1876

Beaver bridge

James E. McGrath

THESIS

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MISSOURI SCHOOL OF MINES AN

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A Thesis

For the Degree of C.E.

BY

J. E. M^c GRATH

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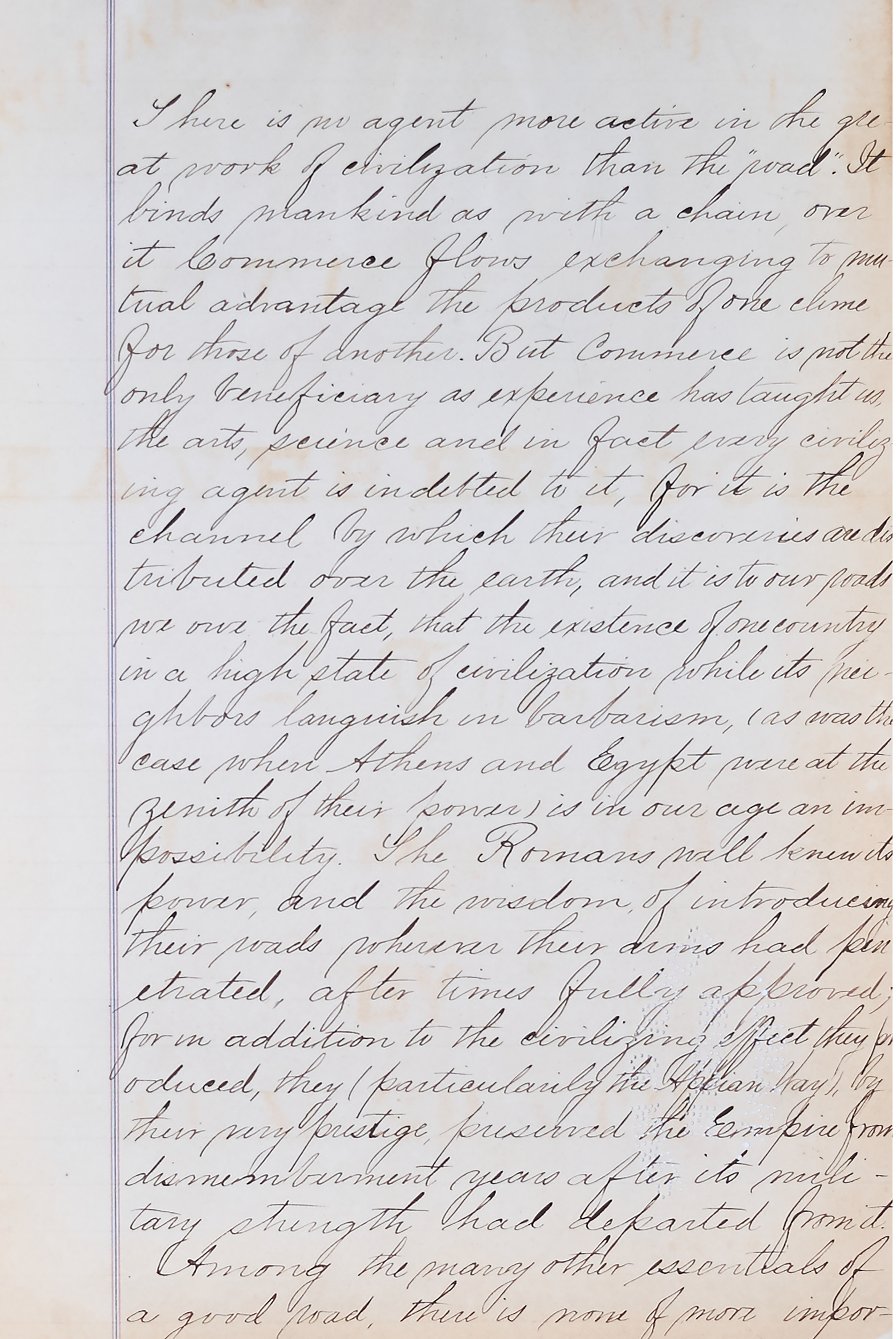
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There is no agent more active in the great work of civilization than the "road." It binds mankind as with a chain, over it Commerce flows, exchanging to mutual advantage the products of one clime for those of another. But commerce is not the only beneficiary, as experience has taught us. The arts, science, and in fact every civilizing agent is indebted to it, for it is the channel by which their discoveries are distributed over the earth, and it is to our roads we owe the fact that the existence of one country in a high state of civilization while its neighbors languish in barbarism (as was the case when Athens and Egypt were at the zenith of their power) is in our age an impossibility. The Romans well knew its power, and the wisdom of introducing their roads wherever their arms had penetrated, after times fully approved; for in addition to the civilizing effect they produced, they (particularly the Appian Way) by their very prestige, preserved the Empire from dismemberment years after its military strength had departed from it.

