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### Proposed bridge over Gasconade River

Frank W. Gibb

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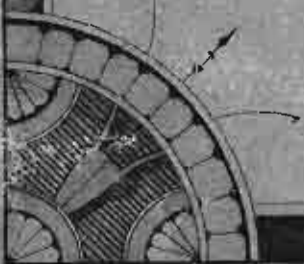
PROPOSED BRIDGE  
OVER  
GASCONADE RIVER

A Thesis  
BY



ROLLA  
1882

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HISTORICAL  
COLLECTION



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

James W. Gibb.

Rolla, Mo.

June, 1882

The Gasconade River <sup>Valley</sup>:

This stream is subject to heavy freshets during the spring months, which would necessitate a structure with copious water-way.

The fluctuation as given by the obsever in the locality of the St. L. & N. O. R.R. <sup>bridge</sup>, across this stream is twenty one (21) ft. The highest recorded flood being that of the year 1876 at which time it is said to have reached to within three <sup>and</sup> one-half (3 1/2) ft. of the top of the pier 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, the bank extends back from the river twelve hundred <sup>and</sup> fifty (1200) ft. where it is met by a bluff of Magnesian Limestone. In order to make the bridge accessible in high stages of water it will be necessary to construct embankments on ~~both~~ work from the bluff to approach of bridge.

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

formation, position and adjacent

### The Survey:-

This portion of the river was surveyed by me in March (1882) at which time the water was three feet <sup>2 1/2</sup> or four inches above low water mark, as given by the engineer then at the St. L. & N. R. bridge.

Soundings were made <sup>2 1/2</sup> and the velocity of the current taken, all information that could at this time of water be obtained was secured.

Plate I shows a map of a part of the river above <sup>and</sup> below the location of proposed bridge. It was compiled from several maps in the possession of the School of Mines.

Plate II shows a map <sup>and</sup> 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 <sup>or</sup> slightly (287) ft per minute.

The slope of the surface of the water at this point is three <sup>or</sup> (3) 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 pier <sup>and</sup> abutment.

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

Sp. Gr. =	2.68
$\text{SiO}_2$	4.14
$\text{Al}_2\text{O}_3$	1.42
$\text{MgCO}_3$	36.45
$\text{CaCO}_3$	57.76
$\text{Fe}_2\text{O}_3$	trace

This stone was used in constructing the  
masonry for the Railway bridge over the  
stream at Helington, Mo.

## Materials:—

In structure 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 dealt.

### Stone:

The valuable property of this which under 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 <sup>and</sup> salt water have but little effect upon it it is well adapted for <sup>and</sup> other marine structures.

The 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 <sup>and</sup> conclusive evidence of its fitness.

### Iron:—

In the 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 <sup>and study</sup>

It should be borne in mind that Iron is by no means a material uniform as to strength but differs in quality as do the localities of its production. There is a wide range and many grades between the best <sup>and</sup> 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. Differences in product differ greatly <sup>and</sup> often a very minute amount of impurity - as Phosphorus may entirely destroy the desirable properties of this metal.

Bessemer Steel remarkable for its strength <sup>and</sup> 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.

Product of the World for 1870	917
" " " " " " " " 1880	7,373,718

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



## Timber:

All timber for bridge purposes should be perfectly "sound" free from "knots & shakes" sap <sup>ing</sup> loose or black knots. In short, what would be called clear timber only, should be used.

In the timber that 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 timber bridges.

The durability of this material may be greatly enhanced by artificial means. In all cases where the parts 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 <sup>and</sup> 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 <sup>and</sup> requirements and see what form would be best accepted for our purpose.

#### Stone Bridge:-

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

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

#### The Iron 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 there having been mathematically calculated determinations of strain 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

own 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 dimension 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 in order to break the structure.

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

As regards material timber bridges may be classed under three divisions, i.e.

I Wooden

II Combination

III Iron

Class I is represented by a few bridges, prominent among them are the Town <sup>and</sup> Long bridges but since the introduction of Iron generally into bridge building they have given way to the Combination <sup>and</sup> Iron bridges.

