Sect. II.—OTHER SELECTED PAPERS.

(*Paper No. 1685.*)

"The Rokugo River Bridge and Foundations on the Tokio-Yokohama Railway, Japan."

By Richard Vicars Boyle, C.S.I., M. Inst. C.E.

It is not intended in this Paper to invite particular attention to the superstructure of the bridge, which is of an ordinary character; the chief object is to give an account of the foundations, which it is thought present features that may be of interest to the members.

The works necessary were of some magnitude and offered unusual difficulties both in design and in execution; and it is believed that the data furnished by experience in carrying them out may probably be useful for engineering practice generally. The bridge herein described is the second constructed to carry the railway, connecting Yokohama, the chief port of Japan, with Tokio or Yedo, the capital, 18 miles distant, over the river Rokugo which is crossed about halfway between the two places. This river, navigable for small coasting craft to a short distance above the railway bridge, is subject to considerable floods during the rainy season, owing to the extent of country which it drains and the elevated and precipitous character of the districts bordering the watershed. Accordingly it is found that the ordinary flow is confined to a channel occupying only from one-fifth to one-tenth of the width comprised between the flood-banks, or about 300 feet out of 2,000 feet at the point of crossing.

The first bridge, on the original line of the railway, was constructed with native timber, the use of which largely in all bridge and culvert works was decided upon by the former Engineer-in-Chief, the late Mr. Morel, Assoc. Inst. C.E., in compliance it is believed with the request of the Government, and with the view of offering facilities for the employment and instruction of native workmen, amongst whom the carpenters form a numerous and intelligent class. The fallacy involved in this decision (no matter how praiseworthy the motives which led to it) must have been evident to the Engineer-in-Chief, and is probably now equally clear to the Government, who, within two years of the opening of the line for traffic, gave orders, under the advice of the Engineer-in-Chief, the Author of this Paper, for the renewal of all the bridges and culverts with iron superstructures and permanent foundations and piers, in view of the advanced state of decay into which the original structures had fallen. The timber used throughout these works was of three descriptions, called Hinoki, Matou, and Keyaki, of which the first two are not unlike American white pine, being soft and easily worked though less durable, while the last in strength and appearance resembles teak. The rapid decay of these materials is, however, to be ascribed in great measure to the circumstances under which the timber was supplied for use. The ordinary trade in timber, a very extensive one in Japan, is founded upon the native system of building, to which such structures as are required in railway bridge-work are entirely foreign; and instead of well-seasoned timber being supplied, it was a frequent occurrence, in order to obviate delay, for the timber to be felled without regard to the time of year, brought on to the works in a green state, and immediately used without any preparation or seasoning.

The result was that in June 1875, only three years after the completion of the work and less than five years from its commencement, the original bridges were reported by the District Engineer, to be in such a state that the life of the largest, that over the Rokugo river, could not exceed one year more. This report was fully verified, as it was only by the greatest care and attention, and constant and costly repairs, that the bridge was made to serve the requirements of the traffic until replaced by the new one, which was opened officially by Mr. Ito Hirobumi, Minister of Public Works, in November 1877. As the construction of the railway was only commenced in 1870, it will be seen that the life of the original timber structure was barely seven years, a surprising result when compared with the more satisfactory experience of timber-work in other countries, but mainly accounted for by the facts already mentioned. At the present day good sound and well-seasoned timber of large size is much less difficult to procure; so that the unfortunate experience herein detailed may be regarded in some degree as attendant upon the changes, social, commercial, and political, that Japan was then undergoing, and in which the introduction of railways was a conspicuous incident.

In selecting a site for the new bridge, which for obvious reasons of convenience was so laid out as not to interfere with the original one, the faulty alignment of the railway at this point was corrected. The timber bridge consisted of seven openings with truss girders of 56½-feet span = 395½ feet, placed at a considerable angle to the stream, and continued by one hundred and twelve openings of 15 feet each = 1,680 feet, great part of which was on a curve of ½-mile radius, giving a total length of 2,075½ feet. By diverging from the original line south of the river with a short curve of ½-mile radius, a straight lead across the bridge was obtained, the junction with the original line north of the river being effected by another curve of ¾-mile radius; the new alignment was less oblique to the main channel of the river than the old one, and the deviation was 2 chains shorter than the original line. It was further considered desirable that greater headway should be given than had been allowed in the old bridge for exceptional floods, and a slight increase of the gradients on both sides of the river was accordingly required, the new bridge being approached by an incline of 1 in 100 for 12 chains on the south, and an incline of 1 in 152 for 16 chains on the north side of the river; the rail level thus attained was 20 feet above ordinary high-water mark and 6 feet above the highest known flood-level.

