

cost; a cost compared with which the simple lowering of a ship's mast now and then bore no comparison at all, for practical purposes. Sir John Fowler and Sir Benjamin Baker made the headway for the Forth Bridge 150 feet when there would have been no difficulty in getting much more than that if it had been desirable. The great East River Bridge at New York was only 135ft., another was proposed not so high, and the quite recent bridges erected over the great North Sea Canal, 138 ft. The Manchester Canal bridges were very much less than that. An ideal bridge for this site would be something like Captain Ead's celebrated structure at St. Louis, which had two spans of 502 feet and one 630 feet. These dimensions would just about fill the gap from Dawes' Point to M'Mahon's Point, the route selected by the Engineer-in-Chief for Railways, Mr. Deane; and certainly the best one, because it made a short and direct connection with the present railway line at the proper level, near the Bay Road Station. No doubt the St. Louis Bridge was a costly one comparatively, because it amounted to over a million and a quarter sterling; but our conditions were entirely different, there was no Mississippi mud here, the season was open for work all the year round, and prices in Sydney now were probably less than half of what they were in Mississippi and Illinois thirty years ago. It was therefore possible that a similar structure could be erected here with a double line of railway, and with a carriage road and footways above, for £600,000; if so, it would not be too high a price to pay for it. If there was one place in Sydney more than another where a monumental structure of this kind would attract the attention of every visitor to the colony, and in the erection of which they should be justified in spending money on appearance, as well as for utility, it would be a bridge connecting the city to North Shore. The picture (Plate XXXVI.) showed Milson's Point and McMahan's Point joined by a double cantilever which had been adopted for several reasons connected with economy in cost. Abutments to a bridge 150 feet high, with 500 feet

spans, would involve an immense mass of masonry to resist the thrust. In this design, two heavy piers were used to anchor the shore ends of the cantilevers down, and were a less serious consideration. The railway runs on the lower deck to keep down the railway grade, while the carriage road was above with the footways on cantilevers. The design of bridge which was submitted to the Royal Commission was estimated at that time to cost £200,000 for the work *above water alone*; it was similar in design to this, but was only for a railway bridge with single deck. No more need be said now about the details of this design, because it was only shown to the meeting as illustrating one way of providing the accommodation that would soon be absolutely required to meet the wants of the metropolitan population of the colony, and, although an interesting and popular picture, it was not an engineer's drawing.

Coming back again to Mr. Howarth's Tunnel, all must admit that there was great attraction in the idea of getting a communication across the harbour for £185,000; but if such a work was to be successfully carried out, it would have the effect of indefinitely putting off the construction of the more important bridge. There was not in that sum, however, much allowance made for meeting contingencies, and such might not arise; it was well, however, to remember that the Hudson River tunnel was commenced over 20 years ago, and was not finished yet. The cost so far had been fabulous, and twenty men were drowned at one time by an accident in 1880. Look at the Spottiswoode tunnel at Melbourne, and the recent accident there. The Detroit River tunnel, commenced in 1872, was abandoned, owing to the interruption of sand, clay and water. The enormous cost (£500,000 per mile) of the Severn tunnel was beyond what was expected, and the continual expense of pumping 66,000,000 of gallons a day most serious. No doubt we had the advantage of the experience gained already at the Sarnia tunnel, and other places, but the most trifling accident, remember, might wreck a tunnel of this sort just on the eve of

completion. The writer had the advantage of being through the Severn and the Mersey tunnels before completion, and the Thames and Tower tunnels since. Considering the success of the South London tunnel the question of course arises whether it would not be better to drive two cast iron tubes on the same principle through the silt with longer approaches, to allow for a little extra depth, that was if the silt was found to be solid ? With nothing but soft mud, however, Mr. Howarth's proposal, carried on absolute piers, was a more certain method. The map of Sydney and suburbs exhibited, showed that a railway bridge to North Shore, combined with a city extension, would convert the Milson's Point and suburban lines into a circular railway, the importance of which could be understood by those who had watched recent developments on the northern shore of the Harbour. The great success which attended the International invitation to bridge constructors to tender for the Hawkesbury bridge, was known throughout the world ; and it should induce the Government to have a duly qualified officer in the person of the Engineer-in-chief, to instruct that gentleman to prepare conditions, and at once issue similar invitations for a North Shore bridge. This work should precede a tramway tunnel to take the local traffic now served by the cable tram and ferry, and that work might soon follow. New South Wales had spent so much money on useless works that no legitimate complaint of cost could ever be made by the Country Members or other parts of the colony against the erection of a bridge like this in the metropolis ; but, if the Government started with the smaller work of a tramway tunnel first, it would be an excuse to put off the larger and more important bridge. The preceding remarks were made more from a citizen's standpoint perhaps than from an engineer's, but it really seemed that when the inhabitants of both sides of the harbour had combined and obtained the bridge for the greater and more important traffic, and they ought to take it in hand at once, then they might all hope to see as a supplement what there was ample scope for,

