

water necessary for vessels must be added the height of the rise and fall of the tide.

But, fortunately, the neighborhood of the port of Taboga, and the almost constant tranquility of the Gulf of Panama, at the bottom of which is the mouth of the Caimito, permit us, in establishing the entrance of the canal, to take into consideration only the depth of water at high tide.

The place on the coast which appears to me the best to correspond with the required conditions in this respect, is a little bay with an opening of 350 metres, (382 yards,) and a depth of 200 metres, (218 yards,) situated 4,000 metres ($2\frac{1}{2}$ miles) to the eastward of the mouth of the Caimito, at the foot of the small mountain of Vaca de Monte, and to which, therefore, I have given the name of *Eisenada de Vaca de Monte*; it is bordered by rocks, and there flows in at the bottom of it a little stream of very trifling volume. At its entrance the mean depth was found to be 3 metres (9.84 feet) at the low tide of the 3d of July, 1844, (three days after the full moon,) which would give at least 8 metres (26.4 feet) at high tide. There would be but little to do at this point to establish the entrance lock of the canal with such a depth of water that ships might enter, at least at high water, during the neap tides, about the first and last quarters of the moon.

(To be continued.)

Abstract or short Summary of Results from Experiments relative to the proposed Bridge across the Menai Straits, addressed to
ROBERT STEPHENSON, Esq. By W. FAIRBAIRN.

After a series of experiments undertaken at your request, for ascertaining the strongest form of a Sheet Iron Tubular Bridge across the Menai Straits, I have been induced, in order to meet the requirements for such a structure, and to ensure safety in the construction, to call in the aid and assistance of my friend Mr. Hodgkinson.

The flexible nature of the material, and the difficulties which presented themselves in retaining the lighter description of tubes in shape, gave exceedingly anomalous results; and having no formula on which dependence could be placed for the reduction of the experiments, I deemed it necessary, in a subject of such importance, to secure the co-operation of the first authority, in order to give confidence to the Chester and Holyhead Railway Company, with whom you are connected, and the public generally.

It will be observed, that the first class of experiments is upon cylindrical tubes;—the second upon those of the elliptical form;—and the last upon the rectangular kind. Tubes of each sort have been carefully tested, and the results recorded in the order in which they were made; and moreover, each specimen had direct reference to the intended Bridge, both as regards the length and thickness, as also the depth and width.

In the first class of experiments, which are those of the cylindrical form, the results are as follows:

Cylindrical Tubes.

No. of Experiments.	Distance between the supports.	Diameter in inches.	Thickness of Plate in inches.	Ultimate Deflection in inches.	Breaking weight in lbs.	Remarks.
1	ft. in. 17 0	12'18	'0408	'39	3,040	Crushed top.
2	17 0	12'00	'9370	'65	2,704	Ditto.
3	15 7½	12'40	'1310	1'29	11,440	Torn asunder at the bottom.
4	23 5	18'26	'0582	'56	6,400	Ditto.
5	23 5	17'68	'0631	'74	6,400	Ditto.
6	23 5	18'18	'1190	1'19	14,240	Ditto.
7	31 3½	24'00	'0954	'63	9,760	Ditto.
8	31 3½	24'30	'13501	'95	14,240	Ditto.
9	31 3½	24'20	'0954	'74	10,880	Ditto.

With the exception of the first two, nearly the whole of the tubes were ruptured by tearing asunder at the bottom through the line of the rivets.

Finding the cylindrical form comparatively weak, the next experiments were upon tubes of the rectangular shape, which gave much better results. For the present it may, however, be more convenient to take the elliptical kind, as being the nearest approximation, as regards both form and strength, to the cylinders recorded above.

Elliptical Tubes.

