MASS. INSTITUTE,
Department of
CIVIL ENGINEERING,
OF TECHNOLOGY.

THESIS

of

Russell H. Curtis.

Nov. 1, 1870.

Note to Revised Thesis.

The scheme of the revised thesis is as follows:—

Review of the Britannia Bridge.

§1. Sketch of the early history of iron bridge building.

§2. Description of the Britannia bridge.

§3 Description of the method of erecting it.

§4 History of its design.

§5 Comparison of ~~tha~~ it with other bridges.

§6 Discussion of the best form of railroad bridge for the site of the Britannia bridge.

To the matter previously handed in, have been added, the whole of sections, 1, 3, 5 & 6, and so much of section 4 as relates to the erection of the bridge.

Note. (attached to that portion of the thesis first handed in)

The following pages contain about one sixth of the matter the writer intended to put into this essay. The plan, which it was proposed to follow, is given below.

Review of the Britannia Tubular Bridge, the Niagara Suspension Bridge, and the Cast Steel Bridge over the Mississippi River, at St Louis.

(1) Introduction; Brief history of the stages of iron bridge building.

(2) Britannia Bridge.

1) Description of bridge

2) Description of the method of erecting it

3) History of its design.

4) Criticism of Britannia Bridge

5) Comparison of Britannia Bridge with other bridges as to span, strength, deflection weight, cost & durability.

6) Discussion of bridges of various forms and materials in the situation of the Britannia Bridge; & comparison of them with it.

7) Discussion of the limits & capabilities of the tubular bridge in general; and comparison of it with other forms of bridge.

(3) Niagara Suspension Bridge. To be treated in the same manner as the Britannia Bridge, the principle of suspension being discussed instead of that of a tubular beam.

(4) St Louis Cast Steel Bridge. To be treated in the same manner, the steel arch being substituted for the tubular beam

(5) Results of the foregoing investigation; The bridge of the future.

§1. Sketch of the Early History of Iron Bridge Building.*

Iron was first proposed as a material for the construction of bridges in some Italian works in the sixteenth century; but the attempt to use it failed, owing principally to its great cost and to the inability of the iron workers to cast it in large enough masses.

The credit of erecting the first iron bridge belongs to England, the work having been done at a time when a strong impulse had been given to the manufacture of iron by the introduction of the method of smelting with coke. This bridge, erected in 1779, was a cast iron semicircular arch of 100 ft span over the Severn at Coalbrookdale, the arch being cast in two pieces. Several small bridges were next erected on the continent, but iron bridge building re-

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* This sketch of the early history of iron bridge building has been draw in great part from Jeaff[illegible]s "Life of Robert Stephenson". Some facts have also been taken from Smiles's "Lives of the Engineers" & Dempsey's "Malleable Iron Bridges".

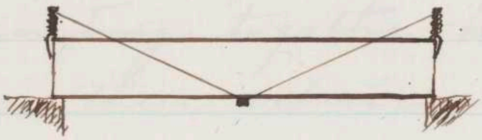
ceived its early development chiefly in England. Telford was one of the first to take advantage of the new material. About 1800, iron bridges began to be generally adopted. They all consisted of cast iron arches, in which the iron castings replaced the voussoirs of the stone arch. The arch, the first form of iron bridge, may be considered as having arrived at its full development with the completion of the Southwark bridge in 1819.

Mean time great improvements had taken place in the manufacture of wrought iron, which was distinguished from cast iron by its greater tensile strength and less liability to fracture. It was not known however until about 1847 that wrought iron offered less resistance to compression than cast iron. These qualities of wrought iron offered an extension of the limit of size possible for iron bridges, the only problem, being to bring the material of the bridge under a tensile strain. Hence arose the suspension bridge, which in its rudimentary forms had been known for ages. The first suspension bridge of engineering pretensions in England was built by Capt. Brown over the Tweed, and opened in 1820.

About 1830 came the introduction of railways. These new works gave a great impulse to bridge building. New conditions were imposed; rapidity of construction, economy of first cost, and liberal headway were of great importance. Of the two kinds of bridge then in use, the suspension bridge was, from its want of stability, quite out of the question for railway purposes, and the cast iron arch, from its great weight and the small span of which it was capable within reasonable cost, was of comparatively small application. To meet the new needs resource was had to the principle of the beam, the earliest form of bridge. The beam used was of cast iron, made in one piece. Its chief advan tages were, its rigidity; its straightness, leaving a uniform height of headway underneath; and its self contained strength, causing only a vertical thrust on the abutments.

