PAPER No. 241

CONSTRUCTION OF A BRIDGE OVER THE SOHAN AT DHOKPATHAN

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Introduction

Fatehjang—Mianwali Road forms Arterial No. 10 in the Punjab Road Development Programme (see Plate I). The Road from Fatehjang to Dhullian having been completed in the year 1938-39, the construction of the bridge over the Sohan with the road from Dhullian to Dhokpathan was sanctioned in December, 1938. The old road from Pindigheb to Dhokpathan is being given up in favour of a new straight cut to Dhokpathan which has easy grades and reduces the distance from Rawalpindi to Dhokpathan by five miles, while the distance to Pindigheb remains practically unchanged. It is expected that the construction of the bridge and the new road will mean a great relief to traffic and particularly passengers who had to hold their breath while negotiating the hairpin bends on the old road and were often stranded at the Sohan Bank.

General

The source of the Sohan lies in the Murree hills where hundreds of small waters merge into a major stream and give it a perennial life. It meets Leih, Ling and Kuring near Rawalpindi and thousands of other nullahs fall in it as it runs its course to enter the Indus. The most important of these streams is the Gambir which collects very nearly the whole of the rainfall of Tallagang Tehsil and joins the Sohan a few miles upstream of Dhokpathan.

The Sohan has cut its course through high banks and at many places it has eaten up the sandstone cover and exposed red clay below it. It is ordinarily fordable by cars in winter, but every rain brings a flood and all through traffic is held up for several days. Thus through traffic is not at all possible during the monsoons. Even swimming across the Sohan is impossible when a major flood is actually passing and transhipment on *charpies* carried shoulder-high—the only means of conveyance across it—is out of question.

Site

The average width of the river-bed is about 1,400 feet but at a convenient bend a little above Dhokpathan it is only 850 feet wide and this neck has been selected for siting the bridge. At this spot the north bank consists of sandstone rock which goes under the bed for some distance. The remaining bed is made of sand and shingle to a depth of over 50 feet and the loose strata encountered during sinking indicate deep scour.

The site-plan (Plate II) shows how the stream, after rounding a curve, enters straight through the bridge. In this circuitous move, the main stream is thrown towards the northern bank which, along with the river-bed, is subjected to severe attacks of the current during flood. The southern portion of the bed is usually dry and is silted up.

The highest known flood was in 1929 when the river rose to R. L. 562.3 and the spill spread to some distance beyond the south abutment. The existence of an old bund in line with the south abutment and a number of wells 50 feet behind this line clearly define the length of the bridge.

Trial Bores

Trial borings were done by the Agricultural Engineer who sank seven-inch diameter pipes and the results are shown in Plate III. A reference to the strata actually met during sinking proves the limitations in the reliability of trial bores of small diameters.

Waterway, Discharge, Scour and Depth of Foundations

The maximum discharge of the stream has been estimated at 120,000 cusecs and a clear span aggregating to 805 feet has been provided. This gives a velocity of 14.5 feet per second under the bridge and the scour depth works out to 48 feet below H. F. L. or to R. L. 514.5. The designed depth of foundations is at R. L. 500.

The trial bores, as will be seen in Plate III, showed clay under the sand and shingle stratum but, on actually sinking the wells, no clay was met with even at R. L. 490. Pockets of clay were, however, found, but further sinking again brought it into sand and shingle. This lower stratum was definitely very compact and at places the sand and clay had been pressed on to the shingle and looked like a natural cement conglomerate.

Design

Plate IV shows the general design of the bridge.

North abutment and piers 1 and 2 were to be founded in sandstone.

The remaining piers and south abutment are carried on two wells 12 feet diameter pitched eight feet apart. These wells were expected to enter clay or sandstone.

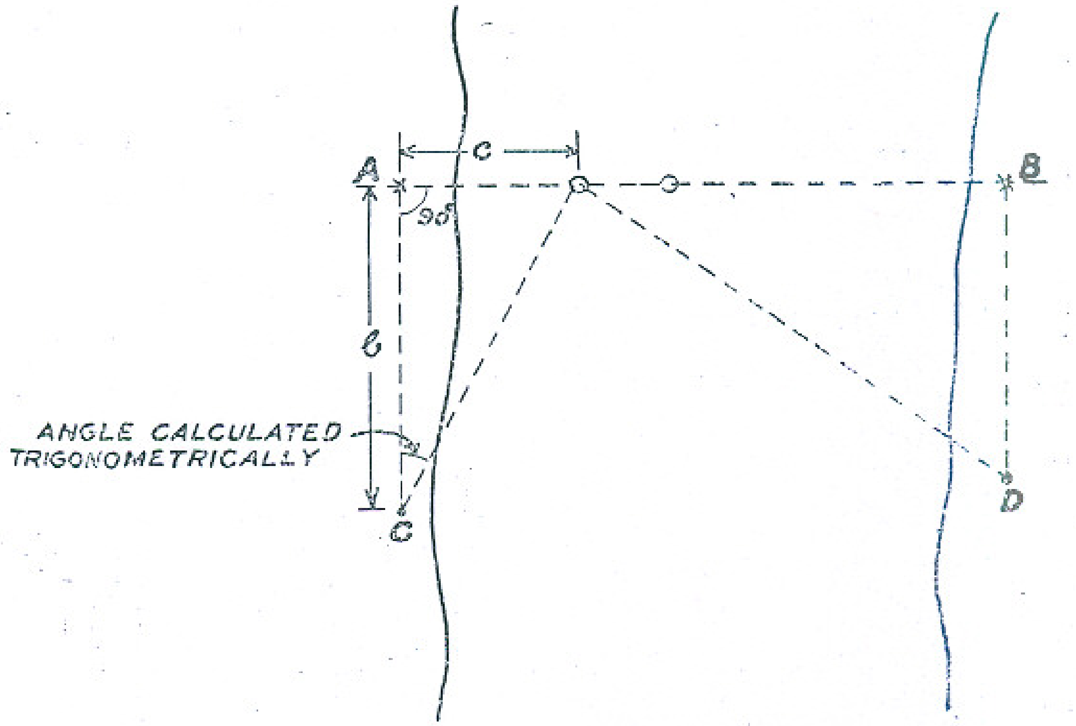
Second-hand steel girders released from the Victoria Railway Bridge at Haranpur were utilised after remodelling to allow 20 feet clear roadway between the wheel-guards and a reinforced cement concrete slab formed the decking.

Working

After calling for competitive designs, the work was given out to S. Uttam Singh Duggal, Contractor, on the design prepared by the Department.

There being no good stone available in the vicinity, a brick-kiln was started at site and all bricks were specially moulded for the required purposes.

The centre-line of the bridge was laid with the help of a theodolite and centres of all piers were marked by cross-lines terminating on *burjis* well clear of the wells. As direct measurements with a steel tape were possible, there was no difficulty in exercising constant check. A double check was also maintained by directly reading the centre of the foundation wells by a theodolite set on the abutments as well as from two points on the banks.



The actual foundation work was started on the 4th February, 1939. The north abutment and first pier were founded in red clay met below five to seven feet of sandstone. The second pier went about 10 feet in sandstone and, except for traces of clay, no clay stratum could be seen even when jumper holes were bored four-and-a-half feet deeper.

In March the stream being about 250 feet wide, extended from pier No. 2 to some distance beyond pier No. 4. The wells for Piers 5 and 6 and the south abutment were tackled first. The well-curbs are made of reinforced cement concrete with ordinary steel cutting-edge (vide Plate V) and were cast *in situ*. The steining consisted of three-foot thick brickwork built with specially moulded bricks laid in 1 : 4 cement mortar. The outside was cement-plastered to reduce skin friction.

Well-Sinking

When the reinforced cement concrete well-curbs had been cured for a fortnight, the steining was built upon and after allowing 48 hours to the brickwork and plaster to mature, dredging was started.

Ordinary 3½-feet diameter Bruce Dredgers worked with steam hoists did the job very successfully.

At the first stage, the slow dredging saved the wells from displacement and tilting.

As soon as the wells had gone down about 20 feet, the dredging was speeded up but the progress was comparatively slow. There was no appreciable skin friction and the only care necessary was uniform dredging all round the circumference of the well.

Whenever a well showed a tendency to lean slightly, it was checked immediately.

A typical operation is described below :

16th June 1939

Pier No. 5—Upstream Well

Sunk to R. L. 517·87

It had developed a tilt of about one foot in the total height. Digging on the outside, dredging on the inside near the higher side of the well and tightening of the coupling attached to the steining guided the well towards its true position. Half the tilt has been corrected and it is expected the other half will also disappear on further sinking.

Up to about R. L. 502.00, the strata met were loose and the sinking proved easy, but below this, very compact sand and shingle mixed with occasional hard-stone boulders obstructed the progress. The sinking became extremely slow and skin friction was enormous. The wells were loaded with sandbags and a load equivalent to 600 lbs. per s.ft. of the area in contact failed to move it until a gelignite charge was thrown in the well.

Official report, dated 4th July, 1939, will be read with interest.

4th July, 1939

Pier No. 5—Upstream Well

R. L. 497·05

At R. L. 498.7 the cutting edge entered a very compact stratum of pebbles and boulders set hard in clay and sand. On going deeper the clay lessened but the stratum continued to be compact. Occasional stones set in natural cementing materials were also met.

Bottom of dredging pit (*kundi*) at R. L. 494.55.

Bottom plug laid.

Rates of Sinking

A complete record was kept for the cost of sinking below 50 feet depth and the rates worked out as follows:

Depth Below Bed

51-52 feet—Rs. 13-8-0 per running foot of depth per foot of well dia.

53-54 feet—Rs. 15-0-0 per running foot of depth per foot of well dia.

55-56 feet—Rs. 16-8-0 per running foot of depth per foot of well dia.

57-58 feet—Rs. 18-0-0 per running foot of depth per foot of well dia.

59-60 feet—Rs. 19-8-0 per running foot of depth per foot of well dia.

61-62 feet—Rs. 21-0-0 per running foot of depth per foot of well dia.

Wells under piers 3 and 4

The curbs for Piers 3 and 4 were laid on 15th October, 1939, after diverting water to the southern bank and making temporary islands to enable casting of reinforced cement concrete curbs *in situ*.

As it was contemplated to sink these wells in rock, special welded cutting edges (as shown in Plate V) were manufactured by the Railway Department.

The sinking of these wells was quite a simple affair till the sandstone rock was encountered at R. L. 520. Calculated maximum scour level for uniformly scouring bed of sand and shingle for this stream works out to R. L. 514.5. It was thus clear that in the case of every major flood, the scour will extend down to the surface of the rock and even the sandstone rock itself will be exposed to further attacks. The sandstone met in the open foundations for piers 1 and 2 being not very hard, it was decided that the wells must go down in the rock by about five feet.

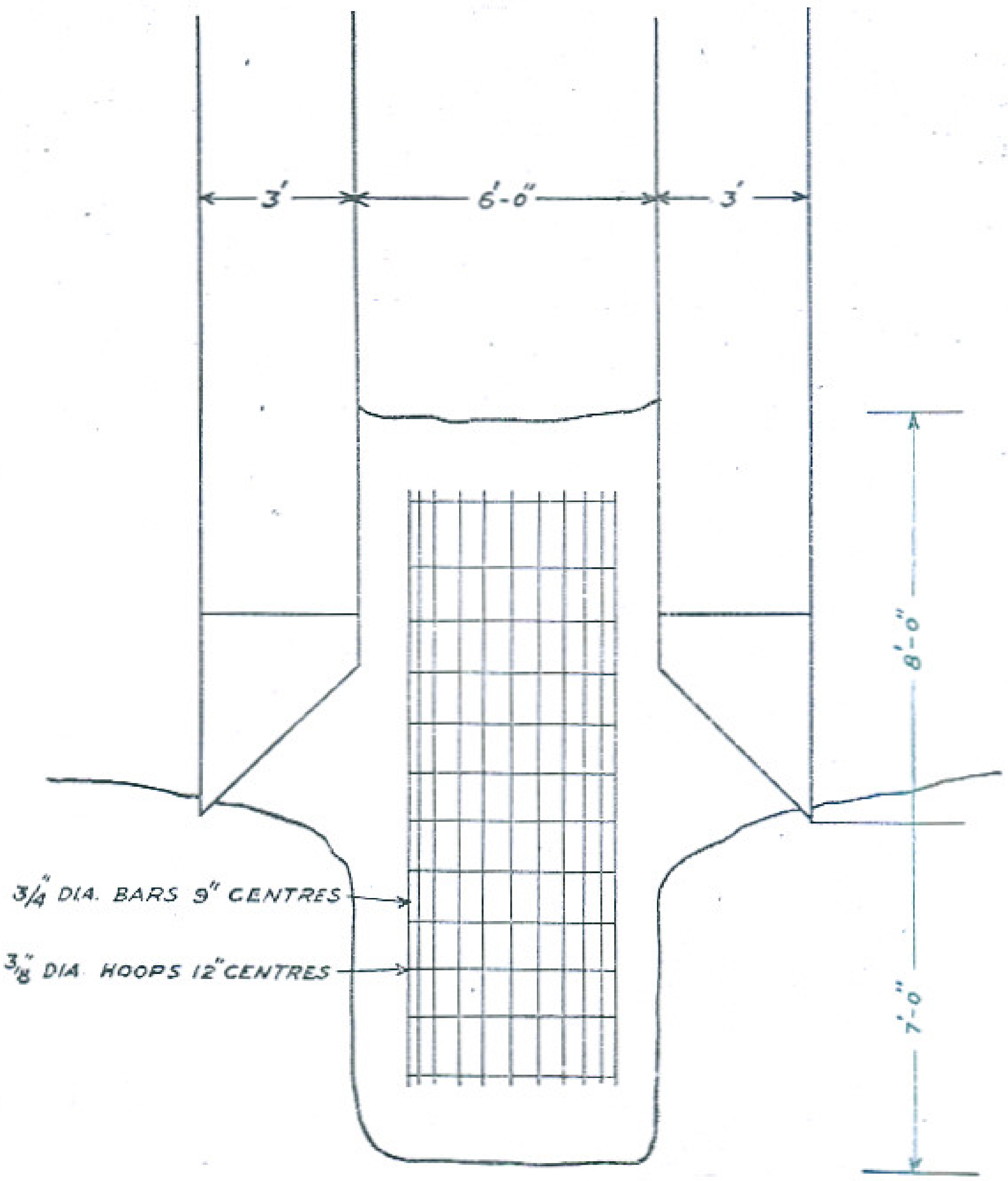
During actual execution, the sinking of wells in rock proved impracticable. The wells could not be pumped dry and the ordinary rail-cluster chisels could not dig a hole greater than three feet in diameter. The dredger was unable to empty this hole and further digging more than a foot or so deep could not proceed.

The rail chisel was redesigned with an eccentric self-weight to enable it to strike at the edge along the inside of the steining. This enabled six feet diameter holes to be dug in the rock and chippings were dredged out.

The question of bonding the wells with the plug especially when not much reliance could be placed on the durability of the sandstone invited further consideration. It was decided to put in reinforcement in the form of a circular crate four-and-a-half feet diameter with three-quarter-inch diameter rods nine-inch centres as verticals and $\frac{3}{8}$ diameter hoops, to stand any eccentric stresses due to possible uneven bedding of the wells.

1 : 2 : 4 cement concrete was used for the plug. As the pouring was done under water and there was possibility of slight blowing, neat cement was thrown down the chutes when depositing concrete near the cutting edge all round.