A careful estimation of the volume of water discharged during maximum floods, and consideration of the general regimen of the river, resulted in its being found possible to reduce the length of the bridge; and a portion of the flood area within the north bank was occupied by an embankment, leaving an intervening distance of 1,650 feet, which was bridged as follows:—

From the north abutment	23 spans of 40 feet clear	=	920 feet.
„ „ „	1 span „ 38 „	=	38 „
„ „ „	6 spans „ 92 „	=	552 „
	Total		1,510 „ waterway.
„ „ „	23 piers 4 feet thick	=	92 feet.
„ „ „	6 „ 8 „ diameter	=	48 „
	Total		1,650 „ between abutments.

The piers of the smaller openings were all placed square with the centre line, the remainder of the piers on a skew corresponding with the angle of the stream, viz. 75°. The twenty-fourth opening from the north side is thus wider upstream than down, and the clear span given is that on the centre line of the bridge. The twenty-four small openings are spanned by plate girders 3 feet deep, placed one under each rail of the double line, and braced together in the usual way; the two outer girders also carry cantilevers supporting footways and handrails; all these girders are discontinuous, and rest upon cast-iron bed-plates. The north abutment and twenty-three piers are of substantial masonry and brickwork founded upon concrete resting upon compact strata of sand and gravel, and protected from scour by sheet piling, as it was decided to make these foundations as shallow as possible to avoid breaking through the gravel, which has a thickness of from 9 to 11 feet and is underlain by more than 40 feet of soft mud and silt.

The larger openings are spanned by Warren girders, 100 feet long each, 11 feet 4½ inches in extreme depth, with a clear width between the two girders composing each span of 22 feet, the double line of rails being supported by cross-beams 2 feet deep in the centre and 1 foot at the ends, resting upon the bottom booms of the main girders, and spaced from 5 to 6 feet apart. The main girders rest upon cast-iron bed-plates, on which they are fixed at one end, while free to slide at the other to provide for expansion.

Piers 24, 25, and 26 are each composed of two brick cylinders or wells 12 feet in external diameter, resting upon a stratum of volcanic ash immediately below the mud and silt at a depth of about 79 feet from the rail level, and are filled with concrete. Just under ground-level the diameter is reduced to 8 feet, and solid masonry columns of this dimension are carried up to the underside of the girders and finished off with a bold capital. The space between the two columns in pier 24 is arched over beneath the ground, and an intermediate wall built to carry the ends of the girders of the adjoining small span.

Piers 27, 28, and 29 each consist of two cast-iron cylinders 8 feet in external diameter, resting upon a hard stratum of gravel a little lower than the volcanic ash above-mentioned, at about 88 feet from the rail level, and filled with concrete. The upper part of these cylinders corresponds in appearance with the masonry columns of piers 24 to 26, and the pair forming each pier are braced together between low-water mark and the cap with horizontal and diagonal bracing composed of channel irons and stiffening bars, attached to the columns by rings around the latter.

The south abutment is founded upon four brick wells similar to those of the piers, the spaces between them being arched over below ground, and this foundation is surmounted by brick front and wing walls with stone groynes.

The works are from the designs of Dr. William Pole, M. Inst. C.E., Consulting Engineer in England, and of Mr. R. Vicars Boyle, C.S.I., Engineer-in-Chief in Japan, and the ironwork was manufactured under the inspection of Dr. Pole, by the Hamilton Windsor Ironworks Company, Limited.

The ironwork having arrived from England, and other materials being in readiness, it was decided in the month of June 1876 to proceed with the works. However, as the highest floods usually take place in the early part of September, it was considered inexpedient to commence the work of sinking the cylinders for piers 27, 28, and 29, forming the piers in the river bed, until after that month. This objection did not apply to the abutment cylinders on the Yokohama (south) side, or to the cylinders of piers 24, 25, and 26, because the level of the ground at the abutment is above ordinary flood-water mark, while on the Tokio (north) side of the river bed, where piers 24, 25, and 26 are placed, the ground is dry at ordinary tides, and it was anticipated that satisfactory progress could be made before the September floods set in. These portions of the work were therefore at once taken in hand.