The weakness and uncertain strength of the lower flange of cast iron girders, lead to the bowstring girder in which the thrust at the abutments, the chief obsticle to the use of the ordinary arch, is taken up by a wrought iron tie-rod. Wrought iron girders had not yet been manufactured, owing probably to the general ignorance of the qualities of wrought iron, and to the difficulty of working it in large masses, it still being supposed necessary to make each girder in one piece.

But the bowstring construction was expensive and cumbrous; and attention became again turned towards the improvement of the simple cast iron girder. Hence arose the "trussed girder", consisting of a cast iron girder strengthened by wrought iron tie rods extending from screws attached to the upper flange at the extremities of the span to the bottom flange at the centre. The figure shows this arrangement.



There were then, about 1845 at the time the Britannia Bridge was designed, five forms of iron bridge in use, of which all but the suspension bridge were used for railway travel.

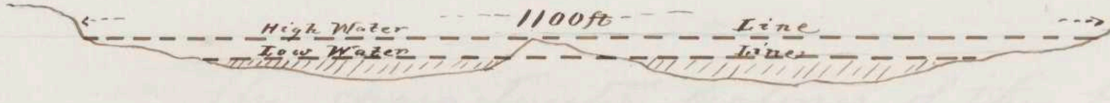
1st The cast iron arch.
2nd The suspension bridge.
3rd The simple cast iron girder.
4th The bowstring girder.
5th The trussed girder.

The steps of iron bridge construction have now been traced as far as is necessary. It only remains to notice the influence of the experiments for the Britannia Bridge upon the art of bridge building. These experiments served to develop the qualities of wrought iron before unknown, and demonstrated the practicability of constructing girders of almost any required strength and size, by riveting together plates of that material. From these experiments, dates a new era in railway bridge construction; the trussed girder became needless; and wrought iron not only superceded cast iron in the simple girder and bowstring girder, but rendered improved forms of girder possible.

§2.

Description of The Britannia Bridge*.

The Menai Straits, crossed by the Britannia Bridge, lie between the coast of Wales, England, and the island of Anglesey. The land on either side of the straits is high & rises rapidly from the shore. Baffling winds, sunken rocks, and a rapid current render the navigation difficult. At the site of the Britannia Bridge the straits are divided into two channels by the Britannia Rock, from which the bridge takes its name. A cross-section in the line of the bridge is shown below.



The bottom & banks of the straits afford a firm rock foundation for piers, except

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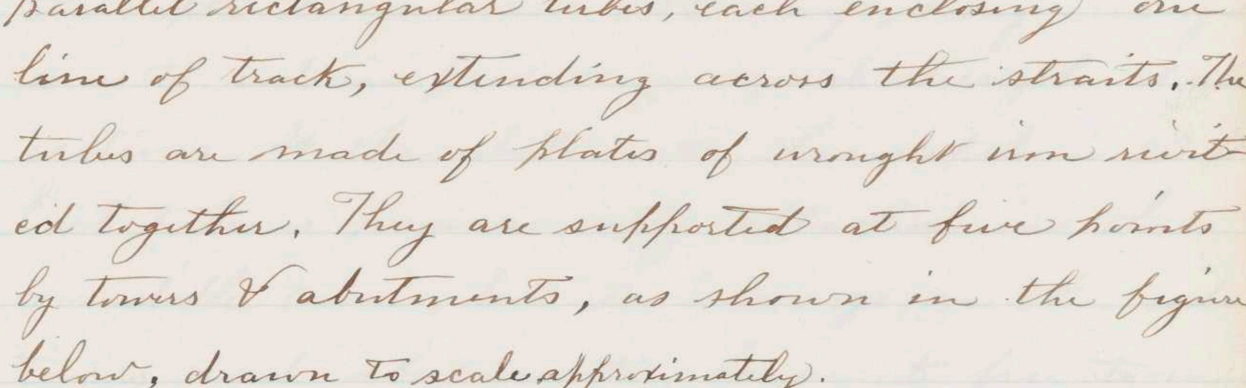
* The description of the Britannia Bridge is drawn almost entirely from Clark's elaborate "Britannia & Conway Tubular Bridges". Dempsey's "Malleable Iron Brides", and Fairbain's "Conway & Menai Tubular Bridges", and Smiles' "Lives of the Engineers" have been consulted also.

close upon the Wales shore where a shaly clay replaces the rock.

