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"The Victoria Bridge, Colombo."

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The trunk road between Colombo and Kandy has hitherto been carried over the River Kelani by a pontoon bridge, known as the Bridge of Boats, situated at Grandpass, about 3 miles north of the port of Colombo. This was completed in 1825, and for forty-two years the whole of the traffic between Colombo and the important planting districts passed over it, until road transportation was to a great extent superseded by the opening of the Ceylon Government Railway in 1867. A large tract of country, not served by the railway, immediately north of Colombo, given over largely to the cultivation of cocoanuts, has, of recent years, greatly developed, and the traffic over the bridge has accordingly increased. The bridge could not be used simultaneously for road and river traffic owing to the height between the roadway and the water-level being insufficient to allow boats to pass under it. The cost of its maintenance amounted to about $1\frac{1}{4}$ per cent. of the total cost of the new bridge; and there was always the liability, during heavy floods, to injury to the pontoons themselves, and to interference with vehicular traffic. It was also considered to offer considerable resistance not only by intercepting the current of the river at the surface, where it is fastest, but also by the collection of river-drift, and to be therefore the indirect cause of much of the flooding of low-lying districts about Colombo during the rainy seasons. The removal of the structure—intended probably in the first instance only as temporary—and its substitution by a permanent one were therefore considered necessary.

Traffic on each side of the Bridge of Boats was at all times so much congested that a site lower down the river, and further to the westward, was selected for the new bridge, Fig. 1, Plate 7, the approaches to which run more or less parallel, but some distance from the old road, so that the traffic has been diverted from the narrow thoroughfares which had formerly to be traversed. The river is here 450 feet wide in its normal state, but it is liable to floods during the months of June and July, following the burst of the south-west monsoon, and in October and November, immediately after the north-east monsoon has set in. The floods are heavier usually at the former period than at the latter, and the rise varies between 6 feet and 9 feet; the highest recorded flood, in 1872, caused a rise of 11·92 feet above normal level. The south-west monsoon brings rain to the watersheds discharging on the southern and western shores of Ceylon, but it is the dry monsoon for the eastern and northern districts, while the effect of the north-east monsoon is the reverse. During the drier months of the year, namely, December (part), January, February, March, and April (part), the river on its lower reaches is tidal, salt water reaching for several miles above the site of the bridge, so that the normal level of the river is taken to correspond with mean sea-level.

The bank of the river on the northern side, and all land traversed by the northern approach embankment, is firm and good; but on the southern shore, with the exception of a narrow strip about 70 feet or 80 feet wide immediately adjoining the river, the ground is soft and marshy, and the southern approach embankment traverses such land for its whole length. This soil for a depth of 30 feet or 40 feet is alluvial; it overlies laterite decomposed *in situ*, and known locally as "kabook"; and this occurs Archæan gneiss, a close-grained primary or igneous formation (corresponding to the stone known in some parts of England as "blue elvan") lying at a depth of between 70 feet and 80 feet below ground level. In most cases kabook, a stiff argillaceous substance, forms a firm foundation protected from erosion, and in many parts of Ceylon one of its varieties, apparently a decomposed porphyritic rock, is used largely as a building material, and can be cut easily into cubes 18 inches by 9 inches by 6 inches from the quarry. It has the advantage of hardening upon exposure to the air.

For obtaining the necessary soil for the embankments, land was acquired by the Government at Madampitiya, in the vicinity, from which it was expected sufficient stone would be procurable for metalling the approach roads, as well as for building the abutments. There was a stone quarry on the land, but closer investigation showed it to be worked out, and in consequence brickwork had to be substituted for masonry. Later, however, rock was, after the removal of many tons of soil, again exposed in another part of the quarry, whence an ample supply of stone for ballasting and metalling the approach roadways, as well as for filling most of the cylinders, was procured. The soil taken from this quarry was kabook, and similar in many respects to that found below the bed of the river in sinking the cylinders of the bridge. In the quarry it varied between hard granular material, containing a large percentage of hæmatite iron, found only on the surface, and argillaceous matter of various colours, but chiefly yellow mottled with red or blue, at lower depths. Other quarries on private lands in the same neighbourhood were also opened, and a large quantity of soil taken from them; but they were only supplementary to the Government quarry.