The following sketch shows the plug:



The official reports describe the event as below:

15th December, 1939

Pier No. 3—Upstream Well

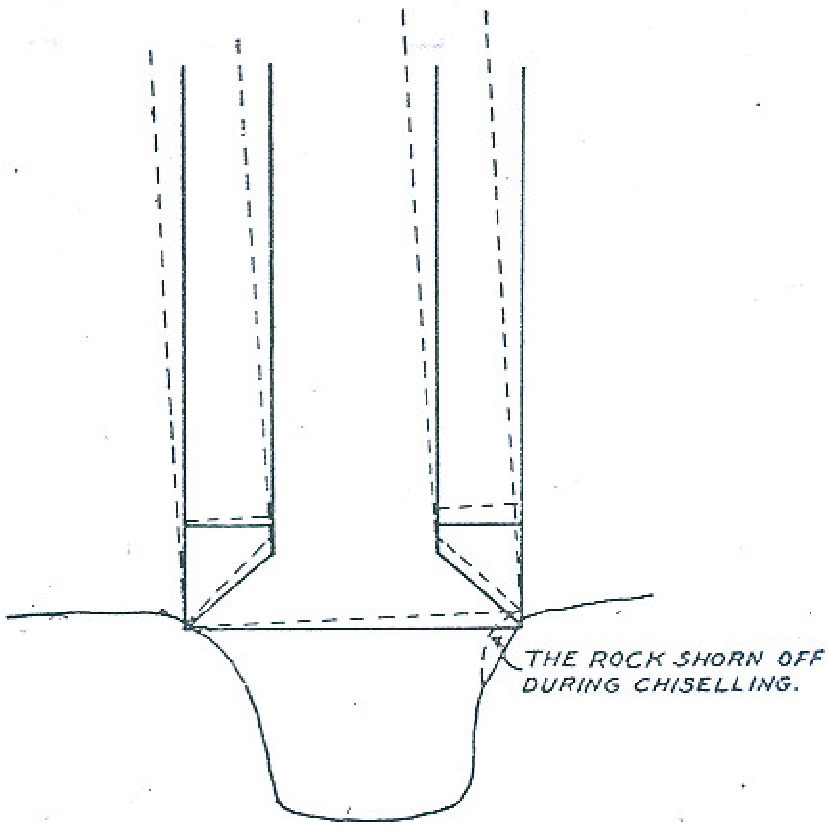
There was very heavy blowing-in of sand. The well was at once loaded and sandbags were thrown in the pit (created on the outside) to enable the bags to sink down and stop blowing. A few charges of gelignite were also thrown in. The blowing diminished and the dredger was able to empty the *kundi* absolutely. Rail-cluster chisel was then worked with the help of the winch. The rock being tough, only small pieces were chipped off. This was continued for 48 hours and then the dredger was lowered to clear the chippings and further charges of gelignite were thrown in to make the well settle. It was then observed that the well had a tendency to tilt. Wire ropes were at once wound round the steining and connected by a coupling to a suitable anchor situated beyond the higher side of the well. By tightening the coupling an effective anchorage was obtained and this proved very successful as the tilt did not increase to more than two inches in 12 feet. After continuous repetitions, the curb settled down a little and there was a one-and-a-half foot deep *kundi* in the rock and it was expected that the well could now be pumped dry. A big *charsa*, a centrifugal pump six-inch suction and five-inch delivery and a pulsometer No. 6 were tried but without success. With the aim to rest the wells evenly on the rock and better still if we can get into it by four or five feet, the contractor has been advised to arrange for pumps for drying the wells and to enable lowering men to cut the rock. The well being already 32 feet below bed level the centrifugal pumps do not help and three pulsometers with boilers and accessories are being collected from different sources in the department and outside and this work is expected to start as soon as the machinery arrives. In the meantime the work with rail-cluster chisels continues on all the wells and the *kundi* is being dug as deep as possible. It is also possible the wells may settle down a few inches and thus lessen the inrush of water.

31st December, 1939

Pier No. 3

Dewatering of wells with the help of pumps and *charsa* proved ineffective and had to be given up. It has now been decided to widen and deepen the *kundi* in the rock and to put in a reinforced concrete plug starting from the bottom of the *kundi* and going about 8 feet up the steining. The up-to-date depth of *kundi* in these wells is about six feet and this has helped in chipping off the rock on the higher side, thus partially straightening the well.

The sketch below illustrates what happened. There is no blowing-in of sand but to be sure that the plug (even on the lowest side of the rock) is at least five feet, it is proposed to deepen the *kundi* to about seven feet.



Pier No. 4

Since commencement, there is no blowing in these wells and the rock seemed more or less level. Five feet deep *kundis* were made and reinforced cement concrete plugs laid.

Soundings were also taken with the help of a galvanised iron pipe which was sunk to rock level all round the inside of the steining. This confirmed the previous decision that the curbs were evenly resting on rock.

15th January, 1940

Pier No. 3

Seven-feet deep *kundis* completed and reinforced concrete plug laid.

For final levels of all wells, please refer to Plate IV.

The sketch of the rail-cluster chisel which enabled six-foot diameter *kundi* to be made is shown in Plate V.

Cost

The approximate cost of making six-foot diameter hole in sandstone rock with the help of rail-cluster chisel works out to Rs. 400-0-0 per running foot of depth of the hole.

Plugs for wells under Piers 5 and 6 and South Abutment

After trial with 1 : 3 : 6 cement concrete 1 : 2 : 4 cement concrete plugs were finally adopted. This made the plugs effective and water-tight.

Transoms

The transoms consist of two-feet thick reinforced cement concrete laid in the form of a trepezoid to fully cover the wells, vide Plate V.

Girders

The Bridge Department of the North Western Railway undertook to supply the girders in pieces each not more than thirty-five feet in length and three-and-a-half tons in weight. These were carried on six-ton Bedford trucks from the railhead to the site and it was really a very creditable performance on the part of drivers who had the nerve to negotiate a dozen hairpin bends one below the other on the *kacha* road while carrying this load.

Hoisting of girders

In the absence of standard stagings and proper machinery an improvised system of sleeper cribwork supported on wooden piles 10 to 15 feet long driven into the bed was adopted and the pieces were raised with the help of a derrick working by means of a steam hoist.

Photographs 4 and 5 show the staging and the hoisting work in hand.

Flood during hoisting

Nothing of any importance happened till the last span (No. 3) was being hoisted. On the night of the 18th June, a sudden flood in the Sohan woke us up at dead of night and, within fifteen minutes of the first rise in water, one of the sleeper crates supporting the girder crashed as the bed round the wooden piles bearing it had been scoured and the piles carried away. This was followed by some more and, before the flood subsided, four supports out of the total of eight had been washed away. The bottom booms of the girders were up and had been bolted. The diagonals were being hoisted in position and were nearing completion but no top boom had yet been tackled. Two end cross-beams had also been fitted. On the sudden removal of the intermediate supports the whole load had to be taken up by the bottom boom and it sagged. The toppling over of the girders under the unstable weight of the diagonals was prevented by the end cross-beams.

The girders with bottom booms badly sagged and diagonals all displaced was a very serious problem to face. Luckily the flood subsided after eight hours duration. Eight 10-ton screw jacks were collected, the scour holes were filled in with stones and the sleeper-stacks rebuilt within twenty-four hours of the subsidence of the flood. The more dangerous of the two girders was tackled first and two 10-ton screw jacks were used to raise each joint. The operation of raising was started simultaneously at each joint and no sooner the lowest joint of the bottom boom was at proper level, further levering was stopped. The higher joints were then easily lowered to the correct level. When the girder was in proper camber, it was not quite straight sideways. This was corrected by jacking up eccentrically and, as soon as the central cross-beams were placed, the girders were bound down in their correct position. The bolts and holes were examined individually and everywhere the bolt was found partially sheared and the hole intact.

The top booms were then hoisted and the span was completed with bolts and drifts on the twenty-eighth June, two days before the floods commenced. These two days were utilized in riveting the main joints and when the supports were again carried away, the girders retained their proper camber. Thus ended a fortnight of day-and-night work and the completion of the operation of hoisting.

Photograph No. 6 shows what happened on the 19th June, 1940.

Riveting

Motive power for riveting hammers and drilling machines was supplied by an Air Compressor Type 20 (petrol-driven) having a piston displacement of 250 cubic feet per minute at 100 lbs. pressure. This machine was lent by the Bridge Engineer, North Western Railway.

As the old girders were used, the rivet-holes were enlarged but these were wonderfully uniform and round and reamering was thought unnecessary. Except for the judicious selection of proper-sized rivets, no other difficulty was experienced in actual assembling and the cambers of the completed spans were within half-an-inch of the original camber for the new girders.

Loads

The girders of this bridge can take a 15-ton steam road roller or a vehicle giving an equivalent load of 10 British Standard Units but not a train of such vehicles.

The decking slab consists of a monolithic slab designed to the Indian Road Congress Standard loading.

The two 40-foot spans have three-foot-three-inch cantilevering decking and there being no definite standard laid for such cantilevers, this had to be examined in detail.

The Indian Road Congress Standard loadings are:

0.34 ton per linear foot of each traffic lane (i.e., 10 feet) with a minimum of 6.8 tons per lane of traffic over the whole loaded lengths.

+6 tons knife-edge load.

In the ordinary, simply-supported slab, the above loads are supposed as distributed on a 10-foot width and the load per linear foot width works out as:

.68 tons distributed load.

+.6 tons concentrated load.

It is equivalent to

.94 tons concentrated load per foot width.

Now it has been suggested that the above load should be halved for cantilevers as only one wheel of vehicle can come on them.

The ordinary load the bridges are called upon to carry these days are the six-ton trucks with a gross weight of eight tons. The tyre-width of such trucks in contact with the road surface is eight inches and the resulting bending moment is about the same as that due to the back wheel of a 10-ton steam road roller with 18-inch wheel-width.

Assuming each wheel of such a truck (gross load=eight tons) to carry two tons and allowing a distribution in three feet width for three feet cantilever, the load per linear foot width works out as .66 tons.

This is very nearly equivalent to:

Full standard distributed live load

+half the standard concentrated load and the slab was designed for this load.

The calculations for the decking slabs are attached as an appendix.

Proportioning of concrete

Very coarse sand and excellent shingle were obtained from sinking of wells. Experiments were carried out with different practical proportions of finer and coarser aggregates (available at site) for

1 : 2 : 4 cement concrete and the following gave the highest compressive strength and was adopted :

90 lbs. cement : $1\frac{1}{2}$ c.ft. sand $+\frac{1}{2}$ c.ft. fine shingle (actually *bajri* and sand below $\frac{3}{8}'' \times \frac{3}{8}''$)

: $2\frac{1}{2}$ c.ft. shingle passing through $1'' \times 1''$ and retained on $\frac{3}{8}'' \times \frac{3}{8}''$ screens$+1\frac{1}{2}$ c.ft. fine shingle (actually *bajri* and sand below $\frac{3}{8}'' \times \frac{3}{8}''$)

—Compressive stress 3,250 to over 3,733 lbs.

Floods

The bridge experienced a flood of R. L. 560.0 (2.3 feet less than the H. F. L.) on 9th August, 1940.

Photograph No. 7 shows the flood actually passing under the bridge.

It is interesting to see an efflux of about four feet just near the nose of Pier No. 3 with an occasional wave the crest of which almost reaches the top of the pier.

Cost

The bridge (excluding the approaches and link road) costs Rs. 3,24,800 as detailed below :

1.	Foundations— North abutment and piers Nos. 1 and 2 on sandstone rock and piers 3, 4, 5, 6 and south abutment on wells	.. Rs.	89,200
2.	Piers and abutments	.. Rs.	19,300
3.	Cost of girders, including hoisting, fixing and painting	.. Rs.	1,89,400
4.	Decking slab	.. Rs.	26,900

The cost per running foot works out at Rs. 370.

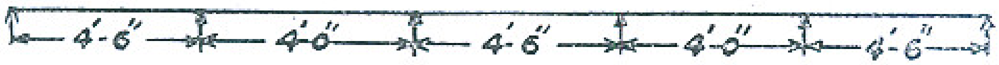
The approaches and link road (six miles) cost Rs. 50,200.

Opening Ceremony

The bridge was formally opened to traffic on the 15th November 1940, by The Hon'ble Major Nawabzada Malik Khizar Hayat Khan Tiwana, O.B.E., Minister of Public Works, Punjab.

APPENDIX A

Calculations for Reinforced Cement Concrete Slab in Main Spans



Maximum span for calculations=4 ft. 6 ins.

The slab being continuous assume B. M $= \frac{WL}{10}$

Dead load—

Weight of slab per s.ft. $= \frac{2}{3}$ @ 150 lbs. = 100 lbs.
Wearing coat $1\frac{1}{2}$ inch $= \frac{1}{8}$ @ 140 lbs. = 18 lbs.

Total = 118 lbs. per s.ft.

$$\text{B. M.} = \frac{118 \times 4.5^2}{10} = 240 \text{ ft. lbs.}$$

Live Load—

(*i*) Distributed load of 6.8 tons over the span +50% impact

$$\text{B.M.} = \left\{ \frac{6.8 \times 4.5}{10} \times 2240 \right\} \times 1.5$$
$$= 1030 \text{ ft. lbs.}$$

(*ii*) Knife-edge load of 6 tons +50% impact

$$\text{B. M.} = \frac{6 \times 1.5 \times 4.5}{5 \times 10} \times 2240$$
$$= 1800 \text{ ft. lbs.}$$

Total Bending Moment $= 1800 + 1030 + 240$
$= 3070$ ft. lbs. per ft. width of slab.

$$d = \sqrt{\frac{M}{R \times b}} = 5.75 \text{ inches.}$$

Assumed depth (overall) 8 in.
Effective depth = 7 in.

$$\text{Area of steel necessary} = \frac{3070 \times 12}{7 \times \frac{7}{8} \times 16000} = 0.38 \text{ sq. in.}$$

or $\frac{1}{2}$ in. bars 6 in. centres.

Shear Stress—

loads—(*i*) 9 tons + 50% impact (knife-edge load).

(*ii*) 6.8 tons + 50% impact (distributed load).

(*iii*) Dead load.

$$\text{Max. shear} = \frac{1}{10}\left\{9\times1.5\times2240+\frac{6.8\times1.5\times2240}{2}+\frac{118\times4.5}{2}\right\}$$

$$= 4200 \text{ lbs.}$$

$$\text{Shear stress} = \frac{4200}{12\times\frac{7}{8}\times7} = 57 \text{ lbs. per sq. in.}$$

which is safe.

Bond Stress—

$$u = \frac{V}{j.\ d.\ \Sigma 0}$$

$$= \frac{4200}{7\times\frac{7}{8}\times\frac{22}{7}\times2\times\frac{1}{2}} = 220 \text{ lbs. per sq. in.}$$

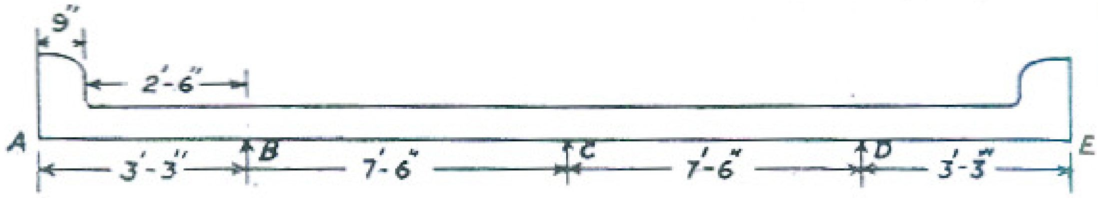
which is very high.

Using $\frac{1}{2}$-in. dia. bars $3\frac{1}{2}$-in. centres,

$$\text{Bond stress} = \frac{4200}{7\times\frac{7}{8}\times\frac{22}{7}\times\frac{1}{2}\times\frac{24}{7}} = 127 \text{ lbs. per sq. in.}$$

It is safe, *vide* page 110 of the Indian Road Congress Standard Specification and Codes of Practice.

Calculations for Slab in Short Spans



PARTS B C AND C D

Span =7′-6″

Dead Load—

Wt. of slab per s.ft. $= \frac{2}{3}$ @ 150 lbs. = 100 lbs.

Wearing coat $1\frac{1}{2}$ in. $= \frac{1}{8}$ @ 140 lbs. = 18 lbs.

