

(*Paper No. 4070.*)

“Some Public Works at Kuching, Sarawak.”

By HARRY FREDERICK CAREW-GIBSON, M. Inst. C.E.

(*Abridged.*)

THE territory of Sarawak, which is ruled by Rajah Sir Charles Johnson Brooke, G.C.M.G., originally extended for some 400 miles along the north-east coast of the island of Borneo, being bounded on the north-west and south by Dutch territory, and on the north-east by Brunei. It has now been extended south and east of Brunei by further concessions and by purchase until it meets that of British North Borneo at the Lawas River. The area is about 50,000 square miles, and it contains a mixed population of 600,000, composed chiefly of Malays along the sea-board, and of Dyaks, Kayans, Muruts, Chinese, and other native tribes in the interior and on the various rivers.

The town of Kuching, having a mixed population of 24,000, situated on the Sarawak River, about 12 miles in a direct line from the sea, is the capital and seat of government. Communication is maintained with Singapore, 440 miles distant, by two steamers of 893 and 903 tons burden, owned by the Sarawak and Singapore Steamship Company, which make weekly trips to and fro throughout the year and carry the mails. The same company also own other steamers which carry the bulk of the coasting trade.

REINFORCED-CONCRETE TANK.

The water-supply of Kuching is derived from Matang mountain, and was inaugurated in 1907. In the following year it was determined to build a water-tower to supply the higher portions of the town, the old service-reservoirs situated at an elevation of R.L. (reduced level) 105 being incapable of so doing. There being no higher ground available, the tower was designed to stand near the existing reservoirs on ground at R.L. 103, with its floor (at an elevation of $51\frac{1}{2}$ feet) at R.L. 154.12, the total height of

the structure from ground-level to final of roof being 83 feet. Estimates were obtained in England for such a tank both in cast iron and steel (see Appendix); but taking into consideration the climate (which is a very humid one, with an average annual rainfall of 160 inches), first cost and upkeep, the Author decided to recommend the construction by the Public Works Department of a reinforced-concrete tank.

The design adopted was for a circular tank of 30 feet internal diameter and 16 feet deep, to hold 70,000 gallons, standing on a braced structure of reinforced concrete. This consisted of three central vertical legs grouped in the form of an equilateral triangle connected at the summit by three semicircular arches of 5 feet 9½ inches clear span, and six battered (1 in 40) legs of like section (18 inches by 18 inches) situated at the apexes of the enclosed hexagon, connected at their caps with one another and with the three central legs by reinforced-concrete girders. These again carried six radial members (built flush with them), extending from the central legs to the circumference of the tank at the centre of each chord, the latter members being designed partly as girders and partly as cantilevers; the whole supporting the floor, consisting of a concrete slab 8½ inches thick reinforced with No. 68 expanded metal. Two 9-inch diameter flanged cast-iron pipes are led into the bottom of the tank in its centre, one being the rising main, which also acts as the delivery, finishing flush with the inside of the bottom of the tank in a stuffing-box formed to receive it, and the other being carried up through a stuffing-box to water-level, and acting as an overflow into the old service-reservoirs.

A "billian" (local iron-wood) roof of umbrella type braced with iron rods was built to cover the tank, a ventilator was formed in it near the top, and an entrance or manhole was also left in the roof, from which an iron ladder was carried to within 18 feet 6 inches of the ground; a lightning-conductor is fitted at the top of the roof, and a cable is carried down from this and well earthed. The water-level is shown on a gauge affixed to the outside of the tank. The estimated cost was \$8,980.

Foundations.—The foundations being in soft white clay, it proved necessary, after going down 6 feet, to drive "baku" piles at 2-foot centres (this timber is practically everlasting when buried), and sixteen of these piles 12 feet long were driven under each leg by hand with a heavy timber dolly. They were then capped with concrete, which was, in the case of the six outer legs, 8 feet by 8 feet, reducing by means of steps (Figs. 1, Plate 5) to 4 feet 2 inches by 4 feet 2 inches at ground-level, with ornamental pilasters 2 feet 8 inches

by 4 feet high forming the base of each of the outer legs. The foundation for the three inner legs was of the same construction, except that the equilateral triangle in the centre was filled with concrete, forming a foundation for the supply and outlet pipes. It will be seen from the Figure that the 9-inch inlet or rising main also acts as the outlet, and by means of a tee-piece, valve, and reduction piece, is connected with a 6-inch high-pressure main.

Legs and Braces.—These are of rectangular section with the corners chamfered so as to avoid sharp arrises, which are objectionable in concrete work. For the legs, eight $1\frac{1}{2}$ -inch mild-steel rods are used as reinforcement, and these are bound together by $\frac{3}{16}$ -inch wire wrapped round them spirally at a pitch of 3 inches, forming a cylinder 1 foot 3 inches in diameter, and are tied together about every 3 feet diagonally with wire. The same construction is used for the 6-inch by 6-inch struts and ties, only that four $\frac{3}{8}$ -inch rods were used. Care was taken that the main reinforcement rods, where jointed, broke joint, and these joints were made with screw collars and the main rods were reduced to $1\frac{1}{4}$ -inch diameter after the first stage was passed. All the steel reinforcement was covered with at least $1\frac{1}{2}$ inch of concrete. It was erected in situ and kept well ahead of all concreting work, being given a brush wash of cement as soon as completed.