Among the many other essentials of a good road, there is none of more tance than the bridge; it is the most important of all its adjuncts. Without it the rapid torrent, yawning chasm or unfordable river, all offer insuperable obstacles; and its universal existence bears sufficient testimony of its importance.

The construction of a bridge, in consequence of the nature of its office, is an undertaking demanding the most painstaking and careful consideration upon the part of the Engineer and we may obtain a fair idea of the skill required from the meed of praise which is everywhere conferred on the successful bridge builder. It was not until within the last Century (for Civil Engineering as a distinct profession is no older), that bridge building became a science; fine bridges were erected previously, but being built by Architects, Carpenters, Masons and others who had no special training to qualify themselves for this department, their work was not distinguished for the design and perfect adaptation of the material to the strain to be borne which characterizes the work of our modern Engineers. The Railroad introduced a new consideration into bridge building

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The main principle which governs the Howe Truss bridge is, that the compressive strain will be borne by cast iron rods while the tensile strain is to be sustained by the wood. Thus the greatest economy is exercised for the two materials are arranged so as to bring the greatest strength of each into play; this arrangement and the ease with which the bridge can be erected and repaired, leave but little to be desired.

The Little Beaver Bridge is situated on the A & P. R.R., 3 3/4 S. W. of Rolla it is built on the "Howe Truss" plan and spans a valley through which flows the "Little Beaver Creek" — it has two approaches (stringers supported by trestles), the length of the northern one is 38 ft., while that of the southern one is 35'5". The bridge is composed of 5 spans and is supported on 6 piers; the length of the bridge proper is 687' 2", with the abutments it is 760'7." The piers are of sandstone and have a batir, from about one half of their hight to the top, of one inch to the foot. In consequence of the comparatively small size of the used in their construction, the

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Railroad Company has commenced to tear them down in order to erect larger piers. The dimensions of the new piers (for the bottom course) will be 13'1" x 30' instead of 7'6" x 24'3" as in the old one – the batir will however in the new piers start from the second course. All the timber used in this bridge (except the ties which are oak) is white pine.

Data

Length of 1st Span	88'6"
" " 2nd "	149'6"
" " 3rd "	149'
" " 4th "	149'10"
" " 5th "	150'4"
No of panels in first span	9
" " " the other spans	15
Length of panel	10'6"
" " pier "	2'6"
Distance between Wall plates	4'
Width from out to out of chords	19'
" in clear between "	14'
Hight of truss from out to out of "	21'10"

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In all calculations where the intention is to determine the dimensions of any material to sustain a given strain, to guard against defective workmanship and unforseen weakness in the material it is the rule to base their calculations on some fraction of the known strength, as 1/6 or 1/10th of it; this fraction is known as the "factor of safety" – the general allowance for the working strength of wood, per square inch of section, is 2000 lbs for its tensile and 1000 lbs for its crushing strength and for cast iron 25,000 lbs is allowed for its crushing strength.

In determining the strain that a certain weight (for bridges of ~~not more than~~ 110 foot span, 1/2 a ton per running foot ~~and~~ the weight of the span itself and 1 ton pr. foot for the load, is generally allowed) will produce in the chords, we must treat them as loaded beams supported at both ends. The greatest horizontal strain will be at the centre of the chords and it decreases thence to the abutments where its value should be zero; the vertical strain on the contrary decreases from the abutments to the centre and in a well designed bridge this would be taken ad-

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vantage of to make the end panels only one half as wide as the centre ones, in order both to economize timber and lessen the strain on the braces. From the principles of mechanism we deduce the rule for the strains on the chords (first premising that the strain will be a tensile one for the lower and a compressive one for the upper chord), $y = \frac{W \times S}{8h}$; in which y represents the strain, w the weight and h the height. Substituting in this equation for W, 132½ tons – S, 88'6" and for h 20'1" and we find the cross section of the lower chord should be 37 sq. in., whereas in reality it is 336 showing a most ample allowance for safety.