Mr. Howarth's carefully thought out proposal for meeting the more local requirements. When one contemplates the many millions which had been spent on the numerous London bridges and tunnels, the multiplicity of ferries at New York, besides the existing and projected Brooklyn bridges, and considers the transpontine traffic in other great cities, it was a foregone conclusion that a North Shore overhead bridge was a necessity; in fact it loomed large in the fog in the immediate future. Whether Mr. Howarth's submerged bridge would precede or follow it depended very largely on the way the public interested influenced the members of Parliament representing them, and how those members influenced the Government. This was a most opportune time for such a discussion as the present one, from which nothing but good could come in the presentation of the subject from every possible point of view.

Mr. HOWARTH, in reply to the discussion, said that the lateness of the hour prevented him from dealing with the practical criticisms and arguments of the various speakers as fully as they deserved. He intended, however, to treat each issue, and as briefly as possible. Mr. Cruickshank's remark that the reference to the "present service of ferry boats being improved beyond recognition" was not justifiable, is best answered by the relative context of the paper, wherein it is stated "that the loss of time spent in transhipment of rolling stock at each end of a ferry trip, would severely handicap the best class of boat, when run in competition with a direct and continuous tramway." It was obvious that if ever the present vessels are enlarged or reconstructed so as to be capable of ferrying a train of tram or railway, "they would have to be improved beyond recognition."

The objection to go into a tunnel under the harbour when a ferry is available, is an expression of very common occurrence, and it was not to be wondered at, especially in view of the fact the alternative has not been presented to them daily and in solid reality. Probably it was not too sanguine to assert, that

the real live business man from or to the city, and to whom time was precious, would never again use the cautiously moving ferry boat, after a few congenial experiences of a rapid, collision proof, and continuous traffic route *via* properly constructed tunnel. Mr. Burge suggested that the viaduct ought to be lowered at the centre of the channel, so as to bring the superstructure into the mud and silt forming the bed of harbour. It was improbable that any good object could be gained by placing the viaduct below the lower levels shown on drawings. The first cost of constructing and founding the tubes would be increased in about the same ratio as the increment of increased depth, or in other words, if the tubes were sunk 18 feet or 33 per cent. so as to bring their upper portions level with the surface of mud, the increase of cost would be about 33 per cent. = £39,000, and which, added to the original estimate, gives a total cost of £224,000. The 18 feet dip in the centre of length, would change the originally suggested gradient of 1 in 300 to 1 in 50, and as it was essential for economic working, that moderate grades and low first cost should be strictly adhered to, it was difficult to see how any improvement could be secured by lowering the viaduct. The suggestion that greater safety would result, is finally met, by the description of the method of founding upon solid rock, and the synopsis of calculated resistance to displacement or stability, as per paper.

Mr. Grimshaw's contentions being in agreement with those of Mr. Burge, are equally answered.

Mr. Haycroft considered the first point of failure in the scheme to be in the fact that no accommodation was provided for those who have no money to pay their fare. This difficulty could be obviated by the construction of a supplementary subway for the free use of pedestrians. The extra cost would be about £70,000. He also contended that no connection to North Shore will be satisfactory that does not provide for ordinary vehicular traffic. The primary object of the scheme now being discussed was the provision of accommodation for tram or railway traffic only.

As an adjunct to this published scheme, a sketch design and estimate have been prepared for a viaduct, to provide for tram or railway, vehicular, and pedestrian traffic, at a total cost of £90,000 in excess of original estimate of £185,000. With reference to the tramway terminal and junction arrangements at Milson's Point, provision had been made for every condition that would conduce to a congestion of preliminary traffic requirements, and directly it was found to be desirable, a loop line could be easily laid, and in such a position as would effectually reinforce the present proposed triangle and car storage sidings. Mr. Haycroft's query as to how a water tight joint could be made at the junction of the tubes, is easily explained by addition to his own following secondary question. It is intended to take the upper camber (*not sag*) out of the tubes as they lie on the piers in their initial stage, before bolting two lengths together. The camber will be removed by admitting a small quantity of water to the air chambers of each span, and of a weight about the same as that exerted by the live rolling load. Thorough consideration of the relative merits of timber versus metal for the outer casing of the tubes, appears to favor metal in almost every item, either in connection with the concrete, or the handling during launching and depositing in position.