The steel skeleton was carried up well above the first system of bracing before the timber moulds were placed and the concrete poured. The forms for the legs were three-sided boxes made of native timber of various lengths, with battens round them and bolted together, one side being closed with short boards as the concrete filling proceeded, thus making it possible to tamp it well in the forms and so ensure clean and dense concrete. The steel reinforcement was then continued above the second bracing when the forms were unclamped and moved upwards, and so on until the springing of the arches or the capstones were reached.

An ordinary scaffolding of native timber was employed to support the timber forms used in forming the floor-girders and as a platform for the workmen. All the concrete was hoisted into position by ropes and buckets, the mixing-stage being situated on the ground under the tower. Hand-mixing was employed until the forms were in position for the floor of the tank, when a 6-HP. Smith mixer was used.

The reinforcement of the floor proper consisted of No. 68 expanded metal; this was overlapped two meshes wherever a join occurred, and was bent up round the sides of the tank so as to form a key to the reinforcement of the tank-walls. The expanded

metal was laid upon the timber floor forms, and concrete was spread over it to the depth of about 2 inches. It was then lifted by men with iron hooks and well shaken, so as to allow the concrete to settle under it, the filling of the concrete proceeding all the time. Care was taken to consolidate the aggregate by ramming, the top surface being purposely left rough to form a key for the plastering.

The reinforcement of the sides of the tank consisted of No. 68 expanded metal for two-thirds of the height and of No. 62 for the top third, all wired together and given at least 6 inches of overlap at the joints of the sheets, which are placed in the centre of the thickness of the wall, and are again strengthened against bursting-pressure by two mild-steel hoops of 2 inches by $\frac{1}{2}$ inch section placed at 3 feet and 7 feet respectively above floor-level. Near the top of the tank some $\frac{3}{8}$ -inch steel rod was used in place of No. 62 expanded metal, of which a shortage occurred.

The timber forms for the exterior were made in sections 5 feet to 6 feet long and 6 feet deep for the first ring, and 5 feet deep, with two timber runners accurately shaped to the radius, the planking being $1\frac{1}{2}$ -inch native timber planed and jointed. Enough was made to form when bolted together a complete shuttering round the tank to its full height. Telegraph-wire was used to tie these to the internal moulds, which were made of $1\frac{1}{2}$ -inch boards on end reaching the full height of the tank, and fastened to timber battens formed of two-ply 2-inch boards shaped accurately to the internal radius, and secured to a rough scaffolding erected on the tank-floor.

The three semicircular arches connecting the centre legs are monolithic, and were formed in timber box-moulds with imitation voussoirs. The six girders spanning the space (11 feet 11 inches between centres of bearing) between the outer legs of the tower and the centre arches are reinforced with four $\frac{5}{8}$ -inch diameter mild-steel rods (except for 3 feet 1 inch in the centre of the span, where there are six) to provide for tension; $\frac{5}{8}$ -inch diameter rods at 12-inch centres are wired to these and bent up at an angle of 45° to resist shearing stresses.

The six stiffening members, which are carried by the centre arches and the exterior girders, are in part girders and in part cantilevers, and to meet the stresses in these, four $\frac{5}{8}$ -inch diameter mild-steel rods are provided on the tension side of the member (crossing over at 45° where the stresses reverse), and a sheet of No. 68 expanded metal set on edge in the centre of the member, and extending to within 2 inches of its full depth on either side.

The six girders spanning the space between the outer legs of the tower, which is 14 feet between centres, are reinforced with a piece

of 4-inch by $1\frac{1}{4}$ -inch flat bar steel situated centrally and within 2 inches of the lower face. These bars are drilled at 1 foot centres, except for the middle 3 feet 1 inch, and $\frac{3}{4}$ -inch diameter rods bent at 45° are threaded and bolted to them to take up the shearing stresses.

The moulds used consisted of $1\frac{1}{2}$ -inch planks on end for the inside shuttering the full height of the tank, and these were nailed to timber forms of 2-inch plank cut to the correct radius, breaking joint in two thicknesses, and bolted together. The forms were spaced vertically at 6 feet centres and supported by struts from a rough timber staging erected upon the floor of the tank, as previously explained. The external forms were for the first ring 6 feet high and 5 feet or 6 feet long and were carefully planed, but no oil or other dressing was used on them; they were stiffened with two plys of 2-inch timber cut to the radius and breaking joint, two of these being used on each form; the planking was $1\frac{1}{2}$ -inch native timber. The two top rings were only 5 feet high, but otherwise were constructed in the same manner as the lower ring of shuttering.

Wall-plates of 5-inch by 5-inch billian timber were laid on the top of the walls of the tank to support the roof, and fang-bolts were embedded in the concrete at 4 feet centres to secure these. All the work was kept well covered with old sacks and native palm mats ("kajangs") to protect it from sun and rain. The interior of the tank was scratched while yet green, to afford a key for the plastering, which was put on in two coats by Chinese masons with wooden floats.

The aggregates used were crushed stone (quartzite) from the Government quarry at Sijinkat, up-river sand taken from a sand-bank beyond the reach of salt water, and Portland cement supplied in barrels containing 3.2 cubic feet. They were in the following proportions:—

For the foundations a 1 : 3 : 5 mixture was used.

