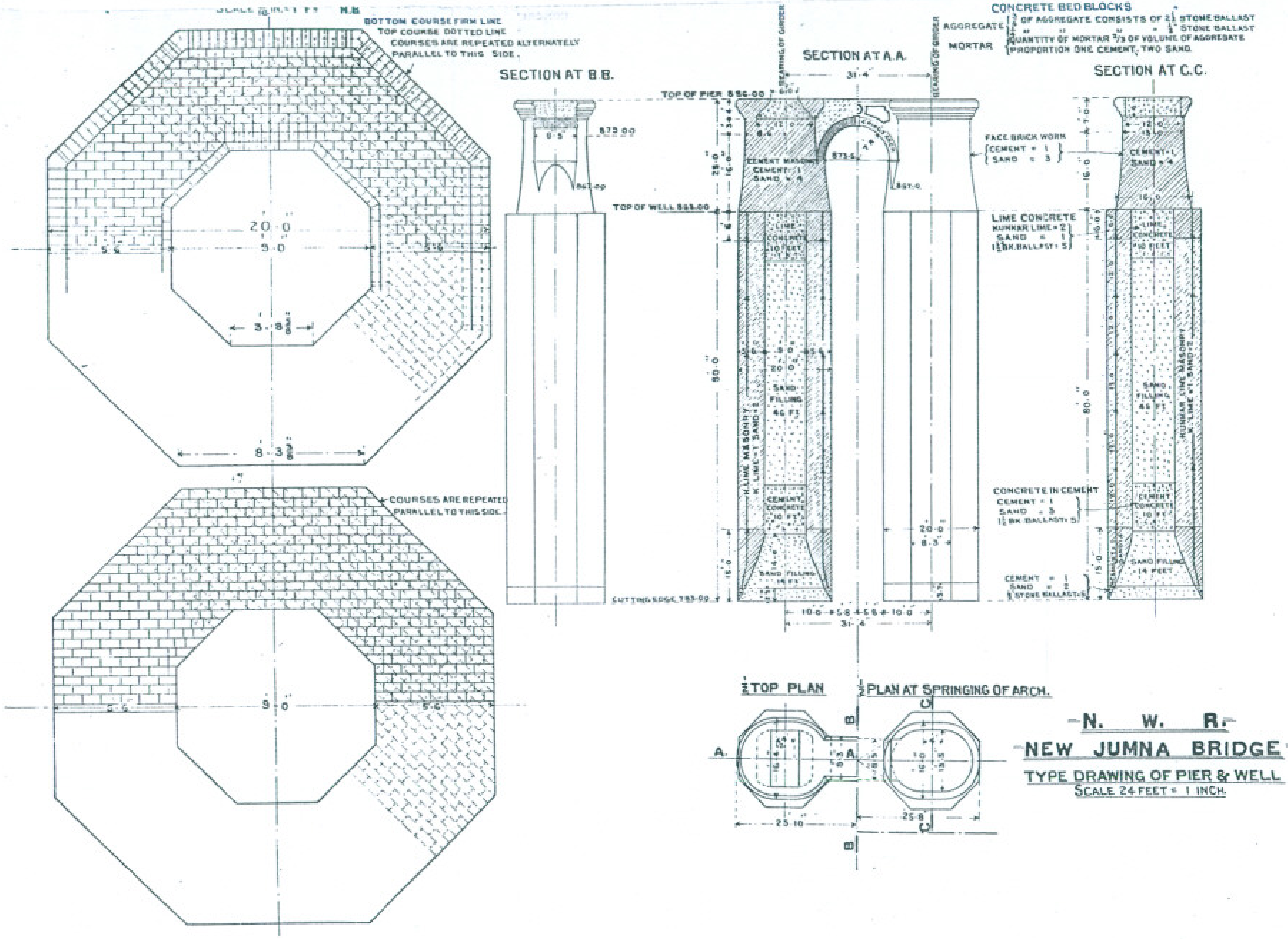
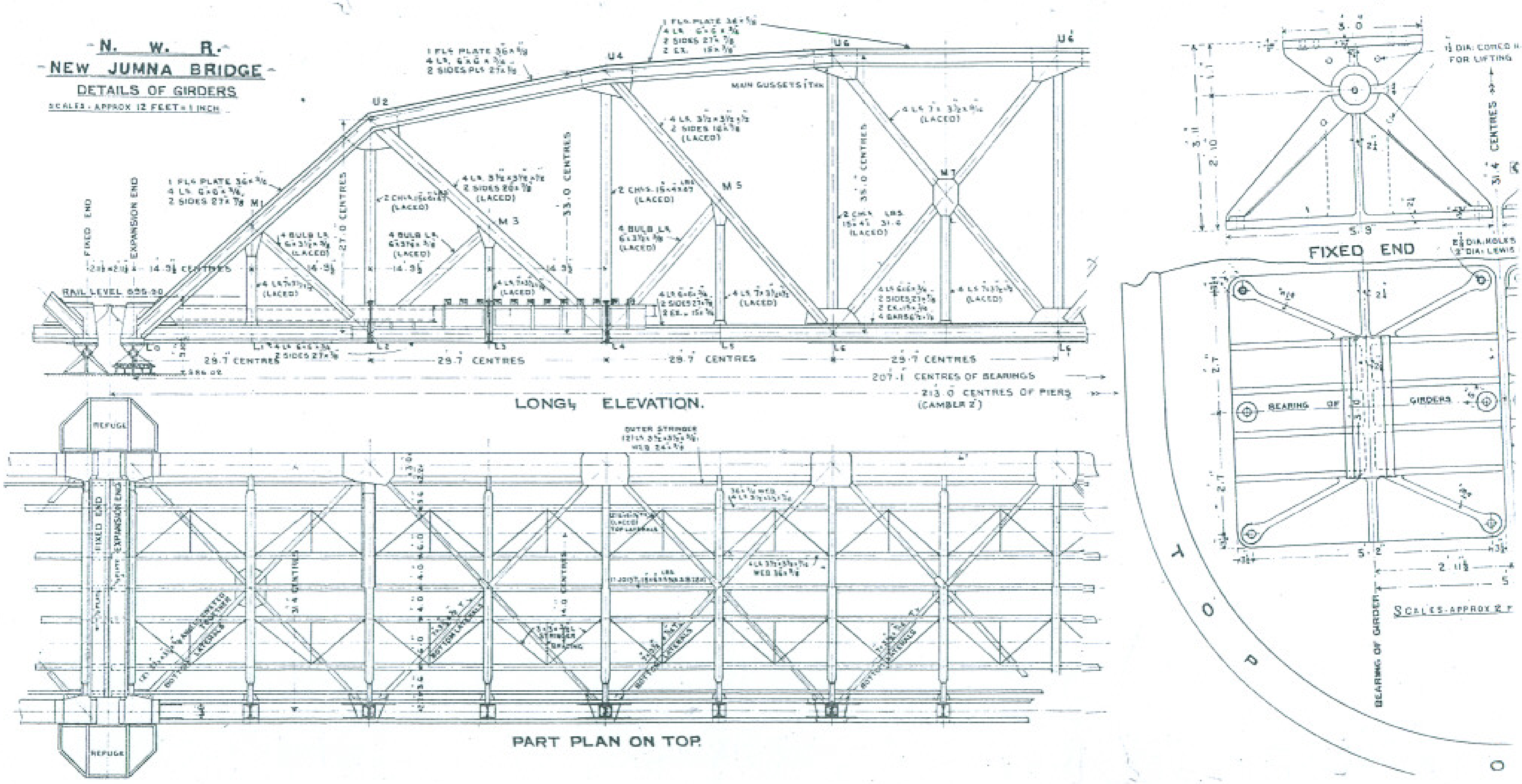
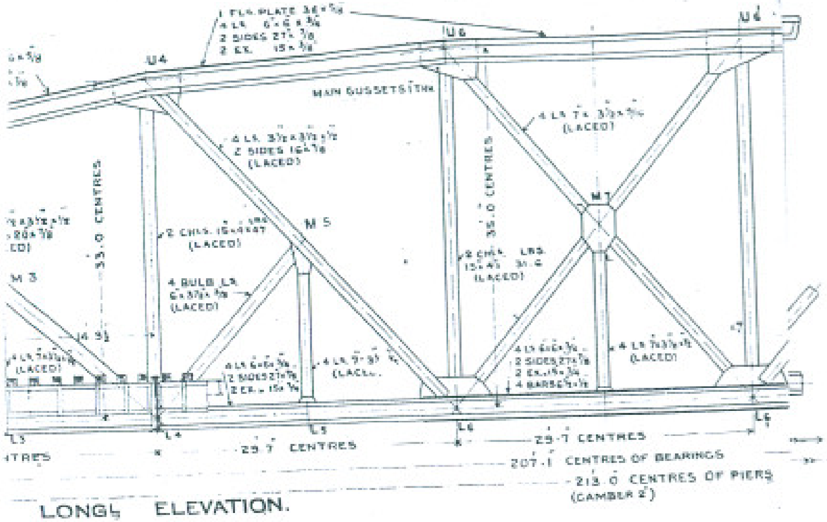

BOTTOM COURSE FIRM LINE
TOP COURSE DOTTED LINE
COURSES ARE REPEATED ALTERNATELY PARALLEL TO THIS SIDE.
COURSES ARE REPEATED PARALLEL TO THIS SIDE.
SECTION AT B.B.
SECTION AT A.A.
SECTION AT C.C.
CONCRETE BED BLOCKS
AGGREGATE
MORTAR
PROPORTION ONE CEMENT, TWO SAND
TOP OF PIER
TOP OF WELL
CUTTING EDGE
FACE BRICK WORK
CEMENT MASONRY
LIME CONCRETE
SAND FILLING
CONCRETE IN CEMENT
TOP PLAN
PLAN AT SPRINGING OF ARCH.
-N. W. R.-
-NEW JUMNA BRIDGE-
TYPE DRAWING OF PIER & WELL
SCALE 24 FEET = 1 INCH.

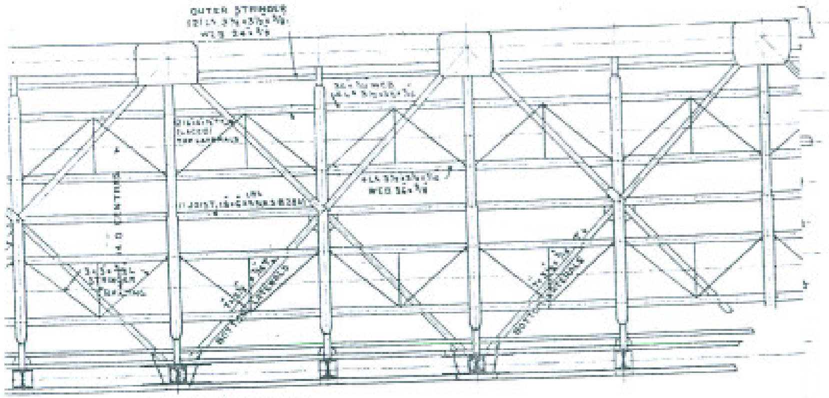


- N. W. R. -
- NEW JUMNA BRIDGE -
DETAILS OF GIRDERS
SCALES - APPROX 12 FEET = 1 INCH
FIXED END
EXPANSION END
RAIL LEVEL 695.90
14.9½ CENTRES
27.0 CENTRES
33.0 CENTRES
35.0 CENTRES
29.7 CENTRES
207.1 CENTRES OF BEARINGS
213.0 CENTRES OF PIERS
(CAMBER 2")
MAIN GUSSETS 1" THK
U2
U4
U6
M1
M3
M5
M7
L0
L1
L2
L3
L4
L5
L6
(LACED)
LONG'L ELEVATION.
REFUGE
OUTER STRINGER
BOTTOM LATERALS
STRINGER BRACING
31.4 CENTRES
14.0 CENTRES
PART PLAN ON TOP.
FIXED END
FOR LIFTING
31.4 CENTRES
BEARING OF GIRDERS
BEARING OF GIRDER
TOP
SCALES - APPROX 2 F