The approaches are 33 lines[1] long on the south bank and 7 lines on the north. The width over the top of the embankments is 40 feet, allowing for a carriage-way of 30 feet with footways on each side 5 feet wide. In the case of the northern approach road there was little or no settlement of the embankment beyond that due to the ordinary shrinkage of the soil, as the land traversed was good, and only liable to inundation during abnormal floods; but with the southern approach road the land is marshy and lies but little above the normal level of the river, hence it is never dry and is inundated to a greater or less depth at every rise of the river. It is quite safe to conclude that the layer of black vegetable clay extends to a considerable depth, so that the settlement greatly exceeded anticipations. From observation at one part, where the top of the bank averages 18 feet above the adjoining country, the depression during a period of nine months amounted to 8 feet. At a later period, after the finished level along the whole embankment had been approximately arrived at, the earthwork having proceeded for eighteen months, the settlement averaged 8 inches per month for three months in succession. This occurred, however, during a flood, and appears to have been the final movement, as little or no further depression was afterwards observed, in spite of the rains having been much heavier and the floods higher during the following monsoon.

For the transport of soil from the Madampitiya Government quarry to the southern embankment, a line of railway of 2-foot gauge was employed; the cost of soil transported thereby, including excavation, was 20 per cent. less than that delivered

[1] The units of length, area and volume employed in the Public Works Department of Ceylon are respectively the "line" = 100 feet, the "square" = 100 square feet, and the "cube" = 100 cubic feet. They were introduced by Sir Guilford Molesworth, K.C.I.E., to replace the previous irregularity of the units in use.

by bullock-carts. The average daily delivery by locomotive and trucks was 27 cubes.[1] The average lead for this embankment was 2,200 feet from the Government quarry and about 3,000 feet from the others on private lands; but the northern approach road necessitated rather more than 1 mile of transport, as most of the soil for this embankment came also from the same quarries. Other quarries were opened on the northern bank at the commencement of the work, but their distance justified their being abandoned in favour of the original quarries. The formation of the embankments commenced in November 1892; the northern was completed in May 1894, and the southern in the following October.

The cubical contents were:—

	Cubes.
South Approach	33,505
North ,, ...	3,791
Total . . .	37,296

An excess over the estimated quantity of 6,745 cubes or 22·07 per cent., much of which probably found its way below ground level.

The $1\frac{1}{2}$ to 1 slopes of the embankment were turfed throughout. The 30-foot roadway was ballasted or "bottomed," with rough spalls 9 inches thick, packed tightly by hand, and laid according to the barrel ($4\frac{1}{2}$ inches) of the road; with a covering of $3\frac{1}{2}$ inches of metal, broken to a 2-inch gauge, and a thin coat of gravel blinding over the surface. Consolidation was performed by 30-cwt. rollers drawn by two pairs of bullocks. Footpaths, 5 feet wide, raised $4\frac{1}{2}$ inches above the road surface, completed the formation, and provision was made for the escape of surface water by fixing 6-inch stoneware pipes under the footways at intervals of 30 feet. Trees were also planted along the slopes to afford shade to the roadway—a practice, established by the Director of Public Works, which cannot be too highly eulogised.

The bridge, Fig. 2, Plate 7, consists of seven spans, each 100 feet in the clear. The abutments are of brickwork on concrete foundations, 4 feet thick, laid over a timber grillage resting on piles driven into the soil. The dressings and mouldings of the abutments are in "Soorkhee," a composition of 5 parts of brick dust to 1 of fine sand to 2 of cement. It was found that without the addition of fine sand the plaster cracked in all directions, not sufficiently to interfere with its adhesion to the brickwork, but enough to render the appearance unsightly. The piers, except in two cases,

[1] See note on p. 317.

consist of two cast-iron cylinders, 6 feet in outside diameter, with internal flanges bolted together with $1\frac{1}{8}$-inch bolts, twenty-four to each joint. The superstructure is composed of wrought-iron lattice-girders supporting a corrugated-steel floor or decking, over which is laid concrete and road metal for the carriage-way and cement rendering for the footways.

In the foundations of the abutments teak piles, 30 feet long and 15 inches square, placed 3 feet 9 inches from centre to centre, were employed, their heads being connected by ties 15 feet by 9 feet, bolted edgewise to the piles, with a floor of 4-inch planking laid over the top for the reception of the concrete. These piles are calculated to sustain together 3,179·4 tons, so that, after deducting the weight of the abutment—concrete foundations and brickwork walling together equal to 1,968·6 tons—a margin of 1,210·8 tons remains, or more than four times the weight of half a span of the bridge when tested to its full capacity. The resistance offered by the concrete foundations, which must alone be considerable, is not taken into consideration. Special emphasis is placed upon these figures owing to a fracture having occurred in the face of the southern abutment in December 1893.

