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Proposed bridge over Gasconade River

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MSM
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PROPOSED BRIDGE

OVER

GASCONADE RIVER

A Thesis

By

ROLLA

1882

MSM
HISTORICAL
COLLECTION

This scheme for a Bridge over the Gasconade River is presented as a thesis for the degree of Civil Engineer.

Henry W. Gibb.

Rolla, Mo.
June, 1882

The Gasconade River and Valley:

This stream is subject to heavy freshets during the spring months which would necessitate a structure with copious waterway.

The fluctuation as given by the observers in the locality of the M.K. and T. R.R. bridge across this stream is twenty one (21) ft. The highest recorded flood being that of the year 1876 at which stage it is said to have reached to within three and one half (3½) ft. of the top of the piers at the R.R. bridge.

At the site of the proposed Bridge, the west bank of the stream slopes gradually to the water edge affording excellent opportunity of approach.

The east bank is of the character of bottom land subject to overflow, this bank extends back from the river twelve hundred and fifty (1250) ft. where it is met by a bluff of Magnesian Limestone. In order to render the bridge accessible in high stages of water it will be necessary to construct embankment or trestle work from the bluff to approach of bridge.

The bed of the stream at this point is of solid rock, furnishing excellent

formation for piers and abutments

The Survey:-

This portion of the river was surveyed by me in March (1882) at which time the water was three feet and ten inches above low water mark, as given by the engineer there at the St. L. and S. F. R.R. bridge.

Soundings were made and the velocity of the current taken, all information that could at this stage of water be obtained was secured.

Plate I shows a map of a part of the river above and below the location of proposed bridge. It was compiled from a general map in the possession of the School of Mines.

Plate II shows a map and profile of the bridge site. This was prepared directly from the notes of survey.

The velocity of the current was determined and found to be two hundred and eighty (280) ft per minute.

The slope of the surface of the water at this point is thirteen (13) in. per mile.

As previously stated the fluctuation is twenty one (21) ft, (about).

An excellent quarry of Dolomite (Magnesian Limestone) about one-half mile from the bridge site would

Furnish a fair sample of stone for the 2nd abutment

The following analysis made by me, of this stone will show the composition

Sp. Gr. = 2.68

SiO_2	4.14
Fe_2O_3	1.42
$MgCO_3$	36.45
$CaCO_3$	57.76
Fe_2O_3	trace

This stone was used in constructing the masonry for the Railway bridge over the Chemung at Elmira, N.Y.

Materials:—

In structures of this class the material of which they are composed should be a matter of deep concern. It is therefore necessary for the Engineer to fully acquaint himself with the properties of the materials with which he deals.

Stone:

The valuable property of this which renders it the most useful of all building material, is that it resists the action of ordinary exposure to the weather, and as the destructive action of fresh and salt water have but little effect upon it it is well adapted for piers and other marine structures.

As yet science has been unable to render any material assistance to the engineer in the selection of stone. For important structures great care should be exercised in the selection of this material. Artificial tests have been devised which may serve to direct the examination. The fact of its having been successfully used for a period of years is the best and conclusive evidence of its fitness.

Iron:—

In this iron age upon which we are now entering it will be well to give this material of which "little knowledge is a

dangerous thing" careful attention and study

It should be borne in mind that Iron is by no means a material uniform as to strength but differs in quality as to the localities of its production. There is a wide range and many grades between the best and the poorest which to the unskilled eye would present no difference.

There are numerous causes of an arbitrary nature operating in the production of this metal which determine its quality. Different ores produce different grades and often a very minute amount of impurity as Phosphorus may entirely destroy the desirable properties of the metal.

Bessemer Steel unavailable for its strength and cheapness is rapidly coming into use by Bridge Engineers. Its quality depends in a great measure upon the pig iron from which it is produced.

The following figures from the U.S. Census report for 1880 will serve to convey an idea of the great increasing demand for Steel.

	Tons
Product of the world for 1810	917
" " " " 1880	4,343,718

The United States furnished about 29% of the above estimate for 1880

Timber:-

All timber for bridge purposes should be perfectly "sound" free from "heart shakes" sap[ing] loose or black knots. In such case where it would be well clear timber only, should be used.