For the legs, bracing, and sides of the tank a 1 : 2 : 3 mixture was used.

For the internal plastering of the tank, "aquabar," mixed in hot water in the proportion of 1 part "aquabar" to 36 parts by measure of hot water, was used with 1 part cement and 2 parts fine sand; but an alum and soap solution was afterwards substituted for this, consisting of 4 lbs. of sulphate of soda to 12 lbs. of soap and 400 lbs. of water, mixed at 112° F. These mixtures, however, are of doubtful efficacy as waterproofing mediums, for which hydrated lime or oil might prove more suitable.

The tank was completed on the 24th December, and was gradually filled with water, being completely full by the 29th December, 1909.

The tank started sweating after standing with 6 feet of water in it for 4 days, and three or four drips began, but most of these took up, though one or two faulty places remained, which in every case were situated in the walls of the tank at the junction of one day's work with another. They might have been avoided by completing the walls of the tank in one pouring of concrete. It was decided, after the tank had stood with water in it for 1 month—during which time it had lost 6,000 gallons—to empty it for inspection, and this was done gradually. It was found that in two places the internal plastering was faulty, not being solidly attached to the walls. This was accordingly cut out and renewed, and the whole of the interior was given two coats of neat cement wash laid on with a stiff brush. These repairs, costing \$321·66, were completed and the tank refilled on the 26th March, 1910. It was handed over to the Waterworks Department on the 7th April, 1910. It was put at once into regular service, and up to the date of this Paper (December, 1912) had remained quite tight, and required no repairs.

The calculated weight of the structure, including the concrete in the foundation, was:—

	Tons.
Concrete in foundations	193·91
„ pedestals to legs	19·70
„ legs, braces, struts, floor-girders and plinth and the walls of the tank	263·70
Total weight of concrete	477·31
Steel in the form of expanded metal	3·70
„ „ rods, wire, etc.	8·90
Approximate weight of the roof	7·00
„ „ iron ladder, etc.	0·30
Total weight empty	497·21
Add weight of water	299·09
Total weight on foundations	796·30

NOTE.—The approximate area of the foundations is 730 square feet.

Tank empty = 496·91 tons, or $\frac{496\cdot91}{730}$ = weight per square foot on foundations
= 0·6806 ton.

Tank full = 796 tons, or $\frac{796}{730}$ = 1·09 ton per square foot on foundations.

The weight of 1 : 2 : 3 concrete being taken as 143 lbs. per cubic foot, the average weight of 1 : 2 : 3 concrete with reinforcement = 149·7 lbs. per cubic foot.

The weight of steel and iron used was, for reinforcement, 12·6 tons, and the weight of the roof was estimated at 7 tons.

In the design of the reinforcement the tensile stress for the steel, or f_s , was taken to be 15,000 lbs. per square inch, and the safe compressive stress for the concrete, or f_c , was taken at 600 lbs. per square inch, the tensile strength of the concrete being neglected.

The actual cost of this tank after testing, including the repairs mentioned, is given in Appendix I, together with the estimated cost of a cast-iron tank of similar elevation and capacity for purposes of comparison. It will be seen that the reinforced-concrete tank works out \$1,926.94 cheaper in first cost, and will undoubtedly cost little or nothing for upkeep, whereas in this climate the cost of painting an iron tank would have been a heavy annual charge.

THE BROOKE DRY DOCK (Figs. 2, 3 and 4, Plate 5).

The construction of a graving-dock capable of taking any steamers frequenting the port of Kuching was resolved upon in July, 1908. The Sarawak River, at the site reserved by the Rajah for the dock, makes a sharp bend to the north-west and is 660 feet wide. It is subject to tidal influence, and the stream is only slack for a period of about $\frac{1}{2}$ hour at the turn of the tide, attaining at other times a velocity of about 6 knots. The banks are of earth, showing some mud at low-water. The river always has soil in suspension, and during the wet season, or north-east monsoon, the fresh water in "spate" often masters the flood-tide, so that vessels moored in the river at such times have been known not to swing with the tide for periods of over a week at a time, though this is unusual.

The highest known flood was R.L. 27.25, and the lowest R.L. 8.00. The mean range of tide is 10.59 feet.

As economy in construction was of first importance, the Author decided to recommend a tidal dock, to be constructed of concrete, with its sill at R.L. 12.66, which is mean low-water level, and its floor (a flat one) at R.L. 10.00, length on the floor 240 feet from the inner side of the sill, and width at entrance 40 feet at sill-level and 45 feet at coping-level, which is R.L. 28.00.

After some study, it was decided to build the side walls in seven steps or altar courses, the chief reason for this decision being that it was anticipated many quite small steam-launches would use the dock and that the same moulds could be used for all the face-blocks. A ship-shaped steel caisson-gate, with centre slapping keel and water-ballast tanks, was to be used for closing

the entrance, chiefly because this form reduced the amount of masonry required at the entrance and because of the difficulty of obtaining the hollow quoins that would have been necessary if gates had been adopted.

One dolphin was provided on the up-stream side and a fender-pier 60 feet long on the down-stream side (to which the caisson is moored when the dock-entrance is open), both of reinforced concrete. A small pumping-plant for dealing with the seepage and rain-water and any water not draining out with the tide was provided for.

