TRANSACTIONS OF THE ENGINEERING ASSOCIATION OF CEYLON

THE CROSSING OF THE MAHAWELENGA VALLEY BY THE BATTICALOA-TRINCOMALIE LIGHT RAILWAY

By JOHN A. POTTS, Assoc.M.Inst.C.E.,
Executive Engineer, Railway Extensions, Ceylon.

The site chosen for the crossing of the Maha-weliganga Valley is about seven miles east of Pollonnaruwa and five miles N.W. of Dimbulagala (Gunners Quoin). It was selected mainly on account of being the shortest distance between the high ground on either side of the river. It is in the midst of Virgin High Forest mostly soft timber, but including Milla, Ranai, Satin, Halmilla and Palu while Kumbuk of enormous size are quite common. It is infested with elephants and wild pig especially in the dry-season.

The railway approaches to this crossing hang on to the high land between the Velankadu Villu and the Ambanganga on the West Bank and strike a spur running between the Gongala Villu and the Galegama Villu on the East Bank. These Villus have permanent water and in big floods spread to the Maha-weliganga and form a continuous sheet of water six miles wide. (See Plan A).

Although we have the narrowest crossing of the Valley in this area, the distance between the high land on either side is three miles. Nearly all of this three miles come under 8' of running water in an ordinary flood. (See Plan B).

(2) There are several points on Plan B to be noticed:

(a) The river itself is only 950 feet wide.
(b) The banks of the river are higher than the adjacent land. In fact the land falls
from the banks of the river until it reaches its lowest level near the Gal Ela and Papilian Ela.

(c) The Gal Ela is a channel, probably artificial, running from the junction of the Ambanganga and the Mahaweli-ganga to Velankadu Villu. The bed of this Ela is over 3 feet lower than the bed of the Mahaweliganga. Its width is 40' to 50'.

(d) The Papilian Ela is a channel, also probably artificial, running from Gongala Villu to Galagama Villu. The bed is even lower than Gal Ela being nearly 8 feet below the bed of the Mahaweliganga. It is 80' to 100' wide.

(3) After a long spell of dry weather both Up-country and locally it is possible to cross the Mahaweliganga by wading. The Gal Ela can also be crossed on foot but we can only cross the Papilian Ela at points some distance from the railway trace.

The Mahaweliganga is now of no great depth but according to old inhabitants it was 30' deep at the railway crossing 30 years ago and only half its present width. It is probable that the river has silted up owing to the opening up of Up-country estates and the consequent soil erosion.

(4) The Mahaweliganga is liable to floods during both monsoons. It has a catchment area of nearly 4,000 sq. miles which is four times larger than that of the Kelani Ganga; about ¾ of this catchment area is above the railway crossing. (See Plan C).

During the S.W. Monsoon the Up-country rains affect it considerably but the floods have never risen higher than 113.3 ft. during our observations. This level is considerably higher than the lands adjacent to the river banks, but the river does not overflow. The low land east of the river is not affected at all whereas, west of the river there is 'flooding' in parts due to water from Gal Ela.
We receive warnings of these floods from the P.W.D. Engineer at Gampola bridge who advises us by telegram the time and height of floods there. This information has been very useful. Up-country floods take about 20 hours to reach the bridge site from Gampola. This gives ample time for preparation.

The N.E. Monsoon gives a higher flood and as soon as the river reaches a level of 109.5' the adjacent low lands on the west are affected but it is not until the level of the river is 114.5' that the low lands to the east come under its influence.

The ordinary high floods which occur every year about the end of December reach a level of 115.0 feet. From the Section on Plan B, it will be seen that there is 8 ft. of water over the banks of the Papilian Ela while the east bank of the Mahaweliganga is 2 ft. above flood level. There is only 2' of water over the west bank, but 10.5 feet over the banks of the Gal Ela.

The high flood water level at Gal Ela is about 2' 6'' higher than that at the Mahaweliganga. This is partly accounted for by the Gal Ela crossing corresponding to a point higher up stream than the Mahaweliganga crossing and partly owing to the jungle banking up the water.

The 1913 flood level was 120.8' so that the east bank was nearly four feet under water during that flood. From information given by an old inhabitant the level reached by this flood was found marked on the Temple building on the east bank of the river.