Total per s.ft. = 118 lbs.

$$\text{B. M.} = \frac{WL}{10} = \frac{118\times7.5^2}{10} = 660 \text{ ft. lbs.}$$

Live load—

(*i*) Distributed load of 6.8 tons+50% impact

$$\text{B. M.} = \frac{6.8\times7.5\times2240\times1.5}{10\times10} = 1720 \text{ ft. lbs.}$$

(*ii*) Knife-edge load of 6 tons+50% impact

$$\text{B. M.} = \frac{6\times1.5\times7.5}{5\times10}\times2240$$

$$= 3000 \text{ ft. lbs.}$$

Total Bending Moment = 660+1720+3000

= 5380 ft. lbs.

$$d = \sqrt{\frac{M}{R.b}} = 7\tfrac{1}{2} \text{ inch.}$$

To keep a uniform depth of slab, *i.e.*, 8 in. overall, the effective depth = 7 in.

$$\therefore \text{Area of steel} = \frac{5380\times12}{\frac{7}{8}\times7\times16000} = 0.66 \text{ sq. in.}$$

use $\frac{1}{2}$ in. bars at $3\frac{1}{2}$ inch. centres.

The increase in concrete stress being nominal is allowed.

Cantilevers AB and DE

Dead Load Bending Moments—

(*i*) B. M. due to roadway $= \frac{1}{2}\times3\frac{1}{4}\times3\frac{1}{4}\times118 = 623$ ft. lbs.

(*ii*) B. M. due to wheelguard $= 2\frac{7}{8}\times\frac{3}{4}\times\frac{3}{4}\times150 = 243$ ft. lbs.

(*iii*) B. M. due to railing $= 20\times3\frac{1}{4} = 65$ ft. lbs.

Live load Bending Moments—

(*i*) B. M. due to distributed live load 6.8 tons+50% impact

$= {}^1/_{10} \times 6.8 \times 1.5 \times 2240 \times {}^5/_4$

$= 2{,}856$ ft. lbs.

(*ii*) B. M. due to knife-edge load of 3 tons+50% impact

$= {}^1/_{10} \times 3 \times 1.5 \times 2240 \times {}^5/_2$

$= 2{,}520$ ft. lbs.

Total B. M. $= 2{,}520+2{,}856+65+243+623$

$= 6{,}307$ ft: lbs.

Adding an additional bar in tension, the area of tensile steel is 1.00 sq. inch. in $12 \times 7 = 84$ sq. in (of cross-section)

i.e., 1.2%

Compression steel being $\frac{1}{3}$ of 1.00= .33 sq. in. or ·4%.

R=130 [R. C. Concrete Design by G. P. Manning.]

$$d = \sqrt{\frac{6307}{130}} = 6.9 \text{ in.}$$

Actual Depth (effective) = 7 in.

Shear Stress—

Testing for parts BC and CD.

Loads—(*i*) 9 tons knife-edge + 50% impact.

(*ii*) 6.8 tons distributed + 50% impact.

(*iii*) Dead load.

$$\text{Max. Shear} = \frac{1}{10}\left\{ 9 \times 1.5 \times 2240 + \frac{6.8 \times 1.5 \times 2240}{2} + \frac{118 \times 7.5}{2} \right\}$$

$= 4210$ lbs.

$$\text{Shear stress} = \frac{4210}{12 \times \frac{7}{8} \times 7} = 57 \text{ lbs. per sq. in.}$$

which is safe.

Bond Stress—

$$u = \frac{V}{jd.\ \Sigma O}$$

$$= \frac{4210}{7 \times \frac{7}{8} \times {}^{22}/_7 \times \frac{1}{2} \times {}^{24}/_7} = 128 \text{ lbs. per sq. in.}$$

It is safe, vide page 110 of the Indian Road Congress Standard Specification and Codes of Practice.

APPENDIX "B"

List of Plant and Machinery Used in the Construction of the Bridge.

Well-sinking Plant

1.	Crab Winch ..	2 Nos. Double.
2.	Steam hoists with wire ropes ..	2 Nos. Double Cylinder, with vertical Boilers.
3.	Portable boilers ..	2 Nos. Ransom & Sons (for working the pulsometers and centrifugal pumps).
4.	Pulsometers ..	2 Nos. Size 7, 5-in. suction 4-in. delivery. 1 No. Size 6, 4-in. suction 3½-in. delivery.
5.	Centrifugal pumps 6″ diameter	2 Nos.
6.	Lift and force pump ..	1 No.
7.	Bull dredgers with iron chains	4 Nos.—4 c.ft. capacity. 2 Nos.—2 c.ft. capacity.
8.	Peter Engine with centrifugal pump. Portable.	1 No.

Erection Plant

1.	Air Compressor ..	1 No. Ingersoll Rand, Portable, Petrol driven capacity 250 c.ft. of free air per minute compressed to 100 lbs.
2.	Riveting hammers ..	4 Nos.—size 8-a.
3.	Holders size "D" ..	4 Nos.
4.	Drilling machines ..	4 Nos.
5.	Camber jacks ..	32 Nos.—10-Ton capacity.
6.	Hydraulic jacks ..	2 Nos.—50-Ton. capacity.
7.	Woulf hand ground forge ..	2 Nos.
8.	Lifting screw-jacks ..	5 Nos.—15 to 20-ton capacity.

APPENDIX "C."

DHOKPATHAN BRIDGE

Chart of General Progress.

Description.	Excavation for Foundation.		Concreting in Founds of Well Curb.		Brickwork.		Sinking of Wells.		Transum Across Wells.		Piers.		Depth of wells below bed.	Nature of stratum when sinking stopped.	Spans.	Girder Erection Inclg: Riveting.		R.C.C. Slab Decking.		Remarks
	Commenced.	Completed.	Commenced.	Completed.	Commenced.	Completed.	Commenced.	Completed.	Commenced.	Completed.	Commenced.	Completed.				Commenced.	Completed.	Commenced.	Completed.	
North Abutment ..	5 4/39	21 4/39	22 4/39	29 4/39	..	..	..	..	..	..	15 5/39	9 6/39	..	..	No. 1.	10 11/39	18 3/40	26 5/40	26 5/40	
Pier No. 1 ..	18 3/39	15 4/39	16 4/39	19 4/39	..	..	..	..	..	..	23 4/39	1 6/39	..	..	No. 2.	20 11/39	22 3/40	10 6/40	10 6/40	
Pier No. 2 ..	5 5/39	1 6/39	2 6/39	3 6/39	..	..	..	..	..	..	4 6/39	5 10/39	..	..	No. 3.	19 5/40	30 7/40	2 8/40	3 8/40	
Pier No. 3 ..	..	..	1 11/39	4 11/39	5 11/39	6 12/39	2 11/39	1 1/40	8 1/40	8 1/40	4 2/40	13 2/40	30 & 28·75	Sand-stone.	No. 4.	6 5/40	20 8/40	22 8/40	24 8/40	
Pier No. 4 ..	..	..	23 10/39	26 10/39	1 11/39	2 12/39	4 11/39	21 12/39	3 1/40	3 1/40	17 1/40	3 2/40	31·10& 36·14	Sand-stone.	No. 5.	4 4/40	7 8/40	16 8/40	18 8/40	
Pier No. 5 ..	18 3/39	9 4/39	11 4/39	11 4/39	24 4/39	6 7/39	25 4/39	10 7/39	23 7/39	23 7/39	31 7/39	15 8/39	53·75 53·50	Compact Sand & Shingle.	No. 6.	25 2/40	23 7/40	25 7/40	27 7/40	
Pier No. 6 ..	18 3/39	23 4/39	25 4/39	26 4/39	9 5/39	15 7/39	13 5/39	28 7/39	2 8/39	2 8/39	13 8/40	11 10/40	56·77& 57·46	Do.	No. 7.	19 1/40	16 7/40	18 7/40	19 7/40	
South Abutment ..	8 5/39	12 5/39	13 5/39	22 5/39	31 5/39	31 7/39	2 6/39	2 8/39	14 8/39	14 8/39	11 10/39	22 10/39	45·4 & 44·8	Do.						

PHOTO NO. 1.—DHOKPATHAN BRIDGE.

The only means of conveyance across the Sohan before the construction of the bridge.

PAPER NO. 241

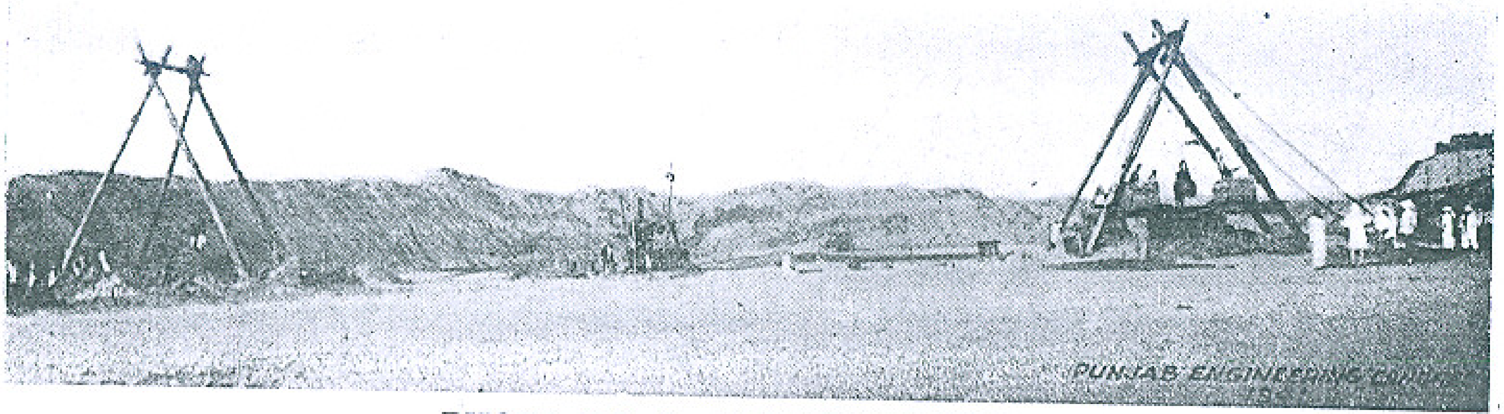


PHOTO NO. 2.—DHOKPATHAN BRIDGE.
Sinking of wells.

PAPER NO. 241

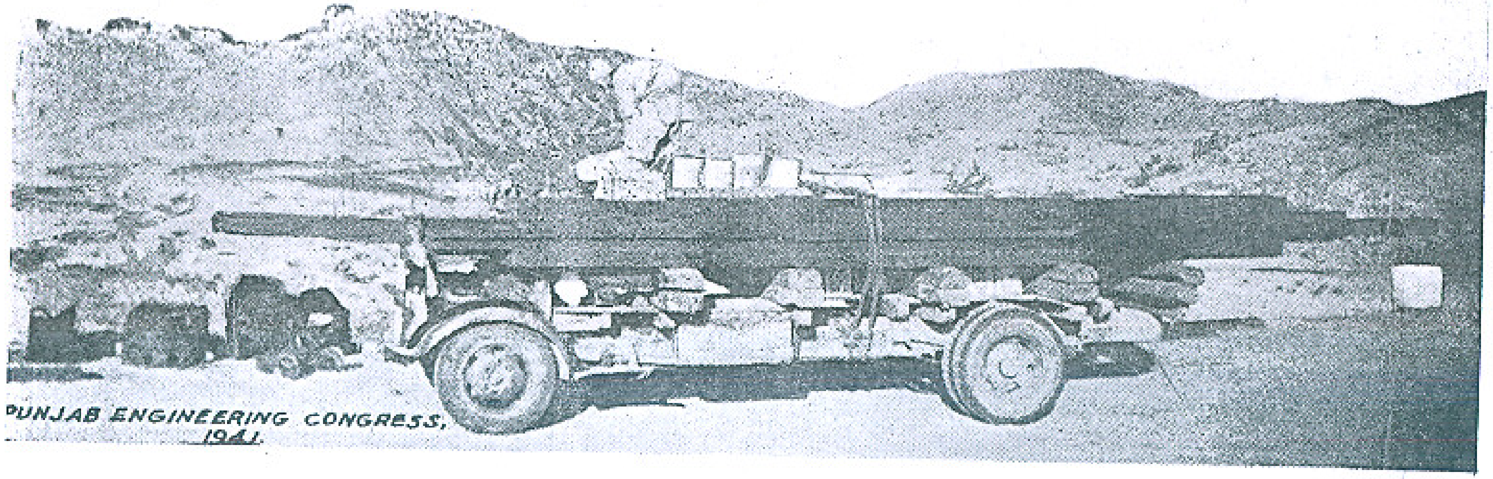


PHOTO NO. 3.—DHOKPATHAN BRIDGE.
Haulage of girders to site.