Borings were put down, and showed hard shale at a suitable depth for the foundations. Rough drawings were prepared, and the estimated cost of the work on these lines came to \$70,000.¹ Situated just up-stream of the dock is a short length of retaining-wall supporting a 15-ton steam swivelling-crane, which is used for lifting masts and boilers from vessels. It was necessary to make good the bank between this and the dock with a retaining-wall, but neither this work nor the pumping-plant was included in the estimate for the dock.

The work had to be carried out by the Public Works Department labour force, supplemented by some Chinese and Javanese coolies, and the rate of progress was limited by the money available from time to time, the work being at one time (January–September, 1909) completely stopped.

The dock has a curved inshore end, the floor being flat in the centre for a width of 6 feet, and 2 inches being allowed for discharge from the centre to the side drains, which are at the toe of the side-walls and sill, and are given 1 foot of fall from the inshore end (where their invert is at floor-level) to the sill; they drain into a sump, which connects with the well by means of a 2-foot culvert. A 12-inch cast-iron pipe with valve situated in the well forms the inlet and outlet, supplemented by a 9-inch valve in the gate. All valves have rods carried up to coping-level where they are operated by ordinary turnkeys, which are removable. There are two flights of steps formed in the concrete splay-walls on either side near the entrance, and nine timber slides are provided, four on either side, and one which has concrete steps on either side of it at the extreme inshore end of the dock. The plant available for constructional purposes consisted of one small 3-foot-gauge locomotive with fifteen side-tip trucks, rails, etc., one 6-HP. Smith concrete-mixer, three Scotch derricks with steam winding-gear safe

¹ This estimate was for a dock only 200 feet long and closed at its inshore end by a timber coffer-dam.

for 3 tons, with skips, etc., one 30-cwt. steam swivelling-derrick and two piling-engines. "Tongkangs" or lighters of from 15 to 50 tons burden were available from the Government quarry at Sijinkat. A gravity concrete-mixer and a small turn-table were built in the Government workshop, and proved very useful.

There being no freestone or granite available locally, it was decided to complete the whole in concrete and to form the bulk of the facework as moulded stones set in courses. Thus all the stones in the bull-noses were moulded; the sill-stones and jambs, and the whole of the dock-walls and altars were faced with moulded blocks set in courses and backed with concrete in mass. The floor, splay-faces and steps at the entrance and the timber slides are monolithic.

The opening closed by the caisson has a batter of 1 in 16·84. The slapping face is 15 inches wide and a groove is formed in the sill with wedge-shaped outer face, and slides 2 inches by 2 inches of wrought iron are let into this at 2-foot centres and stand up 2 inches above the concrete. On these the timber keel of the gate slides as it sits into the groove, and by this wedge action is held up tight to the slapping face of the sill. The groove has a clearance space to allow any small stone or other obstruction to fall clear of the gate; any mud entering the groove is forced out along the 2-inch space formed by the iron slides; provision has been made for cleaning this groove by means of a 1½-inch pipe led into it and connected with the town water-supply; but at low tides this can generally be cleaned out by hand. Eight cast-iron bollards are provided, four on either side, set back 1 foot 8 inches from the face of the dock, and six heavy timber (billian) bollards or mooring-posts are provided, three on either side of the dock and set back 30 feet from its face. Two hand-winches (one on either bull-nose), with 7⁄8-inch diameter wire rope and the necessary sheaves for hauling the gate open or shut, are provided. Recesses are formed in which to house the two turn-buckles, which are provided for holding up the gate to its slapping face 2 feet 3 inches below cope-level.

Caisson (Fig. 4, Plate 5).—The caisson-gate is constructed of steel, and was built by Messrs. Howarth Erskine and Company, Ltd., of Singapore, who were entrusted with the design of the structural details to fulfil the Author's requirements. It is of ship shape with a central slapping keel fitted with hardwood ("penyau," or local greenheart) slapping timbers, these being grooved to contain a 1-inch diameter tarred rope, which is caulked into it and stands out a full ¼ inch, so as to make a water-tight joint with the dressed concrete face when the pressure comes on. The caisson is divided

by bulkheads and a steel stepped deck (fitted with manhole, ladders and air-valve) forming a tank for water-ballast, which is used for sinking the caisson when in position, a 6-inch inlet-valve being provided for this purpose, which is opened or closed from the deck of the caisson by means of a removable key.

The top deck is of $\frac{1}{4}$ -inch steel plate overlaid with tarred felt and 2-inch penyau planks, which are caulked. A folding hand-rail is fitted, consisting of light iron stanchions which fold inwards and carry a chain swung between them. Two 6-inch by 6-inch penyau timber rubbing-pieces are fitted on either side of the caisson, being bolted to light angle-bars riveted to the skin of the caisson for this purpose; mooring-irons are fitted at either end.

As built the caisson weighs about 39 tons, and with $21\frac{1}{2}$ tons of concrete ballast draws 9 feet of water and is stable at any angle of heel. The lower part of the tank has a capacity of 12 tons of water-ballast and the upper off-set of the same tank (which was provided to bring pressure on to the upper part of the slapping faces by tending to tilt the gate inwards when full) holds another 5 tons of water-ballast. In practice it is found that the gate is reasonably tight without making use of either the off-set tank or turn-buckles; its draught is increased 2 feet by the filling of the lower tank only.

