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Design of a Plate-Girder Railroad Bridge

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DESIGN OF
A PLATE-GIRDER RAILROAD BRIDGE

BY

NIXON LAWRENCE BUNN

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THESIS

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IN

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I recommend that the thesis prepared under my supervision by NIXON LAWRENCE BUNN entitled Design of a Plate-Girder Railroad Bridge be approved as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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THE DESIGN OF A PLATE-GIRDER RAILROAD BRIDGE.

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THE DESIGN OF A PLATE-GIRDER RAILROAD BRIDGE.

I-INTRODUCTION.

Art. 1 Situation.

On the south-bound main line of the Chicago and Alton Railroad is an old bridge. The increase in weight of rolling stock made it necessary to replace it by a new structure. The site of the old bridge is over the Sangamon river five miles north of Springfield, Sangamon County, Illinois.

This part of the country contains a number of hills and low places, the latter being under water the greater part of the year. About this particular spot is a stretch of timber on both sides of the river. To overcome the difficulties of having submerged tracks at the time of over-flow the roadbed is built on a fill nine feet above high water about eighteen feet above the average surface of the ground. The tracks approach the bridge at both ends on a plus 0.7 percent grade until within a half mile of the structure where they are level.

The river at this point is about 550 feet wide when the stream is at mean water level. The depth of the river is moderate not being over 18 feet; and this occurs only under one span, the average depth being about 10 feet at mean water level.

Art. 2 Description of Old Bridge.

The old bridge, Fig. 1, was a through truss of five spans and rested on masonry piers and abutments. The spans were of the follow- lengths: 111 feet - 5 inches, 103 feet - 11 3/4 inches, 103 feet - 11 3/4 inches, 99 feet - 9 inches, and 111 feet - 5 inches making a total of 530 feet - 6 1/2 inches.

The superstructure was of the Pratt type, each truss contain-

Fig. 1
The Old Bridge.

-ing seven panels. The height was 22 feet and the width was 12 feet center to center of trusses.

The tops of the piers were 24 feet long and 6 feet - 11 inches wide. The piers rested on wooden piles the tops of which were seven feet below the bed of the stream. The height of the piers was about 25 feet making it 18 feet above mean water level. Fig. 2 gives the dimensions as stated above.
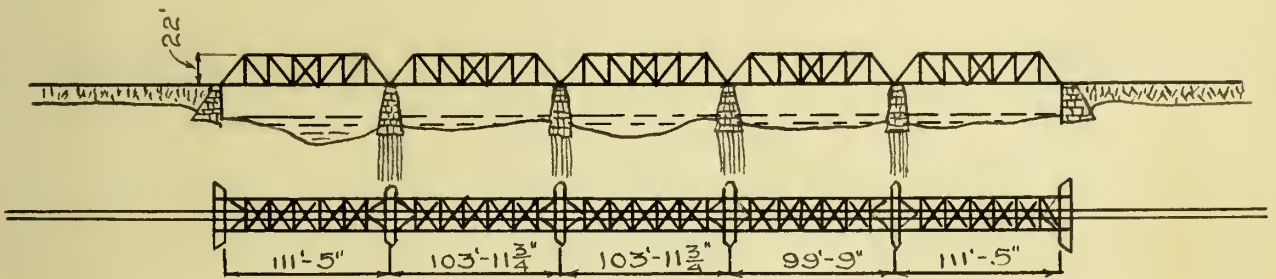
Fig. 2.

Plan and Elevation of the Old Bridge.

Art. 3 Reasons for Replacement.

The bridge was thirty years old when torn down; and before this time several weak places had been found in the structure. The piers had been repaired several times, and the steel work was begining to show signs of deterioration. A slow order for trains had been en-forced for quite a while. However, it was not these facts alone that caused the replacing of the old structure. As time goes on, progress increases and new and more modern methods are introduced.

One of these methods was the introduction of a heavier type of locomotive than that for which the bridge was designed. Although the members were allowed a small but conservative factor of safety, yet with the increased load of the new engines, the disintegration of the

steel, and the weakening of the bridge as a whole the structure could not stand the strain.

II-THE NEW BRIDGE.

Art. 4 Number of Spans.

In determining the number of spans to be used in this bridge there are numerous factors which must be considered. Perhaps the first and one of the most important is the total span which as given above equals 530 feet, 61/2 inches. At the first glance of the above figure it is seen that it would hardly be economical to cross the river with only one span of that length as a much heavier bridge would be required than if more than one span were used. The smaller the span the lighter the structure will be.

Two spans may be used, perhaps three and maybe four or five. But it must be remembered that as the spans increase, the number of piers increase in the same proportion, and also for each pier erected a cofferdam must be built, excavation for the pier must be made , and also the cost the cost of the pier itself must be considered. Although a rather large pier would be needed for two spans and more excavation would be required, yet all of this could be done by the use of one cofferdam, while if two piers were constructed two cofferdams would be necessary and perhaps more material for the piers in this case than in the preceeding.

On account of the nature of the soil below the stream bed arrangements must be made to go down to hard-pan, forty-five feet below the river bed. The pier proper will be made of concrete and will extend down into the bed of the stream for a distance of from five to ten feet. This upper portion of the pier will rest on wooden piles driven down to hard-pan, thus making the lengths of the piles

about thirty-five feet.

With the above statements as an introduction, the number of spans will be figured out by calculating the weights of the trusses for different spans and from these results, figure the cost. To this will be added the cost of material and the erection of the piers and cofferdams.

The formula that will be used in figuring the weights of the different trusses was derived by Mr. F. F. Turneaure and is for the Cooper's E-40 class of loading. This formula is only approximate. It is :

$$W = 7/8\ (650 + 7\ L)$$

where W = weight of steel per lineal foot of span, and

L = length of span in feet.

Table I gives the data regarding the approximate weight, and cost of the superstructure for two, three, four, and five spans.