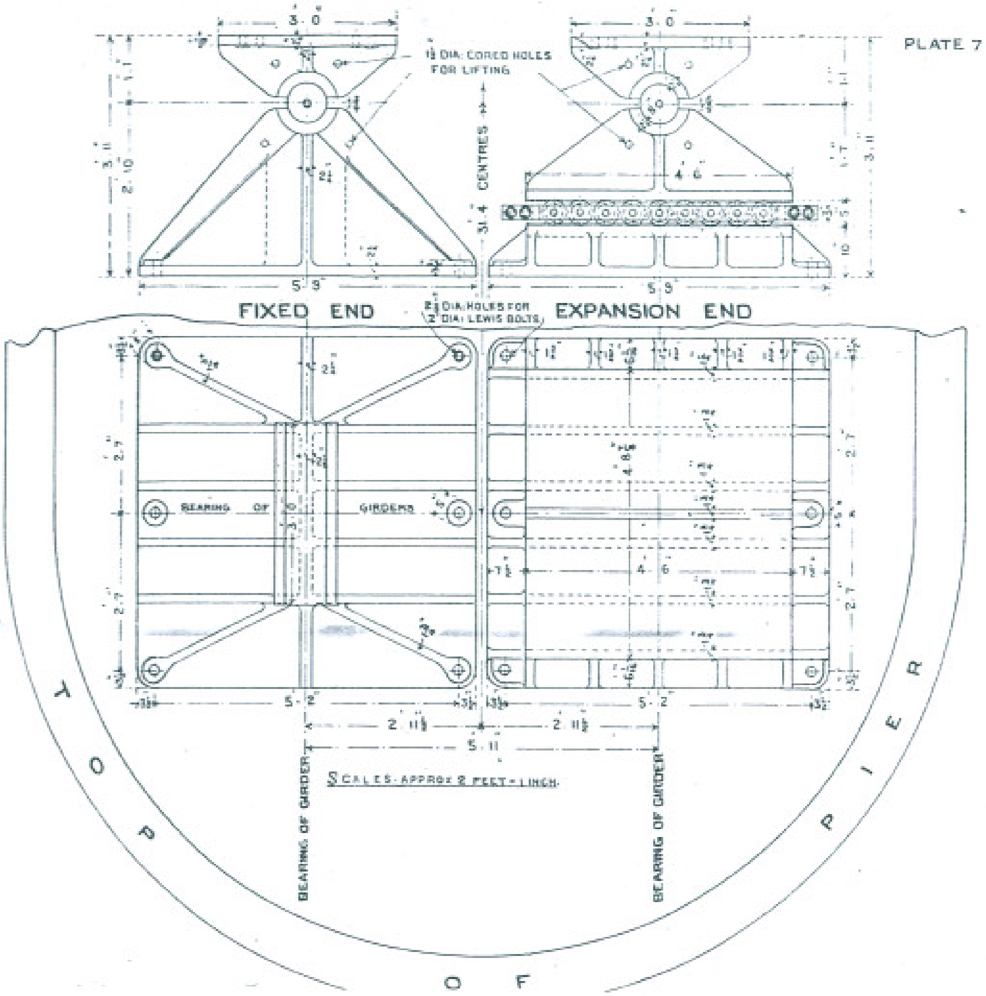
PLATE 7



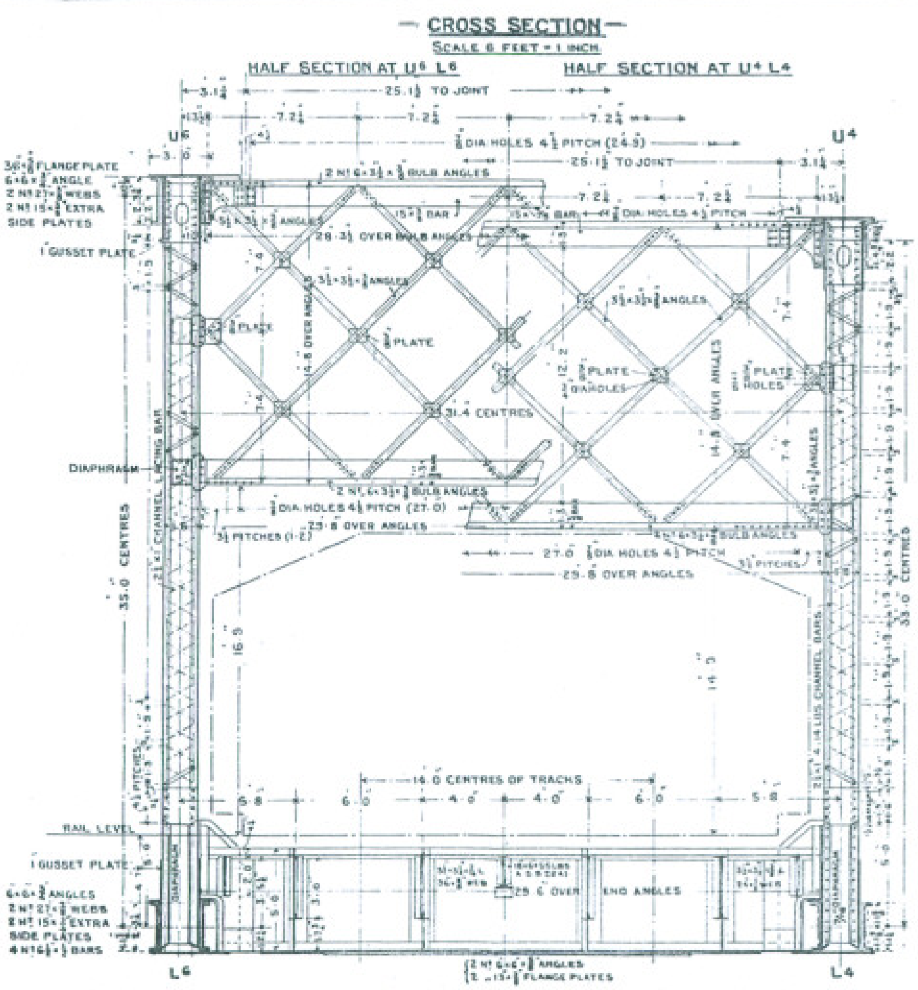
LONGL ELEVATION.



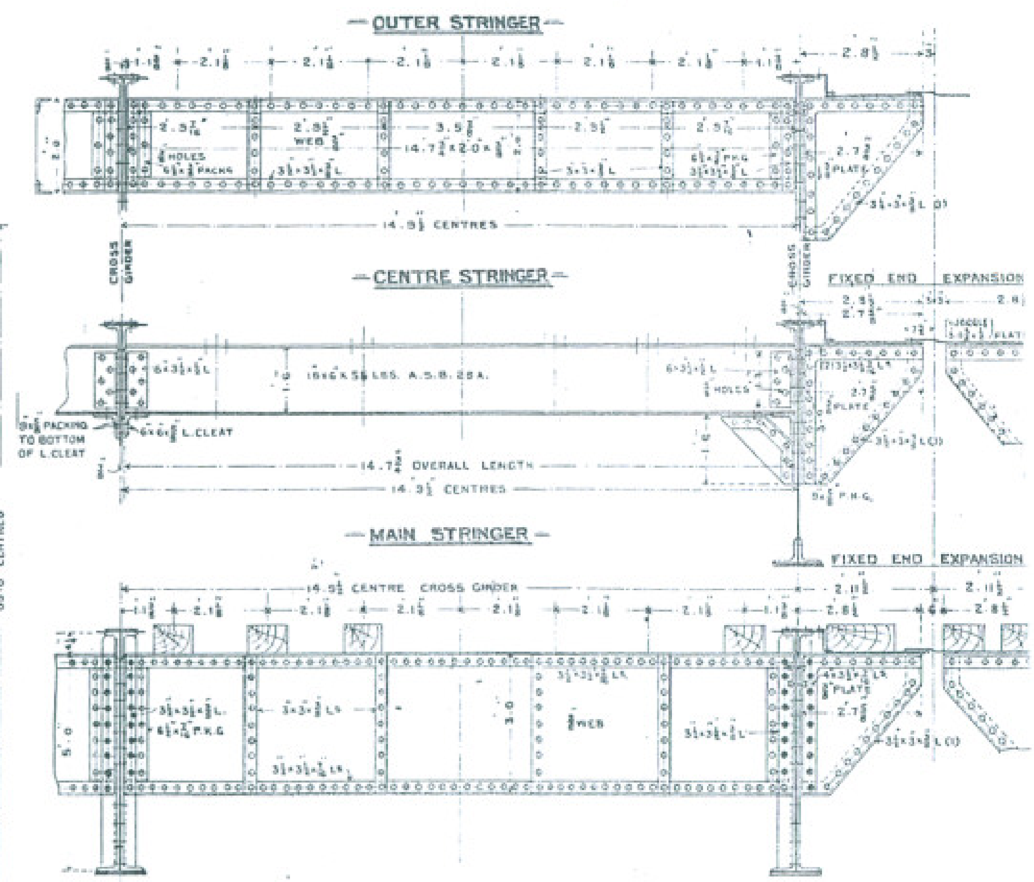
PART PLAN ON TOP.



SCALES - APPROX 2 FEET = 1 INCH.



— CROSS SECTION —
SCALE 6 FEET = 1 INCH.
HALF SECTION AT U6 L6
HALF SECTION AT U4 L4
25.1½ TO JOINT
⅞ DIA HOLES 4½ PITCH (24.9)
2 Nº 6×3½×⅝ BULB ANGLES
28.3½ OVER BULB ANGLES
⅝ PLATE
31.4 CENTRES
14.8 OVER ANGLES
DIAPHRAGM
29.8 OVER ANGLES
27.0 ⅞ DIA HOLES 4½ PITCH
35.0 CENTRES
14.0 CENTRES OF TRACKS
RAIL LEVEL
1 GUSSET PLATE
25.6 OVER END ANGLES
U6
U4
L6
L4



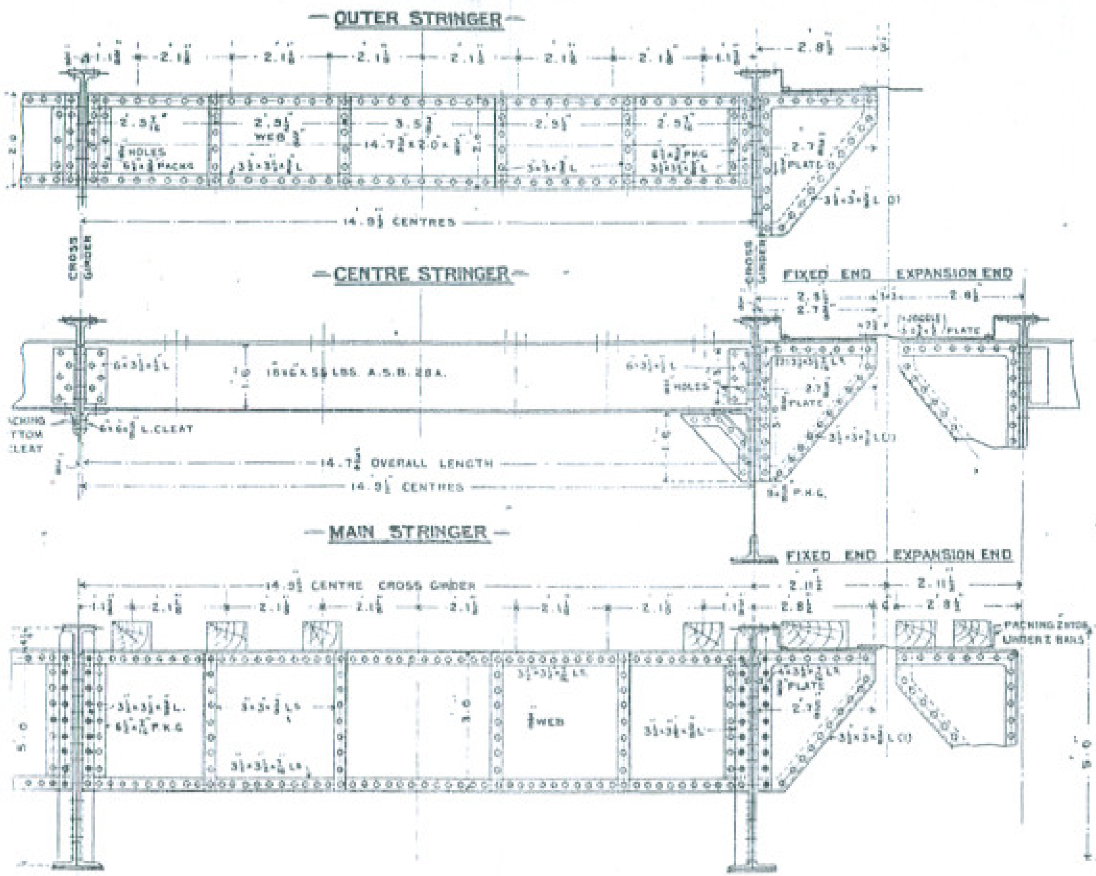
— OUTER STRINGER —
14.9½ CENTRES
CROSS GIRDER
— CENTRE STRINGER —
16×6×56 LBS. A.S.B. 28A.
6×6×⅝ L. CLEAT
14.7¾ OVERALL LENGTH
14.9½ CENTRES
FIXED END EXPANSION
— MAIN STRINGER —
14.9½ CENTRE CROSS GIRDER
FIXED END EXPANSION

