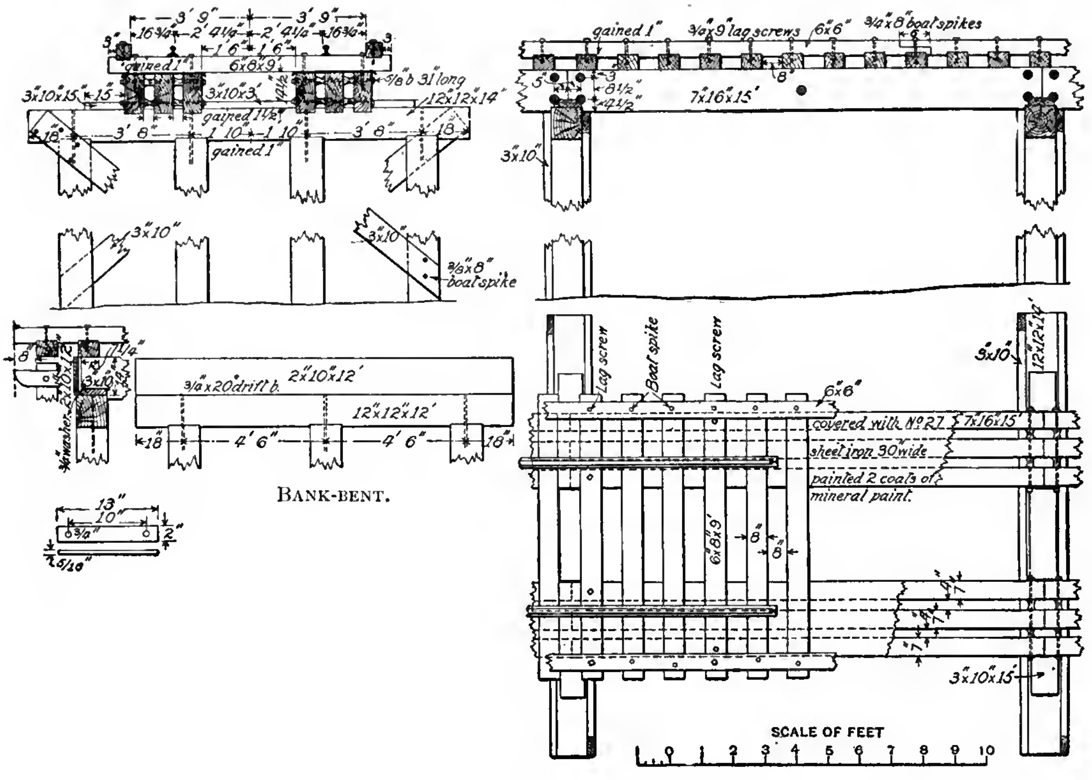


PLATE II.—STANDARD PILE-TRESTLE, TOLEDO, ST. LOUIS & KANSAS CITY RAILROAD.

STANDARD PILE-TRESTLE, TOLEDO, ST. LOUIS & KANSAS CITY RAILROAD.—PLATE II.

Dimensions of Timber.

Floor-system: Guard-rails, 6 in. × 6 in., notched 1 in. over ties.
Ties, 6 in. × 8 in. × 9 ft.
Stringers, 7 in. × 16 in. × 15 ft., notched $1\frac{1}{2}$ in. over caps.
Brace-blocks, 3 in. × 10 in. × 15 in.; 3 in. × 10 in. × 3 ft.

Bents: Caps, 12 in. × 12 in. × 14 ft., notched 1 in. over piles.
Sway-braces, 3 in. × 10 in.
Piles, 4.

Bank-bent: Dump-board, 2 in. × 10 in. × 12 ft.
Cap, 12 in. × 12 in. × 12 ft.
Piles, 3.

Dimensions of Iron Details.

Bolts: $\frac{5}{8}$ in. × 31 in.; stringer-joints, packing-bolts.
Lag-screws: $\frac{3}{4}$ in. × 9 in.; { guard-rails to ties. / ties to stringers.
Boat-spikes: $\frac{3}{8}$ in. × 8 in.; { guard-rails to ties. / sway-braces to posts.
Drift-bolts: $\frac{3}{4}$ in. × 20 in.; caps to piles.
Wrought strap: 13 in. × 2 in. × $\frac{5}{16}$ 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.

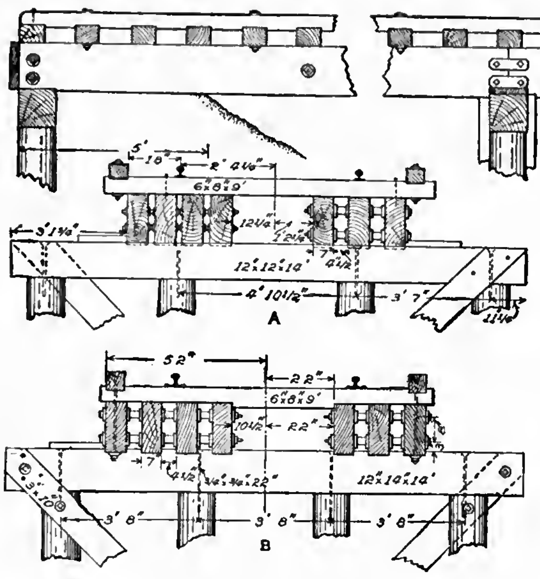


FIG. 1.—DETAILS OF FLOOR-SYSTEMS.

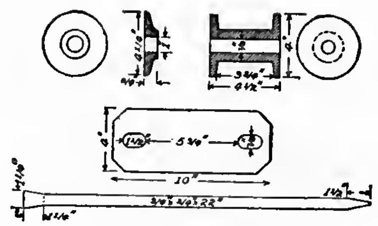
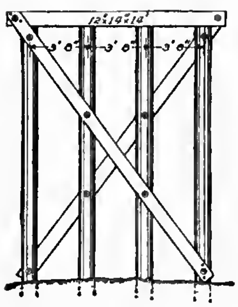
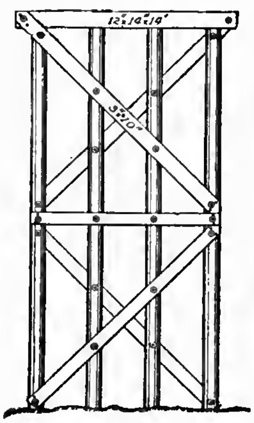


FIG. 3.—IRON DETAILS.

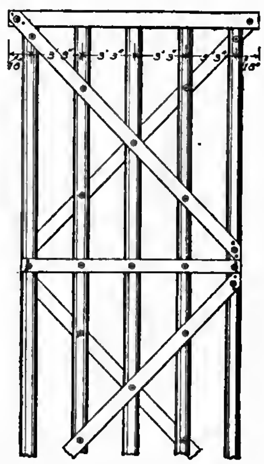


A, UP TO 18 FT. HIGH.



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 & PACIFIC RAILROAD.—PLATE III.

(See also Plate XXXI.)

Dimensions of Timbers.

Floor-systems—Fig. 1, A: Guard-rails, 6 in. × 6 in. × 16 feet.
Ties, 6 in. × 8 in. × 9 ft.
Stringers, 7 in. × 16 in. × 15 ft.
Brace-blocks, 2 in. × 10 in. × 18 in.
Fig. 1, B: same as above.

Bents: Caps, 12 in. × 14 in. × 14 ft.
All sway-braces, 3 in. × 10 in.
Piles, 12 in. diameter.

Dimensions of Iron Details.

Floor-system—Fig. 1, B; Four-piece stringer:
Bolts, $\frac{3}{4}$ in. × 46 in.; stringer-joints.
Packing-bolts, $\frac{3}{4}$ in. × 30 in.; guard-rails to stringers.
Splice-plates: $\frac{13}{16}$ in. × 4 in. × 10 in.; stringer-joints.
Cast separators: 4 in. × $4\frac{1}{2}$ in.; between stringer-pieces; $\frac{3}{4}$-in. bolts.
Cast washers: $\frac{3}{4}$ in. × $4\frac{1}{4}$ in.; under head and nut of each bolt.
Spikes: Boat, $\frac{3}{8}$ in. × $\frac{3}{8}$ in. × 7 in.;
Cut 20-penny.

Three-piece stringer: Bolts, $\frac{3}{4}$ in.; × 34 in.; stringer-joints; packing-bolts.
$\frac{3}{4}$ in. × 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. × 20 in.; sway-braces to piles.
Drift-bolts: $\frac{3}{4}$ in. × $\frac{3}{4}$ in. × 22 in.; caps to piles.
Boat-spikes: $\frac{3}{8}$ in. × $\frac{3}{8}$ in. × 7 in.; sway-braces to piles.
Cast washers: $\frac{3}{4}$ in. × $4\frac{1}{4}$ in.; under head and nut of each **bolt.**

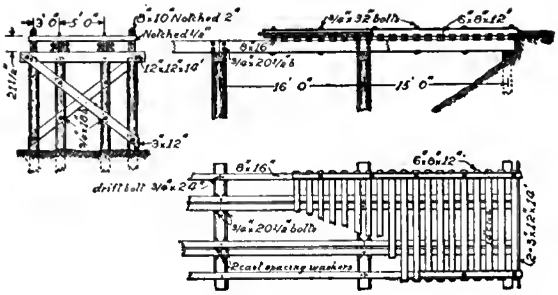


FIG. 1.—PILE-TRESTLE.

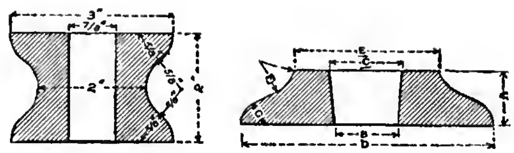


FIG. 2.—DETAILS OF SEPARATOR AND CAST WASHERS

PLATE IV.—STANDARD PILE-TRESTLE, CHICAGO & WEST MICHIGAN RAILWAY.

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.
$\frac{5}{8}''$—$\frac{3}{4}''$	$\frac{3}{4}''$	$\frac{7}{8}''$	$1''$	$3\frac{1}{2}''$	$2''$	$\frac{1}{2}''$	$\frac{5}{16}''$	$1\frac{1}{4}$ lbs.
$\frac{7}{8}''$—$1''$	$1''$	$1\frac{1}{8}''$	$1\frac{1}{4}''$	$5''$	$2\frac{1}{2}''$	$\frac{5}{8}''$	$\frac{3}{8}''$	
$1\frac{1}{8}''$—$1\frac{1}{4}''$	$1\frac{1}{4}''$	$1\frac{3}{8}''$	$1\frac{1}{2}''$	$6''$	$3''$	$\frac{3}{4}''$	$\frac{7}{16}''$	
$1\frac{3}{8}''$—$1\frac{1}{2}''$	$1\frac{1}{2}''$	$1\frac{5}{8}''$	$1\frac{3}{4}$	$7\frac{1}{4}''$	$3\frac{1}{2}$	$\frac{7}{8}''$	$\frac{1}{2}''$	
$1\frac{5}{8}''$—$1\frac{3}{4}''$	$1\frac{3}{4}''$	$1\frac{7}{8}''$	$2''$	$8\frac{1}{2}''$	$4\frac{1}{4}$	$1''$	$\frac{5}{8}''$	
$1\frac{7}{8}''$—$2''$	$2''$	$2\frac{1}{8}''$	$2\frac{1}{4}''$	$9\frac{1}{2}''$	$5''$	$1\frac{1}{8}''$	$\frac{3}{4}''$	

Cast separators: 3 in. × 2 in. thick; between stringer-pieces.
These trestles are built with spans of 12 ft., 14 ft., and 16 ft.

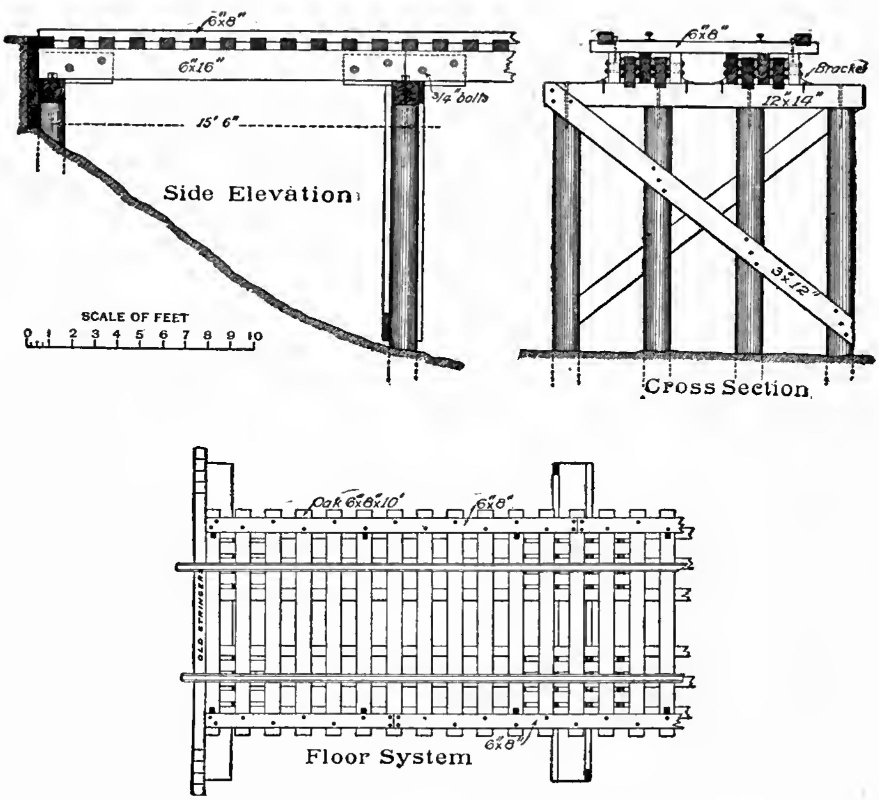


PLATE V.—STANDARD PILE-TRESTLE, MINNEAPOLIS & ST. LOUIS RAILWAY.

Standard Pile-trestle, Minneapolis & St. Louis Railway.—Plate V.

(See also Plate XXII.)

Dimensions of Timbers.

Floor-system : Guard-rail, 6 in. × 8 in., notched 2 in. over ties.
Ties, 6 in. × 8 in. × 10 ft., white oak.
Stringers, 6 in. × 16 in. × 15 ft. 6 in.
Packing-block, 6 in. × 16 in. × 5 ft. 4 in., notched 2 in. over caps.

Bent : Cap, 12 in. × 14 in. × 14 ft., laid flat.
Sway-braces, 3 in. × 12 in.
Piles, not less than 11 in. diameter.

Bank-bent : Dump-plank, old stringers.

Dimensions of Iron Details.

Bolts : $\frac{3}{4}$ in. × 41 in. ; stringer-joints ; packing-bolts.

Lag-screws : Stringer-brackets to caps.

Spikes : Boat, $\frac{1}{2}$ in. × 8 in.; guard-rails to ties.

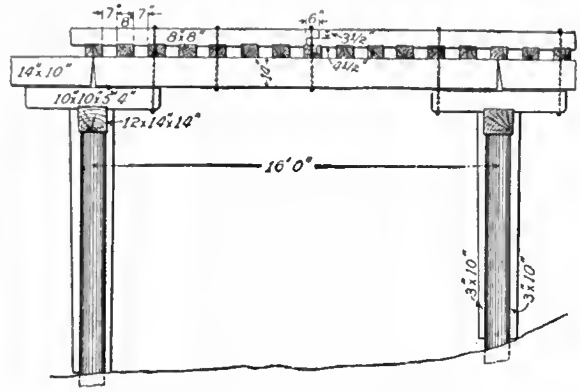
Drift-bolts : $\frac{5}{8}$ in. × 12 in.; ties to stringers.
$\frac{7}{8}$ in. × 22 in.; caps to piles.

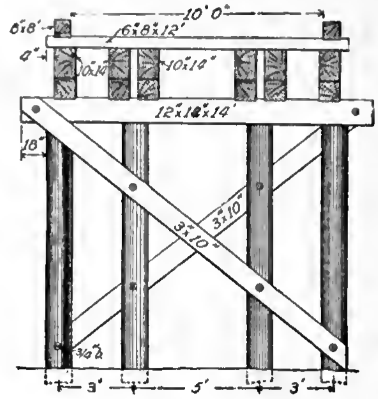
Cast separators : 2 in. wide ; between packing-blocks and stringers.

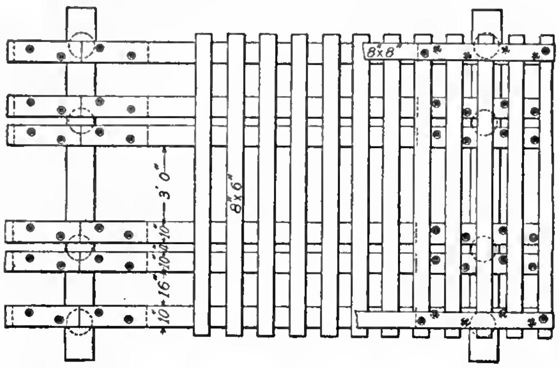
Cast washers : Under head and nut of each bolt.

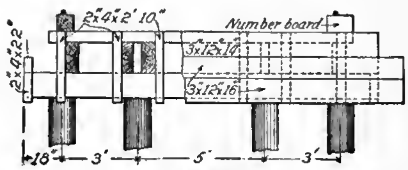
Cast brackets : Stringers to caps.

For arguments in favor of and description of this trestle, see *Railroad Gazette*, April 17, 1891.

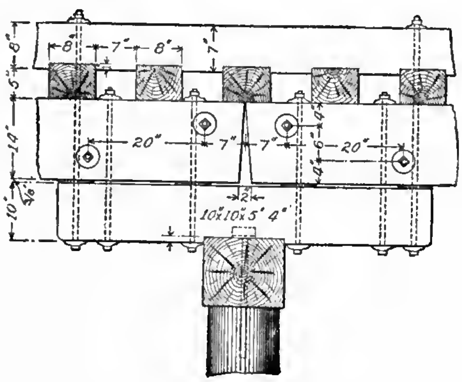


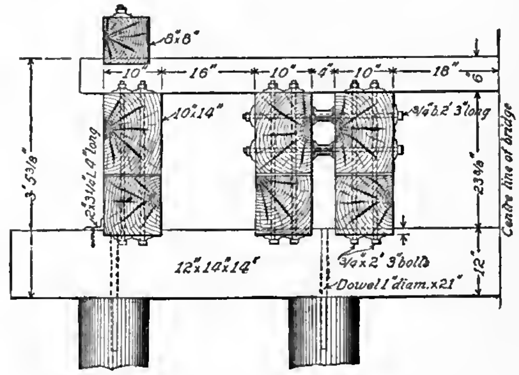


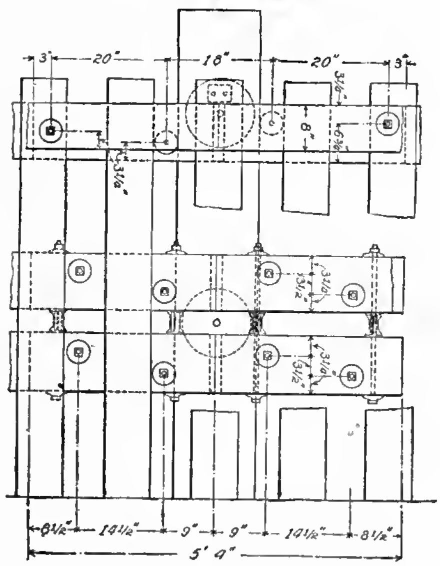




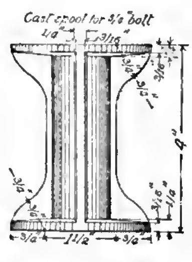
Bank bent.

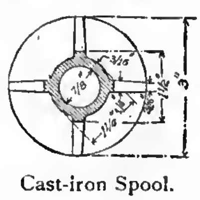




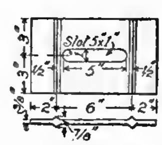


Details of Stringer-joint.

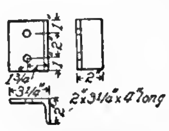




Cast-iron Spool.



Corbel-stringer Separator.



Angle-lug.

Iron Details.

PLATE VI.—STANDARD PILE-TRESTLE, CHICAGO & NORTHWESTERN RAILWAY.

Standard Pile-trestle, Chicago & Northwestern Railway.—Plate VI.

Dimensions of Timbers.

Floor-system : Guard-rails, 8 in. × 8 in. × 16 ft., notched 1 in. over ties.
Ties, 6 in. × 8 in. × 12 ft., white oak.
Track-stringers, 10 in. × 14 in. × 16 ft.
Jack-stringers : 10 in. × 14 in. × 16 ft.
Corbels, 10 in. × 10 in. × 5 ft. 4 in., notched 1 in. over cap, and used only on bridges of two spans or over.

Bents : Cap, 12 in. × 14 in. × 14 ft.
Sway-braces, 3 in. × 10 in.
Piles, 12 in. diameter.

Bank-bent : Dump-plank, { 3 in. × 10 in. × 16 ft.; 3 in. × 12 in. × 14 ft.; 3 in. × 12 in. × 16 ft.
Battens, { 2 in. × 4 in. × 34 in.; 2 in. × 4 in. × 22 in.

Number-boards : $1\frac{1}{2}$ in. × 8 in. × 12 in.

Dimensions of Iron Details.

Bolts : $\frac{3}{4}$ in. × 2 ft. 3 in.; stringer-joints; packing-bolts; also stringers to corbels.
$\frac{3}{4}$ in. × 2 ft. $5\frac{3}{4}$ in.; guard-rails to stringers.
$\frac{3}{4}$ in. × 3 ft. $4\frac{1}{2}$ in.; guard-rails to corbels.
$\frac{3}{4}$ in. × $19\frac{3}{4}$ in.; sway-braces to caps and piles.

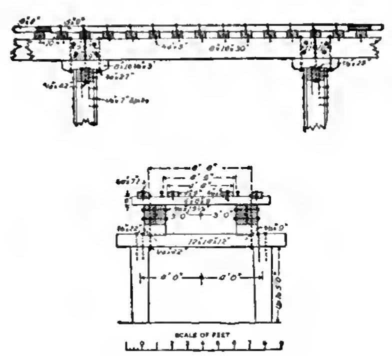
Dowels : 1 in. × 21 in.; caps to piles.

Spikes : Boat, $\frac{5}{16}$ in. × 5 in.
Cut 30-penny.

Cast separators : 3 in. × 4 in.; as per detail drawing; between stringer-pieces.
6 in. × 10 in.; as per detail drawing; between stringers and corbels.

Cast washers : Under head and nut of each bolt.

Angle-iron lugs : 2 in. × $3\frac{1}{4}$ in. L × 4 in. long; hold stringers in place.



Figs. 1, 2.—For Heights of 5 ft. or under.

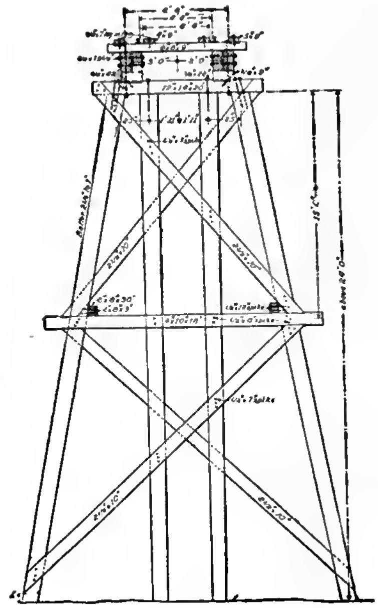
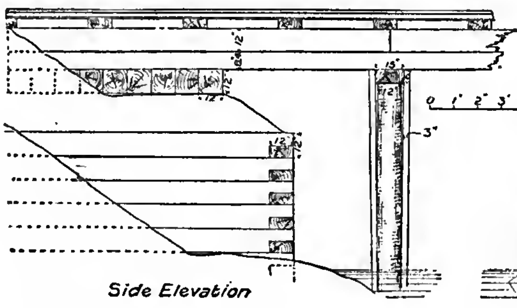
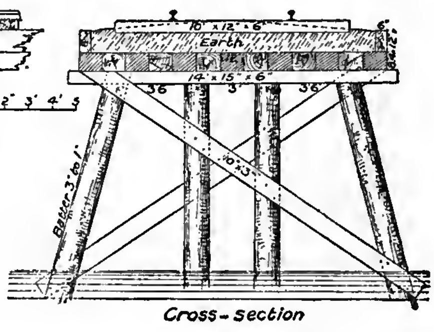


Fig. 3.—For Heights above 24 ft.

PLATE VII.—STANDARD PILE-TRESTLE, LOUISVILLE & NASHVILLE RAILROAD.





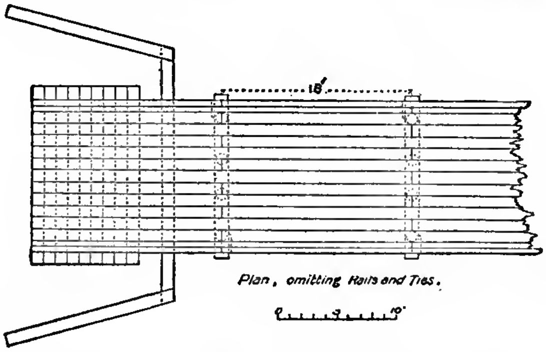


PLATE VIII.—PILE-TRESTLE WITH EARTH ROADBED, LOUISVILLE & NASHVILLE RAILROAD.