TABLE I.

Comparative Costs of Spans.

No. of Spans.	Length of Span Feet.	w Lbs. 1 Truss.	Cost/ Lin. Ft. 1 Truss.	Wt. of Span Lbs. 2 Truss.	Cost of Steel/Span 2 Trusses.	Total Cost of Steel.
2	265.27	2190	$87.60	1160000	$46,400.	$92,800.
3	176.85	1650	$66.00	584000	$33,380.	$100,140.
4	132.64	1380	$55.20	366000	$14,630.	$58,520.
5	106.11	1184	$47.38	251395	$10,056.	$50,280.
6	88.42	1007.7	$40.31	178202	$7,128.	$42,768.

To these values must be added the cost of the cofferdams and piers and all labor and material included in their erection. An example will further illustrate the method used in obtaining the total approximate cost of the structure as given in Table II. The case that will be considered in this example is the one in which two spans are to be used. The example is as follows:

From Table I the length of the span is 265.27 feet and the total approximate cost of the steel superstructure is $92,800.00

The following rule taken from Baker's Masonry Construction, page 558, and used as a standard by the New York Central Railroad, will be followed in the design of the piers:

> "For square crossings and spans of forty feet or less, the width on top of the pier is four feet and it increases six inches for each twenty feet increase in the length of span, up to one hundred feet and then the same amount for each twenty-five feet increase up to two-hundred fifty feet."

The inside clearance is 16 feet, and allowing 1 foot on each side for the width of the chord the remainder, or 2 feet on a side, is common practice for a bridge pier. The batter will be 1 in 12. The length on top of the pier as determined from the above figures will be 22 feet. The width is determined as follows:

$$Span = 265.27 \text{ feet.}$$

$$4.0 + (0.5 \times 6.0) = 7 \text{ feet for 100 foot span.}$$

$$\frac{150.0}{25} \times 0.5 = 3 \text{ feet, the increase for 150 feet.}$$

$$\frac{15.27}{25} \times 0.5 = \underline{0.366} \text{ feet, the increase for 15.27 feet.}$$
$$10.366 \text{ feet.- Total width.- Top of pier.}$$

The height of the pier is taken as 36 feet, and since the batter is 1 in 12 an increase of 6 feet for each top dimension of the pier will give the bottom dimensions or

$$\frac{36}{12} = 3 \text{ feet, is the increase on each end.}$$

By adding the two lengths 22 feet and 28 feet and dividing by two the mean dimension will be obtained.

$$\frac{28 + 22}{2} = 25 \text{ feet.}$$

By the same process the mean width may be calculated.

$$\frac{10.366 + 16.366}{2} = 13.366 \text{ feet.}$$

Fig. 3 shows the top view of the pier giving the top, bottom and mean dimensions.
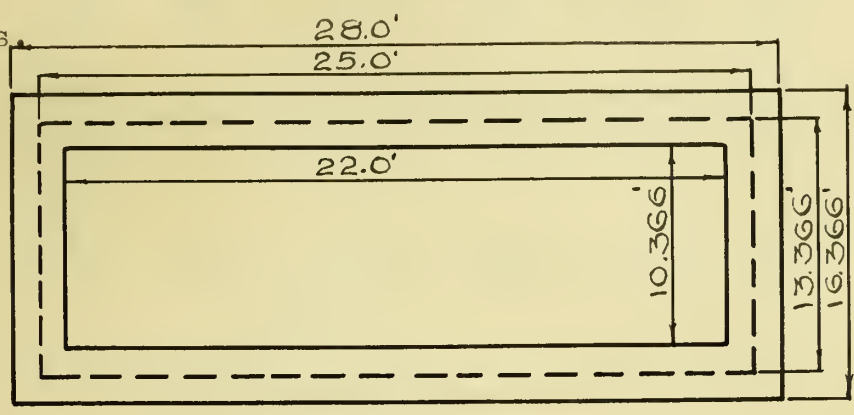
Fig. 3

Top View of Pier.

Multiplying the mean dimensions to-gether and the result by the height, and dividing by 27 gives the contents of the pier in cubic yards.

$$\frac{13.366 \times 25 \times 36}{27} = 445.$$

The cost of the concrete pier, figuring concrete at $8.00 per cubic will be:

$$445 \times 8.00 = \$3550.$$

Since the piers are to rest on wooden piles driven to hard-pan a distance of 40 feet, another item, that of piles must be added to the list of costs. The piles are to be driven 4 feet apart and cover the entire bottom of the pier. For this particular case 40 piles are required; and figuring the cost at $0.70 per lineal foot gives a total of $(40 \times 20 \times 0.70 = \$560.00)$ $560.00 The cost of driving $0.30 per lineal foot is:

$$40 \times 20 \times 0.30 = \$240.00$$

making a total of $800.00 Fig. 4 shows a plan of the pier at the
bottom and the arrangement of the piles.
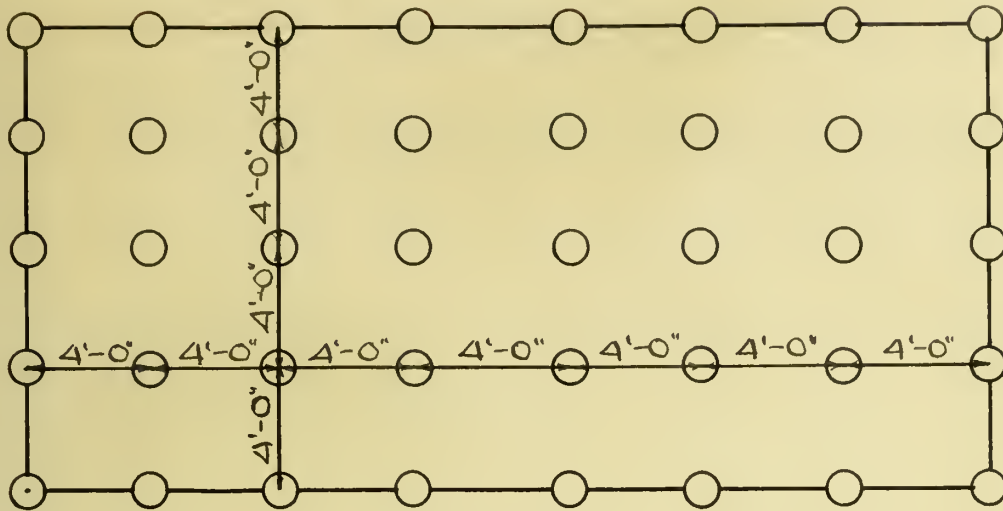
Fig. 4

Plan of Bottom of Concrete Pier for Two Spans
showing Piles.