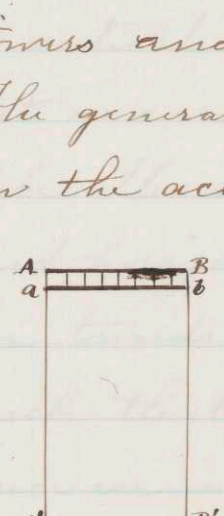
The Britannia Bridge is designed exclusively for railroad travel. It consists of two parallel rectangular tubes, each enclosing one line of track, extending across the straits. The tubes are made of plates of wrought iron rivet-ed together. They are supported at five points by towers & abutments, as shown in the figure below, drawn to scale approximately.



Elevation.

The characteristic features of the bridge are the use of tubular beams, the formation of those beams by plates of wrought iron rivited together, and a great span between supports.

The total length of each tube is 1511 ft. The greatest span in the clear is 460 ft. Each tube is 14 feet 8 inches in width throughout its entire length. The depth of the tubes from the outside of the top to the outside of the bottom is 30 feet at the central tower: from that point the depth diminishes both ways, being arranged so as to aid in producing equal strength at all sections. At the abutments the depth is 23 ft. Each tube is permanently attached in the middle tower, but its bearings, in the side towers and abutments, leave it free to move. The general structure of a cross-section is shown in the accompanying figure. The top & bottom are made of cells formed by two platforms united by vertical plates. The top is made up of 8 cells 1 ft 9 in square. The platforms AB & ab are each formed of a single layer of plates, varying in thickness according to their position. The stoutest plates used, being 12/16 of an inch thick, are at the centres of the large spans. Angle irons are placed in the corners of the cells & in all other positions where it is neces-



Cross-Section, of Tube.

sary to stiffen the plates. The bottom is formed of 6 cells 1 ft 9 in high, and 2 ft 4 in. or 2 ft 8 in. in width according to location. The platforms A'B' & a'b' are each composed ~~to~~ of two layers of plates. The thickness of all the plates at the centres of the large spans is 9/16 of an inch, diminishing to 6/16 of an inch in the small tubes.

The sides are made of vertical plates, 2 ft. wide, The vertical joints are covered on both sides by vertical angle irons, forming fillers, every two feet on each side, throughout the length of the tube. The sides are further stiffened by vertical and horizontal angleirons increasing in number towards the towers. The side plates are 1/2 of an inch thick at the centres of all the spans, and increase in thickness towards the points of support. The construction of the roadway is very simple. The rails rest on longitudinal wooden stringers, which are supported by transverse iron keelsons, bolted to the bottom, which occur every 6 ft. throughout the length of the tubes.

With the exception of the roadway in

in the interior, the bridge consists entirely of wrought and cast iron. The latter is confined to those portions of the tubes which pass through the towers.

The sectional area of one tube at the centre of a large span, is:—

Top —— 648.25 square inches.
Sides —— 302.00 " "
Bottom —— 585.43 " "
Total —— 1535.68 " "

The weight of one tube, 1511 ft long, is:—

Wrought iron 4680. tons.
Cast iron —— 508. "
Roadway —— 82. "
Total —— 5270 "

The weight of that portion of a tube situated between the towers is 1150 tons.

The breaking weight of the bridge, supposing the bridge itself to have no weight, is 2569 tons applied at the centre of one of the large spans or 5138 tons distributed equally over the span. Allowing for the weight of the bridge, the breaking weight is 1792 tons applied at the centre of a large span, or 3584 tons distributed over the whole span; or 7.8

tons per foot run. The preceding numbers are taken directly from a description of the bridge by Edwin Clark, resident engineer. The calculations, by which they were obtained, were made on the supposition that each span was an indipendent beam. By connecting the ends of the spans so as to form one continuous beam the strength of the bridge was much increased. The greatest working load was taken at one ton per foot run, which is equivalent to a train of ordinary engines with their tenders extending through the whole length of the tube.