STANDARD PILE-TRESTLE, LOUISVILLE & NASHVILLE RAILROAD.—PLATE VII.
(See also Plates VIII and XVII.)

Dimensions of Timbers.

Floor System : Guard-rails, outside, 5 in. × 9 in., notched 1 in. over ties.
inside, 4 in. × 9 in., not notched.
Ties, 6 in. × 8 in. × 9 ft.
Stringers, 8 in. × 16 in. × 30 ft.
Corbels, 8 in. × $16\frac{3}{4}$ in. × 3 ft., notched 1 in. over caps.

Bents : Caps, 12 in. × 14 in. × 12 feet.
Sway-braces, diagonal, $2\frac{1}{2}$ in. × 10 in.
horizontal, 4 in. × 10 in.
Piles, 12 in. diameter.

Girts : 6 in. × 8 in. × 30 ft.

Splice-blocks : 2 in. × 8 in. × 3 ft.

Dimensions of Iron Details.

Bolts : $\frac{3}{4}$ in. × 27 in.; stringers to corbels.
$\frac{3}{4}$ in. × $19\frac{1}{2}$ in.; stringer-joints; packing-bolts.
$\frac{3}{4}$ in. × 42 in.; floor-system to caps.

Drift-bolts : $\frac{7}{8}$ in. × 22 in.; caps to piles.

Dowels : $\frac{3}{4}$ in. × 5 in.; ties to stringers.

Spikes : $\frac{5}{8}$ in. × 9 in.; corbels to caps.
$\frac{1}{2}$ in. × 8 in.; horizontal sway-braces to piles.
$\frac{1}{2}$ in. × 7 in.; diagonal sway-braces to piles.
$\frac{1}{2}$ in. × 12 in.; girts to piles.

Lag-screws : $\frac{3}{4}$ in. × 7 in.; guard-rails to ties.

Cast washers : Under head and nut of each bolt.

Cast separators : Between stringer-pieces.

PILE-TRESTLE WITH EARTH ROADBED, LOUISVILLE & NASHVILLE RAILROAD.—PLATE VIII. (See also Plates VII and XVII.)

Dimensions of Timbers.

Ties, 6 in. × 12 in. × 10 ft.
Side-timbers, 6 in. × 12 in. × 32 ft.
Floor-timbers, $8\frac{1}{2}$ in. × 12 in. × 32 ft.
Caps, 6 in. × 15 in. × 14 ft.
Sway-bracing, 3 in. × 10 in.
Piles, 12 in. diameter.
Revetment-timbers, 12 in. × 12 in.

All timber creosoted yellow pine, spiked together. No bolts or mortise and tenon joints used.—*Eng. News*, Oct. 29, 1887.

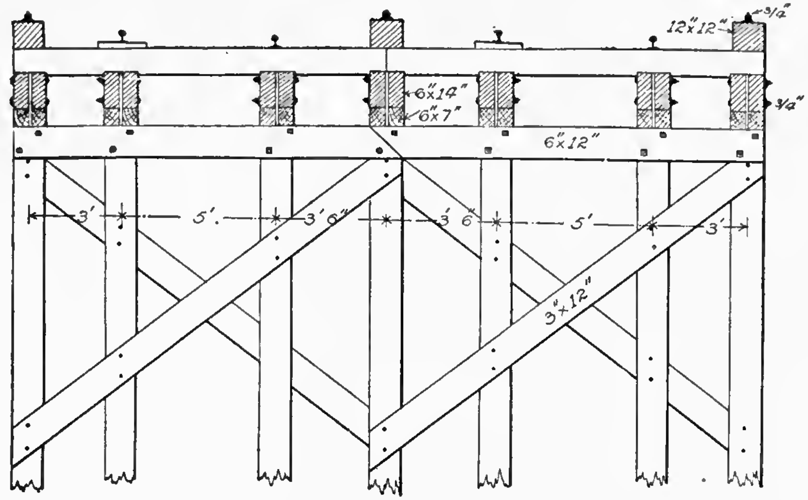


Fig. 1.—Cross-section.

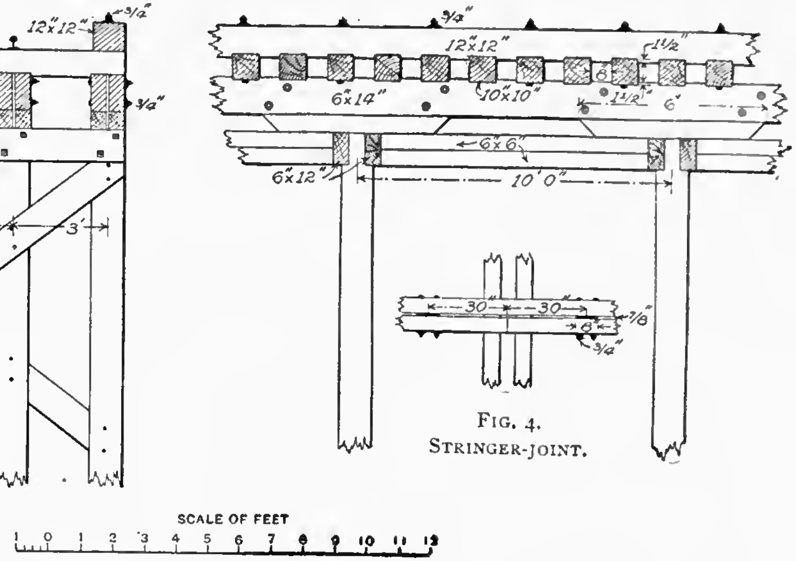


Fig. 4.
Stringer-joint.

Fig. 2.—Side Elevation.

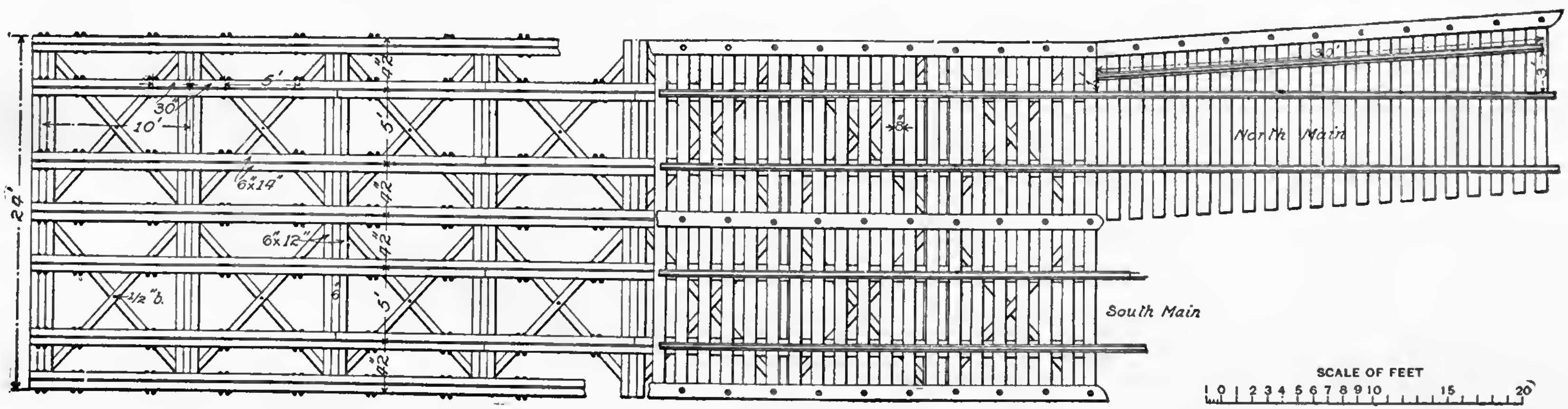


Fig. 3.—Plan.

142 PLATE IX.—STANDARD PILE-TRESTLE, BOSTON & ALBANY RAILROAD—BRIDGE No. 35.

STANDARD PILE-TRESTLE, BOSTON & ALBANY RAILROAD.—PLATE IX.

Dimensions of Timbers.

Floor-system: Guard-rails, 12 in. × 12 in., notched $1\frac{1}{2}$ in. over ties.
Ties, 10 in. × 10 in. × 12 ft., notched $1\frac{1}{2}$ in. over stringers.
Stringers, 6 in. × 14 in. × 30 ft.
Corbels, 6 in. × 7 in. × 6 ft.

Bents: Caps, 6 in. × 12 in. × 12 ft. 6 in.
Sway-braces, 3 in. × 12 in.
Piles, 12 in. diameter.

Lateral braces: 6 in. × 6 in.

Dimensions of Iron Details.

Bolts: $\frac{3}{4}$ in. × $23\frac{1}{2}$ in.; guard-rails to ties.
$\frac{3}{4}$ in. × 16 in.; stringer-joints; packing-bolts
$\frac{3}{4}$ in. × 21 in.; caps to piles.
$\frac{1}{2}$ in. × $13\frac{1}{2}$ in.; lateral brace intersections.

Spikes.

Cast separators.

Cast washers.

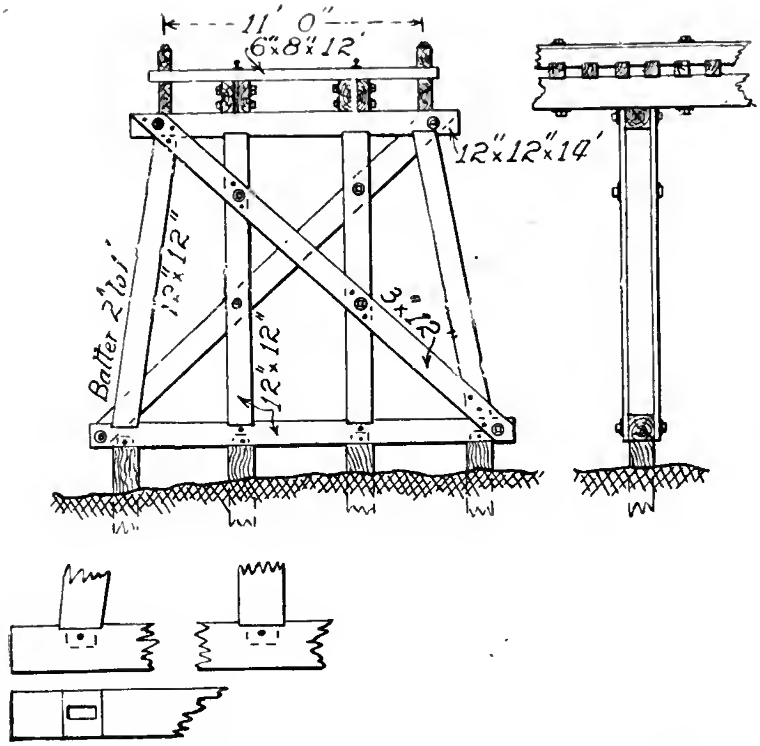


PLATE X.—STANDARD FRAMED TRESTLE, CHICAGO & WEST MICHIGAN RAILWAY.

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. × 10 in., notched 2 in. over ties.
Ties, 6 in. × 8 in. × 12 ft., notched ½ in. over stringers.
Stringers, 8 in. × 16 in. × 32 ft.

Bent: Cap, 12 in. × 12 in. × 14 ft.
Plumb-posts, 12 in. × 12 in.
Batter-posts, 12 in. × 12 in.; batter, 2 in. to 1 ft.
Sill, 12 in. × 12 in.
Sway-braces, 3 in. × 12 in.

Sub-sills, 12 in. × 12 in × 6 ft

Dimensions of Iron Details

Same as for Plate IV.

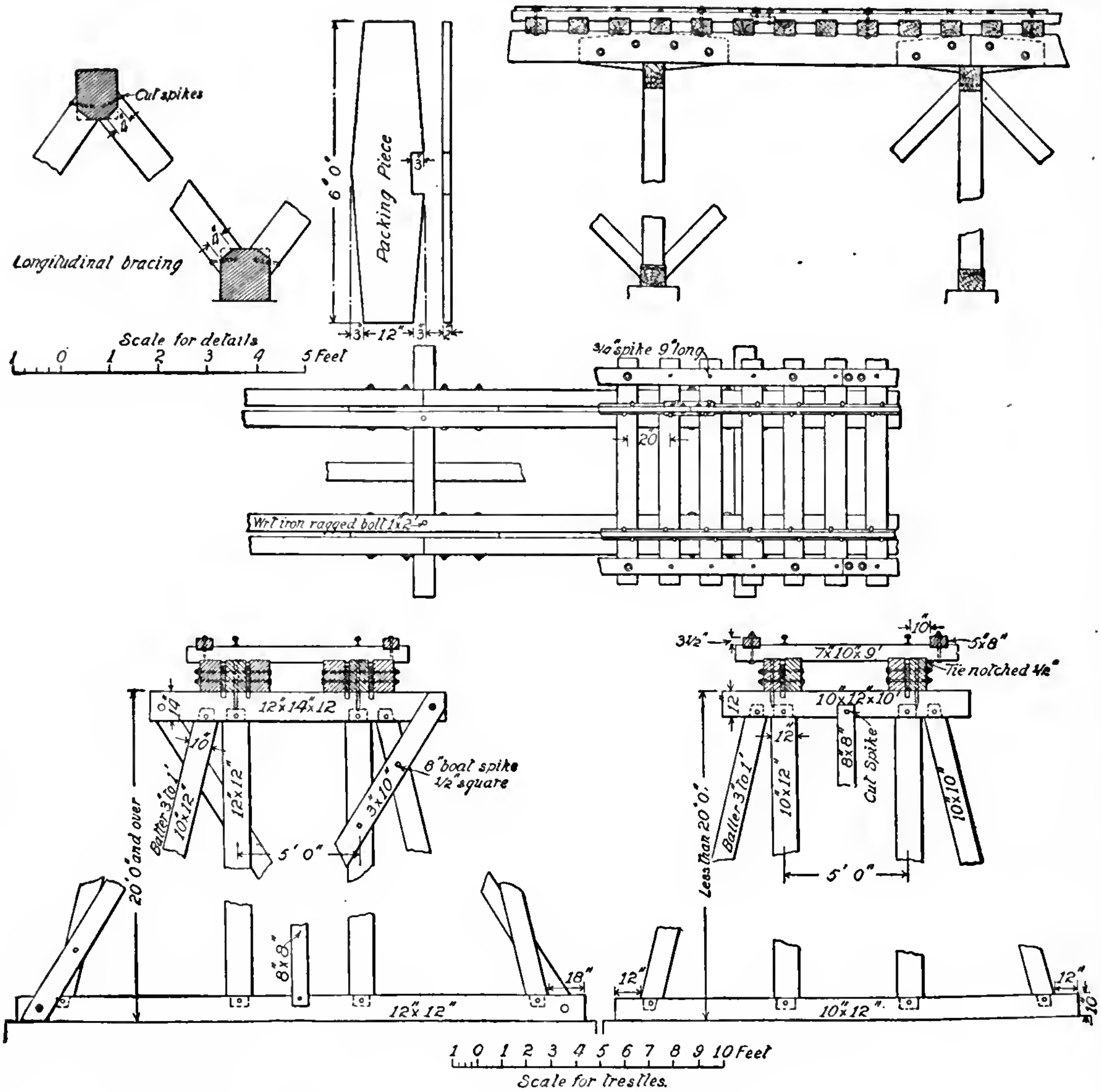


PLATE XI.—STANDARD FRAMED TRESTLES, PENNSYLVANIA RAILROAD.

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 ½ in. to receive guard-rails, and ½ 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: ¾ in. ×——; guard-rails to ties.
¾ in. ×——; guard-rail joints.
¾ in. ×——; stringer-joints; packing-bolts.

All of above bolts have 2½-in. flat heads, with 2½-in. wrought washer under nuts.

¾ 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, ¾ in. × 9 in.; guard-rails to ties.
½ in. × 8 in.; sway-braces to posts.
Cut ——×——, longitudinal braces to caps and sills.

Wrought washers: 2½ in. square for ¾-in. bolt.
3 in. round for ¾-in. bolt.

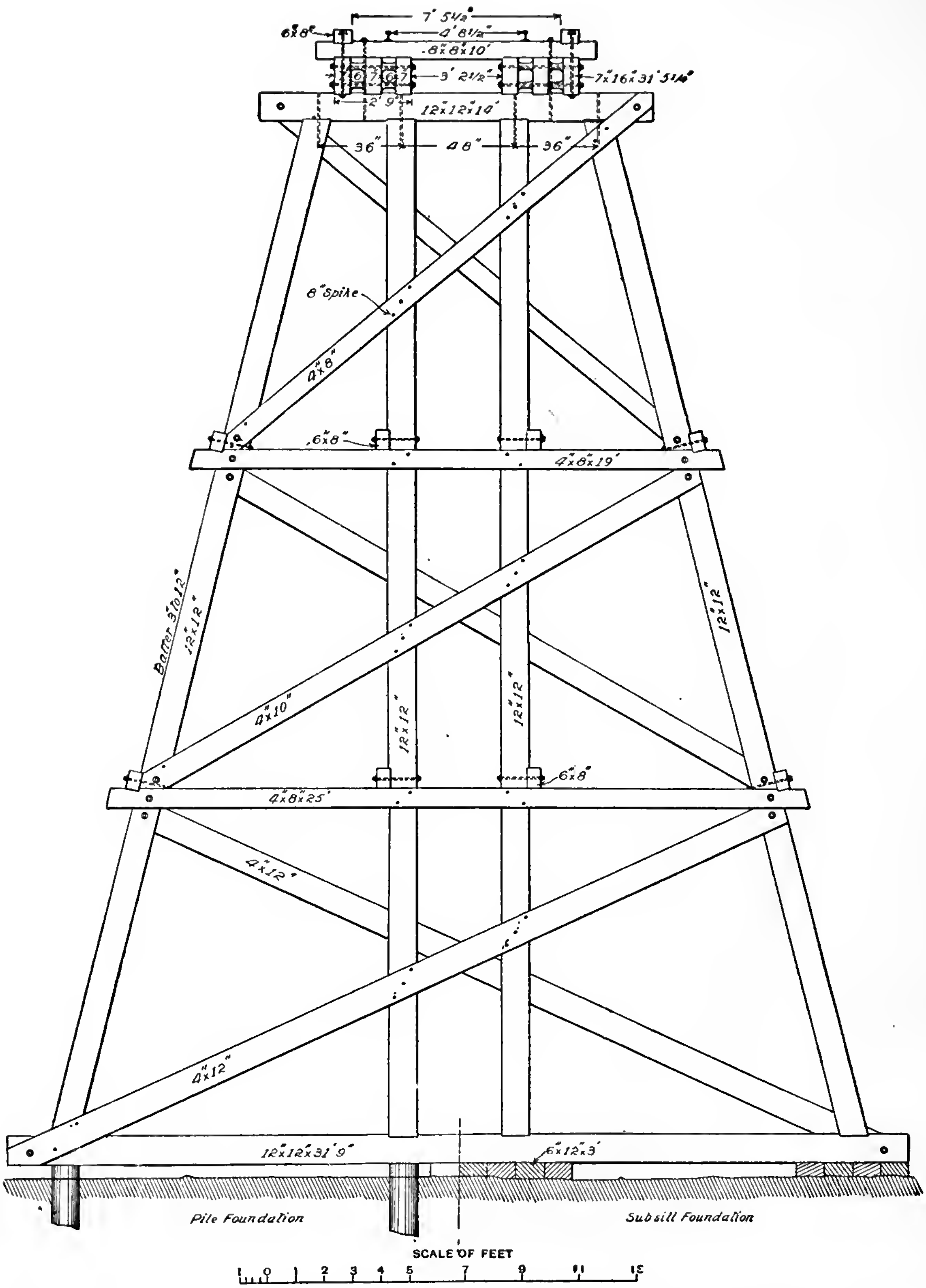
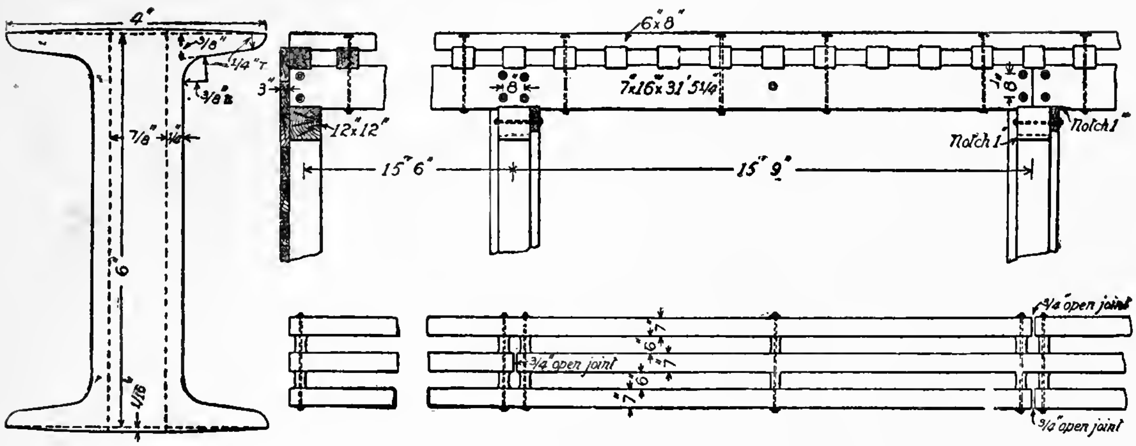


PLATE XII.—STANDARD FRAMED TRESTLE, SAN FRANCISCO & NORTH PACIFIC RAILROAD.



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. $5\frac{1}{4}$ 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: $\frac{3}{4}$ in. × 37 in.; floor-system to cap.
$\frac{5}{8}$ in. × 36 in.; stringer joints; packing bolts.
$\frac{5}{8}$ in. × $28\frac{1}{2}$ in.; guard-rails to ties and stringers.
$\frac{5}{8}$ in. × $21\frac{1}{2}$ in.; horizontal sway-braces to posts.
$\frac{5}{8}$ in. × $18\frac{1}{2}$ in.; longitudinal braces to posts.
$\frac{5}{8}$ in. × $17\frac{1}{2}$ 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 $\frac{5}{8}$-in. and $\frac{3}{4}$-in. bolts.

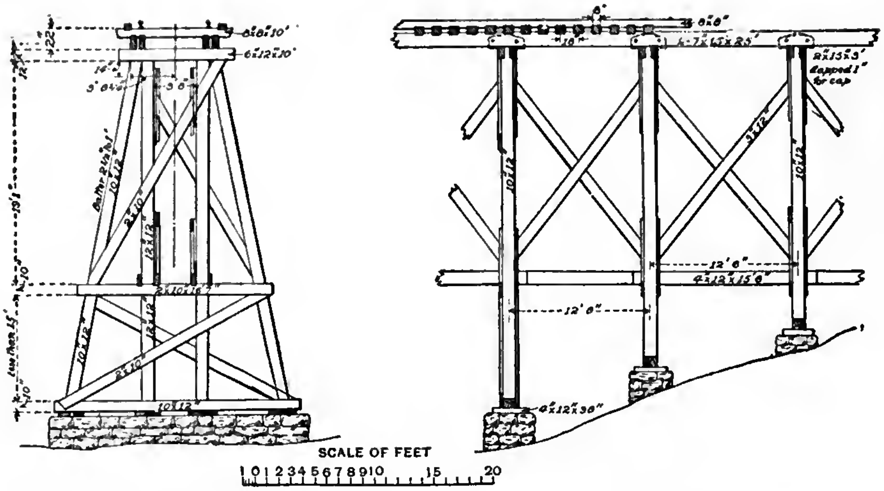


FIG. 1.—CROSS-SECTION. FIG. 2.—ELEVATION.

GENERAL PLAN SINGLE-DECK TRESTLES.

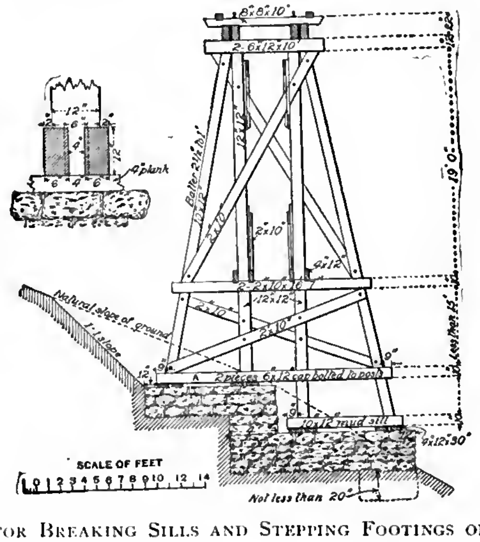


FIG. 3.—PLAN FOR BREAKING SILLS AND STEPPING FOOTINGS ON STEEP SLOPES.

PLATE XIV.—STANDARD TRESTLES, NORFOLK & WESTERN RAILROAD.