The next part to be considered in the cost of the structure is
that of the coffer-dam. The coffer-dam must be of such a size as to
allow a clearance of 4 feet on all sides at the bottom of the pier.
This will make the size of the coffer-dam for this particular case
21 feet by 32 feet. The depth of the coffer-dam will be 7 feet. The
Lackawanna steel sheet piling will be used in the construction. The
size of the section of the steel piling is 12-3/4 inches by 3/8
inches, straight web section, weighing 37.187 pounds per lineal foot
and 35 pounds per square foot of wall surface.

For the size coffer-dam given (21×32) 106 of these bars ten
feet long will be needed and at a cost of $1.60 per 100 pounds the
total will be $630.00

The cost of driving at $0.10 per foot will be :

$$106 \times 10 \times 0.10 = \$106.00$$

The bracing is to consist of 6 -- 4×6 inch timbers 21 feet
long and 3-4×6 inch timbers 28 feet long which, at $45.00 per M.

cost $18.90

The cost of excavation at $1.50 per cubic yard will be:

$$\frac{21 \times 32 \times 5}{27} \times 1.50 = \$185.00$$

The total cost is :

Steel in superstructure ------------------$92 800.00

Concrete in pier-----------------------------3 550.00

Wooden piles----------------------------------- 560.00

Driving piles-----------------------------------240.00

Steel in coffer-dam-------------------------- 630.00

Driving steel piles------------------------- 106.00

Bracing coffer-dams ----------------------- 55.00

Excavation---------------------------------------185.00

Labor for bracing etc. --------------------------153.00

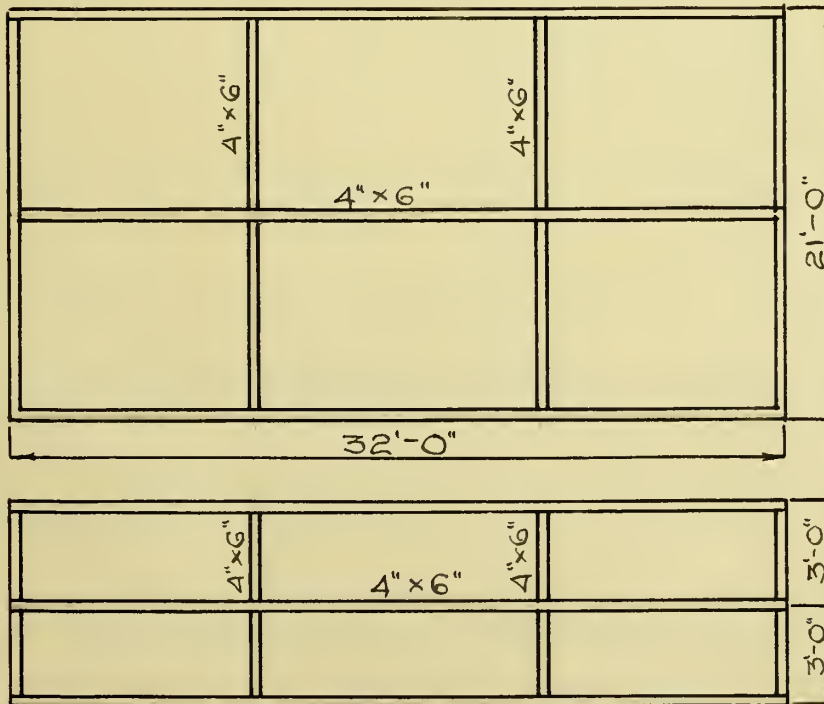$98 279.00

Fig. 5 shows a plan of the coffer-dam.

Fig. 5

Plan and Elevation of Coffer-dam.

Table II gives the results, obtained the same way as in the example, of 3, 4, 5, and 6 spans.

TABLE II.
Data Showing Calculation of Spans.   10

	Ref. No.	1	2	3	4	5
	Lgth. of Span	265.27	176.85	132.64	106.11	88.42
	No. of Spans.	2	3	4	5	6
	Total Cost of Steel.	$92,800.	$100,140.	$85,520.	$50.280.	$42,768.
PIERS	Top Feet.	10.5×22	8.5×22	8.0×22	7.5×12	5.25×12
	Bot. "	16.5×28	14.5×28	14.0×28	13.5×18	11.25×18
	Concrete Cu. Yds.	437	756	1100	653	643
	Cost @ $8. per cu. yd.	$3500.	$6050.	$8800.	$5220.	$5140.
PILES	Number	40	64	72	80	80
	Cost @ $.70 per lin. ft.	$560	$890	$1010.	$1120.	$1120.
	Length in Feet.	20	20	20	20	20
	Driving Cst @ .30/lin.ft	$240	$384.	$432.	$480.	$480.
COFFERDAMS	Size-Feet	21×32	18×32	18×32	18×22	18×22
	Size of Wall Sec.	12-3/4" 3/8" 10'	12-3/4" 3/8" 10'	12-3/4" 3/8" 10'	12-3/4" 3/8" 10'	12-3/4" 3/8" 10'
	No. of Bars.	106	200	300	320	400
	Lbs. Wt. per lin. ft	37.187	37.187	37.187	37.187	37.187
	Cst.of Steel @1.60/100#	$630.	$1190.	$1785.,	$1900.	$2380.
	Amt. driven Ft. for piles	742	1400	2100	2800	3500
	Cst. @ $.10 per lin. ft	$74.20	$140.	$210.	$280.	$350.
	Cst. of frt. Steel piles	$98.50	$185.00	$279.00	$297.00	$372.00
	Cst. of Bracing.	$55.00	$104.00	$156.00	$172.00	$215.00
	Cst. of Labor etc.	$153.00	$305.00	$457.00	$598.00	$747.00
	Total Cost.	$1011.00	$1924.00	$2887.00	$3247.00	$4064.00
	Exc. Cu. Yds.	118	214	320	426	533
	Cst. @ $1.50 per cu. yd.	$175.00	$322.00	$480.00	$639.00	$800.00
	Total Cost.	$98,286.	$109,710.	$103,017	$60,986.	$54,372.