The brickwork was commenced on the 3rd October, and had been carried up 14 feet by the 28th December, when the fracture first appeared. The main wall or face of the abutment was 9 feet 6 inches thick at the base, diminishing to 6 feet at the top; the wing walls, 21 feet apart inside measurement, were 9 feet 4 inches at the base and 6 feet at the top, and were 32 feet 6 inches in length, measured from the back of the main wall at the line of foundations. The fracture occurred at the angle between the eastern wing and the main wall, and traversed it from top to bottom parallel with the direction of the former and more or less in continuation of the inner face of the wing. Soil had been deposited inside the abutment simultaneously with the raising of the brickwork. There were no weepers nor any provision for the escape of water which might accumulate inside the walling and so tend perhaps to the expansion of the soil. The fracture was wider at the back than at the front, and careful observation showed the outer end of the wing was moving; the total movement being $2\frac{3}{8}$ inches. The cause may have been a lateral movement of the soil, consequent on the weight of the embankment and the unstable nature of the land around, and it may also have been due to the length of the wings offering greater leverage than the cohesion of the brickwork in the main wall could resist. A large quantity of brickwork at the quoin was removed, and the fracture followed down and found to disappear in the concrete. There was no perceptible alteration in the level of the detached wing at each end, and it was concluded there could have been no vertical subsidence of the walling. However, to deter further movement a concrete apron was laid against the outside of the foundations, and two wrought-iron straps were fixed over the surface across the line of fracture. They were secured at their ends with iron bars let into the foundations, and keyed tight with steel cotters. A first course of dressed granite stones, each weighing between 1 ton and 1½ ton, bedded and jointed in cement mortar, was laid, and the brickwork was again rebuilt. A trench was cut round the inside and close to the walling, the heavy plastic soil was removed and the space filled again with coarse sand. Careful observations for twelve months have disclosed no further movement here, and it may be concluded that the stability of the bridge is in no way impaired.

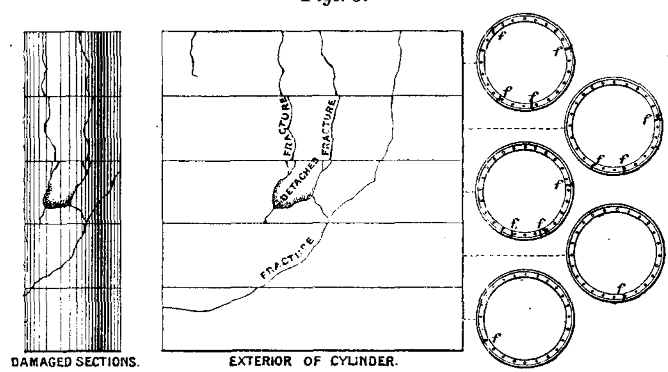
The bricks for the abutments were procured from the villages of Saidawatte and Kohilwatte on the banks of the Kelani, about 4 miles above Grandpass. They are made by hand for the native market from clays found along the banks of the river. The clay is of an excellent description, and experiments conducted by the Government with the aid of brick-making and pressing machinery, have proved that a first-class article can be made, but the native hand-made brick is considerably cheaper, and quality is not so much sought by native builders as quantity and cheapness. All bricks for this work, however, were carefully selected, and only those of regular shape and evenly fired were accepted. The sizes were generally 8¾ inches by 4½ inches by 2¼ inches, and they weighed when dry 5·33 lbs. and when moist 6·33 lbs., showing a considerable excess in absorption; and required about 1,300 per cube of brickwork. These were the best procurable. The prices paid in the first instance to a contractor were Rs.15 per thousand for "bests" and Rs.11 for "seconds." These prices being considered too high, and the quality of bricks being indifferent, the contract was cancelled, and bricks purchased direct from the kilns, at a cost on delivery at the bridge of Rs.8 75a. per thousand. A larger proportion of "bests" and a superior article generally was thus procured at a lower rate.

It was not originally intended to sink the cylinders into or below the kabook; but during the progress of the work, it was thought desirable to penetrate it until rock was reached, consequently the estimated depth was much exceeded. Excavation was conducted by means of a circular grab or digger suspended on a slip-hook and single chain.

The cylinders were sunk by loading them with old rails. At the commencement of the work these were so laid as to completely close the mouth of the cylinder, Figs. 6, Plate 7, excavation being necessarily suspended during application of the weight. In this way rails would be added until the cylinder moved; at times the movement was only a few inches, while at others it was as many feet.

Previously to November 1893 four cylinders had been sunk to the rock at Nos. 1 and 5 piers, the lengths from the extreme top level of the cylinders being 69 feet 6 inches upstream and 69 feet 9 inches downstream in the former, and 78 feet upstream and 80 feet $4\frac{1}{2}$ inches downstream in the latter. The cylinders at Nos. 4 and 6 piers were being sunk. On the 27th of that month the upstream cylinder of No. 4 pier was in course of being weighted,

Figs. 3.



Scale, 1 inch = 12 feet.

