TRANSACTIONS OF
THE ENGINEERING ASSOCIATION OF CEYLON

CONSTRUCTION OF A CONCRETE RAILWAY VIADUCT IN CEYLON.

BY

HAROLD CUTHBERT MARWOOD,
M.Inst.C.E.,

Executive Engineer, Railway Construction Department, C.G.R.

The Badulla Railway Extension starts from Bandarawela at an elevation of 4,100 feet above sea level and descends through mountainous country for a distance of twenty miles to Badulla, a provincial town situated in the midst of a large tea-growing district, at an elevation of 2,000 feet above sea level.

2. The railway, being an extension of the main up-country line from Colombo has a 5 feet 6 inches gauge, with minimum curves of five chains radius and a ruling gradient of 1 in 44.

The nature of the country traversed made heavy earthwork, and rock cutting unavoidable throughout, and six tunnels of 100 yards or so in length had to be constructed where cuttings would have proved more costly.

3. Numerous viaducts, bridges and culverts had to be constructed to span the many mountain torrents that crossed the centre line. The largest concrete viaduct is situated at 9m. 20c. from Bandarawela and 1¼ miles from Ella, the nearest station.

A brief description of the design and construction of this viaduct is recorded here, as it is the largest one of its kind in Ceylon, constructed entirely by native labour under British supervision and direction.

4. The railway is on a nine degree curve (6.37 chains radius), at the site of the viaduct and the gradient is 1 in 44. The sharp curve and nature of foundation made it desirable to adopt nine spans of 30 feet; and semi-circular arches of 15 feet radius left the least room for failure due to acts of carlessness arising from the class of labour employed, and the shortage of skilled supervision.

The greatest height from rail level to bed of stream is 100 feet 6 inches and the length of the viaduct is 400 feet.

5. *Design*:—The considerations which governed the design of this structure were threefold, namely, the curve, the gradient and the foundation.

The curve limited the spans to 30 feet, as already mentioned.

The gradient, which is severe, is provided for on the piers, and the two springings of each arch are at the same level.

The foundation material consists of cabook with small quantities of mica, and the resistance of this material to considerable pressure was doubtful, especially as cuttings in the vicinity were slipping badly. It was, therefore, desirable to found well into the slopes of the ravine and spread the weight as far as possible.

The dead and live load, together, on the foundation of the heaviest pier is approximately 3.3 tons per square foot.

Piers 4 and 5 were founded on a bottom of cabook and boulders.

6. By reference to the plan, it will be seen the curve is provided for in the piers, the spans being parallel and the piers wedge shape.

Jack arches are left in the piers to save materials which would otherwise have been built into the work unnecessarily.

7. Provision for supporting the arch centres during construction was made by introducing concrete cornice blocks at four feet centers, which projected beyond the springing face of the pier, nine inches, and supported the temporary timbering and wedges used for holding the arch-centers in position. Drawings of this detail, and of the arch centers used for the work, accompany this paper. The arch centers, as designed, were placed 4 ft. center to center and were supported on wedges which were struck after the arch had been turned two weeks. The wooden centers were supported vertically by timber bracing, and 3 inch laggings, laid over the centers, completed the false work upon which the permanent arch was turned.

The arches were designed to consist of concrete blocks the full width of the arch (2 feet 6 inches), but on the ground, blocks of that size proved difficult to handle without the necessary plant, and blocks of smaller size were adopted, each arch was formed of two rings of these. Semi-circular arches are usually adopted in high viaducts where head room would not be restricted. The advantage they have over shallow segmental or elliptical arches in a viaduct of several spans is their greater stability, the thrusts on the supports being more vertical, tending less to overturn the pier, should any accident to the temporary centering occur before the material of which the arch is made has set. In appearance, the elliptical arch has the advantage. The writer was some years ago engaged on the construction of an elevated railway carried on steel bridges and brick viaducts through a thickly populated district of London. One of the viaducts had 80 spans of 30 feet and in order to restrict the enormous damage that might result from the collapse of an arch during construction, "stop" walls were built in every fifth span. Fortunately no such calamity arose on that work but cases have occurred, within the memory of most of us, where carelessness in workmanship or faulty centers have led to failure and caused the collapse of a series of piers in a long viaduct under construction.

8. *Setting Out*:—This was done with one theodolite from one end, the centre of each span on the centre line of the railway being permanently fixed in concrete. When this was done the centre line of each of the spans was permanently fixed by concrete pickets placed well away from the work, on each side of it. From these lines indicating the centers of spans the work was set out and constructed. These centre lines were at right angles to the tangent of the curve of the railway at the centers of the spans. All works of construction require accurate working drawings to obtain the best results, and in the case under review this important fact was emphasised, as without them, and constantly checking dimensions and levels at the site, the necessary accuracy could not have been obtained to provide the correct spans at the top of the piers for the arches to be turned.

