THE RESTORATION OF TABBOWA TANK

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Tabbowa Tank is situated about 8 miles E.N.E. of the town of Puttalam, North Western Province, on the Puttalam-Anuradhapura road. In the neighbourhood are found signs of ancient occupation, ruins of Vihares or temples and other buildings. Old red bricks are often unearthed during excavation.

Nevill identifies the edge of Tabbowa Tank as the site of the ancient city of Tawisikiyanagara. He derives the name from 'tawa,' an old Tamil form of 'tapas,' 'penance' or 'prayer,' and 'giri,' 'rock.' Tawa-giri-ya, Tawa-rigri-ya, or in any kindred language to Tamil, Tawa-kiriya, Tawa-rikiya, Tavarikiya, Tabarikiya, Tabowiya, Tabbowa. This is interesting because to this day people come from as far as Kuruwegala, Anuradhapura, Dambulla and Nattandiya to worship at an altar on the bund; and ancient Snake Stone was unearthed a few years ago from a ruined temple near the same spot. This temple is said to be the 'Nindagama' or 'place belonging to' the Hindu God 'Ayyana.'

An old Sinhalese book called 'Wittipota' translated by the late Mr. Macready, C.C.S., proves how numerous must have been the ancient population, and how extensive the cultivation of this district. An extract is as follows:—"'Maha Tabbowa,' sowing extent
350 Anunams (i.e., 875 acres) two ‘horawas’ (sluices), thirty two abandoned ‘Vihares’ (temples)."

There is also a tradition that water was once taken from the Tank via the Mi Oya river to Puttalam. This is to some extent substantiated by the discovery of traces of a channel leading from a point on the Mi Oya below the tank towards the tank Nadunkulam, near Puttalam.

The land is at present covered with fairly dense, but secondary, jungle, and there can be no doubt that in early times Tabbowa Tank supplied water for cultivation over an area extending possibly as far as the Puttalam-Jaffna road.

The crest level of the ancient bund was about 90.00 feet above mean sea level, and about 50.00 above the bed of the tank, the full supply level was probably about 75.00 feet and the area of the tank at F.S.L. about 2,000 acres. The tank has as its source of supply the Nanneri-Oya, which runs across the bed and through a large breach in the bund.

In 1868 Mr. Macready reported to Government the existence of a very large bund, and traced the Nanneri-Oya up to the Anuradhapura road.

In 1896 Mr. Mohammad Cassim and a number of Puttalam inhabitants petitioned Government for the restoration of the tank, stating that they wanted the land opening up for cultivation in order to afford employment for the poorer classes during the slack season of the salt manufacture, which is Puttalam’s chief industry.

In 1897 Mr. Baumgartner, A.G.A., suggested that the locality should be examined by surveyors. He gave an accurate description of the tank and pointed out how it would be filled by the Nanneri-Oya. In his report is an interesting note to the effect that the local headmen stated that if the tank were filled it
would submerge a part of the Puttalam-Anuradhapura road.

This is perfectly true, but considering that the Headmen could have had only very rough idea of the levels, it is difficult to understand how they possessed the information. It is an illustration of the value of tradition. Mr. Baumgartner pointed out that the position of the tank near Puttalam and an important main road was advantageous for the disposal of produce.

In 1902 the Survey Department completed a topographical survey of the district showing the contour of the tank, position of the bund, etc.

This survey however only embraced the district North of the Main Road, and matters had to be delayed pending the production of a map of the district S.E. of the road, in order that catchment of the Nanneri-Oya could be ascertained.

Meanwhile the Moor Headmen were still petitioning Government for the restoration. A map showing the whole catchment area was published in about 1904, and 1905 the scheme was more closely examined following a petition from the Puttalam Head Moormen to Sir H. A. Blake. The Moormen and other influential residents offered to purchase 8825 acres at Rs. 10 per acre, and to deposit Survey fees immediately; they stated in their petition that the tank would irrigate thousands and thousands of acres: a certain D. A. Cuntze of Udugama, Galle, also offered to purchase a block of two thousand acres under the tank for coconut cultivation. Rs. 2,000 was then sanctioned to the Director of Irrigation for an investigation and survey of the tank and bund, and the irrigable area was found to be in the neighbourhood of 4,800 acres. A scheme was prepared, suggesting that the land should be sold for Rs. 100 per acre with a one rupee water rate, or at Rs. 125 per acre without water rate.
At this time it was considered that water from Tabbowa would be required to augment the Puttalam supply. In dry years Puttalam is often very short of water, and in 1911 the Irrigation Department worked out and submitted to Government three alternate schemes for the restoration of the tank, the one adopted being the irrigation of 4,000 acres under the Right Bank Channel, 800 acres under the Left Bank Channel, and the supply of water to Puttalam by means of a syphon under the Mi-Oya and pipe line from the end of the Left Bank Channel.