DIAGRAM SHOWING DAMAGE TO THE UPSTREAM CYLINDER OF NO. 4 PIER.

and when 48 tons had been imposed a run of 15 feet 9 inches occurred, carrying down the cylinder, which consisted of thirteen sections of 4 feet, until the top was level with the water, a loud report as of an explosion accompanying the movement. When the rails had been removed it was found that the cylinder had sustained injuries through five sections, or 20 feet of its length, *Figs. 3.* The first or uppermost section was fractured in four places. In the second there were three fractures, both of these sections being above the level of the bed of the river. The third section was considerably damaged, and a large portion projected into the interior of the cylinder. The fourth was traversed obliquely or in a spiral direction by one crack, about $\frac{3}{4}$ inch wide, which extended down into the fifth where it disappeared at about one-third of the depth of this section. Below this there were no injuries. There was at this time a depth of about 8 feet of water in the river, so that repairs had to be conducted at a depth of 12 feet below the river-bed, and in 20 feet of water, thus necessitating the services of a diver. Before any of the broken sections could be removed it was necessary to construct timbering around the cylinder to prevent silt and river-drift from running in and hampering the movements. The four guide piles, 30 feet long and 12 inches square, driven into the river-bed, and employed in pitching the cylinder, had been left standing, and it was decided to employ them in constructing a casing by merely closing the four sides with sheet-piling made out of 2-inch planking 25 feet long, Figs. 4, Plate 7. Thus a square shaft was sunk into the river around the cylinder, in which the diver could work without hindrance. Fine running sand, however, found its way through the joints of the boarding, and it was necessary to lay sandbags around the outside of the casing. Having removed the damaged part of the cylinder some difficulty was experienced in connecting on the sound sections. Sand bags and close boarding were together insufficient to keep out very fine material aided by the current of the river, and a circular caisson, open at both ends and constructed of 2-inch close boarding on angle-iron rings, having a minimum internal diameter of 6 feet 9 inches, was lowered over the top of the uppermost sound section. New sections were lowered through this caisson and bolted on to the existing cylinder, and on the 5th March, 1894, the cylinder once more appeared above water. Excavation and boring showed that during the run the cylinder had penetrated 9 feet 9 inches of white kabook, 5 feet 6 inches of blue sandy clay, terminating on a bed of fine indurated sand, into which it had sunk about 6 inches, *Fig. 5.* Both the kabook and sandy clay *in situ* and saturated with moisture are soft, plastic and easily penetrated; the change to sand hardened under pressure may therefore have been quite sufficient to cause the injuries.

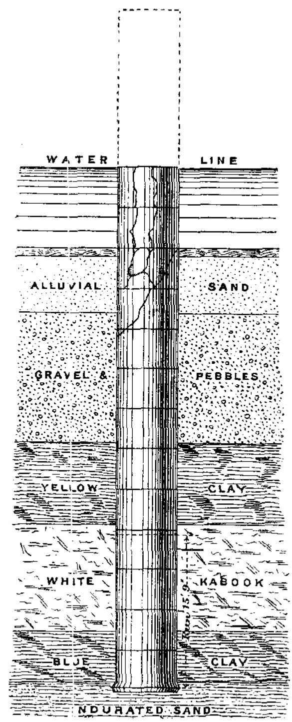
On the 30th of the same month a run of 22 feet occurred in the downstream cylinder of the same pier loaded with 44 tons, but in spite of an examination by a diver at the time of the occurrence, no injury was discovered. On the 16th July following, however, after four days of excavation, and with a weight of 100 tons on the cylinder, a piece of a broken flange was found caught in the teeth of the excavator. An examination by the Author showed the injuries to be similar to those of the upstream cylinder.

After November 1893, when these occurrences took place, the test weights were applied around the circumference of the cylinder in such a manner as to admit of the digger being kept at work, Fig. 7, Plate 7, and testing and excavation were carried on simultaneously. The result was that the movements of the cylinders were more easily controlled, less weight was needed to effect a movement, and the progress of sinking expedited; it is significant that no further mishaps occurred, though two-thirds of this part of the work remained.

The method of repairing this cylinder need not be described. It was considered advisable to insert a third or central cylinder at No. 4 pier to give it greater stability, and for the sake of appearance a third cylinder was sunk also at No. 3 pier (these two being the central piers of the bridge).

The cylinders reached the relative depths shown in the following Table. The measurements are from the extreme top (finished level of cylinders) to the cutting-edge. It will be seen that there was a slight dip in the surface of the rock from south to north. Rock was in no case penetrated by the cutting-edge beyond the thickness of the overlaying ferruginous shaley matter, which varied in thickness between 9 inches and 1 foot 6 inches, but the bearing of the cylinder was in every case examined sometimes by causing the water to be baled out—only possible in a few cases—and in other cases by a diver. The former method was preferred, since it permitted a careful examination of the whole of the inside of the cylinder.