In reviewing the contents of Table II it will be seen that the bridge containing six spans is the most economical one considering the cost. However, this is not the only factor to be considered in determining the number of spans, although it is perhaps the most important. Every day that construction is going on trains will be delayed somewhat and part of the time traffic must be suspended altogether over the particular line of the road where the bridge is being built. If five spans are to be used,it is true the cost will be a few thousand dollars more, but the time of erection will be decreased a considerable amount and thus the traffic will not be delayed as much as in the first case. These facts thus resolve them- selves into a problem of quick erection with a few thousand dollars more expense and less delay or a reduced expense by taking a longer time for construction and retarding traffic considerable. If the expense to be added for quick erection is much smaller than the expense incurred by the delay of traffic the former should prevail, while on the other hand if the opposite is true the latter should prevail.

It is true that the facts mentioned in the preceeding paragraph will control any determination as regards the number of spans to be used in a bridge, but there is one case in which these factors will not control. If the railroad has two parallel main lines and these maybe connected at points not far from each end of the bridge, traffic can be transferred from one line to the other while a bridge is being built. Fortunately this is the case with the Chicago and Alton Railroad. The new bridge will be on the south-bound main line and about a half mile further north from the site of the bridge is a "Y"connecting with the north-bound. It will be an easy matter to switch over at this point; and traffic will not be delayed to any

extent whatever.

As this is the case it will be more economical to save the ten thousand dollars and use the design containing six spans.

Art. 5 Approximate Weight.

Since the approximate weight will be needed in the figuring out of the dead load stresses, the weight as previously determined by the formula will be considered. As this weight includes only one plate girder, the result obtained by the formula must be multiplied by two and to this amount must be added the weight of the ties and rails which is most generally assumed as 400 pounds per lineal foot of span.

Weight of total span (2 girders)----- 103,000 Lbs.
Weight of ties and rails-------------- 35,000 Lbs.
Total dead load ----- 138,000. Lbs.

Art. 6 Determination of Type of Superstructure.

The determination of the type of superstructure is an easy matter after the number of spans have been figured. The customs and ideas of engineers have changed considerably since the erection of the old bridge on this site. This structure as has been described before, consisted of five spans of the Pratt type each span being about 106 feet. It is a difficult matter to erect a truss of the above type and thus costs more for erection, while if a plate girder had been used it could have been erected in the shop and delivered as one piece. However it is not the erection of the structure that is so very important, but the weight of the steel used plays a great

part. A truss compared with a plate girder is much more expensive
both in erection and in material and as a plate girder serves en-
tirely the same purpose; that is for spans from 20 to 120 feet, the
girder should be used for spans in place of trusses in such a case.

Reasoning from the above facts and also from the fact that the
space above the waterway is entirely sufficient for a deck plate
girder. this style of superstructure will be used in the design.

Art. 7 General Dimensions.

The only dimension of the bridge known positively at this time
is the span. There will be six spans, each being 88 feet long,
making a total of 528 feet. As the depth of the plate girders and
also the spacing of them center to center of web plates will have
to be figured in the design, they can not be given at this particu-
lar place. The general dimensions should also include the length of
span under coping as well as the over-all length, but these cannot
be given until the size of the bearing plate is known. This bearing
plate will be determined in the next article.

III - THE PIERS.

Art. 8 The Character of the Soil.

The character of the soil underlying the stream bed at the site
of this bridge has been determined to a depth of about 50 feet. It
is deeper than this in some places, due to the irregularities of the
bed, while in other places it is somewhat shallower. The top layer
is comprised of a silt which extends down to a depth of about 25
feet. In one place it reaches 45 feet while in another location the
thickness of layer is only 10 feet. Below this silt is a fairly

uniform bed of soft blue clay with a thickness of 15 feet. Extending
from the bottom of the blue clay through the remaining 10 feet is a
layer of hardpan. At different places throughout the entire length
of span, small patches of both large and small gravel were found.

Art, 9 Size of the Piers.

The size of the piers will be determined from the formula or
rule used as a standard by the New York Central Railroad and given
in article 4 page 8. According to this standard the width of the top
will be 6 feet - 0 inches, while sufficient length is required to
fit the superstructure. The superstructure will be composed of deck
plate girders spaced 7 feet center to center. To allow for the crush-
ing of the masonry due to the bearing plate being to near the edge,
2-1/2 feet from the center of the girder to the edge of the coping
will be used. This will prove a sufficient margin for the bearing
plate used. The length of the pier will thus be 12 feet. The top
dimensions taken are 6 feet - 0 inches by 12 feet 0 inches, out to
out of coping.

The size of the bearing plate is determined by the weight of
the girders and the load applied. For this particular case a plate
29 inches by 33 inches is sufficient to transform the pressure from
the girders to the masonry. The smallest dimension for the top of a
pier is usually taken to be such that twice the length of the bear-
ing plate is not more than the distance under coping.