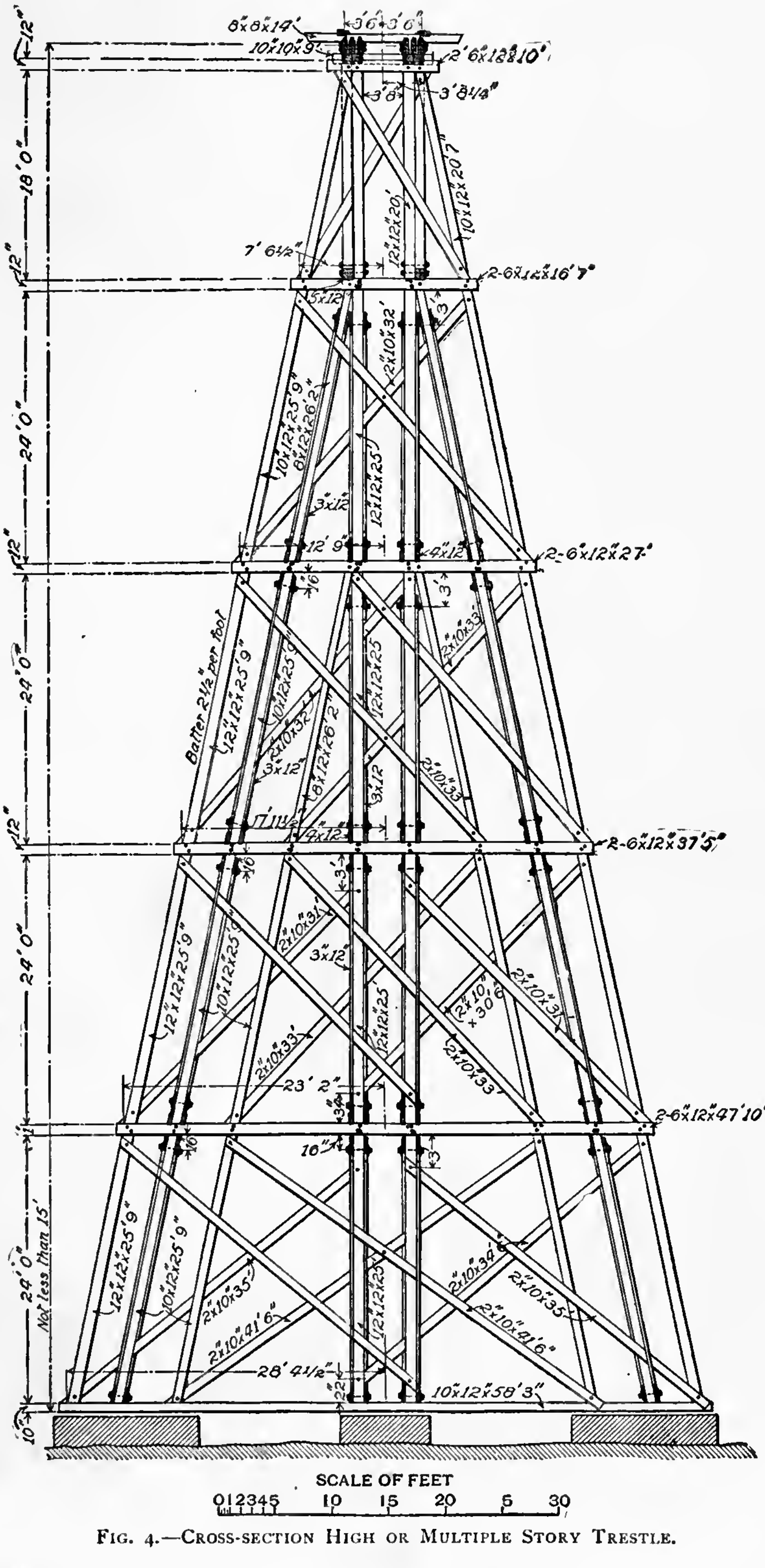


Fig. 4.—Cross-section High or Multiple Story Trestle.

PLATE XV.—STANDARD TRESTLE, NORFOLK & WESTERN RAILROAD.

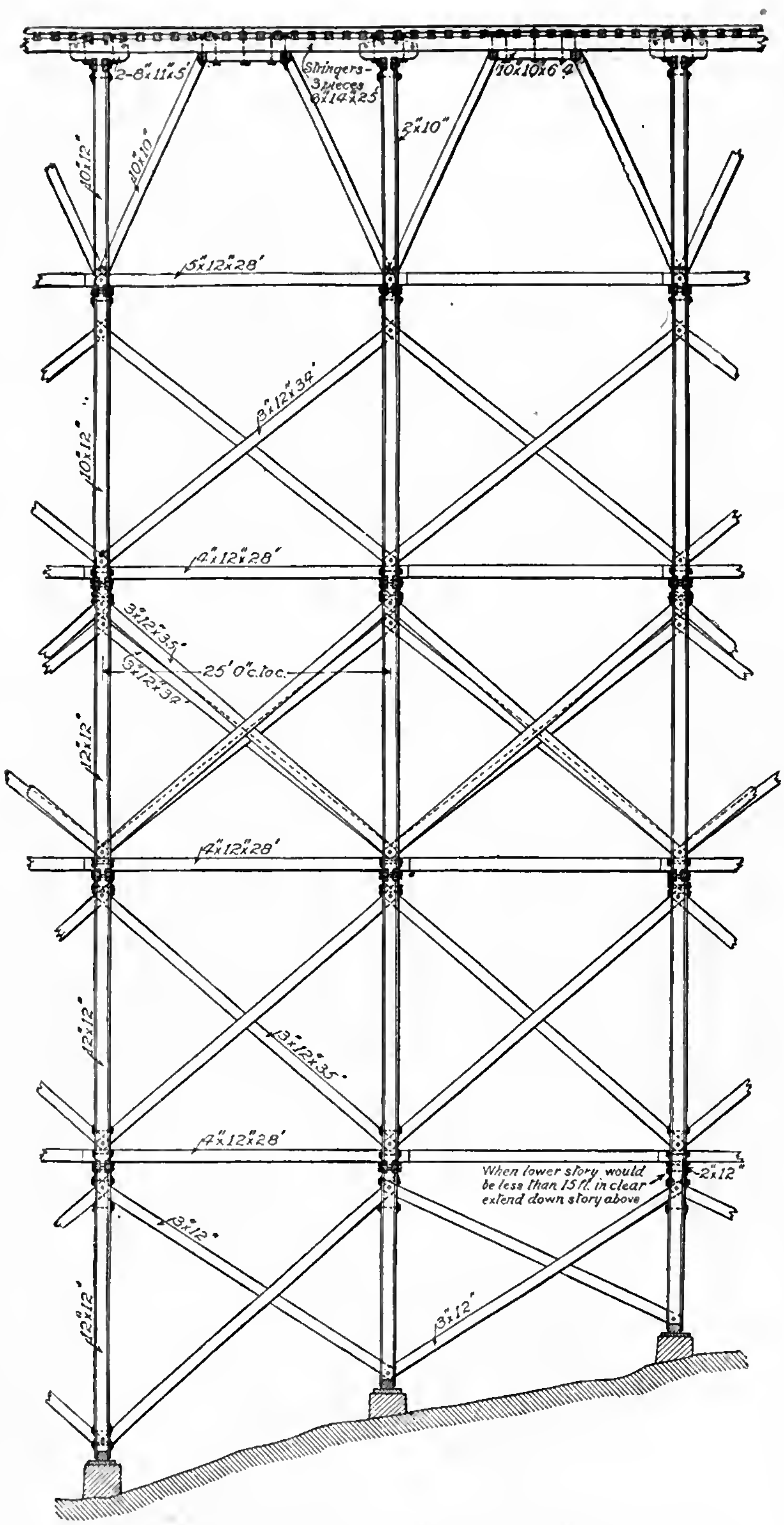


FIG. 5.—ELEVATION HIGH OR MULTIPLE STORY TRESTLE.

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. × 8 in., notched.
Ties, 8 in. × 8 in. × 10 ft., notched.
Stringers, 7 in. × 15 in. × 25 ft.
Packing-blocks, 2 in. × 15 in. × 3 ft., notched 1 in. over cap.

Bent: Cap, 6 in. × 12 in. × 10 ft.
Plumb-posts, 12 in. × 12 in.
Batter-posts, 10 in. × 12 in.; batter, $2\frac{1}{2}$ in. to 1 ft.
Sill, 10 in. × 12 in.
Sway-bracing: Diagonal, 2 in. × 10 in.
Horizontal, 2 in. × 10 in.

Longitudinal bracing: Horizontal, 4 in. × 12 in. × 15 ft. 6 in.
Diagonal, 3 in. × 12 in.

Sub-sills: 4 in. × 12 in. × 2 ft. 6 in.

PLATES XV AND XVI.

Floor-system: Guard-rails, 6 in. × 8 in.
Ties, 8 in. × 8 in. × 14 ft.
Stringers, 6 in. × 14 in. × 25 ft.
Packing-blocks, 2 in. × 14 in. × 5 ft.
Corbels, 8 in. × 11 in. × 5 ft.

Bent: Cap, 6 in. × 12 in. × 10 ft.
Plumb-posts, 12 in. × 12 in.
Outside batter-posts, 10 in. × 12 in., and 12 in. × 12 in
Inside batter posts, 8 in. × 12 in., and 10 in. × 12 in.
Sway-braces, 2 in. × 10 in.
Intermediate caps, 6 in. × 12 in.
Sill, 10 in. × 12 in.

Longitudinal bracing: Horizontal, 4 in. × 12 in. × 28 ft.
Diagonal, 3 in. × 12 in.

Knee-braces: Straining-beam, 10 in. × 10 in. × 9 ft.
Top chord, 10 in. × 10 in. × 6 ft. 4 in.
Bottom chord, 5 in. × 12 in. × 28 ft.
Diagonals, 10 in. × 10 in.

For method of elevating rails on curves, see Part I, Fig. 125.

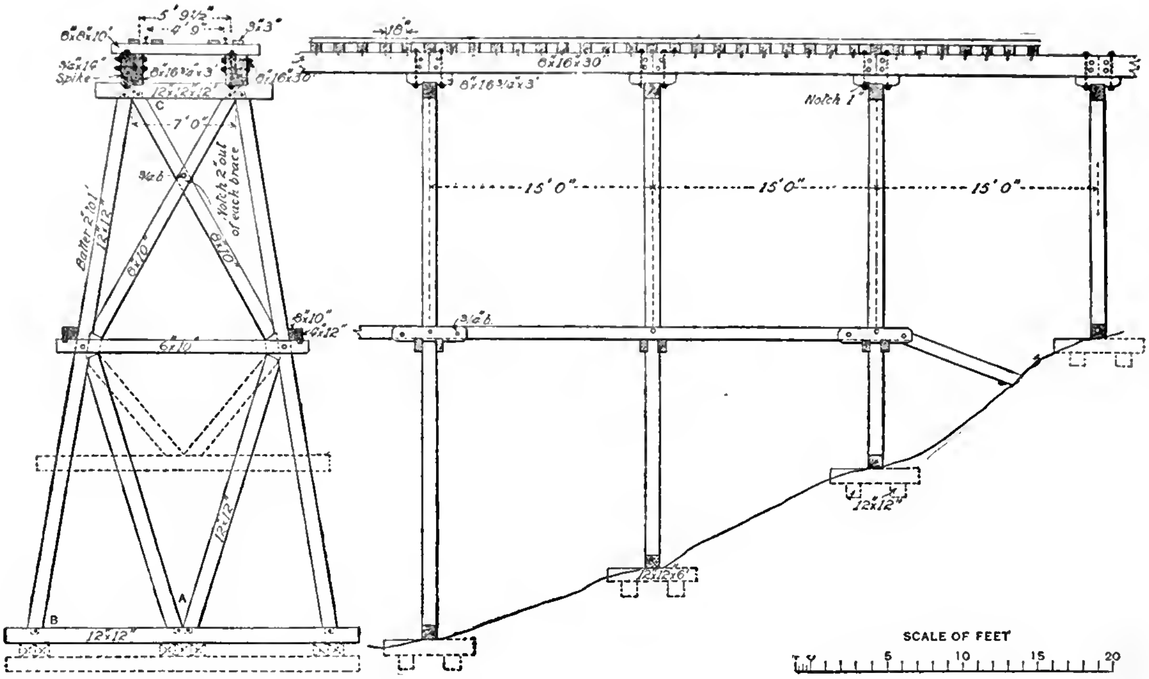


Fig. 1.—General Plans.

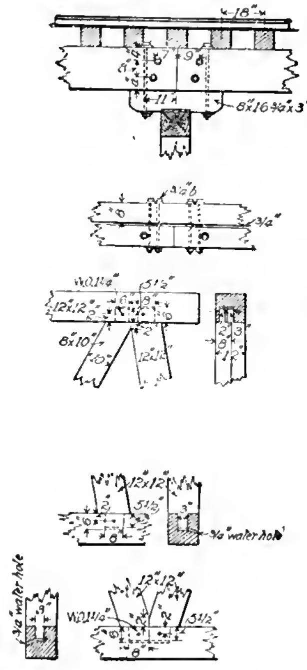


Fig. 2 —Details of Stringer and Post Joints.

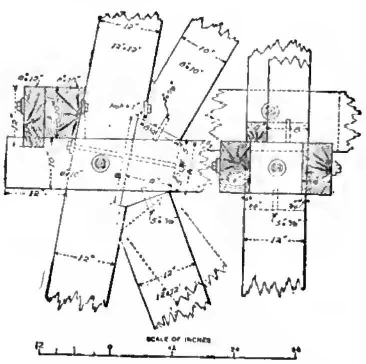


Fig. 3.—Detail of Joint of Diagonal Posts.

PLATE XVII.—STANDARD FRAMED TRESTLE, LOUISVILLE & NASHVILLE RAILROAD

Standard Framed Trestle, Louisville & Nashville Railroad.—Plate XVII.

(See also Plates VII and VIII.)

Dimensions of Timbers.

Floor-system: Guard-rails, 3 in. × 9 in.
Ties, 8 in. × 8 in. × 10 ft.
Stringers, 8 in. × 16 in. × 30 ft.
Corbels, 8 in. × 16$\frac{3}{4}$ in. × 3 ft.

Bent: Cap, 12 in. × 12 in. × 12 ft.
Batter-posts, 12 in. × 12 in.
Diagonal posts, 8 in. × 10 in., notched 2 in. each at intersection.
Intermediate cap, 6 in. × 10 in.
Sill, 12 in. × 12 in.

Longitudinal braces: Horizontal, 8 in. × 10 in. × 30 ft.
Splice-block, 4 in. × 12 in.

Sub-sills: 12 in. × 12 in. × 6 ft.

Dimensions of Iron Details.

Bolts: $\frac{3}{4}$ in. × 27 in.; stringers to corbels and intermediate cap to posts.
$\frac{3}{4}$ in. × 20 in.; stringer-joints; packing-bolts.
$\frac{3}{4}$ in. × 15 in.; splice-block to girts.
$\frac{3}{4}$ in. × 23 in.; angle-block to posts.

Spikes: $\frac{3}{4}$ in. × 14 in.; corbels to caps.

Dowels: $\frac{7}{8}$ in. × 5 in.; diagonal posts to angle-blocks.

Cast washers: Under head and nut of each bolt.

Cast separators: $\frac{3}{4}$ in. × ——; between stringer-pieces.

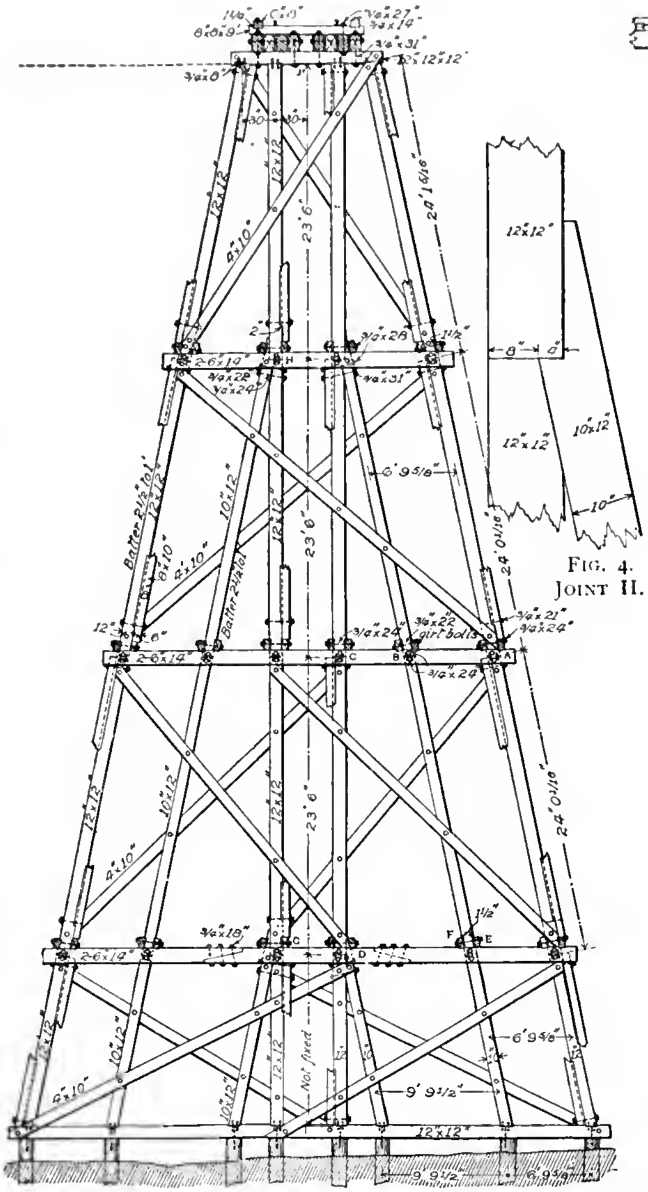
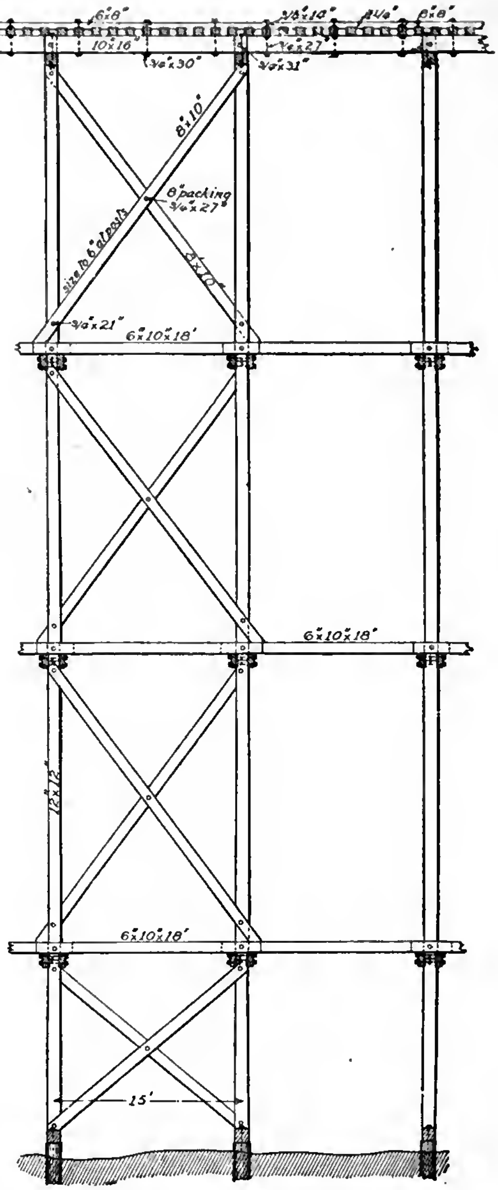


Fig. 4.
Joint H.



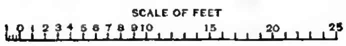


Fig. 1.—Cross-section.

Fig. 2.—Elevation.

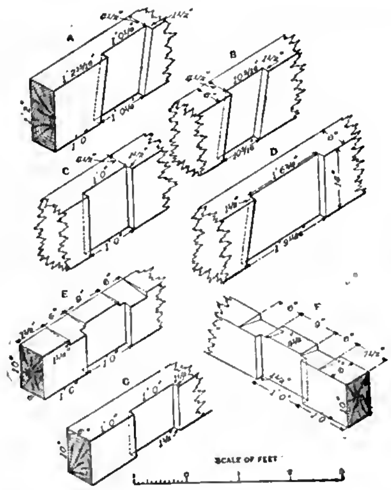


Fig. 5.—Details of Walls and Girts.

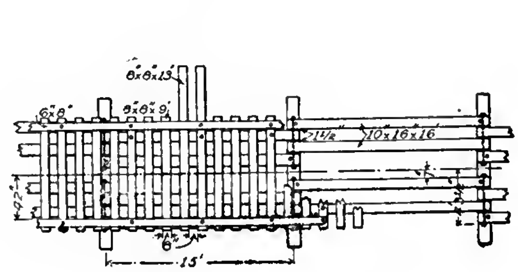


Fig. 3.—Floor-system.

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.

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* So in original blue print, but rather too close to work to in this size timber.

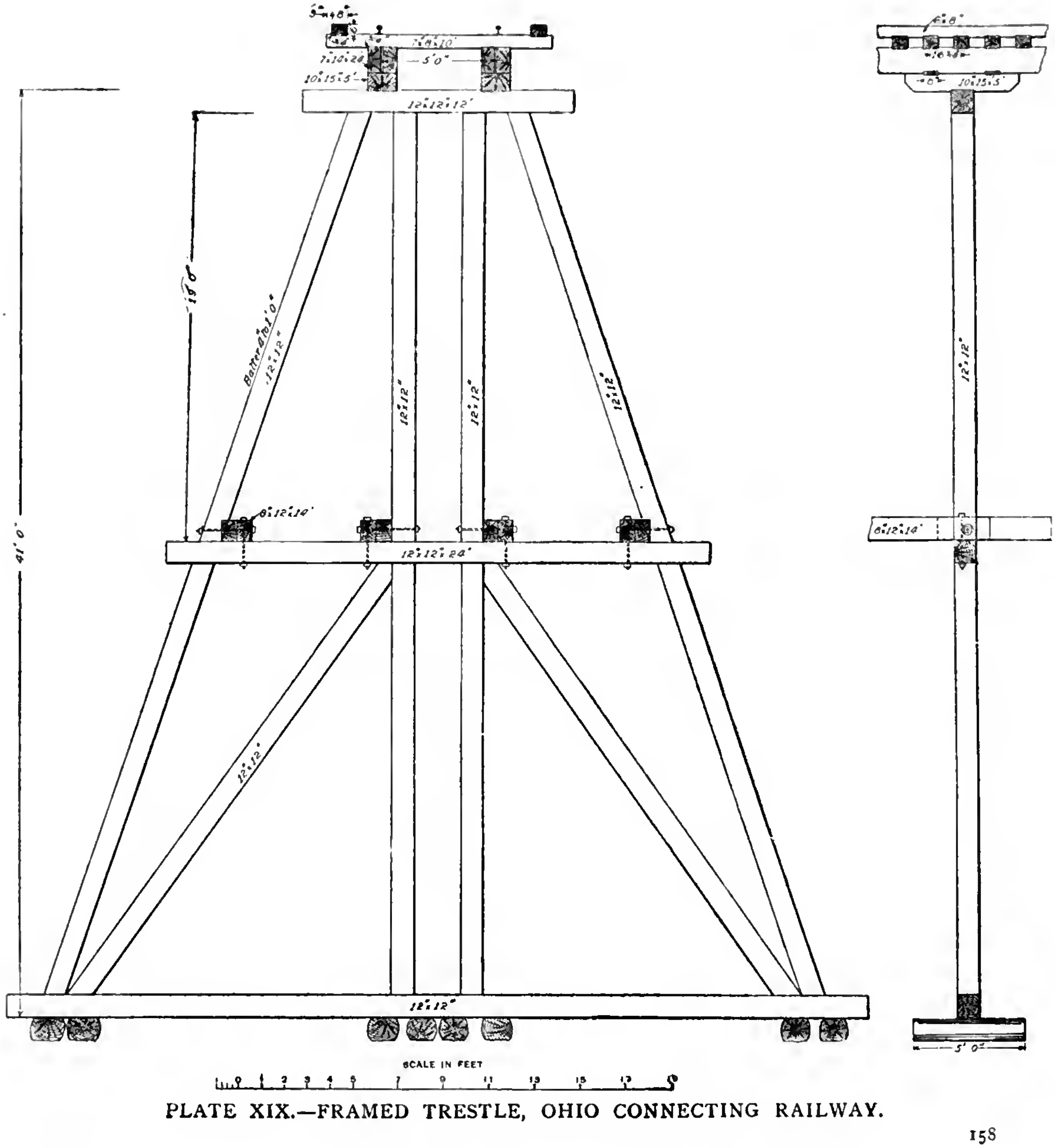


PLATE XIX.—FRAMED TRESTLE, OHIO CONNECTING RAILWAY.

Framed Trestle, Ohio Connecting Railway.—Plate XIX.

Dimensions of Timbers.

Floor-system: Guard-rails, 6 in. × 8 in., notched ¾ in. over ties.
Ties, 7 in. × 8 in. × 10 ft., notched ¾ in. over stringers.
Stringers, 7 in. × 14 in. × 24 ft.
Corbels, 10 in. × 15 in. × 5 ft., notched over caps.