Fig. 5.



Scale, 1 inch = 20 feet.

UPSTREAM CYLINDER OF No. 4 PIER.

The test of 100 tons was imposed on each cylinder, with certain exceptions above enumerated, and since the ratio between the resistances when the cylinder is empty and full is as 1 : 16·25, each when filled will sustain a weight of 1,625 tons or each pier 3,250 tons; thus placing their capacity to sustain the superstructure beyond all question.

Cylinder.	Extreme Length. Ft.	Ins.	Remarks.
No. 1 pier upstream .	69	6	Sunk to rock.
,, ,, downstream	69	9	,, ,,
No. 2 upstream . . .	66	4	,, ,,
,, downstream . .	64	11	,, ,,
No. 3 upstream . . .	71	1	,, ,,
,, centre . . .	46	0	Penetrating kabook a depth of 3 feet 9 inches; fixed in keeping with No. 4 pier.
,, downstream . .	74	11	Sunk to rock.
No. 4 upstream . . .	77	4½	,, ,,
,, centre . . .	56	0	Penetrating kabook 8 feet, and tested with 70 tons on empty cylinder for ten days.
,, downstream . .	70	2¾	Sunk to indurated sand; tested previous to discovery of injuries with 100 tons.
No. 5 upstream . . .	78	0	Sunk to rock.
,, downstream . .	80	4½	,, ,,
No. 6 upstream . . .	73	6	Sunk into 7 feet of indurated sand, and tested for twenty days with 100 tons on empty cylinder.
,, downstream . .	79	6	Sunk into 9 feet 9 inches of indurated sand, above which was a layer of 2 feet 9 inches of running sand, which, finding its way inside cylinder, caused large depression around the outside at ground-level.

Each main girder measured 106 feet 8 inches in length, 10 feet 4 inches in depth, and 2 feet 4 inches in width, and weighed 31½ tons. Sixteen tension-members of T-bar and sixteen compression members of lattice design divided the length of the main girders into sixteen bays; the joints at the lower boom made by the lattices supported the roadway girders, seventeen per span, each weighing 1½ ton; so that the weight of the roadway reposed on the lower boom of the girder, the upper part being in the nature of a parapet for the traffic. The whole of the superstructure ironwork was made in England, from drawings prepared in the colony and was delivered in pieces at the site of the bridge, so that it only remained to erect and rivet the parts together in Ceylon.

The river is liable to floods which come down suddenly and with little or no warning. The rise of such rivers is often to be feared less than the increased velocity of the current. A heavy rainstorm, occurring at an altitude of between 5,000 feet and 6,000 feet above sea-level in the higher reaches of the river, while the sky may be clear and cloudless in the neighbourhood of Colombo, as often happens, causes an unexpected freshet in the river. With these considerations, therefore, it was desirable that the erection of ironwork should be so conducted as to be unhampered by the condition of the river; hence the girders of only three spans were erected on fixed scaffoldings, the others being floated to their positions. Choosing a time of year when floods are infrequent, provision was made for erecting No. 1, the shore-span on the north bank, in the early part of January 1894. The scaffolding for this span was merely a series of square teak trestles 15 feet high, the uprights or legs being 12 inches square, bolted together so that they might, if required, be taken to pieces and removed for use elsewhere. Five such trestles supported each girder, Figs. 8, Plate 7, the ironwork being hoisted into position by a 3-ton steam locomotive-crane travelling at ground-level. Upon completion of the main girders, this crane was raised on a series of inclined planes to the level of the bridge roadway, and the cross girders were laid. The first span was completed in April, the slow progress being due to defects in the crane.

The next, or No. 2, span extended partly over the north bank of, and partly over, the river. As the state of the water permitted it, a piled staging was constructed over the part of the river to be covered. The teak trestles referred to were re-employed here for the support of the travelling-crane, the scaffolding for the bridge consisting of a number of trusses, Figs. 8, built of old double-headed rails, each truss being in the shape roughly of the letter "A," the girder being allowed to rest in the triangular upper half, and supported by the horizontal base of the triangle. This span required a much shorter time to erect, both girders were erected in nine working days, and the whole scaffolding was removed some days before the floods following the burst of the south-west monsoon came on.

Upon completion of these two spans, the four main girders of the third and fourth spans were riveted up on the roadway of the bridge so far constructed; and, as the piers for their support were not ready, attention was turned to the seventh or shore span on the opposite bank of the river. The same staging used for No. 1 span was employed here; but the erection of ironwork had to be performed with manual gear in the absence of the steam-crane formerly used. The span was, however, completed by the end of August, when another crane arrived and was set to work upon the erection of No. 6 span, the girders of which were put together on the roadway of No. 7.