(5) No reliable data about these floods existed except the heights which for ordinary floods proved fairly accurate. The flood water in the jungle was stated to be practically stagnant by sportsmen who knew the district. The villagers, however, maintained that it flowed rapidly. It is possible that the sportsmen formed their opinion from flooded Villus

**Velocities During Floods**
which could almost be called backwaters, while the villagers would get an exaggerated idea of the velocity owing to the obstruction caused by the jungle.

In our original investigations a velocity of 1.5 ft. per second through the jungle was assumed. From observation taken since we find this is approximately correct with velocities of 2.5 ft. per second at Papilian Ela and Gal Ela.

(6) The level of the embankment being constructed to carry the railway across the valley is 118.5' rising to 121.0' at Gal Ela. This is 3' 6" above ordinary flood level but nearly 2' 6" below 1913 flood level. This bank will have an average height of 12 feet.

The openings required through this embankment were considered in three sections:

(a) The Mahaweliganga itself (b) West of the river (c) East of the river.

For the Mahaweliganga a bridge of six spans each 150' clear is being erected. The bridge completely spans the main channel and is being built above 1913 flood level. It is designed to carry the road which is under construction between Pollonnaruwa and Vakaineri as well as the railway. The Piers consist of two cast iron cylinders 10' diameter tapering to 8' diameter. The abutments are two cylinders of 8' diameter throughout. (See Plan D, 1). These cylinders are sent out in sections, each section being 1/4 of a ring 6' deep. The joints of these sections are machined and when they are bolted together, a thin coating of red lead makes them watertight. The bottom ring has a cutting edge. To get the top of the cylinders to the correct level there are making up rings of 4", 2", 8" and 1' 4" depth, any difference less than 1' 4" can be made up by adjusting the cylinder cap. The weight of the heaviest section is 1 ton 9 cwt., the thickness of the 10' section being 1 1/4" and the 8' section 1 1/4".
The Superstructure is made up of through Pratt Trusses 22' 4" deep with the usual cross girders and rail bearers for railway traffic and in addition troughing to carry the macadam for road traffic, (Plan D).

The steel work in each span weighs 214 tons. This is 57 tons heavier than the spans over the Deduru Oya on the Puttalam extension which are of the same general design, but which do not carry a roadway. The heaviest pieces are over 5 tons weight which is excessive for construction purposes in out-of-the-way places. The length of some pieces is 44'. This adds to the difficulty of getting the material on site.

The steelwork was ordered in 1921 at a cost of £20 16s. per ton including inspection, shipping and freight charges. Complete detail plans are on the table for anyone who cares to examine them.

On the west of the river 47 spans of 30' are to be erected. On the east bank 16 spans of 30', 11 spans of 12' and one span of 150' are being used. The 150' span is to be erected at Papilian Ela above 1913 flood level. The 30' spans are three feet lower which is ample height for any but very extraordinary floods. The weight of each 30' span is 54 tons. This steelwork was ordered in 1923 and cost £91 7s. 2d. per span including freight, etc.

The calculated velocity through these openings is 61' per second. The formation level of the embankment between the openings is 2' 6" below the formation level of the bridges. Should another 1913 flood occur there would probably be damage to the banks, but the bridges should remain.

(7) To construct these permanent bridges in the heart of the jungle before railhead reaches the vicinity is practically impossible. It was decided to run a construction line across the valley for the following reasons:—(a) To facilitate and expedite the erection of the permanent bridges. (b) To lay the permanent
(c) To transport the superstructure of the Valaichchenai bridge so that its construction could be carried out simultaneously with the Mahaweliganga bridge. This construction line runs along the toe of the bank and is under 10' of water at high floods, but as these floods do not last more than 10 days and usually occur only once in the year this interruption is not of vital importance.

Temporary timber bridges are built across the Gal Ela and the Mahaweliganga to carry construction trains and to assist in the erection of the Permanent bridges without additional falsework. They are constructed of trestles made with four 12" x 12" piles at 6' centres and spans of 12' with the necessary runners and bracings. There are 76 spans across the Mahaweliganga and these are built 3' 6" below ordinary flood level.

The first high floods bring down an enormous amount of debris which includes very large trees. The water itself is hardly visible and it would appear almost possible to walk across the river on the debris. The bridge is built below flood level to allow this debris to pass over it.

Transport (8) Even to construct these timber bridges the transport difficulties have been very great. No plant could be delivered on site until the railhead reached two miles beyond the Kandy-Anuradhapura road crossing. From this railhead to Pollonnaruwa there was a transport of 2½ miles on gravel roads and 31 miles on metal roads. This had to be done by bulls as buffaloes cannot work on metal roads more than a day or two at a time.