The batter will be 1 in 12. This will give the bottom dimensions
of 12 by 18 feet. These dimensions given in this paragraph and the
preceeding ones are only for the top and bottom. The remaining
dimensions and the design are in Fig. 6,
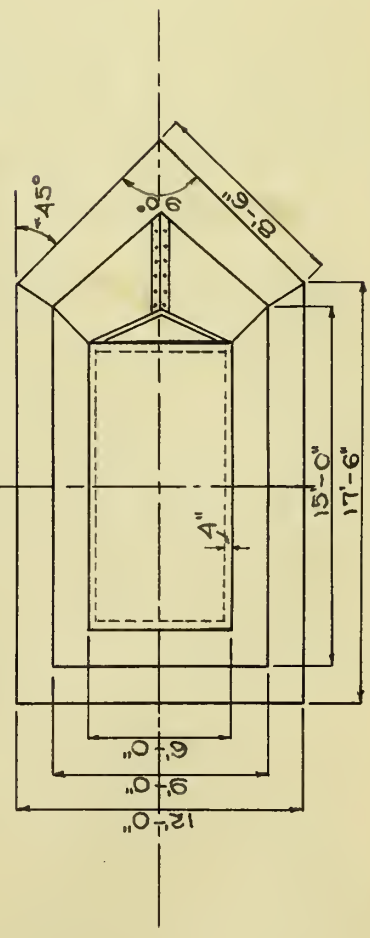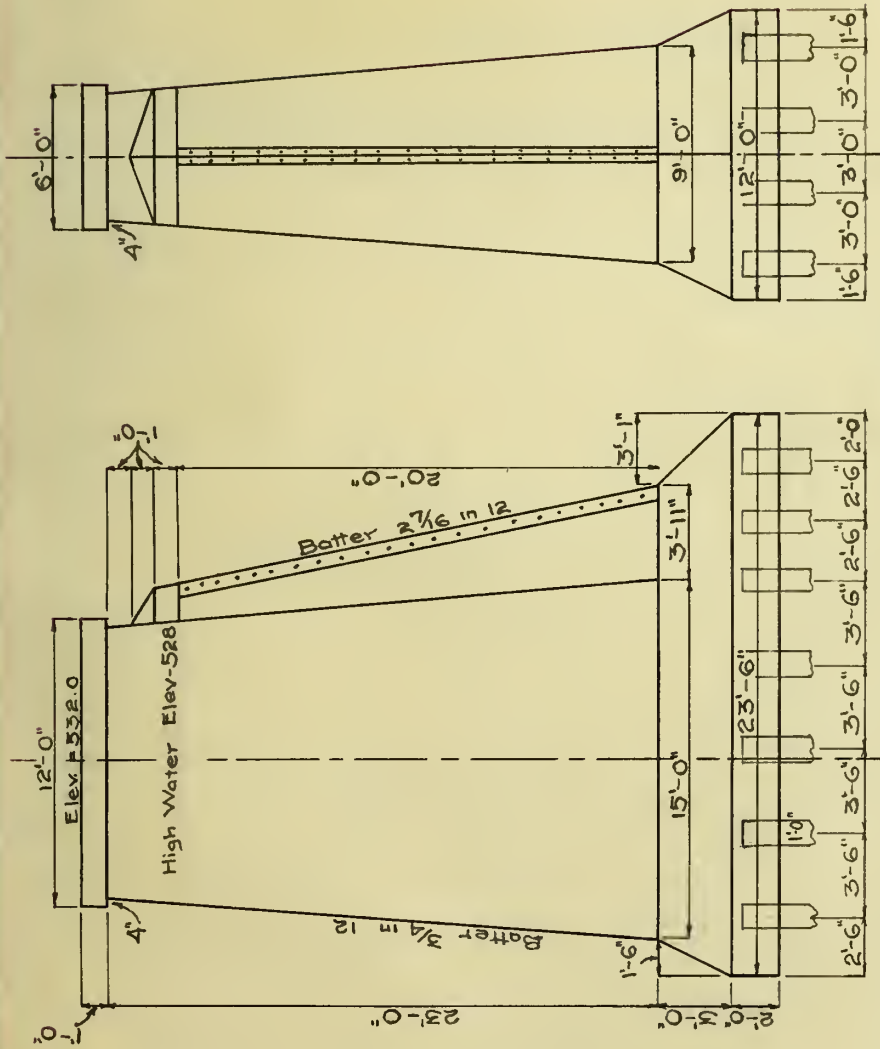
Bill of Material –

Concrete –
1:2:4 10 Cu. Yds.
1:3:6 135 Cu. Yds.

Steel –
1 L 5"×8"×½" – 20'-6"

Piles
26 – 45'-0" Pine –

PIERS
FOR
DECK PLATE GIRDER R.R. BRIDGE
OVER
SANGAMON RIVER

CHICAGO & ALTON. R.R.

SCALE 1"= 8'-0"

March 12, 1913.

N.L.Bunn – ENG.

Fig 6

Art. 10 Depth of the Foundation.

The places where the five piers are to be stationed are such that the elevation of the bottom of all of the piers will be practically the same. This will make the depth of the foundation below stream bed vary from five to seven feet according to the location of the piers. The piers will be such as to extend below the bed of the stream at its least elevation, and they will rest on piles.

Art. 11 Material.

Concrete will be used for the piers and abutments. This material is not only economical but it can be moulded into practically any shape that is desired. It is used in almost all kinds of bridge work as well as many other structures. The old style piers were usually made of masonry which proved very efficient, but these piers were certainly made at a much greater cost than those made of concrete. Each stone had to be shaped. This took time and money and also more labor than that required by using concrete. The concrete piers can be built much faster than masonry piers. One may say that the erection of the forms takes up a great deal of time and labor, but if they are not too complicated they may be built in a reasonable length of time and at a reasonable cost. After the forms are up the only thing necessary to complete the pier is to pour the concrete and perhaps retouch the surface, while in masonry piers the stone blocks have to be laid and placed by hand.