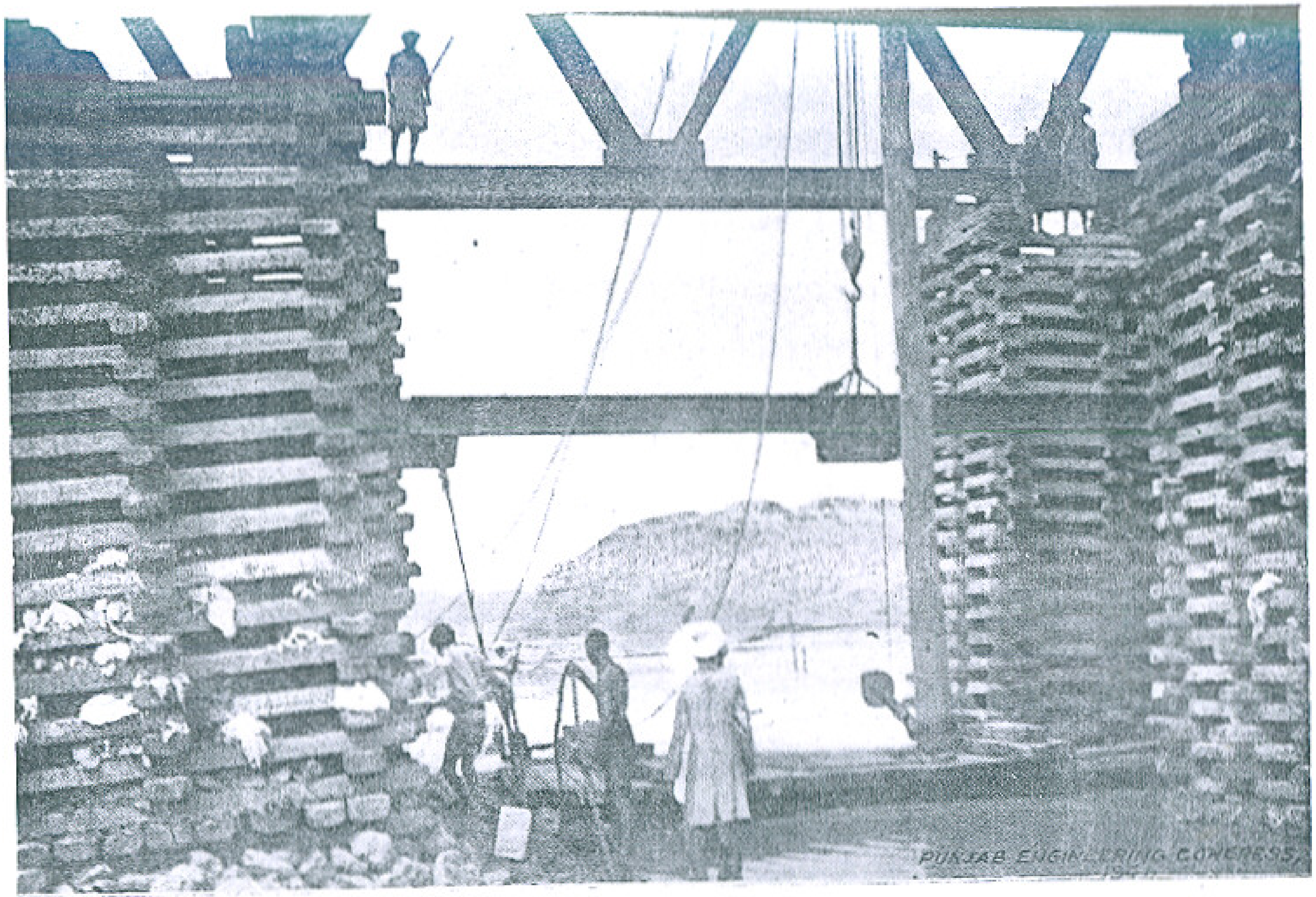


PHOTO NO. 4.—DHOKPATHAN BRIDGE.
Hoisting of girders,

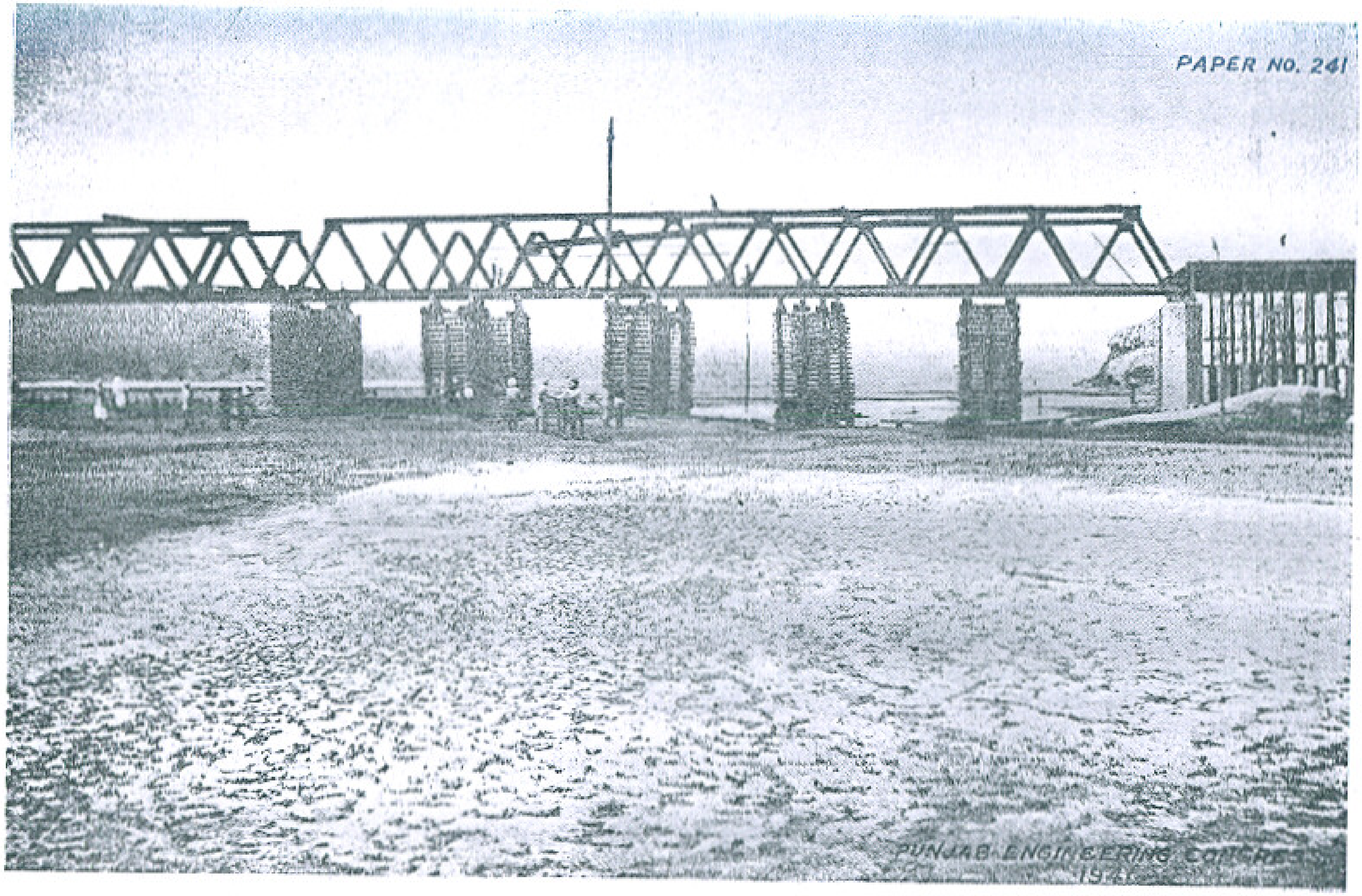


PHOTO NO. 5.—DHOKPATHAN BRIDGE.
Hoisting of girders.

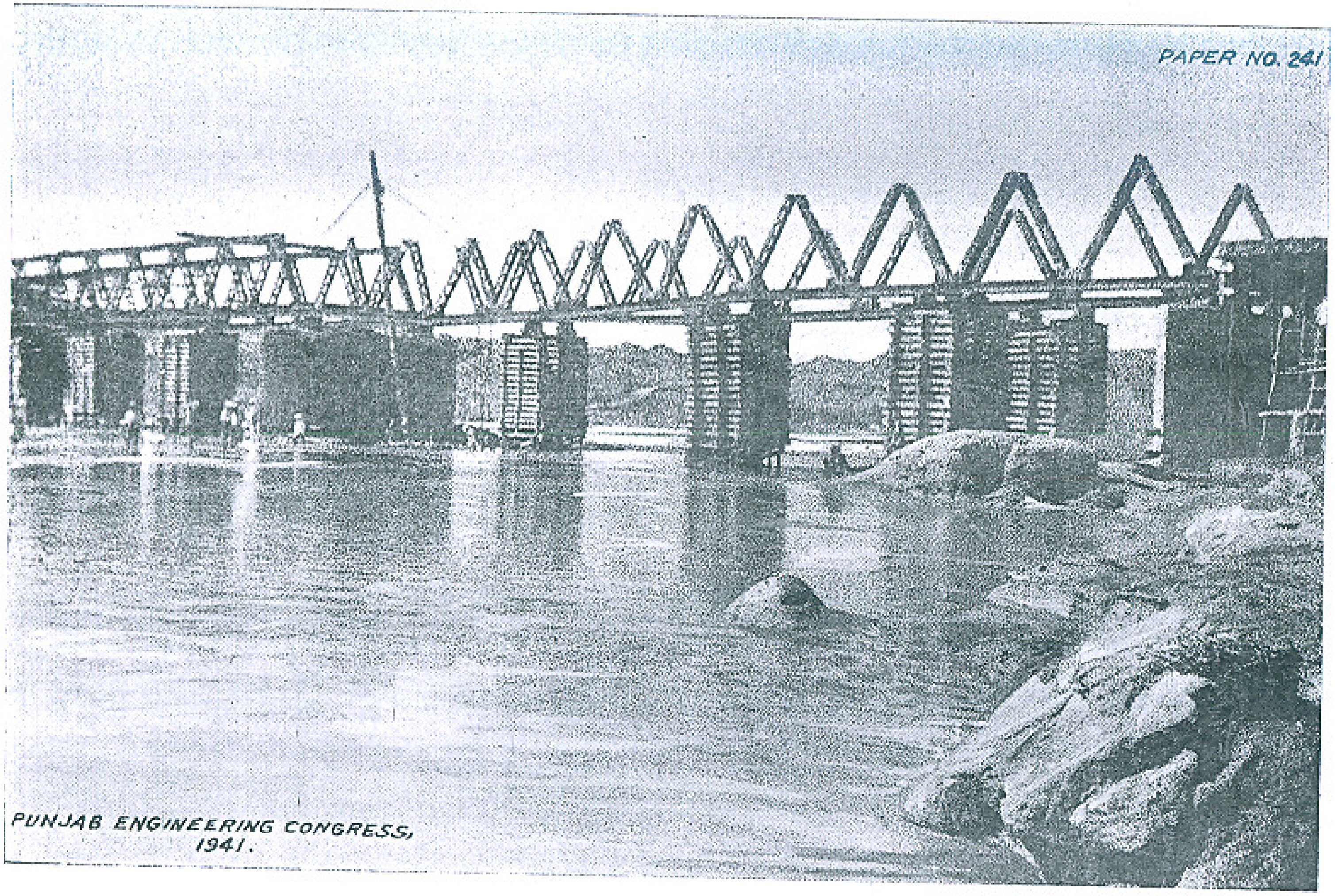


PHOTO NO. 6.—DHOKPATHAN BRIDGE.
A view of sagged girder of Span No. 3 after the flood of 19-6-1940

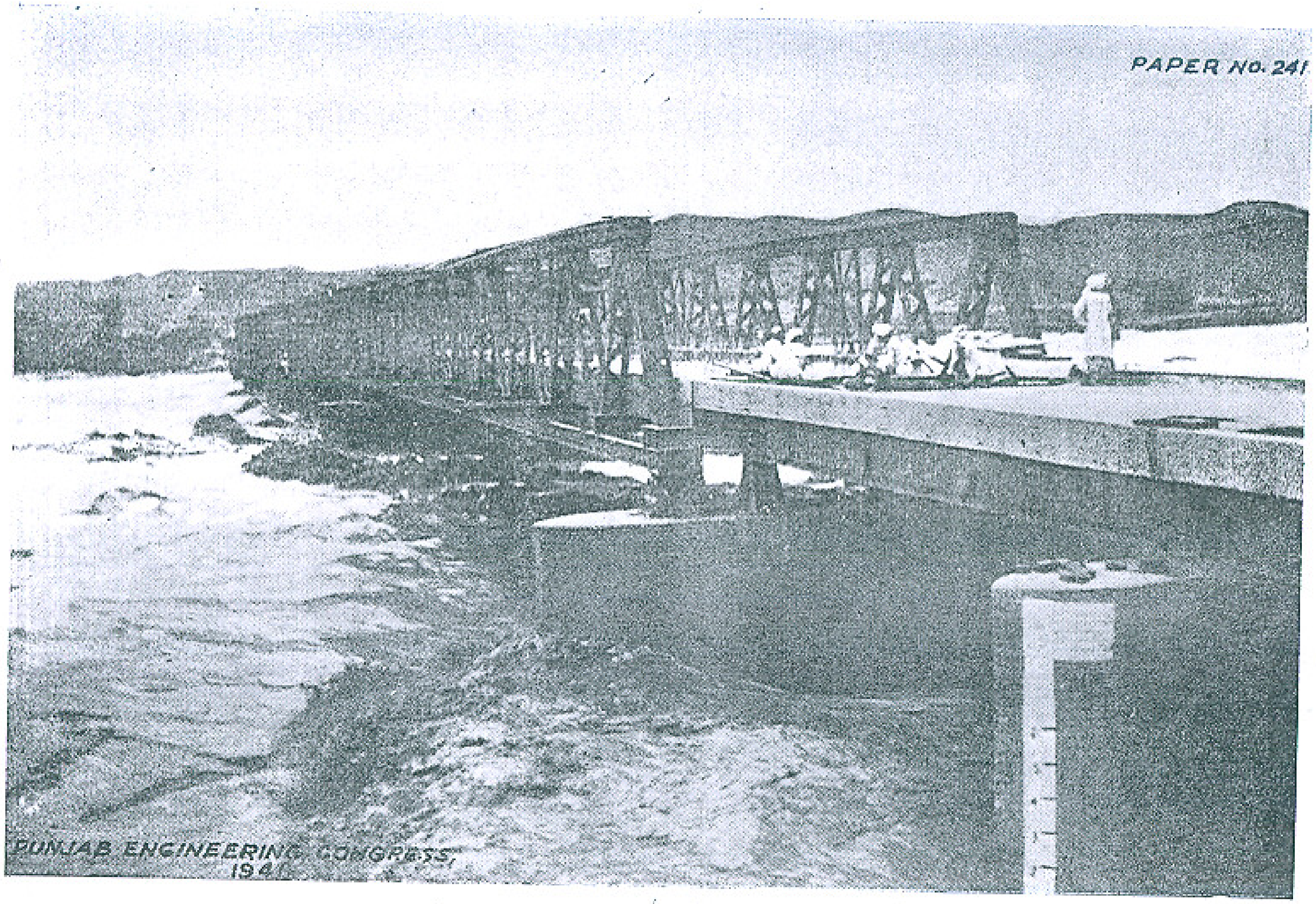


PHOTO NO. 7.—DHOKPATHAN BRIDGE.
Flood of 9th August, 1940.

PAPER NO. 241

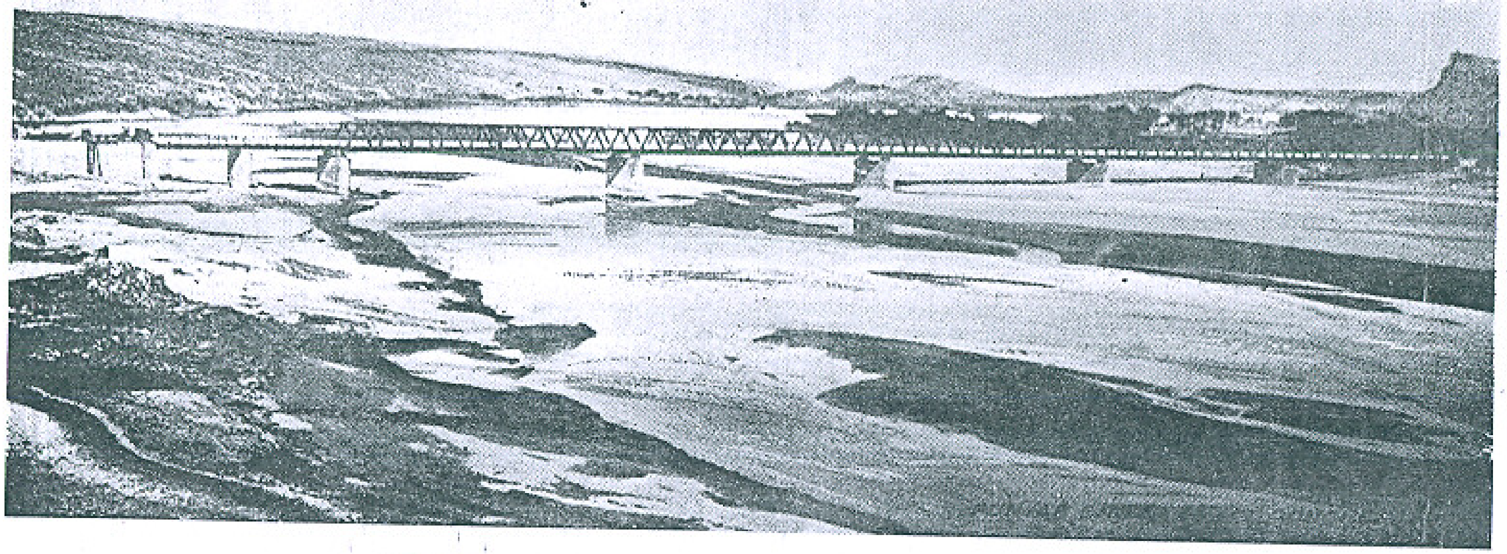
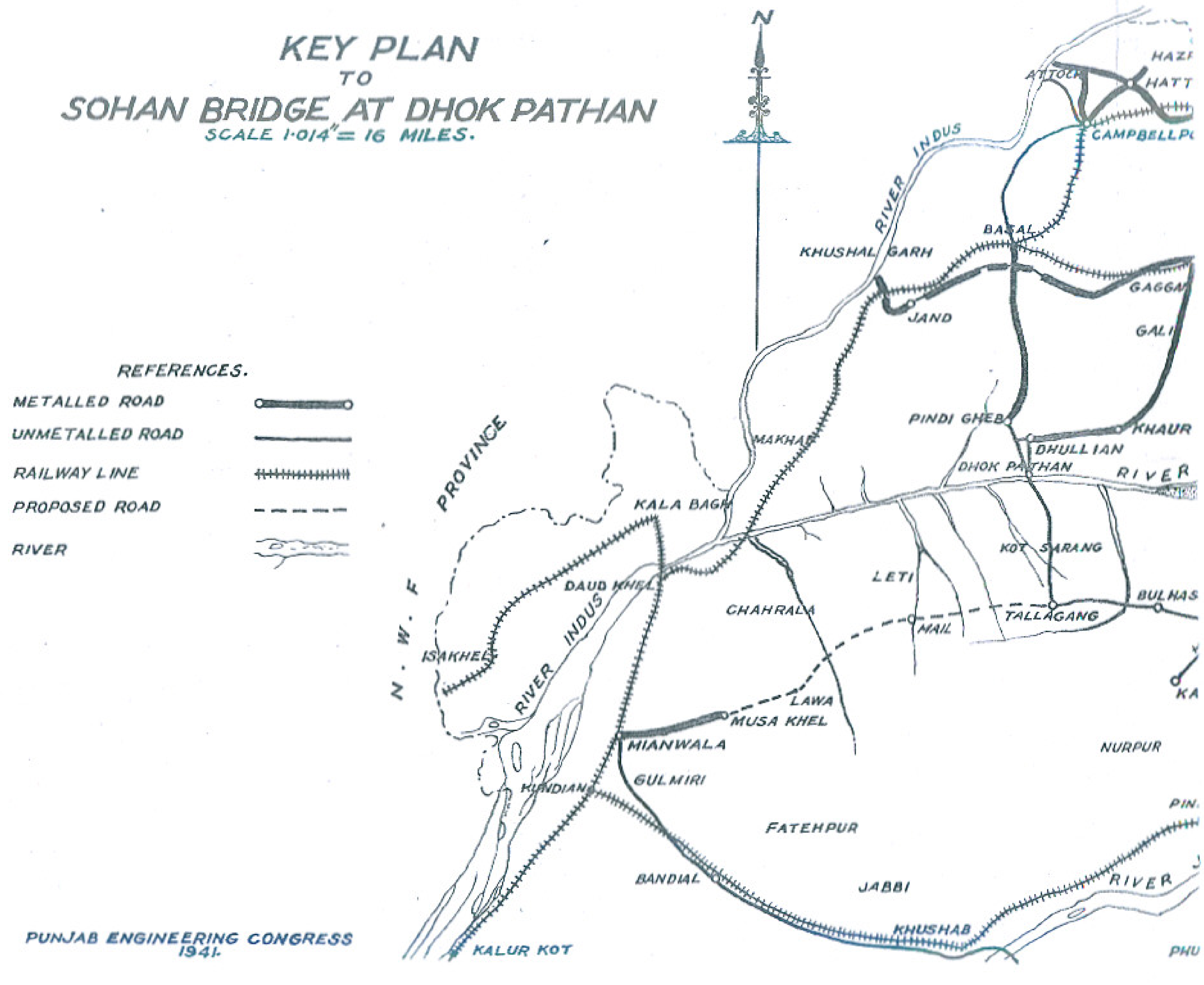


PHOTO NO. 8.—DHOKPATHAN BRIDGE.
Completed bridge.