From Pollonnaruwa buffaloes had to be used as there was a rough jungle track of 8 miles to the Mahaweliganga including the crossing of the Gal Ela where the carts had to be pulled
through with block and tackle. It was impossible to transport along this track once the rains had set in. There are practically no transport animals in this neighbourhood and carting contractors from other parts would not undertake work in this district. Eventually this work was taken up at Rs. 0.90 per ton mile up to Pollonnaruwa and Rs. 1.00 per ton mile from Pollonnaruwa to the Ganga.

(9) Construction work has been interrupted all the year round by floods which reach the runners of the bridge and make pile driving impossible. The main temporary bridge has about 20,000 c. ft. of timber mostly Ranai which was obtained locally. Owing to the length of piles (30') considerable difficulty was experienced in getting the quantity. To transport this timber to the bridge site meant cutting many tracks through the jungle and bridging the streams. The difficulty of getting a 30' log slung below a cart through virgin jungle with only 6' clearance can be well imagined. Buffaloes from Batticaloa district were used for this work. On the up-stream side of the bridge the timber was brought to the side of the river, formed into rafts and floated down. As the timber would not float itself logs of Wild Mango and Lunimedilla had to be used to give it the necessary buoyancy. These rafts cannot be floated down when the river is low so that a small flood has to be utilised. The high S.W. Monsoon flood of June, 1923, caught two rafts before warning could be given and took these some miles down-stream. It was fortunate that no lives were lost. The men in charge of these rafts managed to scramble ashore with difficulty. This flood came down in a 4' wave. In the transport of this timber seven buffaloes were lost at different times in the floods.

(10) To construct the Temporary Timber Bridge, a double Pile driver made from a design by Mr. Clifford Lake was used and as the design is unusual and it worked very much better than an ordinary pile driver a sketch is given (Plan E). Unfortunately it was not
mobile and was caught by a flood and thrown into the river. After this a two-and-a-half ton crane with leaders was used. This worked even better than the double pile driver, and although not a new idea there are probably sufficient members not acquainted with it, to justify a sketch (Plan F).

(11) The timber structure for controlling and sinking the cylinders of the Permanent Bridge is being erected, and cylinder sinking has commenced on the West abutment. Plan G shows the timbering for this work. A single-chain Priestman's Grab is being used. Only one pair of cylinders has been sunk and up to the present no very interesting difficulties have been encountered.

When about 30' down the formation is partly coarse sand and a sand conglomerate approaching soft sand stone. We have had to break down this material as the grab would not tackle it. Pointed rails were partially successful but a heavier breaker improvised with a 1 ton monkey and four pieces of pointed rails as shewn in sketch has done this work much better. (Plan H).

(12) The foregoing part of this paper was written before the flood of December, 1923, which proved an exceptional one being 2' 6" higher than any normal flood which has been registered. This high flood coincides with the cycle of floods in Ceylon which occur approximately every ten years. During this flood continuous investigations of velocities and depths of flood water were taken. Stationary maximum velocity meters improvised by Mr. J. L. Sanders (one of which is on view on the table) were placed in different parts and velocities were also taken throughout the flooded area by means of current meters used from boats.

At highest flood, velocities of the main river could not be taken. When the flood was at various lower levels velocities were taken. The graph plotted gave a maximum velocity at
the highest flood of 9—10 ft. per second. The silt from the river was reported to be visible for 40 miles out to sea.

(13) The Mahaweliganga Temporary Bridge was about 1/5 built before the 1922—23 floods and stood the test well. It was practically completed before the 1923—24 flood. This flood came down, not as one flood, but as a series of 3, one on top of the other. On the 12th December, 1923, there was a flood slightly below normal high floods. This flood went down and we were able to clear the bridge of the debris that had collected before a second flood came down on the 15th of December. This second flood reached a little above ordinary high flood level and then began to subside. It did not subside enough for the bridge to become visible but a smooth space in the water made us assume that about 10 spans in the middle of the bridge had gone although no one had seen it go. Before the second flood subsided even to the level of the bridge which would have enabled the debris to be cleared away a third flood came on top of it and rose to 2½ 6" above ordinary high flood level.

The bridge could not stand the strain and a large part of it broke away in three parts rolling over in its progress down stream.

(14) The bridge itself would naturally produce scour and the debris, which did not pass over it but got entangled on the up-stream side, would decidedly increase this scour. When the bridge went, the downstream piles seemed to act as a fulcrum, the force of the current on the debris and the upstream side of the bridge tending to lift and turn it over.