- N. W. R. -

- NEW JUMNA BRIDGE -

DETAILS OF GIRDERS

SCALE 3/8 INCH = 1 FOOT



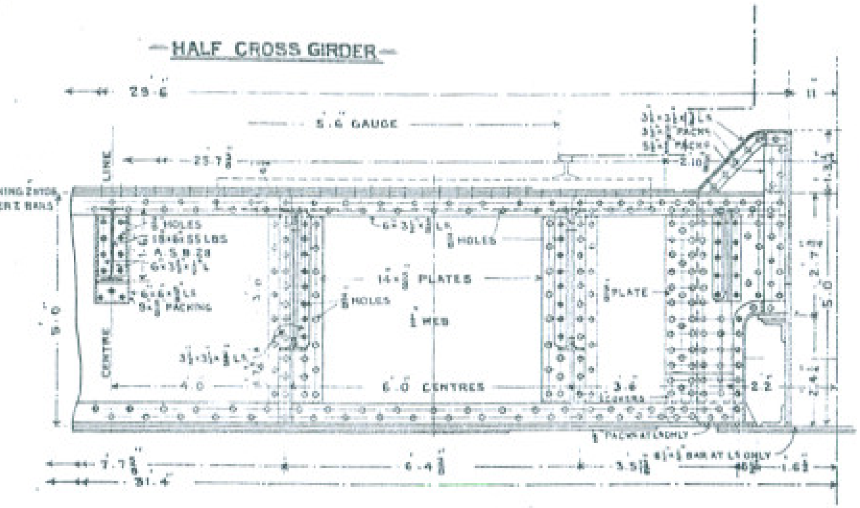
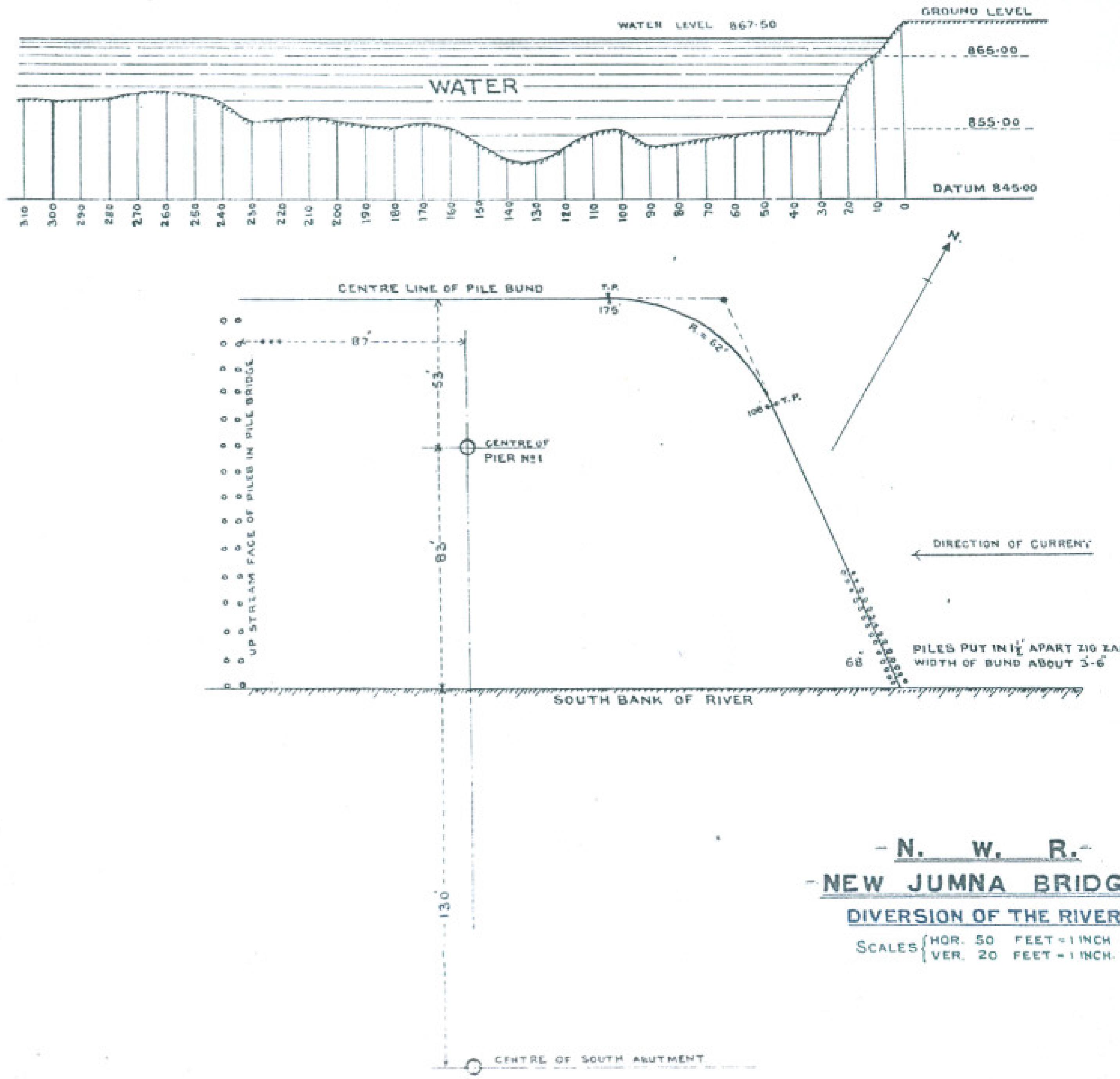


PLATE 9



– N. W. R. –

– NEW JUMNA BRIDGE –

DIVERSION OF THE RIVER

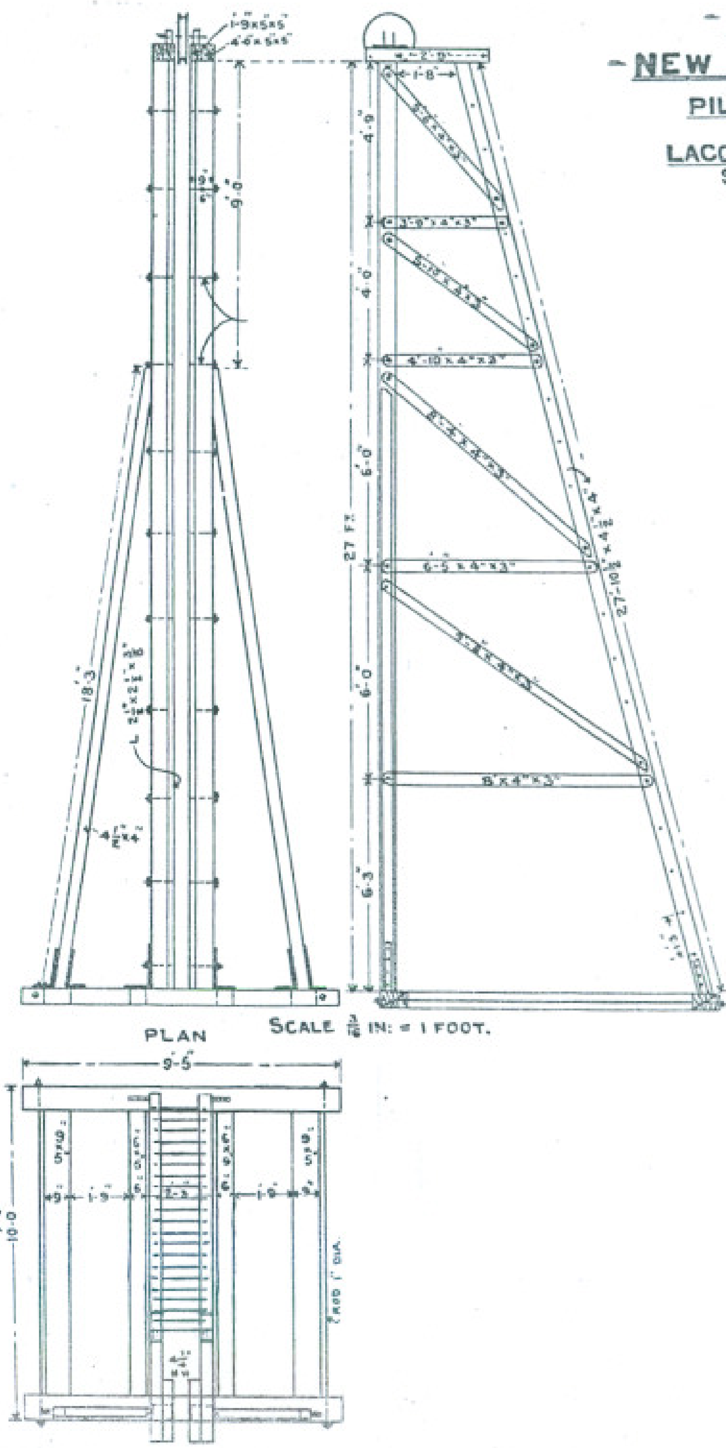
SCALES { HOR. 50 FEET = 1 INCH
VER. 20 FEET = 1 INCH.

-N. W. R.-

-NEW JUMNA BRIDGE-

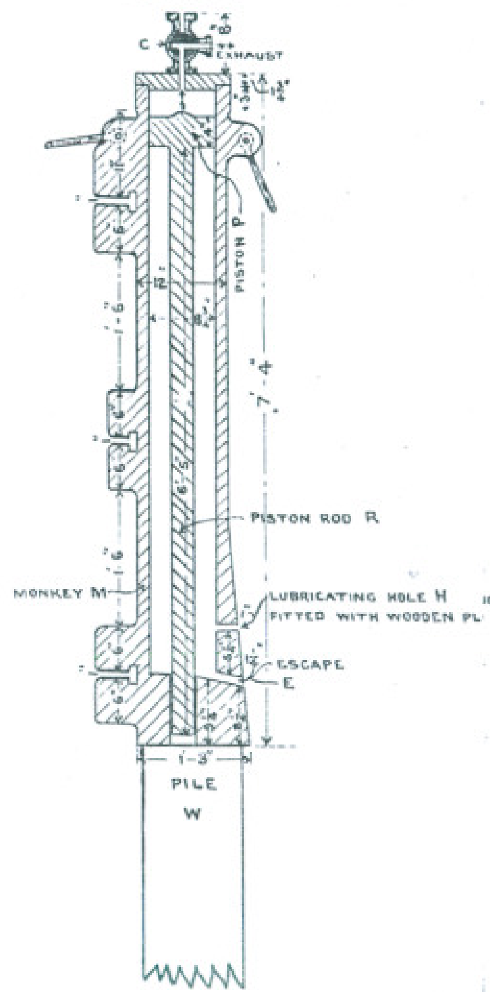
PILE DRIVER FRAME AND LACOUR STEAM MONKEY

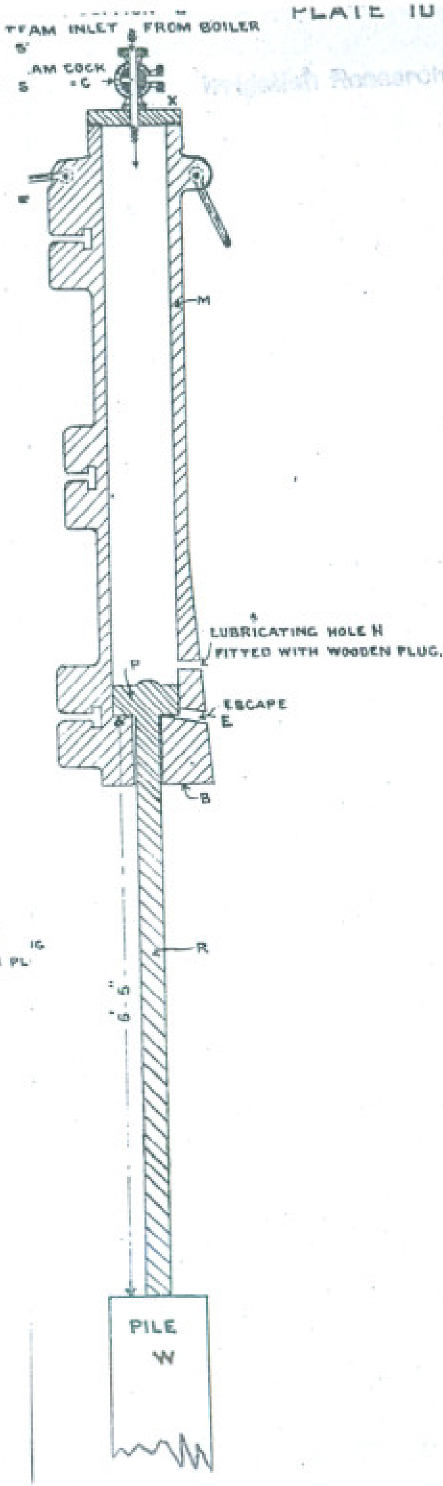
SCALE 2 FEET = 1 INCH.