Since the top of the pier and the up-stream side or starck water are subjected to great strains, by the top being in contact with the bearing plate and the starck water exposed to the action of the ice, these parts will be made of a better grade of concrete than the remaining parts. The concrete in the top and starck water

will be a 1:2:4 mixture, while the main part will be composed of a
1:3:6 mixture.

Art. 12 Method of Construction.

In order to erect the piers some method must be used to keep
the water out and away from the work. The cofferdam process will be
used. Cofferdams are one of the most expensive items in erecting a
bridge but they must be used wherever there is any water. During
construction the depth of the stream will not be more than three
feet at low water, so no great difficulty should be encountered in
building the cofferdams.

Art. 13 Cost of Masonry Substructure.

In determining the cost of the masonry substructure the follow-
ing items, which have reference to the piers only, will be considered:

        1.) Cost of concrete in place.
        2.) Cost of surfacing the concrete.
        3.) Cost of the foundation piles.
        4.) Cost of driving the foundation piles.

The costs of the different materials and labor have been ob-
tained from recent engineering journals.

The following is the itemized cost of each pier:-

        135 cubic yards 1:3:6 concrete @ $8.00 --------- $1080.00
        10 cubic yards 1:2:4 concrete @ $10.00 --------- 100.00
        1170 feet-foundation piles @ $0.35 --------------- 410.00
        Cst. of driving same @ $0.30 ------------------ 350.00
        Cst. of surfacing 1050 sq. ft. @ $0.20 -------- 210.00
                    Cst. of one pier ------$2150.00

IV - THE COFFERDAMS

Art. 14 Size.

The size of the cofferdams will depend on the dimensions of the foundation of the pier and the clearance allowed for the workmen. A plan of the pier is shown on Fig. 6, page 15. The length is 23 feet 6 inches, while the width is only 18 feet. Allowing for a clearance of four feet on all sides except the starck water where two feet from the edge will be used, the dimensions of the cofferdam will be 29 feet - 6 inches by 20 feet. This rather large allowance is made so that the steel piles of the cofferdam will not interfere with the driving of the foundation piles.

Art. 15 Piles.

There are numerous ways of making cofferdams some of which will be discussed briefly in this article. Perhaps the oldest way occured when bags filled with earth were packed together so as to form a wall which would keep out the water. This method was practically abolished when the puddle wall was introduced. The cofferdam formed in this way consisted of two rows of wooden piles driven about three or four feet apart.. the space between them being filled with packed earth commonly called puddle. This proved very efficient and is used to a great extent at present. An improvement over the puddle wall cofferdams is the one composed of steel piles. These piles are usually about a foot wide and of sufficient thickness so as not to buckle when being driven. On each side or edge is a device to lock one pile to another one. Cofferdams made of steel piles are used on all kinds of work, especially on large jobs such as the raising of the battleship " MAINE " They are very efficient and easily handled

because only one row of piles have to be driven and thus no puddle needs to be used. Steel piles are not so apt to break as a wooden pile would in the case of striking a log or boulder.

The style of the piles to be used in the erection of the piers will be the Lackawanna steel piles 12-3/4 inches by 3/8 inches straight web section, weighing 35 pounds per square foot of wall surface and 37.187 pounds per linear foot of pile.

Art. 16 Methods of Driving Piles.

There are two methods of driving piles, both of which are very efficient. The first method consists of a heavy weight supported by side guides and dropped a certain distance on the top of the pile. This method is most efficient when the frame work can be transferred readily from one pile to another as in the case when piles are driven from a machine on a boat or wagon. The steam pile driver is more modern and it will be used in this work. The apparatus is easily moved from one place to another since it is supported by a derrick or movable crane, and is not as cumbersome as a falling weight. Although the blow from a steam hammer does not have 1/10 the effect of a falling weight, yet the blows are so rapid that in the same amount of time the steam hammer can do a much greater amount of work.

Art. 17. Excavation.

In considering the matter of excavation there is one thing that will prevent rapid work. This is the fact that braces are used on the inside of the cofferdam. The orange peel dredge bucket will be used wherever possible, but hand labor will be necessary directly under the braces and in other places where the bucket cannot be manipulated.

The excavation will be made to an average depth of eight feet

and the cubic yards will be figured on this basis. The total yard-
age for each pier is :-

$$29.5 \times 20 \times 8 = 47,200. \quad \text{Cubic Feet.}$$

$$= 1,745. \quad \text{Cubic Yards.}$$

Art. 18. Cost.

The cost of the cofferdams includes the cost of the steel piles
the freight on the same, and also the driving. The lumber for inside
bracing, the labor and the excavation will also be included. The
costs of the piles and the driving have been obtained direct from
the Lackawanna Steel Co. of Buffalo, New York, while the cost of
the lumber for bracing, the labor and the excavation have been ob-
tained from the latest engineering jouranls.

The cost for five cofferdams is as follows:-

1745 cubic yards excavation @ $ 1.50 ----------	$ 2,620.00
98 piles 20'- 0" 72,900. lbs. @ $1.60/100------	1,170.00
392 piles 15'- 0" 218,000 lbs. @ $1.60/100-------	3,490.00
4 piles 20'--0" 2,970 lbs. @ $1.60/100 --------	62.40
16 piles 15'- 0" 8,900 lbs. @ $1.60/100--------	187.00
Freight on steel piles 302,770 lbs @ $0.25/100 ----	755.00
Driving piles 6396 lin. ft. @ $0.10/lin. ft.--------	639.60
Bracing 5.5 M @ $ 45.00/M --------------------	250.00
Labor for bracing and erection -------------------	800.00