Although a similar flood to the 1923—24 flood is unlikely to occur for another 10 years it has been decided not to risk the construction of another temporary bridge.

(15) To erect the superstructure of the Permanent Mahaweliganga Bridge, Falsework is being erected consisting of trestles made up
of four piles at each panel point with the necessary runners and bracing. The girders will be built on site. Not more than two spans of falsework will be in the river at one time and erection will be discontinued during the N.E. floods.

The abutments and the piers of the smaller spans are being built with 6 to 1 cement sand facing blocks with concrete hearting. The girders will be placed in position by a crane working on the construction line.

Labour.

(16) The labour question has been extremely difficult. Malaria and dysentery which usually accompanies the opening up of land in the low jungle country was experienced. Contractors and coolies will only work for spells of two or three months at a time; this does not facilitate the forming of highly trained gangs. Food-stuffs have been brought mostly from Batticaloa. Up to the present this has necessitated transport of 20 miles metal road, 12 miles of gravel road and 23 miles of jungle track, which is almost impassable during the rainy season.

(17) Mr. J. I. Sanders is the Assistant Engineer, in charge of the section of which the Mahaweliiganga forms part, and Mr. Barrow is the Bridge Erector.
21 SPANS MAHAWELIGANGA TEMPORARY BRIDGE
ROCK BREAKER

1 Ton Monkey

Fitted with Rail Teeth

1" Dia. Bolt - 2 No.
at upper end of Monkey

1" O.D. Bolt - 4 No.
at lower end of Monkey

1" O.D. Bolt in 6" pipe

Rail 40 lb. section

Length 7 ft.

1.5" Tensile strength

Monkey - Cast Iron 3' high x 1.2' x 1.2'

With boss for leader bolts

PLANT H
DISCUSSION.

3rd Paper.

The CHAIRMAN: Unfortunately for the third time the author of the paper is not here. Mr. Bakewell has kindly undertaken to introduce it.

Mr. BAKEWELL: Gentlemen, if you will kindly take this paper as read, I will endeavour to answer any questions:

Mr. MEADEN: Mr. President, and Gentlemen, I should like to open this discussion by asking a few questions:

1. What is the anticipated difference of water level upstream and downstream of the embankment across the Mahaweli Ganga during both moderate and high floods?

2. I should like to ask whether any special provision will be made for protecting the railway embankment against damage due to such conditions.

3. Has the probable increased high flood level due to the artificial interference with the natural river flow been taken into account and provided for by waterways under the bridges and over the low sections of the embankment?

Mr. BAKEWELL: The calculated difference of water level up and down stream is about 12 inches for moderate and 15 inches for high floods. This head of water will disappear as the stream scours out.
The ends of all embankments will be protected by stone pitching and the sides of the embankment protected with wattles.

The main bridge only was designed to be above 1913 floods. The embankments and flood outlets have been raised to be above 1923 flood.

If a flood much over 1923 flood occurs the banks will be topped.

Mr. A. C. Cooper.

Mr. A. G. Cooper said:—Mr. President and Gentlemen: The problems connected with the bridging and training of rivers are of high interest to Engineers, especially in countries such as Ceylon, where owing to extraordinary rainfalls, they are subject to heavy floods and the difficulties in dealing with them greatly increased. In locating and designing a bridge with its flood openings, such as that crossing the Mahaweli, the Engineer will have a number of points to take into consideration.

In referring to the site, the author says that it was selected mainly on account of being the shortest distance between the high ground on either side of the river, while in another part of the paper he gives us the information that in sinking the cylinders for the West abutment, at a depth of 30 feet the formation was found to be partly coarse sand and a sand conglomerate approaching soft sandstone. He makes no further reference to the location of the site, but no doubt a number of places were investigated before the final selection was made.

The main bridge over the Mahaweli consists of 6 spans of 150 feet; the remaining openings consisting of 1 of 150 feet, 63 of 30 feet, and 11 of 12 feet, span the two Ellas and provide the flood opening required. The calculated velocity of the water through these openings being 64 feet per second or about 44 miles per hour. The highest flood level recorded is that of 1913, and the information is given that the six spans of 150 feet over the Mahaweli and the single span of 150 feet
over the Papilian Ella, will be built above this level, the remaining spans grouped as shown on Plan B will be built slightly below it.