The contract time for delivery of the caisson was 20 weeks, but owing to delays and alterations this was considerably exceeded: it arrived in Kuching on the 20th April, 1911. Pending the arrival of the Chinese riveters and erectors, the steelwork was unloaded into lighters and transported to the dock. Timbers were placed on the inner sill and the gate was erected on them at a slight angle to the sill. Before the riveting was completed it had become apparent that the keel was not straight. During the Author's absence in England the slapping timbers were fitted and the gate jacked into position and tested, this being done under contract by Messrs. Howarth Erskine, whose representative had sole charge of this work. On the Author's return work was accordingly hurried on, and as the concrete work of the dock had been almost completed, it was decided to float out the caisson and test it. On this being done it was found that spun-yarn had been used on the slapping face instead of a tarred rope inset, and the gate had sprung so that on reclosing it the leakage was very bad. It was therefore determined to dock the caisson and correct the timber slapping-pieces by packing them out with tarred felt introduced between the steel and the timber in those places which had been marked as leaking badly. This work was done at low water by the Chinese

carpenters employed by the Public Works Department, the bolts were tightened up again, and a groove was cut extending all round the timber slapping face 3 inches from the outer edge of these timbers (so as to leave room for a second packing-rope if necessary). Into this a tarred rope was caulked by hand and allowed to stand up a full $\frac{1}{4}$ inch. The gate was then undocked and floated into position, and after one or two adjustments it proved quite tight. Although it has been opened and closed about twelve times since, nothing more has been done to the slapping face, the seepage and leakage amounting only to about 1,000 gallons in 24 hours in dry weather and perhaps twice that quantity in wet weather.

A small concrete well covered with a grid is built over the end of the 12-inch pipe and is carried up to sill-level so as to be clear of the mud, and this pipe has a common inlet and outlet formed in deep water by a billian box-drain which enters the well at the same level as the pipe; this is situated clear of the entrance and is buried in the ground and anchored to short billian piles driven a few feet into the earth. A 9-inch valve has since been fitted in the centre of the caisson to assist in filling and emptying the dock. The centre-line of the dock was pegged out and the coffer-dam was commenced in August, 1908. A single line of timber sheet-piles was driven to form a coffer-dam where the natural bank left in was not considered strong enough. While this was going on a railway was laid from the head of the dock along the road for a distance of about 1 mile to the tipping site. As soon as possible an incline road was run down into the dock-bottom and the excavation started, the locomotive hauling the trucks up by means of a steel rope and snatch-block when the incline became too steep for it to climb. It was decided not to sink timbered trenches for the walls, but to use strutted walings with poling-boards, and to take out the whole of the excavation in short lengths to foundation-level, beginning at the river end. This permitted the concrete floor to be put in, and extended under the side walls in short lengths without a longitudinal joint, as soon as the hard shale bottom was reached. It was found that 5 or 6 feet could be got in in this way during a day's work. Care was taken not to leave the surface of the shale exposed longer than necessary, the last 6 inches of the excavation being taken out within 24 hours of the depositing of the concrete. Sumps were formed where necessary as the work proceeded, and were, as a rule, sunk under the side walls. For the greater part of the time two 3-inch pulso-meter pumps were found sufficient to deal with the water. No blasting was necessary, except for the curtain wall and permanent

sump, which were founded on hard black shale. Only light charges of gelignite were used to avoid starting cracks in the shale; this work was carried out by Malay workmen from Sijinkat quarry.

On the 30th November, 1908, the sheet-piling near the entrance on the east side of the dock, which had been driven because the bank here was considered weak, developed a serious leak under the piles, which were found to be resting on a mattress formed of old shavings and timber refuse. As they could not be driven through this, the sheet-piling was carried farther along the river-bank in the line of the coffer-dam and clay was dumped behind it, effectually cutting off the seepage from the river at this point. On the 23rd January, 1909, the poling-boards on the right-hand side of the dock were driven in, owing to excessive pressure caused by a heavy rainfall; this was repaired and the weight of earth lightened. On the 6th February a further slip occurred and more lightening had to be resorted to. On the 1st March, 1909, during the night the river rose very rapidly to river-level 27·00 (i.e., 2 feet 10 inches higher than the previous highest water recorded), topping the coffer-dam and flooding the dock excavation; this was the most serious mishap met with during the 3 years that the dock was under construction and took 6 weeks to repair. The sheet-piling, where damaged, was drawn and redriven, extra walings and struts fixed, and about 2,000 gunny bags three-quarters full of sand were built up to R.L. 28·00 on the outside of the sheet-piling. More clay was then tipped on the crown of the coffer-dam, so that work was able to proceed again towards the end of April. No further mishaps of any consequence occurred.

The first concrete deposited for the floor of the dock was in No. 3 section. This was put in on the 25th January, 1910, and consisted of a length of 6 feet, the full width of the dock, including the thickness of the side walls, i.e., 56 feet 3 inches. From this time until the end of the year the work progressed without incident up to section No. 25; the sill, bull-noses, sump and well, and a considerable portion of the dock-walling, as well as the floor, were completed. From section No. 25 bad ground was encountered, the shale dipping away rapidly towards the head of the dock, and heavy timbering with two rows of king-piles and struts had to be resorted to to prevent the dock road coming in. From this point up to the springing of the arch forming the head of the dock the walls were increased in thickness.