The estimated cost of the scheme was Rs. 374,700, and this expenditure was sanctioned by Government on August 19th, 1912. The scheme was mainly for coconuts, it having been found too expensive to provide the storage necessary for paddy cultivation.

The Department commenced work in 1913 on clearing jungle, building lines, stores, offices, etc., a bungalow for the resident Engineer, and a service road joining the main road to the works. A considerable amount of earthwork was also done on the bund.

In 1915, however, owing to retrenchment, the work had unfortunately to be stopped, and cement, plant, and tools removed.

In January, 1920, the works were reopened under Mr. J. H. Fraser, Divisional Irrigation Engineer. Mr. Fraser handed over to Mr. C. Harward, D.I.E., in August, 1920, and Mr. Harward to Mr. O. W. Hennan, D.I.E. in November, 1920. The writer took over from Mr. Hennan in March, 1921, and has been in charge of the works since that date.

In 1922 owing to the increased cost of labour and materials it was found necessary to completely revise the original estimate, and in addition closer investigation of the available sources of water for the Puttalam supply by the P.W.D. indicated that at any rate for some considerable time there is sufficient water for the needs of the town stored in a sand
pocket about one mile to the South. A new estimate amounting to Rs. 620,000 was therefore framed, exclusive of the Puttalam Water Supply Scheme. This revised estimate was sanctioned on April 11th, 1922.

The bulk of the runoff from the catchment area of about 160 square mile is collected in the river Nanneri-Oya, which flows through the bed of the tank, and at present escapes through a large breach in the bund.

The closure of this breach will be the final act in connection with the restoration of the tank itself. The average annual rainfall is 68.61 inches and the anticipated maximum flood discharge 27,500 cusecs. The full supply level for which the tank is now being reconstructed is 68.00 and the area of the tank at this level is 1,140 acres. The outlet sill level is 55.00, and the area at this level 190 acres. The capacity of the tank above outlet sill level is 7,900 acre feet; and the irrigable area under the tank being approximately 4,800 acres, the volume of water stored would be sufficient, neglecting losses, to flood this area to an even depth level of 1'7".

The bund is one mile 665 feet in length and is being restored to maximum crest level of 80.00.

The Spill wall is 508' long and of the clear overfall type. The Spill crest level is 68.00, and the maximum anticipated depth of discharge over the spill six feet.

There are two sluices, the Left Bank Sluice being at the extreme southern end of the bund and the Right Bank Sluice about 1,700' from the Northern end. The Sluices will control the supply of water to two main channels, the R. B. Channel being 10 miles in length and the L. B. three miles.

The main feature in the restoration of the Spill Tabbowa Tank is the construction of the 508' clear overfall type Spill wall. This was designed by Mr. J. A. Balfour, and as will
be seen later is distinctly interesting in that full use has been made of a quantity of loose boulders and rubble found on the spot.

The choice of the site for so large a spill was by no means easy, and a series of trial pits and borings were sunk in different places in an endeavour to find suitable foundations. The strata, consisting of alternate beds of rock and reddish marl, dip at a fairly steep angle towards the North and North West. At first sight the rock, which in some beds is about eight feet thick, appears to be a semi-decomposed granite, but closer examination reveals water borne pebbles, etc., proving the rock to be of aqueus origin, which is of fairly obvious from the general formation.

There are, however, frequent intrusions of igneous rock in the neighbourhood from which the actual concrete metal has been obtained.

The best site obtainable for the Spill was, however, none too good from the point of view of foundations, and it will be explained later what steps were taken to ensure safety.

The drawings herewith show the general design of the wall and apron. The latter is simple, consisting of a bed of 1:3:6 plum concrete with a downstream drop-wall, and a facing of hard stone masonry in cement to take the fall of water. It will be noticed that the apron is divided into fourteen sections with an expansion joint between each section. Six of these sections or 'bays' are built to a level of 46.00 and the remainder to 50.00. This was done for the sake of economy, the lower sections requiring deeper excavation before a firm bottom was reached. A water cushion is provided for by means of rubble mound which will be constructed to a crest level of 55.00 below the apron.

Owing to this difference in level in the apron, six bays of the wall are 24' high, and the remaining 8 bays 18' high, measured from the apron to the crest.
The abutments are quite simple, U shaped in plan, thirty feet high, eight feet broad and the space between the walls filled with puddle clay. The abutments tie into each end of the bund, which are protected from erosion by heavy battered wing walls and rubble pitching in cement mortar.