In erecting the third, fourth, fifth and sixth spans, eight girders in all, on the bridge roadway, provision was made for inserting below them a series of bogies to travel on a line of 3-foot gauge placed immediately upon the roadway girders of the bridge so that their launching might be facilitated. The lower booms had to be laid on camber blocks, which were removed after completion of the riveting and replaced by the bogies. There were in all six bogies, five of which were four-wheeled and destined for distribution throughout the length of the girder, while the sixth was eight-wheeled and designed to carry the end. When the weight was taken on the trollies the load on each axle was 2·25 tons, and when the floating cradle was in use to support one end of the girder, the eight-wheeled bogie at the opposite end had to sustain a load of about 4 tons per axle, Figs. 10 and 11. It was intended to move the girder out upon the trollies till a sufficient length projected over the water to be borne by the floating stages or cradles, and carried across the span partly on the pontoons and partly on the eight-wheeled bogie, till the latter could reach no farther and the second pontoon was called into requisition.

The cradles were constructed upon two iron pontoons, each having a displacement of at least 30 tons, secured side by side, upon which was constructed a framed and trussed timber scaffolding supporting a cradle in which the girder was to rest, Figs. 9, Plate 7. The pontoons were not specially made for the work, and were of different dimensions, the largest being 50 feet long, 10 feet wide, and 4 feet deep; but an adjustment of ballast rendered the displacement of the two equal. The staging and cradle weighed 22 tons, and were constructed partly of the teak trestles mentioned, but for the most part of a native timber called "hora," weighing 66 lbs. per cubic foot. There was therefore a considerable margin of safety over the half weight of the girder which was to rest on the cradle. Economy was studied so far that no new timber was procured for these cradles, the whole being constructed either of the trestles or of old guide-piles after the cylinders had been sunk and completed and the piles withdrawn.

The girder lay in the cradle transversely to the pontoons, crossing them amidships, thus minimising the chance of overbalancing, though when first launched and before lowering had commenced the bottom of the girder was 20 feet above the decks of the vessels. Capsizing broadside was prevented by attaching guys from the gunwales of the pontoons to the lower boom on each side, tightened by means of a twist and toggle, as the girder was lowered deeper into the cradle. When once the girder was secured in its position in the cradle the pontoons could be moved in any direction required. In the case of the girders of No. 6 span, only one floating cradle was employed, as the span was only partly over the water, and the river bank provided sufficient base on which to place a stage to take the shore end.

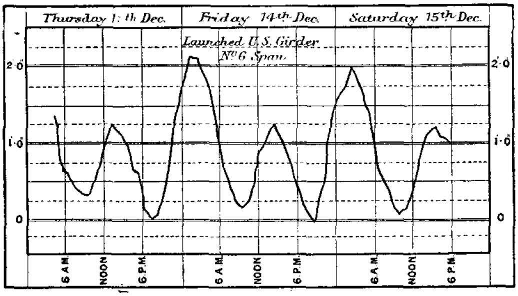
The operation of launching the first girder, the upstream of this span, was commenced on the 14th December. The girder was projected over the river, and through the frame of the cradle, until the centre of the latter was 19 feet from the outer extremity of the girder. Raising the pontoons was then commenced by the removal of ballast, corresponding with the load to be supported, aided by the rising tide. The water rose, *Fig. 13*, at 2 A.M. on the morning of that day to 2 feet $1\frac{1}{2}$ inch above zero, then began to fall until 10 A.M., when it stood at 2 inches, rose again to 1 foot 3 inches at 3 o'clock in the afternoon, and then fell to zero, which was touched at 9 P.M. The maximum variation was therefore 1 foot $11\frac{1}{2}$ inches, and the minimum 1 foot 2 inches. Instead of a few hours it took three days to get one girder into its proper position. The delay was caused entirely by the hydraulic jacks having become stiff or defective through disuse or want of careful and regular attention. However, by the end of 1894, both girders of this span were in position, and preparations were made for completing the bridge thus far while the river piers were being prepared for the other girders.