The brick cylinders are 12 feet in external diameter and 2 feet thick. The bricks are laid in hydraulic mortar, composed of 2 parts of selenitic cement, 1 part of Portland cement, and 6 parts of fine clean washed sand. The whole is well tied together by rings of wrought iron built in the brickwork, through which tie-bolts $1\frac{1}{2}$ inch in diameter run vertically the entire height of the cylinder. These bolts are securely fastened to the curb-shoe and cottered tight on to the rings, which are placed at an interval of 10 feet apart. The curb-shoe is formed of plate- and angle-iron filled in with wood to a depth of 2 feet, the whole well bolted together and making a solid platform for the brickwork to rest upon. The outer side, constituting the cutting edge of the shoe, is in a line with the sides of the cylinder, while the inner side is formed with a slope or angle of 60°. To facilitate sinking, and to give some clearance to the body or outer surface of the cylinder, the shoe is made 12 feet 6 inches in external diameter, and the first 4 feet in height of brickwork built upon it is made to taper backwards to 12 feet. The experience gained on this work, as well as on similar works executed in Japan, makes it doubtful if any advantage is derived from constructing the shoe and lower portion of the brick cylinder of larger diameter than the remainder of the latter; the earth settled round the body of the cylinder as it sank, causing a side friction as great perhaps as would have been the case had the shoe length been of similar diameter to the whole cylinder.

The cylinders are sunk through an average depth of 56·80 feet (the maximum depth being 60·67 feet from ground-level) by the following operations: The site having been levelled and the shoe placed in position, the building of the brickwork upon it was commenced, the workmen being guided by suitable templates.

A height of 10 to 15 feet of brickwork was first completed, the outer surface being coated with selenitic cement in the proportion of 1 part of cement to 4 parts of sand, with the object of presenting a smooth surface to reduce side friction. Fifteen to twenty days were allowed for the cement to become thoroughly set before sinking commenced. The two cylinders forming each pier were sunk alternately in lengths; this was found to be the most expeditious way of executing the work, and by avoiding any great difference of level at any time between the two cylinders, the tendency which was observed for the last sunk of a pair to diverge from the perpendicular was avoided.

For excavating inside the cylinders various appliances were employed. Bull's hand dredger was at first used, and did satisfactory work in the stratum of fine sand near the surface, but in coarse gravel and soft mud the efficiency of the hand dredger became much reduced. Kennard's improved sand pump was accordingly tried; this did good service in the coarse gravel, but was not found suitable for dealing with the mud. When this latter was reached, at an average depth of 14·73 feet from the position of the shoe before sinking was commenced, the rapid inflow of water, which had not been met with to any material extent up to this stage of the operations, caused considerable difficulty. It was feared that throughout the mud stratum the same difficulty might continue to recur at intervals; so, in order to obtain definite information on this point beforehand, a small trial well was sunk, and the result was to establish the fact that the flow of water occurred at the junction between the coarse gravel and the mud, below which point for several feet the mud was comparatively dry. The excavation was continued to a depth of several feet below the shoe by a bag excavator (Plate 4, Figs. 1, 2, and 3), and the building of an additional height of cylinder was proceeded with in the expectation that the increased weight thus applied would force the cylinder past the water-bearing stratum, thus stopping the inflow and enabling the excavation to be continued. It was found, however, that even an extra height of 20 feet of brickwork, which raised the dead weight of the cylinder to more than 100 tons, produced not the slightest appearance of sinking, notwithstanding that the outside had been carefully cemented. It was then decided that one cylinder should be weighted until sinking took place. The result led to the conclusion that side friction in cylinders used for foundations is of much more importance than has generally been allowed or taken into account; and to enable more decided conclusions to be formed from actual data, careful records were kept throughout the subsequent progress of the sinking operations. On this first occasion the actual weight of the cylinder, together with the load applied, amounted to nearly $7\frac{3}{4}$ cwt. per square foot of side surface before the cylinder moved, when it sunk through a depth of over $2\frac{1}{2}$ feet. The inflow of water ceased, and, the cylinder being cleared out, the excavation was continued by hand labour, additional weight being applied to cause sinking from time to time.

The bag excavator is a simple tool, which was found most useful for excavating under water, and had been previously used on similar works on the southern main line in Japan. It consists of two bags, each fastened to a frame of iron, the lower part of which formed a cutting edge; these frames were fixed on opposite sides of a vertical bar, by which they were made to turn round and dredge out a circular hole. The original details were much improved upon at the Rokugo bridge, and for use in deep wells the two frames were bolted to a square intermediate socket, fitting loosely on a vertical rod which remained suspended in the cylinder while the frame and bags were lifted and emptied at the surface. Any required pressure upon the bottom, to make the cutting edges effective, was obtained by loading the frame with weights slipped into a cross-bar attached to it. This bag excavator was superior in power and handiness to Stoney's helical excavator, which was tried in several of the cylinders; and when the presence of water in the bottom prevented hand labour being employed in excavation, the bulk of the work was executed by this means. In general eight men were able to turn the bag excavator by bearing upon tillers keyed to the vertical rod, and under favourable circumstances from four to six lifts an hour could be made, each operation bringing to the surface 5 or 6 cubic feet of material with the small-sized excavator first tried, and 12 to 16 cubic feet with the larger one subsequently made for use in the cast-iron cylinders.