Bents: Caps, 12 in. × 12 in. × 12 ft.
Plumb-posts, 12 in. × 12 in.
Batter-posts, 12 in. × 12 in.
Counter-posts, 12 in. × 12 in.
Intermediate caps, 12 in. × 12 in.
Sills, 12 in. × 12 in.

Longitudinal braces, 8 in. × 12 in. × 14 ft.

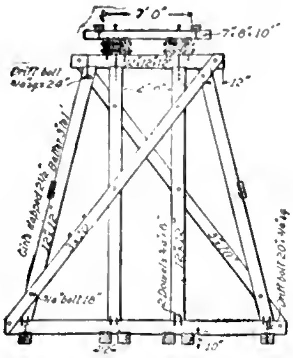


FIG. 1.—CROSS-SECTION.

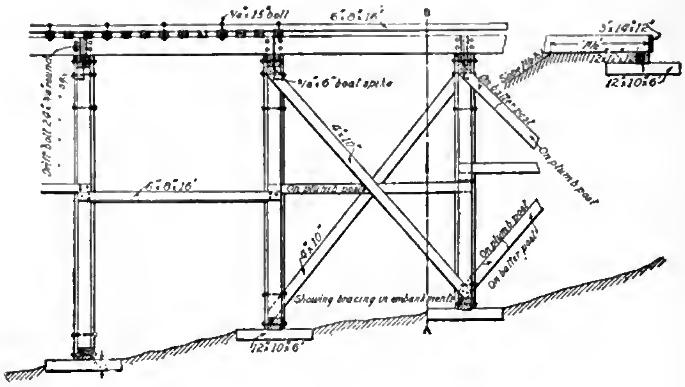


FIG. 2.—ELEVATION.

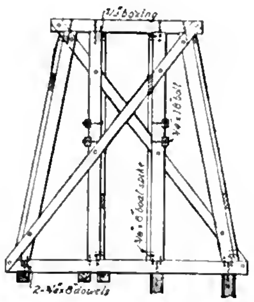


FIG. 4.—SECTION A B, SHOWING BRACING IN EMBANKMENT.

FIG. 5.—PACKING-WASHER.

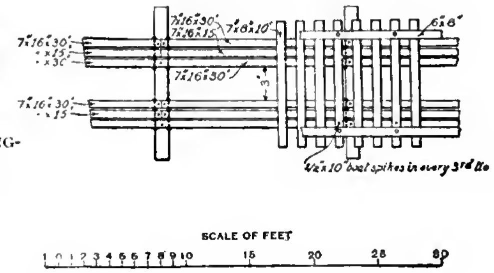


FIG. 3.—PLAN.

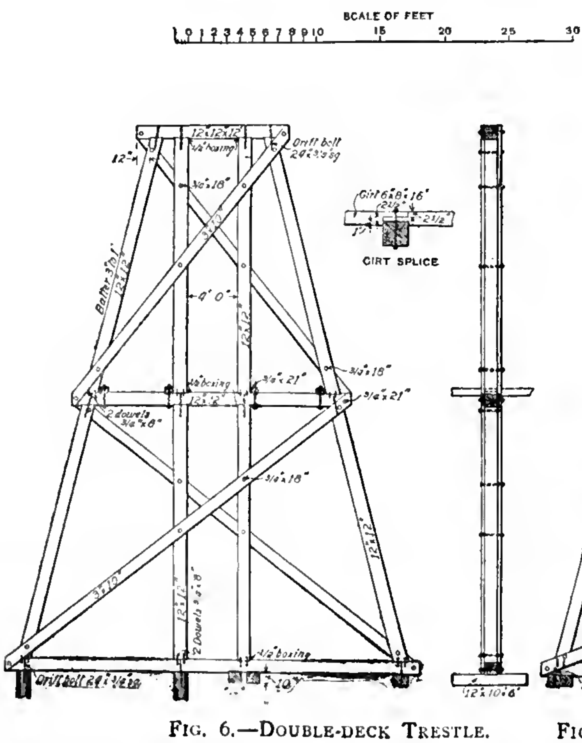


FIG. 6.—DOUBLE-DECK TRESTLE.

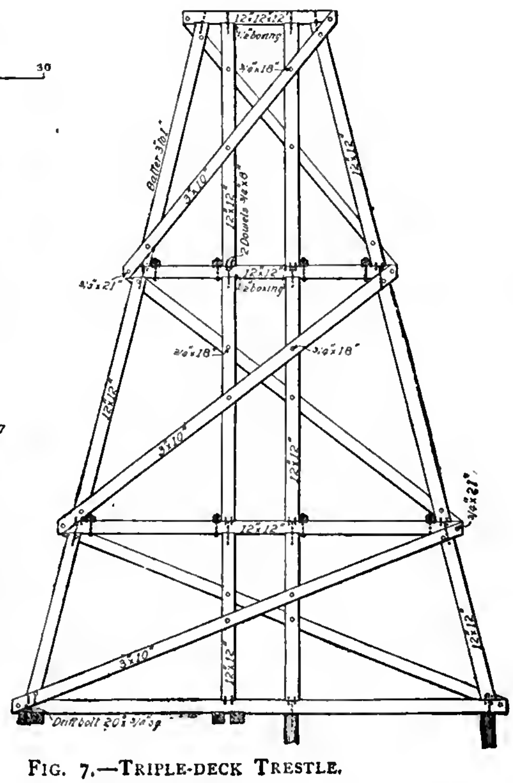


FIG. 7.—TRIPLE-DECK TRESTLE.

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.

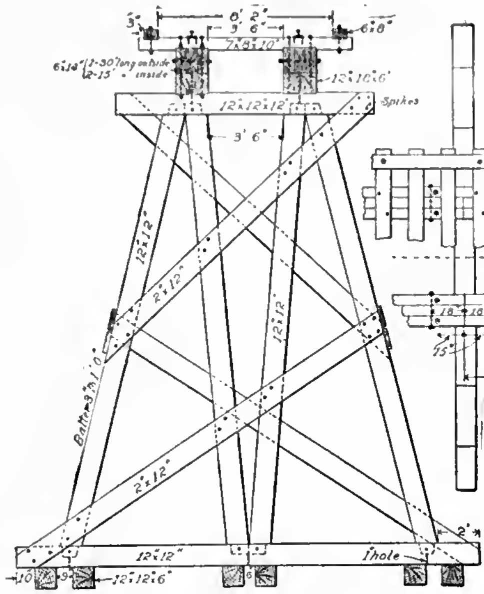


FIG. 1.—CROSS-SECTION.

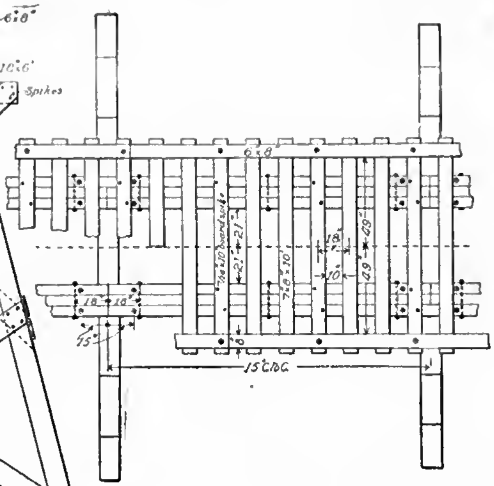


FIG. 3.—PLAN.

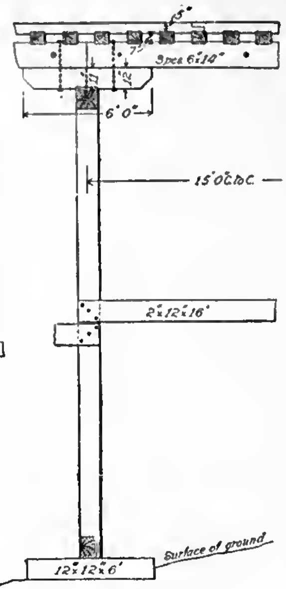
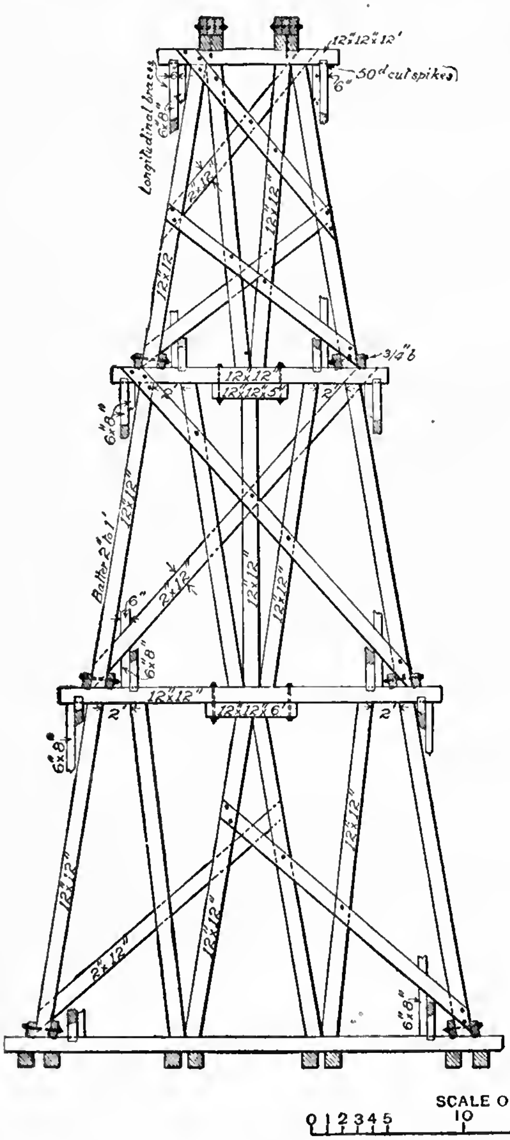
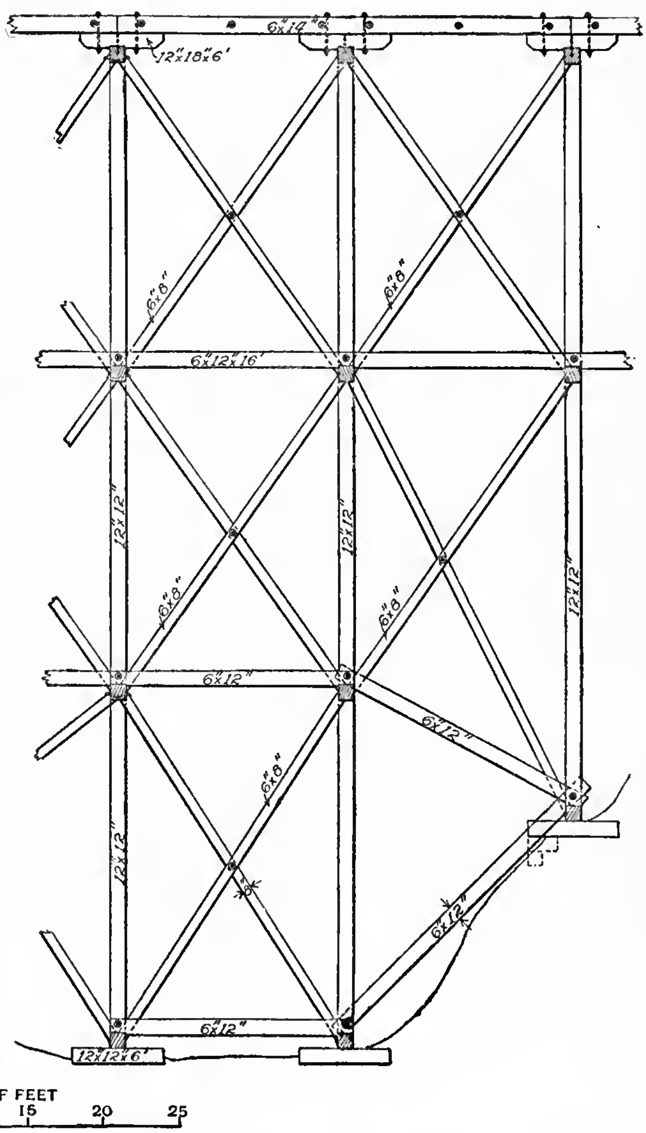


FIG. 2.—ELEVATION.

SINGLE-DECK TRESTLE.





SCALE OF FEET

0 1 2 3 4 5 10 15 20 25

FIG. 4.—CROSS-SECTION.

FIG. 5.—ELEVATION.

TRIPLE-DECK TRESTLE.

PLATE XXI.—FORMER STANDARD TRESTLE, CHARLESTON. CINCINNATI & CHICAGO RAILROAD

PLATE XXI.

Dimensions of Timbers.

Floor-system: Guard-rails, 6 in. × 8 in.
Ties, 7 in. × 8 in. × 10 ft.
Stringers, 6 in. × 14 in. × 30 ft. and 15 ft.
Corbels, 12 in. × 18 in. × 6 ft.

Bent: Cap, 12 in. × 12 in. × 12 ft.
Posts, 12 in. × 12 in.
Intermediate caps, 12 in. × 12 in.
Sway-braces, 2 in. × 12 in.
Sill, 12 in. × 12 in.

Longitudinal braces: Horizontal, 6 in. × 12 in. × 16 ft.
Diagonal, 6 in. × 8 in.

Sub-sills, 12 in. × 12 in. × 6 ft.

Dimensions of Iron Details.

Bolts: $\frac{3}{4}$ in. × 15 in.; guard-rails to ties.
$\frac{3}{4}$ in. × 19 in.; stringers to corbels.
$\frac{3}{4}$ in. × 21 in.; stringer-joints; packing-bolts.
$\frac{3}{4}$ in. × 27 in.; longitudinal braces to posts, and post-caps to intermediate caps.
—— × 15 in.; intersection of diagonal longitudinal braces.

Drift-bolts: $\frac{3}{4}$ in. × $\frac{3}{4}$ in. × 18 in.; corbels to cap.

Spikes: Boat, $\frac{7}{16}$ in. × 10 in.; ties to stringers.
Cut 50-penny; bracing to posts.

Cast washers: Under head and nut of each bolt.

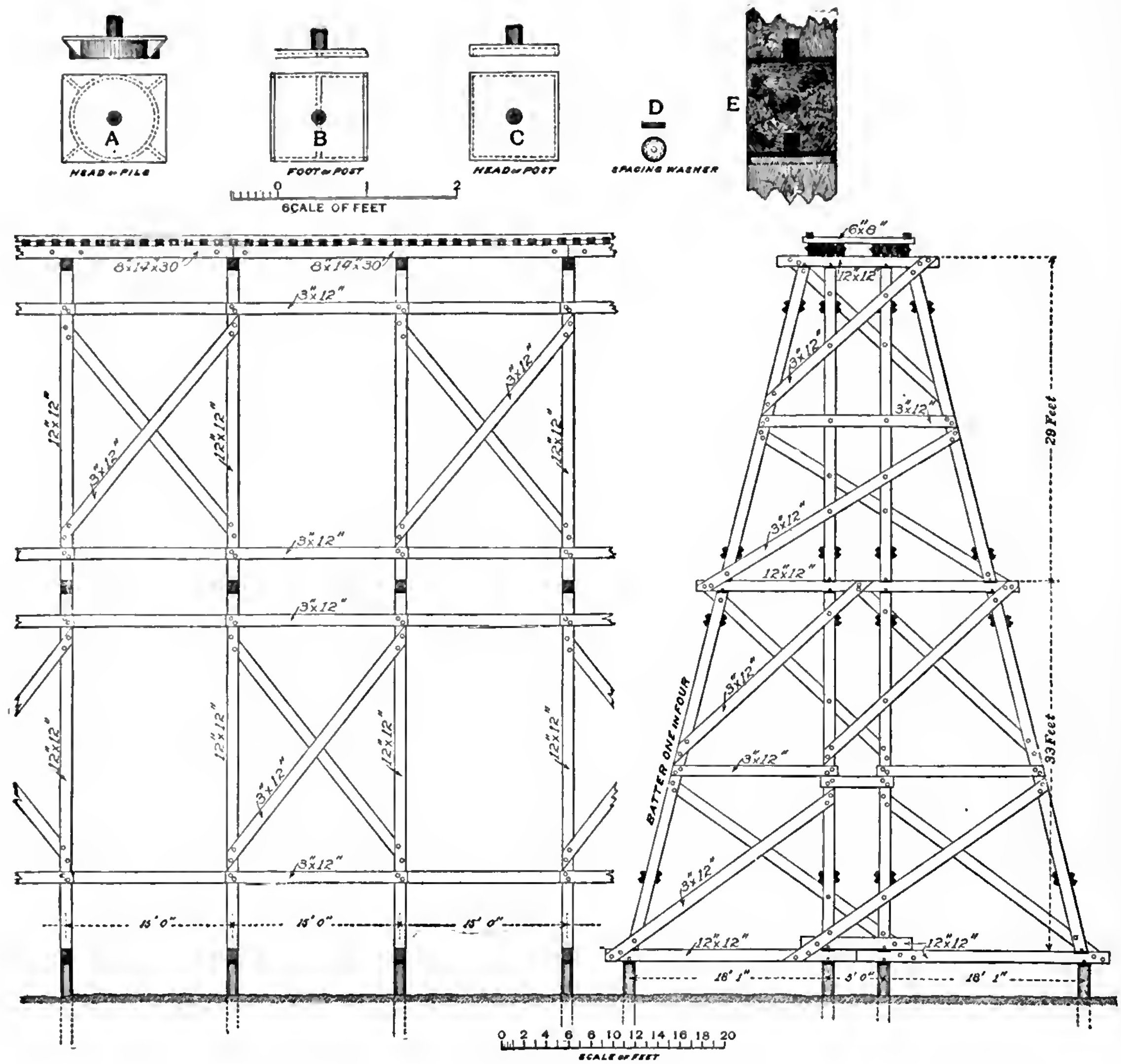


PLATE XXII.—HIGH FRAMED TRESTLES, MINNEAPOLIS & ST. LOUIS RAILWAY.

HIGH FRAMED TRESTLES, MINNEAPOLIS & ST. LOUIS RAILWAY.—PLATE XXII.

(See also Plate V.)

Dimensions of Timbers.

Floor-system: Guard-rails, 6 in. × 8 in.
Ties, 6 in. × 8 in. × 10 ft.
Stringers, 8 in. × 14 in. × 30 ft.

Bent: Cap, 12 in. × 12 in. × 14 ft.
Plumb-posts, 12 in. × 12 in.
Batter-posts, 12 in. × 12 in.
Sway-bracing: Horizontal, 3 in. × 12 in.
Diagonal, 3 in. × 12 in.
Intermediate cap, 12 in. × 12 in.
Sill, 12 in. × 12 in.
Sill-splice, 12 in. × 12 in.

Longitudinal braces: Horizontal, 3 in. × 12 in.
Diagonal, 3 in. × 12 in.

Dimensions of Iron Details.

Bolts: ¾ in. × ——; stringer-joints; packing-bolts.
—— × ——; braces to posts.

Lag-screws: —— × ——; stringer-brackets to caps.

Spikes, boat: ½ in. × 8 in.; guard-rails to ties.

Drift-bolts: ⅝ in. × 12 in.; ties to stringers.

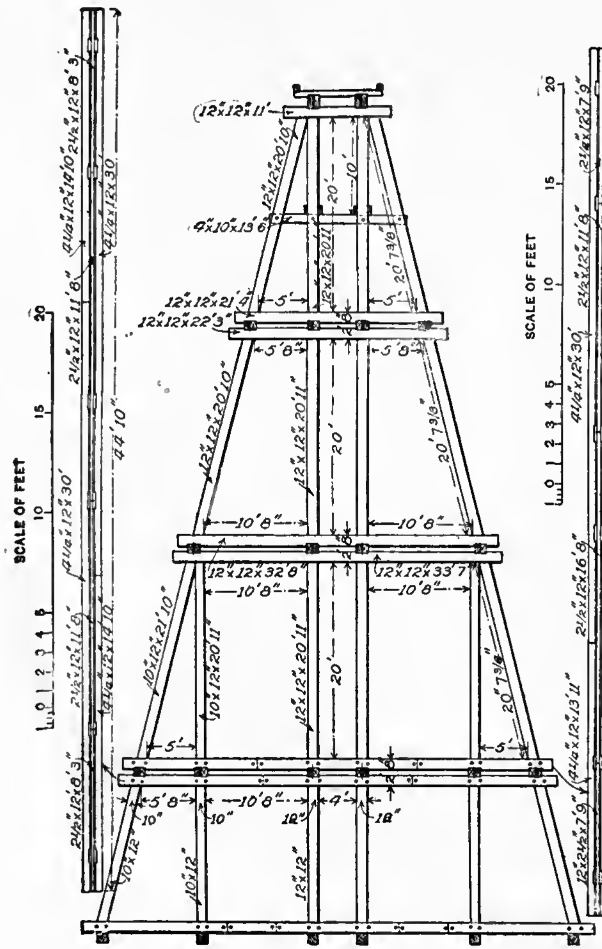
Cast separators: Between stringer-pieces.

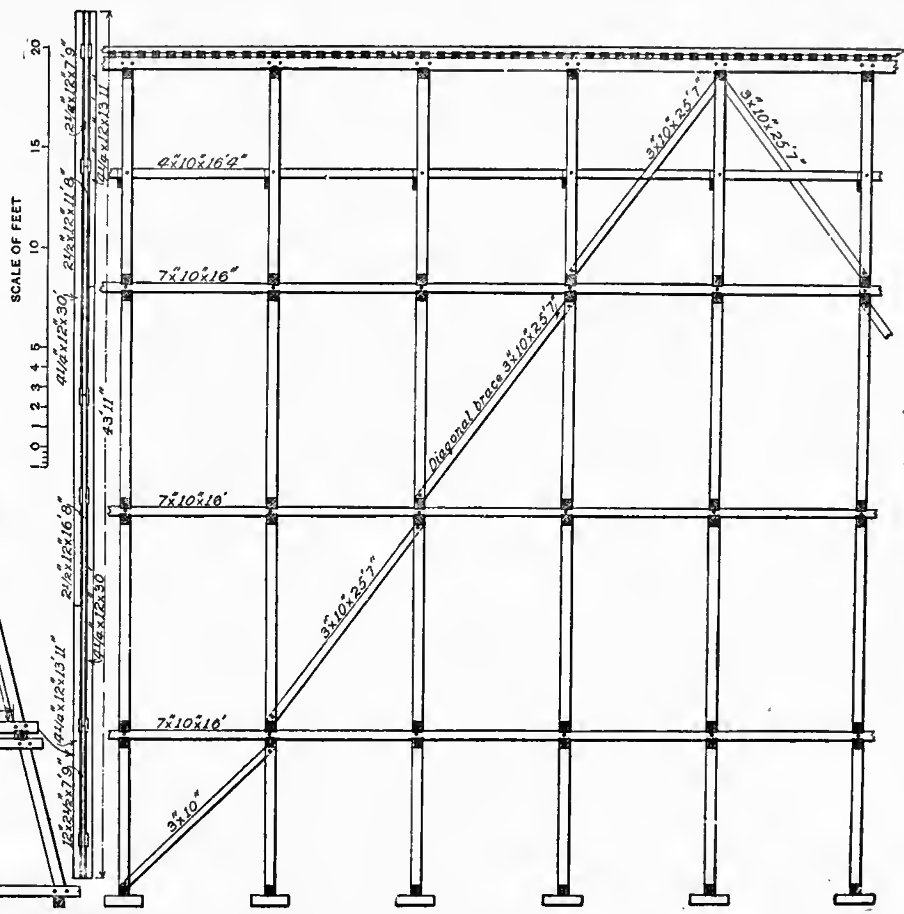
Cast washers: Under head and nut of each bolt.

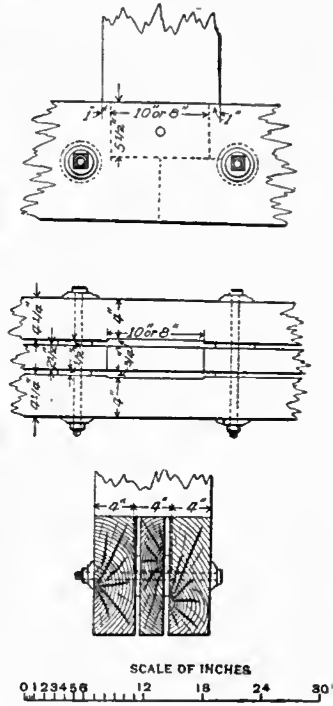
Cast brackets: Stringers to caps.

Cast pile-caps:
Cast post-caps:
Cast post foot-blocks: } As per details.

For complete description, etc., of this trestle see *Railroad Gazette*, April 17, 1891.







SCALE OF FEET

0 1 2 3 4 5 10 15 20 25 30 35

FIG. 1.—CROSS-SECTION.

FIG. 2.—ELEVATION.

FIG. 3.—DETAILS OF SPLIT-CAP AND SILL-JOINTS.

PLATE XXIII.—STANDARD FRAMED TRESTLE, GEORGIA PACIFIC RAILWAY.

STANDARD FRAMED TRESTLE, GEORGIA PACIFIC RAILWAY.—PLATE XXIII.

Dimensions of Timbers.