The fifth span girders were built together on the roadway of the sixth span, and were ready for launching by the beginning of March. On the 12th of that month, operations were commenced at 2 o'clock in the morning, and experience with the two already launched had suggested many improvements, chief of which was the reduction in the number of jacks employed. In the case of the first girder, four 10-ton hydraulic jacks were used—two for each end of the girder—at the edges of the bottom boom; but it was found that, the strokes of the plunger of one jack not corresponding with those of the other on the opposite side, a rocking motion was given to the girder, which increased at each stroke of the plunger, so that a pause had to be observed every few minutes while the girder steadied itself. Raising and lowering, therefore, took considerable time. These jacks were discarded in favour of two of 50 tons capacity each—one for each end—and worked immediately under the centre of the bottom boom and at the exact centre of the cradle. It was also found that as little reliance as possible should be placed upon the tide, since, unless it was taken at the precise moment, it tended rather to impede than advance the work. Ballasting the pontoons was also avoided, since the removal or addition of weight entailed much time, and only sufficient rails were deposited on the decks of the vessels to ensure stability and at the same time leave sufficient free-board after the weight of the girder had been transferred to the pontoons. Instead, therefore, of commencing to launch on the flood tide, it was best to do so as soon as possible after the turn and on the ebb, and also experience had shown that the girder should be across and the pontoons released before the tide turned again to rise. This was not so in the case of No. 5 span upstream girder, as the tide turned at 9 A.M. before sufficient time had elapsed to place the girder across. The river rose to 2 feet 1 inch above zero, and little or nothing could be done till it turned again at 3 P.M., when lowering proceeded. It was 9 P.M., after nineteen hours' continuous work, before the pontoons could be released, and only very shortly before the tide turned again to rise. In Fig. 10, Plate 7, the girder is shown resting on five four-wheeled bogies placed somewhat in front of its half length, while the inner end is supported by the eight-wheeled bogie. This was found to be the best arrangement, so that as soon as the girder projected a sufficient distance through the frame of the cradle, which is shown moored ready to take it, the weight of the forepart could be taken on a jack, the four-wheeled bogies removed, and the girder lowered directly on to the pontoons. Fig. 11 shows the same staging carried across beyond the half span; packing is inserted under the girder in the cradle, and the girder itself has a declination of about 1·50 per cent., due chiefly to the displacement of the pontoons—in this case about 11 inches—as well as to the falling of the tide so as to bring the head about 2 feet above the bed-plate intended for its reception. This depression, giving a slight impetus to the girder, greatly assisted its removal. The movement of the trollies was effected by means of "pinch" bars worked behind the wheels, augmented by hauling on the warps and hawsers laid out from the pontoons. A tackle, composed of $\frac{3}{4}$-inch chain, rove through double and single blocks, was attached to the inner or tail end of the girder, thus regulating the forward movement and preventing the weight taking charge. One side of the cradle on the second staging had been removed so that the pontoons could be brought to their proper positions under the girder. Fig. 12 shows in plan two positions of No. 1 cradle. That inserted in full line represents the first position it occupied, the dotted outline represents the cradle half-way across and secured by three hawsers upstream secured to piles driven into the river-bed, these in turn being made fast to anchors at a distance of about 20 feet further upstream. The centre pile, which had to bear the greatest stress, was secured as shown to two anchors. Downstream, two hawsers were laid out to two other piles which were not, however, attached to anchors. These five hawsers, three up- and two downstream, were passed around the drums of winches fore and aft, and employed according to the direction it was desired to move the pontoons, but only two guys at a time were worked together, the one tightened and the other slackened; the third upstream guy, having merely a turn taken round a bollard or cleat on the vessels, was employed as a check or for use in the event—a very unlikely one--of one or other of the hawsers parting. Besides these up- and downstream hawsers, warps were laid out laterally or parallel with the direction of the girder in order that movement of the pontoons should be made to correspond with that of the girder. The whole of the operations were under perfect control, and the slightest movement even to the fraction of an inch could be ensured. Such control was found to be of the greatest service in the movement of the last two girders—those of No. 4 span—which were inserted in the centre of the length of the bridge after all the others had been fixed. A space of 2 inches at each end of the girder was allowed for expansion and contraction, and in order to obtain the precise distance great caution had to be observed. Without such complete control over them the girders could not have been inserted properly. The same tactics were followed in the case of all the remaining girders. From the following Table of times taken for each girder it will be seen what an improvement took place in the execution of the work.

					Hours.
Upstream girder,	No. 5	span,	March	12	19
Downstream ,,	,,	,,	,,	14	15
Upstream ,,	3	,,	,,	19	6½
Downstream ,,	,,	,,	,,	20	7½
Upstream ,,	4	,,	,,	29	4
Downstream ,,	,,	,,	,,	31	3¼

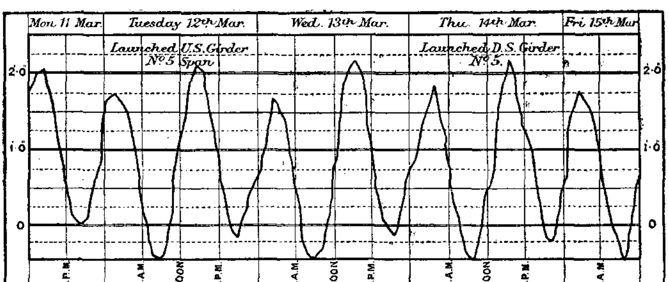
The tidal readings, *Figs. 13* to *16*, show the movements of the river on days when launching was performed. *Fig. 13* shows the readings for the 13th December and following days when the girders of No. 6 span were launched. Observations showed that the tide rose higher as a rule by night than by day. This is remarkable in the case of the readings for the 13th December, when full moon took place. Spring-tides were taken advantage of whenever possible, and *Fig. 14* records the tide for the 11th March and following days during the launching of No. 5 span girders, full moon having occurred on the first of those dates. *Fig. 15* records the tidal variations from the 18th to the 21st during the days No. 3 span girders were launched. The movements will be seen to be very erratic, and it was as well that little or no reliance