As previously stated there is an abundance of loose rubble available at the spill site, and the main mass of the wall is composed of this rubble, kept in position and protected by a comparatively thin concrete wall. The wall itself is held up by a series of steel tie bars formed of old rails, anchored in a reinforced concrete foundation slab, upon which the weight of the rubble bears. A glance at the drawing will make this clear. Watertightness is obtained by a thick wall of puddle extending down to solid and completely covering the rubble. An earth backing supports the upstream side of the puddle wall, and enables the requisite high discharge co-efficient outline to be obtained.

The wall is faced with machine-made Winget Blocks of 1:24:5 concrete, the metal being broken to pass a 1" ring. The wall, counterforts, and foundations are constructed of 1:3:6 concrete with plums, 14" metal being used. The coping is made of 1:24:5 concrete.

The calculation of the stability of a wall of this type, when backed with saturated earth, is by no means as simple as it looks. All sorts of different positions for the resultant line of thrust are obtained, depending entirely on the assumptions made. It will be realised however that the external pressure on the wall will lie between the extremes of pure hydrostatic at high flood level, and that produced by well drained but damp earth filling. Hydrostatic pressure produces a thrust line which lies just outside the middle third when the wall is considered by itself and without taking into account the resisting moment produced by the water cushion over the apron, and the static resistance of the apron itself. In practice however it is
extremely improbable that the wall will ever be subjected to full hydrostatic pressure, but even if this should occur, the wall will still be stable.

A far more serious consideration is the safety of the foundations. The pressure on the downstream toe under the most adverse conditions works out at just about three tons per square foot, and doubts were entertained as to whether this pressure would be safely borne by the softer portions of the strata. This material, which is a reddish yellow marl, intimately mixed with pure white kaolin, becomes very soft indeed when treated with water in such a way that, the kaolin is allowed to be washed out. There is however, little likelihood of there being any appreciable flow of water under the foundations, and it is extremely improbable that the kaolin will be washed out. It will be seen, however, from the drawings that the base of each bay of the wall is composed of a solid slab of reinforced concrete. The majority of these slabs are supported in several places on ridges of rock, and in only three bays was there any doubt as to the safety of the foundation. In these three bays vertical wells 2' x 2' were excavated underneath the downstream toe of the wall, and sunk to varying depths until rock was reached. The wells were then filled with concrete to foundation level, forming a series of supporting columns where the load will be a maximum.

In order to explain the reason for what is probably a unique feature in the Tabbowa Spill Wall, I quote the following passages from an article which appeared in the American Engineering News Record of July 19th, 1923:

"What appears to be a strongly marked case of the comparatively rare phenomenon of vibration being transmitted through the air to a considerable distance occurs about once a year on the Sudbury section of the Metropolitan Water-works, at Framingham, Mass. The occurrence is noted on two dams, each:
having a face with a batter of but one in twelve (see sketch). A third dam of similar section, but having the sheet of water broken by a continuous rod passing just above the crest of the dam is free from such vibrations. As a result of these vibrations windows rattle, dishes sometimes fall from shelves, and insecure piles of boxes topple over, when the effect is most pronounced, over a mile from the dam. At times the sound effect is similar to that produced by an explosion except that it is more like a series of mild explosions. A like phenomenon has given trouble near Fitchburg and slight vibrations are reported from a few other dams.

As the dams are built on compact sand and no rock is in evidence, the only explanation of a phenomenon is a partial vacuum between the sheet of water and the face of the dam, which causes a fluttering which appears to operate on a large scale much as does the diaphragm of a telephone receiver. The sheet of water flowing over the dam and vibrating uniformly, imparts to the atmosphere a series of waves which resemble wave translation in water, or sound waves in the air.

The dam where phenomenon is more frequently observed—and this is due to the fact that this dam is used to discharge all the waste from Sudbury River—is 168.67 feet in length and has a fall of water of about 11 ft. Little vibration is felt until the volume of water passing over the dam amounts to over 300 m.g.d., corresponding to a 6 in. depth of water on the crest. At one time it was attempted to mitigate the effect of the vibrations, as at least one complaint was made of rattling noises at night, by introducing timbers under the sheet of water so that air might freely enter, but this was abandoned.

Several engineers of note, in charge of large dams have never had similar vibration experiences and some have never heard of its occurrence anywhere. At Lawrence, Mass, vibrations have been observed when the volume of water was sufficiently large, or when
the depth of water is about one foot. At Lowell, Mass., the fluttering has been observed when the flash-boards have been raised several feet in height and there is six in. of water flowing over the dam—generally with a slight breeze at the same time. Vibration has also been observed at several vertical timber dams along the Pawtuxet River in Rhode Island—in every case where there is little or no opportunity for access of air at the ends of the dam—but the vibration has not been so pronounced as to be noticed in the neighbourhood.