Floor-system: Guard-rails, 8 in. × 8 in.
Ties, 8 in. × 10 in. × 9 ft.
Stringers, 8 in. × 16 in.

Bent: Cap, 12 in. × 12 in. × 11 ft.
Plumb-posts, 12 in. × 12 in.
Batter-posts, 12 in. × 12 in., and 10 in. × 12 in.
Vertical counter-posts, 10 in. × 12 in.
Intermediate caps and sills, 12 in. × 12 in.
Compound sills and caps, $4\frac{1}{4}$ in. × 12 in., and $2\frac{1}{2}$ in. × 12 in.

Longitudinal bracing: Horizontal, 4 in. × 10 in. × 16 ft. 4 in., and 7 in. × 10 in. × 16 ft.
Diagonal, 3 in. × 10 in.

Sub sills, 12 in. × 12 in.

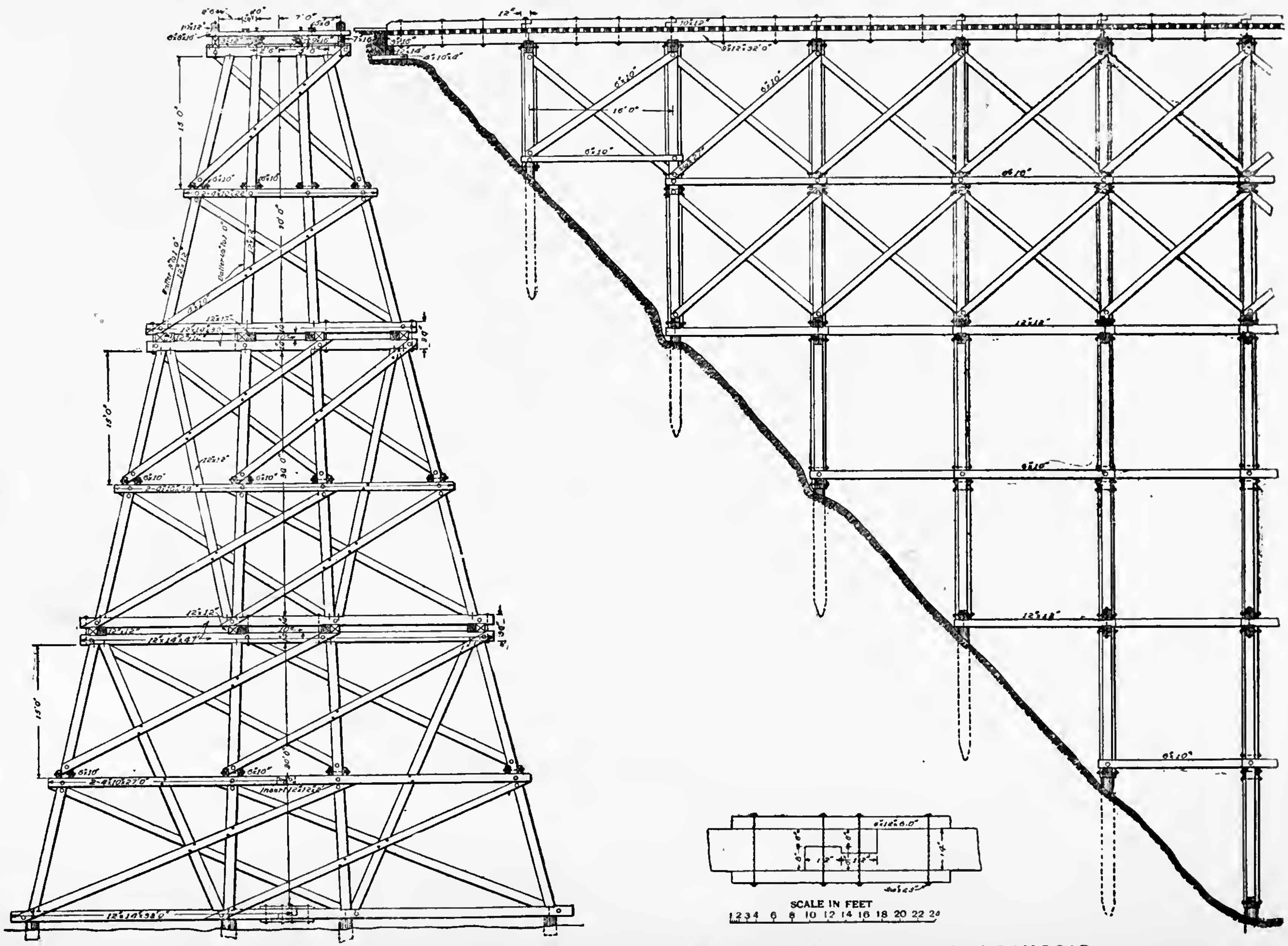


PLATE XXIV.—STANDARD FRAMED TRESTLE, OREGON & WASHINGTON TERRITORY RAILROAD.

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.; } longitudinal bracing.
 $\frac{3}{4}$ 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.

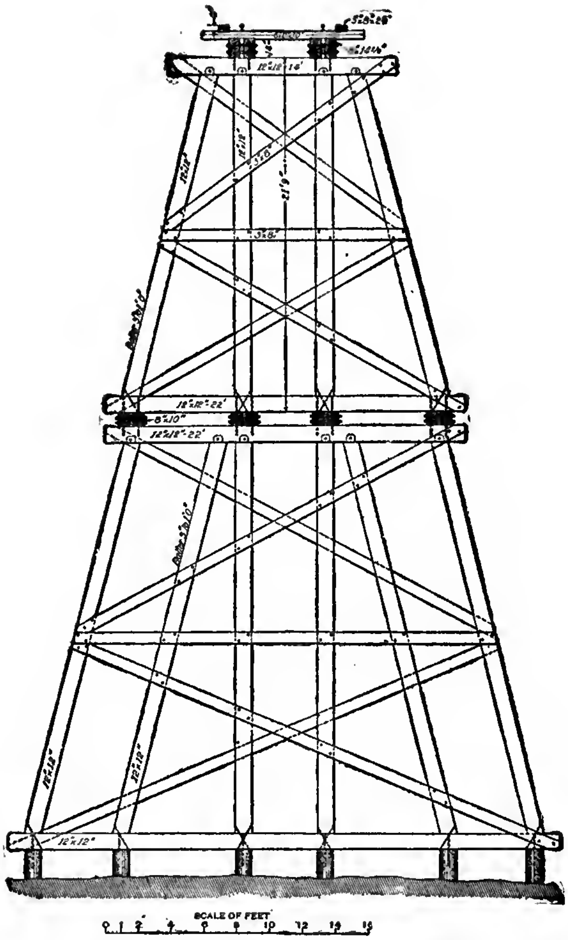


PLATE XXV.—STANDARD FRAMED TRESTLE, FORT WORTH & DENVER CITY RAILWAY.

STANDARD FRAMED TRESTLE, FORT WORTH & DENVER CITY RAILWAY

PLATE XXV.

Dimensions of Timbers.

Floor-system: Guard-rails, 5 in. × 8 in. × 29 ft.
Ties, 6 in. × 8 in. × 10 ft.
Stringers, 8 in. × 14½ in.

Bent: Cap, 12 in. × 12 in. × 14 ft.
Plumb-posts, 12 in. × 12 in.
Batter-posts, 12 in. × 12 in.
Intermediate cap and sill, 12 in. × 12 in.

Sway-bracing: Horizontal, 3 in. × 8 in.
Diagonal, 3 in. × 8 in.

Main sill, 12 in. × 12 in.

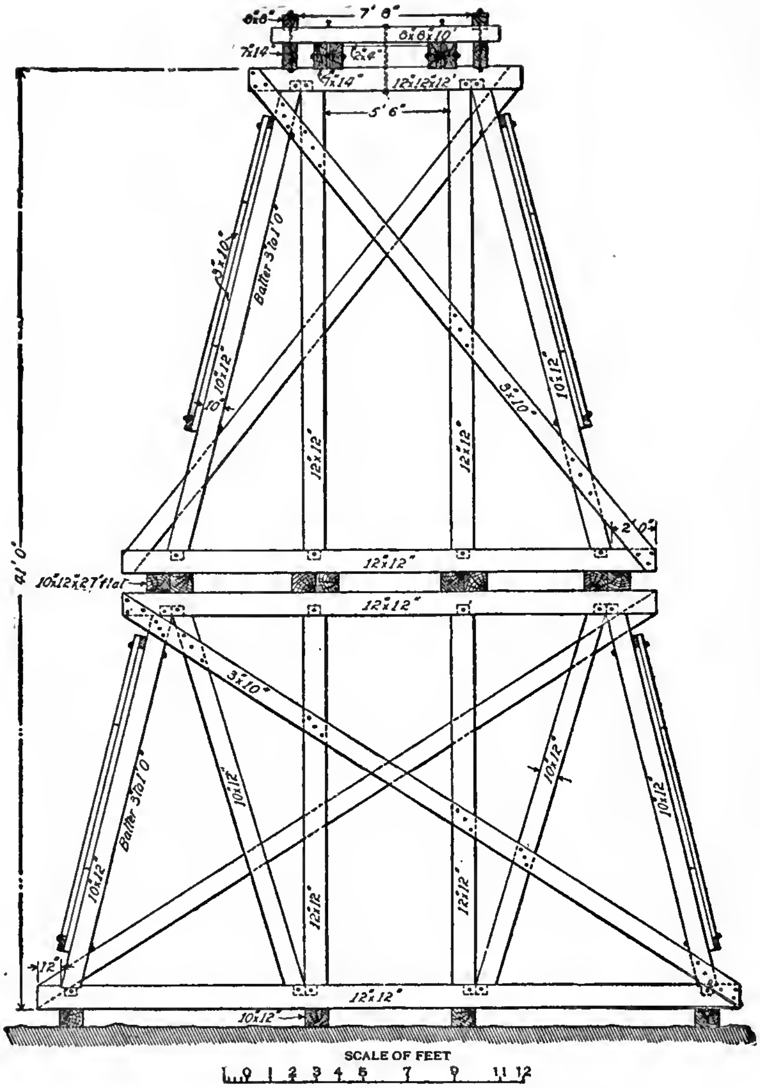


PLATE XXVI.—DOUBLE-DECK TRESTLE, RICHMOND & DANVILLE R. R.

Standard Framed Trestle, Richmond & Danville Railroad.—Plate XXVI

Dimensions of Timbers.

Floor-system: Guard-rails, 8 in. × 8 in.
Ties, 8 in. × 8 in. × 10 ft.
Stringers, 7 in. × 14 in.
Spreader, 2 in. × 4 in. × 3 ft. 9 in.

Bent: Cap, 12 in. × 12 in. × 12 ft.
Plumb-posts, 12 in. × 12 in.
Batter-posts, 10 in. × 12 in.
Counter-posts, 10 in. × 12 in.
Intermediate sills and caps, 12 in. × 12 in.
Sway-braces, 3 in. × 10 in.
Main sill, 12 in. × 12 in.

Purlins, 10 in. × 12 in. × 27 ft.
Sub-sills, 10 in. × 12 in.
Longitudinal braces, 3 in. × 10 in.

Dimensions of Iron Details.

Bolts: —— × ——; guard-rails to jack-stringers.
$\frac{5}{8}$ in. × ——; stringer-joints; packing-bolts.
—— × 36 in.; floor-system to caps.
$\frac{7}{8}$ in. × ——; longitudinal bracing to posts.

Spikes: —— × 7 in.; sway-braces to posts, etc.
——; spreaders to ties.

Cast washers: Under head and nut of each bolt.

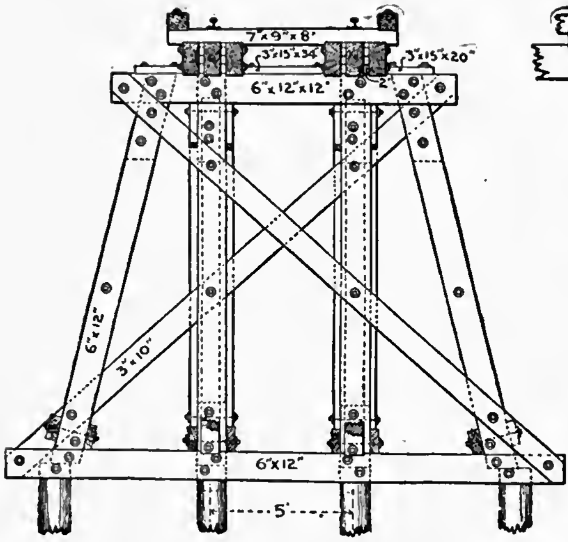


Fig. 1.—Cross-section.

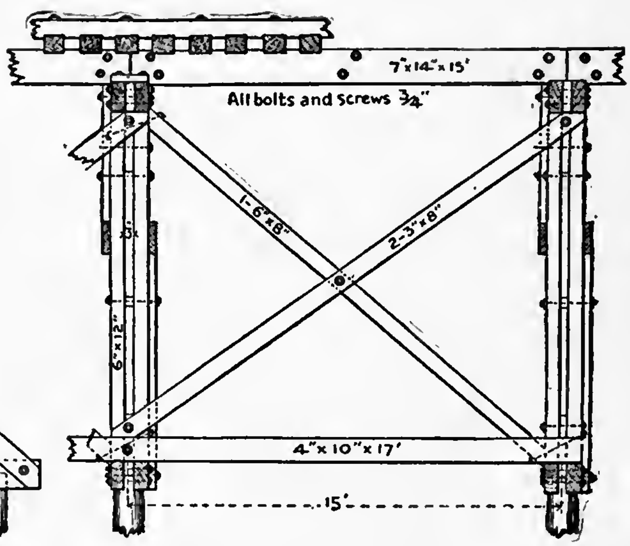


Fig. 2.—Elevation.

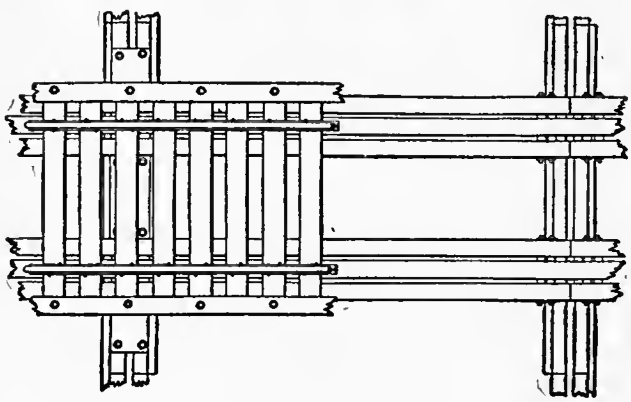


Fig. 3.—Plan.

PLATE XXVII.—STANDARD FRAMED TRESTLE, CLEVELAND & CANTON RAILROAD.

Standard Framed Trestle, Cleveland & Canton Railroad.—Plate XXVII

Dimensions of Timbers.

Floor-system: Guard-rails, 8 in. × 8 in., notched 1 in. over ties.
Ties, 7 in. × 9 in. × 8 ft., notched 1 in. over stringers.
Stringers, 7 in. × 14 in. × 15 ft., notched 1 in. over caps.
Brace-blocks, { 3 in. × 15 in. × 20 in.
3 in. × 15 in. × 34 in.

Bents: Caps, 6 in. × 12 in. × 12 ft.
All posts, 6 in. × 12 in.
Sills, 6 in. × 12 in.
Sway-braces, 3 in. × 10 in.
Tenon-blocks, 3 in. × 12 in. × 3 ft.

Longitudinal braces: Girts, 4 in. × 10 in. × 17 ft.
Diagonals, { 6 in. × 8 in.
3 in. × 8 in.

Dimensions of Iron Details.

Bolts: $\frac{3}{4}$ in. × 18 in.; post, sill, and cap; packing-bolts.
$\frac{3}{4}$ in. × 28 in.; stringer-joints; packing-bolts.
$\frac{3}{4}$ in. × 21 in.; sway-braces to posts.
$\frac{3}{4}$ in. × ——; diagonal longitudinal braces to pos
$\frac{3}{4}$ in. × 17 in.; diagonal longitudinal braces to posts; intersection of diagonals.

Lag-screws: $\frac{3}{4}$ in. × ——, { guard-rails to ties.
brace-blocks to caps.

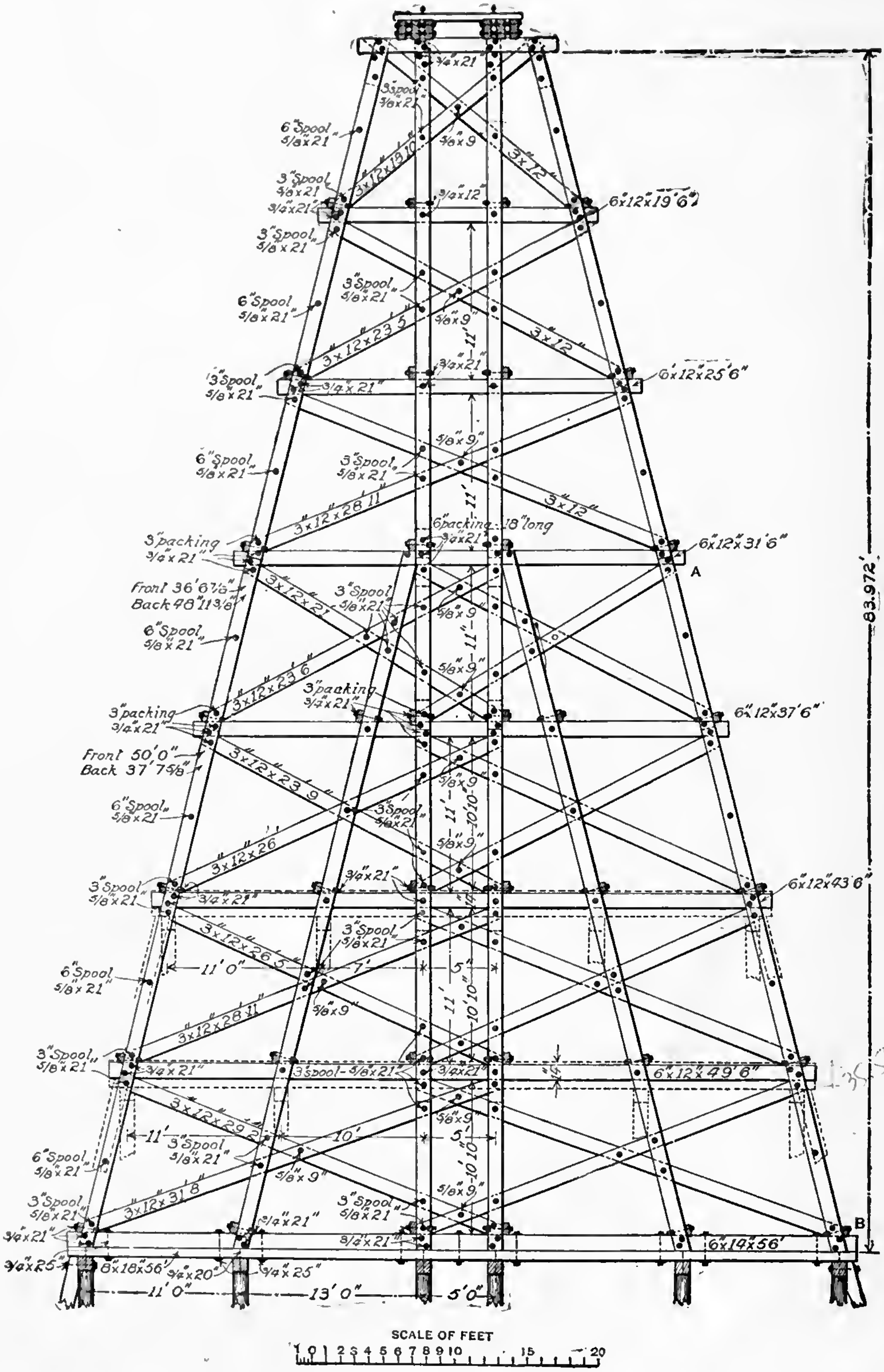


FIG. 1.—CROSS-SECTION.

PLATE XXVIII.—STANDARD TRESTLE, CALIFORNIA CENTRAL RAILWAY.

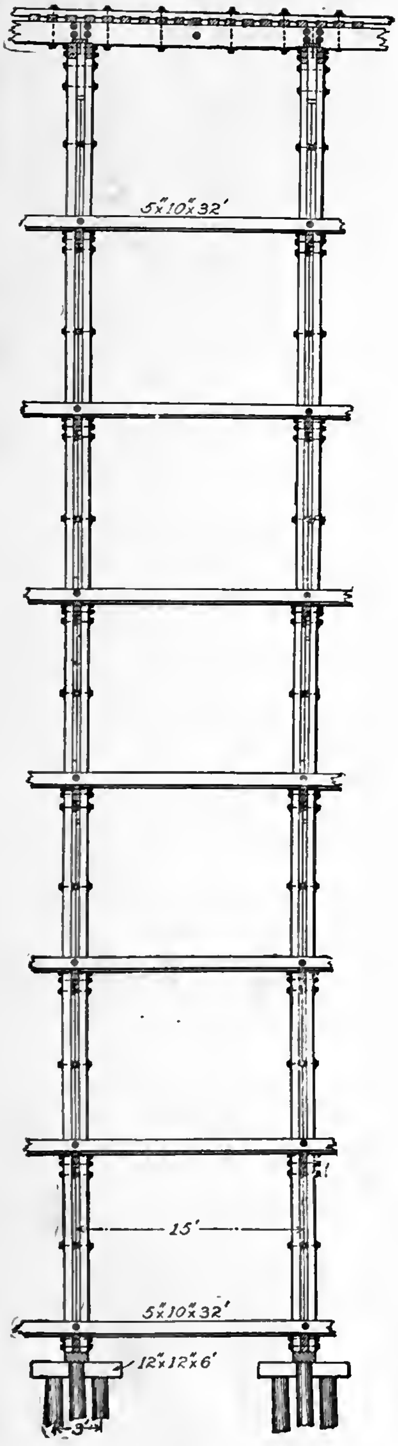


FIG. 2. –ELEVATION.

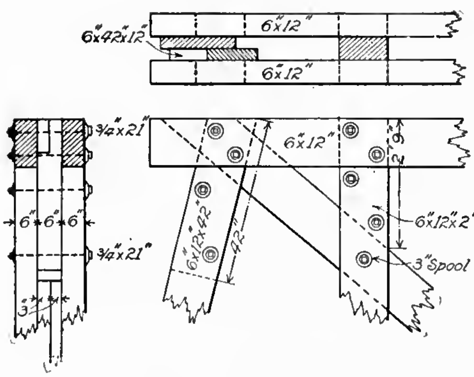


FIG. 3.—CAP AND POST JOINT.

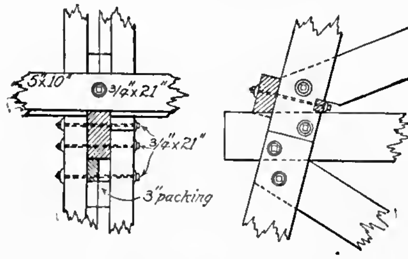


FIG. 4.—POST-SPLICE.

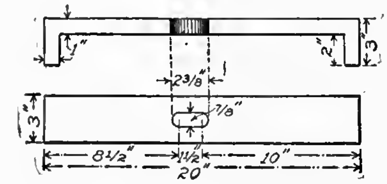


FIG. 5.—STRAP.

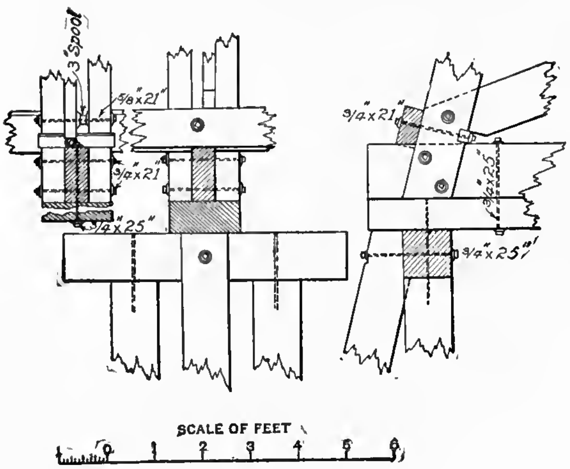


FIG. 6.—SILL AND POST JOINT DETAILS.

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. × 8 in., notched.
Ties, 6 in. × 8 in. × 9 ft., notched.
Stringers, 8 in. × 16 in. × 30 ft.
Bents: Caps, 6 in. × 12 in. × 14 ft.
All posts, 6 in. × 12 in.
Intermediate caps, 6 in. × 12 in.
Diagonal sway-braces, 3 in. × 12 in.
Sill, 6 in. × 14 in.
Under part of sill, 8 in. × 18 in.
Pile-caps, 12 in. × 12 in. × 6 ft.
Packing-blocks between posts and cap-pieces, 6 in. × 12 in. × 42 in., and 6 in. × 12 in. × 2 ft. 9 in.
Longitudinal braces, 5 in. × 10 in. × 32 ft.

Dimensions of Iron Details.