9. As regards materials, cement of British manufacture was employed.

Stone and sand for concrete were obtainable in the vicinity of the work. Arch centers and other woodwork were made locally from imported Burmah Teak.

10. The mass concrete in piers and abutments was made in the proportion of 6 parts broken stone, 3 sand and 1 cement, and the arch blocks and cornice blocks of 3: 2: 1 concrete.

The spandril filling consisted of 8 : 4 : 1 concrete rendered and sloped to drain away surface water to pipes built through each arch to discharge it. The mass concrete and face work were built up in 2 ft. layers.

11. In view of the expense of timber for shuttering and the difficulty of obtaining satisfactory results locally from this source the concrete is faced with sand cement blocks, 20 inches by 10 inches by 6½ inches, in size. These blocks were made in moulds locally, in the proportion of 1 part cement to 6 parts sand. The ingredients are mixed together dry and again, slightly damp. The material is then rammed into the mould, smoothed off, taken out as a block and allowed to dry for one day, after which it is placed in water for a week, or longer if possible, where it matures and becomes ready for use.

12. The only plant used on the work was a concrete mixer, one crane and two Scotch Derricks. Temporary scaffolding was erected and built up with the piers, forming platforms between them and consisting of rails bolted and braced together.

13. The work was completed in January, 1919, two years after commencement, and it has stood the wear and tear of railway traffic since, without settlement.

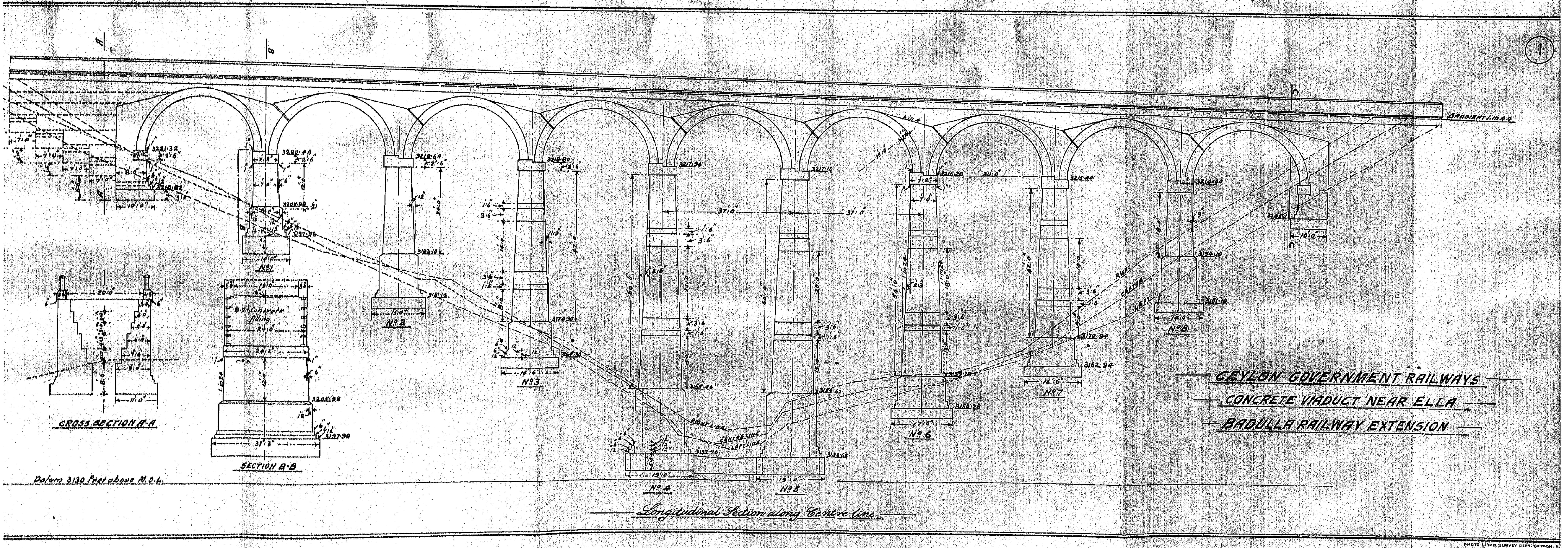
14. Railway Construction in Ceylon is carried out by the Railway Construction Department, a temporary branch of the Public Service.

The work is carried out Departmentally and with the assistance of local petty contractors who supply the labour.