A more marked case has been reported from Fitchburg, Mass, where it became necessary to devise some method of preventing the trouble. The Fitchburg dam was a small concrete structure (see sketch) on the North Branch of the Nashua River, about 150 ft. long, and with a maximum height of 15 ft. The vibrations were at their worst when the water was about 6 in. over the crest, and became lesser as the depth of flow either increased or decreased. Near this dam the ruffling of windows and general noises in the houses became so marked that the residents threatened legal action, and an engineer was called into devise a remedy.

The article does not say what remedy was devised, but it may be assumed that arrangements were made to allow free ingress of air under the sheet of water.

The Tabbowa Wall is very similar in shape to the Framingham and Fitchburg dams, three times as long, and in the lower bays, more than twice as deep as the former. It is therefore reasonable to suppose that unless precautions were taken similar vibrations would be set up. In the original design three massive concrete piers were provided on the crest of the Spill to break up the sheet of water, but it was considered that these piers were not given sufficient support from underneath, and in addition would cause an increase in the overturning moment on the bays over which they were to be built.
Various suggestions were made, including building out horizontal cantilevers from the crest of the Spill, but the device finally adopted was the provision of an Air-Duct running underneath the coping for the entire length of the Spill, with openings at regular intervals, and air intakes at each end. In order to keep these intakes clear of water two small deflecting piers have been provided jutting out from each abutment. The piers will have an additional effect in providing a direct air inlet at each end of the sheet of water, which otherwise would be sealed against the abutments. It is possible that the piers alone would be sufficient, but it will be an interesting experiment to note the effect, if any, of blocking the Air Duct when the tank is spilling.

The actual construction of the apron and wall presented no difficulties once the layout had been decided on, and all of the concrete, with the exception of a small amount of hand-mixed, has been placed without any alteration in the position of the steam mixing plant. A crane was only found necessary for handling the 3 cu. ft. blocks of stone which form the masonry of the apron.

In order to keep down the cost as much as possible a scheme had to be devised for getting the concrete mixed and deposited with a minimum of man-handling, and for this purpose gravity was used as much as possible. During the excavation on the Spill foundations a construction road was built to a level of 56.00 running parallel to and about 30' upstream of the centre-line of the wall. The embankment served three purposes:

(a) Kept out water from the Spill foundations,

(b) Formed part of the earth filling on the upstream side of the wall, and

(c) Enabled concrete to be run on trucks from the mixer to wherever required.
A mixing platform was then constructed near the Left Bank Abutment and so arranged that carts coming direct from the quarry could tip metal and sand into their respective compartments. Below this platform was the mixer, a small power-driven Ransome—the charging hopper being level with the mixing platform floor. Very little labour was needed to serve the machine, one man, two boys and two or three women being sufficient to load sand and metal and cement into the proportioning boxes, and tip them into the mixer. An experienced man was employed to add the water necessary to the mix, as it was found that the automatic supply was not satisfactory.

The mixer was driven by belt from an eight H.P. vertical steam engine, which, owing to the position of the driving pulley of the mixer, had to be erected on the top of the half finished abutment as being the only place available. This however formed a satisfactory foundation. A vertical Cradley boiler erected on a piece of solid ground between the mixing platform and the abutment supplied the necessary steam.

Below the mixer a track line was laid running the entire length of the construction road, and on the downstream edge of same.

At right angles to the track, portable metal lined wooden shoots were provided leading from the track down the bank, and from the bottom end of these shoots another track led over the apron. Ordinary side-tipping waggons were used. The progress of the material was therefore as follows:—Sand and metal, brought to the works in carts, were tipped down their respective shoots on to the mixing platform. Here coolies shovelled the ingredients into wooden proportioning boxes, a woman always being employed for the cement as having a lighter touch than a man. Another cooly tipped the contents of the boxes into the mixer, and the mixer discharged the concrete direct into trucks. These were then run out along the construction road and tipped sideways into one of the shoots down the bank. A truck waiting at the bottom of
the shoot then took the concrete out to wherever it was required over the apron, where it was tipped out on to a \( \frac{3}{4} \) iron sheet. Here it was given one or two final turns with a shovel, placed andrammed. Plums were added during the placing. The rail track over the apron was moved along laterally as the work progressed.

The same process was used for the wall with exception that the lower track was no longer required. As the wall rose, the rubble and rubble backing was filled in, so that at no time was it necessary for the coolies to lift the concrete more than a foot or so. All unavoidable handling was done in 'one man' metal bins specially obtained. The ordinary cooly basket is not at all satisfactory for handling concrete and falls to pieces after very little use.

153 cubes of 10" x 9" x 9" Winget Blocks were required for facing the Spill Wall, and the drop and wing walls of the apron. The 5:2:1 concrete for these blocks was mixed in a hand operated mixer, and hand loaded into a Winget Block moulding machine. The blocks were laid out in rows to set, and watered twice or three times daily for a fortnight.