The upper chord while being equally strained and having a smaller allowance for strength demands less of a cross section because as the strain it supports is one of compression the fact of the chord having to be built with joints, which militates most severely against the lower chord whose strain is one of tension, this is the reason why they have allotted 252 sq. in. of cross section to the upper chord. The fact of this most excessive allowance of strength in these chords can only be accounted for by the

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necessity of making these chords uniform
with those of the larger span -- the
length of their span being but little more
than half as long as that of the others.
Substituting in the equation already
given the values of those terms for the
2nd span (S = 149’6”, h = 20’1” and w = 223 ⅓
tons), we obtain for the lower chord the
cross section, 104” sq. in. and for the upper
one 208 sq. in., this although a closer
result shows that still they are unnecessarily
long.

In consequence of the abutments and
piers being finally compelled to sustain
the whole load, it is evident that the
end braces and rods will have the
whole weight thrown on them; in
this calculation we will confine ourselves
to the larger span as it is a better type.

The weight of truss whose length is
149’6” together with its maximum load
will be 446,666 ⅔ lbs., this will throw
223,333 ⅓ lbs. on each end or 111,666 ⅔
for each panel but as the braces are arranged
in pairs the strain upon each brace will
be 55,833 ⅓, the braces being diagonals
of the parallelogram formed by the panel
the strain will be increased on them in the

ratio of the value of their length over that of the perpendicular heigth between the trusses, this gives us for the strain 66,508 lbs and as the brace is in compression it will necessitate a cross section of 67 sq in the section used is 89¼ sq. in; to ascertain whether there is any danger of the beam yielding by flexure per substitute, in, the empirical formula for white pine $l^2 = \frac{9000\ bd^3}{w}$ and get a value of 30 ft for (l), and as the brace is only 21'8" we see it is amply sufficient.

In each of the rods, for the same reason there will be a strain of 55,833⅓ lbs. these being vertical the strain is direct, and for this weight a cross section of 2⅕ sq in which would be that of a rod whose diam is 1¾" the diameter of those in use.

The counterbracing on account of its object (giving stiffness to the truss) will never have to sustain only the greatest variable load which would be 289000 lbs. By rules already adverted this would necessitate a cross section 37" sq. in. or a beam of the dimension 6"x6", the dimensions of the one in use are 7¾" x 7".

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The diagonal bracing, which is always

necessary in a bridge of the character of the one under discussion (i.e. one in which the roadway runs on top), is intended for the prevention of side motion and as no rule can be laid down for the exact determination of its dimensions, it is the custom to make them 5" x 7", which differs but little from the dimensions used in the Beaver Bridge, 6" x 6 3/4".

The horizontal bracing which is intended to prevent lateral flexure in the roadway from the wind and other causes, is (The greatest strain upon) composed of braces and ties differing from those in the truss, in the fact that only two braces are used instead of three, but both braces are of equal strength. The greatest strain possible would be, when the sides were weather boarded, in a strong gale. Allowing 15 lb. per sq. ft. for the strength of the wind we would have 47935 lbs. for the whole strain or 23,963 lbs. for each series top and bottom as the braces are diagonals, on reduction we would find 16.8 sq. in. would be what the strain demanded. 30 sq. in. are used in the bridge and as it is an open one the waste of material is evident. The 1"

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rods in use are amply sufficient.

The superstructure consisting of the flooring timbers (2½' apart, 6" x 14"), the stringers (forming a double built beam 14" x 24"), and the ties (6" x 6"), require no calculation and their dimensions are in conformity with the laws laid down by Town and Haupt.

From the previous pages it will be readily seen that although the timbers no where are of less dimensions than those required by the strain, still the bridge is not a commendable one. Most of its members possess excessive strength and this strength instead of adding to usefullness of the bridge, detracts from it, by adding to its superfluous weight; the parts are ill arranged and knowing this, the constant repairing of this bridge need surprise no one.