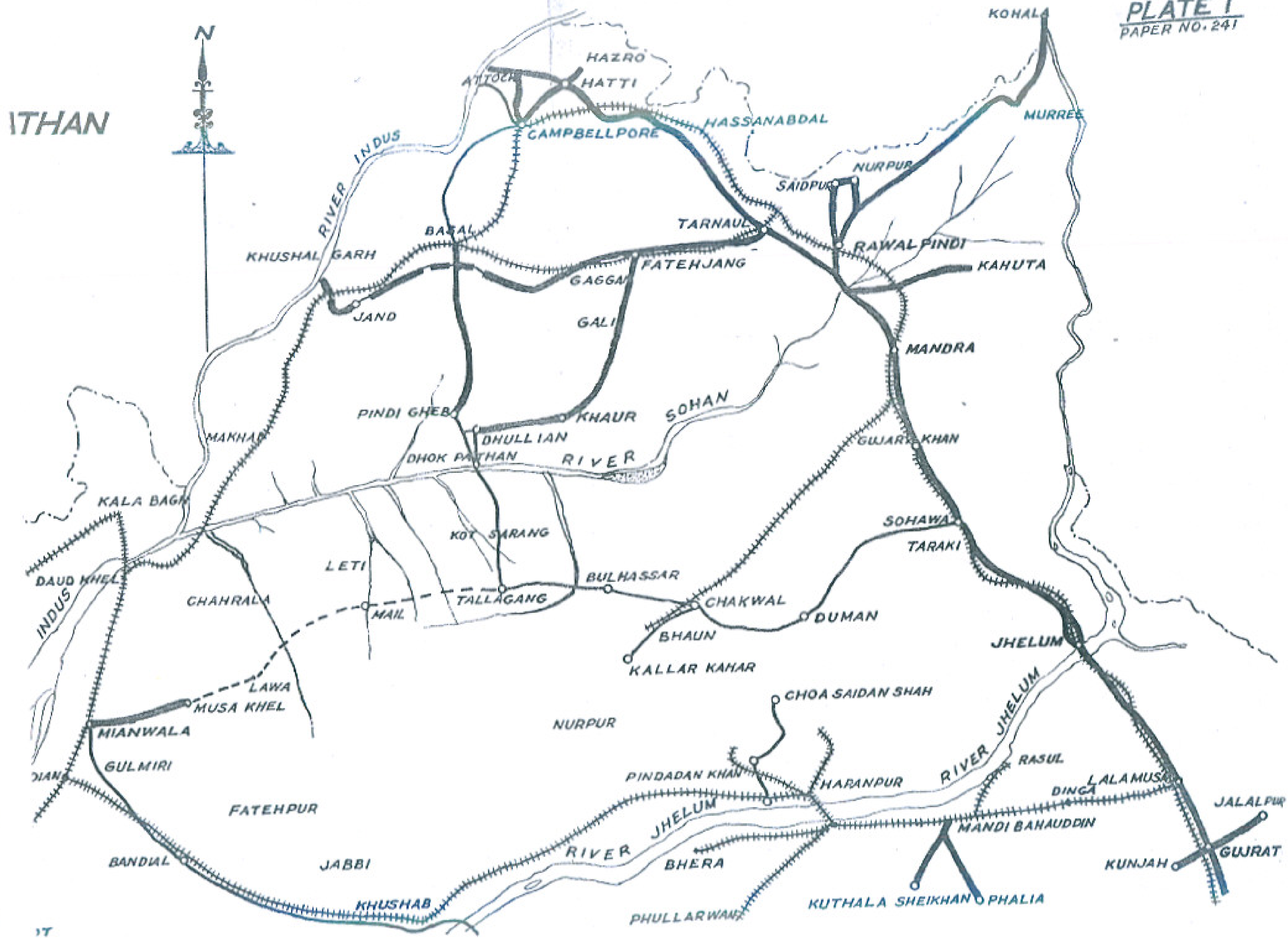
KEY PLAN TO SOHAN BRIDGE AT DHOK PATHAN

SCALE 1·014" = 16 MILES.



PUNJAB ENGINEERING CONGRESS 1941.

PLATE I
PAPER NO. 241



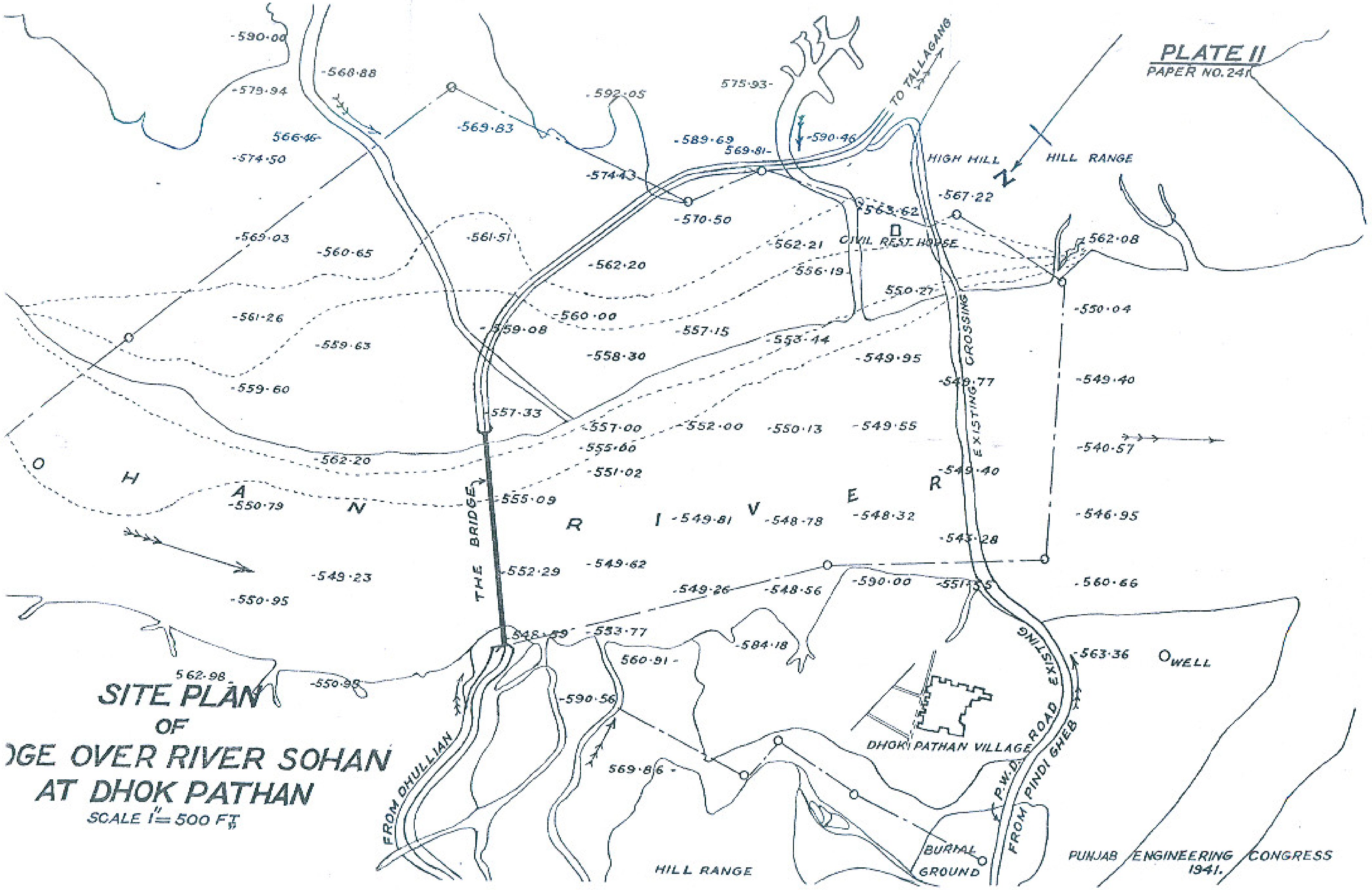
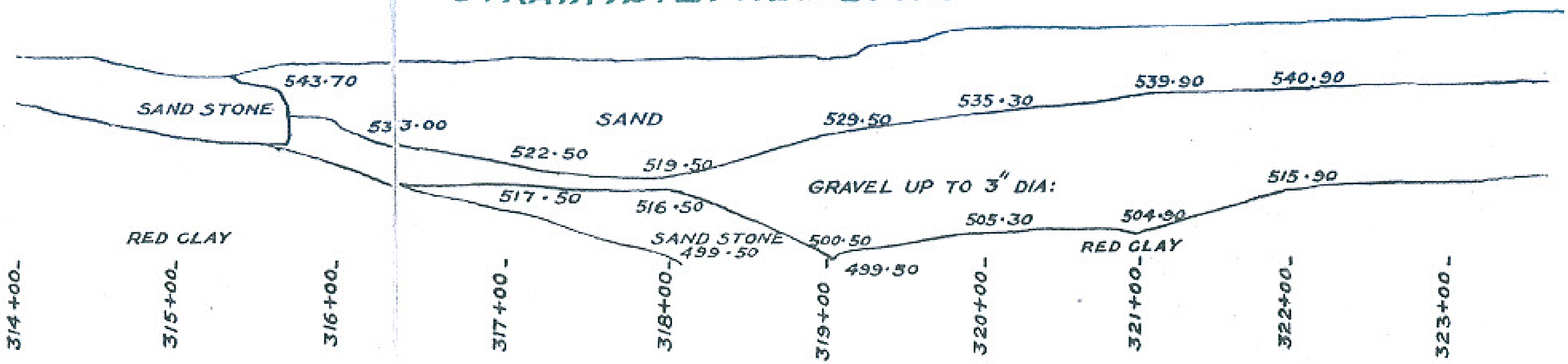


PLATE II
PAPER NO. 241
THE BRIDGE
RIVER SOHAN
TO TALLAGANG
HIGH HILL
HILL RANGE
CIVIL REST HOUSE
EXISTING CROSSING
DHOKI PATHAN VILLAGE
P.W.D. ROAD EXISTING
FROM PINDI GHEB
FROM DHULLIAN
BURIAL GROUND
WELL
HILL RANGE
PUNJAB ENGINEERING CONGRESS 1941.
SITE PLAN
OF
DGE OVER RIVER SOHAN
AT DHOK PATHAN
SCALE 1" = 500 FT.

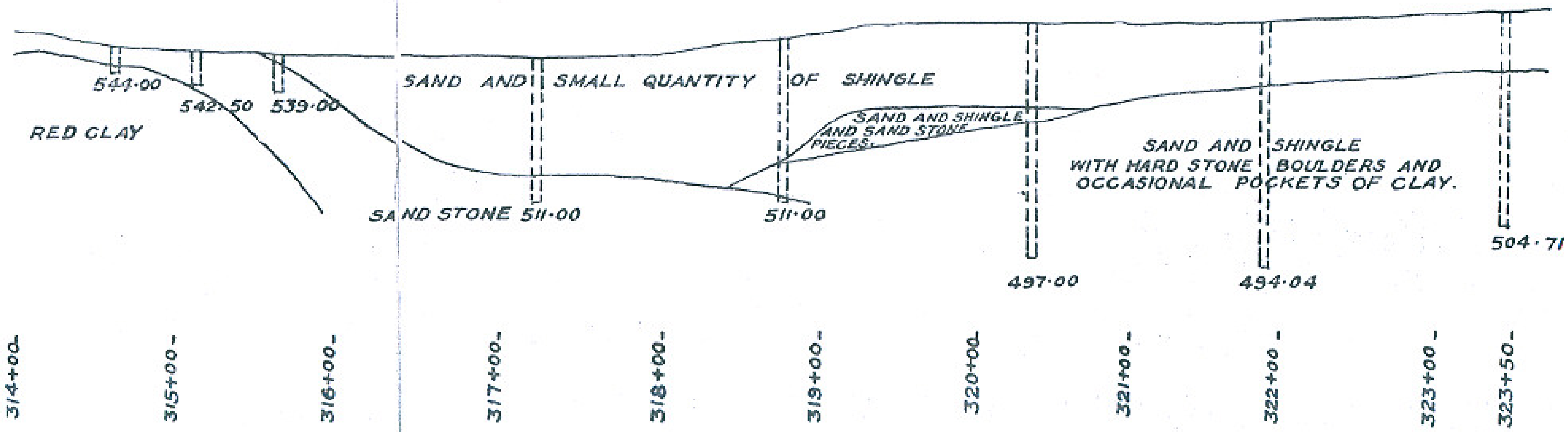
PLATE III
PAPER NO. 241

SOHAN BRIDGE AT DHOK PATHAN

STRATA AS PER TRIAL BORING



STRATA AS ACTUALLY MET

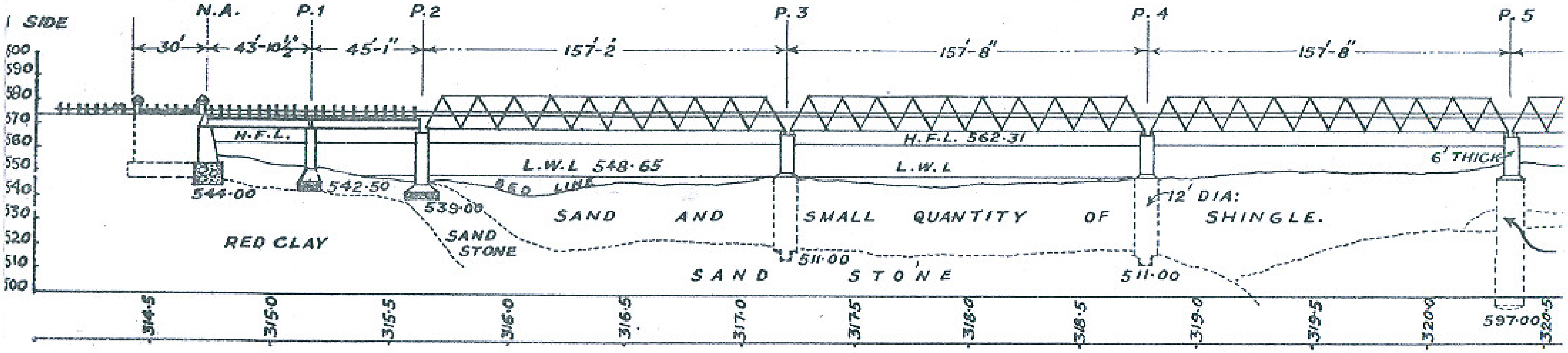


PUNJAB ENGINEERING CONGRESS
1941.