Bolts: Guard-rails to stringers.
Stringer-joints; packing-bolts.
$\frac{5}{8}$ in. × 21 in.; sway-braces to posts.
$\frac{5}{8}$ in. × 9 in.; intersection of sway-braces.
$\frac{3}{4}$ in. × 21 in.; intermediate caps to posts; girts to posts.
$\frac{3}{4}$ in. × 25 in.; two parts of sill together; brace-pile to pile-caps.
Drift-bolts: $\frac{3}{4}$ in. × 20 in. sill to pile-caps; caps to piles.
Cast washers: Under head and nut of each bolt.
Cast separators or spools: 3 in. × —— and 6 in. × ——.
Cast strap: 20 in. × 3 in. × 1 in. as per detail; girts to posts.

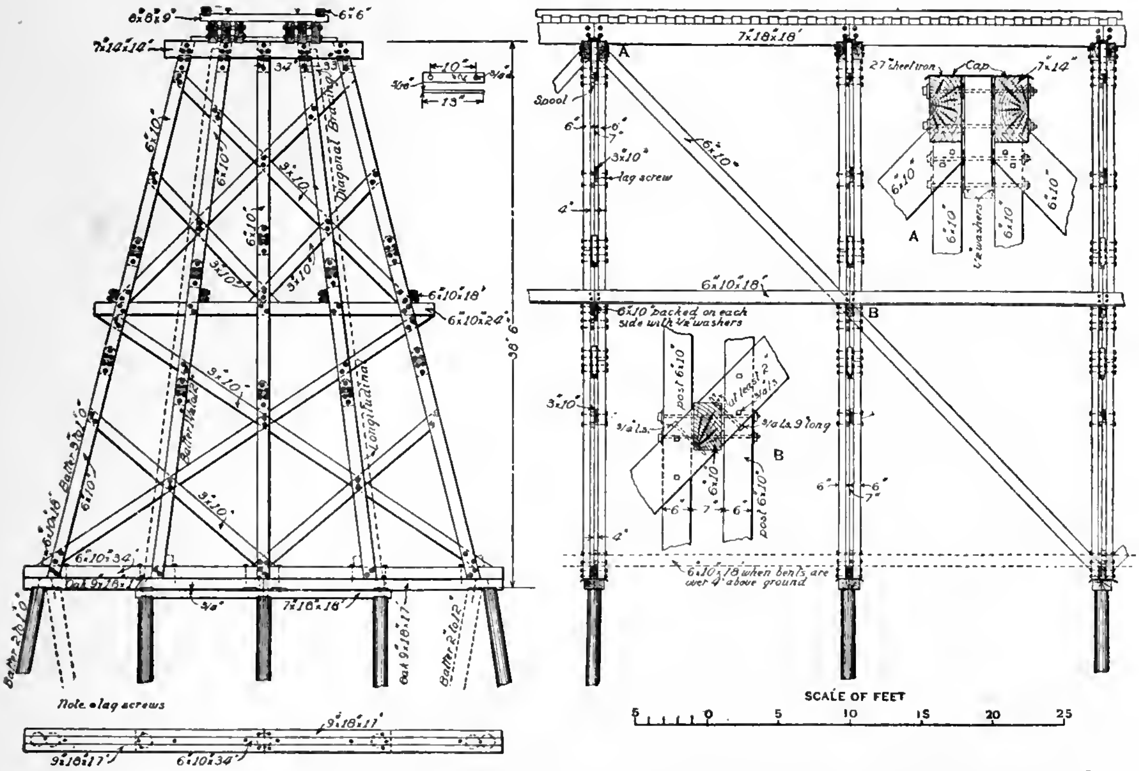


PLATE XXX.—STANDARD FRAMED TRESTLE, TOLEDO, ST. LOUIS & KANSAS CITY RAILROAD.

STANDARD FRAMED TRESTLE, TOLEDO, ST. LOUIS & KANSAS CITY RAILROAD.
PLATE XXX.

Dimensions of Timbers.

Floor-system: Guard-rails, 6 in. × 6 in. × 18 ft.
Ties, 6 in. × 8 in. × 9 ft.
Stringers, 7 in. × 18 in. × 18 ft.
Spreader, 3 in. × 12 in. × 3 ft.
Brace-blocks, 3 in. × 12 in. × 15 in.

Bent: Cap, 7 in. × 14 in. × 14 ft.
Plumb-post, 6 in. × 10 in.
Inclined posts, 6 in. × 10 in.
Splice-blocks, 6 in. × 10 in. × 2 ft.
Sway-bracing: Horizontal, 6 in. × 10 in.
Diagonal, 3 in. × 10 in.
Sill, 6 in. × 10 in., 9 in. × 18 in., and 7 in. × 18 in.

Longitudinal bracing: Horizontal, 6 in. × 10 in. × 18 ft.
Diagonal, 6 in. × 10 in.

Dimensions of Iron Details.

Bolts: $\frac{5}{8}$ in. × 31 in.; stringer-joints; packing-bolts.
$\frac{5}{8}$ in. × 23 in.; cap-pieces together.
$\frac{5}{8}$ in. × 21 in.; post-splices, sway-brace intersections, posts to tenon-blocks, posts to sill.

Lag-screws: $\frac{3}{4}$ in. × 9 in.; sway-braces to posts, longitudinal braces to posts, etc.; spreader and brace blocks to cap.
$\frac{3}{4}$ in. × 14 in.; sill-pieces together.

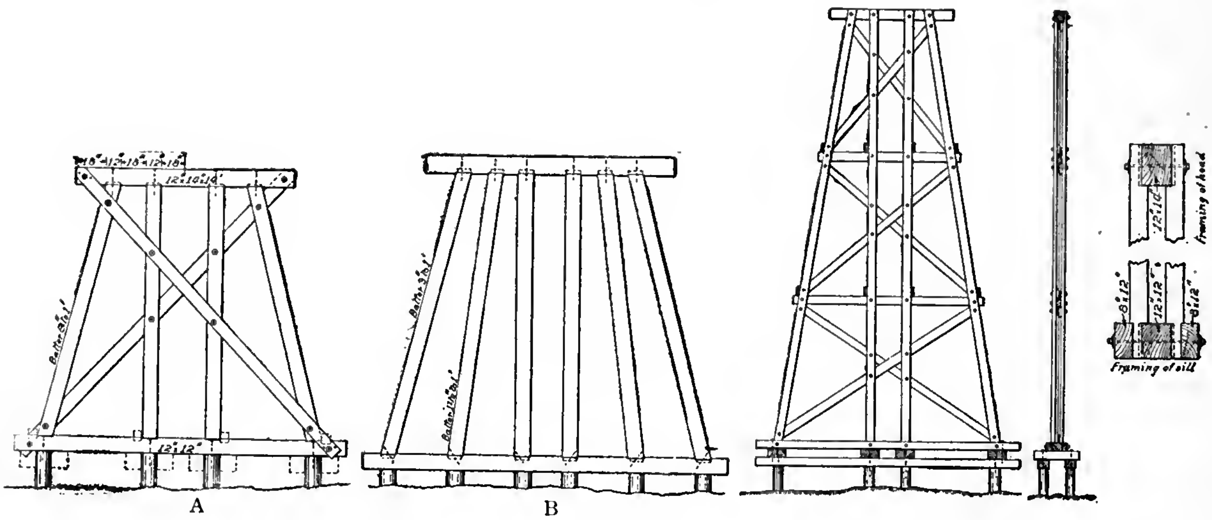
Drift-bolts: $\frac{3}{4}$ in. × $\frac{3}{4}$ in. × 20 in.; sill to piles.

Cast-separators: 4 in. thick, $\frac{1}{2}$ in. " } for $\frac{5}{8}$-in. bolts.

Cast-washers: Under head and nut of each bolt.

Splice-plates: $\frac{5}{16}$ in. × 2 in. × 13 in.; stringer-joints.

Sheet-iron: No. 27, 30 in. × 36 ft.; covering stringers.
No 27, 24 in. × 14 ft.; covering caps.
No. 27, —— × 34 ft.; covering sill.
Also, sheet-iron to cover all places where fire can lodge.



A B

FIG. 1.—FRAMED BENTS. FIG. 2.—40 TO 90 FT. HIGH.

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.

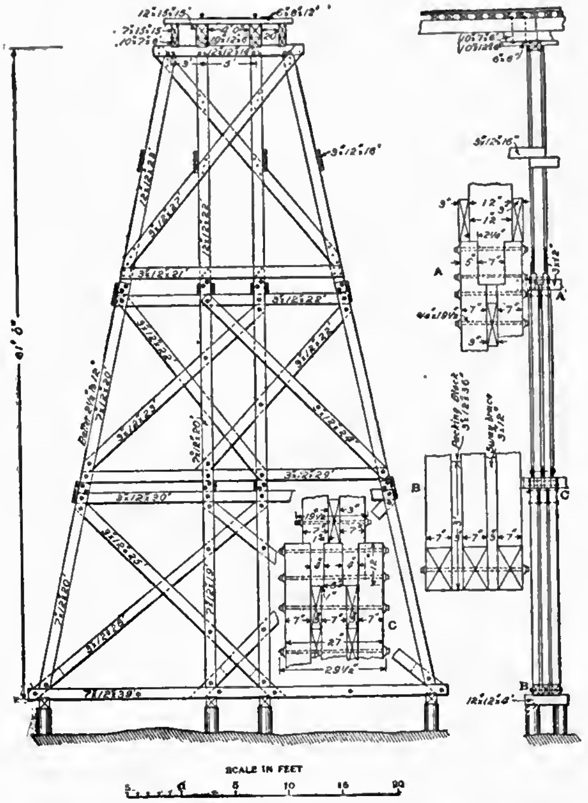


Fig. 1.—Double and Triple Deck Framed Trestle.

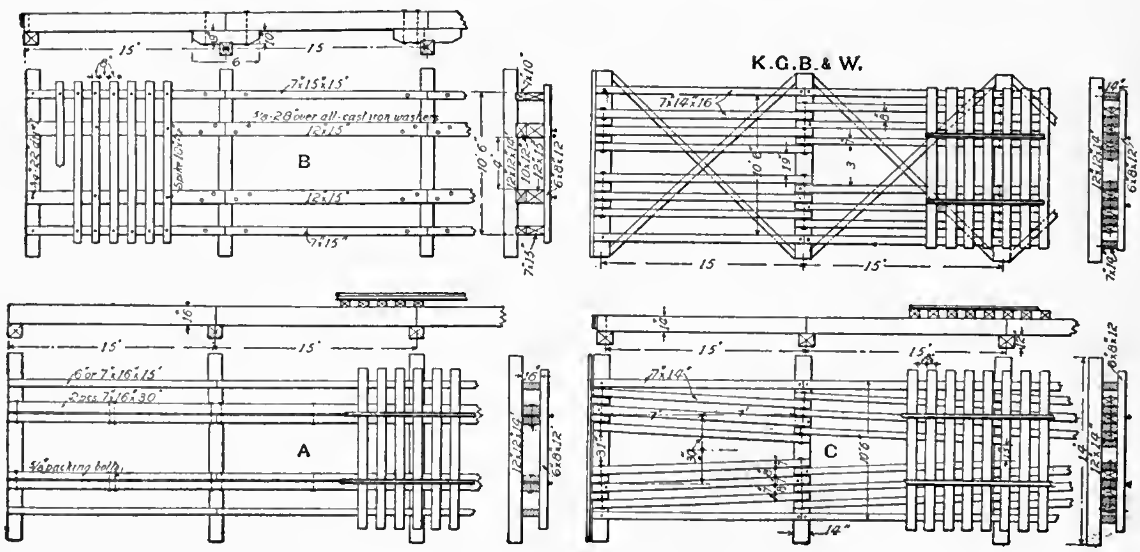


Fig. 2.—Floor-systems of Trestle-bridges.

PLATE XXXII.—STANDARD FRAMED TRESTLE, MILWAUKEE & NORTHERN RAILROAD.

STANDARD FRAMED TRESTLE, MILWAUKEE & NORTHERN RAILROAD.—PLATE XXXII.

Dimensions of Timbers.

Floor-systems—A: Ties, 6 in. × 8 in. × 12 ft.
Track-stringers, 7 in. × 16 in. × 30 ft.
Jack-stringers, 6 in. or 7 in. × 16 in. × 15 ft.
B: Ties, 6 in. × 8 in. × 12 ft.
Track-stringers, 12 in. × 15 in. × 15 ft.
Jack stringers, 7 in. × 15 in. × 15 ft.
Track-stringer corbels, 10 in. × 12 in. × 6 ft.
Jack-stringer corbels, 7 in. × 10 in. × 6 ft.
C: Ties, 6 in. × 8 in. × 12 ft.
Track-stringers, 7 in. × 14 in. × 16 ft.
Jack-stringers, 7 in. × 14 in. × 15 ft.
K., G. B. & W. R. R.:
Ties, 6 in. × 8 in. × 12 ft.
Track-stringers, 7 in. × 14 in. × 16 ft.
Jack-stringers, 7 in. × 14 in. × 16 ft.

Bent: Cap, 12 in. × 12 in. × 14 ft.
Plumb-posts, 12 in. × 12 in., and 7 in. × 12 in.
Batter-posts, 12 in. × 12 in., and 7 in. × 12 in.
Intermediate caps and sills, 3 in. × 12 in.
Sway-braces, 3 in. × 12 in.
Main sill, 7 in. × 12 in.
Packing-blocks, 3 in. × 12 in. × 3 ft.

Pile-caps: 12 in. × 12 in. × 4 ft.

Longitudinal braces: 3 in. × 12 in. × 16 ft.

Dimensions of Iron Details.

Bolts: ¾ in. × 19½ in.
¾ in. × 22½ in.
¾ in. × 29½ in.

Spikes: —— × ——.

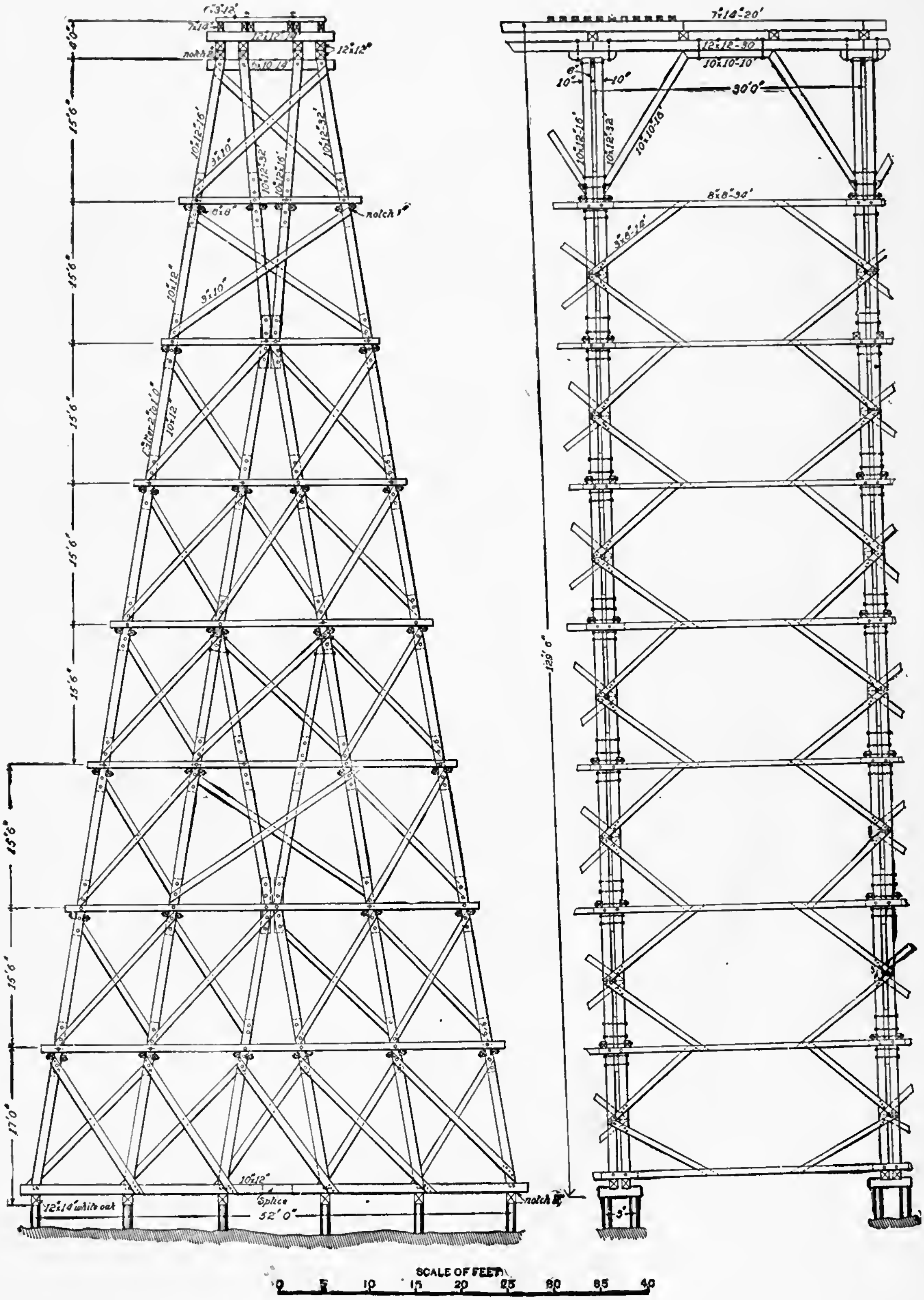


FIG. 1.—CROSS-SECTION.

FIG. 2.—ELEVATION.

PLATE XXXIII.—FRAMED TRESTLE, ST. PAUL, MINNEAPOLIS & MANITOBA RAILROAD.

FRAMED TRESTLES, ST. PAUL, MINNEAPOLIS & MANITOBA RAILROAD.—PLATES XXXIII AND XXXIV.

Dimensions of Timbers.

FIGS. 1 AND 2.

Floor-system: Ties, 6 in. × 8 in. × 12 ft.
Track-stringers, 7 in. × 14 in. × 20 ft.
Jack-stringers, 7 in. × 14 in. × 20 ft.
Floor-beams, 12 in. × 12 in. × 14 ft.
Sub-stringers, 12 in. × 12 in. × 30 ft.
Corbels, 12 in. × 12 in. × 5 ft.

Bent: Cap, 6 in. × 10 in. × 14 ft.
Posts, 10 in. × 12 in.
Sway-bracing: Horizontal, 8 in. × 8 in.
Diagonal, 3 in. × 10 in.
Splice-blocks, 6 in. × 12 in. × 6 ft.
Sill, 10 in. × 12 in.

Pile-caps, 12 in. × 14 in.

Knee-braces: Top cord, 10 in. × 10 in. × 10 ft.
Diagonals, 10 in. × 10 in. × 18 ft.

Longitudinal braces: Horizontal, 8 in. × 8 in. × 34 ft.
Brackets, 3 in. × 8 in. × 14 ft.

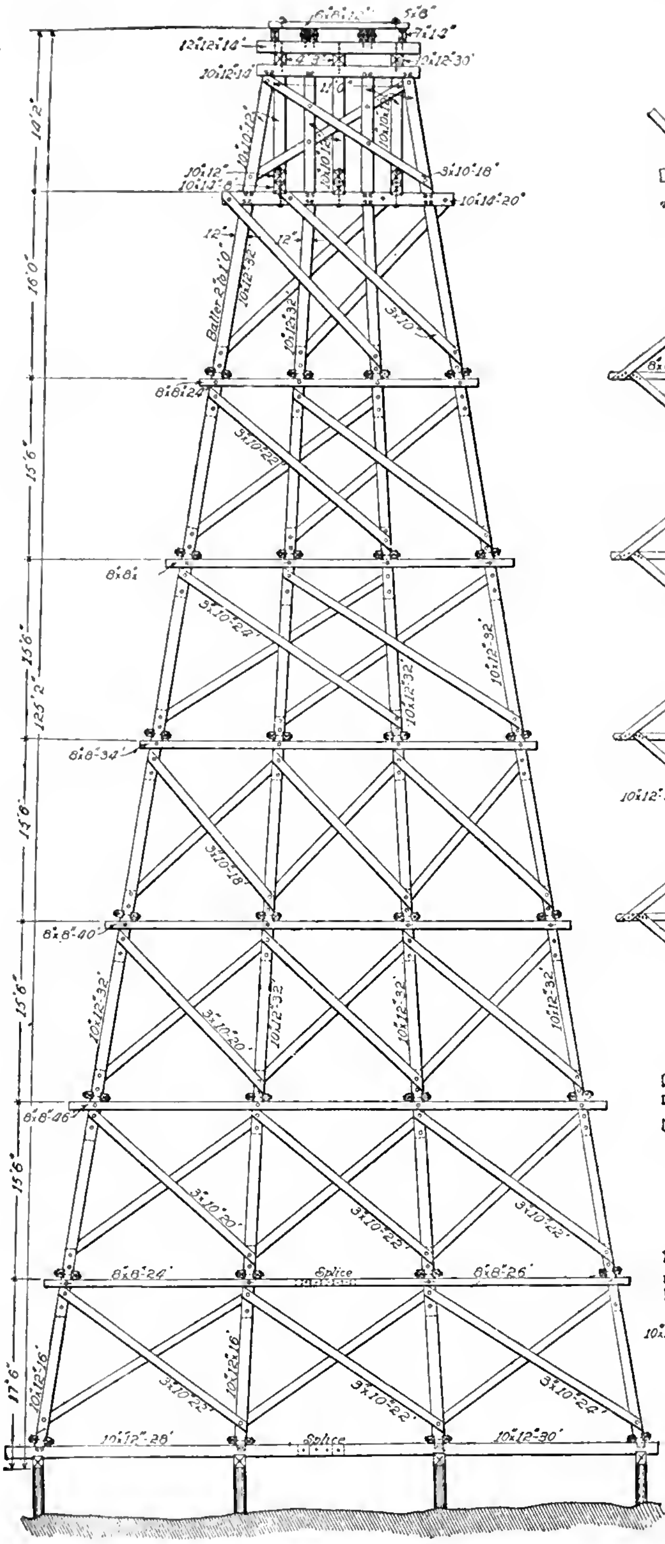
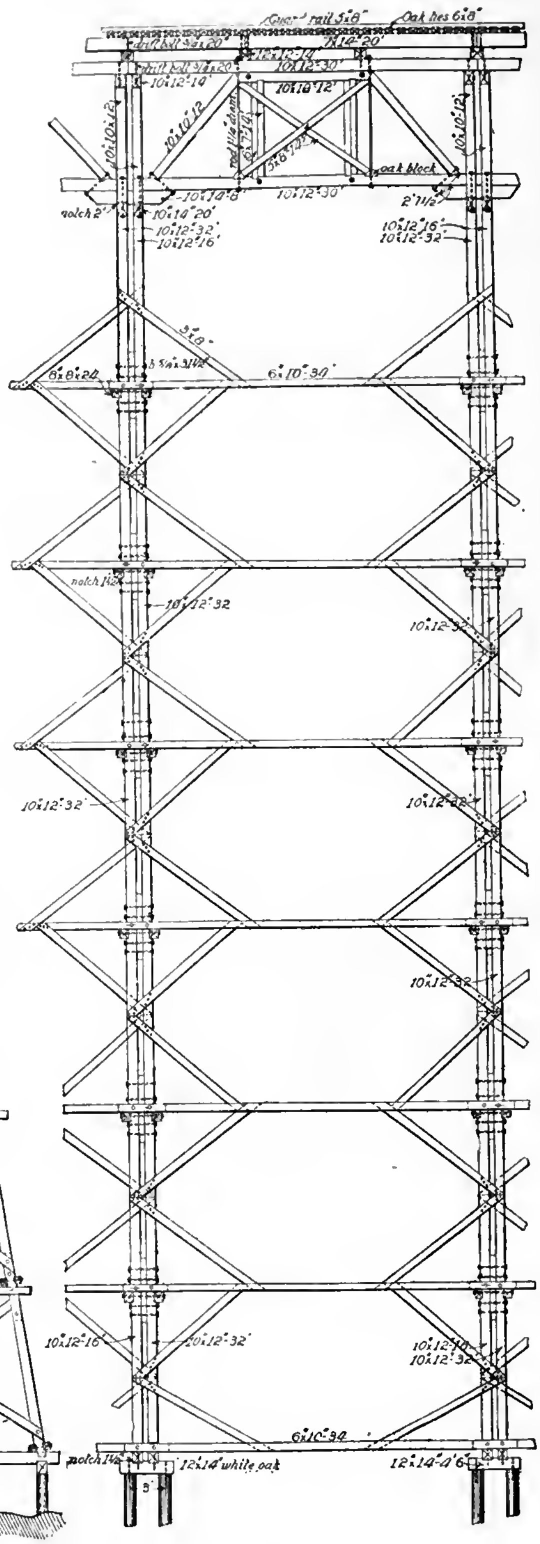


Fig. 3.—Cross-section.



SCALE OF FEET
0 5 10 20 30 35

Fig. 4.—Elevation.

PLATE XXXIV.—FRAMED TRESTLE, ST. PAUL, MINNEAPOLIS & MANITOBA RAILROAD.

FIGS. 3 AND 4.

Floor-system: Guard-rails, 5 in. × 8 in.
Ties, 6 in. × 8 in. × 12 ft.
Track-stringers, 7 in. × 14 in. × 20 ft.
Jack-stringers, 7 in. × 14 in. × 20 ft.
Floor-beams, 12 in. × 12 in. × 14 ft.
Sub-stringers, 10 in. × 12 in. × 30 ft.