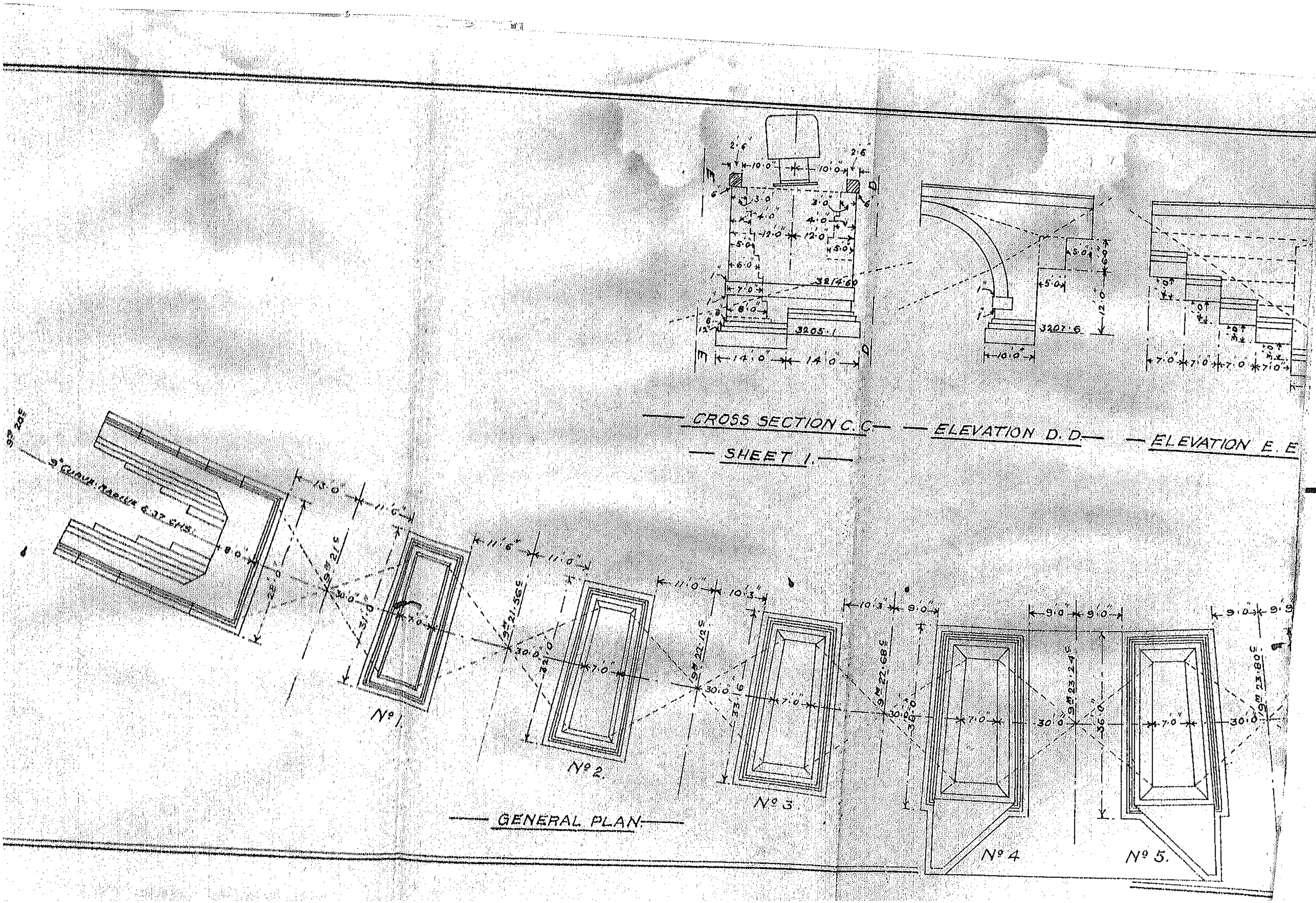
This Department, with the authority of Government, usually fixes the rates for the work and provides accommodation and rice for the labour in outlying districts, such as the one under review, which is approximately 170 miles from Colombo, the base of supplies.

