PAPERS

Relating to the building a Bridge over the *Menai Strait*, near *Bangor Ferry*; &c.

Ordered, by The House of Commons, *to be Printed*,
18 *February* 1819.

LIST OF PAPERS: viz.

ERRATA.

Page 3. l. 20. from bottom, *for* " upon combined," *read* " when combined."

4. l. 17. from bottom { *for* " 130, 140, and 240 - feet arches," - - - -
read " 130, 150, and 240 - feet arches."

ib. l. 7. from bottom, *for* " broadway," *read* " Roadway."

5. l. 10. *for* " Bruerton and Co." *read* " Brunton and Co."

18. l. 29. *for* " N. Gout," *read* " N. Greet."

—No. 1.—

REPORT, Plan, and Estimate, for building a Bridge over the *Menai Strait*, near *Bangor Ferry*.

AT all times when the subject of improving the great line of communication between Dublin and London has been under consideration, the inconveniency and danger attending the passing the Menai Strait, which separates the Island of Anglesea from Carnarvonshire, has been constantly discussed, and numerous Plans have been proposed, with the view of accomplishing a regular and unobstructed passage, in the place of the present Ferry.

I shall not attempt to detail what have been considered imperfect or objectionable modes; it seems quite sufficient to say, that in the years 1810 and 1811, plans of bridges made of cast iron, of sufficient width of span and height of elevation, not to obstruct the navigation, were proposed, and, after due investigation approved of by the Committee of the House of Commons, as suitable for the road communication, and not injurious to the navigation.

In the plan upon this principle, which, in 1811, by order of the Lords of the Treasury I furnished, and which consisted of one arch of cast iron of five hundred feet span, and one hundred feet above high water in the middle of the arch, and which although the least expensive of any cast iron bridge of those dimensions, was estimated to cost 127,331 *l.* The chief difficulty in constructing this bridge was fixing proper centering, which from the rocky bottom of the channel and depth and rapidity of the tideway, could not be accomplished by ordinary means from below. I was therefore led to substitute a new mode of suspending the centering from above; and along with my plan of a bridge, furnished a design for this purpose. These designs were engraved and annexed to the Report of the Committee of the House of Commons upon the Holyhead Road, in 1811.

In 1814, on being applied to for a design for a bridge to cross the river Mersey at Runcorn, where it was necessary to preserve a waterway of one thousand feet in breadth, a bridge upon the principle of suspension occurred to me as the only practicable means, and with that view I instituted a regular set of experiments upon rods of malleable iron, viz. from thirty to nine hundred feet in length, and from one-twentieth of an inch to two inches diameter; and these both in regard to elementary parts, and also upon combined, partly by welding and partly by jointing in a model. The nature and result of these experiments are detailed and commented upon in an excellent Treatise on the Strength of Materials, lately published by Mr. Barlow, of the Royal Military Academy at Woolwich.

From these I had reason to conclude, that by means of malleable iron properly combined, a substantial bridge of one thousand feet might be constructed; and accordingly gave a design for that purpose.

The facility and economy with which a bridge of this kind may be constructed, where the shores are bold and high, led me to consider it as peculiarly well adapted for passing the Menai Strait a little to the westward of Bangor Ferry, where a cast iron arch of five hundred feet span had been formerly proposed. I have therefore drawn a Plan upon this principle, for the consideration of the Commissioners for improving the Holyhead Road. It consists of one opening of upwards of five hundred feet in width, and a hundred feet in height, between the high water line and the lower side of the roadway; and the roadway being horizontal, this height is uninterrupted for the whole five hundred feet, unless where the natural rock which forms the western abutment now interposes. But in addition to this five hundred feet, there are four arches on the western, and three on the eastern side of the main opening, each fifty feet span, that is,

 making

making in all eight hundred and fifty feet of opening, all as shown on the annexed drawing. This drawing also shows, that in regard to the navigation, it is preferable to any bridge of an arched form, because the latter affords the full height of an hundred feet only in the middle, whereas the former, as has just been observed, affords the same full height for the whole of the five hundred feet. In regard to economy this bridge, on the principle of suspension, has equally the advantage, as I have estimated the expense only at about 60,000 *l.*; and allowing for the possible rise in the price of iron, and any unforeseen trouble in procuring stone, it cannot amount to more than 70,000 *l.* whereas the cheapest of the arched form with cast iron, was nearly double that sum.

With respect to the facility of execution, it must be evident to any person the least conversant with mechanical operations, that the bridge part of the large opening in this design, may be constructed nearly as readily as the centering only of the same size for one of cast iron.

The results from a bridge upon the principle of suspension, can be satisfactorily ascertained by previous experiments; because with a given length and curvature, it is known that malleable iron of a good quality can support a certain weight more than its own, and therefore when the weight to be supported is known, a safe rule is obtained to determine the quantity of iron required, and the goodness of the quality of each separate portion of iron to be employed, can be effectually proved. The most advisable mode of combination may also be determined by similar means; and although I have already from my experiments formed a plan which is practicable and substantial, yet I shall certainly during the time the stone work is constructing, claim the privilege of repeating and extending my experiments, in order to arrive at the most perfect mode this principle is susceptible of.

The principle I have here recommended, of constructing bridges by suspension, although hitherto not generally practised in this country, is not new; they were in existence over rivers and deep ravines in South America, previous to the arrival of the Spaniards in that country; they have been long carried to a great extent in the East Indies and China, and of late years eight have been constructed in North America. If these, with very inferior materials and workmanship, have been in some instances with perfect success carried to about five hundred feet in length, it is certainly not assuming too much in expecting more from British dexterity, upon superior materials. It is only a few years ago that bridges of cast iron, of one hundred feet span were ventured upon with timidity, and now, although they have in some instances been mismanaged by bungling constructors, they have in others been successfully extended to 130, 140, and 240 feet arches, with scarcely any other approach to a maximum, than what is determined by locality and expense. But bridges upon the principle of suspension being simpler in the management, and much more expeditious and economical, afford to a certain extent even still greater facilities than those of cast iron, and therefore promise to become of at least equal importance.

London, 5th May 1818. (Signed) *Thomas Telford.*

ESTIMATE.

I ESTIMATE the expense of constructing a bridge over the Menai Strait, near Bangor Ferry, the broadway to be one hundred feet above high water, and the distance between the points of suspension five hundred and sixty feet, including the expense of approaches from the present roads, of quarries, land and damages, at Sixty Thousand Pounds.

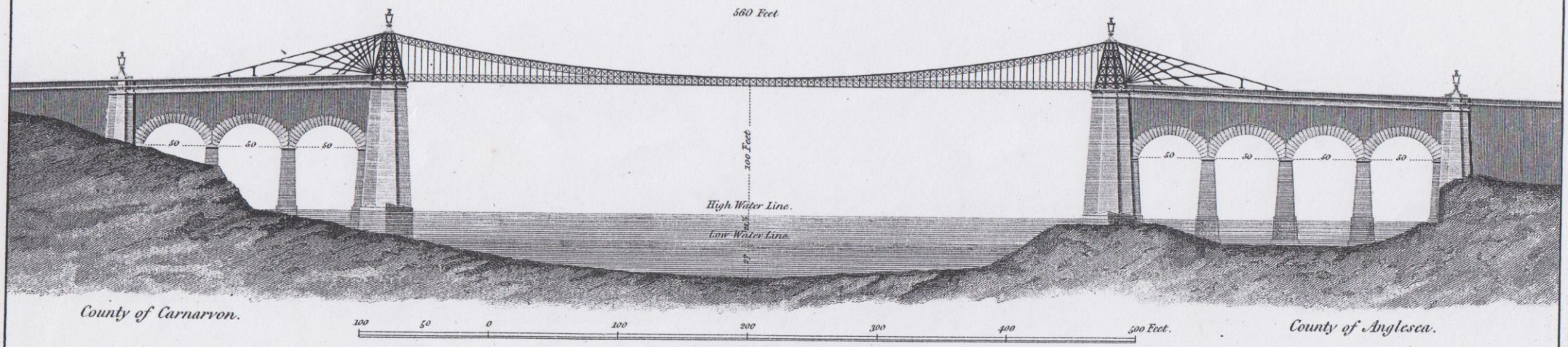
London, 7th May 1818. (Signed) *Thomas Telford.*

N. B.—May be completed in three years from the time of commencement.

No. 7.

DESIGN for a BRIDGE over the MENAI STRAITS at YNYS-Y-MOCH.

By Thomas Telford, F.R.S.E. &c.



Drawn by W. A. Provis.

Engraved by Edwd. Turrell.

Ordered by the HOUSE OF COMMONS, to be printed, 18th February 1819.

Luke Hansard & Sons, Printers.