A base line was constructed along the construction road parallel to the centre line of the Spill, and divided into 13 lengths of 37 feet and one length 27 feet, these being the dimensions of the bays.

At right angles to the prolongation of the base line about 200' North of the Right Bank Abutment, a line of concrete blocks were buried across the bund and so spaced that centre marks on the blocks lay on the vertical planes through various construction lines on the apron and wall. On the high ground near the Left Bank Abutment a line of substantial concrete pedestals were built at right angles to the base line, and on the pedestals sockets were arranged to take the tiribrach of a theodolite. The instrument positions were made to
correspond exactly with the position of the centre blocks beyond the R. B. Abutment. In setting out any line, say for example the downstream edge of the apron, the instrument would be set up on the required pedestal, levelled and sighted on the corresponding centre block on which a surveying pole would be held. The line then swept out by the telescope along the ground would be the line required.

For the batter of 1 in 12 on the wall face different position for the instrument and corresponding sighting points were worked out for each successive course of winget blocks.

Reinforcement. All reinforcement for the concrete in the wall and foundations was formed of old steel rails. Before being laid, each rail was thoroughly cleaned, and in case of the vertical reinforcement the ends of the rails were bent as shown in the drawing. The vertical rails were erected by means of guy ropes, and temporarily supported in position by timber struts and lashings.

Shuttering. This was all done by panels formed of two 9" x 1½" planks nailed together by cross battens. No elaborate construction was found necessary and rough timber struts, distance pieces, and occasional bolts were all that was required. In the case of the abutments support was obtained for the panels by means of iron staples previously fixed in the concrete. The staples were half cut through with a hacksaw before being inserted, and were easily broken off after use, the hole being plugged with mortar.

The only special shuttering required was for the Spill and Abutment coping, and for the deflecting piers. This was built up and lined with zinc sheeting. The method of support by means of temporary iron brackets is shown in one of the photographs.

Sluice. The two sluices are of simple design, consisting of concrete culvert and staunch ring, tower, forebay and wing walls. The sluice gates are of a rectangular sliding pattern.
manufactured by Glenfield and Kennedy. The R. B. Sluice gate has an orifice 5' x 3' 6" and the L.B. one of 4' x 2' 8". The lifting gear is of the usual geared screw type.

The bund is about a mile and a quarter in length and is constructed with an upstream slope of 1 in 3 and downstream 1 in 2. Whenever a breach in the ancient bund had to be filled, a central puddle wall has been provided. In cross section this wall varies in thickness according to the level. Its top width is 4 feet at High Flood Level (74.00) and the width increases by 1 foot for every five feet of depth, i.e., the side walls are built to a batter of 10 to 1.

In order to facilitate the work of closing the main river breach, the lower part of the puddle wall has already been constructed across the bed of the river. This necessitated excavating a trench 12 feet wide and 14 feet deep in the river sand in order to reach a hard clay bottom. Timbering was required, and also a small Merryweather Steam pump to deal with the water. The work was of course done during the driest part of the year, but a continual flow of water and running sand gave some trouble. 6" x 14" pinning boards and 6" x 4" walings were used for the timbering. The bottom having been reached and thoroughly cleaned of sand and debris, puddle clay was rammed in up to the existing bed levels, all struts and walings, but not the pinning boards, being taken out as the level of the puddle rose. The upstream boards were left in as they will probably be required in future when the sand upstream of the puddle wall is excavated and replaced by earthwork. The sand in the downstream side will be left where it is, as it will form a good drain, this being an essential feature of a large earth dam. Details for the actual closure of the breach have not yet been worked out, but it will doubtless be done by means of truck lines and the coolly with his inevitable basket. About 7,000 cubic yards of earthwork (26,000 cubic yards) will be required.
Materials

Metal was first obtained from a quarry in the bed of the tank, but owing to the difficulty of transport over a bad cart track and also to the rather inferior quality of the stone, this quarry was eventually abandoned in favour of a quarry near the 10th mile post on the Anuradhapura road. The stone here was found to wedge well and to be of very good quality; and although the distance from the works was greater, this was balanced by the easier transport over metalled roads.

Sand was obtained from the bed of the river and was clean and sharp. Good puddle clay was found in the bed of the tank. Cement and other materials were railed from Colombo to Anuradhapura, and carted to Tabbowa. All timber for shuttering, etc., with the exception of some special teak planks, was cut in the Irrigation Reserve, Halmilla being used. This was hand sawn into planks as required.