Evidently an old creek connecting the Sungei Gertak had once existed here, as the remains of piles such as natives build their houses on were found in the mud overlaying the shale, and much

water and mud came in on the down-stream side of the dock, causing some settlement which was afterwards made good.

The solid shale was not reached here until a depth of 16 feet below floor-level was attained. Large displacement stones were used liberally, with the object of economizing cement, in all concrete deposited in mass, in the floor of the dock or elsewhere. All the stone used came in lighters from Sijinkat quarry, which is about 12 miles below Kuching and is worked by the Public Works Department. The stone from this quarry is a hard quartzite rock, and the actual cost price of the stone was charged against the dock. All the cement used was imported from Singapore.

Relief-holes about 2 inches in diameter were left wherever necessary in the dock-floor; generally two in alternate sections were required, and were formed by the use of bamboo, which rotted after a few months and was then easily split up and removed. These relief-holes were left open until the completion of the dock, when they were gradually closed by careful grouting with liquid cement under pressure, working from the river end of the dock.

Special moulds were made for the bull-nose stones, which were bedded in cement mortar in seven courses, one set of moulds serving for two courses. The special stones forming the jamb for the sill are 2 feet 3 inches deep by 3 feet 7½ inches by 1 foot 6 inches, care being taken in moulding these to use 3 inches of fine stuff on the slapping-face, which was axed and rubbed down true after they were set. The inner sill is formed of stones 3 feet by 1 foot 6 inches by 1 foot 6 inches, set in cement mortar on concrete in mass and breaking joint both vertically and horizontally. The jambs are treated in the same way, but are formed of larger stones. The altars are formed of stones 2 feet 6 inches by 1 foot 3 inches by 1 foot 3 inches with a chamfered edge, 3,216 of these being required.

The retaining-wall previously referred to on the up-stream side of the dock was completed and the ground behind it was reclaimed before the dock was opened. This wall, which is 91 feet long, is of dry stone, founded upon two rows of concrete blocks resting on hard clay, and is coped with cement flags; it was completed for \$1,020, or \$11·20 per lineal foot.

A buoy with mooring-chain was anchored 300 feet from the dock on the centre-line of the entrance; this is intended for vessels to moor to while awaiting the tide to enter the dry dock. Any large vessel entering would make fast to this mooring, and at slack water of high tide send her bow ropes ashore and attach them to the bollards at the dock, and then haul herself in by her own deck-winch.

The Fender Pier and Dolphins.—In the construction of these reinforced concrete was used, and the steel reinforcement in most cases consisted of old rails, weighing about 11 lbs. to the yard, and $\frac{1}{4}$ -inch binding wire. The reinforced-concrete piles were moulded horizontally in hexagonal timber moulds, and were generally 21 to 26 feet in length, the reinforcement terminating in an iron shoe, except in a few cases where shoes were dispensed with and the rails forming the longitudinal reinforcement were bent to a point.

The method adopted in making the piles was to make small wooden templates of 1-inch board with notches cut in them to take the longitudinal reinforcement, which generally consisted of four old rails of light section, or, in some cases, of six $\frac{3}{4}$ -inch or 1-inch diameter steel rods. These were held together temporarily with a wire lashing, templates being introduced wherever necessary to prevent sagging and to keep the correct spacing. One end was then bent in and housed in the pile-shoe, which was attached with wire, and the whole was wrapped round by hand with $\frac{1}{4}$ -inch iron fencing-wire at about 3 inches pitch, the winding being kept in place by light binding-wire. This steel skeleton was quite rigid and was placed in the timber mould and centred in it by supports at either end. The mould was then closed except for the top board, and the aggregate was poured and well rammed. The piles were left in the moulds on an average 8 days, but were not moved or driven under 4 to 6 weeks' time. In most cases holes were got out 2 feet or 6 feet deep at low water in the red clay overlaying the shale, and the piles were then driven with a 30-cwt. monkey as far as they would penetrate. The heads of the piles were not protected in any way while being driven, as it was necessary to bring them to their correct length by splicing the reinforcement, encasing their heads with moulds, and pouring concrete to the correct height, so that some concrete had to be removed by chisel and hammer before the joints could be made.

The longitudinal and transverse runners or beams were formed in timber moulds in situ, anchor-bolts being left in where necessary to hold the wall-plates to which the penyau timber floor is treenailed.

The timber rubbing-pieces are of 6-inch by 6-inch billian timber, strapped to the piles with iron straps fitted with clamping bolts and recessed in the timbers. The heads of these form mooring-posts for the caisson when it is berthed alongside, and heavy billian timber logs are bedded in the clay for it to rest upon when not water-borne.

A gauge is fitted to the dolphin on the up-stream side of the entrance showing the depth of water over the sill in feet.

Keel-Blocks.—These are of heavy native timber (billian and perpat) in four parts, weighing between 70 and 80 lbs. per cubic foot. They are not anchored to the floor of the dock in any way, and are placed 6 feet apart between centres.

There were only two accidents of a serious nature to the men employed during the construction of the dock, neither being fatal.