—No. 2.—

REPORT from the Commissioners for improving the Road from London to Holyhead, to the Chancellor of the Exchequer, on Mr. Telford's Report and Estimate for building a Bridge over the *Menai Strait.*

Sir, Whitehall Place, 18th May 1818.

IN consequence of the wish you have expressed, that we should examine some other engineers, besides Mr. Telford, as to the practicability of constructing an Iron Hanging Bridge across the Menai Straits, near Bangor Ferry, we proceeded to examine Mr. Donkin, Mr. W. Chapman, and Mr. Rennie, civil engineers; Mr. Bruerton, of the Firm of Bruerton and Co. iron cable manufacturers; Mr. Barlow, mathematical master of Woolwich Academy; and Mr. Fitchett, secretary to the Runcorn Bridge Company.

The points to which we examined these gentlemen were, the practicability of forming iron cables of the requisite length, and of sufficient strength to support the weight which a bridge to be perfectly safe ought to sustain beyond that of its own materials; the practicability of forming supports for suspending these cables without risk of their being broken down.

Mr. Barlow having published an account of the experiments which were made by Mr. Telford, for obtaining data for making an iron hanging bridge over the river Mersey at Runcorn, where the centre span is to be one thousand feet, and also various theoretical calculations of his own upon this sort of bridge building, we were of opinion, that his evidence would contribute very much to remove all doubts, if any existed, in respect to the perfect safety of iron hanging bridges.

We beg leave to refer you to what he has communicated to us upon the subject, and also to the uniformly concurrent evidence of the other witnesses, as forming a very satisfactory confirmation of Mr. Telford's opinion, of the practicability of constructing such a bridge sufficiently strong and safe for all purposes, across the Menai, and by which the navigation cannot be in any degree obstructed.

And, in respect to the plan that Mr. Telford has laid before us, of the manner in which he proposes to build it; although the evidence of the witnesses goes to show that it is generally suitable to the design, if Parliament should think proper to vote a sum of money for carrying it into execution under our superintendence, we shall feel it to be our duty again to examine very minutely into all the computations of the strength of the materials which are to be made use of, and also of the loading which it will be able to bear, before we give our permission for the commencement of the building of it.

We have the honour to be, Sir,
Your most obedient Servants,

(Signed) Wm Smith.
Henry Parnell.
Tho' Mostyn.
J. M. Barry.

To the Right Honourable
N. Vansittart, M. P.
&c. &c. &c.

Minutes of Evidence, taken before the Commissioners for the Improvement of the Holyhead Road; Saturday, 16th May 1818.

William Smith, Esq. in the Chair.

Mr. *Peter Barlow*, called in; and Examined,

Mr. Peter Barlow.

WHAT office do you hold?—Mathematical master in the Royal Military Academy at Woolwich.

Have you examined a course of experiments, which have been made by Mr. Telford, with a view to obtain the best data with respect to the strength of the materials proposed by him to be made use of, in building an iron hanging bridge across the river Mersey at Runcorn?—I have.

Explain the general object of the experiments, and at whose request they were

Mr. Peter Barlow.

were made?—I do not know at whose request; they were made for the purpose of obtaining the data relative to the bridge at Runcorn.

Describe generally the nature of the experiments?—Bars of iron were fixed at certain distances, with certain degrees of curvatures, and weights hung upon them in the middle, and at different parts, till they broke; and from that Mr. Telford inferred the probable strength of the bridge. I computed the strength, and I found that what his experiments brought out, and what my theory brought out, agreed very nearly with each other; very correctly indeed.

Do those experiments appear to you to have been performed with accuracy?—Yes; I did not see them performed, but from all that I saw on paper, they appear to have been done with very great care indeed.

State to the Commissioners what appears to be the medium strength of an iron bar an inch square?—Twenty-seven tons.

That is, that it requires the weight of 27 tons to draw that bar asunder?—Yes, I broke one myself of an inch and half in diameter; I did not see the whole of the experiments, but I saw that myself.

What was the weight required to separate a bar of an inch and a half diameter?—An inch and 5-16ths of a square bar required 48 tons; the bar which I saw broken was an inch and 2-9ths in diameter, and it required 43 tons and a half to break it.

State to the Commissioners by whom those experiments upon the strength of the iron were made?—By Mr. Telford; this one just described was made by me at Captain Brown's cable manufactory; the others were made by Mr. Telford, at Mr. Brunton's cable manufactory.

Have you compared the results of those experiments with those drawn from theoretical computation?—Yes, I have.

Is there an agreement between the two deductions?—A very close one.

Are you of opinion that confidence may be placed on the basis of the two deductions, as to the computations for constructing an iron hanging bridge?—Yes.

Does the general result of the computation, from experimental data and theoretical principles, prove, that an iron hanging bridge may be so constructed, as to make it capable of sustaining an absolute weight, much beyond that of the materials of which it is built?—Yes, within certain limits of its length; it depends entirely upon its length and curvature; a bridge under a thousand feet is far within those limits.

What was the centre span of the proposed Runcorn bridge?—A thousand feet.

According to the calculations you have made, supposing this bridge were built according to Mr. Telford's first plan, what weight might be distributed over before it would give way?—Fourteen hundred and seventy-two tons.

What would be the weight of the bridge itself?—Mr. Telford has estimated it at 573 tons, independent of what weight might be put upon it in passing over it.

The loading of that bridge might be carried to 899 tons?—Yes; 899 tons would be the limit which it would bear beyond its own weight.

Supposing a bridge of 1,000 feet in length to be capable of bearing a weight of 1,472 tons, have you calculated what weight a bridge of 500 feet, constructed with equal strength, and with bars equal in number, would bear?—No; I have not computed that, nor can I readily do it.

Is it not certain, that a bridge, 500 feet in length, where the angles of the chains by which it is supported at the point of fixture to the bridge, shall be nothing near so acute as in this of 1,000 feet, may be made to support a far greater weight?—If the curves were the same, the 500-feet bridge would be far the strongest.

Is there any difficulty in so constructing it as that the curves should be the same?—Not at all; that part of the bridge on which the curve depends.

Have you ever calculated what the weight of a drove of cattle might amount to, such as would be sufficient nearly to fill a bridge of the dimensions you have been speaking of, 1,000 feet?—No; I do not know that I could make the estimate in a moment.

Mr.

Mr. *Bryan Donkin*, called in; and Examined.

Mr. Bryan Donkin.

YOU are a civil engineer by profession?—I am.

Have you made any experiments, or are you acquainted with any that have been made, for the obtaining practical data connected with the erection of iron hanging bridges?—I witnessed several experiments made at Mr. Brunton's chain manufactory, on bars of iron of different dimensions.

Those were made with a view of ascertaining the strength of an inch square bar?—They were.

What appeared to be the strength of such a bar?—Nearly that which was stated by Mr. Barlow; that was the ultimate strength at which they broke.

Did these experiments appear to you to be conducted with accuracy?—With perfect accuracy, so far as we depended upon the machine with which they were made, which I have no doubt was sufficiently so for any practical purpose.

What is that machine?—A hydrostatic; a hydro-mechanical pump, they are generally called.

Have you examined the plan of the proposed Runcorn bridge?—I saw it.

Are you of opinion that that plan might be carried with safety and propriety into execution?—I am quite confident it might.

You are acquainted with the manner in which the bars were to be laid together?—I have a specimen of the proposed manner lying in my yard now.

Can you give any account of the manner in which the bars are either laid or joined together?—We took a number of bars of iron, half an inch square, and composed them into a square piece consisting of thirty-six, that composed a square of three inches, and upon the outside of each of the sides we put a circular piece, so as to form the whole into a round bar or a round cable; these bars were not welded but laid together; the intention was, to have each half-inch bar of the whole length of the bridge, namely, 1,000 feet; it was proposed, therefore, that as many of the half-inch bars as would be required to make out the 1,000 feet, should be welded together longitudinally, so as to be united into one bar, and the whole laid together as I have described; it was proposed, after the whole were laid together, to envelope the whole with wire twisted round, and fill the interstices with some substance which would render the whole impervious to water.

Was any experiment tried on the strength of the whole bar so united?—No; I do not suppose there are any means in the kingdom of trying it?

That is to say, you do not apprehend that it would have been possible, by any mechanical apparatus of which we are in possession, to have applied a sufficient weight or force to have broken that bar asunder?—I do not know of any such apparatus.

Are you perfectly satisfied, that by the application of a number of similar cables, the sufficiency of which should be ascertained by experiments, to a bridge of 500 feet water-way, every thing necessary for absolute and entire security may be attained?—I am quite certain of it.

Do you apprehend that the means of applying such cables are easy to any practical engineer in the present state of the science?—That is giving great latitude; but I should say, in the hands of any prudent and skilful engineer, certainly it is quite practicable and easy.