With reference to the metal and sand it may be mentioned that a system of measurement and payment by 'cart loads received' was introduced, the ordinary piling by cubes being found to lead to abuses on the part of the contractor. Carts were provided with wooden sides and ends, the internal dimensions of which were painted on each cart. Thus to measure a cart load of metal received from the quarry all that was necessary was to measure the depth of metal in the cart, and to note the length and breadth of same. This information together with the date, size of metal, name of metal breaker and name of carter was entered in a numbered counterfoil of a book of numbered 'tear off' chits, a chit being given to the carter as a receipt, a similar chit, bearing the same series number as the receipt and counterfoil, but without the dimensions, having been previously given by the carter to the metal breaker in exchange for the metal received. The quantity of metal was quickly calculated from the counterfoil by means of a Ready Reckoner and entered daily in a book kept for the purpose, and at the end of the month payment was made on presentation of their chits by the carters and metal breakers,
the chits being checked by the counterfoils. This system saved a great deal of trouble and worked very well. The coolies liked it as they were able to tell approximately how much money was due to them at any time from the number of chits they held, and it prevented the possible swindling, and certain waste of time, of the piling method.

A similar chit system was used for checking the quantities of sand, puddle, and wedged stone brought to the works, except that in the case of the latter actual dimensions of the blocks had to be taken.

The boiler, engine, mixer, crane, winget block machine, merryweather pump, track, and tip waggons have already been mentioned. In addition there are two concrete skips with collapsible bottom for use with the crane, portable forges, bellows, anvils, blocks and tackle, including a very useful differential pulley, some 5,000 feet of galvanised piping, several hand and three steam pumps. One of these a small Worthington, pumps water to two storage tanks, one near the bungalow and office for the use of the Staff, and the other at the works. The latter supplies the cooly lines and all water required on the works.

The force consists of two detachments from the 1st and 2nd divisions of the Ceylon Pioneers under a Sergeant and Sergeant Major respectively. These men are more or less skilled masons, blacksmiths, carpenters, etc., and are very useful on work of this nature. They are however expensive when used on earthwork, and their employment is certainly not recommended for the purpose. They are kept under a sort of military discipline and are entitled to a pension and various privileges which the ordinary cooly does not get.

There is a Check Roll Force of about a 100, and contract labour varies from about a 100 to 200 coolies. Including women and children there are about 400 persons on the works. Rice is issued weekly at cost price, and the value deducted from the coolie's pay. Two
small boutiques sell curry-stuffs and various things the cooly wants. There is also a Dispensary.

The Staff consists of the Irrigation Engineer, Two Irrigation Sub-Inspectors, a Clerk, Overseer and Sub-Overseer, a Store Keeper and an Apothecary. The work is being carried out under the direct supervision of the Irrigation Head Office, Trincomalee, and is inspected at regular intervals by Mr. R. F. Morris, Director of Irrigation.
UPSTREAM VIEW SHOWING COUNTERFORT REINFORCEMENT, RUBBLE AND SAND PACKING & PUDDLE

DOWNSTREAM VIEW SHOWING APRON & PARTIALLY COMPLETED WALL
UPSTREAM VIEW SHOWING RUBBLE & SAND LOADING FOR STABILITY

UPSTREAM VIEW SHOWING RUBBLE PACKING & COUNTERFORT ABORCEMENT
DEPOSITING CONCRETE IN WALL WITH CRANE AND SKIP

DEPOSITING CONCRETE IN SPILL WALL WITH CRANE AND SKIP
COMPLETED RIGHT ABUTMENT AND WING WALL

PARTIALLY COMPLETED SPILL WALL WITH WORK IN PROGRESS RIGHT ABUTMENT
VIEW OF DOWNSTREAM APRON AND WALL

GENERAL VIEW OF PORTION OF COMPLETED SPILL
SECTION OF FRAMINGHAM AND FITCHBURG DAMS

When water flowing over the dams reaches a depth of about 6 in., air vibrations occur which are transmitted for considerable distances, and sometimes rattle windows and dishes in houses. Note almost vertical downstream face of the two dams—Reproduced from "Engineering News"—Record—July 19, 1923.
In the absence of the author, the paper was introduced by Mr. C. G. Harward, A.M., Inst., C.E., Divisional Irrigation Engineer.

Mr. Harward in introducing the paper said:—Your Excellency, Mr. President and Gentlemen. This paper begins with a brief but interesting account of what is known of the ancient history of Tabbowa Tank and of the reasons which led to the final decision to restore it. It then gives a full description of the scheme and of the special features in the design of the works and the methods adopted in their construction.

The photographs which are reproduced at the end of the paper give a very clear idea of the nature of the work carried out on the spillway, which was by far the most important part of the work.

The paper is so clearly written and so well illustrated by photographs and diagrams that it requires practically no introduction. There is only one point of importance of which the author has made no mention, namely that the work has been carried out in an extremely malarial locality and has been greatly handicapped by the consequent ill health of the staff and labour force, and by the difficulty of obtaining and keeping a labour force under those conditions.

