1882

Proposed bridge over Gasconade River

Frank W. Gibb

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over

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A Thesis

By

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ROLLA

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

Henry W. Gibbs.

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 Mo. 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 date 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 (1200) ft. where it is met by a bluff of Magnesian Lime-stone. 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 thirteen feet and ten inches above low water mark, as given by the engineer there at the St L and I. M. 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 aerial 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 fine quality of stone for the piers and abutments.
The following analysis made by me, of this stone will show the composition

Sp. Gr. 2.68

SiO_2	4.19
Al_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 stream at Arlington, Mo.

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 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 pier 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 this metal.

Bessemer Steel invaluable 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 "wind shakes" sap ing loose or black knots. In such what would be call clean timber only, should be used.

In the truss this timber is used almost wholly to resist compression and before the introduction of wrot posts of cast 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, requirements and see what form would be best adapted to our purpose.

Stone Bridge:-

Notwithstanding the abundance of suitable material in this vicinity for any structure of this class, the requirements are not such as 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.

The Truss Bridge:-

Bridge building as a science is of comparatively recent origin, for relating to none of what might be called ancient bridges do we read of their having been mathematically calculated determinations of strains upon the component elements of the bridge. At present we with extreme accuracy estimate by aid of our applied mathematics the load to which each member of the truss will be subjected and by consulting....

our tables of the strength of materials we are able to determine the exact size of the member necessary to carry the load. Thus by giving to each member its proper dimention we obviate 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 unforeseen 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 inorder to break the structure.

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

As regards material truss bridges may be classed in three divisions i.e.

I Wooden

II Combination

III Iron

Class I is represented by a few trusses prominent among them are the Howe and Long trusses 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.

Owing to 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 - Among them 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 tensil strain Iron Eye-bars and the pin have been largely used in a modification of this truss -

Among the noted Howe truss bridges may be mentioned the St. Paul R.R. bridge across the Mississippi River. It consists of Six (6) spans of Howe 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 pier and abutment 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 increased velocity due to the obstruction by the pier.

So it will be necessary only to investigate the effect of the current which tend to revolve the pier about its axis 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 lever arm 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

$$269 \times .6 = 161.4$$ = 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 trestle connecting the pier end 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 dimensions.

Strains: —

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

Then

(6 × 1000)/155 = 3400 sq ft = area of bridge

3400 × 55 =

Moving Load = 187000.

Cost of Bridge (700 lbs per ft) (For timber) 108500.

Total load = 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 & live load with factor of safety

$$296050 \times 3 = 888150 = 445 \text{ tons (nearly)}$$

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

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 r) 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 (1/2) the load of the center panel is transmitted to each abut Commencing at (B) with a panel load (18.54) and moving to (A) where it divides one half (1/2) going to the right abutment and one-half (1/2) to the left. The the latter being communicated to (y) taken 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

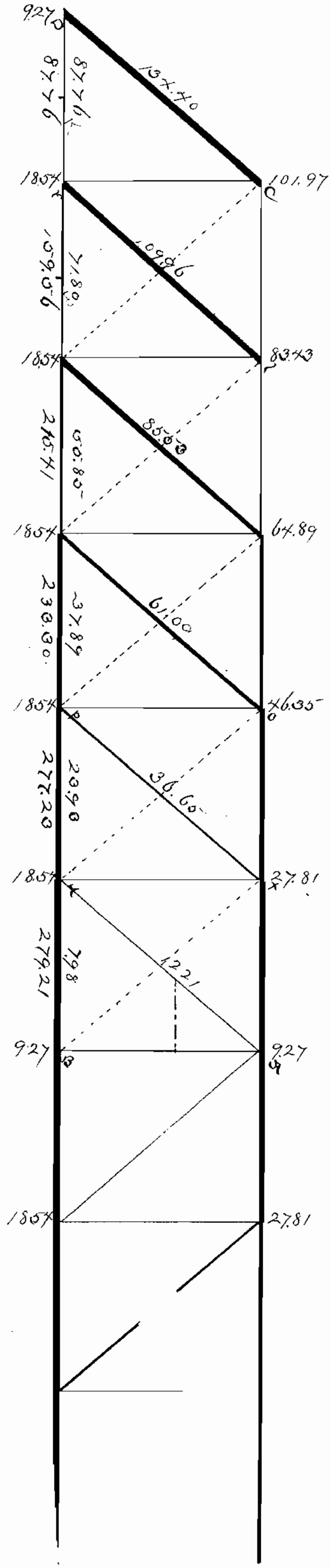

DIAGRAM I

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 incline and the base that of the cord.

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

$\angle\ yAB = 40°-43$

R (vert. strain on AB) $= 9.72$

Nat. Tangent $40°43 = .8606$

$\therefore .8605 \times 9.72 = 7.98$

Nat. Sec. $40°43 = 1.3183$

$\therefore 1.3183 \times 9.72 = 12.21$

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

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

The requirements 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 chord 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 dimension 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 scaffolding, hoisting mortaring & 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 out for pier, cofferdam 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 work
at Sixteen (16) dollars per thousand = 17604.16

13212 pounds cast iron for
2000 [illegible] @ 4¼ cts per pound 556.51

7500 pounds iron castings for
washers etc @ .4 per pound 300.00

Bolts, Nuts and Etc 160.

Labor of Mechanics 800

Total cost of Superstructure = $19420.67
" " " Substructure = 10992.10
" " " Bridge 30412.77