Mr. *Thomas Brunton*, called in; and Examined.

Mr. Thomas Brunton.

YOU are a proprietor of the patent chain and cable manufactory?—I am.

Are you acquainted with any experiments that have been made on the strength of iron?—Yes; we have made many hundred experiments, several for Mr. Telford, at different times.

Where do you reside?—Our manufactory is in the Commercial Road.

Describe the experiments which you have made at Mr. Telford's request, for the purpose of ascertaining the strength of iron?—The machine we have got is a hydrostatic power, which has been examined by a number of the first engineers in the kingdom; and there is, I believe, but one opinion with regard to the accuracy of it; the force we consider it capable of applying is 250 tons; an inch circular bolt of iron will carry on an average from 22 to 24 tons, according to the quality of the iron, but we have seldom or never found it to exceed 24 tons; from the experiments we have made upon larger bolts, we find that they increase in strength; a two-inch bolt, for instance, will carry near

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near upon a 100 tons, from 95 to 100 tons, sometimes as high as 103; the difference of a round bolt to a square we consider to be, that a square, the side of which is equal to the diameter of the round, will be about one-fifth stronger, a two-inch bolt is the largest we have drawn asunder.

What is the greatest length of any of the bars you ever tried?—About two feet six inches was the length of those upon which we have made experiments.

Have you, from experiment or observation, any opinion whatever to give respecting the accuracy of the application of these results to bars of any very considerable length?—I should say there could be no difference if the bar was ten times the length, provided the bar was all equally joined.

Are the short bars of which you speak made in those short lengths, or are they parts only of longer bars cut into those lengths?—Cut into those lengths.

May it not then very easily happen, that the defect of which you speak might occur in the shorter bar as well as in the longer one?—On trying the experiment, we in general endeavour to get a piece of iron as sound as possible for the experiment.

Are not those means of ascertaining the soundness of the bar equally applicable to the longer bar as to the shorter ones?—It might be, but still I should apprehend, that there was more danger in the longer than in the shorter bar.

Are not the means of ascertaining it equally applicable?—Certainly.

You rather mean then, that it requres greater care and attention to ascertain the uniform strength of a long bar than of a short one?—Certainly.

Do you not apprehend, that two bars of iron, with the reasonable care that is to be demanded upon those occasions, may be so welded together, as to be no more liable to separate where they are welded than in any other part; the question, supposing the best iron, and in the most convenient shape, and with every advantage which can be given to it for the convenience of welding?—Certainly, you may weld a large bar together, and I think with attention you may make it as strong as any other part.

Have you any doubt, whether a square bar may be equally well welded with a round one, and if you think there is any difference; can you give any opinion as to the amount of the difference?—I do not think there will be any difference.

Have you any reason to believe, that if a square bar or bolt of any certain length would require 100 tons to separate it, two or any greater number of bars added together would not require nearly an increase of four in proportion to the number of bars so united?—There is no question that they would bear equally, provided the force should be equally applied to them at the same time, but if there is the least deviation from that, of course the strain comes all on one.

Are you aware of any difficulty in adding bars together longitudinally by the side of each other, so as that the strain upon each should be nearly equal, and sufficiently so to be reckoned upon with safety?—I think that they may be laid one at the side of the other, so that they would come all to one bearing; and if there was one bore more stress than the other, it would most likely stretch till the bearing came equal upon the whole.

You conceive it practicable to form any reasonable number of bars into one cable, so as to acquire a strength sufficient for any given purpose?—I should have a doubt in welding a piece of iron, when you come to such an immense length as 500 feet, whether there would not be a difficulty in the working of it; a piece of iron, in order to make a sound weld of it, ought to be turned round and hammered; but it is impossible to turn round a piece of iron of which there is 500 feet.

Do you or do you not apprehend, that a die might be made to receive the bars, or some other mechanical means practised, by which the weld might be made sufficiently strong for any practical purpose?—I should still have my doubts with regard to making it so strong as the other part of the bar, which is drawn regularly through the rollers.

Supposing means to be invented, of turning a long bar as perfectly and as frequently as a short bar could be turned, should you then entertain those doubts, and to what degree?—I should still doubt; I do not think it is possible to move such a large piece of iron as that so quickly out of the fire, and to take a force upon it, without the heat being considerably gone; the heat is gone in two seconds.

It depends then, according to your idea, upon the degree of celerity with which

Mr. Thomas Brunton.

which the hammer can be applied to the iron, when in a fit state for welding?—Decidedly so.

If this difficulty of applying the hammer with sufficient quickness were surmounted, does any other appear to your mind?—If those objections which I have started can be got over, I do not see any other.

You make iron cables?—We do.

What strain are your largest iron cables calculated to bear?—What we make for the first-rate men of war, will carry about 200 tons.

Are they chain cables?—Yes.

What is the cubical content, or more properly the section of the weakest part of that chain cable?—Two inches and 1-8th in diameter; the proof that we put upon that is 110 tons.

You mean, then, that having proved it as far as 110 tons, you conclude by calculation on its dimensions, that it is capable of carrying 200 tons?—We do, and beyond that we consider that the chain made will carry as nearly as possible double the bolt.

How long are those cables made?—We make them 150 fathom.

That is to say 900 feet?—They are put together in lengths of twelve fathoms and a half; they are all tried in those lengths in a machine.

You have no difficulty whatever in making those cables?—None whatever; we have never had a failure since we have been in business, not one for five years.

You have a perfect confidence, that a chain cable, such as you make for a first-rate man of war, is capable of supporting the strain of 200 tons?—Above 110 tons is all presumption, but we could prove that chain up to 150 tons, and I have no doubt of its capacity of supporting the 200.

If you then wanted a sufficient strength for any given length of 500 or 1,000 feet, and you did not chuse to trust to a welded iron wrought of that length, do you think you should find any difficulty in making a cable which should be sufficiently and satisfactorily strong?—I think a bridge may be made sufficiently strong by chain cables, and that is the only way in which I conceive at present it can be made with certainty; you have double the strength of the bolt, and all the additional weight is in the curve in the end of the link, and there is one great advantage in making it, that you can prove your chain when you have not the means of proving the rod.

Do you not consider there would be a greater curvature in a chain cable than in a bar cable?—They must be much the same in that respect, the more they curve the more the bridge will carry.

Do you think that the bridge is proportionably stronger when made of chains with the same weight of iron as would be employed in bars?—I should think there is more dependence upon the chain than upon the other, weight for weight. In welding together flat iron six inches by 3-4ths of an inch thick, to the length of from 32 to 35 feet, we found the difficulty so great, that after the bars were welded, there were four out of twenty that would not bear their own weight; they broke at the weld in consequence of the part being hardened; they would bear a great weight if they were kept on a straight pull, but the iron being harder and stiffer in that part, would not bend uniformly with the other part of the bar.

You apprehend then, the occasion of the iron breaking in the instances which you have mentioned, was from its being by the action of some force, and that there was a tendency to put it considerably out of its straight position in some particular part?—It was put out of the straight position by the men taking it up, there being three or four men at each end, it bent down in the middle and came asunder.

Do you or do you not apprehend, this was owing to its being bent rather sharply?—Not more than any other part of the bars; if the weld had been as sound as the original bars, we might have turned them round.

Do you not consider the strain upon that weld you describe, to be considerably greater than it would be in a bar of half an inch square?—The strain is greater, but there is a greater strength of iron to support the strain.

Do you not think that the tenacity of iron varies in proportion to its weight, and that the tenacity proportionably is less in a larger than in a lesser weight?—If you go to a great size of iron, the tenacity is certainly less in proportion to its weight.

Then is it not very possible, that a number of half inch bars, when merely laid together, and not welded, would support a weight, in addition to

Mr. Thomas Brunton.

their own, greater than the same number of bars would support if welded together?—If the original bolt is not too large, I certainly think that the larger bolt is the best and strongest.

Do you mean the strongest in proportion to its size?—If you go above a certain size, you certainly do not gain strength; as for instance, a two-inch bolt will carry very near 100 tons, where an inch bolt will not carry above 22 to 24; that shows the increase of strength up to that size; but if you go to a size above $2\frac{1}{4}$ or $2\frac{1}{2}$, the iron is not so compressed together, and of course has not that tenacity which it has in a smaller size.

The result then of your answer is, that the tenacity of iron is greater in proportion to its thickness up to a certain point, but not beyond it?—I think so.

Mr. *Bryan Donkin*, again called in; and Examined.

Mr. Bryan Donkin.

HAVE the goodness to look at Mr. Telford's plans?—The witness inspected the same.

According to that plan which you have now before you, do you think an iron hanging bridge may be constructed over the space there represented, of 500 feet between the two piers?—The detail of the plan not having been gone into here, it is impossible to say what may be intended as to the dimensions of the various parts; but I have no doubt a bridge might be built upon a similar figure to the plan now before me, with perfect safety.