On the cylinders of 24 pier reaching a depth of about 58 feet from the level at which the sinking was commenced, a stratum of volcanic ash, overlaid by 2 or 3 feet of yellow clay, was met with, the inflow of water from which was so rapid that it was with great difficulty the workmen in the cylinder escaped before the cylinders were filled, and overflowed at a level of 5 feet above the water in the river. As this discharge evidently was derived from some elevated source, it was allowed to take its course for several days, without however diminishing in volume; but by sinking the other cylinders into the same stratum, the flow was distributed amongst the whole, and after a time became inconsiderable. It was thought that this stratum, below which was a bed of hard blue clay overlying the gravel upon which it had been at first intended to found the cylinders, would afford a sufficiently good base without further sinking, and the brick cylinders were therefore cleaned out on attaining this depth. The final weight was then applied, equal with the brickwork of the cylinders to 506½ tons on each, and allowed to remain for eight days, during which a sinking of only a few inches resulted. The weights being removed the cylinders were cleared of water without difficulty, and filled with concrete. The average rate of sinking was a little more than 2 feet per working day of ten hours, during the actual process of excavating, in each cylinder.

No material interruption of the work on the brick cylinders was caused by floods, and the season for these having passed by, operations were commenced without delay on the cast-iron cylinders of piers 27, 28, and 29. As the sinking had to be commenced in a depth of water varying from 4 to 9 feet at low water, different arrangements were made to those adopted for the brick cylinders. An ordinary staging (Plate 4, Figs. 4, 5, and 6) was constructed over the river, supported on timber piles driven 14 feet apart in the width of the river and 17 feet apart up and down stream. This staging extended from the north side of the main channel to a short distance beyond the position of pier 29, leaving an unobstructed passage for the boat traffic alongside the south bank. All materials for the cylinders and superstructure were landed on the north side of the channel, except two of the main Warren girders for the last span, which were put together on the southern side. Around the site of each of the cylinders the staging piles were driven close together in groups of four piles to each cylinder, and cross and guide timbers were bolted to them, the lowest of which were set some distance below low-water mark; these guide pieces were adjusted to keep the cylinders in true position during the process of sinking. Planking was placed to form a platform around the top of each cylinder, and a centre gangway, along which a tramway was laid, traversed the entire length of the staging. The outer beams of the staging were 39 feet apart, and provided with rails upon which a 30-ton Goliath traveller was mounted so as to command the whole of the staging and cylinders. The central tramway was put in communication with another leading to the landing-place, by means of a turntable between piers 26 and 27. At a convenient spot the segments of each ring of the cylinders were bolted together and placed on a truck, which was then brought along the central tramway to the cylinder for which the ring was required, and on to which it was lifted by the travelling crane. As many rings were loaded on each cylinder at one time as could be conveniently done before moving the travelling crane to another spot.

The bottom ring, forming the shoe of the cylinders, was 4 feet deep, with a suitable cutting edge, being made extra strong and stiffened internally with ribs; the metal was 2 inches thick, and the whole weighed 4 tons. The succeeding rings were all 6 feet deep, of metal $1\frac{3}{8}$ inch thick, and weighed 4 tons each. Each ring was composed of four segments, and the vertical and horizontal joints were provided with flanges planed to a true surface; the segments of the 6-feet rings were of the same dimensions and interchangeable, and the bolts were alike throughout. All the joints were caulked with iron-cement so as to be watertight. The first two or three lengths of each cylinder were united before being lowered into position, so that the subsequent operations of joining the rings could be carried on above water.

The excavation was conducted nearly in the same manner as in the brick cylinders. After the first strata of fine sand and of gravel had been passed through, the mud seemed of a less compact character than had been the case at the other piers. A trial was again made with the various excavators previously used, but the most satisfactory results were afforded by the bag excavator made on the works, which seldom failed to bring up a full load of spoil, and the excavation and sinking of the cylinders proceeded regularly until the hard gravel was reached. The final loading amounted with the weight of the cylinder itself to a little more than 253 tons, and this was allowed to remain for eight days, during which time an average sinking of 4 feet took place.