Each large span was tested by placing upon it a train of coalcars, weighing 248 tons, and extending to within 38 ft of each end, equivalent to a load of 0.65 tons per running foot.

The test load of 248 tons produced a deflection, at the middle of the large spans, of 0.7 of an inch. Ordinary trains passing through the tubes produce a deflection of from 2 to 3 tenths of an inch, while at the same time the adjoining tubes are raised about (1/3), one third, that amount. Changes of temperature produce greater motion in the tubes than heavy trains or the most violent winds. The dayly alteration in the length of the tubes, due to change of temperature, varies from 1/2 of an inch to 3 inches. The sun shining upon one side of a tube will sometimes cause a vertical or horizontal deflection of 2.5 inches.

§3. Description of the Erection of the Bridge.

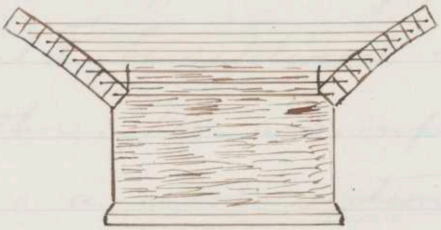
The large spans of both tubes were constructed upon staging on the shore of the straits, near the site of the bridge, and floated to their positions between the towers by pontoons. They were then raised to their proper places by powerful hydraulic presses, placed on top of the towers. In building, a grove was left in the face of each tower to receive the end of the tube; and as fast as the tube was raised the grooves were built up with masonary, so that it was impossible for the tube to fall back. The land spans were constructed in situ. The four spans were then united, so as to form one continuous beam.

§4. History of the Design of the Bridge.

As early as 1776, it was proposed to bridge the Menai Straits. Between that time and 1820, various plans were suggested, but nothing was done towards carrying them out. The plans proposed were, an embankment with a bridge in the middle; a wooden viaduct with draw bridges; a cast iron arch of 450 feet span, the springing being 100 feet above highwater; with stone arches on either side; three cast iron arches, with a stone arch between each two iron ones to resist their lateral thrust; and a single cast iron arch, 500 feet span, with its crown 100 feet above highwater. All these plans fell to the ground chiefly because they interfered with navigation. In 1826 Telfred built a suspension bridge over the straits, with a clear height of 103 feet above highwater, to accommodate highway travel.

Twenty years later it became necessary to cross them by a railroad. It was not thought advisable by those in control to carry the railroad over the suspension bridge; and it was decided to build a new bridge which should cross the straits at the Britannia Rock. The government, acting in the interest of navigation, prohibited more than one pier between the shores, and it limited the size of that. The government also required, acting in the same interest, that the bridge should have a clear height of 103 feet above the water throughout its entire length, and that navigation should not be obstructed during its construction. The rapid current of the straits rendered the erection of scaffolding from below almost impossible, if the artificial conditions imposed had not excluded its use. The science of engineering at the time offered no ready solution of the problem. It was supposed impossible to stiffen a suspension bridge sufficiently to allow of the passage of railway trains at high velocities; and no other form of bridge seemed applicable. The span of the largest stone arch on record, that of the Dee Bridge, Chester, is 200 feet; and the span of the largest iron arch then built is 240 feet; yet the minimum length of the spans of the proposed bridge was 350 feet. The impossibility of erecting centering made all the ordinary methods of constructing arches impracticable; and the necessity of keeping the bridge 103 feet above the water throughout its entire length was unfavorable to their use.

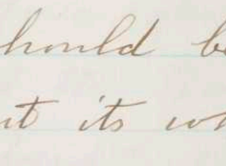
George Stephenson, the engineer of the work was equal to the occasion. He invented a form of bridge capable of satisfying the imposed conditions. It is interesting to follow the steps by which he was lead to the conception of a tubular bridge, and to trace the modifications his first idea underwent. His first plan, prepared before the government had restricted the height of the bridge above the water, was to cross the straits by two cast iron arches, each of 350 feet span. To avoid the necessity of centering, the arches were to be built out from the piers, by placing equa and corresponding voussoirs on opposite sides of a pier at the same time tying them together by horizontal tie-bolts, as shown in the following figure.