The dock was officially opened on the 31st May, 1912, by H.H. The Ranee Muda, when it was named the "Brooke" Dock.

The works described in this Paper were designed and carried out by the Author while holding the position of Commissioner of Public Works and Surveys to the Sarawak Government. He wishes to express his thanks in the first place to H.H. The Rajah of Sarawak, G.C.M.G., for permitting this Paper to be presented to The Institution; to all the members of his staff for valuable assistance; to Mr. H. W. Clarke, Assoc. M. Inst. C.E., for valuable assistance and advice in designing the dock and caisson-gate; and to Mr. D. Macdonald, M. Inst. C.E.

The Paper is accompanied by 10 sheets of drawings, from which the Figures forming Plate 5 have been selected.

APPENDICES.

APPENDIX I.

THE HIGH-LEVEL TANK.

Cost of Reinforced-Concrete Tank.

Materials—	\$
Cement	1,601·87
Stone	320·00
Expanded metal	462·42
Iron and steel	777·78
Timber	237·19
Other materials	697·45
Total	4,146·71
Labour	5,512·57
Supervision	624·31
Total	10,283·59
Total cubic feet of reinforced concrete	7,477
Average cost per cubic foot	$\frac{7,477}{10,284} = \text{say, } 1\cdot375$

The dollar used = 2s. 4d.

ESTIMATED COST OF CAST-IRON TANK.

	£	s.	d.
70,000 gallons cast-iron tank f.o.b. Liverpool	784	0	0
Foundations (actual)	253	0	0
Shipment to Sarawak, including transhipment } at Singapore, say, 85 tons at £2 5s. per ton. }	191	5	0
Transporting $\frac{1}{2}$ mile from wharf to site, say, } 75½ tons at 2s. per ton }	7	11	0
Erecting with native labour, say, £2 per ton	151	0	0
Painting one coat after erection and caulking, } including pipe-connections, say }	12	0	0
Water-gauge, say	10	0	0
Insurance against loss and breakage from } Singapore, say }	16	0	0
Total	1,424	16	0
Or in dollars	\$12,210·53		
Actual cost of reinforced-concrete tank, as } erected in Kuching }	\$10,283·59		
Difference in favour of reinforced-concrete tank	\$1,926·94		

APPENDIX II.

THE BROOKE DRY DOCK.

Summary of Cost.

The dollar used = 2s. 4d.		\$
Materials—		
Cement		21,720·67
Stone		8,874·95
Sand		1,110·35
Fuel (coal)		2,951·40
Timber		1,143·47
Other materials		1,844·51
Sundries		4,948·36
	Total	42,593·81
Labour		48,443·38
	Total	91,037·19

The total quantity of cement used in the work was 5,430 barrels.

NOTE.—Up to and including section 27 the actual quantity of concrete as it came from the mixer was carefully noted, and if 13·24 per cent. is allowed for shrinkage when rammed and consolidated in situ, this gives about 20 per cent. as the volume occupied by displacement stones, which, in the Author's opinion, is approximately correct.

The total calculated quantity of concrete used in constructing this dock was 5,795 cubic yards.

PUBLIC WORKS AT KUCHING.

PLATE 5.
PUBLIC WORKS
KUCHING.

Fig. 1.