The cylinders were next cleared out by a diver, and all earthy matters that had lodged on the sides and flanges removed. They were then filled with concrete to a depth of 10 feet, lowered in boxes, and composed of 1 part of selenitic cement, 1 part of Portland cement, and 10 parts of gravel. Fourteen days were allowed for this to set, after which the water was drawn out, and the filling continued up to within 15 feet of the top by the boxes, and the remainder thrown in. The average rate of sinking during the actual process of excavating was over $2\frac{1}{2}$ feet per working day of ten hours in each cylinder.

The piers of the smaller openings, and the abutments above the foundations, present no special features calling for a detailed description.

The whole of the ironwork for the superstructure was sent from England in pieces, which were put together and the joints riveted-up on the works.

The ten Warren girders on the north side of the main channel were first erected on a convenient site near the bridge, and then brought by ordinary appliances into the line of the piers, the upper masonry of pier 25 having been left unfinished to the last in order that this might be done with facility. Each girder was lifted by the two travelling cranes, which, with their load, were hauled forward to the required position, and the girder was lowered on to the bedplates. On the cast-iron cylinders of piers 27, 28, and 29 the bedplates were held in position by adjustable bed-frames built into the concrete, by which arrangement any slight deviation of the cylinders from the vertical position was corrected.

The two Warren girders, which had been put together on the south side of the river, and intended for the span between pier 29 and the south abutment, were launched on sliding ways until they projected sufficiently over the river for the outer ends to be supported by boats, after which they were again moved forward until within reach of the travelling crane on the staging, by which they were placed in position on the bedplates.

The pieces composing the plate girders for the smaller spans were put together alongside the respective openings they belonged to, and after being riveted-up were lifted on to the piers by the travelling cranes, and the bracing and cantilevers fitted and riveted on.

The total weight of ironwork in the bridge is as follows:—

	Tons.
Cast iron in six cylinders	360
„ „ bedplates, &c.	15
Wrought iron in cylinder bolts, bracing, curbs, &c. . .	35
„ „ 24 spans of 40 feet each	490
„ „ 6 „ 100 „	420
Total	1,320

The time occupied in erecting the entire work was seventeen months. The works were placed in the special charge of the late Mr. Theodore Shann, Assistant-engineer, as Resident, under the superintendence of Mr. T. R. Shervinton, M. Inst. C.E., and the late Mr. John England, M. Inst. C.E., successively.

The following Table, representing the effect of side frictional resistance, has been compiled from the notes made during the process of sinking the cylinders. For simplicity the various minor weights applied to assist the descent of the cylinders have not been quoted in detail, though taken into account in the totals given as necessary to move the cylinders at the respective depths noted. The difference of diameter between the brick and the

BRICK CYLINDERS.

—	A. Pier 24. Up-stream Cylinder.	A. Pier 25. Down-stream Cylinder.	A. Pier 26. Up-stream Cylinder.	A. South Abutment. Front Down-stream back Cylinder.		A. Average Results.
Depth from surface of ground when weights were applied. . in feet	13·08	11·50	13·75	17·66	17·66	14·73
Sinking weights, including cylinder . . . . in cwt.	3,830	4,180	4,180	4,090	4,700	4,196
Distance sunk under above weights without further excavation, in ft.	3·25	2·25	2·66	1·91	1·33	2·28
Area of surface of cylinder below ground . . . . in sq. feet	493	433	518	666	666	555
Weight per square foot of surface exposed to friction . . in cwt.	7·77	9·64	8·06	6·14	7·06	7·73

—	B. Pier 24. Up-stream Cylinder.	B. Pier 25. Down-stream Cylinder.	B. Pier 26. Up-stream Cylinder.	B. South Abutment. Front Down-stream back Cylinder.		B. Average Results.
Depth from surface of ground when weights were applied. . in feet	29·50	18·75	16·33	45·75	44·75	31·02
Sinking weights, including cylinder . . . . in cwt.	3,720	5,192	5,180	5,814	4,812	4,944
Distance sunk under above weights without further excavation, in ft.	4·50	5·50	6·58	7·25	7·50	6·27
Area of surface of cylinder below ground . . . . in sq. feet	1,112	707	615	1,724	1,687	1,169
Weight per square foot of surface exposed to friction . . in cwt.	3·34	7·34	8·40	3·37	2·85	5·06

—	C. Pier 24. Up-stream Cylinder.	C. Pier 25. Down-stream Cylinder.	C. Pier 26. Up-stream Cylinder.	C. South Abutment. Front Down-stream back Cylinder.		C. Average Results.
Depth from surface of ground when weights were applied. . in feet	56·50	54·25	52·84	59·75	60·67	56·80
Sinking weights, including cylinder . . . . in cwt.	10,520	9,907	10,100	9,974	10,154	10,131
Distance sunk under above weights without further excavation, in ft.	0·50	0·75	0·66	0·25	0·83	0·60
Area of surface of cylinder below ground . . . . in sq. feet	2,129	2,044	1,992	2,252	2,287	2,141
Weight per square foot of surface exposed to friction . . in cwt.	4·94	4·84	5·07	4·42	4·44	4·74

CAST-IRON CYLINDERS.