From the engineering point of view by far the most interesting point about this work is the design of the spill. It was originally
anticipated from the preliminary investigations and trial holes that a fairly decent spill foundation would be obtained. When, however, the site was properly opened up, it became evident that some special design of spill wall would have to be adopted.

The idea of building a gravity spill wall was abandoned principally because the ability of the ground to carry a load varied so greatly in different parts of the foundation area that serious uneven settlement was bound to take place and to cause shear to occur in such a wall. The unfitness of the ground to stand erosion by water necessitated a wide and heavy downstream apron, and the porosity of the ground necessitated a design which would give a long creep line.

Under these circumstances Mr. Balfour prepared the design of the spill as it is shown in the diagrams accompanying this paper. In order to meet the condition of probable uneven settlement the entire structure was made in 14 bays separated from each other by vertical joints, and the spill wall was separated from the apron by a vertical joint. These vertical joints were obtained by whitewashing the smooth surface between the bays to prevent adhesion.

The apron was constructed of mass concrete with a maximum percentage of plums with heavy masonry flooring on the upstream half. Each bay of the spill wall is built on a reinforced platform to provide the flexibility necessary for a support of uneven elasticity. The wall itself which is only 4 feet thick is tied back to the platform by reinforced counterforts and stabilized by loading consisting of rubble stone with the interstices filled with sand.

Weep holes are provided in the lower part of the wall to provide against any possibility of hydrostatic pressure developing.

The whole structure is backed by a puddle wall and a 2 to 1 earth slope which is protected on the surface by thin concrete, and stone pitching.
The wall itself is a simple earth retaining wall, fairly well drained by the weep holes along its lower edge and by reason of the porous nature of the sand and rubble loading, but subject to an additional load of water above the earth when a heavy spill is taking place.

The heavy downstream apron renders it quite impossible for this wall to slide on its base and also gives it a very large measure of support against overturning. In the latter respect, however, it is quite stable without the support of the apron.

There is a vertical joint between the two end bays of the spill wall and the abutments, which are simply designed to provide a watertight joint between the spill wall and the bund.

The airduct along the crest of the spill wall was a recent addition to the original design, which was adopted on account of the publication of the articles published in the Engineering News Record which are quoted by the author. It is hoped that if any of the members present today have had experience of similar phenomena they will help to throw some light on the subject.

It is hoped that the somewhat unusual nature of the design of this spill will lead to some discussion at this meeting.

It is certain that its actual performance under service conditions will be watched with great interest and care, in order to note if any measurable movement, due to unequal settlement, takes place between the various bays.

Mr. Brown.

Mr. Brown commenting on the paper said:—

Your Excellency, Mr. President and Gentlemen, In a review of the restoration, of any ancient tank a note on its former history is always interesting and frequently extremely useful to those placed in charge of the work subsequently, for enquiries as to its origin will frequently be made.

Unfortunately in none of the available records of the Island's history can any reference to the construction of Tabhowa Tank
be found, and as the writer of the paper points out the references in the Puttalum Kachcheri mainly deals with applications by the townspeople for its restoration.

The Tank was a fairly large one and irrigated an extensive tract of fields extending almost down to Puttalum itself. The present day condition of the jungle points to the fact that the Scheme must have functioned for some considerable time and down to a very remote date. The manner in which the tank was put out of action is a matter for conjecture, but from its state of ruin certain deductions can be made and some lessons can be learnt by us engineers engaged on its reconstruction.

The old bund had several small breaches and one large breach where the present course of the Naneri-Oya has found its way through the bund. Reference to the plan of the scheme—the last diagram attached to the paper—shows by the horseshoe bend of the Oya near and through the bund that this breach did not occur at the river bed; unless of course, the river has considerably deviated from its former course which is extremely improbable. Traces of the old spill have been almost completely obliterated, but it was obviously a natural channel spill protected with stone work. The inside slope of the bund was protected with stone pitching indicating probably that the tank stood long enough for the jungle in its bed to decay and perish and for the waves to derive the full advantage of the 3½ mile fetch of the Tank during the S.W. Monsoons.

There are three possible ways in which the bund may have failed:

(i) By wave erosion,
(ii) By percolation owing to faulty construction,
(iii) By overtopping.

The first method can be ruled out of count at once for the N.E. Monsoon prevails during the time of floods and as the prevailing direction of the wind is away from the bund no
waves would be formed and, by the S.W. Monsoon the water in the tank would be lowered for cultivation and the slopes protected.

The second method is disproved by the fact of there being several small breaches and one serious. The small breaches are almost certain to have been caused by overtopping and this being so, we are justified in concluding that the large breach was due to the similar cause.