Fig. 13.



was placed upon them. This diagram may be taken as recording the variations during neap tides. *Fig. 16* gives readings on the days when the last two girders were launched. The maximum variation of the tide is shown to have occurred on Friday, the 29th March, when it rose to 2 feet 3½ inches above zero at 2 A.M. and sank to 6 inches below at 9 A.M., a total variation of 2 feet

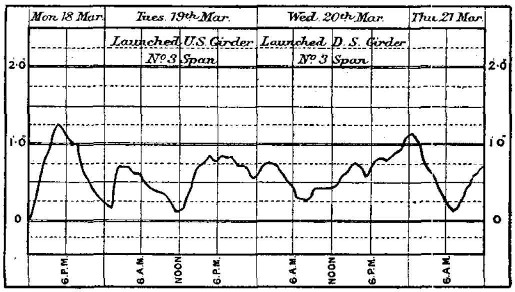
Fig. 14.



9½ inches. New moon occurred on the 26th March. The minimum variation was recorded on Wednesday, the 20th March, when the movement was confined to 10½ inches, the lowest point touched being 3 inches above zero at 8 A.M., after which it rose 2 inches, remained almost stationary for three hours, then rose between noon and 3 P.M. 4 inches, and fell again 2 inches by 5.30 P.M., after which it proceeded to rise till 1 A.M. on the following day, Thursday, the 21st, when it reached 1 foot 1½ inch above zero.

The heaviest part of the construction having been successfully completed, there only remained, after the 31st March, to lay the flooring of the bridge and form the roadways and foot-

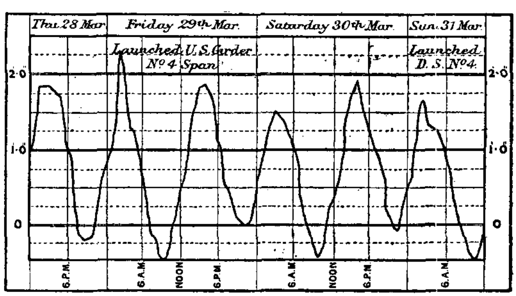
Fig. 15.



paths. All this was finished by the 4th May, or in six weeks after the last girder had been placed, and the roadway on the embankments and bridges was available for traffic on this date. It was, however, not until the 24th, to celebrate Her Majesty's birthday, that the Victoria Bridge was thrown open to the public.

The estimated cost of the bridge was Rs.429,072.00. Extra

Fig. 16.



work found necessary in the progress of construction necessitated a supplementary vote of Rs.74,200.00, of which over Rs.6,000 remained unspent upon completion. The whole work, bridge, approaches, &c., was executed for somewhat less than Rs.670.00 per lineal foot of span, and occupied from start to finish two-and-a-half years in building.

The workmen employed consisted of Sinhalese, Tamils, Moors and Burghers, Eurasians or European descendants. The cost of labour in Ceylon varies with the district; but in Colombo, where it is high, as skilled labour is of a higher order, and a larger number of better workmen are procurable, the daily rates are as follows:—

Trade or Occupation.	Minimum.	Maximum.
	Rs.	Rs.
Clerks and Overseers	1·00	2·50
Fitters, Smiths, Masons, Carpenters, and Riveters, &c.	1·00	2·00
Tamil Coolies	0·37	0·50
Classies	0·50	1·00
Engine-drivers, &c.	1·50	2·50

Sarangs, Kanghanies and head-workmen are generally paid a higher wage than that shown for their particular class. In other parts the rates are much lower; it is possible in one district, where living is cheap and labour plentiful, to obtain road coolies for as little as 17 cents a day, and overseers at 50 cents to 75 cents. These rates are, however, exceptionally low.

The Victoria Bridge was constructed by the Public Works Department, Ceylon. Plans and estimates were prepared departmentally under the direction of Mr. R. K. MacBride, C.M.G., M. Inst. C.E., Director of Public Works, Mr. T. Smith, Assoc. M. Inst. C.E., being Provincial Engineer, and the Author Executive Engineer.

The Paper is accompanied by three sheets of drawings, from which Plate 7 and the *Figs.* in the text have been prepared.