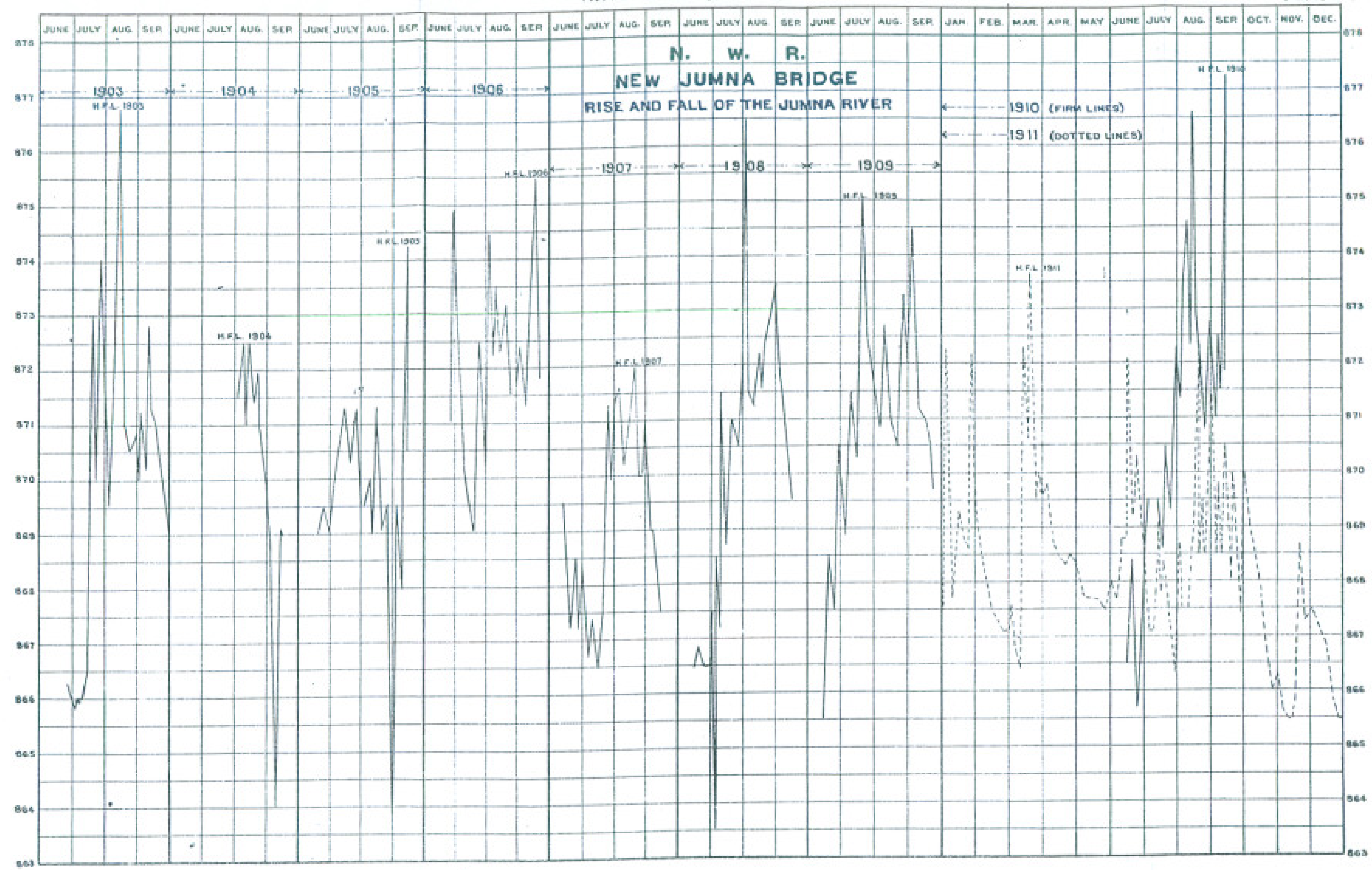
SCALE $\frac{3}{16}$ IN: = 1 FOOT.

POSITION 1





H.F.L. 878·32 (9-11-8-1872) PLATE II



N. W. R.
NEW JUMNA BRIDGE
CONTINUOUS KILN
SCALE 10 FEET = 1 INCH.

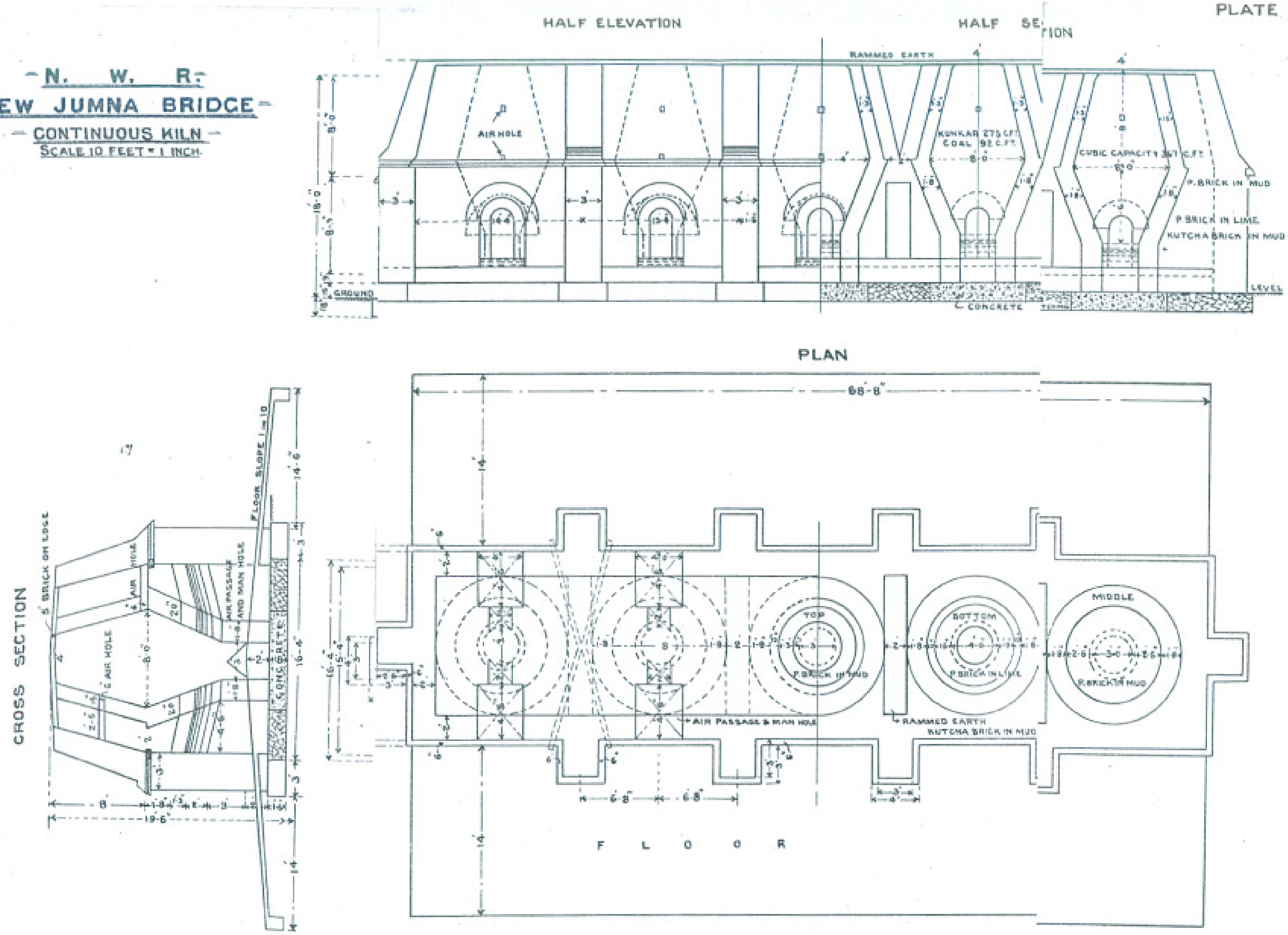


PLATE 13

= N. W. R. =

= NEW JUMNA BRIDGE =

PROGRESS AT END OF EACH MONTH OF WELL SINKING

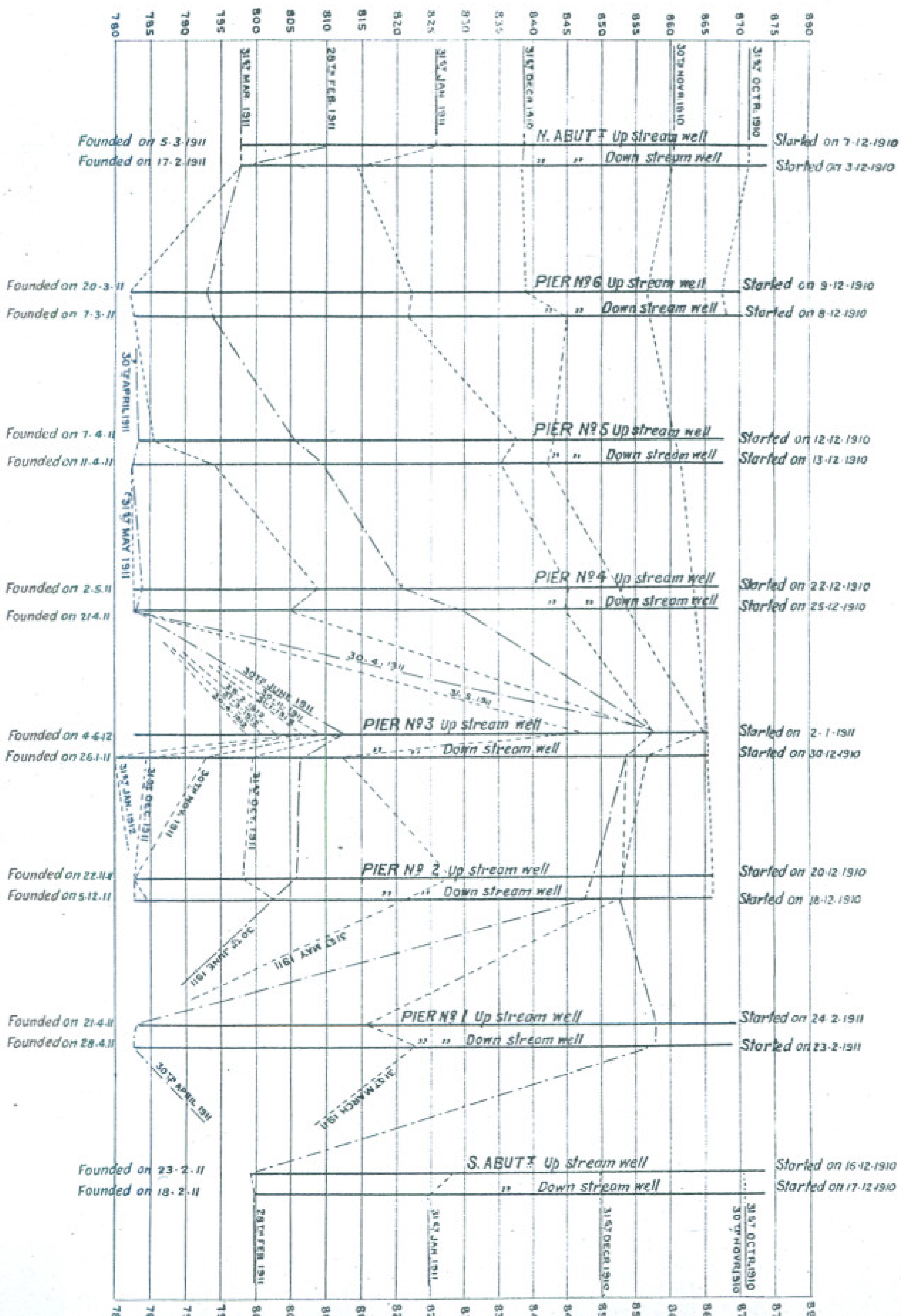


PLATE I.