In the truss this timber is used almost wholly to resist compression and before the introduction of web posts of rolled iron it was used in the majority of truss bridges.

The durability of this material may be greatly enhanced by artificial means. In all cases where the pieces are exposed to the action of the weather they should be protected by paint or other covering to exclude them, as far as possible, from the air and moisture.

It does not come within the scope of this article to enter into a general discussion of the merits of the various classes of Bridges. But we will here briefly consider the materials at hand and requirements and see what form would be best adapted to our purpose.

Stone Bridge:-

Notwithstanding the abundance of available material in the vicinity for a structure of this class, the requirements are not even met would justify the great outlay which would attend its construction.

This class of Bridge is confined to localities thickly populated and where architectural effect is desired.

Iron Truss Bridge:-

Bridge building as a science is of comparatively recent origin, far relating to none of which might be called ancient bridges do we find of them having been mathematically calculated determinations of strains upon the component elements of the bridge. All present are with extreme accuracy estimated by use of our applied mathematics the load to which each member of the truss will be subjected and by calculating

our tables of the strength of materials we are able to determine the exact size of the members necessary to carry the load. Thus by giving to each member its proper dimension and avoiding any superfluous weight which may tend to weaken the entire structure.

Factor of Safety:-

In bridge building more strength is always given than requirements demand that no contingency may arise from unforseen weakness - defective material or poor workmanship - This excess is called the Factor of Safety and may be defined as the number of times that the maximum load should be increased in order to break the structure.

In calculating the greatest load that may come upon a commercial bridge it is customary to consider the weight of the bridge covered with men as closely as this can conveniently be done and by allowing a weight of One hundred and fifty (150) pounds for man we find the load to be, about Fifty five (55) pounds per square ft.

As regards material truss bridges may be classed in another division i.e.

I Wooden

II Combination

III Iron

Class I is represented by a few trusses prominent among them are the Howe and Long truss but since the introduction of Iron generally into bridge building they have given way to the Combination and Iron bridges.

The former class is represented by the Howe and Post trusses these are so designed that the tensile strain is borne by the Iron members and that of compression by wood.

As in the design of Iron trusses still the guiding point in their arrangement of the members is to take advantage of great tensile strength of that material.

As the combination truss will fill all the technical requirements and at the same time is the cheapest in this case, there being good timber in the locality which can be had at reasonable, if not low figures, we will adopt the Howe Truss design on account of its several desirable features - They are

I Simplicity of construction, (as many of the members are of the same dimention.)

II Economy of material.

The Howe Truss:-

This truss consists of an upper and lower cord connected by web members of Wood and Iron.

Upon the upper side of the lower cord and lower side of the upper cord "saddles" are inserted in shallow notches which form a support for the ends of the inclined members, of wood through these saddles long bolts provided with screws pass vertically from top to bottom thus holding the cords together In the earlier Howe Truss wooden saddles were used but now they have almost wholly given place to saddles of Cast Iron -

The lower cord being subjected to tensile strain Iron Eye-bars and the join

have been largely used in a modification of this truss -

Among the notable New Hampshire bridges may be mentioned the St. Paul R.R. bridge across the Mississippi River Consisting of Six (6) spans of New Iron Truss One hundred and Fifty (150) ft long each.

The proposed Wisconsin River Bridge:—

The Bridge will consist of two spans of the Howe truss One Hundred and Fifty five (155) ft long, each, supported upon piers and abutments of Magnesian Limestone.

There will be a roadway Sixteen (16) ft in the clear also a foot path Six (6) ft wide.

The bridge will be proportioned to carry in addition to its own weight Fifty five (55) pounds per sq. ft. of surface.

There shall be an allowance for factor of safety of not less than Three (3).

Structure: -

Plate III Represents the masonry designed for the structure. It is to be of Limestone set in good hydraulic cement. The pier shall be wholly of dressed stone while the abutments may be of rubble with dressed stone facing.

The bed of the stream being of solid rock the scour of the current will not effect the masonry of the pier notwithstanding the increase velocity due the the obstruction by the pier.

So it will be necessary only to investigate the effects of the current which tend to revolve the pier about its end or slide it upon its foundation.