—	D. Pier 27. Down-stream Cylinder.	D. Pier 28. Up-stream Cylinder.	D. Pier 29. Down-stream Cylinder.	D. Average Results.
Depth, as above . in feet	5·91	5·00	3·66	4·86
Sinking weights, as above in cwt.	648	940	660	749
Distance, as above. in feet	2·75	4·00	3·91	3·55
Area, as above in . sq. feet	149	126	92	122
Weight, as above . in cwt.	4·36	7·48	7·17	6·34

—	E. Pier 27. Down-stream Cylinder.	E. Pier 28. Up-stream Cylinder.	E. Pier 29. Down-stream Cylinder.	E. Average Results.
Depth, as above . in feet	17·32	13·50	10·50	13·77
Sinking weights, as above in cwt.	1,064	660	652	792
Distance, as above. in feet	6·00	8·50	7·25	7·25
Area, as above in . sq. feet	435	339	264	346
Weight, as above . in cwt.	2·44	1·95	2·45	2·28

—	F. Pier 27. Down-stream Cylinder.	F. Pier 28. Up-stream Cylinder.	F. Pier 29. Down-stream Cylinder.	F. Average Results.
Depth, as above . in feet	23·32	23·00	19·82	22·05
Sinking weights, as above in cwt.	1,188	1,220	1,213	1,207
Distance, as above. in feet	13·58	10·00	14·00	12·53
Area, as above in . sq. feet	586	578	498	554
Weight, as above . in cwt.	2·03	2·11	2·43	2·19

—	G. Pier 27. Down-stream Cylinder.	G. Pier 28. Up-stream Cylinder.	G. Pier 29. Down-stream Cylinder.	G. Average Results.
Depth, as above . in feet	36·90	33·00	34·00	34·63
Sinking weights, as above in cwt.	1,958	2,891	2,023	2,291
Distance, as above. in feet	13·00	15·33	14·00	14·11
Area, as above in . sq. feet	927	829	854	870
Weight, as above . in cwt.	2·10	3·48	2·36	2·65

—	H. Pier 27. Down-stream Cylinder.	H. Pier 28. Up-stream Cylinder.	H. Pier 29. Down-stream Cylinder.	H. Average Results.
Depth, as above . in feet	61·59	58·59	52·59	57·59
Sinking weights, as above in cwt.	5,038	5,120	5,040	5,066
Distance, as above. in feet	4·41	4·41	3·41	4·08
Area, as above in . sq. feet	1,548	1,472	1,322	1,447
Weight, as above . in cwt.	3·25	3·48	3·05	3·26

cast-iron cylinders, as well as the different characters of their surfaces, has led to the separation of the two into different Tables to facilitate comparison of the results. As there were almost identical results with each of the two cylinders forming one pier, only one of each pair has been noted in these Tables, which thus give the mean results of five of the brick cylinders and three of the cast-iron cylinders.

In passing through the first strata of fine sand and of gravel, the highest frictional resistance was met with, both in the brick and in the iron cylinders, the greatest being 9·64 cwt. and 7·48 cwt. per square foot of surface below the ground respectively, whereas no friction approaching this was encountered lower down in the stiff mud and blue clay. Taking, however, the average of each set of Tables, it appears that a resistance of 5·84 cwt. per square foot of surface exposed to friction was met with in sinking the brick cylinders to a depth of 56·80 feet, and of 3·34 cwt. per square foot of surface in sinking the cast-iron cylinders to a depth of 57·59 feet, the pressure being greater upon the cylinders having the larger diameter. It is however uncertain to what extent the nature of the materials of the cylinders affected the frictional resistance.

In any case it appears a fair conclusion that side friction is worth taking into consideration when determining the diameter and depth of cylinders, suitable for sustaining given loads, and sunk in strata of ascertained character; and that such consideration may turn the scale in favour of either small cylinders sunk to a considerable depth, or larger cylinders sunk to a less depth, according to local circumstances, and that the most economical results might follow the adoption of the latter system. It is not however to be assumed that the values found to exist in the case of the Rokugo bridge should be taken in practice as correct for purposes of calculation. The subject has not, so far as the Author is aware, been generally considered in estimating the stability of foundations of this description, and further observations, and a careful comparison of results, will probably show its importance.