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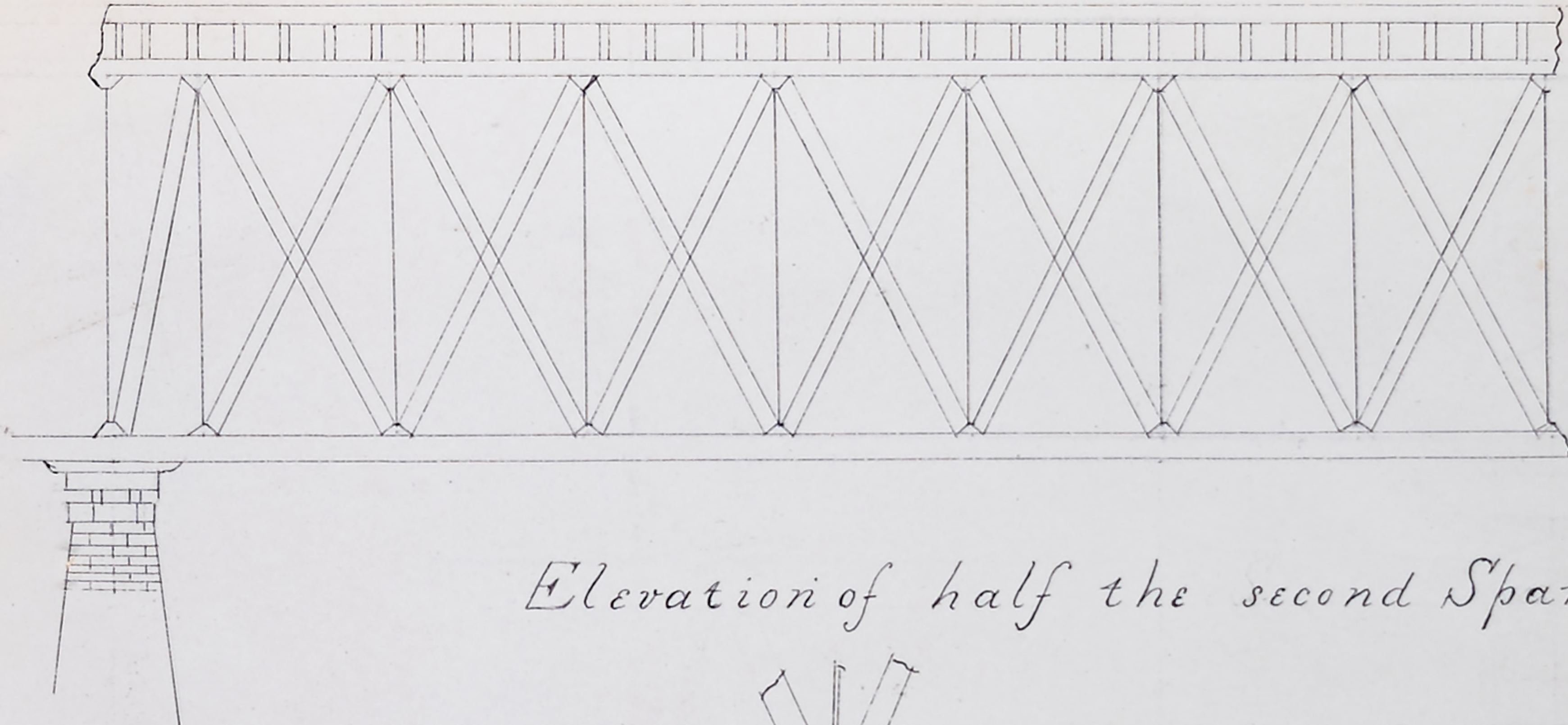
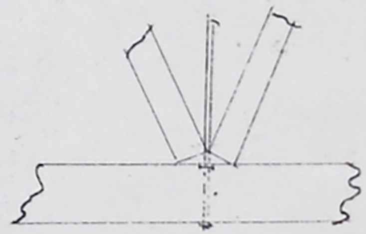


Elevation of half the second Span.



Brace adjustment.