The form of the pier is that usually adopted for bridges in a stream of similar character - not subject to heavy "drift rafts" or floating ice.

The approx. cubical contents of the pier is 3210 ft -

62.5 × 2.68 = 167.5 = wt 1 cubic ft of masonry, ∴ 3210 × 167.5 = 537675 = 269 tons (nearly)

The moment of the weight with respect to the outer edge will be represented by

$$269 \times 12.5 = 3362.5$$

But ~~the~~ considering the water at high water mark. the pier will act with a

eleven one of eight (8) nearly
hence : $\frac{3362.5}{8}$ = 420.3 tons = pressure
required to overturn the pier.
To resist sliding:
Considering the coefficient to be Six hundredths
(.6) we will have
$$269 \times .6 = 161.4 = \text{the power}$$
in tons required to slide it along its foundation -
We see that if the pier is thick enough to prevent rotation it is heavy enough to resist sliding
In making these calculations we have not considered the fact that the weight of the superstructure upon the pier adds materially to its stability.

Construction of Masonry

The stone may be properly dressed to shape at the quarry and transported to the bridge by wagon.
During low stage of water little trouble will be encountered in laying the pier foundation. I would suggest that a coffer dam of two (2) thickness of (3) or (4) inch plank be built for that purpose. A crane for handling heavy pieces of rock will be found necessary, also a scaffold supported upon trestles connecting the pier site with the East bank

Great care should be taken in properly preparing the bed rock for the pier, and every stone laid should have good "bond"

The Superstructure:

The chief element in good bridge designing is to have one part as strong as another, — the joint as strong as the part it serves to connect. For the entire structure is as weak as is the weakest part.

The absence of one foot of timber or one pound of Iron may result in the destruction of the entire bridge. On the other hand excess of material and therefore weight is also objectionable.

We will now investigate the strains on the Howe truss and give to each member of our bridge its proper dimension.

Strains: —

We have computed that the greatest load that can come upon the bridge is fifty-five (55) pounds per square ft.

Then

[illegible] = 3400 sq ft = area of bridge

3400 × 55 =

Moving Load = 187000.

Wt. of Bridge (700 lbs per ft) (For [illegible]) Total load = 108500. / 296050.

This load is equally divided between the two trusses of each span. And also

the load on each truss is divided between each of the twelve panels

∴

Total a p[illegible] load with factor of safety
$296050 \times 3 = 888150 = 445$ tons (nearly)

$\frac{445}{2} \div 12 = 18.54$ = load per panel

By consulting diagram 1 (which represents a portion of one truss) we see that the weight comprised between (C) and (D) must be sustained by (C) also the portion between (D) and (K) by the support (pier or abut) at (K) and in like manner throughout the truss -

As all the panel loads are eventually transmitted to the abuts it is obvious that each abut sustains just one half the load of the truss.

Let us now find the loads sustained by the vertical members. One half (½) the load of the center panel is transmitted to each abut. Commencing at (B) with a panel load (18.54) and going to (A) where it divides one half (½) going to the right abutment and one-half (½) to the left. The the latter being communicated to (y) takes up the load (18.54) already there and produces at (x) a vertical strain of (27.18) by continuing this process we find the strains on all the vertical members.

To find the strain on the inclined members and cords we set off on (A.B) with the