Have you considered the subject of welding bars of iron together, so as to obtain a cable of considerable length?—When Mr. Telford first mentioned the subject to me of the Runcorn bridge, I turned my attention particularly to the manner in which the bars could be welded; and from the investigation I gave the subject at that time, I am quite convinced, that bars might be welded as effectually to any length, as bars of a shorter length.

You mean to say, that any difficulty in welding arising from the length of the bar may be overcome?—Certainly; I do not mean to say it could be done with the same facility, but that it could be done with certainty with regard to the quantity of tension to be brought upon all the bars composing the bridge; when I considered the subject I was relieved from any anxiety on that head, after having attended the experiments and breaking the bars at Mr. Brunton's; the inch bars of a foot long, some of them stretched nearly three inches before they broke; iron has this peculiar property, that when it is put into the stretching-machine, a certain weight extends the length of the bar; after standing some time, the bar remains of that length, and it requires an additional weight to give it an additional stretch; so that although the actual dimensions of the sectional area of the bar becomes less, yet it bears a greater weight, so that should any one of the bars in the bridge when first placed there bear a greater weight than its neighbour, or any other bar, and be exposed to a stretch, it would soon accommodate itself to the length of the whole, and in that state be capable of bearing more weight than it was at first.

Do you conceive a bridge would be equally secure if made with chain cables?—Admitting the curvature of the two bridges to be the same, and the iron equally good, the chain-cable, that is the cable carried with links, must of necessity be the heaviest, and consequently the weakest.

Mr. *John Fitchett*, called in; and Examined.

Mr. John Fitchett.

YOU are secretary to the Runcorn Bridge committee?—Yes, and solicitor.

Can you communicate to the Commissioners any thing concerning an experiment that was made at Liverpool, for the purpose of trying the strength of an extended rod of iron?—I will state to the Commissioners what I know upon the subject: I did not myself personally attend the trial of that experiment, having more particularly confined my attention to my own professional department, but in the course of that having been engaged in the business from the commencement, I am acquainted with the proceedings of the Runcorn Bridge committee, from the possession of the book; I have it not here; it is at my residence. I had only last night notice of this meeting, or I would have referred to the results of that experiment. Mr. Telford, in his Report to the Runcorn Bridge committee, after he had been selected to be the engineer employed for them, stated, that he had made upwards of two hundred experiments

riments upon malleable iron of different lengths, varying from 31 to 900 feet; the plan delivered to the Runcorn Bridge committee at first by Mr. Telford, was to be upon a span of 1,000 feet; the gentlemen of the Runcorn Bridge committee considered the undertaking to be of so much magnitude and novelty, that they wished personally to make some experiments themselves to the full extent of the intended bridge at Runcorn, that is 1,000 feet; therefore a committee was specially selected out of the general body, for the purpose of making experiments, and an experiment was made; I did not personally attend it, but I have entered the proceedings in the book of proceedings, and therefore it is, that I know that an experiment was tried over a valley or dingle in the neighbourhood of Liverpool, to the extent of 1,000 feet, the result of which experiment confirmed, and I believe exceeded, the calculations that had been delivered in by Mr. Telford, to the strength of iron under different degrees of curvature. Doubts had been entertained in the minds of several of the gentlemen of the committee, but the result of the experiment when made by themselves, which were publicly exhibited for some time, completely satisfied most of the gentlemen, and several subscriptions that had been withheld until the result of the experiments had been known, afterwards were put down, in consequence of the experiments having been satisfactory; the subscriptions at present amount to about 25,000*l.* and a petition was presented to Parliament this session, for the purpose of introducing the bill, but in consequence of the subscriptions not being full, and from other circumstances, the business has been postponed, and is intended to be brought forward again the ensuing session, if the subscriptions should come up to the required sum.

Mr. John Fitchett.

This bridge has been in contemplation, and a subject of repeated experiments during the last four years?—By Mr. Telford I believe it has; he states it so in his report.

There prevails on the part of the committee and persons interested in making this bridge, no doubt at present as to the practicability of Mr. Telford's plan?—Not knowing the opinion of each individual, I cannot speak to it; but the general opinion of the committee, I know to be in favour of the practicability of the undertaking.

To the extent of 1,000 feet?—Yes; there has been a wish expressed on the part of the Mersey and Irwell Navigation Company, that the span should be 1,200 feet, which would completely clear the tide-way and every part of the river, and place it above high-water mark. Mr. Telford has been consulted by the committee, in consequence of that wish having been so expressed to them, as to the practicability of the bridge being upon a span of 1,200 feet; and Mr. Telford's answer has been, that he conceives it is equally practicable as at 1,000 feet, though, of course, with some difference of expense; that he does not entertain any doubt upon the practicability of the 1,200 feet span, by reason of any danger from the stress of iron. The precise plan is not yet determined upon by the Runcorn Bridge committee, whether it shall be upon a span of 1,200 feet or 1,000 feet; but that, with other modifications, having in view a reduction of the expense as much as possible, for obvious reasons, not only to meet the probable subscriptions, but also to afford more profit to the subscribers, are still under consideration. Mr. Telford has very recently sent in some answers to questions which had been proposed to him by the gentlemen of the committee.

Mr. *William Chapman*, called in; and Examined.

YOU are a civil engineer?—I am.

Are you acquainted with the scheme for building a bridge over the Mersey at Runcorn?—Yes, I am; and I have also attended to the relative strength of iron in various places, particularly at Newcastle. I shall give the strength of half-inch bars, because it is proposed to form the bridge of bars of half an inch, which appears to me to be a very eligible plan; the half-inch bars tried at Newcastle of different species of iron bore from five to ten tons each; and according to the experiments in Mr. Barlow's publication, they bore from nearly six to six and a half tons. I deem the mean proportionable stress of tolerably good iron to be six tons to a half-inch bar, but iron will elongate at not much more than half that stress; and therefore I conceive, three tons per half-inch bar to be a sufficiently great load, even provided the iron be of good quality; but it

Mr. William Chapman.

Mr. William Chapman.

it will be prudent to be content with two tons. I find, by Mr. Telford's experiments, that when the versed sine of the chain was 1-50th of its chord, and the weight was equally diffused, it bore 104, or between 1-10th and 1-9th of the stress that it would do vertically, and when the versed sine was 1-20th of the chord it bore 337, or a little more than 1-3d of its direct stress; which I shall assume as a datum for comparison.

That is to say, that where the curvature was as two to five, it bore 1-5th part more than in proportion to its deflexion?—Yes, it is so stated. From those circumstances, it is of much importance to have as great a deflexion or versed sine as you conveniently can. In consequence of being desired to turn my attention to the subject, and not knowing what plan would be produced, I made estimates of the relative strength of two different modes, one upon the principle already exhibited, and the other upon the principle of dividing the bridge into a number of portions, supported by rectilinear stays extending from those points of the bridge to the point of suspension or summit of the column. The strength of each rectilinear half-inch bar may bear two tons in supporting a vertical weight, but when the weights are suspended diagonally, there requires an increase of strength, as the secants of the angles, and therefore additional strength must be added in this ratio, and the length would likewise be in the ratio of the secants. On this principle, I estimate the weight in the one plan as 30 to a little more than 90, viz. in round numbers as one to three.

You mean that one plan would be as strong with 30 tons as the other would be with 90?—Yes, as the curved plan would be with 90 tons; but a considerable quantity of iron would be wanted along the horizontal line of the bore of the bridge, and the strength of these will progressively diminish as they go inwards from the centre.

Are you of opinion, that either of the modes to which you have alluded may be employed for a linear hanging bridge to the width of 500 feet, with perfect safety?—I am; and the second mode, that by stays, which I have mentioned, is a mode that was practised in America some time ago.

Have you seen the plan, constructed by Mr. Telford, for a bridge over the Menai Strait?—Yes, I have, since I came into the committee-room.

As far as your knowledge of the subject extends, and your opportunity of examining that plan, have you any doubt in your own mind, whether or not such a bridge might be constructed, so as to be perfectly safe for the passage of any cattle or wheel-carriages whatever, which might at any time have occasion to pass by it?—By making the quantity of iron proportionate I have no doubt of it; and as to the welding of the iron I see no difficulty in that, for a half-inch bar is very pliable in 30 or 40 feet; it will in about that length turn half way round, which is all that is wanted.

Do you apprehend there will be any difficulty arising from the danger of crushing the points of suspension by the weight of the iron?—No, I do not. I beg to add, that I approve very much of the mode of combining the iron by joining the individual bars longitudinally, and then laying them together without welding them.