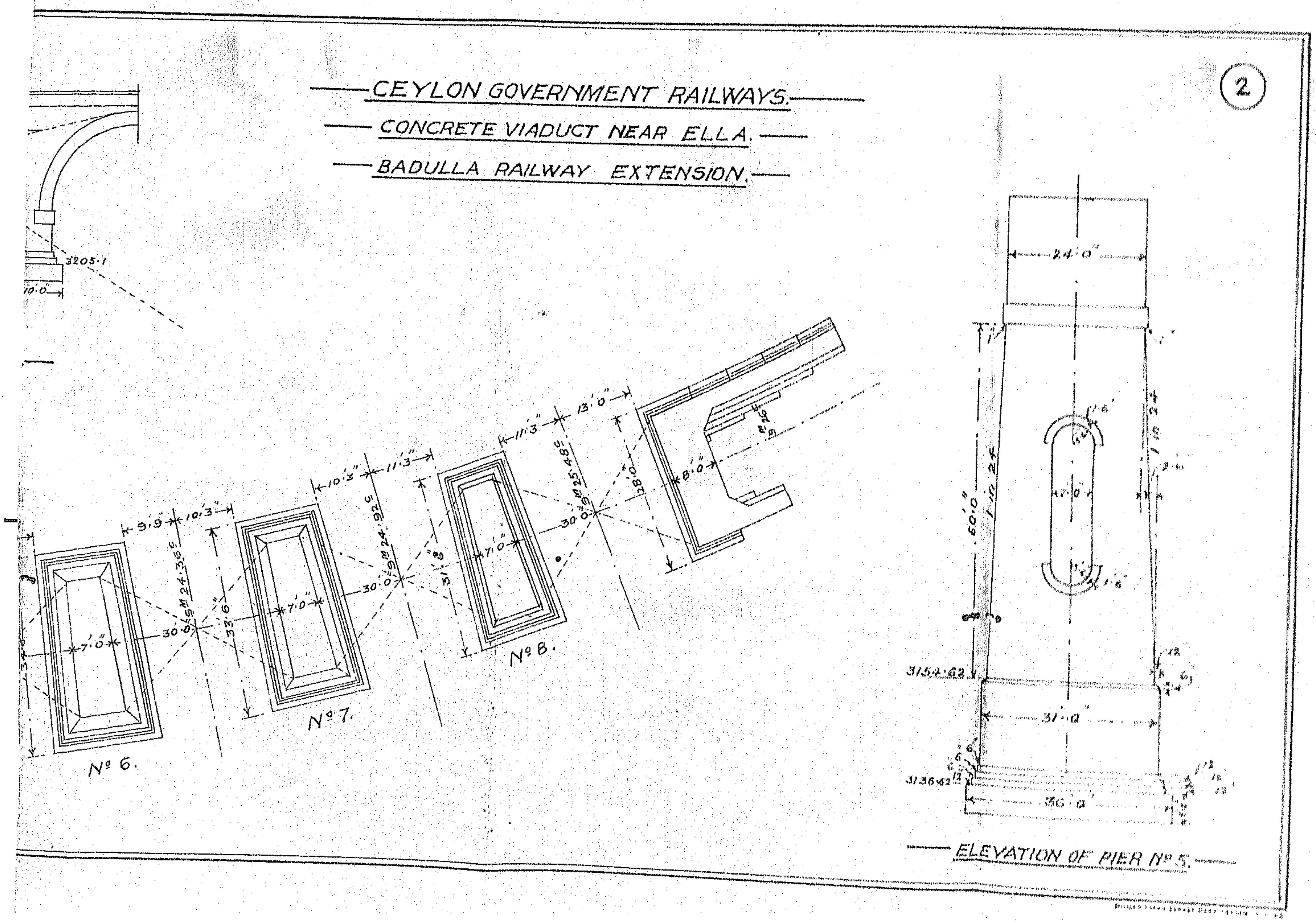
The viaduct was one of three on the Ella Section of the Railway Extension referred to herein, and a portion of the work of the Department above mentioned.

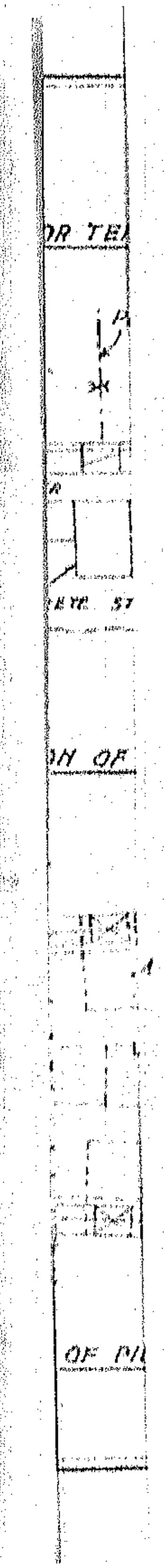
15. The designs were prepared and the work put in hand by the author as Engineer in charge of that Section of the railway, to the approval of Mr. M. Cole Bowen, B.A.I., M. Inst.C.E., Chief Construction Engineer, Railway Extensions, to whom the writer is indebted for permission to furnish these particulars and copies of the two drawings attached



CEYLON GOVERNMENT RAILWAYS
CONCRETE VIADUCT NEAR ELLA
BADULLA RAILWAY EXTENSION
Longitudinal Section along Centre line
CROSS SECTION A-A
SECTION B-B
Datum 3130 Feet above M.S.L.
GRADIENT LIN 44
No 1
No 2
No 3
No 4
No 5
No 6
No 7
No 8
RIGHT LINE
CENTRE LINE
LEFT LINE
8-2-1 Concrete filling
PHOTO LITHO SURVEY DEPT. CEYLON