The former class is represented by the Howe <sup>and</sup> Post truss there are so designed that the truss action is born by the Iron members <sup>and</sup> that of compression by wood.

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

As the combination timber 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 dimension.)

II Economy of material.

The Howe Truss:-

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

Upon the upper side of the lower cord <sup>and</sup> 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 screw caps 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 <sup>and</sup> the pin

have been largely used in a modification  
of this type -

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 <sup>and</sup> fifty (150) ft  
long each.

## The proposed Yucconah River Bridge:—

The Bridge will consist of two spans of the Howe truss type. Each span will be fifty five (55) ft long, supported upon pier <sup>and</sup> 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 facings.

The bed of the stream being of solid rock the scour of the current will not affect the masonry of the pier notwithstanding the increase of velocity due to 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 raft" or floating ice.

The Approx. cubical contents of the pier is 3210 ft<sup>3</sup> -

$12.5 \times 2.68 = 167.5 =$  wt. 1 cubic ft. of masonry,  $\therefore 3210 \times 167.5 = 537675 = 269$  <sup>tons</sup> (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 must <sup>"</sup>the piers will act with a



turn on of right (8) nearly

hence :  $\frac{3362.7}{8} = 420.3 \text{ ton} = \text{pressure}$   
required to over turn the pier.

To resist sliding:

Considering the coefficient to be six hundredths  
(.6) we will have

$$269 \times .6 = 161.4 = \text{the power}$$

is ton required to slide it along its founda-  
tion -

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) men placed 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 cut with the East  
bank.

Goal: one should be taken in properly  
preparing the bed rock for the piers, <sup>and</sup>  
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 joints as strong as the  
part it seems 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 thus for  
weight is also objectionable.

We will now investigate the strains on  
the Howe truss <sup>244</sup> 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

$$(6 = 1000) / 55 = 3400 \text{ sq ft} = \text{area of bridge}$$

$$3400 \times 55 =$$

$$\text{Moving Load} = 187000.$$

$$\text{Cost of Bridge (700 } \frac{\text{lb}}{\text{sq ft}} \text{)} \quad \text{Total Load} = \frac{108500.}{296050.}$$

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 seven panels.

∴

Total span load with factor of safety  
 $296000 \times 3 = 888000 = 4 \times 5$  (nearly)

$$\frac{4 \times 5}{2} \div 12 = 18.54 = \text{load per panel}$$

By consulting diagram I (which represents  
a portion of one truss) we see that the  
weight comprised between (A) & (B) must  
be sustained by (C) also the portion  
between (D) & (E) by the supports (pin or abut)  
at (A) and in like manner throughout  
the truss.

In all the panel loads are eventually  
transmitted to the abut. 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 member. One half ( $\frac{1}{2}$ ) the  
load of the center panel is transmitted  
to each abut. commencing at (B) with a  
panel load ( $18.54$ ) coming in to (A) where  
it divides one half ( $\frac{1}{2}$ ) going to the right  
abutment and one half ( $\frac{1}{2}$ ) to the left. The  
the latter being communicated to (C) half  
of the load ( $18.54$ ) already there and  
produces at (A) 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 rods we set off on (A.B) with