The author says that the formation level of the embankment between the openings is 2°6" below that at the bridges. No longitudinal section of the bank is given, but, presumably, it dips between the groups of openings, with the object of allowing a maximum flood to spill over it somewhere between them. No mention is made of any form of protection to the embankment, and if this be not provided, it is probable that a maximum flood would scour out and breach it between the bridges with consequent interruptions to traffic while repairs were effected.

The distance between the high land on either side of the crossing is given as 3 miles, and if short periodical interruptions to the train service on this line are not considered serious, a very considerable saving in first cost might possibly be effected, by building the openings over the main channels, above maximum flood level, grading down the formation between and on either side of these openings and laying the track through the dips on a stone causeway with well consolidated stone ballast to allow the flood to pass over the top of it. If this were possible, a large number of the flood openings might be omitted.

The 150 feet spans are to be carried on cylinders, and if these are sunk well into the sandstone, there should be no danger from scour, although, as a precautionary measure, it might be advisable to tip a certain quantity of rubble stone round them. The abutments and piers of the smaller spans are to be of concrete, the foundations, I understand, being taken down about 6 feet below ground level. The embankment between these openings crosses the flood area. During a flood, the current coming up against the bank will turn along it towards the openings where it will sweep round, tending to breach the embankment in the rear of the bridges, and will attack the abutments in flanks, tending to undermine the foundations.
In the discussion on a paper read by Mr. Stoney, M. Inst. C.E., before the Institution of Civil Engineers in 1908 on "Extraordinary Floods in Southern India, their causes and Destructive Effect on Railway Works," Sir Bradford Leslie, R.C.I.E., and other speakers, in referring to shallow foundations for piers of bridges under similar conditions to those obtaining in the bridge under discussion, advocated protection in the form of inverts between the abutments and the piers, with drop walls, both on the Up and Down stream sides and rubble stone outside the drop walls forming aprons to prevent scour. An economy might be made by placing rubble stone between the drop walls instead of building the inverts.

One need not draw the attention of Engineers to the value of large rubble stone, or rip-rap, in arresting scour, and I would advocate the pitching of the embankment across the flood area along the Up stream side, where it will be affected by the current. Also on the Down stream side near the openings and where the level of the formation is such that a maximum flood will spill over it.

With regard to the Steelwork, I understand that the 150 feet spans are designed for the Ceylon Government Railway Maximum Probable Loading, which is the standard for all new spans and in which the heaviest axle load is taken as 18 tons, while the smaller spans are designed to carry a loading in which the heaviest axle load is assumed to be 10 tons. The new Northern Line engine has an axle load of approximately 9 tons, which at ordinary running speed is nearly as much as the rail laid on the B.T.L.R. which weighs 46½ lbs. per lineal yard, will safely take. If during the life of the spans, owing to increase in traffic it is decided to relay this line with heavier rails, in order to carry more powerful and heavier engines, it would be necessary also to renew or strengthen the large number of smaller spans. As the 150 feet spans have been designed to carry the Maximum Probable Loading, it might have been ad-
visable to have designed the smaller spans to the same standard.

Mr. Bakewell: In regard to the site, the river was examined, both up and down stream of the present bridge site, before deciding upon the crossing. No borings were taken except at the actual site. The sand stone encountered in the west abutment has not been met with in sinking No. 1 Pier and it is probable that it is quite local.

The embankment dips between the flood openings with the object of allowing a maximum flood to flow over. The banks have not been protected against a maximum flood and, if any occurs the banks will breach and traffic will be interrupted as has happened in other parts of the railway system in maximum floods.

If the railway formation were graded down to a causeway on ground level from the main openings there would be considerable interruption to traffic from minor floods throughout the year. If the causeway were placed high enough to escape minor floods it would cost as much if not more than the flood openings.

It is intended that a certain amount of scour should take place in the river bed. Should this tend to become deeper than is considered safe rubble will be tipped into the bed of the river.

It is proposed to protect the flood openings by rough stone inverts between drop walls.

The 150 feet spans carry both road and railway, the flood openings carry the railway only: If at any time it is found necessary to carry heavier engines over this railway it would be an easy matter either to replace or strengthen the small span bridges without interruption to traffic, whereas it would mean a total stoppage of traffic to replace the 150 feet spans.

The Chairman: Is there any gentlemen to ask any questions or offer any remarks to this discussion. There being none the Chairman thanked Mr. Potts for the Paper and Mr. Bakewell for the way in which he took Mr. Pott's place.