— N. W. R. —
— NEW JUMNA BRIDGE —
— FINAL INCLINATION OF ALL WELLS —

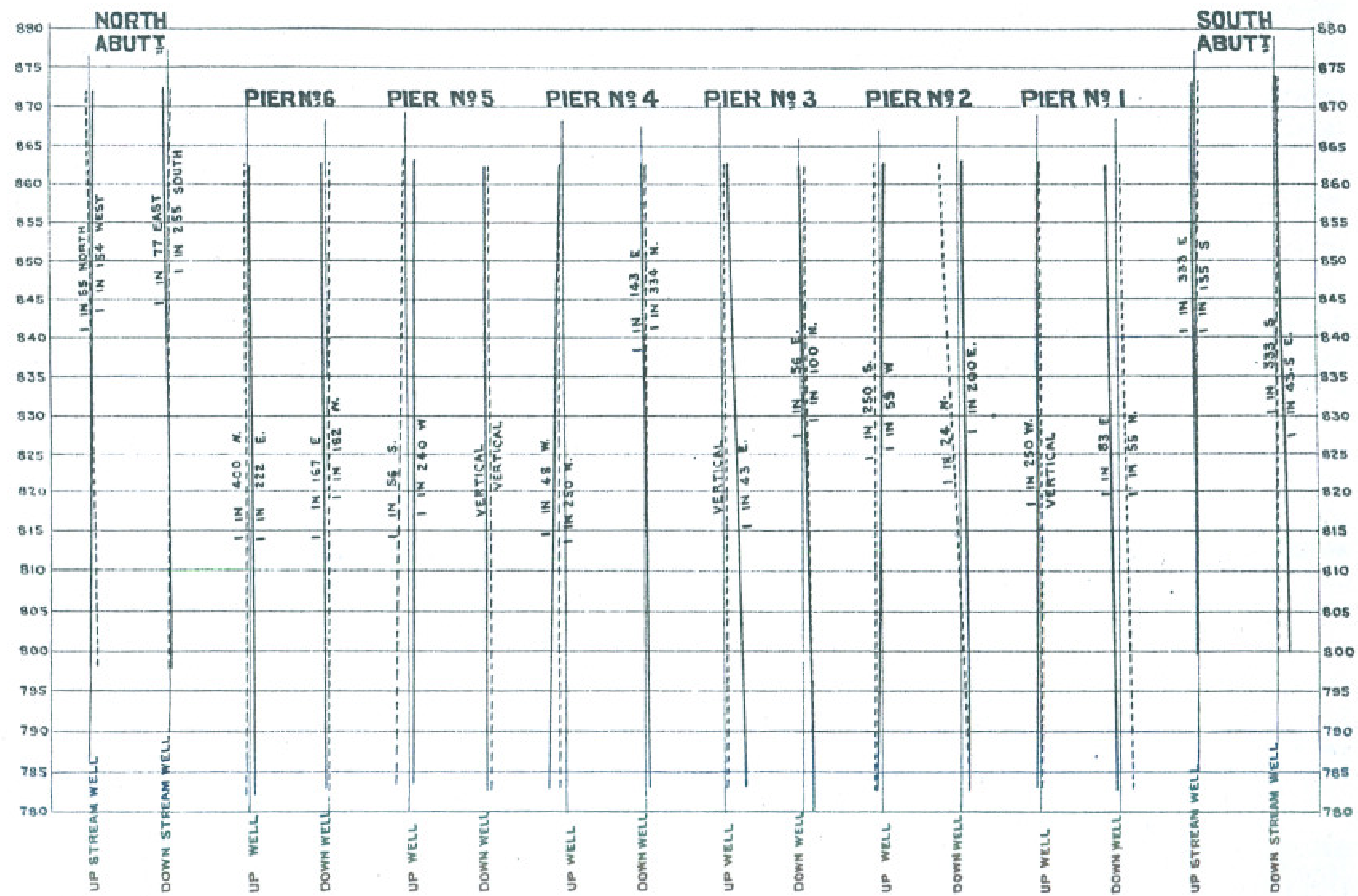
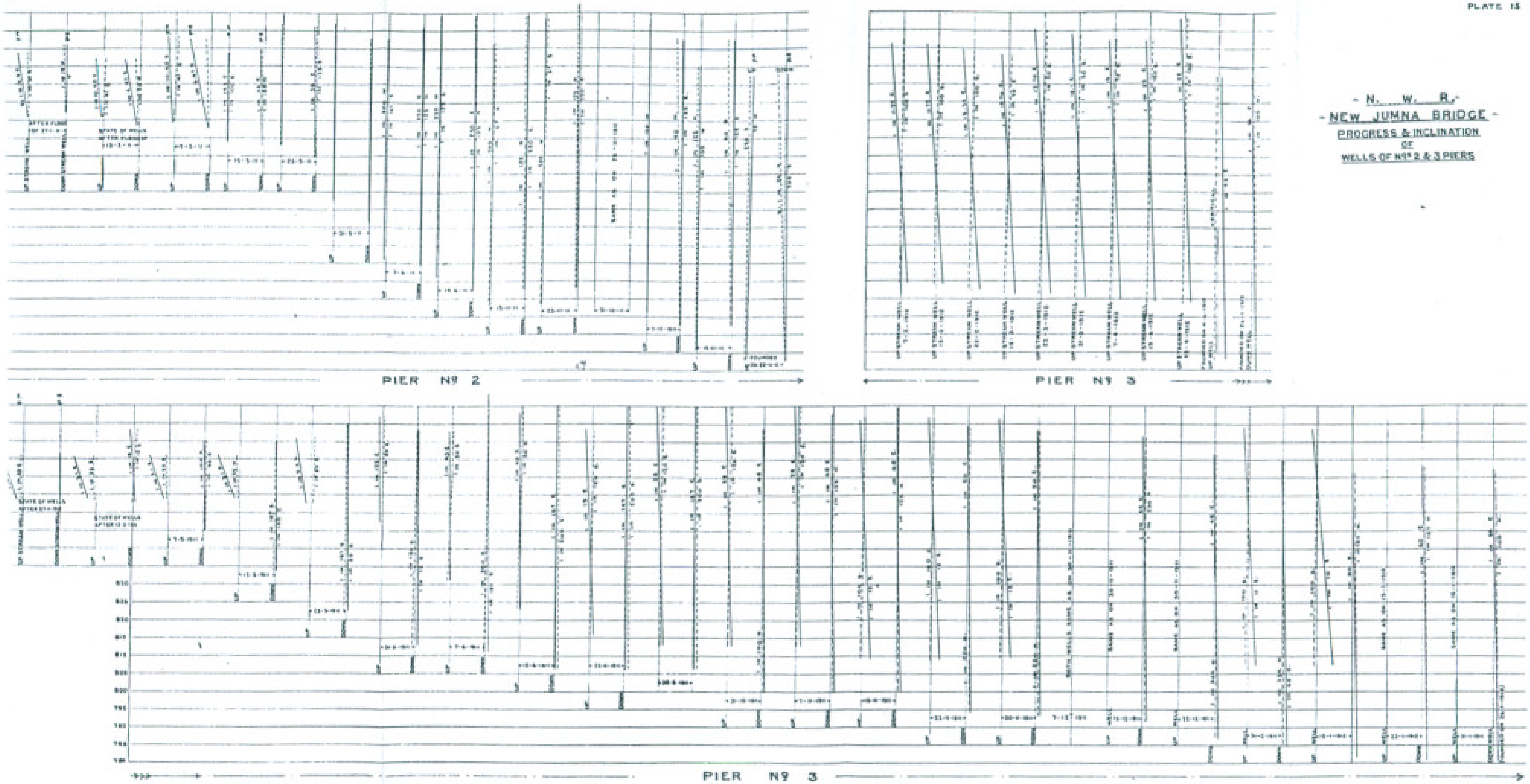


PLATE 15

- N. W. R. -
- NEW JUMNA BRIDGE -
PROGRESS & INCLINATION OF WELLS OF Nos 2 & 3 PIERS



Ballast and Permanent-Way.—

At the end of the working season of 1910-11, as the south approach, except for the portion over a pot hole at the back of the south abutment, was completed, and the portion of the north approach up to the low right bank of the river (*i.e.*, opposite the north abutment of the old bridge) was finished, we were able to keep our gangs at work on laying the permanent-way during the summer months The banks, as they were being built, had been well deluged with the winter rains, so that the question of settlement was not a vital one.

The new deodar sleepers 10 ft. × 10 in. × 5 in. from Wazirabad were adzed level to receive bearing plates, and then bored through a box template, consisting of two boxes 10in. × 10in. × 6in. high (without sides) made of $\frac{3}{4}$ in. planking. Over the bottom of the boxes a thin iron sheet was nailed. Through these boxes $\frac{5}{8}$ in. holes were drilled, each box having four holes, at the same distances apart as those in a bearing plate. The two boxes were connected by a 3 in. × $\frac{5}{8}$ in. wooden lath. Two sets of these templates were used, one set for sleepers on the straight for a gauge of 5 ft. $6\frac{1}{8}$ in, *i. e*, $\frac{1}{8}$ in. slack, the other set being for sleepers on the curves (radius of curves 5,730 feet or 1°) for a gauge of 5 feet $6\frac{1}{4}$ inches or $\frac{1}{8}$ in. slacker than that for sleepers on the straight. Sleepers bored with templates for curves were distinguished from the other sleepers by a cross painted with coal tar.

The holes in the sleepers were drilled with $\frac{1}{2}$ in. augers, the screw spikes being well oiled and screwed with a $\frac{3}{4}$ in. bar, two feet long, the end of which was flattened and punched to receive the head of the screw spikes. Every sleeper had eight screw spikes, as the straight approaches were not very long, and the extra cost was small. The rail joints on the curve were staggered so that all the joints were supported by two sleepers. The number of sleepers per thirty-six feet rail was thirteen on the straight and fourteen on the curves.

On the bridge the rails were laid on special bearing plates notched for screw spikes, (two on the outside and one on the inside), and two clip bolts, one passing through the stringer girder flange, and the other gripping on to the underside of the flange. Plate 16 shows details of the special bearing plate. The sleepers were of Nepal sal 8 ft.-6 in × 10 ins. × $6\frac{1}{2}$ in. (minimum), spaced 2 ft. $1\frac{1}{2}$ in apart and bound with $\frac{1}{4}$ in. wire.

On the outside of the rails hard wood timber guards 7 in. in width and 8 in. in depth were bolted to the sleepers. The sleepers for the portion lying between the rails were covered with old corrugated iron sheets with two inches of kankar on top.

On the approach banks the track was laid and roughly levelled up with earth packing. Ballast trains loaded with ballast were then run on this track, the ballast was spread three inches in depth for the second track, and the earth packing of the first line was removed and three inches of ballast put under the sleepers. Construction trains, ten-ton steam cranes, bogies and trucks loaded with girder pieces, etc., in passing helped to consolidate the track, which was very carefully maintained.