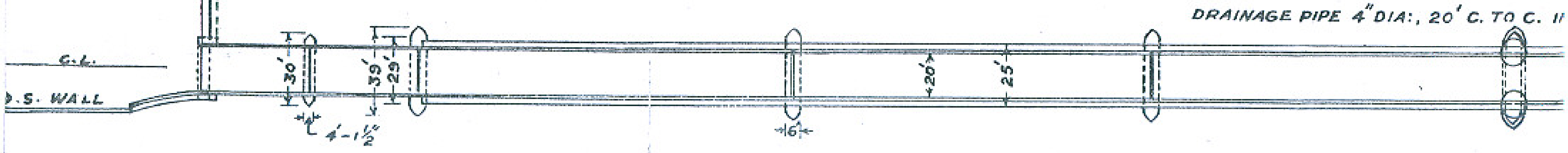
BRIDGE OVER SOHAN AT DH

SCALE 1" = 60 FT.

LONGITUDINAL SECTION



PLAN



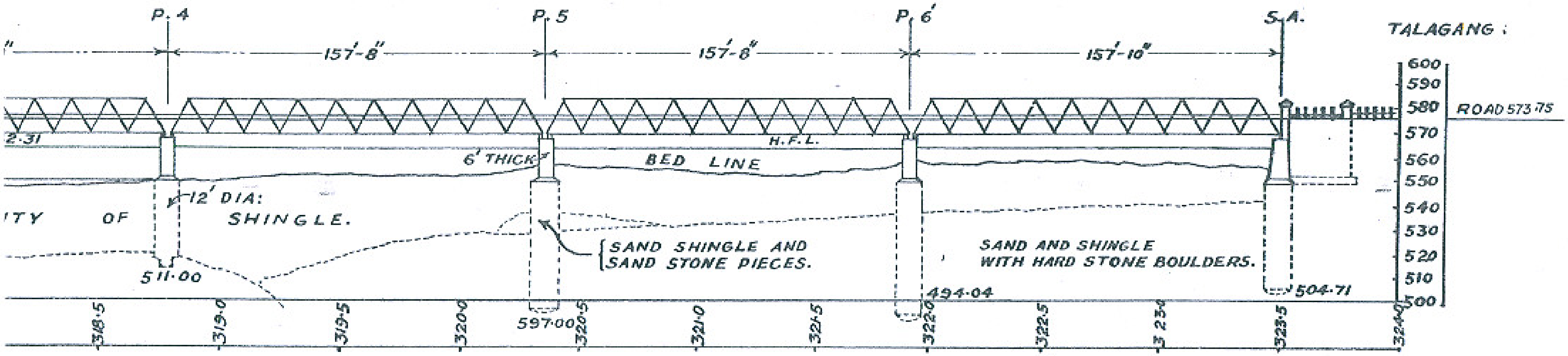
BRIDGE OVER SOHAN AT DHOK PATHAN

SCALE 1" = 60 FT.

PLATE IV

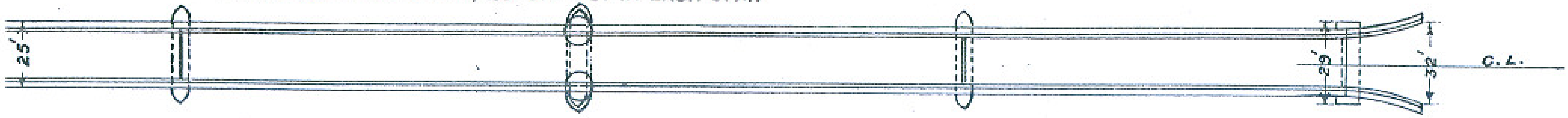
PAPER NO. 241

LONGITUDINAL SECTION



PLAN

DRAINAGE PIPE 4" DIA:, 20' C. TO C. IN EACH SPAN

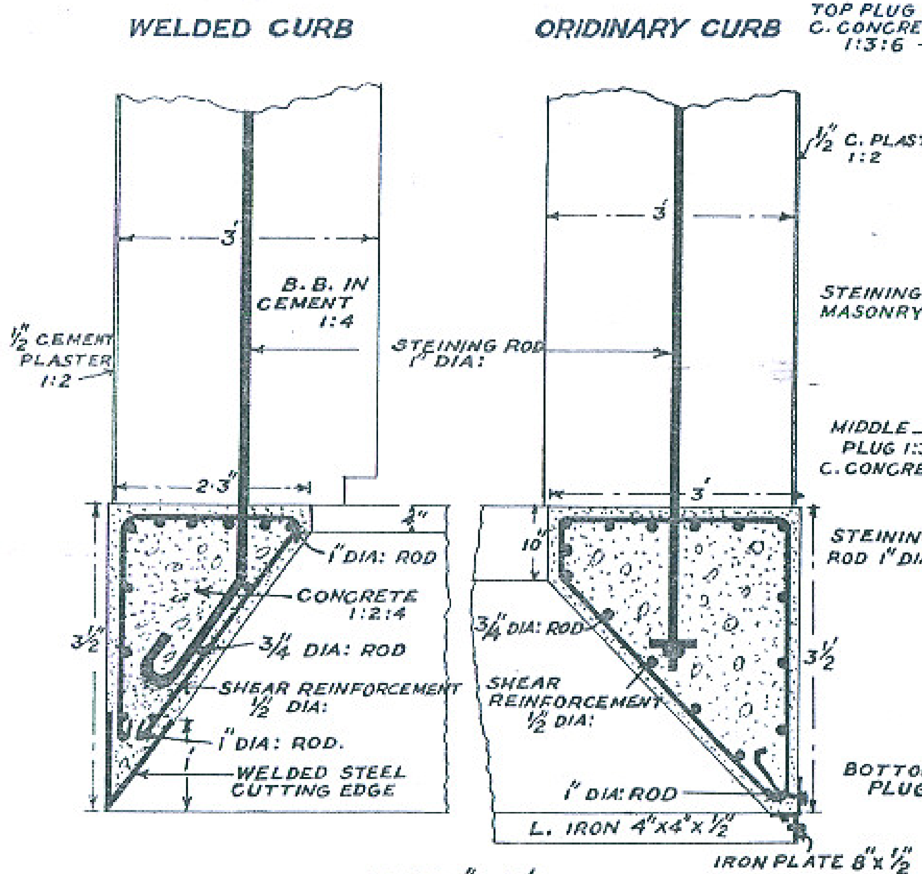


PUNJAB ENGINEERING CONGRESS.
1941.

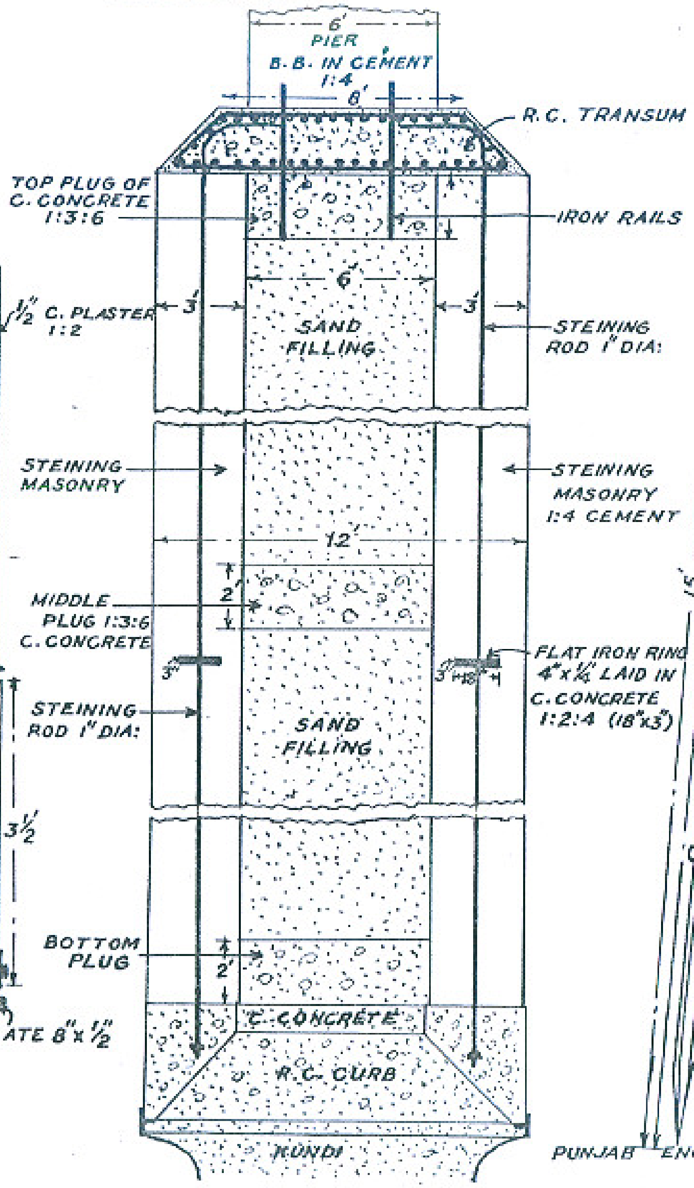
PLATE V
PAPER NO. 241

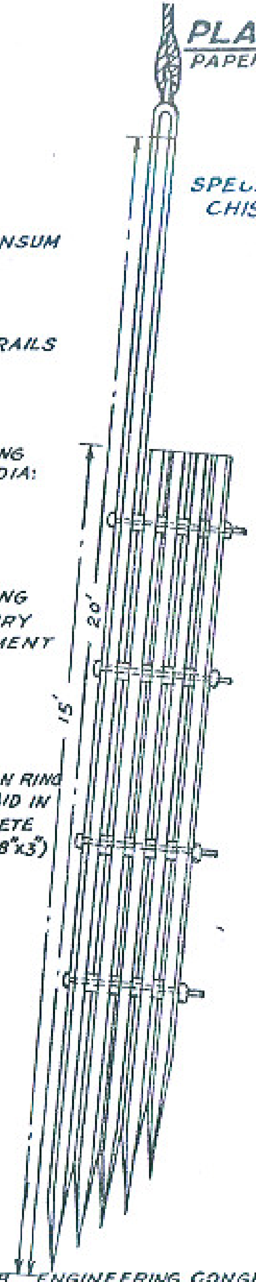
SOHAN BRIDGE AT DHOK PATHAN

DETAILS SHOWING R.C. CURBS, KUNDI, PLUGS TRANSUM AND SPECIAL RAIL CHISTLE.



SCALE 1" = 20'





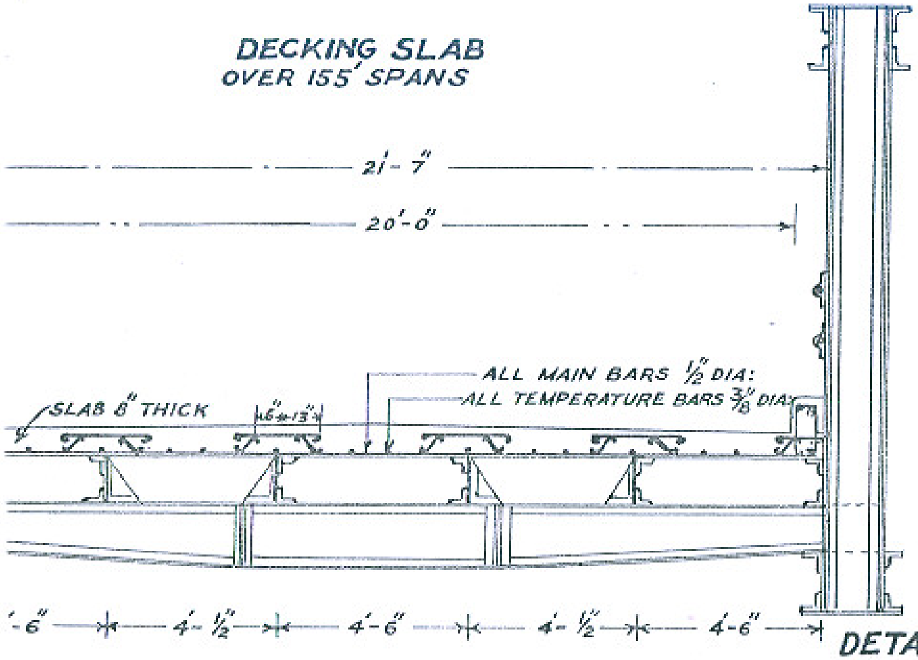
PUNJAB ENGINEERING CONGRESS. 1941.

PLATE VI
PAPER NO. 241

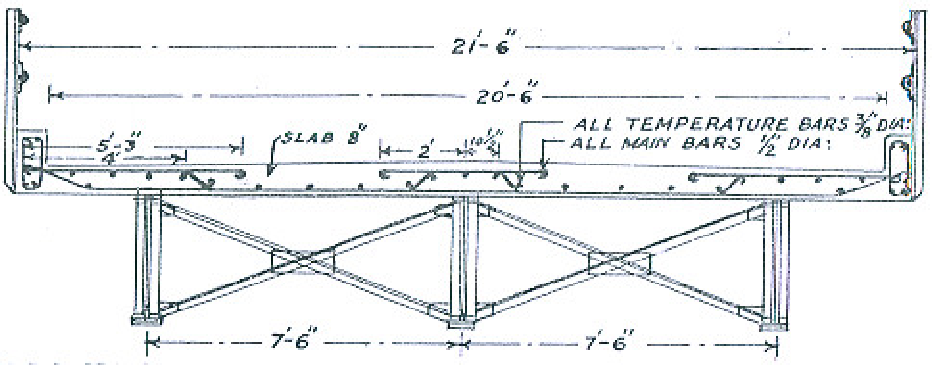
SOHAN BRIDGE AT DHOK PATHAN

SCALE 1" = 4'