Mr. Haycroft said the City and Suburban Railway Committee did not recommend or suggest a large bridge of one span for connecting Sydney with North Shore. On referring to the Committee's report, page 68, the following excerpts will be found:—"Presuming that there be need in the future for the construction of the bridge, the evidence seems to point to 160 feet as the proper headway. This with a rise and fall of tide of four feet, gives a possible passage of 164 feet," or *4 feet more than mentioned by the author.*" The Secretary of the Commission, after considering evidence on the point, and as to the height of masts were of opinion that when the bridge is erected 160 feet will be sufficient headway, and that

“if it is possible to throw a bridge across in one span, such a plan should be adopted, but if not, two spans, 500 to 700 feet, with a CENTRAL PIER would meet the requirements of a *bridge not obstructing the navigation of the harbour.*” The 27 ton stress mentioned by Mr. Haycroft are so-called American tons of 2,000 lbs., and if Mr. Cooper’s specification for the Hudson River Bridge be closely read, it will be found in the first clause relating to permissible unit stresses, that the main tension cables are allowed a maximum stress of 54,000 lbs. per square inch,

54,000
and ——— equals 27 short tons. Mr. Selfe desired to know
2,000

whether the exhibited cross section of the harbour had been plotted from actual borings or approximations only. The cross section was correctly plotted from borings taken in 1887, on a line very nearly parallel to, and slightly overlapping the centre line of proposed viaduct. The materials passed through did not seem to be capable of carrying a ballasted dyke as proposed by Mr. Selfe. His remarks in answer to the letter of a correspondent to the daily press *re* silting up of harbour by proposed viaduct, were so thoroughly anticipatory of the author’s intended reply, that further comment was needless. The gradient of 1 in 13 for sketch bridge, ought to have been printed 1 in 30. Mr. Selfe mentioned the three conspicuous failures that had occurred in submarine tunnel driving. He also refers to a few well known successes, amongst which are the Thames, Sarnia, Severn, Mersey, Tower Subway, and South London tunnels. To those mentioned, the author would contribute the following list of sub-aqueous engineering triumphs—Vyrnwy Aqueduct Tunnel under the Mersey, Liverpool; Manchester Sewerage Tunnel under the Bridgewater Canal; Main Sewerage Syphon under the River Seine, Paris; Underground Railway’s Tunnel under the River Spree, Berlin; East River Gas Main’s Tunnel under the Hudson River, New York; Niagara Power Tunnels, Niagara City; Milwaukee Water Tunnels under Lake Michigan, Illinois;

Chicago Water Tunnels under Lake Michigan, Illinois; Cleveland Water Tunnels under Lake Erie, Ohio; Toronto Water Tunnels under Lake Ontario, Canada; Mystic River Tunnel, Charleston, Massachusetts; Jeddo Mines Drainage Tunnel, five miles through water bearing country (1887 to 1895), Hazleton, Pennsylvania; Cable Tramway Tunnel under the Chicago River, Chicago; Shirley Gut Syphon, Metropolitan Water Works; three tunnels for vehicular and pedestrian traffic under the Clyde at Glasgow, and one of similar construction at Edinburgh. Two electric tramway tunnels are now being driven under the Thames, near Blackfriar's Bridge. At Blackwall, a subway tunnel 28 feet diameter is now being constructed under the Thames, for vehicular and pedestrian traffic. At Boston, Mass, a pair of tunnels for railway and pedestrian traffic are about to be driven under the harbour. At Chicago, the Lake Michigan Tunnel is to be extended 2,114 yards with a uniform diameter of 10 feet; and at Cleveland, it is intended to immediately extend the Lake Erie Tunnel to a position of 4 miles from the shore. If time would permit, it would not be difficult to considerably lengthen the list of completed works, and to any student of current engineering literature, it is almost needless to mention that the propositions for future sub-aqueous undertakings are legion. The author said he wished the meeting to understand that he was not responsible for the design of the high level bridge as sketched and exhibited. He was highly gratified to find that his paper on sub-aqueous transit had been so much appreciated, and in conclusion, sincerely thanked those who had contributed to its success.