Are you of opinion, that a bridge, constructed in either of the manners of which you have been speaking, would be sufficiently steady for carriages and other things to pass quickly, and without danger or inconvenience?—Yes; but the latter bridge, that by stays, would be less subject to undulation.

Do you think, on such a bridge as that proposed by Mr. Telford, there would be much perceptible motion in passing over it in a carriage?—If that proper attention, which may be expected, be paid to every point, I have no idea that there will.

Did you hear the calculation by which the Runcorn bridge was capable of sustaining about 900 tons, exclusive of its own weight?—I did.

Have you calculated what would be the weight of a drove of cattle, regularly distributed over the whole passage of the bridge, from end to end?—Yes, I have; I make it to be about 330 tons. Supposing a body of men, or a military detachment, to walk over in close columns, I think it would take about 2,000 men, which, therefore, at sixteen stone each, would amount to 200 tons.

You have mentioned a bridge in America; have the goodness to describe it?—I do not recollect exactly where it is; but I recollect reading an account of it a long time ago, and that I drew a sketch similar to this now before me, when it occurred to me last night, not knowing what this plan would be.

(A.)

Calculation of the Stress and Strength of the projected Iron Hanging Bridge over the *Menai Strait.*

ONE of the most important data connected with this calculation, is the strength of direct cohesion of malleable iron.

It appears from the results of various experiments performed by Mr. Telford and others, by Messrs. Brunton and Co. as also by Captain Brown, at the latter of which I was present, that the medium ultimate strength of this metal is about 27 tons to the square inch section, and that the strength, within certain limits, is proportional to the area. The apparent deviation from this rule, mentioned by Mr. Brunton, in favour of the larger bars, is rather to be attributed to the particular nature of the action of his machine, than to any real increase of proportional strength.

To the same cause is also to be attributed the apparent superior strength of iron bars, when tried at Mr. Brunton's manufactory, over those submitted to the action of Captain Brown's engine.

Mr. Brunton's machine appears to me to over-rate its own action; that of Captain Brown's to register less than its full power. According to the former course of experiments, the strength on a square inch section is $29\frac{1}{4}$ tons, while the latter gives only 25 tons. I assume the mean of these two as the medium strength; viz. 27 tons to the square inch. The bars on which these experiments were performed, varied from less than an inch to more than two inches in diameter. This datum being established, Mr. Telford was next desirous of ascertaining the strength of iron when suspended at its extremities, loaded with weights in different parts of its length, the results of which experiments he supplied me with for my publication on the strength of wood and iron. They appear to me to have been made with great care and accuracy. I have computed theoretically what weight ought to have been expected to produce the fracture; and the agreement between the theory and the practice was very remarkable, in some cases the difference was not one part out of one hundred of the actual weight. It is this agreement which leads me to place entire confidence in the computations I have made relative to the Runcorn Bridge, as also in the following, with respect to that proposed to be thrown across the Menai Strait.

The length or distance between the piers of the Menai Bridge is proposed to be 500 feet, and the greatest deflection 30 feet, which will require the length of the cable or bar to be 505, and the weight of 505 of a square inch iron rod will be about 1,704lbs. which will produce a strain on each point of suspension of 3,632 lbs. The strain necessary to produce a fracture on the same rod is 27 tons, or 60,480lbs. Such a bar would therefore bear a load (including its own weight) of 28,372lbs. to be uniformly distributed over it before a fracture would take place. This weight multiplied by the number of square inches in the section of all the bars, will give the extreme weight the bridge would support, or rather, the least weight that would break it.

I believe it is intended to have four cables, each of 15 inches area, or 60 inches section in the four; therefore $28{,}372 \times 60 = 17{,}023{,}200$lbs. or 760 tons, is the whole weight the bridge would be just able to support.

Mr. Telford estimates the whole weight of the Runcorn Bridge (independent of any passing load) at 574 tons, and assuming half this for the Menai Bridge, viz. 287 tons, there will remain a surplus strength of 473 tons; but this may be increased ad libitum, by increasing either the number of bars or the section of each. If therefore the bridge be erected agreeably to the proposed plan, I am confident, as far as the strength of materials is concerned, no danger is to be apprehended. With regard to the strain and pressure on the top of the piers, I have made the following computations:—

The tension being assumed equal to 380 tons, the vertical pressure is found to be equal to 89 tons, (viz. $380 \times \sin 13° 34'$) as arising from the centre catinary; and I estimate (but I have not actually computed it) that part of the cable which passes over the piers and serves as a brace, will adjust itself to about an angle of 20°, with the horizontal line passing over the pier. The vertical pressure arising from this brace is therefore about $380 \times \sin 20° = 130$ tons, and the whole vertical pressure on each pier will be 210 tons.

I conceive there will be no difficulty in finding materials to resist this pressure.

The horizontal strain on the piers inwards is $380 \times \cos 13° 34' = 369$ tons, and outwards it is $380 \times \cos 20° = 356$ tons; there will therefore be a horizontal force acting inward on each pier equal to about 13 tons; this strain Mr. Telford proposes to counteract by the two pier braces, which will obviously be amply sufficient for the purpose.

The weight of masonry above the bed to which the cables are ultimately attached, ought to exceed as much as possible 180 tons; with less weight they would give way.

In conclusion, I beg to state, that I am not competent to judge of the practicability of the construction; but supposing it erected, I am convinced from the above computation, that as far as strength is concerned, no danger whatever need be apprehended.

(Signed) *Peter Barlow.*

MINUTES OF EVIDENCE, before the Commissioners for the Improvement of Holyhead Road, Monday, 18th May 1818.

WILLIAM SMITH, Esq. in the Chair.

Mr. *Peter Barlow,* called in; and Examined.

Mr. Peter Barlow.

HAVE you made the calculations requested of you on Saturday last, respecting the comparative strength of bridges of 500 and 1,000 feet?—Yes; I have.*

* Vide p. 6, supra.

Do you conceive that an iron bridge of tension, loaded with a weight equal to one half of what theory gives as being capable of sustaining, would be a bridge to be relied upon in practice?—I think it would.

In the statement you have read to the Commissioners, the area section of 60 inches, on which you have made your computation, is it not an assumed datum of your own?—I have not received Mr. Telford's account of the section, and therefore I assume it as the most probable.

If then cables of the same sectional area with the Runcorn Bridge were used, of course the proposed Menai Bridge would be capable of sustaining four times the weight you have calculated?—Yes; nearly so.

John Rennie, Esquire, called in; and Examined.

John Rennie, Esq.

YOU are a civil engineer?—Yes.

You have been accustomed to make experiments to ascertain the strength of iron, particularly in a state of tension?—I have.

Be so good as to give some general idea of the manner in which you have made these experiments, and of their result?—The first experiment I made upon iron in a state of tension was ten years ago, and it was upon a machine invented and made upon that principle by Captain Huddart. On that occasion, I made a number of experiments for the use of the Navy Board, and I found that the best iron which I could get, bore upon an average from 25 to 26 tons, very few indeed bore 26 tons square inches; 25 tons may be reckoned about the average, and in trying these bars by the machine, I found them lengthen in a very extraordinary degree. Some of the bars of three feet long and one inch square, lengthened eight inches before they broke. I have also tried some experiments upon Captain Brown's machine, and the result has turned out pretty nearly the same as the experiments made upon Captain Huddart's.

Have you ever tried any experiments upon bars welded together, so as to ascertain the strength of the bars, and the parts with which they were welded?—None upon any of these machines.

What is your general opinion as to the comparative strength of the welded parts of bars, when carried to any length?—I have generally found that at the welded places the strength is very uncertain. I wish, however, to observe, that I have not ascertained by experiments on machines of the description I have mentioned, the strength of iron bars at the welded places; but my general practice shows, that it is very irregular, and mostly weaker than the solid bars.

Does that arise from the imperfection of the operation?—I should apprehend from the imperfection of the operation, and on account of the distortion it gets in the course of the welding.

By distortion, do you mean any alteration in the texture of the metal?—The metal

John Rennie, Esq.

metal is very frequently injured by overheating, and frequently the calx of iron gets into the metal, and prevent all the parts from being properly connected.

Have you not then made any experiments upon a large scale, sufficient to enable you to give an accurate idea of the general proportion which the welded part may bear to the other part in point of strength?—I have not.

Have you from any of these experiments formed any idea how far iron, in a state of considerable tension, may be depended upon when drawn to a great length, to be applied to the purpose of bridges, or any purpose of that kind?—No; I have not made any experiments for that purpose.

From your general knowledge of the texture and nature of iron when drawn into bars, can you form any opinion which you yourself can depend upon, on the subject just mentioned?—I have no doubt that chain bridges, or bridges of iron, may be made to answer the purpose extremely well. I have no doubt of it, provided they are made sufficiently strong; but my opinion is, that the strength should be much greater in proportion to the actual weight to be sustained, than what Mr. Barlow has stated.