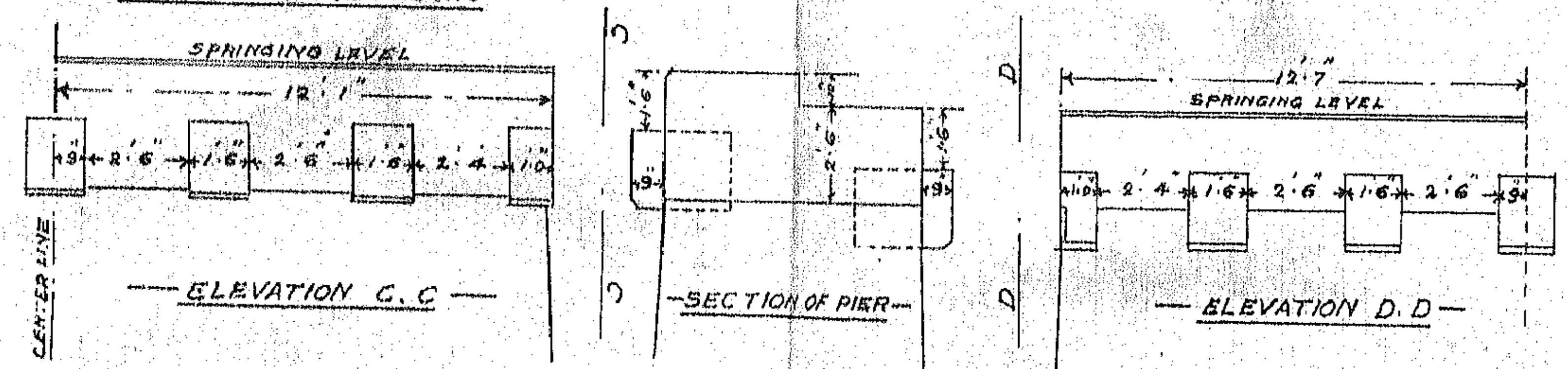

CROSS SECTION C.C
ELEVATION D.D.
ELEVATION E.E
SHEET 1.
GENERAL PLAN
No 1.
No 2.
No 3
No 4
No 5.
3214.60
3205.1
3207.6


CEYLON GOVERNMENT RAILWAYS.
CONCRETE VIADUCT NEAR ELLA.
BADULLA RAILWAY EXTENSION.
2
3205·1
Nº 6.
Nº 7.
Nº 8.
9·9
10·3"
10·3"
11·3"
11·3"
13·0"
30·0
7·0"
33·6
24·0"
50·0"
1 in 24
31·0"
36·0"
3154·62
3136·62
ELEVATION OF PIER Nº 5.



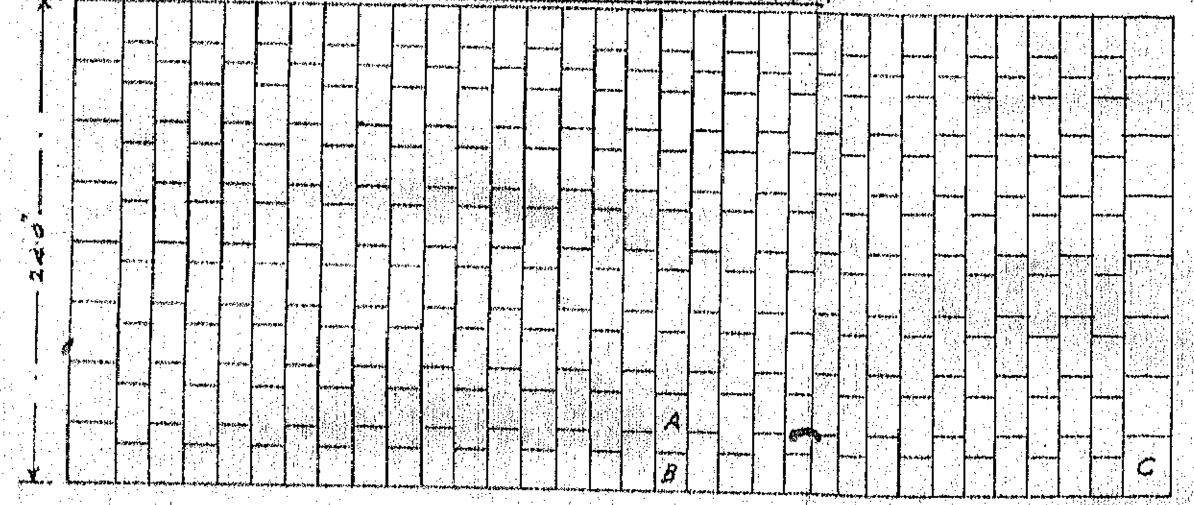
CEYLON GOVERNMENT RAILWAYS
CONCRETE VIADUCT NEAR ELLA
BADULLA RAILWAY EXTENSION
DETAILS OF WORKS