No. of Experiments.	Distance between the supports.	Diameters, transverse and conjugate in inches.	Thickness of Plates in inches.	Ultimate Deflection in inches.	Breaking weight in lbs.	Remarks.
19	ft. in. 17 0	{ 14'62 9'25	'0416	'62	2,100	Crushed on top.
20	24	{ 21'66 13'50	1'1320	1'36	17,076	Broke by extension.
21	24 0	{ 21'25 14'12	'0688	'45	7,270	By compression
22	18 6	{ 12'00 7'50	'0775	'95	6,867	{ By compression. This tube had a fin on the top side.
24	17 6	{ 15'00 9'75	'1430	1'39	15,000	{ Both sides were ruptured

It will be observed that the whole of these experiments indicated weakness on the top side of the tube, which, in almost every case, was greatly distorted by the force of compression acting in that direction. It is probable that those of the cylindrical form would have yielded in like manner, had the riveting at the joints been equally perfect on the lower side of the tube. This was not, however, the case, and hence arise the causes of rupture at that part.

The next experiments, and probably the more important, were those of the rectangular kind; they indicate a considerably increased strength when compared with the cylindrical and elliptical forms; and, considering the many advantages which they possess over every other yet experimented upon, I am inclined to think them not only the strongest but the best adapted (either as regards lightness or security) for the proposed bridge.

Rectangular Tubes.

No. of Experiments.	Distance between supports	Depth in inches.	Width in inches.	Thickness of Plate in inches.		Ultimate Deflection in inches.	Breaking Weight in lbs.	Remarks.
	ft. in.			top.	bot. tom.			
14	17 6	9'6	9'6	'075	'075	1'10	3,738	Broke by Compression.
14	17 6	9'6	9'6	'272	'075	1'13	8,273	(Revers'd) Extens.
15	17 6	9'6	9'6	'075	'142	0'94	3,788	Compression.
15	17 6	9'6	9'6	'142	'075	1'88	7,148	Extension.
16	17 6	18'25	9'25	'059	'149	0'93	6,812	Compression.
16	17 6	18'25	9'25	'149	'059	1'73	12,188	Ditto
17	24 0	15'00	2'25	'160	'160	2'66	17,600	Ditto.
18	18 0	13'25	7'50	'142	'142	1'71	13,680	Ditto.
23	18 6	13'00	8'00	'066	'066	1'19	8,812	{ Compression.
29	19 0	15'40	7'75	'230	'180	1'59	22,469	{ Circular bot- tom, fin at top. { Sides distorted. { Corrugated top

On consulting the above table, it will be found that the results, as respects strength, are of a higher order than those obtained from the cylindrical and elliptical tubes; and particularly those constructed with stronger plates on the top side, which, in almost every experiment where the thin side was uppermost, gave signs of weakness in that part. Some curious and interesting phenomena presented themselves in these experiments,—many of them are anomalous to our preconceived notions of the strength of materials,—and totally different to any thing yet exhibited in any previous research. It has invariably been observed, that in almost every experiment the tubes gave evidence of weakness in their powers of resistance on the top side, to the forces tending to crush them. This was strongly exemplified in experiments 14, 15, 16, &c., marked on the drawings and the table. With tubes of a rectangular shape, having the top side about double the thickness of the bottom, and the sides only half the thickness of the bottom, or one-fourth the thickness of the top, nearly double the strength was obtained. In experiment 14, (marked in the margin of the above table,) a tube of the rectangular form, 9½ inches square, with top and bottom plates of equal thickness, the breaking weight was

3,738 lbs.

Riveting a stronger plate on the top side,

the strength was increased to

8,273 lbs.

The difference being 4,535 lbs.,—considerably

more than double the strength sustained by the tube when the top and bottom sides were equal.

The experiments given in No. 15 are of the same character, where the top plate is as near as possible double the thickness of the bottom. In these experiments, the tube was first crippled by doubling up the thin plate on the top side, which was done with a weight of 3,788 lbs.

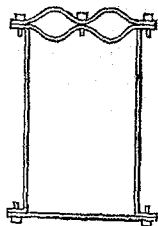
It was then reversed with the thick side upwards, and by

this change the breaking weight was increased to 7,148

Making a difference of 3,360 lbs.
or an increase of nearly double the strength, by the simple operation of reversing the tube, and turning it upside down.