State what further allowance you would think it prudent to make?—In my opinion, I should not be disposed to make a bridge of that description on which I could depend, if it was much less than double the strength that he has stated. I have found from my experiments, particularly in mill-work, such as shafts and all such machinery, that unless it is from four to five times the strength of actual calculation, you can never depend upon its standing; I speak of cast as well as wrought iron.

Supposing an iron cable bridge to be constructed, is it your opinion, that if the cables are made sufficiently strong to sustain double the weight likely to be put upon it, that is sufficient?—My opinion is, that the iron cables ought to be of a strength equal to sustain at least four times what is likely to be put upon them.

According to your practice or theory, as to the mode of constructing the cables or chains, by which such a bridge should be supported, would you prefer bars extended longitudinally the whole length, or cables made in the common chain way, supposing an equal weight of iron to be employed in both?—If I conceived it practicable to make single bars of homogenous quality, and their junctures perfect in all their parts, I should certainly prefer straight bars; but as I am very doubtful of the practicability of rendering them perfect in all their parts, I am inclined to think that a chain might be made to be upon the whole as much depended upon—nay more indeed; and a chain of the same weight would be more desirable, inasmuch as it would have this advantage, that if any of the parts were imperfect, they could be taken out separately and repaired, without deranging the bridge.

Do you apprehend that a chain is capable of being extended across from one point to another, with as small a curve as whole bars may be?—I should apprehend it might.

Do you conceive that there is any advantage in having the curve made as small as possible?—The smaller the curve is made the more convenient the bridge; but it would require a stronger chain.

Do you apprehend that there is any difficulty in so regulating the strength and construction of the piers, as to make them sufficiently strong for the purpose of supporting any bridge which may be wanted?—I should think not; but I must beg to mention this observation; namely, that if the dimensions are taken from theory, although that serves to guide practical persons, they will be found very far inferior to what practice requires.

Have you ever, in your own practice, contemplated the use of chains for such purposes as these, of which the Commissioners have been speaking?—When I made a design for a cast iron bridge over the Bangor Ferry, I had it in contemplation to use chains for the purpose of strengthening the centering upon which the cast iron arches were to be erected. The length of these chains was 450 feet, being the distance between the abutments of the arches; and, indeed, I proposed a bridge of chains over Bangor Ferry, in a letter to the Right Honourable John Foster, about eight or nine months ago, but I never received any answer to that letter.

Can you give us any information respecting bridges constructed on this plan in America, or other countries or places?—There is a chain bridge on the Meremack River, about three or four miles above Newberry Port in North America, the span of which is 240 feet; and I understand it answers the purpose very

John Rennie, Esq.

well. There is another one mentioned by Turner, in his account of his journey to Mount Thibet, in India; to the best of my recollection, this is about 100 feet in the span. There is another over the river Tees, in the county of Durham, a little below Middleton, near to Barnard Castle; the span of that is 70 or 80 feet. My son has been over it two or three times, and he can give the Commissioners more accurate information respecting that bridge than I can give.

Do you conceive, that bridges on this principle, may be constructed without any inconvenience, or danger to passengers, on account of the unsteadiness of its motion?—I think they might.

Do you apprehend that a bridge constructed over the Menai Strait, the road way of which should be 100 feet above high water mark, would be any obstruction to navigation?—I should think not, from the construction of the vessels that navigate the Strait.

What effect do you apprehend the wind would have upon a bridge over that Strait, of such a construction as that to which the Commissioners allude?—My opinion is, that from the strength of tide, and altogether, there would be no injury in that way.

Do you not apprehend, that bridges suspended by chains, may be constructed at far less expense than cast iron arches?—In suitable situations they may; and I conceive that the introduction of chain bridges will be a very great advantage to the country in certain cases and situations.

Mr. *Chapman* again called in; and Examined.

Mr. Chapman.

HAVE you any alterations or amendments to make in the evidence you gave on Saturday?—I have some amendments to make, but not any alterations; the amendments that I would wish to make are, to the latter part of my evidence, in which I said that there were bridges constructed in America upon the principle of diagonal suspension in its different parts; but upon inquiry of Mr. Samuel Wright of New Hampshire, where a bridge was erected over the Meremack, he informs me that it was a chain bridge, and not a bridge of diagonal suspension in its different parts. My calculation was formed, according to my own ideas, of what I then thought the plan of the bridge was, or ought to be, having no perfect recollection of it. This system of constructing bridges has this advantage, namely, that it affords a facility of repairing, if any particular stay broke; and it would also have the advantage of producing little or no undulation, as each stay bears its own respective proportion of weight, whereas a weight moving from one part of a chain to another, must necessarily depress that portion over which it is passing. In my haste to make the calculations of the proportionate quantities of iron, in the two different descriptions of bridges, on Saturday morning, I happened to make the quantity of deflection in the bridge of oblique stays, different from that of the other, and consequently, although the principles of calculation were just, the results were erroneous. On revision I find them to be as follows; namely, in a bridge of 500 feet span and of 25 feet depression in the middle, formed of different inverted arcs, composed of bars laid side by side, assuming the weight of iron in those arcs to be 92 tons, or any proportionate weight, there will be requisite to form a bridge of a similar span and depression, after the plan of using diagonal stays, the following proportions; viz. weight of iron, in the diagonal stays about 55 tons, and in the bottom braces on each side to retain those stays in their proper position about 26 tons. Their combined quantity, therefore, is 81 tons, which is not very essentially different from the other, to which has to be added, the weight of the suspending bars, which will be of no great amount. In corroboration of the idea I before mentioned, I inquired of Mr. Wright, who saw the bridge over the Schuylkill, and he told me that it gave way in consequence of a herd of cattle getting together and fighting, which produced such an accumulation of weight that the bridge could not bear it, so that the chain broke, and the cattle and men were in general killed. Since then they have constructed a wire bridge, fastened to the same places, the different wires being laid side by side, and bound or slightly twisted together. The bridge is only four feet wide, and suspended at different intervals from inverted arcs. Its undulation upwards and downwards is so great, that many people are afraid of passing. I have also seen the bridge over the Tees, and passed over it. It has a considerable portion of undulation, but not so much as to terrify any persons but those who are very timid.

How

Mr. Chapman.

How many times the strength given by theory, is adequate to support the weight in a bridge of suspension, which you think it fit to adopt in practice?—I would not assume less than three times, but I should prefer four times the calculated strength.

Mr. *Thomas Brunton*, again called in; and Examined.

Mr. Thomas Brunton.

DO you wish to add any thing to your evidence of Saturday last?—Yes. I believe I expressed myself particularly against the expediency of using welded rods, that they could not be made sound with any security; but in forming my idea of joining suspended rods, I find that they can be put together with buckling fully as strong, and even with double the strength of any other part of the rod, by an infallible method, and I think myself able to prove by actual experiments, that such is the fact; and the mode which I propose I am ready to explain. I think the bars may be joined together in such a manner as to be fully as strong, or even with the same weight much stronger than cables.

—No. 3.—

MEMORIAL of sundry Persons interested in the Navigation of the Menai Strait, to the Lords Commissioners of His Majesty's Treasury, praying a Grant of Money for improving the same.

To the Right Honourable the Lords Commissioners of His Majesty's Treasury.

The Memorial of the undersigned Persons, interested in or acquainted with the Navigation of the Menai Strait;

Sheweth,

THAT the navigation of these Straits is of great importance to the Trade of the Western Coast of England and Wales, but that it is very much interrupted by the Swilly and other Rocks, which cause numerous and violent eddies, and thereby narrow the navigable channel so much, as to expose all vessels when passing through them to very imminent danger.

That the difficulty of this navigation would be very much diminished, if certain portions of these rocks were cut away to the level of low-water mark; that is to say, two projecting points on the Carnarvonshire shore, opposite the large Swilly Rock, part of the Cribinnian Rock, and also part of the Britannia Rock. The consequence of this improvement would be a sufficient space of uninterrupted tideway, to allow vessels to navigate the channel between the Carnarvonshire shore and these Rocks, without being constantly liable to become unmanageable by getting into a back-water current.

Your Memorialists, though far from thinking the new intended bridge from Ynys-y-moch to the opposite side of the Straits will injure the navigation, are clearly of opinion, that if the removal of these Rocks were made to form a part of a general plan for serving those who are interested in the navigation of the Strait, and as well for promoting the communication between England and Ireland, the taking away of the existing obstructions will more than counterbalance any inconvenience which the bridge might possibly occasion, by forming any fresh eddies in the wind or tide.