VIADUCT AT 9 MLS 23 CHS



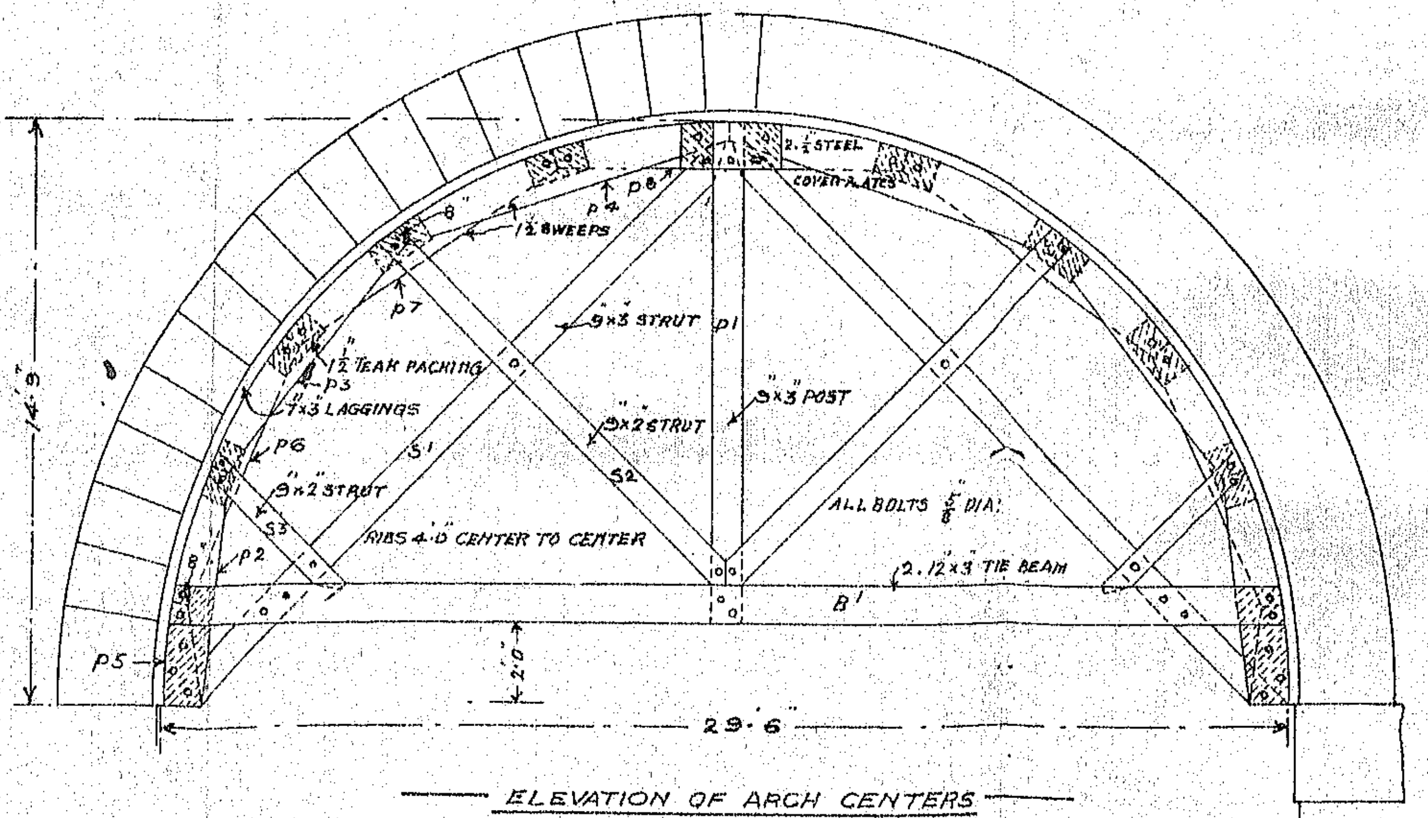
ELEVATION C.C — SECTION OF PIER — ELEVATION D.D