DECKING SLAB
OVER 155' SPANS

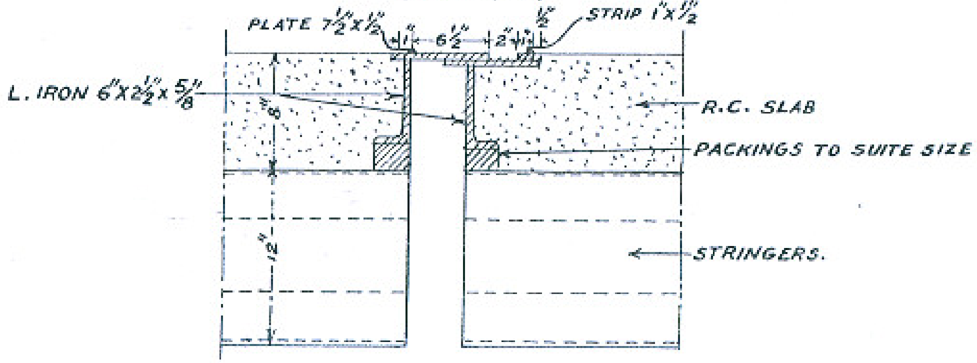


DECKING SLAB
OVER 40' SPAN



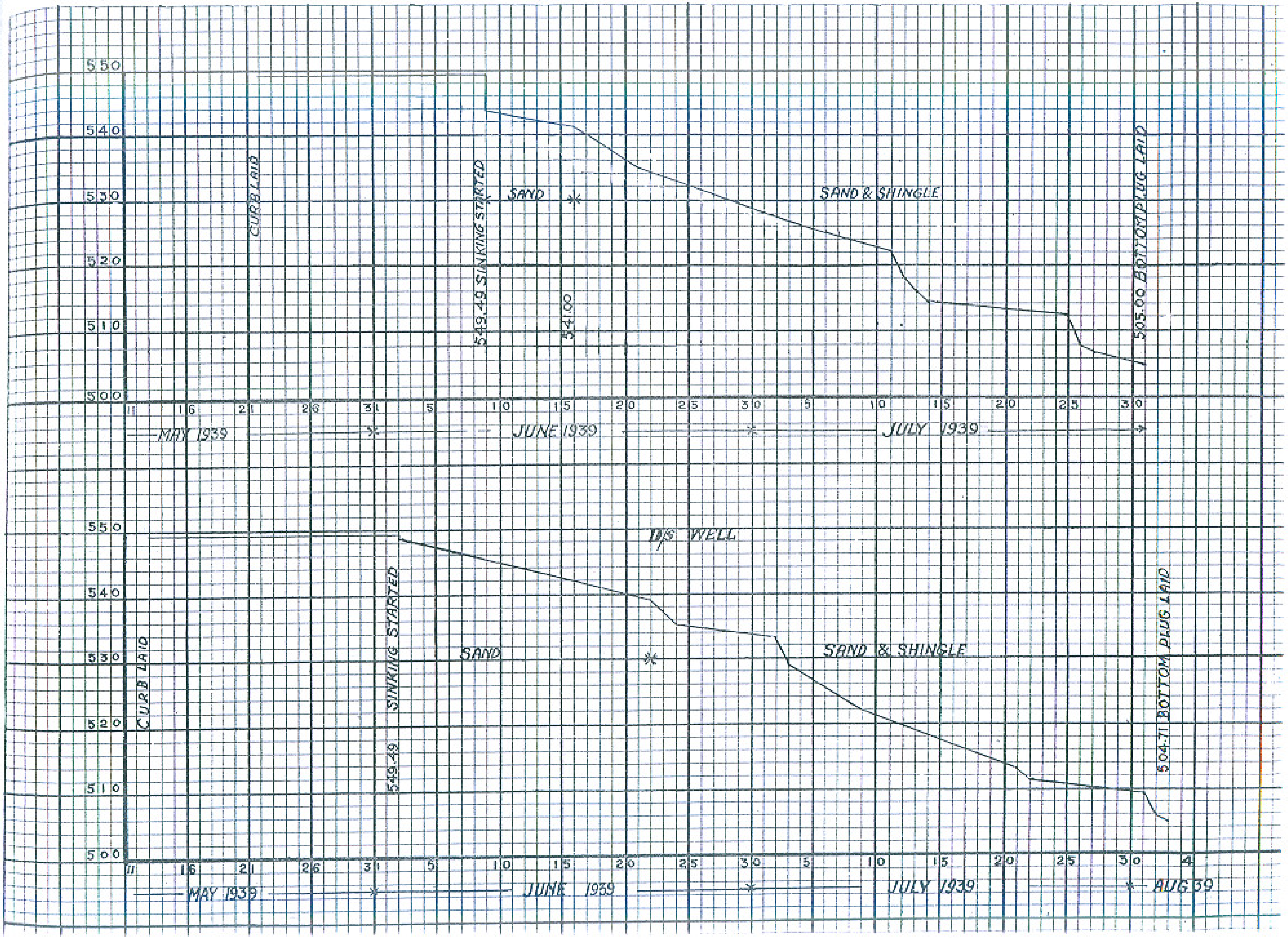
DETAIL OF EXPANSION JOINT

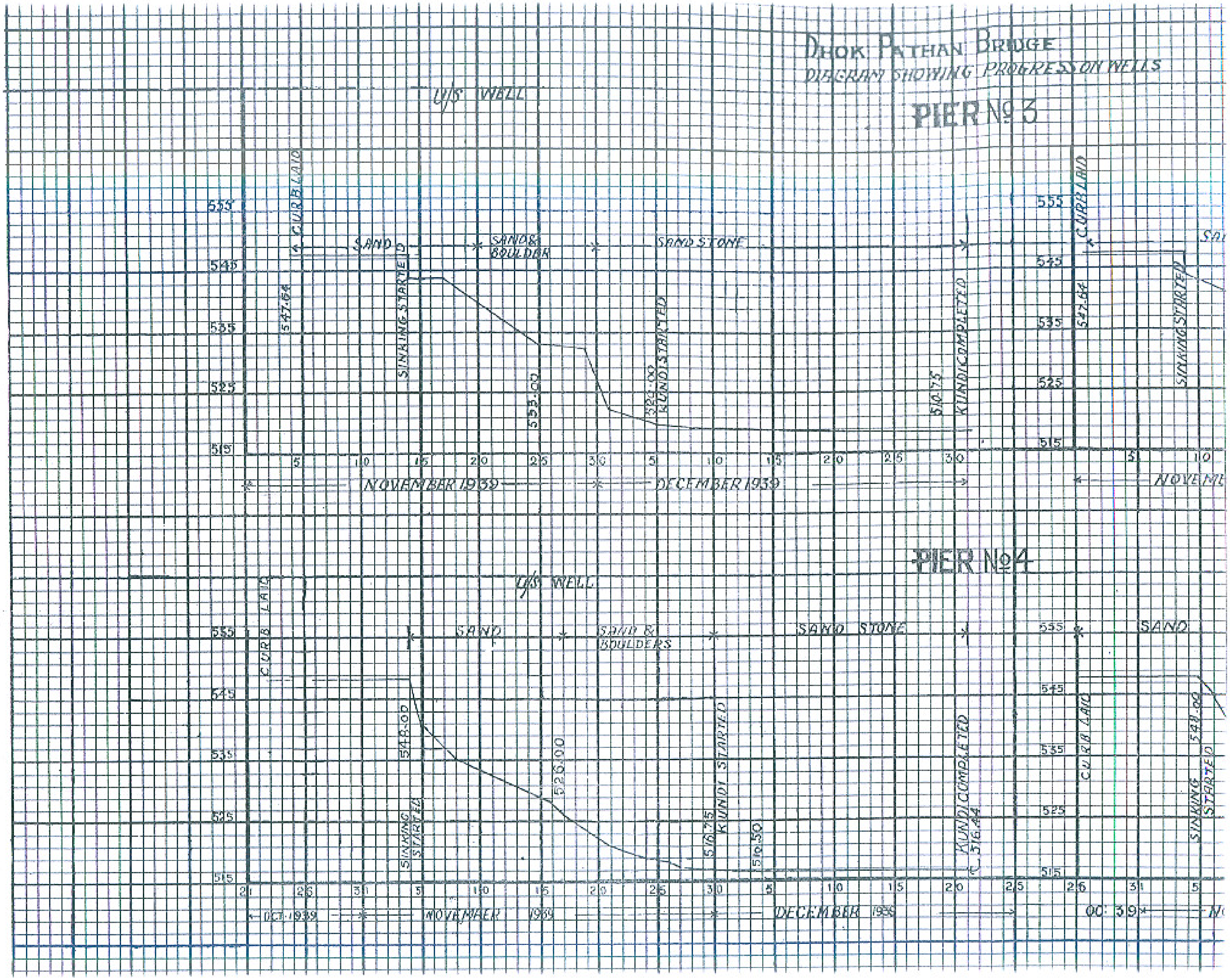
SCALE 1" = 1'

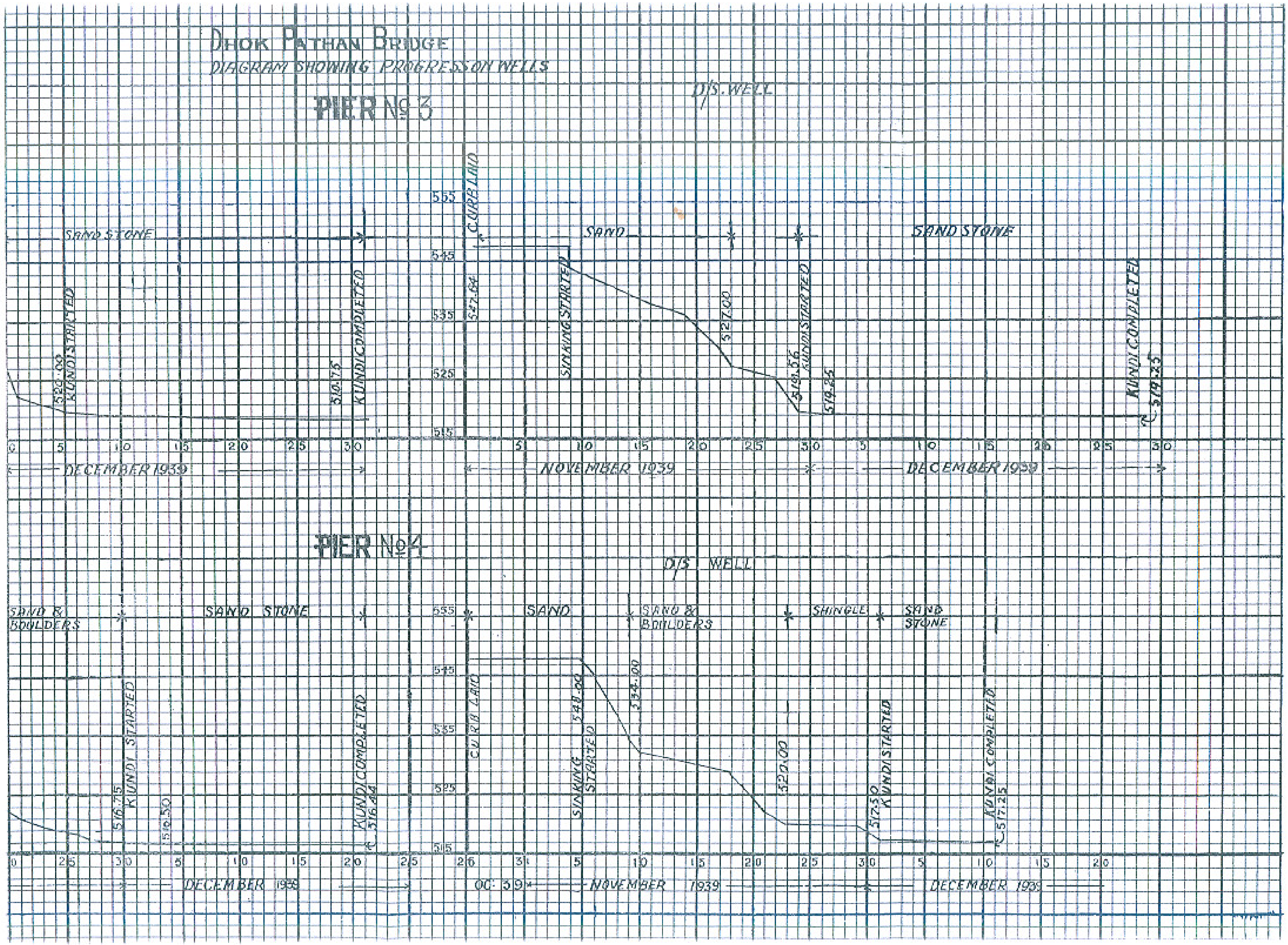


PUNJAB ENGINEERING CONGRESS
1941.