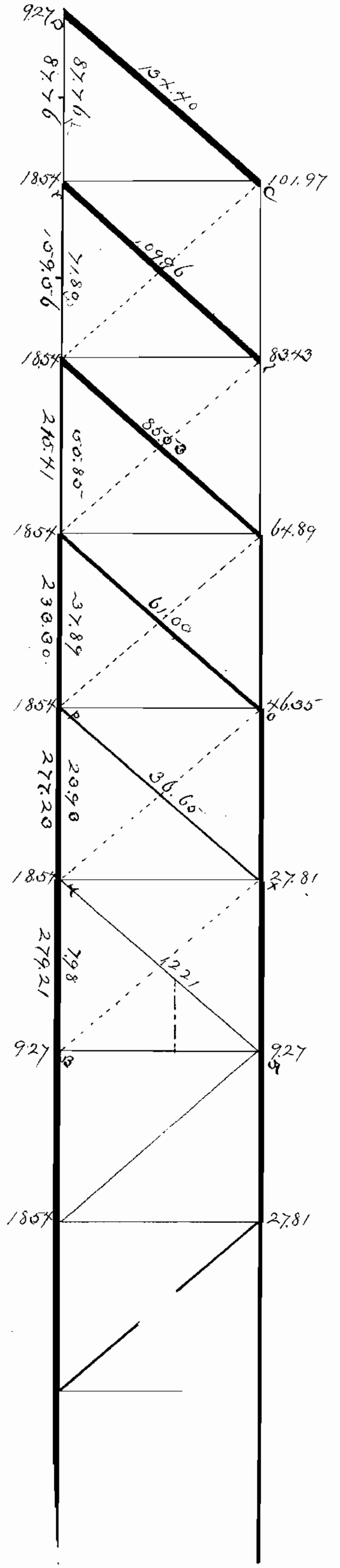
9.27
101.97
1854
83.43
1854
64.89
1854
46.35
1854
27.81
1854
9.27
9.27
1854
27.81

DIAGRAM I

any convenient scale a line to represent the vertical strain on that member, and from the foot of this line draw a perpendicular the diagonal of the triangle thus formed will represent the strain on the inclined and base strut of the cord.

Besides this graphic method Trig. functions may be used:- Thus

L ySAB = x0°-x3

R (our strain on AB) = 9.72

Nat. Tangent x0°x3 = .8606

∴.8606 x 9.72 = 7.98

Nat. Sec. x0°x3 = 1.3183

∴ 1.3183 x 9.72 = 12.21

The strains upon the counter braces are in the same manner determined.

It will be seen by inspecting the strains as found that the brace and rods should decrease towards the centre while the counter braces should increase.

The segments of the different parts of the cord are not the same but it is customary to have it of equal dimentions throughout.

After consulting approved tables of the strength of materials I have prepared the following giving dimentions of the various parts-

Resistance to compression of timber Eight hundred (800) pounds per sq. in.
Iron requiring from (50000) to (60000) to break it.

Upper cord 7 pcs 6"x10"
Lower " 2 " 6"x10" and 2 pcs 5½"x10"

Braces Counter Braces

Begining at End, 1 -	2 pcs 10"x10",	1 pc 5"x6",	3 rods	2¼" dia.
2 -	" " 9"x10",	1 " 6"x7",	"	2⅛" "
3 -	" " 8"x10",	1 " 6"x8",	"	2" "
4 -	" " 7"x10",	1 " 7"x8"	"	1⅞" "
5 -	" " 6"x9",	1 " 8"x8"	"	1¾" "
6	" " 5"x9",	1 " 8"x8"	"	1½" "

to center

Floor beams 7"x14"
Stringers 4"x6"
Floor for Roadway 3½ in
" " Foot way 3 in
For dimention of other pieces see Plates IV and V.

Estimate:

Approximate Cost of Bridge:-

Masonry:

Getting out stone from quarry allowing for waste	2.70	
Dressing and working to shape	10.20	
Cost at quarry		13.00
Hauling to Bridge		.90
Cement and Etc		.60
Laying including scaffold, hoisting machinery & Etc		1.80
Net cost per cubic yard =		$16.30

For Rubble

Getting out stone for work at quarry, allowing for waste	2.60	
Hauling to Bridge	.90	
Cement and Etc	1.90	
Laying	2.10	$7.40

689 cubic yds rubble @ 7.40 = 5098.60

345 " ashlar masonry @16.30 = 5623.50

Excavation for abutments, pumping the water for piers, coffer dams and Etc - = $270.00

Total cost of Masonry $10992.10

Superstructure:

110,026 ft. first class (timber and lumber) of required sizes including all bridge seat at [illegible] (16%) [illegible] per thousand = 17604.16

13212 pounds gross casting iron for

[illegible] @ [illegible] per pound 556.51

7500 pounds iron castings for

[illegible] @ .4 per pound 300.00

Bolts, Nuts and Etc 160.

Labor at Mechanics 800

Total cost of Superstructure = $19420.67

" " " Substructure = 10992.10

" " " Bridge 30412.77