DEVELOPED PLAN OF ARCH



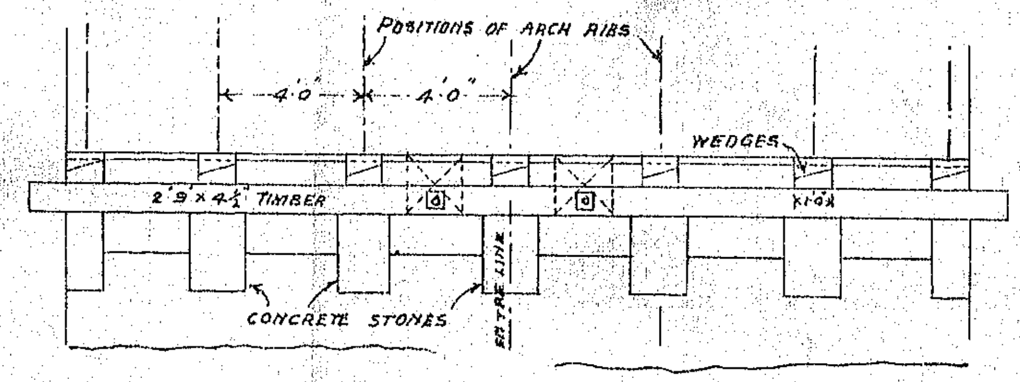
LIST OF BLOCKS REQUIRED FOR ONE ARCH

	Nº REQ	DIMENSIONS OF BLOCKS LENGTH	HEIGHT	TOP BREADTH	BOTTOM BREADTH	APPROX. WT OF EACH BLOCK
A	216	3'·0"	2'·6"	1'·6 3/4"	1'·3 1/4"	1442 LBS
B	48	2'·0"	2'·6"	1'·6 3/4"	1'·3 1/4"	975 LBS
C	16	3'·0"	2'·6"	2'·4"	2'·0"	2193 LBS

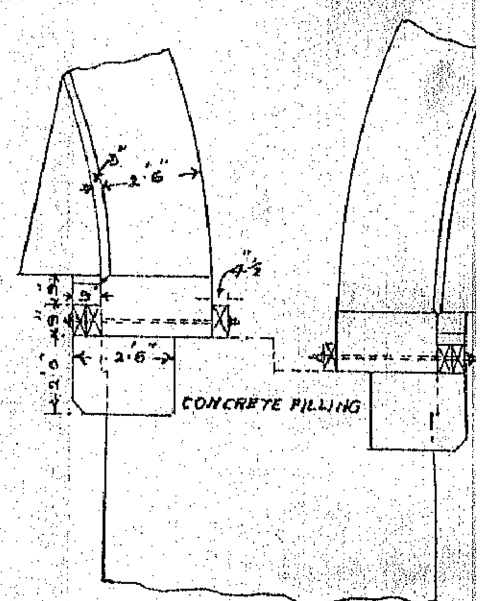


ELEVATION OF ARCH CENTERS

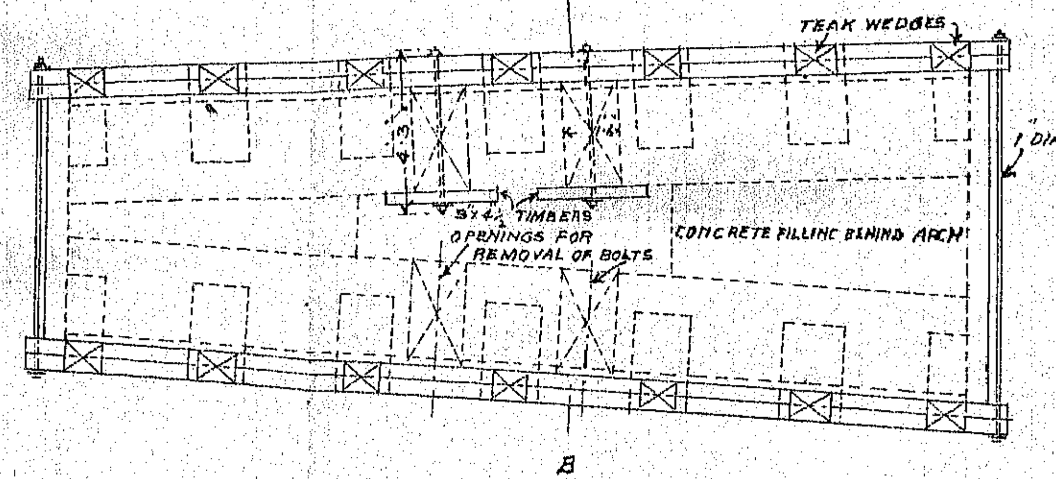
METHOD FOR TEMPORARILY SUPPORTING ARCH RIBS



ELEVATION OF PIER AT SPRINGING OF ARCH



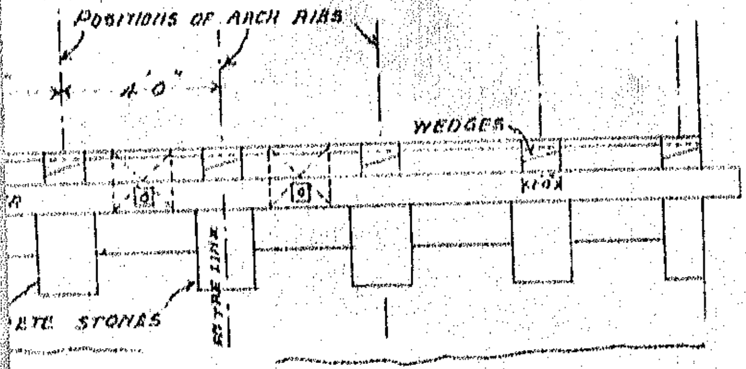
SECTION A.B.