Before opening the bridge a depth of five inches of ballast was packed under the line, fourteen cubic feet of ballast per foot run was supplied, mostly from Delhi, only a small portion being obtained from the ballast quarries at Pathri. The remaining two cubic feet per foot run was left to be put in as might subsequently be required.

The rails are of the British Standard flat footed section weighting 90 lbs. per yard, with the fish plates notched for screw spikes. Expansion joints were not provided in the track across the bridge, and up to date the necessity for them has not appeared.

Girder erection:—

The heavy winter floods of January and March 1911 gave much food for thought as to the best way to tackle the girder erection. To erect staging on piles might court disaster, and yet one might be justified in taking the risk of such an exceptional winter not occurring again.

The proposed plan was to erect span No. I from the south abutment to pier No. 1 on Sullivan staging placed on the apron of the left guide bank, and for the portion between the apron and pier No. 1 on piles driven twenty-five feet into the bed of the river, this portion being protected by a substantial bund of a double row of hand driven piles, filled with pilchi and sandbags and brought up to R. L. 875·0. As soon as the erection of the first span was started, piles were to be driven between piers Nos. 2 and 3 and Nos. 3 and 4, about sixteen feet into the bed of the river, and on these piles the timber staging was to be erected. The loss of all the timber staging, if the piles were washed away, would be less than that of the Sullivan staging, while probably most of the timber would be recovered after the flood.

The erection and rivetting of the main joints of the first girder having been completed, and the weather being propitious, it would be lowered on to trollies (2 ft. 6 in. gauge with $3\frac{1}{2}$ in diameter axles, there being sixteen trollies for the span, *i. e.* one at each panel point) and pushed out to span No. 3.

A second span would then be erected, the main joints rivetted, and the girder trollied out to span No. 2. Span No. 4 would be erected in the same way, but trollied from the span between piers Nos. 4 and 5.

To trolly the girders out, it was proposed to start them moving with hydraulic jacks, and then pull them with locomotives attached to suitably arranged tackle with the necessary back tackle to prevent the girders overshooting the mark, &c.

Spans Nos. 1, 5, 6 and 7 were to be erected on Sullivan staging, Nos. 5, 6 and 7 being protected with a bund. The Sullivan staging was to be placed parallel with the centre line of the bridge, and not, as is generally done, at right angles to the centre line, as in the latter position the length of one set would be insufficient for the width of the bridge with the space required for the gantry, while the length of two sets would be far in excess.

During the summer months of 1911, the trollies and necessary material were collected for starting the work of girder erection on this principle as soon as the river fell sufficiently to allow of a start being made. The delivery of the girders at home was, under contract, to be commenced from 11th October 1911.

When the river fell in September, the winter channel deserted the left bank of the river and stretched across pier No. 2 to pier No. 4, the depth of water in the fourth span being only a few inches. There was, however, a deep pool (about fifteen feet in depth and twenty-five feet in radius) around pier No. 1. The poposal for girder erection was, therefore, somewhat simplified, as there was one span less to pile. Piles were driven across the pool, a substantial bund being placed from the edge of the apron to pier No. 1 and raised to R. L 875·0. From pier No. 1 to pier No. 2 a sand bund was thrown up with a brick bat apron ten feet wide and two bricks in depth, the slope being pitched with two layers of brick The top of this bund was at R. L 871·00. The idea was to allow two spans for waterway with a flood level up to R. L. 871·0, and above that to allow the river to rip through span No. 1 to No. 2. The wooden staging across span No. 2 rested on the river bed, except for the portion across the pool, which was on piles.

Piles for the fourth span were driven, and the staging erected for spans Nos. 1, 2, 5 and 6, when intimation was received that the manufacture of the girders had been delayed by strikes at home, and that delivery would not start till the beginning of 1912. The S. S. "Merton Hall" with the first span reached Karachi on 20th March and the first pieces reached the bridge on 19th April, 1912. The second consignment (two girders) reached Karachi at the end of the first week of April.

To attempt to launch girders out at that time of the year would have been absurd, and it was therefore decided only to erect and rivet spans Nos. 1, 2 and 6 during the hot weather.

The Sullivan staging for span No. 5 was therefore dismantled, and the piles pulled up from span No. 4. The bund from pier No. 4 to No. 5 was stripped of all material such as stone, brick bats, etc., and at the same time the bund from pier No. 1 to No. 2 was brought up to R. L. 875·0 so that the waterway for a heavy flood would be from pier No. 2 to No. 5. The first span to start work on was No. 2, as this was obviously in the most dangerous position for an attack by floods; the bed of the river being over 873·0 in span No. 6, erection on this could be deferred.

Erection—

The method employed in erection was on the same lines as that adopted on the bridges already mentioned * but owing to the extra width of the double track girder, and the increase in weight of the pieces, a specially designed gantry had to be used. Plate 17 shows the gantry designed by Mr. Everall, Assistant Bridge Engineer, N. W. Ry. This gantry was designed to lift fifteen tons at the centre, or double the actual weight of the heaviest piece, the extra factor of safety of 2 being allowed for a chain slip or break.

Plate 17 shows in detail the travelling trolly which was worked backwards and forwards across the gantry by blocks and tackle. The girder pieces were lifted with a steam hoist. The wire rope used for the purpose $1\frac{1}{2}''$ in circumference was composed of six strands, each strand having twenty-four wires, made of crucible steel. The breaking strain of the rope was $6\frac{1}{4}$ tons, its weight per fathom about two lbs. The gantry was traversed by hand. For details of gear see Plate 17.

* See page 3.

So as to be able to use this gantry in dismantling the girders of the existing bridge, of which the weight of each span complete was nearly sixty tons or about twenty-nine tons per girder, the centre portion of the girder of the gantry was arranged so that it could be removed and the width of the gantry reduced. The legs of the gantry were rivetted, but the top girders were only bolted. Plate 18 shows gantry, gantry line, camber jacks, &c., on Sullivan staging.

Progress of erection :—

On 28th April 1912 the bearing plate of the fixed end of span No. 2 was laid, and on 1st May the erection of this span was started, the three days delay being due to some pieces not being clean and ready to be placed in position.

The pieces of this span were unloaded on the south approach bank as close to the south abutment as possible, and as they were unloaded they were sorted as far as circumstances permitted, the width of the approach bank having been increased for three chains from the abutment to afford sufficient room for the purpose.

A ten-ton crane picked each piece up, and propelled itself along the permanent line over the south abutment and along a timber staging carried well over the slope of the guide bank. The piece was then lowered on to a trolly, on a service line laid from the toe of the guide bank slope to pier No. 2. The gantry then picked the piece up off the trolly and dropped it into its place. This was of course a more economical way than having a service line laid on staging, carried on girders stretching from one line of Sullivan staging to the other, though it was rather slower work.

By the 11th May, the bottom boom, cross girder, main stringer (or rail carrier) and the girders (outer stringer and centre girders) for the roadway were erected.

The ties, struts, and diagonals were next placed in position, and then the top booms. As the top booms were erected bay by bay the bottom girder of the wind bracing was bolted in position. The last piece U_4 U_6 of the top boom (*vide* Plate 6) was dropped into its place on 19th May.

The next span to be erected was No. 6. A service line was laid from the north approach bank through the right guide bank (*vide* siding G. E., Plate 1), to the river bed as far as pier No. 5. The trucks with girders were brought down this siding and the pieces unloaded in the river bed.

A ten-ton crane (there were two of these cranes on the bridge) lifted the pieces, and dropped them on to a trolly travelling on a service line starting from the apron of the right guide bank and close to the river bed siding (but not connected to it), and extending along the centre line of the bridge up to pier No. 5, the trolly running through the arch of pier No. 6.

The pieces for spans Nos. 3 and 4 were unloaded on the south approach bank, and those for spans Nos. 5 and 7 on the north approach, both banks being made extra wide for the purpose. The service lines were laid on the girders as they were erected.

The following was the time taken to erect the various spans, the weight of each span being 474 tons :—

Span.	Erection started.	Erection completed.	Time taken.
No. 2	1st May	20th May	20 days
,, 6	20th May	7th June	18 ,,
,, 1	8th June	25th June	18 ,,
,, 7	13th October	26th October	14 ,,
,, 5	6th November	19th November	14 ,,
,, 3	1st December	12th December	12 ,,
,, 4	20th December	25th December	6 ,,

Both gantries were used on the last span. It will be noticed that girder erection was only in progress on one span at a time, the reason for this being that up to June it was with difficulty that we could muster the necessary men on the work which was most trying, the heat being almost overpowering, and moreover we had to concentrate first on span No. 2 and then on No. 6, as any heavy rise in the river would have endangered the work, the staging being on the river bed, and only protected with a sand bund pitched with brick bats.

No. 1 span was well protected, and the bunds were sufficient to hold any ordinary summer flood, so that there was no cause for anxiety on this span.

In the working season of 1912-1913, before span No. 3 could be erected, piles had to be driven, and it will be noticed that the erection of span No. 3 was done with Sullivan staging on piles, and not as originally proposed, the reason being that this was the last span but one, and the men, being well acquainted with the method of procedure, were able to rush the work.

The following points received particular attention during erection :—

(*i*) An absolutely correct centre line.

(*ii*) The camber was checked and corrected twice daily during erection.

(*iii*) All plates, &c., forming a joint were scraped, thoroughly cleaned, and then painted. Judging from the way this was done, it would have been better to have cleaned and painted the joints some days before erection. Any paint which got knocked off could then have been made good when the piece was being dropped into position.

(*iv*) At least fifteen per cent. of the holes were filled with cold rivets, and about forty per cent. with bolts thoroughly tightened, *i. e.* the men were made to use long spanners. The bolts were placed so as to give the best result for tightening the plates. In struts and diagonals at least twenty-five per cent. of the holes were filled with cold rivets, and of course the forty per cent. of bolts was also used.

(*v*) Before the top boom pieces were erected, the bottom wind bracing girders were placed in position.

(*vi*) When traversing the gantry with a top boom piece, the piece was raised just sufficiently to clear the cross girders, etc., and the service line laid on the main stringers.

Rivetting of Girders.

The entire rivetting was done by pneumatic hammers, partly by the Boyer long stroke hammer (supplied by the Consolidated Pneumatic Tool Company) and partly by the Globe hammer made by Messrs. Armstrong, Whitworth and Company).

Two Schram's air compressors, each drawing four hundred cubic feet of free air per minute, were supplied with steam by a Cornish boiler, while the air, after leaving the compressor, passed into one of two receivers (capacity eighty cubic feet). Plate 19 shows the position and main dimensions of the plant.

A three-inch diameter wrought iron pipe was laid to the south abutment for spans Nos. 1, 2, 3 and 4, and another three-inch pipe was laid along the old bridge till opposite pier

No. 6, and then laid along the river and up to the new bridge. The latter supplied the air for spans Nos. 5, 6 and 7. From this main air line, four $1\frac{1}{2}''$ diameter distributing pipes took off, one pipe being laid along each side of the bottom boom and one pipe along each side of the top boom. The pneumatic hammers and pneumatic drills were supplied with air from the $1\frac{1}{2}''$ distributing pipes with $\frac{3}{4}''$ diameter armoured hose pipe attached to $\frac{3}{4}''$ connections taking off a tee on the $1\frac{1}{2}''$ pipe. The pneumatic holder-on only required a half inch pipe. On the $1\frac{1}{2}''$ distributing pipes, along each side of the bottom boom, there were five $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times \frac{3}{4}''$ tees, and along each side of the top boom three tees.

The air pressure varied from eighty to ninety lbs. per square inch at the pressure dials, one of which was on pier No. 2 and the other on pier No. 5. To guard against loss of pressure in a long length of air line (exceeding 1,000 feet) and the probabiliy of four or five hammers working simultaneously on a span near the compressor, it would have been advisable to have provided for a receiver near the abutment farther from the Power House.

In rivetting, special attention was given to the following points :—

(*i*) The *entire* rivet was heated to a bright *red* heat ; this is most essential when the grip of a rivet is over $3\frac{1}{2}''$. On this bridge the longest rivet was $6\frac{3}{8}''$ (grip about $4\frac{1}{2}''$, diameter $1''$).

(*ii*) The hammers were kept in one position, no circling being permitted. This is a fault which rivetters invariably make, the object being to form the head quickly without filling the hole. It was also found that the snaps break very easily when the hammers are circled.