Total ----$ 9,974.00

Cost of one cofferdam ------$ 1,980.00

Cost of cofferdams per cubic yard of earth excavation -$5.70
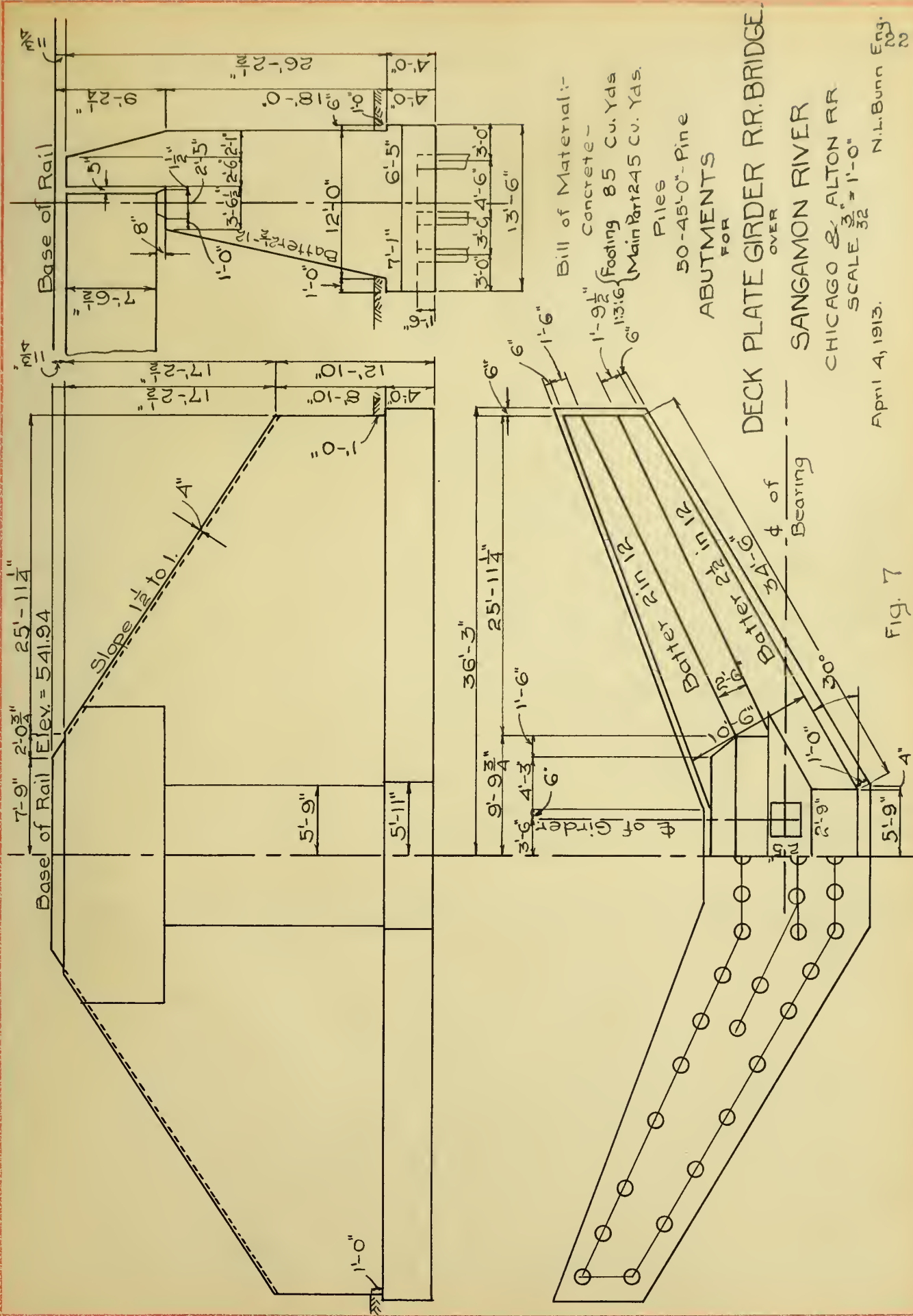
V-THE ABUTMENTS.

Art. 19 Size.

The size of the abutment depends on the load to be carried and also upon its shape. In this case the standard adopted by the Chicago Milwaukee and St. Paul railroad will be used. The bridge seat must be of such a size, that the distance from the edge of the bearing plate to the outer edge of the coping is not less than one foot and the distance from the other edge of the bearing plate to the back of the seat must be equal to two and one half inches. Since the bearing plate is two feet - five inches long the bridge seat will be three feet - seven and one half inches. The batter on the face of the wall will be 2-1/2 in 12. The batter on the front of the wing wall will be the same. The batter on the back of the wing walls will be 2 in 12. See Fig. 7, page 22.

Art. 20 Material.

The same reasons, as mentioned in regard to the material for the piers will apply to the abutments. It will not be necessary to enumerate again the reasons why concrete is to be used. The cubic contents of the abutment are divided into two parts, first, the footing which contains 85 cubic yards and second, the main part which contains 245 cubic yards.

Art. 21 Cost.

The cost of the concrete and piling are based on the same principles as were considered in the piers.

Bill of Material:-
Concrete-
Footing 85 Cu. Yds.
Main Part 245 Cu. Yds.

Piles
50-45'-0"-Pine

ABUTMENTS
FOR
DECK PLATE GIRDER RR. BRIDGE.
OVER
SANGAMON RIVER
CHICAGO & ALTON RR.
SCALE 3/32" = 1'-0"
April 4, 1913.   N.L.Bunn Eng.

Fig. 7

The following is the itemized cost of one abutment:

330 cu. yds. 1:3:6 concrete @ $ 8.00 ---------$2,640.00

2250 lin. ft. foundation piles @ ¢ 0.35--------- 787.50

Cost of driving same @ ¢ 0.30------------------- 675.00

Total-----$4,102.50

Cost of two abutments -----------$8,205.00

Fig. 7 gives a detail of the two abutments.

VI-DESIGN OF SUPERSTRUCTURE.