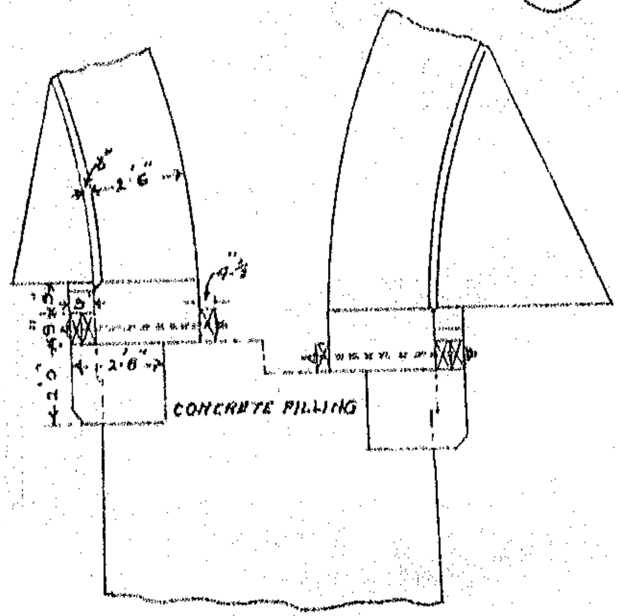


PLAN OF PIER AT SPRINGING OF ARCH

③

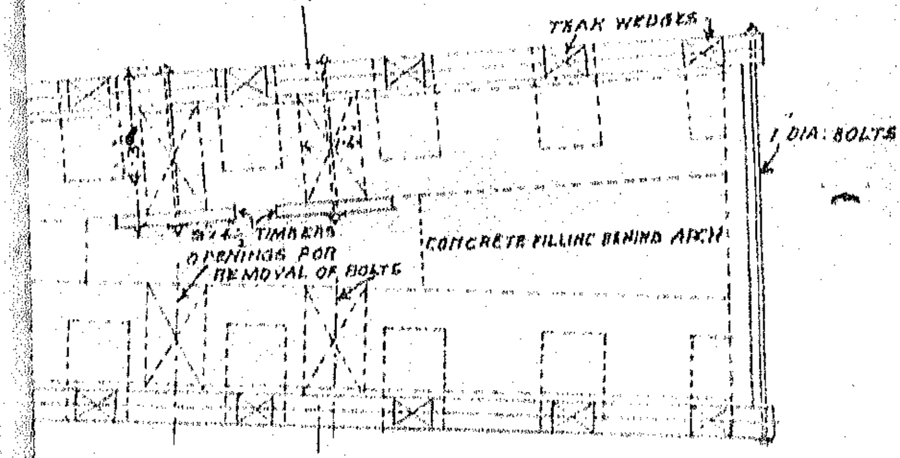
OR TEMPORARILY SUPPORTING ARCH RIBS





ON OF PIER AT SPRINGING OF ARCH

SECTION A.B.



OF PIER AT SPRINGING OF ARCH

DISCUSSION

Mr. M. Cole Bowen: Mr. President and Gentlemen, I think we are indebted very much to Mr. Marwood for having written this paper. Mr. Marwood is chiefly concerned with the design in his paper but I am sorry to say I do not think he has dealt enough in detail. The difficulties of building a viaduct like that are due to the very difficult transport which we had of all materials. The viaduct as stated is some two miles from any road in steep country and nearly all the transport had to be done by pack bulls. The reason that a concrete viaduct was decided on and not a steel one was that steelwork was impossible to obtain from England. A large amount of cement was available at a reasonable price in the Colony. So it was decided to build the viaduct of cement concrete. When the cement ran short, the cost of getting new cement was very high indeed. We had intended to carry out the same designs on other bridges between Demodera and Badulla, but with one difference, increasing the span of thirty feet to forty-five feet arches. This we intended doing with the advice of the Consulting Engineers in London, I am glad to say the bridge is throughout on very good foundations, no settlement has occurred or is likely to occur. We must again thank Mr. Marwood. I am sorry he is not here to read his own paper, owing to his illness and to Mrs. Marwoods' illness.

The President: Unless any other Member present would like to make some remarks on this very interesting paper, the business for the day is concluded.