(*iii*) After ten rivets have been closed in quick succession, a second snap should be used, as the snap becomes so hot that the rivetters, finding the hammer difficult to hold, dip the portion containing the snap into cold water, and as often as not the snap cracks.

(*iv*) As large a pneumatic holder-on as possible was used on one inch diameter rivets with $4\frac{1}{2}''$ grips.

(*v*) In closing the rivets connecting the cross girders and the main stringer girders (rail carriers), as these were the most important, and the pneumatic holders-on were too large and could not be used, two hammers were used, one on the head and the other closing the rivet.

(*vi*) The jam rivetter was used as seldom as possible, as it is a most unsatisfactory tool.

(*vii*) Giant drills were used, but the close quarter drills supplied by the same firm, the Consolidated Pneumatic Tool Company, are handier.

When reading the analysis of the cost of rivetting and erection, it must be borne in mind that three spans were erected and rivetted between 20th May and 31st July, and in consequence the progress and the cost of the work was high compared with that done under favourable conditions.

On an average, including the tightening up of plates and the drifting of holes, a set of rivetters closed sixty rivets per day, there being 26,000 rivets in a span. Every rivet was tested, the rejected ones being painted red, and those passed, white. The passing was particularly strict on the first span, and the rivetters soon learned to appreciate the necessity of doing good work. It took twenty sets of rivetters twenty-five days to complete a span, this included replacement of rejected rivets,

Painting of girders.—

The cleaning of the girders was done departmentally, and all surfaces cleaned were inspected before any oiling was permitted. No chemicals were used. It was decided to use the pneumatic blast on all the joints, and hand scrapers made of old files on the more accessible surfaces. Plate No. 20 shows a section and plan of a sand blast made by Mr. J. England, Works Foreman. This sand blast gave most excellent results. It was made light enough for two men to carry from place to place. A brief description of the blast is as follows :—

An ordinary oil drum $1\frac{1}{2}' \times 1\frac{1}{3}'$ diameter was fitted with a conical shaped " hopper" at the top. At the bottom a one-inch pipe was inserted with a T piece in the middle of it to receive and pass the sand on to the sand pipe. The air pipe entering the drum at one end was half an inch in diameter. Off this pipe a return pipe of three quarters of an inch in diameter was led in to the top of the hopper. The reason for this was to prevent the sand in the hopper from being blown up through the funnel by the air passing from the half inch through the one-inch pipe and on to the nozzle, which was three-eighths inch in diameter. The air and sand mixed in the one-inch pipe, and were projected on to the surface of the steel by means of the nozzle, which was attached to the sand pipe by a long length of flexible armoured hose. This sand blast was used with an air pressure of eighty lbs. to the square inch. The old paint and rust were removed completely without any 'pitting' of the steel.

The cost of cleaning by hand under favourable conditions including all charges, worked out to Re. 1-8 per hundred square feet, and that by means of the 'Sand Blast', excluding the cost of installation of pneumatic plant and of supervision charges, to Rs. 2-8 per hundred square feet.

The girders were painted with one coat of oil and two of red lead in the following order :—

1. A priming coat of boiled linseed oil applied warm.

2. A coat of red lead mixed with raw linseed oil in the proportion of 7 to 1 by weight.

3. A covering coat of red lead mixed with raw linseed oil in the proportion of 5 to 1 by weight, and to one pound of this mixture $\frac{1}{6}$ oz. of lamp black was added.

The cost and weight of paint used in the different coats, and the cost of application per hundred square feet, were as follows (the figures being the result of careful observations made on two spans. The actual total cost is noted when dealing with detailed costs.)

1. Weight and cost of oil and paint used in the different coats.

(i) Priming coat—

		Per hundred square feet.
Boiled linseed oil ...	Weight ...	1·13 lbs.
	Cost ...	Re. 0-5-0

(ii) 1st coat of red lead—

Red lead	Weight ...	8·87 lbs.
	Cost ...	Re. 0-15-10
Raw linseed oil ...	Weight ...	1·28 lbs.
	Cost ...	Re. 0-5-8

(iii) 2nd coat of red lead—

			Per hundred square feet.
Red lead ...	... Weight	...	5·23 lbs.
	Cost	...	Re. 0-9-4
Raw linseed oil	... Weight	...	1·046 lbs.
	Cost	...	Re. 0-4-8
Lamp black	... Cost	...	Re. 0-0-2

Total cost of oil and paint, adding ten per cent. for wastage, comes to Rs. 2-12-9 per hundred square feet.

2. Cost of applying oil and paint, including grinding and mixing.

Per hundred square feet.

			Rs.	A.	P.
(i) Priming coat of boiled oil—Cost		...	0	2	2
(ii) 1st coat of red lead—	,,	...	0	7	5
(iii) 2nd coat of red lead—	,,	...	0	7	5
(iv) Supervision charges	,,	...	0	2	0
Total cost of applying paint	...	...	1	3	0

3. Cost of Tools and Plant.—

			Per hundred square feet.
(i) Paint brushes ...	Cost	...	Re. 0-5-0
(ii) Paint tins	,,	...	,, 0-0-6
(iii) Log-line	,,	...	,, 0-0-6
(iv) Scaffolding rope ...	,,	...	,, 0-1-0
(v) Paint grinding machines.	Depreciation		,, 0-0-6
(vi) Scaffolding planks.	Depreciation	...	,, 0-0-6
Total cost of Tools and Plant		...	,, 0-8-0
4. Carriage charges ...		...	,, 0-1-0

Reverting to the rates given for cleaning by hand, and for the cost and application of paints.

Total cost of painting ... ... Rs. 6-1-0 per hundred square feet, equivalent to Rs. 6-6-0 per ton.

Before using any of the linseed oils or red lead on the bridge, samples were sent down to Mr. James Cleghorn, Consulting Engineer, Calcutta, for tests. The tests he carried out gave very satisfactory results and were as follows :—

(i) *Red lead.*

Specific gravity 8·5 at 60° Fahn. correct.

Analysis—Over 99 per cent of red lead.

0·75 per cent. of insoluble matter.

Required grinding before being used as paint.

(ii) Red lead mixed with 16 per cent. raw linseed oil.

Red lead mixed with 15 per cent. boiled linseed oil.

Glass slabs were painted over and treated to the following tests :—

(*a*) Exposed to weather for seven days.

(*b*) 72 hours exposure to weather.—
24 ,, at 150° F.
6 ,, at 200° F.

(*c*) 72 ,, exposure to weather.—
24 ,, at 40° F.
24 ,, at 150° F.
6 ,, at 200° F.

(*d*) 72 ,, exposure to weather.—
24 ,, at melting ice 32° to 38° F.
24 ,, at 150° F.
6 ,, 200° F.

These tests were considered to be equivalent to those of age.

The paint on the slabs subjected to the first test was found to be still " green." On all the other slabs the paint had become as hard as it would become with age, and on none of them had the paint cracked.

In the red lead and boiled linseed slab subjected to test (*c*) a spot had flaked off, and a similar slab subjected to test (*d*) showed cloudy patches.

Mr. Cleghorn's concluding remarks were that as red lead is the best of all driers, so boiled oil containing driers, the nature of which is not known, does not appear from the tests to be as suitable for mixing with red lead as pure raw linseed oil.

In a subsequent letter, in answer to certain questions, Mr. Cleghorn stated that he had found no signs of 'cracking' in paint consisting of lead and raw linseed oil which had been exposed to the air for ten days. He also strongly emphasised his preference for red lead as a paint for steel work, and pointed out that the red lead paint on the steel work of the spire of St. Paul's Cathedral, Calcutta, and the steel which it covered, were found to be in excellent condition, although exposed to all weathers for over fifty years.

(iii) Raw linseed oil.

Drying test. In contact with cotton waste at 176° F. fired in four hours. Should have fired in two hours.

Glass slab covered with oil and drained took six days to dry. Should have dried in two days.

Specific gravity ·932 at 60° F. and ·920 at 100° F. } Correct.

Fluidity or viscosity at 100° F. $\frac{\text{four minutes twenty secs.}}{\text{water one minute}}$ = very good.

The oil dried without leaving any stickiness and mixed with red lead as paint dried in one and a half days.

(iv) Boiled linseed oil.

Glass covered with oil and drained. Dried in one and a half days, but remained sticky for fourteen days.

Specific gravity ·939 at 60° F. and ·926 at 100° F. } Correct.

Fluidity or viscosity at 100° F. $\frac{\text{6 minutes 25 secs.}}{\text{water one minute}}$ = good.

Mixed with red lead as paint dried in one day, but remained sticky for some time.

As a result of these tests it was decided to apply boiled linseed oil in the priming coat, and to mix raw linseed oil with red lead in the second and third coats. Boiled oil dried more quickly than the raw, and this was a desideratum where rapid progress in painting was necessary.

Camber and girder tests—

An extra camber was given to the girders while they rested on the camber jacks, so that the full two inches camber allowed for in the design of the girders might be obtained after the girders had taken their permanent set.

Spans Nos. 1, 2, 6 and 7 were given an erection camber of $3\frac{1}{4}''$ Span No. 5 of $2\frac{3}{4}''$, and spans Nos. 3 and 4 of $2\frac{1}{2}''$, *vide* Plate 21.

The camber jacks were removed after the main panel and sub-panel joints had been rivetted. The rivetting of the main stringer and roadway girders to the cross girders, and the rivetting of the top and bottom wind bracing, was started after the camber jacks had been removed. This was done to permit of the easy settlement of the girders under their own weight.

Before laying the permanent track on the bridge, two trains each consisting of two S. G. engines and four trucks loaded with stone ran over the service lines at slow speed, the idea being to let the girders take as much of their permanent set as possible prior to laying the permanent track. The deflections for these trains are shown on Plate No. 21. The two final test trains, each train consisting of two H. G. engines coupled tender to smoke box, with a train load equivalent to 1·37 tons per foot run, ran over the bridge on 22nd March 1913. Plate No. 21 also shows the final camber on the bridge after this test.

It will be observed on inspection of Plate No. 22 that the deflection in the bottom boom, with the test trains travelling at forty miles per hour, was $\frac{3}{4}''$, or in proportion to length of span from centre to centre of bearing of 1 in 3312, also that the oscillation at this speed measured on the bottom boom was $\frac{1}{16}$th of an inch.

Conclusion—

The bridge was opend for traffic on the 24th of March 1913, two years and nearly four months after the laying of the first brick. Until the Lower Ganges Bridge at Sara is opened for traffic, this bridge will be the largest double track girder bridge in India.

COST OF WORK.

The project estimate, amounting to Rs. 18,65,718 provided for double line approach banks, wells, and piers, but for only single track girders for a bridge of eight spans of two hundred feet clear. The permanent-way on the approach banks was also single track.

Below is given in detail the cost of the double track girder bridge of seven spans, two hundred feet clear. This has been estimated at Rs. 19,68,152, or only 5·5 per cent. in excess of the project estimate. Up to the time of writing, the completion report has not been made out, but there is no doubt that the actual cost will be considerably less than Rs. 19,68,152, as the plant obtained from the Beas and Sutlej Bridges was taken over at a greatly reduced rate owing to the plant requiring a good deal of repair. In order that the figures in this statement may be a guide towards the preparation of estimates for similar work, the value of plant, etc., has been raised to that which would have been given for plant in thorough working order.