The invention of this method of erecting an arch is sometimes attributed to Brunel, but according to Smiles, it is due to Telford.

Stephenson in speaking of this plan, says:— "If the voussoirs could be constructed or weighed, so that an arch of equilibrium could be formed, all the horizontal tie-bolts might be removed, except the last one, for in such an arch the thrust is every where equal. In practice the bolts should be left."

The idea of arches was abandoned when the government required that the bridge should be 103 feet above high water throughout its whole span. Stephenson's next idea was to give a suspension bridge sufficient stiffness to allow the passage of railway trains by adding to it a system of trussing, in which wooden braces should be replaced by plates of wrought iron rivited together. The accompanying figure shows a cross-section of such a bridge, consisting of a rectangular iron tube, with a cable on either side. Afterwards he conceived of the tube, as a beam, and from this conception he passed to that of a tube without chains supporting itself. In order to test the feasibility of the new plan, and to determine the most suitable form for the tube and the best manner of distributing the material in it, he caused an elaborate series of experiments to be made, by Messrs. Fairbairn & Hodgkinson, upon small rectangular, circular and elliptical wrought iron tubes. ~~The results of the experiments, and a consideration of the compar-~~



These experiments were the more necessary as at the time only a theoretical knowledge of the strength of tubes existed, and the qualities of wrought iron were little known. The fact, that wrought iron unlike cast iron resists tension better than compression was then first brought to light. Of the three forms of tube tested, the circular form was found the weakest, the elliptical the strongest and the rectangular intermediate in strength*. The comparative ease with which a tube of rectangular section could be put together and repaired lead to the adoption of the rectangular form.

It was found impossible to get wrought iron plates of good quality thick enough to form singly the top or bottom of the tube. The problem was therefore to unite thin plates so as to get great stiffness, and at the same time to allow of free access to all parts for construction and repair. The problem was solved

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* Dempsey draws a different conclusion from the experiments. He considers that the rectangular tubes were proved to be the strongest as well as the most expedient.

by making the top and bottom of the tube of cellular form. If single plates of sufficient thickness could have been obtained, Mr. Stephenson would have preferred them.*

Various methods of erecting the bridge were discussed. The method, which was adopted and adhered to, until after some of the masonary of the towers was laid, is thus described:*—

1st To construct a suspension bridge of sufficient strength to carry the tube and any load that might be required.

2nd To prepare platforms at each approach to the suspension bridge, and on these platforms as well as across the suspension bridge to lay down a railway.

3rd To construct the tube on the railway on a line of trucks moveable bodily on wheels or rollers.

4th To load the suspension with a distributed weight, supported on trucks, about equal to that of the intended tube.

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* Clark's "Britannia & Tubular Bridges"

And lastly, to draw the tube thus supported onto the bridge at one end simultaneously with the withdrawal at the other end of the line of loaded trucks.

The tube was to be made strong enough to support itself, and any load that might come upon it; but it was decided to leave the chains permanently and to attach their ends to the ends of the tube after it was in position. The chains and the tube would then expand and contract together.

Before much progress was made with the masonry, the method of erecting the bridge was changed to that actually adopted, a description of which is given in §3. In 1846 the bridge was begun and in 1850 it was completed.

§5. Comparison of the Britannia Bridge with other Bridges.

The following table shows the chief feat ures of some of the most interesting bridges which have been built since the introduction of iron as a material for bridge construction.

Name of the Bridge	Form of Bridge	Material	Largest Span	Total length of bridge	Date of Completion	Engineer.
			feet	feet		
Sunderland B. over the Wear.	Arch	Cast iron	236*		1796	Wilson
Southwark B.	"	"	240		1818	Rennie
London B.	"	Granite	152		1831	Rennie
Dee B. Chester (Largest stone arch in existence.)	"	Sandstone	200		1833	Hartley
Pont du Carrousel over the Seine	"	Cast iron	187		1836	Polonceau
Menai Suspension B.	Suspension Bridge	Chains made of iron links	580	1710	1820	Telford
Clifton Suspension B.	"		703			Brunel
Highlevel B. Chester	Bowstring	Chiefly cast iron	125	1372	1849	Robert Stephen
Britannia B.	Tubular	Wrought iron	460	1511	1850	"
Victoria B.	"	"	330	6650	1860	Robert Stephenson & Ross.
Kehl B. over Rhine	Lattice Girder		200	About 800	1861	
Niagara Falls B.	Suspension Bridge	Chains made of wrought iron wire.	821	About 800	1855	Roebling
Kansas City B.	Lattice Girder	Wood, Wrought iron Cast iron	248		1870?	O'Chanute
St Louis B. over the Mississippi.	Arch	cast steel	515	About 1500	Unfinished	Eads