There is also evidence that the spill must have been subjected to very severe usage. We may conclude then that the tank failed by overtopping caused by insufficient spill accommodation, i.e., insufficient width of spill and freeboard. With the excellent topographical maps available it is now possible to realise that the spill of Tabbowa Tank must have had and will have a considerable maximum flood discharge to deal with. The catchment area of the Tank is 160 square miles, the average annual rainfall about 50 inches and the tank proportionately to the extent of the catchment has practically no flood absorptive capacity—an effective run-off of less than 1" from the catchment will suffice to fill the tank which has a capacity of some 7,900 acre feet. The masonry spill—the key of the whole scheme—is now built substantially in concrete on up-to-date lines of economic design to a width of 508 feet so as to pass a calculated cyclonic flood of 27,500 cusecs at a depth of flow over its crest of 6 feet. The freeboard of 6 feet between Cyclonic Flood Level and top bund level allows a liberal factor of safety.

The scheme is said to be capable of irrigating 4,800 acres for coconuts, but in view of the very small run-off from the catchment necessary to fill the tank and the probability of frequent and late replenishment it is doubtful whether a more ambitious estimate of its irrigating capacity is not justified.

Any failure of the spill which will be very frequently in action and will be the factor on which the whole scheme will depend will be costly to repair.
The design of the spill wall and the precautions taken to strengthen the foundations where any doubt arose from the nature of the subsoil met with would appear to have made this structure reasonably safe, but it will be interesting to note whether the wall will be watertight for all heads. It seems probably when the tank is full that there is bound to be a certain amount of leakage between the straight joint of the top layer of puddle and the back of the spill wall just under crest level.

Leakage if small will not be of much consequence and can easily be remedied if it assumes serious proportions. On page 8, the author gives his opinion of the extreme improbability of the wall ever being subjected to full hydrostatic pressure but a glance at the section of the spill shows that this contingency has been provided for by the 9" x 9" weep holes built in the wall itself about a third up from the bottom; these are clearly seen in the photo at the bottom of plate 3. The section also shows a drystone drain running the full length of the wall floor just behind the upstream curtain wall and connected outlets through the floor to the rubble backing between the counterforts. This arrangement will obviate any pressure under the floor wall.

The aid duct so far as is known is an innovation in this type of design and its action will be watched with interest. It replaces large cutwater piers in the original design resting partly on the spill coping and partly on the concrete slabs on top of the puddle. These were bound to settle unequally and to be unsightly if they were not bodily washed off their insecure perch by high floods.

A 6 foot flood dropping over a free-fall will have some propulsive effort. The danger of having a large sheet of falling water without adequate means of air ingress to prevent adhesion to the wall is the possibility of the formation of a partial vacuum between the nappe and the wall and the setting up of indeterminate stresses.
The experience given of the American dams would tend to show that the condition of partial or complete vacuum is apt to recur with frequent periodicity.

The majority of writers on hydraulics hold that the main objection to non-aeration of the nappe is the interference with the discharge as given by accepted formula. Some hold that the discharge is less, others that it is greater than the calculated discharge, while Trautwine steers a safe course and says, "the discharge is greatly modified." There is no doubt that these writers were not thinking in terms of weirs of 500 feet length, where the result of non-aeration will be something more serious than mere modification of a formula.

**Mr. C. G. Harward.**

Mr. Harward said:—Mr. President and Gentlemen, Mr. Brown’s remarks do not require much in the way of reply. In the main I agree with him heartily that it is a very great pity that more former history of this tank is not known. With regard to the method of failure, it is possible that one of the sources of the failure of the tank may have been a breach in the line of the old Bisokotuwa. The usual ancient Sinhalese manner of building the culverts of Bisokotuwa was a very well-known source of danger to the earth bank. Leakage, owing to want of cement mortar washing away of sections of the earth work and resulting in a breach. If the breach happened in this way the rush of water must have removed nearly all the stones in the Bisokotuwa, because there is practically no trace of any ancient stones at all. With regard to the possibility of leakage through the puddle at the back of the spill wall, the backward slope of the masonry towards the earthwork would prevent leakage for if subsidence of the puddle occurs the backward slopes makes it water-tight. I do not think there is any serious danger of leakage taking place in that manner. I do not think any more of Mr. Brown’s remarks call for a reply. I very much regret the author himself is not here on the occa-
sion of the consideration of his paper. He would have answered any remarks very much better than I have done.

Chairman: Gentlemen, we have to thank Mr. Hillman for writing this paper. I am very sorry indeed we have not had the opportunity of visiting Tabbowa. I remember being there three or four years ago, when I saw some first-class work indeed. I hope sometime Members will get the opportunity of visiting this big irrigation work. I think we have to thank Mr. Harvard for the very able way in which he took Mr. Hillman's place.