Your Memorialists therefore pray, That your Lordships will be pleased to propose to Parliament, to grant a sum of money for the purpose of improving the navigation of the Menai Straits. They trust no heavy expense will be incurred, if proper advantage is taken of the opportunity which the building of the bridge will offer, of effecting it with economy, because the broken rocks will be of use in the mason work, and further, because little loss need result from the rise of the tides stopping the operations, as the persons employed on them may be immediately transferred to the bridge works.

The undersigned, Pilots of the Straits of Menai, having acted as such for periods of seven to forty years and upwards, being required to state their opinion of the first and most essential improvement which might be made on that part of the navigation called The Swilleys, do unanimously agree, That the main and important point to obtain, is an abatement of the rapid and dangerous eddies

occasioned by the obstruction of rocks sunken and otherwise, of different heights and extent, and do therefore recommend, in the first place, the cutting away from high water on a level to low water-mark, two projecting points of the Carnarvonshire Main at the east end of the Swillys.

The next object should be, to cut away to low water-mark a reef of rocks called the Cribinnian, which occupy a considerable part of the South Channel; further, it would be highly expedient to cut off the skirting reefs attached to the Britannia Rock. The above objects being effected, it is presumed, that the current of both ebb and flood would run in so fair a direction, that there would be no difficulty in guiding a vessel in its true course, whether by the sails or boats a-head. These observations refer to the South Channel only, the direction of which is nearly straight; but the North Channel of this dangerous navigation having a more bending course, is preferred with a beating wind, and in it there are sunken rocks most desirable to be cut off as far as low water-mark; namely, the Donkin Rock and the skirts of the Beulas Rock.

Your Memorialists beg leave to refer your Lordships to the annexed depositions of several experienced Pilots, as corroborating this opinion.

John Jones, Town Clerk of Beaumaris.

J. Lloyd, J. Jones, J. W. Hampton, } Chief Burgesses of the Borough of Beaumaris.

J. B. Sparrow, W. Sparrow, J. H. Hampton, Eras. Griffith, } Commissioners of Pilotage for the Port of Beaumaris under the Trinity House.

Edward Rice, G. Roberts, } Bailiffs of Beaumaris.

R. Williams, Mayor of the Borough of Beaumaris.

J. B. Sparrow, W^m Williams, W^m Sparrow, Hugh Davieson, Robert Williams, Robert Allen, Hugh Wynne, Richard Lewis, Hugh Lloyd, Edward Edwards, William Hughes, } Chief Burgesses of the Borough of Beaumaris.

N. Gout, commander of His Majesty's revenue cutter Success.

Names of Landed Proprietors:—Henry Lord Bishop of Bangor, J. H. Cotton, Magistrate for the County of Carnarvon and Vicar of Bangor, Wm. Peacocke, H. Rowlands, J. Williams, O. G. Williams, H. Wynne Jones, Jas. Greenfield, J. Bradley, John Kyffin, Magistrate for the County of Carnarvon, R. Evans, J. Jones, J. Jones, R. Row, R. Lloyd, John Parry, H. T. Evans, Benjamin Henitt, Richard Davies, Robert Williams, Hugh Price, J. Toft, J. Roberts, T. Ellis, J. Pring, G. T. Barlow, Edward Parry, John Bogger, G. H. D. Pennant, O. Williams, Nolan Thomas Stanley, John Jones.

Names of Pilots:—Humphrey Tyer, Robert Roberts, Humphrey Jones, Wm. Roberts.

Names of Merchants:—Jas. Harris, jun. Wm. Peers and Co. Eras. Griffith, James Harris, Thomas Redding, Thomas Parry, Robert Hughes, R. H. Griffith, Wm. Lewis, Thomas Rathbone, John Hughes, David Roberts, W. Hughes, T. Davies, G. Fletcher, John Jones, Richard Hughes, Richard Edwards, Robert Jones, Thomas Roberts, John Roberts, Thomas Evans, Wm. Elias, John Taylor, Wm. Jackson.

Names of Ship Owners:—Robert Williams, John Jones, R. Williams, waterbailiff, Lewis Hughes, Edward Thomas, Thomas Griffith, Thomas Ellis, P. Roughton, W. Haslehurst, Jas. Yond, Geo. Dale, John Nanney.

Walter P. Wade, Lieut. R.N. commanding His Majesty's revenue cutter Defence.

The undersigned Pilots beg leave humbly to observe, that the Straits of Menai are a great shelter and protection to the coasting traders from London to Liverpool, and the intermediate ports, both to and from the last-mentioned important trading town, inasmuch as they afford secure anchorage for a space of upwards of twenty miles, excepting a few hundred yards of the rocky navigation already described, besides the course of vessels being considerably shortened by this passage.

The

The undersigned Pilots humbly beg to testify, that if labourers could be detached from the bridge works at Bangor Ferry, the ebb-tide would carry them to the rocks in question in less than five minutes, and when overpowered by the flood, they might return to their regular occupations in the same space of time, by which the expense would be rendered comparatively small.

Signed,

The mark of Henry ⋈ Roberts.
John Williams.
John Roberts.
John Owen.
The mark of Morris ⋈ Edwards.
The mark of Hugh ⋈ Prichard.
Richard Roberts.
The mark of Richard ⋈ Owen.
The mark of Robert ⋈ Jones.
The mark of Wm. ⋈ Roberts.

Witness, H. Jones.

—No. 4.—
(1. 2. 3. 4.)

MEMORIAL and Reference to the Elder Brethren of the Trinity House, relating to Plan of proposed Bridge across the Menai; with Report thereon to the Lords of the Treasury; and Letter from their Lordships to the Commissioners for the Improvement of the Roads from Holyhead to London.

No. 4. (1.)

To the Right Honourable the Lords Commissioners of His Majesty's Treasury.

The humble Petition of the Gentlemen, Freeholders, Merchants, Traders, and other Inhabitants of the Town and Neighbourhood of Carnarvon, interested in the free Navigation of the Straits of Menai;

Sheweth,

THAT your Petitioners have lately heard with great regret, that your Lordships have sanctioned an attempt to construct a bridge over an arm of the sea, between the counties of Carnarvon and Anglesey, called The Straits of Menai, near Bangor Ferry, from a certain rock there adjoining the Anglesey shore, called Ynys-y-moch, to the Carnarvonshire side.

That your Petitioners firmly believe, in which they are supported by the most incontrovertible proof, arising from the experience and testimony of a numerous body of masters of vessels, pilots, and others that have constantly navigated the Menai, that constructing a bridge over the said Straits from Ynys-y-moch, or any other place near the Swilly Rocks, would cause eddy tides and baffling winds, and other dangerous effects, so as to be most injurious, if not a total ruin to the passage of ships and vessels navigating the same.

That the free navigation of the said Straits is of the utmost importance to the coasting trade, carried on in all the ports within the Principality, and to several ports in England and Scotland, as they afford the most direct communication from the port of Carnarvon, and all other ports on the southern coasts of the Principality, as well as Bristol and several other English ports, to the ports of Beaumaris, Bangor, Conway, Rhyddlan, Chester, Liverpool, Runcorn, and Lancaster, and to several of the inland parts of the kingdom, by canals from Liverpool and Runcorn, and also to Glasgow, Whitehaven, and several other ports in Scotland.

That a source of extensive and inexhaustible trade and commerce with those ports, arising within the county of Carnarvon and those adjoining, by the rapid improvements of public works, would be very considerably impeded, if not in a great measure stopped, if the navigation of the said Straits was obstructed, which in its present state is so hazardous, as to make it invariably necessary for masters of vessels to have recourse to the aid of experienced pilots.

That your Petitioners humbly submit to the consideration of your Lordships, whether you are duly authorized by any Act of Parliament, to sanction the building of a bridge over the said Straits of Menai at Ynys-y-moch, or any other place near the Swilly rocks; if you are, such an Act was passed unknown to your

Petitioners, for want of such public notice as your Petitioners conceive is usually given, before an Act is obtained for erecting any public bridge.

That when the propriety of building a bridge over the said Straits was brought under the consideration of Parliament some years ago, your Petitioners, with several others interested in the free navigation thereof, opposed the measure, and examined pilots and others experienced in the navigation of the said Straits, before a Committee of the House of Commons, whose evidence your Petitioners humbly conceive had considerable weight and influence with the Committee, which your Petitioners humbly hoped would have prevented another attempt of constructing a bridge, that will evidently be most injurious and destructive to so valuable a navigation.

That if your Petitioners had notice of an Act being brought before Parliament, for the purpose of constructing a bridge over the said Straits, they would have most strenuously opposed the same ; and if your Petitioners had any knowledge of the intentions of your Lordships to sanction the attempt of building such a bridge, at an earlier period of the present session of Parliament, they would have taken the most prompt steps to bring such measures under the consideration of the Honourable House of Commons of the United Kingdom, and satisfy the members, by the most incontestible proof, that such a bridge would be most injurious, if not a total ruin to the navigation of the said Strait.