* Some authorities give the span as 240 ft.

In the Niagara Bridge the ultimate tensile strength of the wire of the cables is 49.67 tons per square inch of section; and the greatest tension to which the wire is likely to be subjected is 9.36 tons per square inch. The ratio of this tension to the ultimate capacity of the cables is 1 : 5.3 without considering the support afforded by the stays. The tension produced by the permanent load is 7.49 tons per square inch. The tension, which the cables could bear without injury to their elasticity, if it has ever been determined, is unknown to the writer.*

In the St Louis bridge, now being erected the compressive strains upon the steel ribs is limited to 12.5 tons and the tensile strain

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* These tensions were got as follows:—

(Ultimate capacity of the cables = 12 000 tons) ÷ (Aggregate solid wire section of the cables. = 241.6 sq in) = 49.67 tons per sq in.

(Tension existing when bridge is loaded with 250 tons equally distributed. = 2262 tons) ÷ (") = 9.36 tons per sq. in.

(Tension due to the fixed load alone = 1810 tons) ÷ (") = 7.49 tons per sq. in.

The aggregate tensions & sectional area are taken directly from Roebling's article on the Niagara Bridge in Weale's publications.

to 10 tons per square inch. The limit of the elasticity of the steel used, under compression, is not less than 25 tons per square inch, and recent experiments point to the limit being over 30 tons per square inch.*

In designing the Newark Dyke Bridge, a Warren girder of cast and wrought iron 240 ft span, which may be considered a model of its class, no strain was allowed to exceed 5 tons to the square inch.

x In the Kancas City Bridge the wrought iron ties and truss rods of the floor beams are allowed to bear a strain of 5 tons per sq. in., and the end ties and chord links 6 tons per square inch, thus allowing a greater strain per square inch on those parts which are fully strained only under a maximum load than on those which are liable to be strained to the full calculated amount by any heavy locomotive. Several experiments upon samples of iron similar to that used in the bridge show

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* Report of the Engineer of the Illinois & St. Louis Bridge Company May, 1868.

ed an ultimate tensile strengh of 56 tons to one square inch of original section. A bar, 1.75 inches square by 38 feet long, of the same iron, showed no permanent set after sustaining a tension of 14 tons.

In the Britannia Bridge the ultimate tensile strength of the bottom of the tube is 18.6 tons per square inch, and of the top tons per square inch. The strain on the bottom at the centre of the span, due to the weight of the tube is, is, taking the mean of the results of two methods of calculation, 5.62 tons per square inch; the strain on the top due to the same cause is 5 tons per square inch. The tension on the bottom due to a uniformly distributed load of 1 ton per running foot in addition to the weight of the tube, is 7.26 tons per sq. inch, and the corresponing compression on the top is somewhat less. The ratio of the greatest strain to which the tube will be subjected, to its ultimate capacity is 1:1.23; and the ratio of the greatest travelling load to the breaking travelling load is a little greater than 1 : 8. These ratios do not agree very well with the results arrived at by Mr. Clark who states that the factor of safety of the bridge is somewhere between 5 and 7. The method by which the writer got his results is given in the foot note.[A]

[A] Let S = strain on either top or bottom due to a uniformly distributed load of 1 ton per running ft. Span = 460 ft. Depth of tube from centre to centre of cells = 27.5 ft. Area of bottom 585 sq. in.