Bent: Upper cap, 10 in. × 12 in. × 14 ft.
Lower cap, 10 in. × 14 in. × 20 ft.
Upper posts, 10 in. × 10 in.
Main posts, 10 in. × 12 in.
Sway-bracing: Horizontal, 8 in. × 8 in.
Diagonal, 3 in. × 10 in.
Splice-blocks, 6 in. × 12 in. × 6 ft.
Sill, 10 in. × 12 in.
Sway-brace splice-block, 6 in. × 8 in. × 5 ft.
Sill splice-block, 6 in. × 12 in. × 4 ft.

Pile-caps, 12 in. × 14 in. × 4 ft. 6 in.

Longitudinal bracing: Horizontal, 6 in. × 10 in. × 34 ft.
Brackets, 3 in. × 8 in.

Floor trusses: Upper chord, 10 in. × 10 in. × 12 ft.
Lower chord, 10 in. × 12 in. × 30 ft.
End-posts, 10 in. × 10 in. × 12 ft.
Diagonals, 5 in. × 8 in. × 14 ft.
Lateral braces, 6 in. × 7 in. × 14 ft.
Foot-blocks: Corbels, 10 in. × 14 in. × 8 ft.

Dimensions of Iron Details.

Bolts: $\frac{5}{8}$ in. × $12\frac{1}{2}$ in.; guard-rails to ties.
$\frac{5}{8}$ in. × $17\frac{1}{2}$ in.; stringer-joints; packing-bolts.
$\frac{5}{8}$ in. × $27\frac{1}{2}$ in.; longitudinal braces to posts.
$\frac{5}{8}$ in. × $28\frac{1}{2}$ in.; post-joints.
$\frac{5}{8}$ in. × $31\frac{1}{2}$ in.; diagonal sway-braces to posts.
$\frac{5}{8}$ in. × $41\frac{1}{2}$ in.; horizontal sway-braces to posts.

Drift-bolts: $\frac{3}{4}$ in. × 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. × 10 in.; ties to stringers.
$\frac{3}{8}$ in. × 7 in.; sway-bracing to posts; bracket-braces to posts; and longitudinal bracing.

Iron in trusses: Rods, $1\frac{1}{4}$ in. × 11 ft. 4 in.; between upper and lower chords.
Tie-rods, —— × ——; three trusses together.

Bolts: —— × ——; intersection of panel diagonals.
—— × 2 ft. 11 in.; end-posts to lower chords.
—— × 3 ft. $5\frac{1}{2}$ in.; lower chords and corbels to caps.

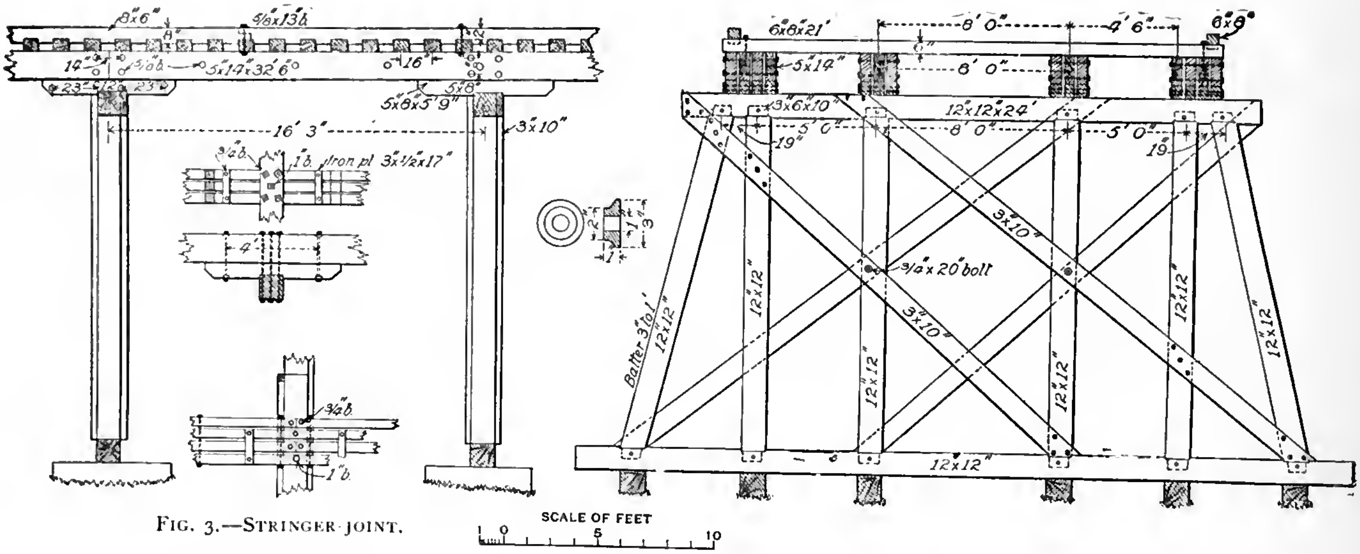


FIG. 3.—STRINGER-JOINT.

FIG. 1.—ELEVATION.

FIG. 2.—CROSS-SECTION.

PLATE XXXV.—DOUBLE-TRACK FRAMED TRESTLE, NEW YORK, WOODHAVEN & ROCKAWAY RAILROAD.

DOUBLE-TRACK FRAMED TRESTLE, NEW YORK, WOODHAVEN & ROCKAWAY RAILROAD.—
PLATE XXXV.

Dimensions of Timbers.

Floor-system : Guard-rails, 8 in. × 6 in.
Ties, 6 in. × 8 in. × 21 ft.
Stringers, 5 in. × 14 in. × 32 ft. 6 in.
Corbels, 5 in. × 8 in. × 5 ft. 9 in.

Bent: Cap, 12 in. × 12 in. × 24 ft.
Plumb-posts, 12 in. × 12 in.
Batter-posts, 12 in. × 12 in.
Sway-braces, 3 in. × 10 in.
Sill, 12 in. × 12 in.
Sub-sills,

Dimensions of Iron Details.

Bolts: $\frac{5}{8}$ in. × 13 in.; guard-rails to ties.
$\frac{5}{8}$ in. × —— in.; stringer-joints; packing-bolts.
$\frac{3}{4}$ in. × —— in.; stringers to corbels.
$\frac{3}{4}$ in. × ——; } stringers to caps.
1 in. × ——; }

Plates: $\frac{1}{2}$ in. × 3 in. × 17 in.; corbel-bolts.
Spikes: Ties to stringers.
Cast-washers: 1 in. × 3 in.; under head and nut of each bolt.

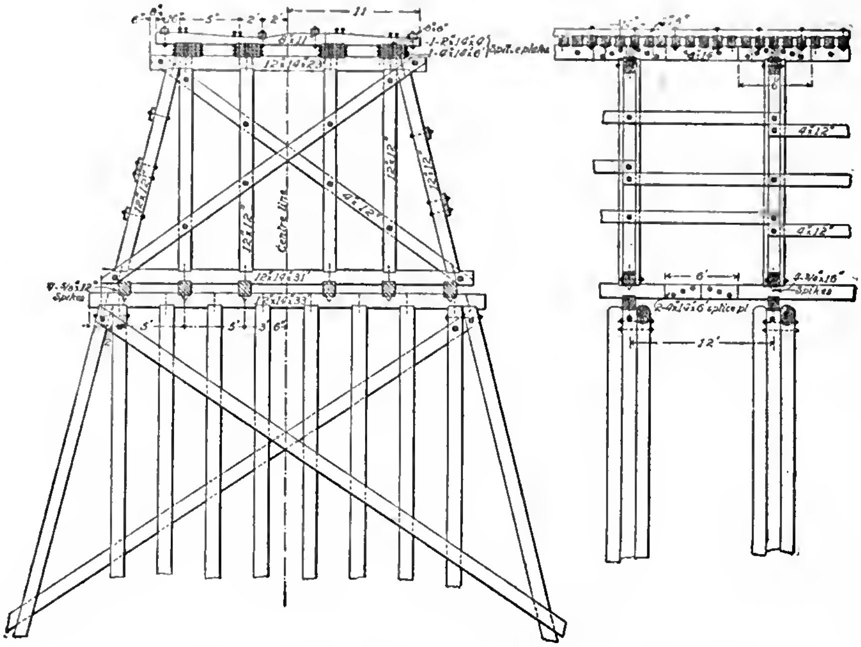


Fig. 1.—Sectional and Side Elevations, Winthrop's Cove Trestle.

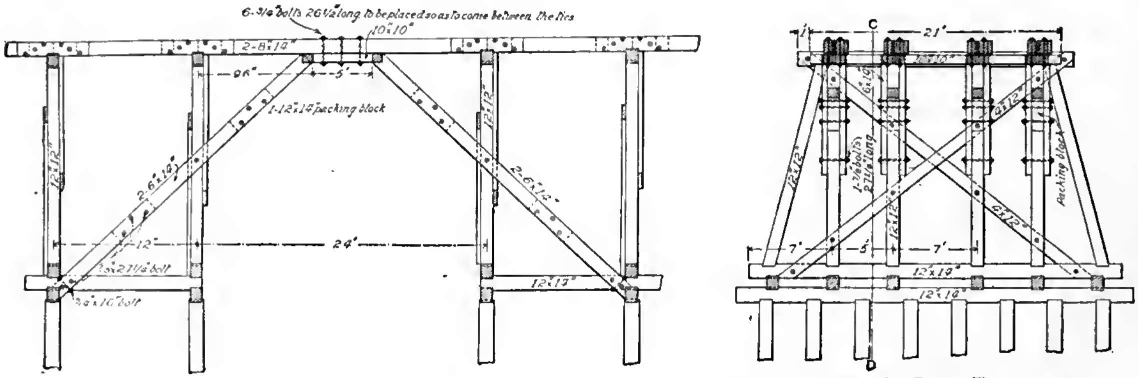


Fig. 2.—Longitudinal and Transverse Sections of 24 Ft. Bay, Winthrop's Cove Trestle.

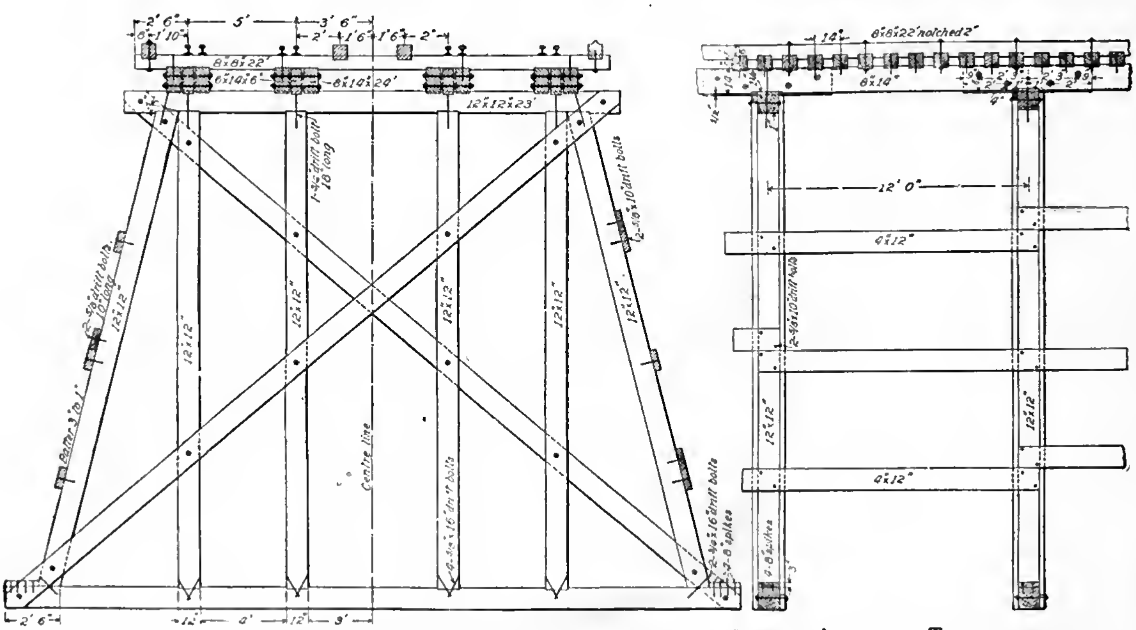


Fig. 3.—Sectional and Side Elevations, Thames River Bridge Approach Trestle.

PLATE XXXVI.—TRESTLE PLANS, NEW YORK, PROVIDENCE & BOSTON RAILROAD.

Framed Trestles, New York, Providence & Boston Railroad.—Plate XXXVI.

Figs. 1 and 2: Winthrop's Cove Trestle, on 8° 15′ Curve and 0.714 Grade.
Fig. 3: Thames River Bridge Approach.

Dimensions of Timbers.

Floor-system: Guard-rails, 8 in. × 8 in.
Ties, 8 in. × 11 in. × 22 ft.
Stringers, 8 in. × 14 in. × 24 ft.
Splice-blocks, { 2 in. × 14 in. × 4 ft.; 4 in. × 14 in. × 6 ft. }
Bent: Cap, 12 in. × 14 in. × 23 ft.
Plumb-posts, 12 in. × 12 in.
Batter-posts, 12 in. × 12 in.
Sway-braces, 4 in. × 12 in.
Sill, 12 in. × 14 in.
Longitudinal braces, 4 in. × 12 in. × 25 ft.
Purlins, 12 in. × 14 in.
Purlin splice-blocks, 4 in. × 14 in. × 6 ft.
Foundation: Pile-cap, 12 in. × 14 in.
Piles, 12 in. diameter.
Brace-piles, 12 in. diameter.
Knee-braces: Upper chord, 10 in. × 10 in. × 5 ft.
Straining-beams, 10 in. × 10 in. × 21 ft.
Diagonals, 6 in. × 14 in.
Splice-block, 12 in. × 14 in. × 4 ft.

Dimensions of Iron Details.

Bolts: $\frac{3}{4}$ in. × $15\frac{1}{2}$ in.; $\frac{3}{4}$ in. × $19\frac{1}{2}$ in.; } guard-rails to ties.
$\frac{3}{4}$ in. × $18\frac{1}{4}$ in. sway-braces to posts, etc.
$\frac{3}{4}$ in. × 22 in.; purlin splice.
$\frac{3}{4}$ in. × $26\frac{1}{2}$ in.; upper chord to stringers.
$\frac{3}{4}$ in. × 16 in.; foot of knee-brace to prevent splitting.
$\frac{7}{8}$ in. × $27\frac{1}{4}$ in.; knee-braces to purlins, to packing-blocks, to posts.
1 in. × 18 in.; longitudinal braces to posts.
1 in. × $22\frac{1}{2}$ in.; 1 in. × $26\frac{1}{2}$ in.; } stringer-joints; packing-bolts.
$1\frac{1}{8}$ in. × 34 in.; batter and sway-brace piles to piles.
Drift-bolts: $\frac{3}{4}$ in. × $\frac{3}{4}$ in. × 21 in.; stringers to caps.
1 in. × 18 in.; sills to posts.
1 in. × 20 in.; cap to posts; pile-cap to piles.
Spikes: —— × ——; ties to stringers.
$\frac{5}{8}$ in. × 12 in.; purlins to pile-caps.
$\frac{3}{4}$ in. × 16 in.; sills to purlins.
Washers, wrought: $\frac{3}{4}$-in. bolts; guard-rail bolts.
4 in. × 4 in. × $\frac{3}{8}$ in.; sway-brace bolts.
4 in. × 4 in. × $\frac{1}{2}$ in.; longitudinal brace-bolts.
4 in. × 4 in. × $\frac{5}{8}$ in.; sway-brace, pile, etc., bolts.
3 in. × $\frac{3}{8}$ in.; purlin splice-bolts.
$3\frac{1}{2}$ in. × $\frac{1}{2}$ in.; stringer-bolts.
Cast separators: $3\frac{1}{2}$ in. × 1 in.; between splice-blocks and stringers.
$3\frac{1}{2}$ in. × 4 in.; between stringers, where there are no splice blocks.

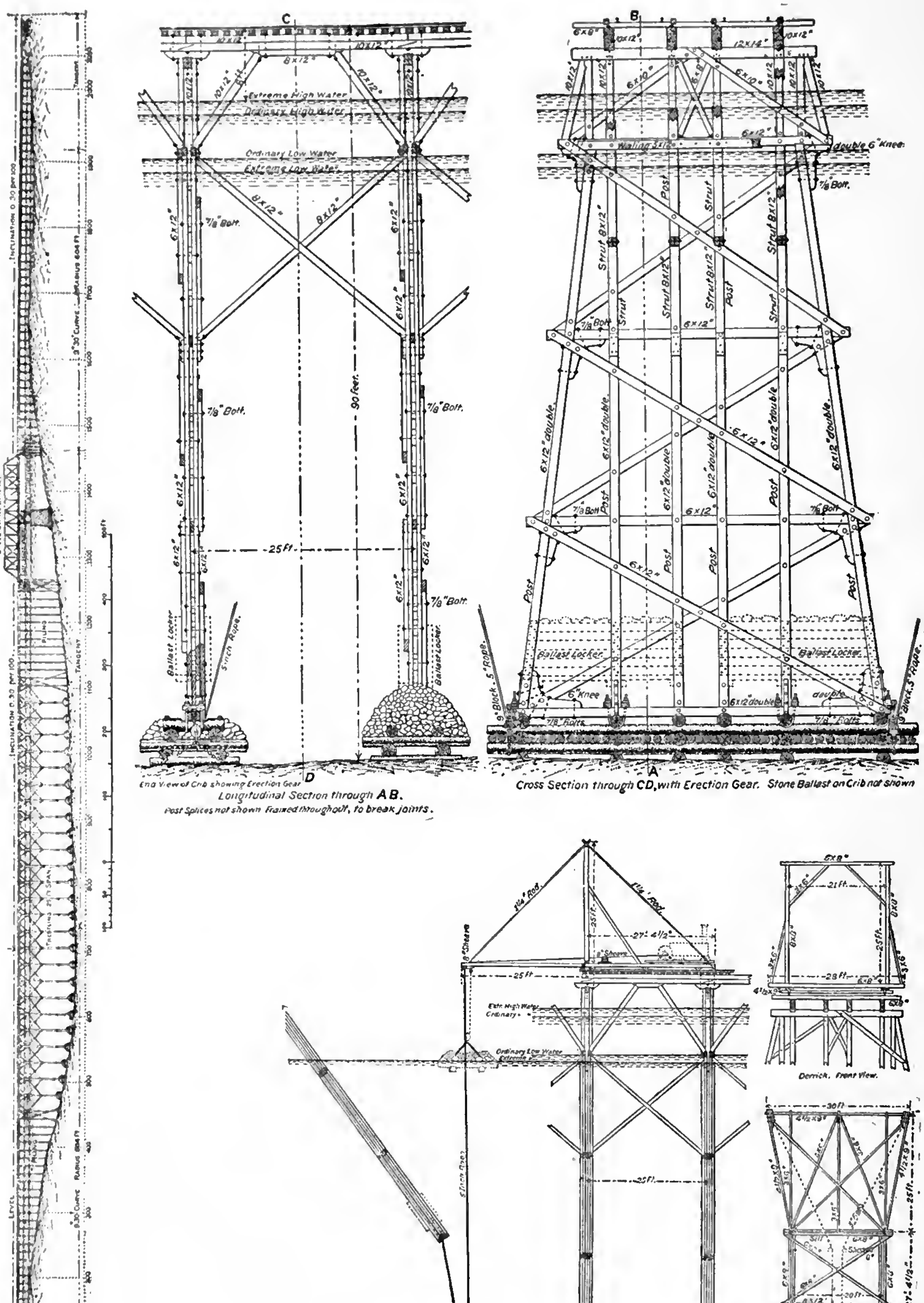


PLATE XXXVII.—DEEP-WATER FRAMED TRESTLE, INTERCOLONIAL RAILWAY.

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 1½ 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 adjust- 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 1¾ 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 sleepered, 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,			$850.00

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.

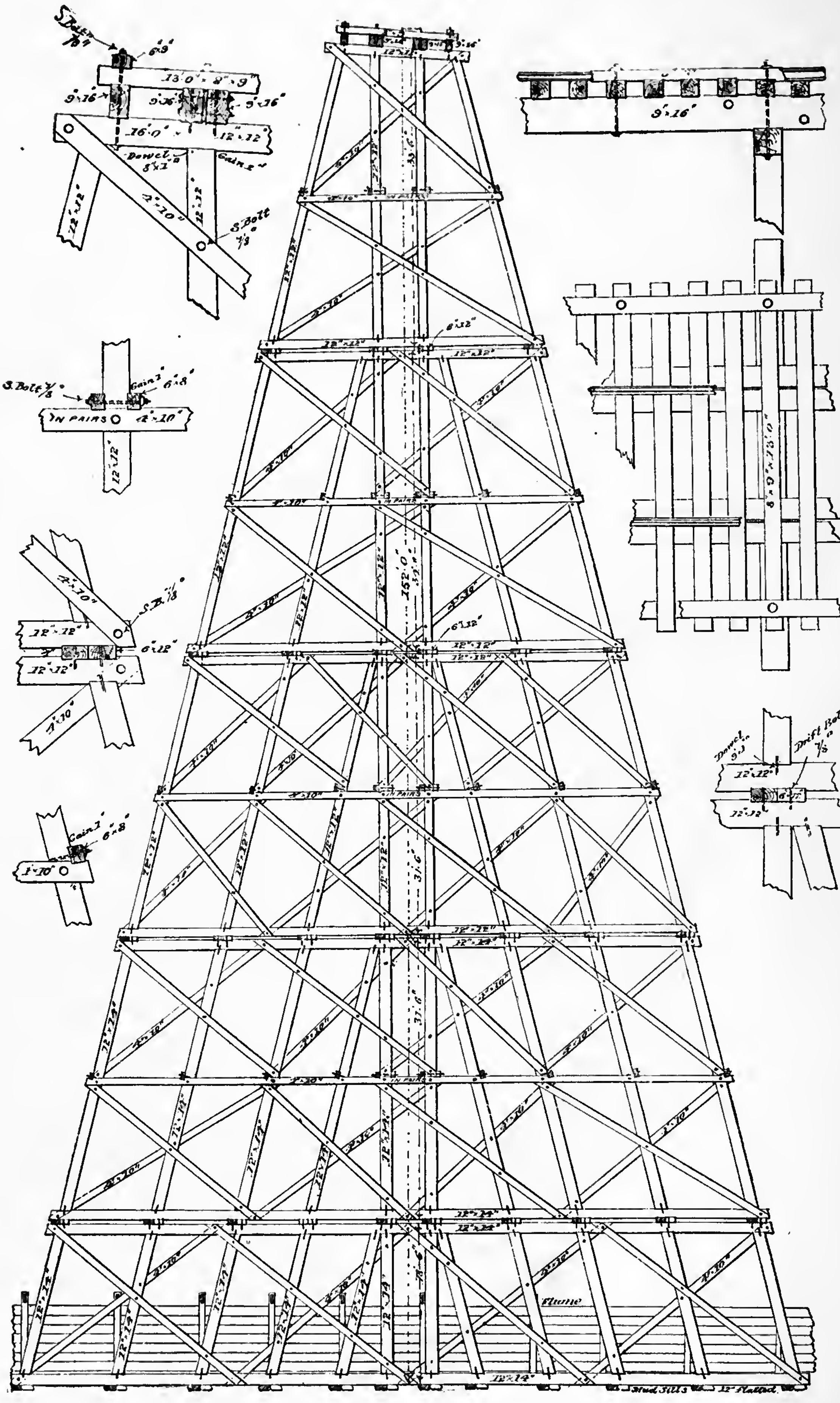


PLATE XXXVIII.—STANDARD FRAMED TRESTLE, ESQUIMALT & NANAIMO RAILWAY.

STANDARD FRAMED TRESTLE, ESQUIMALT AND NANAIMO RAILWAY.—PLATE XXXVIII.

Dimensions of Timbers.

Floor-system: Guard-rails, 6 in. × 9 in.
Ties, 8 in. × 9 in. × 13 ft.
Stringers, 9 in. × 16 in.

Bents: Caps, 12 in. × 12 in. × 16 ft.
Plumb-posts, 12 in. × 12 in., and 12 in. × 14 in.
Batter-posts, 12 in. × 12 in., and 12 in. × 14 in.
Counter-posts, 12 in. × 12 in., and 12 in. × 14 in.
Sill, 12 in. × 14 in.
Intermediate caps and sills, 12 in. × 12 in., and 12 in. × 14 in.
Sway-braces, 4 in. × 10 in.

Longitudinal braces, 6 in. × 8 in.

Purlins, 6 in. × 12 in.

Sub-sills, 12 in. round, flatted.

The trestle illustrated is built on a 10° 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.