Art. 22 Specifications.

In designing a bridge or any structure it is necessary to follow some fixed rules or specifications in order to attain satisfaction in regard to the finished product. Sets of specifications are usually written by men of experience in the particular kind of work specificied. It is the experience which shows what materials should be used for certain structures and what strength these materials will give. In the design for this bridge Coopers " Specifications for Steel Railroad Bridges and Viaducts," 1906 edition will be used.

The following specifications in regard to the concrete, timber and forms to be used, are:-

1.) Portland cement will be used in every case.

2.) Crushed stone will be used and not gravel.

3.) The concrete in the piers will consist of a 1:2;4 mixture in the coping and starck water and a 1:3:6 mixture in the body.

4.) The concrete in the abutments will consist of a 1:3:6 mixture throughout.

5.) The concrete is to be spaded in order to keep the stones

from projecting from the surface.

6.) The surface of the piers and abutments above the foundations must be smoothed off in order to remove any fins left by the forms. or other unevenness.

7.) The forms must be tight so the cement and water will not flow out.

8.) The forms must be well braced.

9.) The rods holding the starck water angle must be imbedded a foot in the concrete and must bent up at the end.

10.) The foundation piles are to be of cresoted long leaf y yellow pine.

Art. 23   The Design.

In considering the design of this bridge a formula was used for the determination of the width of the web plate, while in all other calculations the results were derived by a purely mathematical process. The sizes of the stiffeners and cross frames were obtained from tables in Dufour's Bridge Engineering. In all designs for railroad and highway bridges some method must be used to convey the ideas of the designer to the detailer. The stress sheet is used in this case. All necessary remarks and sizes as well as the stresses produced in the members must be placed on this sheet. This stess sheet should include a moment and shear diagram, an elevation of the plate girder, a view of the cross frames, a rivet spacing diagram, and the more important calculations. The stress sheet for this bridge is shown in Fig. 8 page 25.

Art. 24   The Cost.

The cost of the plate girders include three main items:-

Dead Load W = L(24+12L)
=103,900 + Track
=139,100#
Loading E-50
Specifications Cooper's 1906

Maximum Shears.
Dead Load = 34,775.
Live Load = 165,000.
Total = 199,775
199,775 ÷ 19.97 Sq. in. Net A. Req.
$\frac{10,000}{90 \times \frac{3}{8}}$ = 33.8 □" Gross A. Web.

199,775 = 41 Rivets.
4922

Maximum Moment Lb. Ins.
Dead Load = 9,160,000.
Live Load = 35,000,000.
Total = 44,160,000.

$\frac{9,160,000}{89.13}$ = 102,500 DL.Fl.St.
$\frac{35,000,000}{89.13}$ = 393,000 L.L.Fl.St.

$\frac{102,500}{20,000}$ = 5.125 □"
$\frac{393,000}{10,000}$ = 39.300 □"
44.425 □"
Net A. Req. in Fl.

2 ls 8"×8"×$\frac{3}{4}$ = 19.88 □"
2 C. Pl. 16"×$\frac{3}{4}$ = 24.00 □"
Total = 43.88 □"

STRESS SHEET
FOR
R.R. BRIDGE
OVER
SANGAMON RIVER
CHICAGO & ALTON R.R.
SCALE 1"=8'-0"
April 30, 1913 N.L.B. Eng.
Fig.-8-
25

Lb. Ins.
Moment Diagram
Scale 1"=40,000,000*
40,000,000.
30,000,000.
20,000,000.
10,000,000.
Moments.
Total
Live Load Moments.
Dead Load Moments.

Lbs.
160,000.
120,000.
80,000.
40,000.
Shear Diagram
Scale 1"=160,000#
Total
Shears.
Live Load Shears.
Dead Load Shears.

Top Lateral Bracing
Bottom Lateral Bracing

Rivet Spacing Diagram
Upper Flange

Allowable Rivet Spacing
End & Int. Crossframes

7'-6" c to c webs
88'-0" c to c Bearings
90'-5" overall
7'-6½" b to b of ls

1 Pl. 18"×$\frac{3}{4}$×46'-0"
19 Rivets
Pls. 8"×$\frac{3}{8}$ 90"×$\frac{3}{8}$
14 Rivets
Web Plate
Pl. 8"×$\frac{5}{8}$

Int. Stiffeners 6"×4"×$\frac{3}{8}$
End Stiffeners 6"×4"×$\frac{9}{16}$
Fillers $\frac{3}{8}$
2 ls 8"×8"×$\frac{3}{4}$-88'-0"
1 Pl. 18"×$\frac{3}{4}$×88'-0"
1 Pl. 14"×$\frac{3}{4}$-1'-6"

first, cost of the steel, which includes the original cost and the
cost for fabrication; second, cost of the freight; third, cost of
erection. The cost of the steel will be taken as $ 0.04 per pound,
while the freight cost will be considered as $ 0.15 per 100 pounds.
The cost of one span erected will be:-

Cost of 103,752 lbs. steel @ $0.04 per lb.--------$ 4,150.08

Cost of 103,752 lbs. Freight @ $ 0.15 per 100-----   155.63

Cost of 51.9 tons erection @ $ 14.00 per ton-------   725.00

Total ------ $ 5,030.71

Cost of six girder spans --------------   30,184.26

VI-CONCLUSION.

It is customary to give a general cost of the bridge. This cost
includes everything which goes to make up the structure. In the cost
of the total structure the following items must be included:- cost
of the masonary substructure, cost of the coffer-dams. cost of the
abutments.and the cost of the steel and erection.

The following is a list of the above items with their respec-
tive costs:-

Cost of the masonry substructure---------- $ 10,750.00

Cost of the coffer-dams-------------------   9,974.00

Cost of the abutments---------------------   8,205.00

Cost of the steel, erection, etc. -------   30,184.26

Total --------$ 59,113.26