$$S = \frac{460 \times 460}{8 \times 27.5} = 961.8 \text{ tons}$$

$$\text{Strain per sq inch} = \frac{961.8}{585} = 1.64 \text{ tons}$$

Add strain due to fixed load $\underline{5.62}$

$\therefore$ Strain due to fixed & moving load = 7.26

~~Tons~~

~~Strain on member due to load of 1 ton per running ft = 962~~

~~" " " " " fixed load as given by Clark =~~

Load at 1 ton per running ft = 460 tons

Permanent load ——— 1553

Total load 2013

$$\text{Ratio of } \frac{\text{Total load}}{\text{ultimate capacity}} = \frac{2013}{2569} = 1.23.$$

The ultimate capacity 2569 tons is taken directly from Clark. The strains are proportional to the loads, hence the

$$\text{ratio of } \frac{\text{The greatest strain}}{\text{Ultimate strain}} = 1.23$$

The greatest available load is, by Clark, 1792 tons applied at the centre or 3584 tons equal distributed.

$$\therefore \text{The ratio of } \frac{\text{The greatest travelling load}}{\text{The ultimate travelling load}} = \frac{460}{3584} = \frac{1}{7.8}$$

In this calculation rolling loads are supposed to act statically only, & to be always equally distributed over the whole span. The same suppositions are tacitly made by Mr. Clark in his calculations.

A comparision of the data just given, relating to different bridges, brings out some points of interest. It appears that the wire drawn wrought iron of the Niagara Bridge has a greater ultimate tensile strength than the plate iron of the Britannia Bridge, nearly in the ratio of 5 to 2. The greatest strain to which the iron in the cables of the Niagara Brid is likely to be subjected is 10 tons tension; the greatest strain to which the steel in the arches of the St Louis Bridge will be subjected is 12.5 tons compression; the greatest strain on the truss bridges quoted is 5 or 6 tons or 1/2 as much as upon the two structures first mentioned. The greatest tension in the Britannia bridge is less than 7 tons or a little more than the tension on the truss bridges, & much less than the tension of the Niagara cables. The compression in the top of the Britannia Bridge is probably less than one half the compression of in the St Louis steel arch.

The ratio, in which the ultimate tension of the Niagra Bridge exceeds the greatest tension that the bridge will ever have to bear, is 5.3:1. The corresponding tension for the Britannia Bridge is 1.23:1. The ratio of these two ratios is therefore about 4.3:1; yet the Niagara Bridge will support only 4 times as great a load as may be brought upon it, while the Britannia Bridge will bear 8 times its greatest working load.

The following table shows the deflection of most of the bridges already quoted, under their test loads.

Bridge	Permanent load (one span)	Span tested	Test load, per linear foot	Deflection in inches
	tons	ft	tons	inches
Niagara B.	1000	821	0.4	10.00
Kehl B.		200	2.4	0.5
Newark Dyke B.	292	240.5	1.0	2.75
Nancas City B.		248	0.94	2.07
Britannia B.	1553	460	0.7	0.65

It would be interesting to discuss the deflections of the bridges in the table, and to compare the Britannia Bridge with others as to weight & cost as we have already done in regard to tension, but the time allowed the writer to complete this thesis has expired, and these portions of his subject can not be touched upon.

§6 Discussion of the Best Form of Rail Road Bridge for the site of the Britannia Bridge.

Accepting the artificial conditions imposed upon Stephenson as inviolable it is hard to see, ~~what~~ how he could have acted otherwise than he did, unless he adopted the suspension principle, which was very generally considered by engineers unfit for the purpose. Looking at the ~~plo~~ problem with the light of future experience, it is only doubtful whether Stephenson did not do the best that could be done. It is undoubtedly possible to put a railway suspension bridge across the Menai Straits, for if only one span were employed it would not require to be more than 1000 in span & if three towers were erected the span could be reduced one half. But whether a suspension bridge would allow the passage of trains at such velocities as would keep the lines of a great railway open is an undecided question. Mr Stephenson in his report to the directors of the railroads to cross the Victoria Bridge, says that a suspension bridge would be entirely inadequate for the travel passing over that bridge owing to the low velocities at which trains can be run over suspension bridges.

Time obliges the writer to stop at the very threshold of this portion of his subject. In closing he would suggest as a possible bridge for the site, a rectangu

le(a)d
obstricle
riviting (several times)
supercaded
indipendent
dayly
masonary (~~bis~~ ter)
agregate (bis)
Kancas
Staticly
direcly
strengh