The following are some of the rates paid to Contractors :—

	Rs.	a.	p.
	Per ton.		
(*i*) Unloading curbs	0	8	0
(*ii*) Fitting and rivetting curbs ...	20	0	0
(*iii*) Fitting and screwing tie rods and bond plates	3	0	0
	Per lineal foot of well.		
(*iv*) Well sinking (The Railway supplying plant, timber, petty stores, etc., but not coal, at the Store Depot) :—			
To 15 feet below bed level ...	5	0	0
From 15 feet to 25 feet below bed level	9	0	0
,, 25 ,, 35 ,, ,,	14	0	0
,, 35 ,, 45 ,, ,,	21	0	0
,, 45 ,, 55 ,, ,,	29	0	0
,, 55 ,, 65 ,, ,,	38	0	0
,, 65 ,, 75 ,, ,,	46	0	0
,, 75 ,, 80 ,, ,,	56	0	0
,, 80 ,, 85 ,, ,,	67	0	0
	Per hundred c. ft.		
(*v*) First class brick-work in cement mortar (Railway cement) ...	24	0	0
(*vi*) First class brick-work, in engine-ground kunker lime mortar—all materials supplied by the Contractors	30	0	0

	Rs.	a.	p.
	Per ton.		
(*vii*) Unloading of girder pieces from trucks and sorting	0	8	0
	Per ton per chain.		
(*viii*) Lead of girder pieces to site of erection	0	0	6
	Per ton.		
(*ix*) Girder erection and rivetting with pneumatic hammers (the Railway only supplying the plant and petty stores, the Contractor paying for coal, and all labour in working machines, etc.)	20	8	0
	Per hundred c. ft.		
(*x*) Supply of pitching stone from Delhi loaded in trucks, truck measurements, (most of the stone being paid for at the higher rate on account of the high rates prevailing due to the Durbar) ... 4-8-0 to	5	0	0
(*xi*) Excavating pitching stone from old bund (removal of earth not included)	0	12	0
(*xii*) Unloading pitching stone from trucks, pitching and hand packing on the slope	1	4	0
Extra for lead beyond one chain	0	4	0
	Per thousand c. ft.		
(*xiii*) Earthwork	4	0	0
Lead over one chain ...	0	8	0
Lift above five feet	0	8	0
(*xiv*) Earthwork by ballast trains, excavating, loading, unloading and clearing track (truck measurements)	7	0	0

	Per pile.
(*xv*) Pile driving, by hand pile driver, ballis 6" diameter or less, twelve feet into the bed of the river	Rs. a. p. 1 8 0
	Per bag.
(*xvi*) Filling and placing in position sand bags supplied by the Railway	0 1 0
	Per pile.
(*xvii*) Extracting piles driven by steam monkey	3 0 0
	Per hundred.
(*xviii*) Adzing and boring deodar sleepers	4 8 0
	Per c. ft.
(*xix*) Nepal sleepers 8' × 10" × $6\frac{1}{2}$" to $8\frac{1}{2}$" free on rail at Janesh-nagar	4 0 0
(*xx*) Kikar wood 7' 3" to 9' 3" × 8" × 7" free on rail	2 0 0

Though the statement of detailed cost accompanying this paper is in itself complete, a tabulated statement has also been made as a guide for the preparation of an estimate of a similar work, and for ready comparison with the cost of the various large railway bridges in India, but in perusing this table it must be borne in mind that this bridge is a double track bridge.

STAFF.

Plate No. 23 gives a diagrammatical statement of the Staff employed on the construction of the bridge; the author was only able to see the erection and rivetting of the girders for spans Nos. 1, 2 and 6; the erection and rivetting of the remaining spans, and the completion of the work was done by Mr. P. H. Maflin, Assistant Engineer, to whom the author is greatly indebted for his contribution on the painting of the girders, and the great help he has rendered in the preparation of the paper.

Mr. Maflin has prepared a note on the tools, plant, and stores required for the construction of a bridge of this description which has been printed at the North-Western Railway Press and will be found of enormous practical value to engineers who may be called upon to construct a similar work.

Particulars.	Cost.	Cost per foot height (of each well) measured from bottom of curb to top of pier. Total height = 1,590 ft. (16 wells and piers).	Percentage cost on total cost. Rs. 17,71,785
BRIDGE.	Rs.	Rs.	Per cent.
Wells and piers.			
Well curbs	48,186	30·3	2·72
Islands for pitching curbs ...	8,667	5·4	0·49
Diverting river for pitching curbs	13,468	8·5	0·76
Pile bridge	7,317	4·6	0·41
Well sinking	93,547	58·8	5·28
Cement concrete in plugs ...	5,905	3·7	0·33
Ditto ditto well curbs and bed blocks ...	4,802	3·0	0·27
Lime concrete in plugs ...	2,381	1·5	0·13
Sand plugging	281	0·2	0·02
Brick masonry in cement ...	87,207	54·9	4·93
Ditto ditto lime ...	1,20,665	75·9	6·81
Corbelling stones	427	0·3	0·02
Arch masonry in cement ...	1,790	1·1	0·10
Total Wells and Piers ...	3,94,643	248·2	22·27
* Guide Banks	2,38,648	..	13·47
Total Guide B[illegible]s ...	2,38,648	...	13·47
Girders.			
Cost of girders	7,81,890	...	44·13
Erection and rivetting of girders	1,32,678	...	7·49
Painting girders	30,687	...	1·73
Timber guards	6,911	...	0·39
Total Girders ...	9,52,166	..	53·74
Temporary Sidings	25,978	...	1·47
Total Temporary Sidings ...	25,978	...	1·47
Total Bridge ...	16,11,435	...	90·95
GENERAL CHARGES.			
Direction	27,714	...	1·57
Engineering	1,07,190	..	6·05
Stores	8,000	...	0·45
Audit and Accounts	5,000	...	0·28
Medical and Sanitation ...	12,446	...	0·70
TOTAL GENERAL CHARGES ...	1,60,350	...	9·05
GRAND TOTAL ..	17,71,785	...	100·00

* NOTE—About one-third of the pitching stone was obtained

Cost per lineal foot of Bridge. TOTAL LENGTH 1,491 ft.	Cost per square foot of side area outside abutments from bottom of well curbs to top of piers. AREA = 152,640 sq. ft.	Cost per square foot of side area from top of piers to top of girders. AREA = 48,510 sq. ft.	Cost per square foot of total side area. AREA = 201,150 sq. ft.
Rs.	Rs.	Rs.	Rs.
32·3	0·32	0·99	0·27
5·8	0·06	0·18	0·04
9·0	0·09	0·28	0·06
4·9	0·04	0·15	0·04
62·8	0·61	1·93	0·46
4·0	0·04	0·12	0·03
3·2	0·03	0·10	0·02
1·6	0·02	0·05	0·01
0·2	...	0·01	...
58·5	0·57	1·80	0·43
80·9	0·79	2·49	0·60
0·3	...	0·01	...
1·2	0·01	0·04	0·01
264·7	2·58	8·15	1·97
160·1	1·56	4·92	1·18
160·1	1·56	4·92	1·18
524·4	5·12	16·12	3·89
89·0	0·87	2·73	0·66
20·6	0·20	0·63	0·15
4·6	0·05	0·14	0·03
638·6	6·24	19·62	4·73
17·4	0·17	0·53	0·13
17·4	0·17	0·53	0·13
1,080·8	10·55	33·22	8·01
18·6	0·18	0·57	0·14
71·8	0·70	2·21	0·53
5·4	0·05	0·16	0·04
3·4	0·04	0·10	0·03
8·3	0·08	0·26	0·06
107·5	1·05	3·30	0·80
1,188·3	11 60	36·52	8·81

from the abandoned portion of the left guide bank.

Main Heads of Accounts.	Sub-heads of Accounts.	Quantity.	Cost per unit.	Total Expenditure.
			Rs. A. P.	Rs.
I. Preliminary Expenses	(a) *Survey Expenses*	...	..	23
	(b) *Plant*	...	...	...
	(c) *Establishment*	...	...	83
	Total ...		...	106
		Acres	Per acre.	
II. Land	(a) North approach and Left Guide Bank ...	181·38	66 7 0	12,050
	(b) South approach and Right Guide Bank ...	188·91	136 6 3	25,766
	Total ...	370·29	...	37,816
III. Formation	(a) *Earth-work*—	C. ft.	Per 1,000 c. ft.	
	(1) North approach	4,849,869	8 15 6	43,543
	(2) South approach	5,667,482	9 2 9	53,826
	Total ...	10,517,351	...	97,369
IV. Bridge-work ...	(A) *Major Bridge*—			
	(1) *Well curbs*—	Tons	Per ton.	
	(a) Cost in Calcutta	233·74	171 6 6	40,064
	(b) Freight from Calcutta	...	16 11 5	3,907
	(c) Unloading and leading to site	.	1 8 5	356
	(d) Pitching and rivetting . ..	...	13 4 0	3,097
	(e) Depreciation on Stores, Tools and Plant	..	0 0 10	13
	(f) Freight on ditto ditto ..	...	1 1 7	257
	(g) Workshop charges	...	0 3 9	55
	(h) Supervision	...	0 4 8	68
	(i) Miscellaneous	...	1 9 3	369
	Total ...	233·74	206 2 5	48,186

(2) *Islands for pitching curbs*—	No.	Each.	
(*a*) Earth-work	2	152 0 0	304
(*b*) Cost of ballis	...	745 8 0	1,491
(*c*) Cost of sand bags	...	2,893 8 0	5,787
(*d*) Stores and tools	...	408 0 0	816
(*e*) Carriage on ditto and on sand bags ...	...	51 0 0	102
(*f*) Miscellaneous	...	83 8 0	167
Total	No. 2	4,333 8 0	8,667
(3) *Dry excavation in well sinking*	Nil.	Nil.	Nil.
(4) *Well sinking*—	L. ft.	Per l. ft.	
(*a*) Dredging and removing excavation ...	1,259·6	30 13 10	38,882
(*b*) Depreciation on timber, stores, tools and plant	...	4 15 0	6,221
(*c*) Freight on ditto ditto	...	8 13 10	11,167
(*d*) Workshop charges	...	1 4 8	1,625
(*e*) Supervision	...	1 11 9	2,185
(*f*) Miscellaneous	...	4 10 6	5,866
(*g*) Flood damages		20 11 3	26,073
(*h*) Janeshnagar Station	...	1 3 5	1,528
Total	1,259·6	74 4 3	93,547

Main Heads of Accounts.	Sub-heads of Accounts.	Quantity.	Cost per unit.	Total Expenditure.
IV. Bridge-work—*contd.*	(A) *Major Bridge*—con d	C. ft.	P 100 c. ft.	
	(5) (*a*) *Cement concrete 1½″ brick ballast (in plugs)*—		Rs. A. P.	Rs.
	(*a*) Cost and freight of cement	10,560	28 0 2	2,958
	(*b*) Lead, carriage by boats, and flood damages	..	6 7 11	686
	(*c*) Cost of brick ballast and putting in work	...	17 14 1	1,888
	(*d*) Stores and petty tools	...	0 2 9	18
	(*e*) Workshop charges	...	0 11 4	75
	(*f*) Supervision	...	0 13 0	86
	(*g*) Miscellaneous	...	1 13 5	194
	Total	10,560	55 14 8	5,905
	(5) (*b*) *Cement and concrete ½″ and 2½″ stone balast (in curb and bed blocks)*—			
	(*a*) Cost and freight of cement	7,722	33 3 1	2,563
	(*b*) Cost of stone ballast and ballast train charges	...	3 13 11	299
	(*c*) Lead, carriage, etc., by boats and flood damages	...	3 12 6	292
	(*d*) Breaking ballast and putting in work ...	...	17 2 4	1,324
	(*e*) Stores and petty tools	...	0 3 4	16
	(*f*) Workshop charges	...	0 13 5	65
	(*g*) Supervision	...	1 0 9	81
	(*h*) Miscellaneous	...	2 1 7	162
	Total	7,722	62 2 11	4,802

(6) *Lime concrete in plug—*	C. ft.	Per 100 c. ft.	Rs.
(*a*) Breaking ballast, cost of ballast, lime and putting in work.	10,022	22 1 0	2,211
(*b*) Carriage of kunkar	...	1 11 2	170
Total ...	10,022	23 12 2	2,381
(7) *Sand plugging*	68,609	Per 1,000 c. ft. 4 1 6	281
Total ...	68,609	4 1 6	281
(8) *Brick masonry in cement mortar—*		Per 100 c ft.	
(*a*) Cost and freight, etc., of cement	139,324	19 2 7	26,696
(*b*) Kiln charges, etc.	...	1 4 11	1,821
(*c*) Ballast train charges and carriage of bricks	...	4 15 2	6,895
(*d*) Cost of bricks and putting in work ...	...	25 11 11	35,867
(*e*) Depreciation on plant, stores and tools	...	3 2 9	4,424
(*f*) Workshop charges	...	0 8 10	767
(*g*) Supervision	...	0 9 11	864
(*h*) Miscellaneous	...	1 2 11	1,647
(*i*) Rain and flood damages	...	2 11 4	3,775
(*j*) Janeshnagar Station	...	3 3 1	4,451
Total ...	139,324	62 9 5	87,207