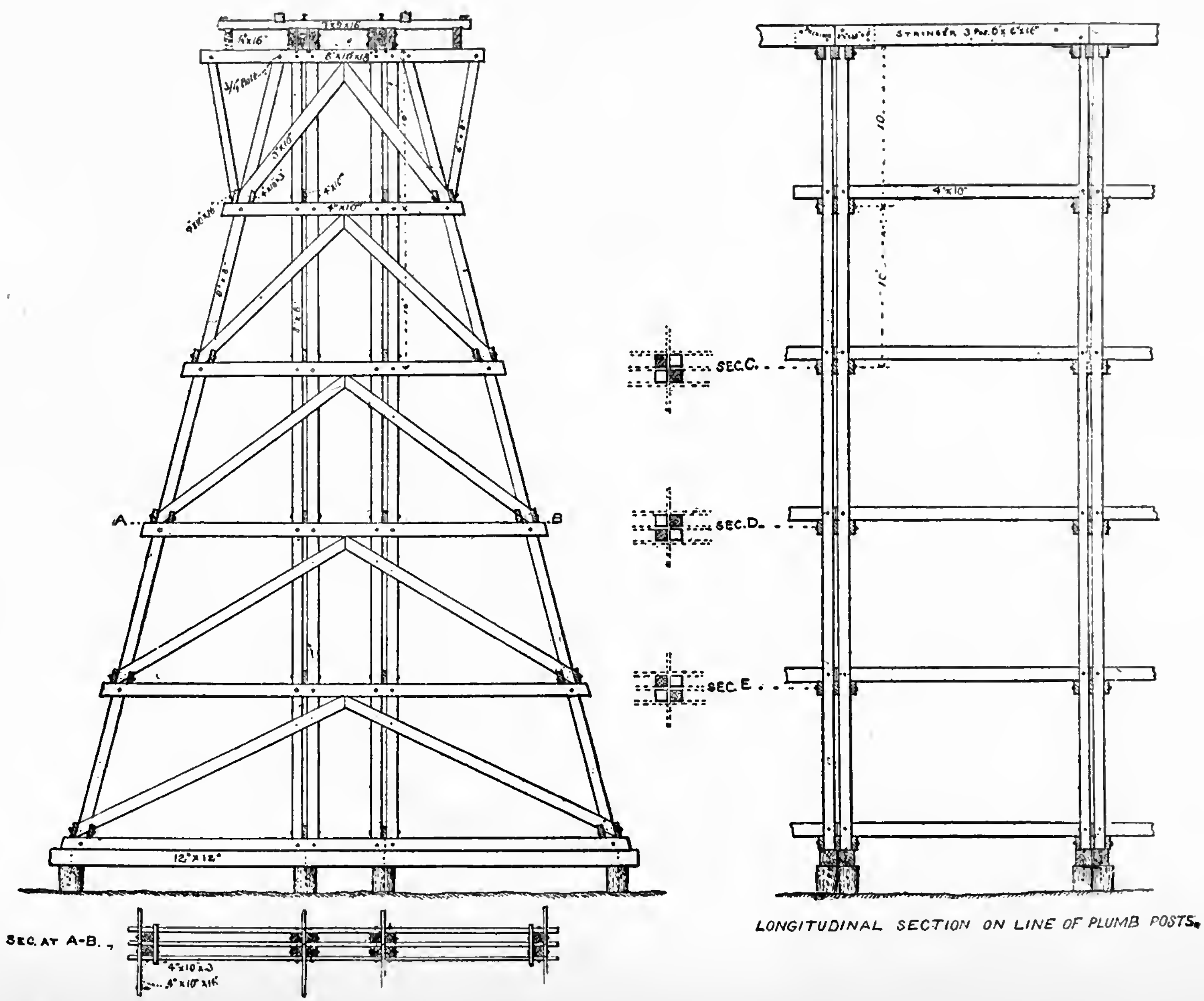


 PLATE XXXIX.—CLUSTER-BENT TRESTLE, CLEVELAND, LORAIN & WHEELING RAILWAY.

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. × 9 in. × 16 ft.
Track-stringers, 6 in. × 16 in. × 16 ft.
Jack-stringers, 6 in. × 16 in. × 16 ft.
Packing-block, 2½ in. × 18 in. × 5 ft.
Guard-rails.
Outside guard-strips, 4 in. × 6 in.

Bent : Cap.
Posts, 8 in. × 8 in.
Sway-bracing : Horizontal, 4 in. × 10 in.
Diagonal, 3 in. × 10 in.
Sill, 12 in. × 12 in.
Knee-braces, 6 in. × 8 in.

Longitudinal braces : Horizontal, 4 in. × 10 in. × 16 ft.

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* *Engineering News*, Dec. 31, 1887.

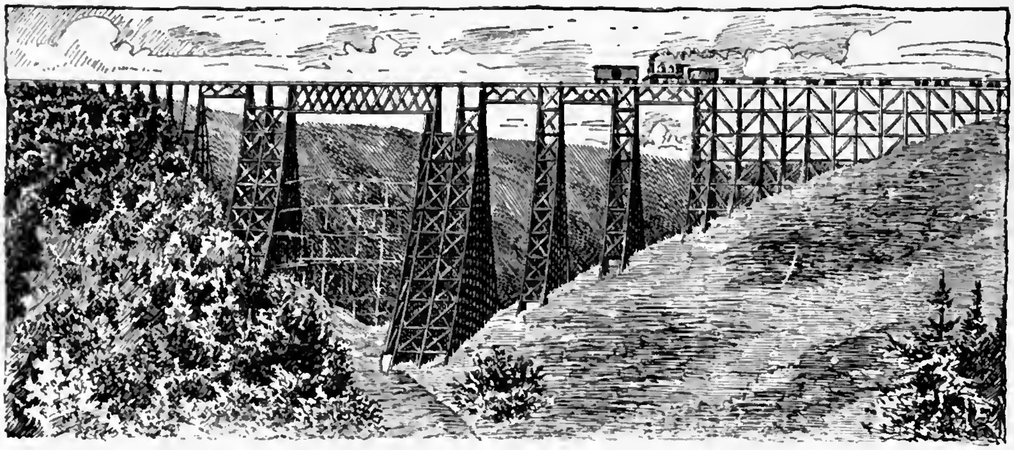

FIG. 1.—VIEW OF TWO MEDICINE BRIDGE (211 feet high).

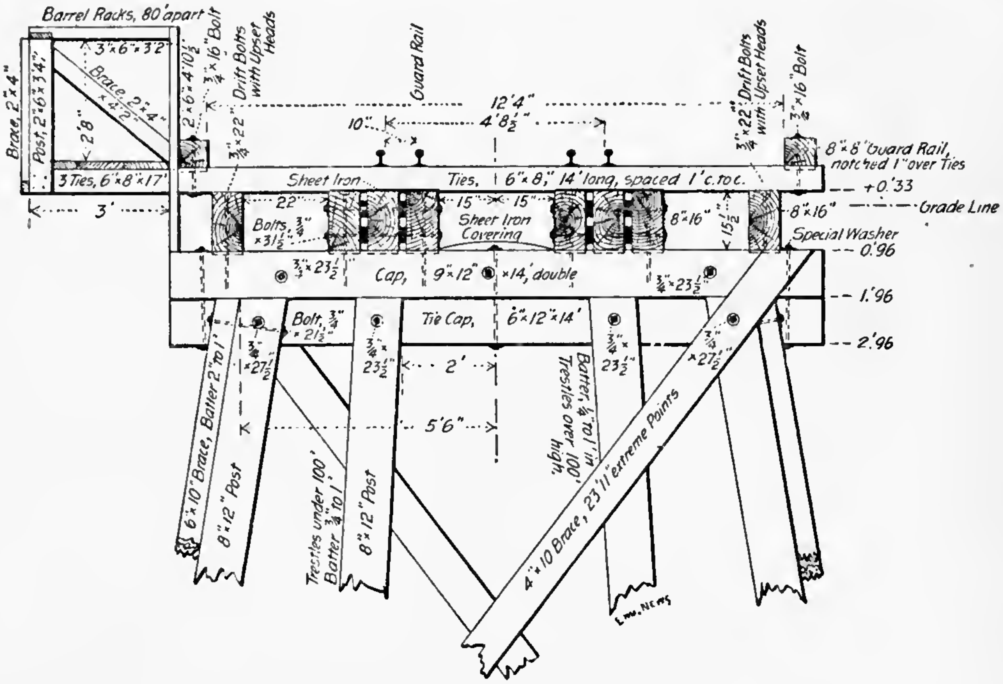

FIG. 2.—FLOOR.

PLATE XL.—TWO MEDICINE BRIDGE, ST. PAUL, MINNEAPOLIS & MANITOBA RAILROAD.

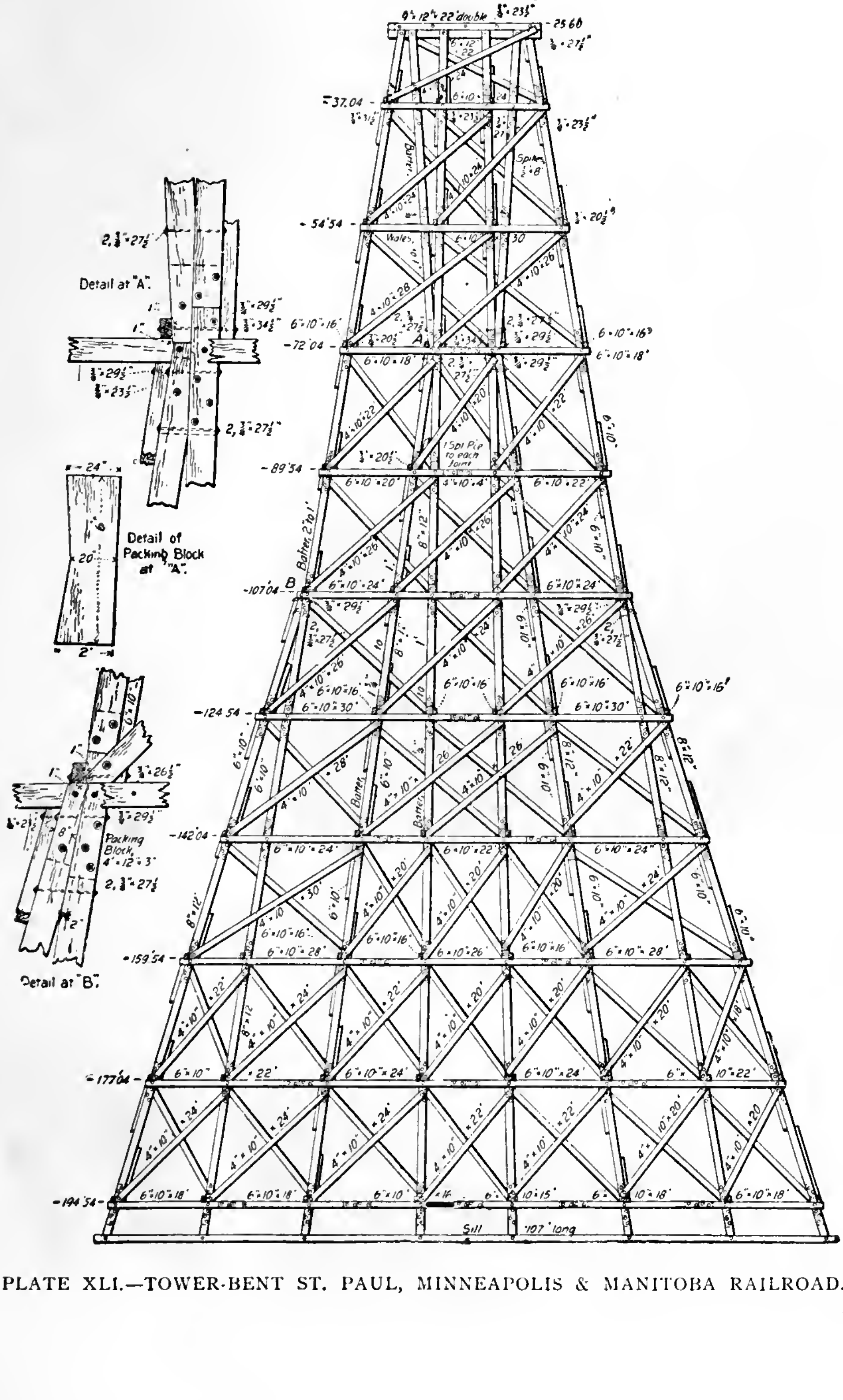

PLATE XLI.—TOWER-BENT ST. PAUL, MINNEAPOLIS & MANITOBA RAILROAD.

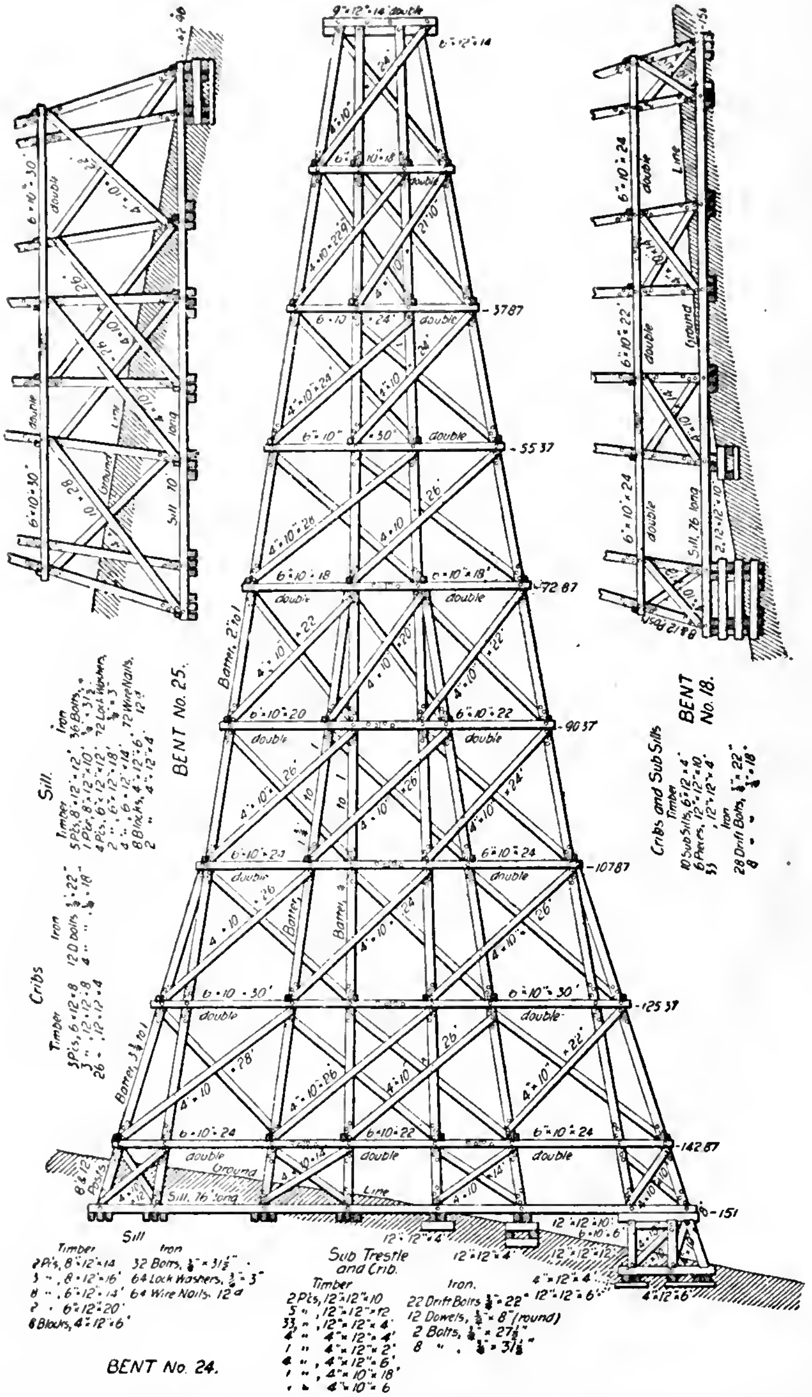

PLATE XLII.—SIDE BENT, ST. PAUL, MINNEAPOLIS & MANITOBA RAILROAD.

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. × 12 in. × 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.

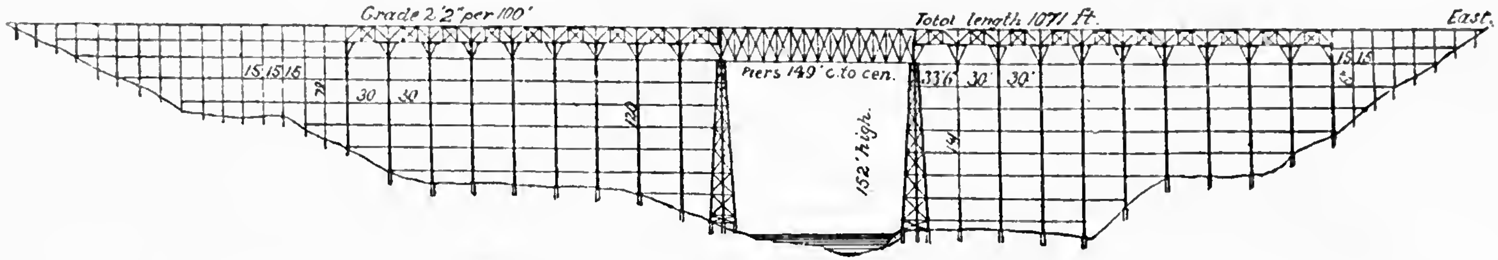

PLATE XLIII.—MOUNTAIN CREEK BRIDGE, CANADIAN PACIFIC RAILROAD.

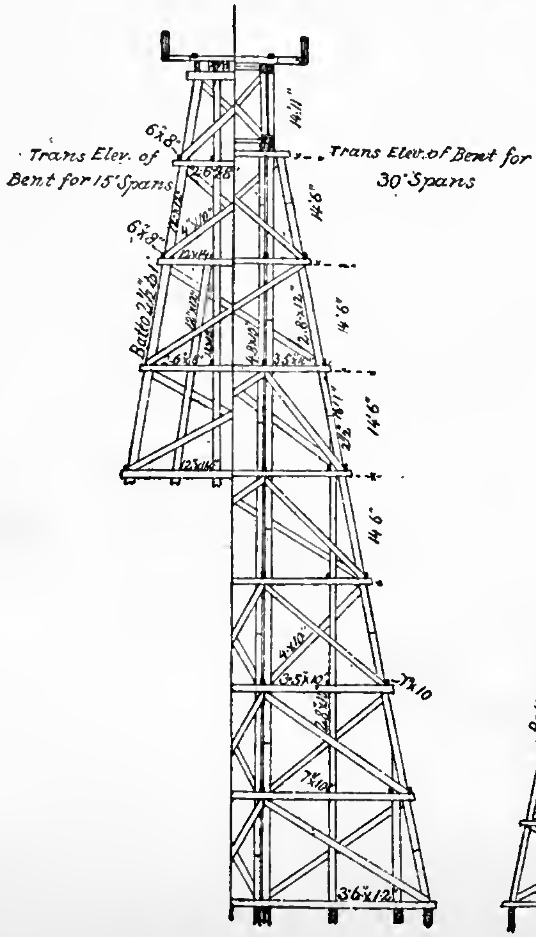

FIG. 1.

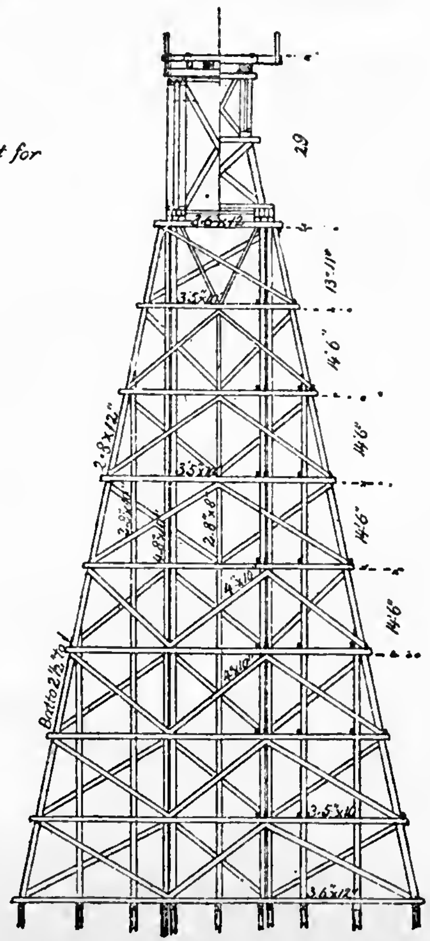

FIG. 2.

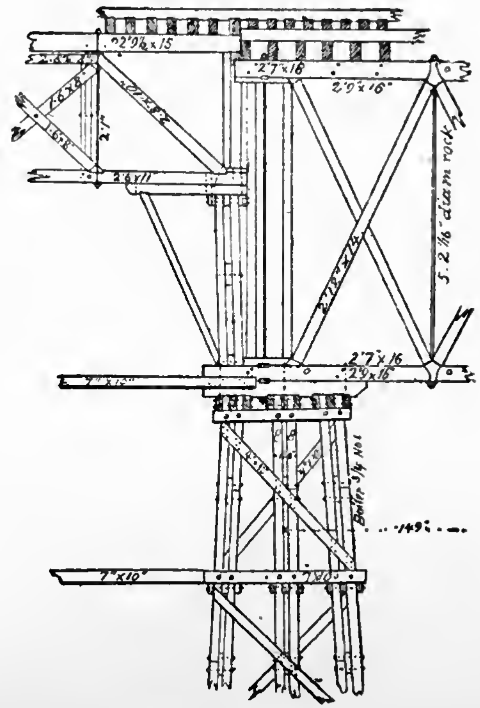

FIG. 3.

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 bowlders, 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. × 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. × 15 in. stringers under each rail; intermediate spans $\frac{3}{6}$ in. × 15 in. overlapping joints; in addition, a line of 9-in. × 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. × 12-in. ties, spaced, etc., as in the 15-ft. spans; being supported by two double lines of $9\frac{1}{2}$-in. × 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. $6\frac{3}{4}$ in.; screw-bolts and washers are used throughout to pack posts at both cross and longitudinal wales, at all joints, etc., and $\frac{1}{2}$-in. × 9-in. wrought spike for all 4-in. × 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. × 8-in. posts in 29-ft. lengths, with 8-in. × 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, riprap, 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
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.

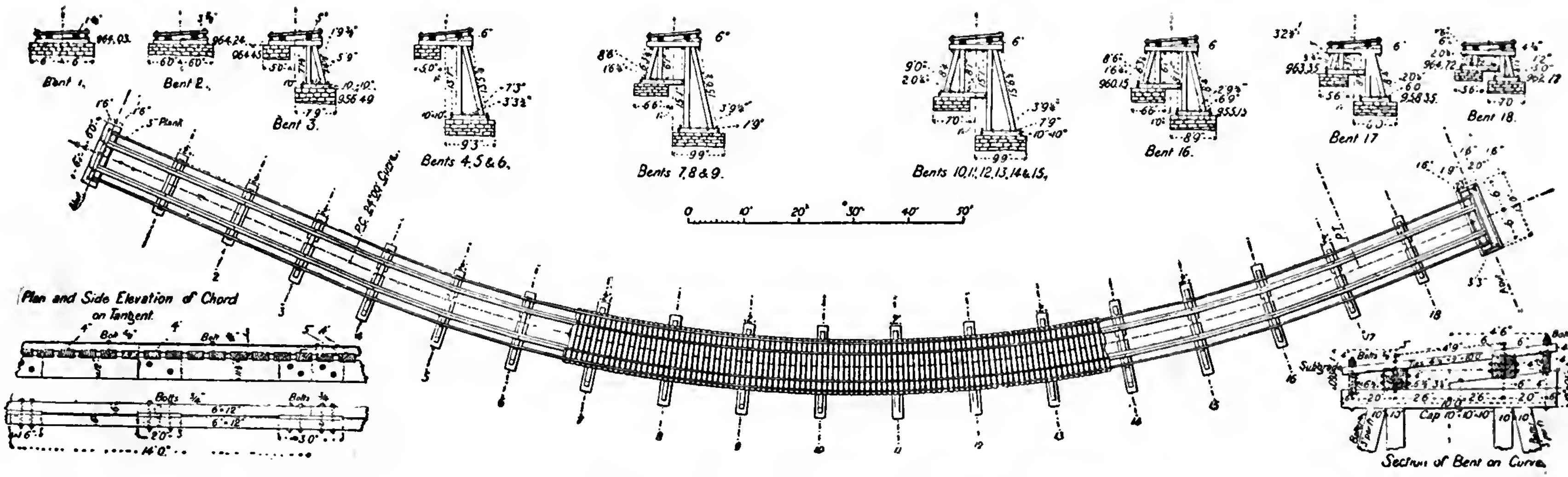

PLATE XLV.—TRESTLE ON 24° CURVE.

Framed Trestle, H. C. Frick Coke Co.—Plate XLV.

Plate XLV shows the details of a trestle built on a 24° 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, 4½ in. × 9 in. × 10 ft.
Track-stringers, 6 in. × 12 in. × 28 ft.
Jack-stringers, 4 in. × 12 in. × 28 feet.
Packing-blocks, 2 in. × 12 in. × 3 ft.
Separating-blocks, 2 in. × 12 in. × 2 ft.
Guard-rails, 4 in. × 5 in.

Bent: Cap, 10 in. × in. × 10 ft.
Posts, 10 in. × 10 in.
Sill, 10 in. × 10 in.

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