The contents of this Paper have been compiled by the present engineer in charge, Mr. E. G. Holtham, M. Inst. C.E., from memoranda and notes left by the late Mr. Theodore Shann, a young engineer who was ready and fertile in resource, and of much promise.

The communication is illustrated by drawings, from which Plate 4 has been engraved.

[APPENDIX.

APPENDIX.

ON THE FLOOD OF SEPTEMBER 16TH, 1878, IN THE ROKUGO RIVER.

This was the highest flood that had occurred for many years, the level attained being identical with that assumed, from inquiry of persons in the locality, as extreme flood height; as to the correctness of which there had been some doubt, owing to its being above the top of the river bank.

The rainfall as observed at Tokio (at a point about 98 feet above the sea), was, on eight days between the 4th and 13th of September, equal in the aggregate to a depth of 7·81 inches, and on the 15th alone above 5 inches additional fall took place. It is probable that this rainfall was largely exceeded over great part of the basin of the Rokugo. The river, which had been but slightly increased in volume up to the 15th, began on the afternoon of that day to rise rapidly, and in the night carried away the road-bridge crossing the river about ⅓ mile below the railway, and burst the banks at several points both above and below the bridge, causing considerable loss of life and destruction of houses. At 8 A.M. on the 16th, when the Author arrived at the bridge (after wading for more than a mile through flood-water passing over the low railway embankment north of the river, the passage of trains being stopped by the washing away of ballast), the flood was pouring over the top of the river bank on the south side, just above the bridge; and at pier 28 the water-level attained the necking of the cylinder cap. There was an apparent difference in height of 18 inches between the water-level at this point, which is the centre of the channel, and that at the northern end of the flood-openings. The flood had however by this time fallen nearly a foot below its greatest height, which was attained about 4 A.M., as observed by the platelayer residing near the bridge, whose house on the top of the river bank narrowly escaped destruction. The water fell continuously throughout the day, although about 3 inches of rain were measured on the 16th, and in about five days the river resumed its usual condition.

No damage was done to the bridge, although there was considerable scour around pier 1, extending to within 6 inches of the bottom of the concrete; and a portion of the down-stream slope of the embankment within the flood-bank slipped away, but was easily repaired with stakes and fascines.

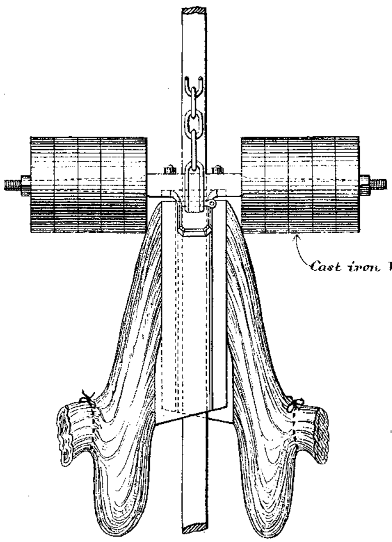
As a precaution against a recurrence of the scour, the whole space under the first two openings on the north side, to a width of 60 feet, has been pitched with large stones, retained by a row of piling on either side of the bridge, at the level of the top of the sheet piling around the piers, which it is believed will effectually withstand any future possible rush of water at this point, around the end of the embankment within the flood space.

ROKUGO RIVER BRIDGE.

PLATE. 4.

DETAILS OF BAG EXCAVATOR.

Fig : 1.



SIDE ELEVATION.

Fig : 2.

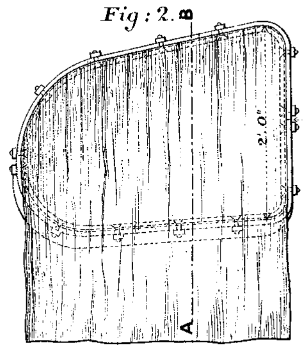
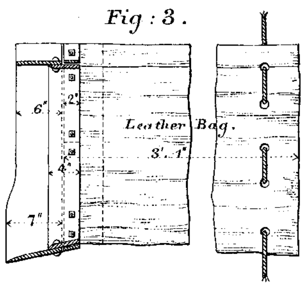


Fig : 3.



SIDE VIEW OF BAG.

Shewing Section of mouth at A.B.

Scale: 1/2 Inch = 1 Foot.
Ins. 12 9 6 3 0 1 2 3 Feet.

Fig : 4.