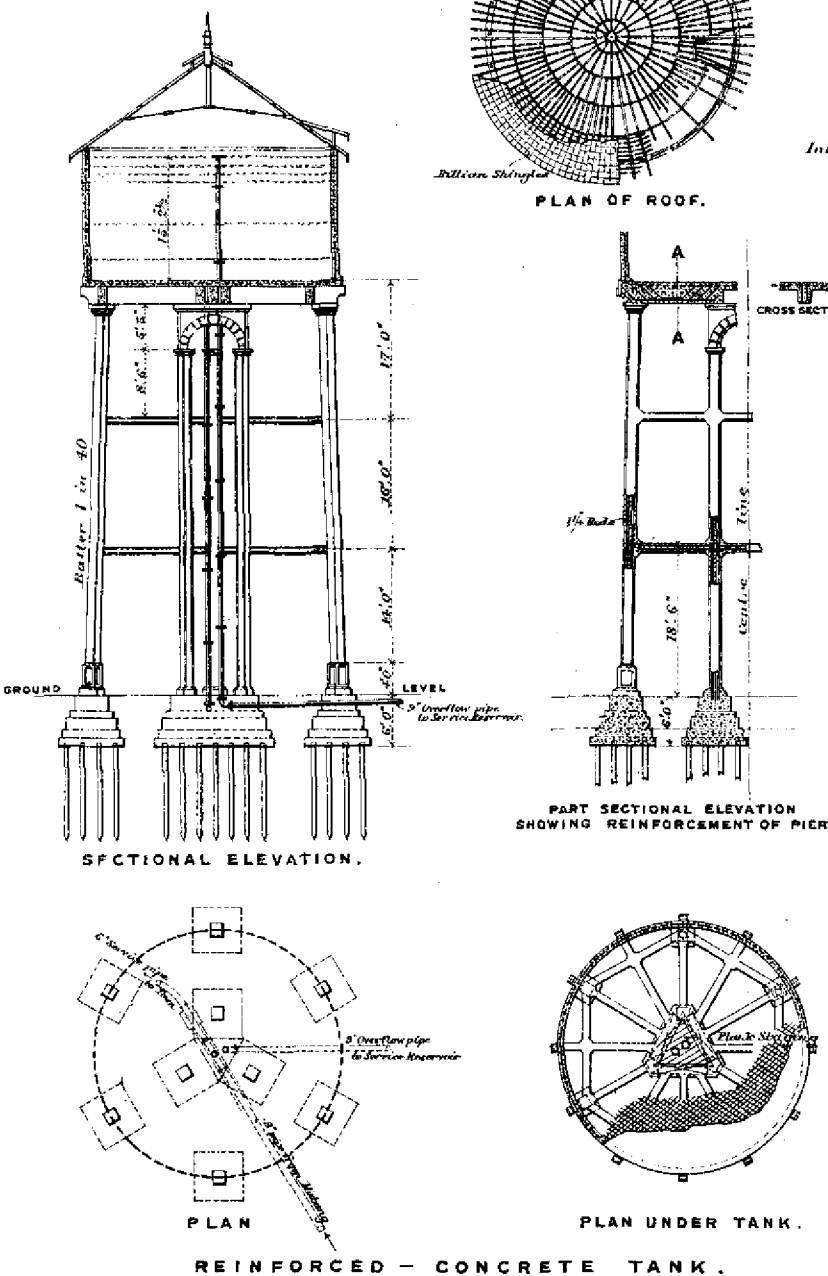


Fig. 3.

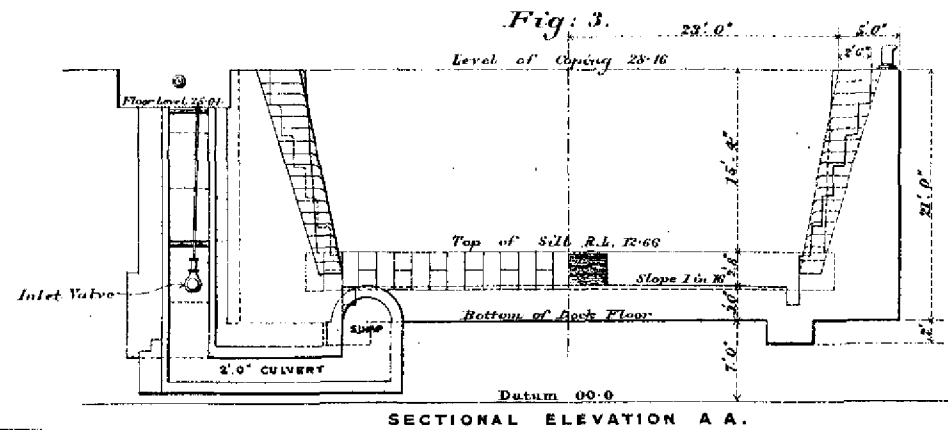


Fig. 4.

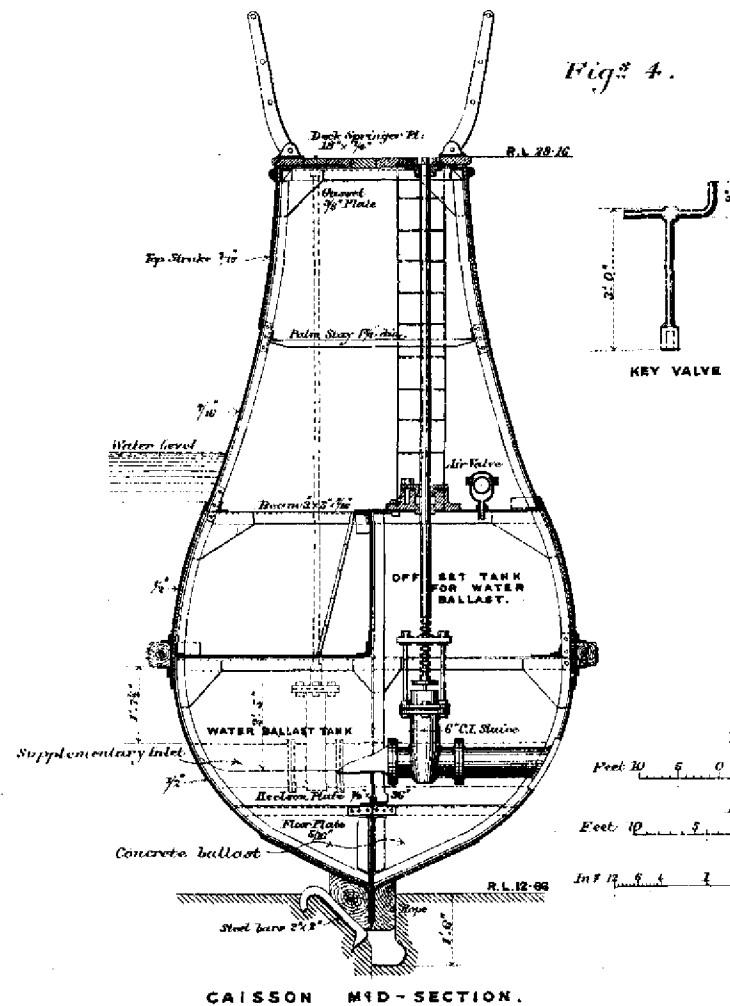


Fig. 2.