The same degree of importance is attached to a similar form, when the depth in the middle is double the width of the tube. From the experiments in No. 16, we deduce the same results in a tube where the depth is $18\frac{1}{4}$, and the breadth $9\frac{1}{4}$ inches. Loading this tube with 6,812 lbs. (the thin plate being uppermost,) it follows precisely the same law as before, and becomes wrinkled, with a hummock rising on the top side so as to render it no longer safe to sustain the load. Take, however, the same tube, and reverse it with the thick plate upwards, and you not only straighten the part previously injured, but you increase the resisting powers from 6,812 lbs. to 12,188 lbs.

Let us now examine the tube in the 29th experiment, where the top is composed of corrugated iron, as per sketch, forming two tubular cavities extending longitudinally along its upper side. This, it will be observed, presents the best form for resisting the "puckering," or crushing force, which, on almost every occasion, was present in the previous experiments. Having loaded the tube with increasing weights, it ultimately gave way by tearing the sides from the top and bottom plates, at nearly one and the same instant after the last weight, 22,469 lbs., was laid on.



The greatly increased strength indicated by this form of tube, is highly satisfactory, and provided these facts be duly appreciated in the construction of the bridge, they will, I have no doubt, lead to the balance of the two resisting forces of tension and compression.

The results here obtained are so essential to this enquiry, and to our knowledge of the strength of materials in general, that I have deemed it essential, in this abridged statement, to direct attention to facts of immense value in the proper and judicious application, as well as distribution, of the material in the proposed structure. Strength and lightness are desiderata of great importance,—and the circumstances above stated are well worthy the attention of the mathematician and engineer.

For the present we shall have to consider not only the due and perfect proportion of the top and bottom sides of the tube, but also the stiffening of the sides with those parts, in order to effect the required rigidity for retaining the whole in shape. These are considerations which require attention ; and till further experiments are made,

and probably some of them upon a larger scale, it would be hazardous to pronounce anything definite as to the proportion of the parts, and the equalization of the forces tending to the derangement of the structure.

So far as our knowledge extends,—and judging from the experiments already completed,—I would venture to state that a tubular bridge can be constructed, of such powers and dimensions as will meet, with perfect security, the requirements of railway traffic across the Straits. The utmost care must, however, be observed in the construction, and probably a much greater quantity of material may be required than was originally contemplated, before the structure can be considered safe.

In this opinion Mr. Hodgkinson and myself seem to agree; and although suspension chains may be useful in the construction in the first instance, they would nevertheless be highly improper to depend upon as the principal support of the bridge. Under every circumstance, I am of opinion that the tubes should be made sufficiently strong to sustain not only their own weight, but in addition to that load, 2,000 tons equally distributed over the surface of the platform, a load ten times greater than they will ever be called upon to support. In fact, it should be a huge sheet iron hollow girder, of sufficient strength and stiffness to sustain those weights; and, provided the parts are well proportioned, and the plates properly riveted, you may strip off the chains, and leave it as a useful monument of the enterprise and energy of the age in which it was constructed.

In the pursuit of the experiments on the rectangular as well as other description of tubes, I have been most ably assisted by my excellent friend Mr. Hodgkinson; his scientific and mathematical attainments render him well qualified for such researches; and I feel myself indebted to him for the kind advice and valuable assistance which he has rendered in these and other investigations. I am also deeply indebted to yourself and the Directors for the confidence you have placed in my efforts, and for the encouragement I have uniformly received during the progressive development of this enquiry.

But, in fact, the subject is of such importance, and the responsibilities attached to it are so great, as to demand every effort to demonstrate, calculate and advise what in this case is best to be done. Both of us have therefore labored incessantly at the task, and I am indebted to my friend for the reduction of the experiments, which I would not attempt to weaken by a single observation.

WM. FAIRBAIRN.

Subject to be Continued.