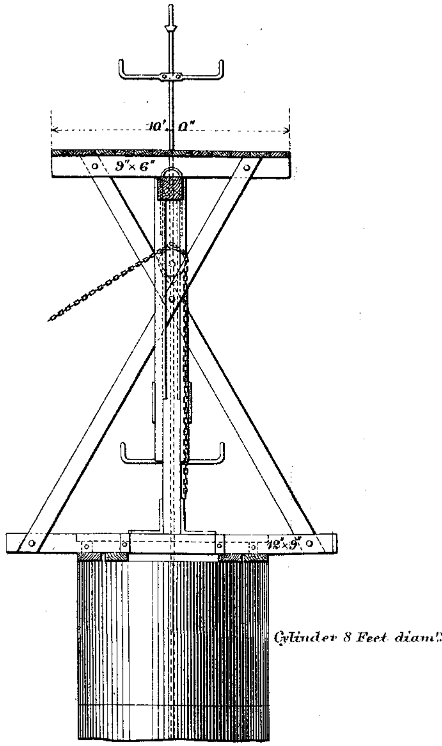


Fig : 6.

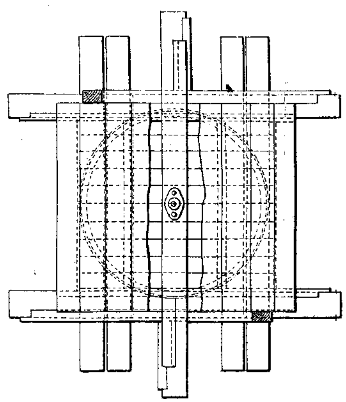
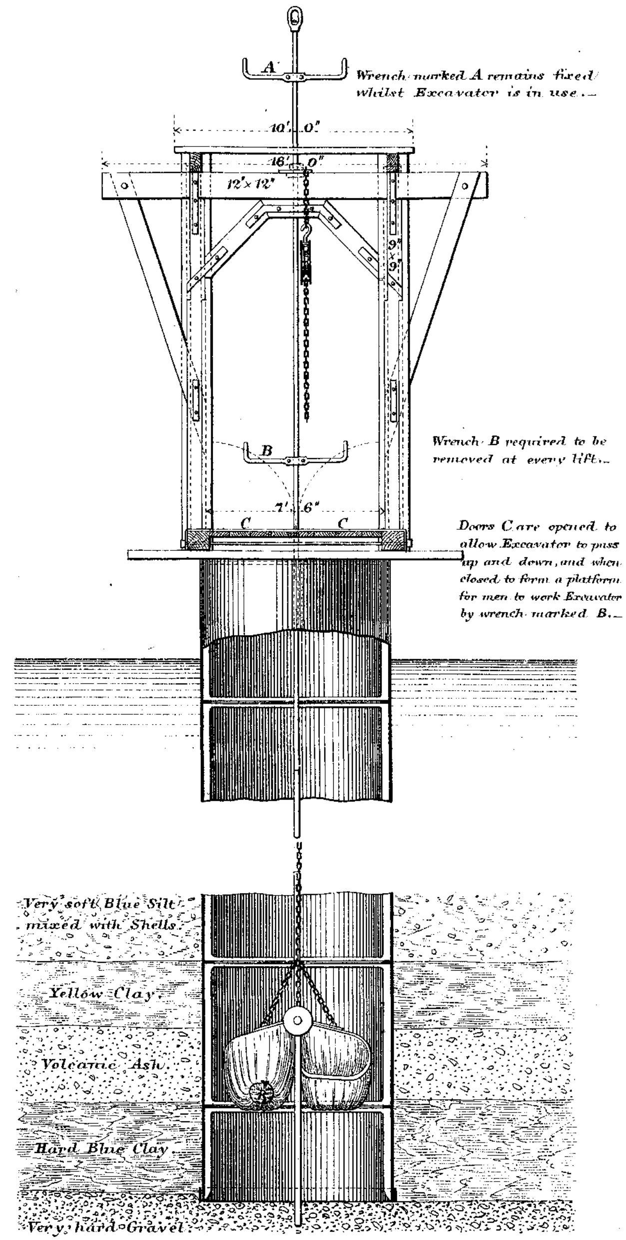


Fig : 5.



ELEVATION AND PLAN OF STAGING,

Fixed on the Top of Cylinders, as used for working the Excavator.—

Scale: 1/8 Inch = 1 Foot.
Ins. 12 6 0 1 2 3 4 5 6 7 8 9 10 20 Feet.

THOS KELL & SON. LITH. 40, KING ST COVENT GARDEN.