That as your Lordships intentions of having a bridge erected over the Menai have been unknown to your Petitioners, until too late to oppose it during the present session of Parliament, and though your Lordships may feel justified to countenance such measure, by virtue of some Act passed unobserved by your Petitioners, still, as it is of such importance to the trade of the several ports hereinbefore stated, and other advantages not to be foreseen or at this time enumerated, your Petitioners humbly hope, That your Lordships will direct the commencement of the erection of a bridge to be suspended until the next session of Parliament, to give your Petitioners an opportunity to convince the Members of the Honourable House of Commons, of the most serious injury that your Petitioners and others will sustain, by the building of such a bridge ; and they humbly hope, that the conveniency of the Public travelling over Bangor Ferry, will not be put in competition with the immense importance of the free and uninterrupted navigation of the Straits of Menai.

Signed,

R. Williams, M. P. ; A. Smith, M. P. ; H. Jones, W. Ironmonger, Rice Thomas, Geo. Wyatt, J. P. Jones Parry, R. N. ; E. Creig, J. Hamer, Clk; Z. Jones, Collector of Customs ; M. Fleming, W. Williams, J. Bevans, W. Williams, W. Griffith, Capt. of Brig William ; H. Roberts, J. Jones, G. Roberts, Capt. of Princess Amelia ; E. Evans, W. Owen, H. Evans, Capt. of the Dinas ; R. Jones, J. Jones, J. Lloyd, O. Williams, R. N. ; Rev. J. B. Lewis, R. Roberts, W. Roberts, W. Evans, T. Lloyd, T. Taylor, H. Jones, J. Holme, J. Jones, L. Owen, Capt. of the Brig Brothers ; R. Owen, Capt. of the Miss Smith ; D. Rowland, Capt. of the Oilgwyn ; S. Samuel, R. Evans, Capt. of the Catherine ; R. Parry, W. Thomas, N. Hughs, Griffith James, J. Thomas, Pilot ; R. Evans, G. Bettiss, J. Jones, Clk. ; R. Woodyatt, R. Pierce, Capt. of the James and Betsey ; W. Jones, D. Roberts, E. Harries, S. Ogden, R. Jones, T. Williams, W. Hughes, R. Thomas, J. Evans, T. Jones, Brig Esther ; R. Roberts, R. Jones, W. Thomas, Capt. Sloop John ; Rice Jones, R. Roberts, H. Parsey, D. P. Evans, T. Jones, W. Thomas, W. Williams, W. Thomas, H. Hughes, D. Edwards, O. Williams, Capt. Sloop Elizabeth ; Capt. E. Parry, Queen Charlotte ; W. Jones, J. Hastern, R. Roberts, O. Jones, G. Jones, R. Rowlands, E. Price, J. Jones, D. Jones, D. Hughes, R. Abel, J. Griffiths, T. Hudson, J. Williams, R. Hughes, G. Drotitle, J. Owen, J. Owen, E. Thomas, R. Parry, J. Price, W. Williams, O. Griffith, W. Williams, Evans Jones, R. W. Williams, W. Holland, T. Hughes, D. Davies, O. Owen, R. Roberts, Master of the Eliza of Carnarvon ; J. Owen, Master of the Elizabeth of Carnarvon ; W. Turner, R. Williams, J. Edwards, J. Griffith, Pilot ; H. Hughes, E. Parry, J. Morgan, E. Lloyd, J. L. Williams, W. Prichard, R. Williams, W. Mathews, J. Byrne, J. Roberts, T. W. Maddocks, W. Jones, W. Roberts, W. Hughes, W. Jones, J. Williams, D. Parry, H. Owen, E. Williams, T. Hughes, W. Roberts, T. Rowlands, R. Charles, E. Griffith Roberts, E. Porcelle.

No. 4. (2.)

Gentlemen, Treasury Chambers, 16th June 1818.

THE Lords Commissioners of His Majesty's Treasury having had under their consideration a Petition of the Merchants and Inhabitants of Carnarvon, praying that the commencement of the erection of a bridge over the Straits of Menai may be suspended until the next session of Parliament, together with a Letter from Mr. Telford of the 9th inst. relative to the expediency of proceeding with the construction of the said bridge;

I have it in command to transmit to you copy of the said Representation, and also of Mr. Telford's Letter; and at the same time to state to you, that such representations having been made of the injurious effect which the erection of a bridge over the Menai might have upon the navigation of the Strait, my Lords could not think themselves authorized to issue the sum granted by Parliament for the said bridge, until they have received more satisfactoy information upon this important point. My Lords therefore request, that you will give directions that the several Plans and Surveys of which you may be in possession, with respect to the intended bridge, be laid before the Corporation of the Trinity House, whom my Lords have desired to take the subject into their consideration, and to favor this Board with their opinion as early as their convenience will admit, (in order that no unnecessary delay may take place in the execution of the said work, if finally resolved upon,) whether the erection of a bridge upon the plan and in the situation proposed, can be attended with any injurious consequences to the navigation of the Menai. And I am to desire, that you will give such further information thereon to the Trinity House, as they may require.

I am, Gentlemen,

Commissioners for Holyhead Roads.

Your obedient Servant,
(Signed) *Geo. Harrison.*

No. 4. (3.)

Sir, Trinity House, London, 27th June 1818.

THE Commissioners for the Holyhead Roads having, agreeable to the desire of the Lords Commissioners of His Majesty's Treasury, furnished the Elder Brethren of this Corporation with the several Plans and Surveys and such other documents as are in their possession, with respect to the intended bridge over the Straits of Menai, (the erection of which is requested to be suspended by the merchants and inhabitants of Carnarvon;) and Mr. T. Telford, their engineer, having attended this Board, and given such further information as was desired in explanation thereof; the Elder Brethren have, agreeable to their Lordships request, communicated by your letter of the 16th instant, taken the subject into their consideration; and having carefully examined the plan and situation of the proposed bridge, and attentively perused and considered the evidence detailed in the several reports laid before the Honourable House of Commons in different sessions of Parliament, with respect to the probable effects of such a structure upon the navigation of the Straits; I have it in command to report to you, for their Lordships information, that the Elder Brethren are of opinion, upon mature consideration of the whole, that the erection of a bridge, upon the plan and in the situation proposed, can be attended with no injurious consequences to the navigation of the Menai.

I am, Sir,
Your most obedient Servant,

George Harrison, Esq.

(Signed) *Ja^s Court.*

No. 4. (4.)

Gentlemen, Treasury Chambers, 29th July 1818.

THE Lords Commissioners of His Majesty's Treasury having resumed the consideration of the representation of Sir Robert Williams and others, on the subject of the erection of the intended bridge over the Menai; I have it in command to transmit to you, for your information, a copy of the Report of the

Corporation of the Trinity House on the subject, and to desire that you will give the necessary directions for proceeding in the work, agreeably to the vote of Parliament.

I am, Gentlemen,
Your obedient Servant,
(Signed) *C. Arbuthnot.*

Commissioners of the
Holyhead Roads.

—No. 5.—

REPORT and Estimate for Improving the Navigation of the *Menai Straits*, at and near the Swilly Rocks.

IN compliance with the directions of the Commissioners, I have duly considered the Memorial of the persons interested in the navigation of the Menai Straits, and the Statement of ten of the Pilots who have acted in that capacity from seven to forty years; by which it appears, that the following operations would greatly improve the navigation of that Strait, viz.—

1.—Cutting away to low water the points of two projecting rocks, which are situated on the Carnarvonshire shore, adjacent to the Swilly Rock.
2.—Cutting down to low water-mark a reef of Rocks called the Cribinnian.
3.—Cutting off a part of the Britannia Rock.
4.—Cutting off to low water the Donkin Rock, the skirts of the Benlas Rock, and lowering the Platters.

After having carefully examined the said rocks, and caused Mr. Provis, the resident engineer upon the Holyhead Road Works, to make an accurate survey, I am of opinion, that what is here proposed is practicable, and if performed during the execution of the Menai Bridge, might be accomplished at a comparatively moderate expense. From correct measurements, I estimate the expense as follows:—

	£.	s.	d.
1.—Cutting away to low water two projecting points of Rock, which are situated on the Carnarvonshire shore	4,814	1	6
2.—Cutting away to low water the reef of Rocks called the Cribinnian	2,494	0	0
3.—Cutting off part of the Britannia Rock	1,032	8	0
4.—Cutting off to low water the Donkin Rock, the skirts of the Benlas Rock, and lowering the Platters	543	6	0
5.—Perches, &c. &c.	100	0	0
	£.8,983	15	6

London, 16th February 1819. (Signed) *Thomas Telford.*