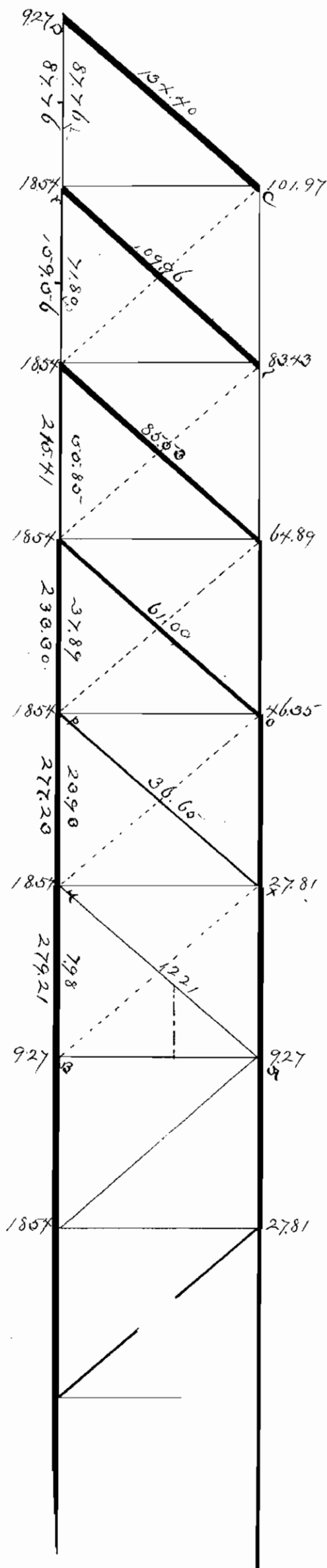


DIAGRAM I

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 <sup>and</sup> the base that of the cord.

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

$$\angle yAB = 40^\circ - 43$$

$$R \text{ (over strain on } AB) = 9.72$$

$$\text{Nat. Tangent } 40^\circ - 43 = .8606$$

$$\therefore .8606 \times 9.72 = 7.98$$

$$\text{Nat. Sec. } 40^\circ - 43 = 1.3183$$

$$\therefore 1.3183 \times 9.72 = 12.71$$

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

It will be seen by inspecting the strains as found that the brace <sup>and</sup> rods should decrease toward the center while the counter brace should increase.

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

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

Resistance to compression of timber Eight  
hundred (800) pounds per sq. in.

Iron requiring from (50000) to (60000) lb  
break it.

Upper cord 7 per 6x10"  
Lower " 2 " 1 1/2 x 10"<sup>and</sup> 2 per 5 1/2 x 10"

Beams Cantilever Beams

Beams at end

1 -	2 per 10x10", 1 per 5x6", 3 rods 2 1/4" dia.
2 -	9x10", 1 " 6x7", - 2 1/8 "
3 -	8x10", 1 " 6x8", " 2 " "
4 -	7x10", 1 " 7x8", " 1 7/8 "
5 -	6x9", 1 " 8x8", " 1 3/4 "
6 -	5x9", 1 " 8x8", " 1 1/2 "

to center

Floor beam 7x14"

Stringer 4x6"

Floor for Roadway 3 1/2"

" " Foot way 3 "

For dimension of other pieces see

Plates IV <sup>and</sup> V.

Excavate:

Approximate Cost of Dredge:

Structure:

Getting out stone from quarry, allowing for waste	2.75	
Dredging <sup>and</sup> working to shape	10.25	
Cost at quarry		13.00
hauling to Buick		.90
Cement <sup>and</sup> Etc		.65
Laying including scaffolding, hardware		
insurance ETC		1.80
		<hr/>
Net cost per cubic yard =		16.30

Low Rubble

Getting out stone for work at quarry, allowing for waste	2.50	
hauling to Buick	.90	
Cement <sup>and</sup> Etc	1.90	
Laying	2.10	8.70

689 cubic yds rubble @ 7.80 = 50.98.60

345 " " " " " " @ 16.30 = 56.23.50

Excavation for abutments, preparing

the bed rock for pier, coping down

<sup>and</sup> Etc -

= 270.00

Total cost as Structure

---

\$ 10,992.10

Supplies:

110,026 ft fast blue (white and black)  
of equal size cuttings at bridge site  
at \$16.00 per ton = 17604.16  
13212 pound gross weight for  
2000 lbs @ \$2.80 per pound 5610.57  
7500 pound iron cuttings for  
recycled steel @ .40 per pound 300.00  
Bolt, Nut and etc 160.  
Labor of Mechanic 800

Total cost of Superstructure = \$19425.67

" " " Structure = 10992.10

" " " Bridge 30417.77