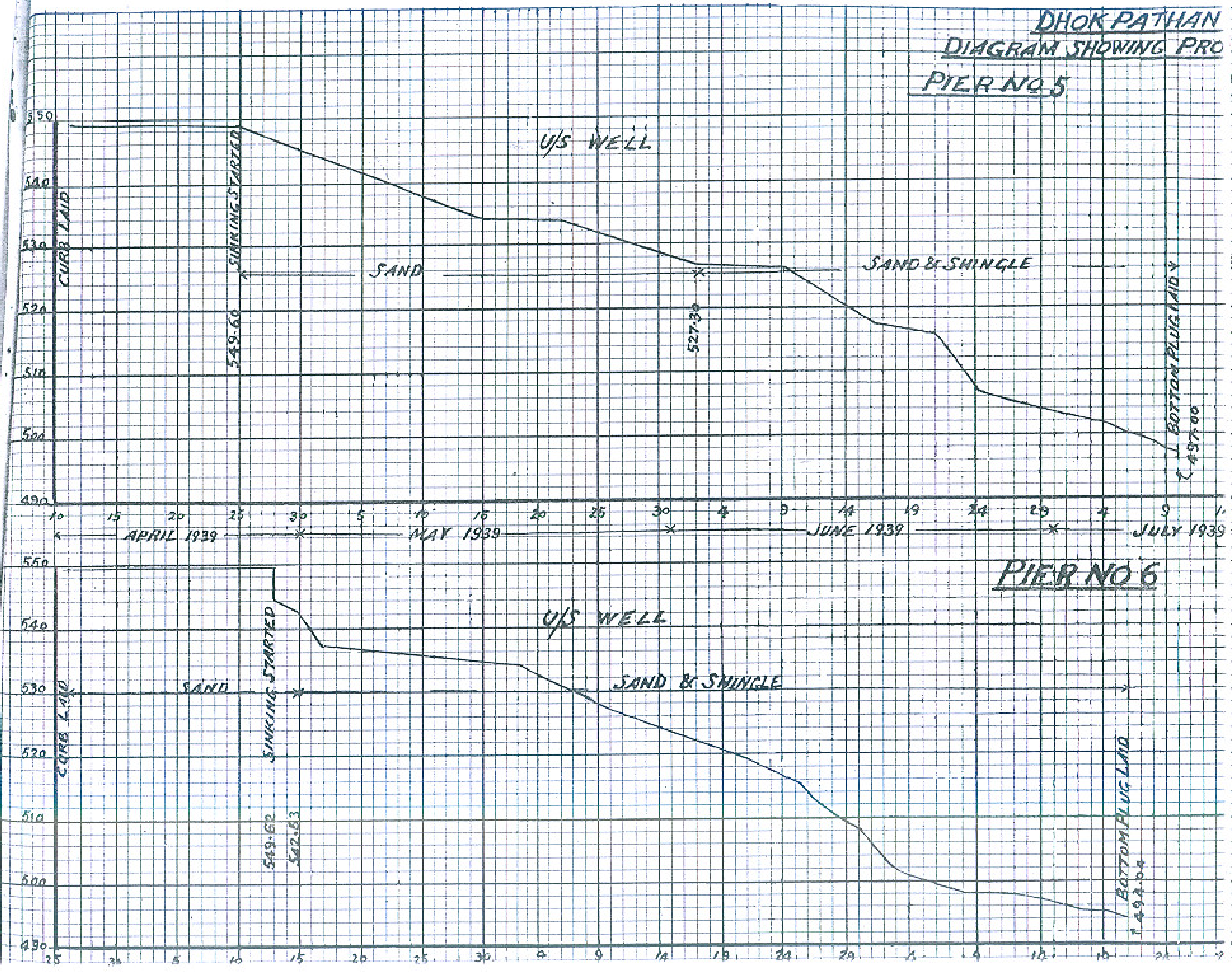
DHOK PATHAN BRIDGE
DIAGRAM SHOWING PROGRESS ON WELL
SOUTH ABUTMENT

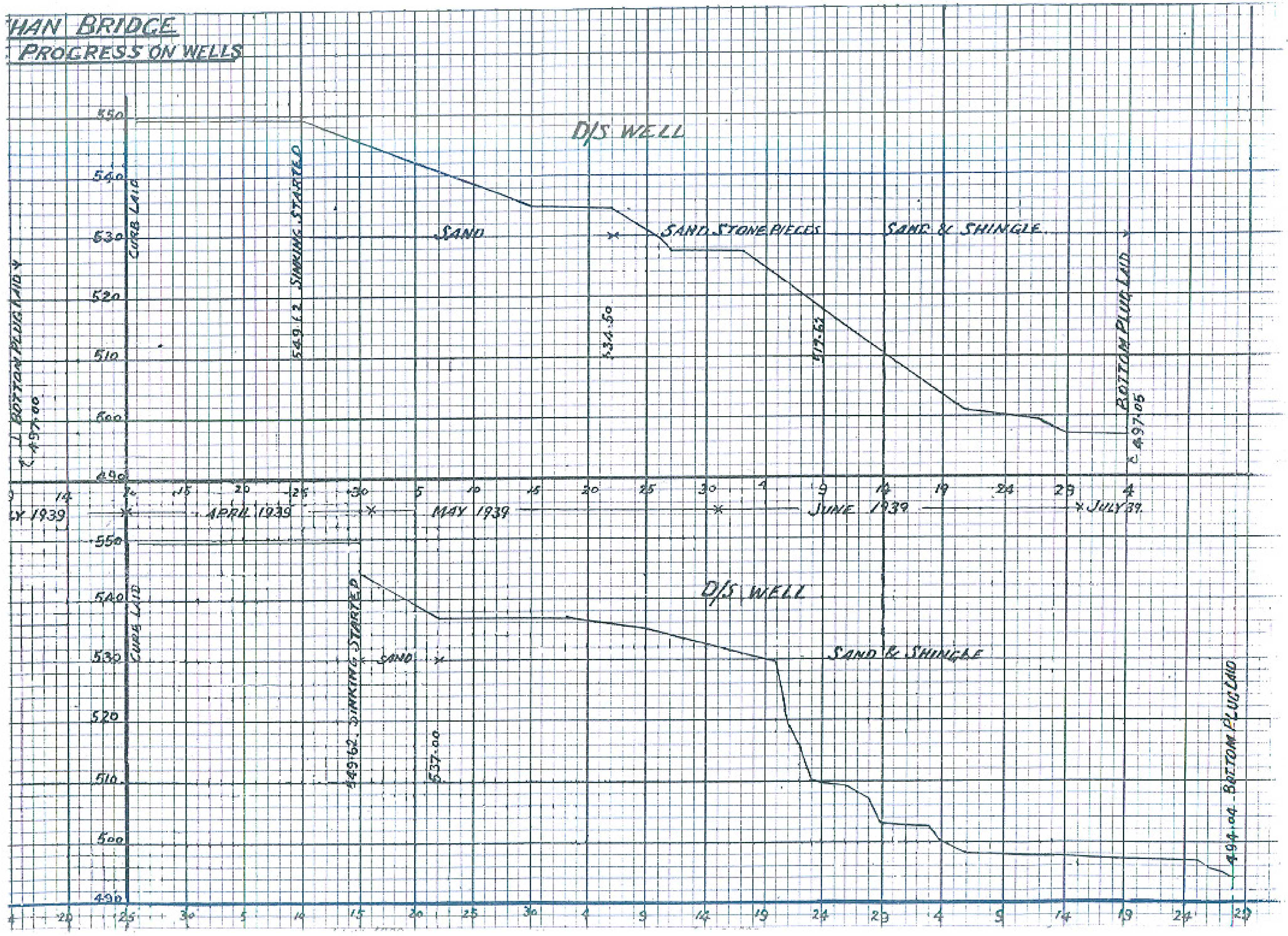



DHOK PATHAN BRIDGE
DIAGRAM SHOWING PROGRESS ON WELLS
PIER No 3
U/S WELL
CURB LAID
547.64
SAND
SINKING STARTED
SAND & BOULDER
SAND STONE
553.00
520.00
KUNDI STARTED
510.75
KUNDI COMPLETED
NOVEMBER 1939
DECEMBER 1939
PIER No 4
U/S WELL
CURB LAID
SAND
SAND & BOULDERS
SAND STONE
548.00
526.00
516.75
KUNDI STARTED
510.50
KUNDI COMPLETED
516.44
SINKING STARTED
OCT. 1939
NOVEMBER 1939
DECEMBER 1939
OC: 39



DHOK PATHAN BRIDGE
DIAGRAM SHOWING PROGRESS ON WELLS
PIER No 3
D/S WELL
SAND STONE
SAND
SAND STONE
520.00 KUNDI STARTED
510.75 KUNDI COMPLETED
547.64 CURB LAID
SINKING STARTED
527.00
519.56 KUNDI STARTED
519.25
KUNDI COMPLETED 519.25
DECEMBER 1939
NOVEMBER 1939
DECEMBER 1939
PIER No 4
D/S WELL
SAND & BOULDERS
SAND STONE
SAND
SAND & BOULDERS
SHINGLE
SAND STONE
516.75 KUNDI STARTED
516.50
KUNDI COMPLETED 516.44
CURB LAID
SINKING STARTED 548.00
534.00
520.00
517.50 KUNDI STARTED
KUNDI COMPLETED 517.25
DECEMBER 1939
OC. 39
NOVEMBER 1939
DECEMBER 1939


DHOK PATHAN
DIAGRAM SHOWING PRO
PIER NO 5
U/S WELL
CURB LAID
SINKING STARTED
549.60
SAND
527.30
SAND & SHINGLE
BOTTOM PLUG LAID
497.00
APRIL 1939
MAY 1939
JUNE 1939
JULY 1939
PIER NO 6
U/S WELL
CURB LAID
SAND
SINKING STARTED
549.62
542.63
SAND & SHINGLE
BOTTOM PLUG LAID
494.04


HAN BRIDGE
PROGRESS ON WELLS
D/S WELL
CURB LAID
549.62 SINKING STARTED
SAND
534.50
SAND STONE PIECES
517.62
SAND & SHINGLE
BOTTOM PLUG LAID
497.05
BOTTOM PLUG LAID
497.00
APRIL 1939
MAY 1939
JUNE 1939
JULY 39
D/S WELL
CURB LAID
549.62. SINKING STARTED
SAND
537.00
SAND & SHINGLE
494.04 BOTTOM PLUG LAID

DISCUSSION.

The Author while presenting his Paper invited members' particular ention to some of the special aspects of siting this bridge with erence to the flow under the bridges, its resulting scour and the essity of adopting a novel method for keying the wells on to the k.

The selection of a bridge site always involves a lot of forethought, said. In this particular case, the general width of the stream was out 1,400 feet and the bridge had been sited immediately below a nd where the stream formed a convenient neck only 850 feet in dth. The decrease in width was naturally accompanied by a pro-rtionate increase in depth. Besides this, the centrifugal force of e current throws the main-stream towards the outside of the bend, ., the North Bank. Now, the Northern Bank consists of sand-one rock which goes under the bed for some distance. The presence the rock, said the Author, does limit the scour in this portion of the ed, but it must be clearly understood that the rock, which is by o means very assuring, may wear out under repetitions of such ttacks.

Then again there being restriction in scour due to the presence f rock under the bed, the centrifugal force heaves up water to a igher level towards the Northern Bank.

Attention of the members was drawn to Photograph No. 7, and the Author remarked that due to presence of pieces of rock in front of piers 1 and 2, the rise in water is most discernible near pier No. 3 and that it would give members some indication of the amount of rise in water-level, the afflux and the horizontal force of the current which hits the pier.

Under the above circumstances, when the cutting-edge of the wells under piers 3 and 4 touched sand-stone rock 30 feet below the river bed, attempt was made to sink wells in rock. This could only be possible by pumping the wells dry and sending down workmen to excavate the rock. The centrifugal pumps would not help as the water column in the suction pipe was too long to be supported by the atmospheric pressure. The pulsometers needed a lot of steam and the time required for the collection of boilers was usefully spent in working the Rail-cluster chisels. Although on digging with the Rail chisels and by throwing a few gelignite charges in the wells, they did settle down a few inches, yet when the pulsometers and pumps were set working, they could not still cope with the inrush of water under the cutting-edge. It made matters rather worse, as inspite of sand-bags sunk on the outside of the wells, they started blowing heavily and got filled up with sand. Pneumatic sinking on account of its cost and the machinery required was not to be thought of and resort had to be made to the laborious process of chiselling.

Hoisting of Girders

Speaking about the methods of hoisting of girders employed, the Author remarked that some of the officers of the Railways would think them primitive, but that he could assure them that as the Road Bridges were mostly situated at out-of-the-way places where arrangements for proper Erection Plant and Machinery became difficult and costly, these simple methods were still the cheapest. He, however, admitted that in the near future, as soon as the war gloom gives place to sunshine of the peace-times and there was a demand for many more Road Bridges, the Road Engineers would require far more elaborate Bridge Plant and Machinery than what existed at present.

Before concluding his remarks the Author said that he was sure that members would like to know the names of Engineers responsible for the above work. The bridge was designed by Mr. S. Bashi Ram, Superintending Engineer, assisted by Sh. Abdul Qadir, Executive Engineer, and Mr. P. N. Gupta, Student Engineer. It had been constructed by Mr. Kundan Lal, Superintending Engineer, and Mr. W. T. Eccleston, Executive Engineer. The Author's share in the job was that of an Assistant Engineer stationed at site.

The Author thanked the Bridge Engineer and Executive Engineer, Bridges, Jhelum, of the North Western Railway for the help in lending riveting machinery, etc., for the above work.

The Author also took the opportunity of thanking his Chief Engineer, Mr. R. Trevor Jones, for encouraging him to present this Paper to the Congress.

Mr. Murari Lal said that the bridge consisted of 5 long spans of about 152′ and 2 short spans of 40′ and that the Author on page 11 under the head "Loads" said that the girders of the bridge could take a 15-ton steam road roller which gave an equivalent load of 10 British Standard Units. Also that the decking R. C. Slabs on the long spans had been designed for the same loading, but that curiously enough the R. C. Slabs in the cantilevered decking on two short 40-feet spans seemed to have been designed for a 10-ton roller only, as alluded to by the Author on page 12.

It would therefore appear, he said, that full use had not been made of the available strength of the girders to take a 15-ton steam road roller, and that but for this cantilevered slab on the short spans the bridge should have taken a 15-ton roller easily and it should have been neither difficult nor expensive to provide a cantilevered slab to take a 15-ton roller.

Turning to the calculations for the above slabs on page 17 he added it would appear that knife-edge loading as prescribed by the Indian Road Congress had been arbitrarily halved. He held that reason given for it was not satisfactory, for in the design of the supported slab also weight of only one wheel of a roller or vehicle came into calculation. Where no definite standards were laid for calculations he thought it was best to design from first principles.

Imagining a 15-ton roller skirting along the hand rail of the bridge on this cantilever, said the speaker, the hind wheel of the roller would impose a load of 12,000 lbs. which would be spread over 40 inches width of the slab at right angles to the length of the cantilever, according to the formula prescribed by the Punjab P. W. D. Reinforced Committee. Adding to this load 50 per cent. impact, he said, it would become 18,000 lbs. and would work out to $18,000 \times 12/40$ or 5,400 lbs. per foot width of the cantiliver.

The bending moment induced in the slab would equal to

$W (l\text{-}l' \times \frac{1}{2})$

W=live load on the cantilever	= 5,400 lbs.
l=length of the cantilever	= $2\frac{1}{2}$ feet.
l'=length of distribution of load through concrete	= (18 plus 9) = $2\frac{1}{4}'$.

Therefore B. M.=$5,400\ (2\frac{1}{2}\text{-}9/8)$

$$=5,400 \times 11/8 = \frac{59,400}{8} = 7,450 \text{ ft. lbs.}$$

He thus deduced that the Author's live load bending moment was 2,856 plus 2,520=5,376, *i.e.*, the slab was under-calculated by 2,000 ft. lbs. for a 15-ton roller. It was therefore evident in his opinion that this bridge could not take a 15-ton roller and a restriction would have to be applied to it to keep the loading to 10-ton roller only.

Mr. G. C. Khanna remarked that the Author had presented an interesting but brief Paper on the subject of construction of Dhok Pathan Bridge. He added that a more exhaustive Paper containing detailed information regarding the various operations of construction would have been read with advantage by many of the engineers. He hoped therefore that he would be excused for asking too many questions.

He then asked the following questions :—

"Would the Author please let him have a cross section of the stream at the bridge site showing low water level, and reduced level of the depths at which water was met with in each well ? At what depths was pumping started, and what sizes of pumps were necessary at various depths of well sinking? Were the pumps working continuously in each well or in shifts ? Were the wells loaded with sand bags to aid in sinking ? Could he give them the cost of pumping per ft. depth of well sinking ? He gave rates for sinking of wells from 50 ft. depth to 62 ft. depth : Could he also give them rates of sinking for smaller depths and if possible the cost of pumping per ft. depth to be given separately ?

"On pages (6) and (7) it has been stated that pits or *kundies* 6 ft. in diameter and about 5 ft. deep, were dug below wells founded on sand-stone rock. The cost of digging was stated to be Rs. 400 per ft. depth or about Rs. 2,000 for each pit.

In these pits, R. C. Concrete reinforcement was placed, which bonded with the concrete plug at the bottom of the well. What was the advantage of these dee/pits. How has the well been made more stable against scour by this costly contrivance? In his opinion the R. C. Concrete projection does very little except key the well to the rock. This could have been secured by having the projection about one ft. or so below the rock."

It was rather difficult, said the speaker, to imagine that a rock which has cost Rs. 15 per c.ft. to cut would have been easily eroded by a flood to such a depth. In his opinion a pit with a bigger diameter but smaller depth would have been more useful, as then the steining would have been supported over the concrete.

He further added that it was stated that during the floods the bottom boom of one of the spans got sagged and questioned whether it was correct to straighten up and re-use a number which had been once over-stressed. He stated that in Appendix A the value of shear worked out was incorrect, because the Indian Roads Congress loading required that for calculation of shear the distributed live load shall be 0·34 ton per ft. run even for spans smaller than 20 ft., plus a knife edge load of 9 tons and that a correct interpretation of the loading would have resulted in about 20 per cent. economy in cost of decking.

Discussing the cost of the bridge, he stated that the cost of substructure was approximately half the cost of superstructure, *i.e.*, Rs. 1,08,000 for substructure as against Rs. 2,16,000 for superstructure, and that the rational and economical practice in design of a bridge being to keep the cost of the foundations equal to that of the superstructure, the disproportionate expenditure on superstructure had been caused on account of spans which were too big. It seemed to him that as the trusses available from the railway department were 160 feet span, therefore those spans had been adopted for the bridge.

It was rather curious but no doubt true, said *Mr. Khanna*, that whenever any bridge of some importance had to be built, the Buildings and Roads Department turns to her sister department, the railways, for guidance and help; the sister department was too eager to help, because it gives her an opportunity for discarding her old and worn out garments, and buying new ones of the latest design for her own use.

According to the speaker this was an ideal site for a concrete bridge as sand, stone shingle, etc., were available in the bed of the river. He thought that a concrete bridge would have been more economical, and of a more permanent nature than the second-hand, mended and patched-up steel structure built now. The Speaker worked out an alternative design and rough cost estimate for a R. C. Arch Bridge with 7 spans of 120 ft. The cost per span including cost of staging, etc., was about 21,000, and the total cost of superstructure worked out to Rs. 1,47,000. Assuming that the cost of the foundation was increased proportionately to the number of piers the cost of substructure would be Rs. 1,40,000. Thus the total cost of bridge would have been Rs. 2,90,000. The economy and suitability of this type of bridge were self-evident in *Mr. Khanna's* opinion.

Mr. Brij Mohan Lal said that *Mr. Murari Lal's* statement that the *R. C. Slab* on the cantilevered decking had been designed for a ten ton roller only, was not correct, because though the Author had compared the load likely to come on the cantilevered portion equivalent to a ten ton steam road roller, he had allowed on page 17 for a live load equivalent to I. R. C. Standard loading. Explaining the reason for halving the knife edge load, he stated that as the knife edge load of 6 tons in I. R. C. loading comes into play when the whole vehicle was on the slab, and as in this case only half the load of the vehicle could come on the cantilevered portion, he considered it quite reasonable to consider only half of the knife edge load. The Speaker, therefore, thought that the cantilevered portion had been correctly calculated for the I. R. C. Standard Loading.

The Paper on the whole he stated, was a very useful one and will prove a good guide to other Engineers employed on similar work.

Mr. P. L. Varma said that from a look of the high flood level in Photograph No. 7, it appeared that the free board was too small, and asked that the circumstances under which such a small free board was permitted may be brought to the notice of the members as from his experience of the Sohan River, he knew that this river brings down during floods trees washed complete with roots.

He asked that circumstances which led to the decision that the wing walls need not be founded on wells should also be explained, as in 1929 the abutment of the Harro bridge was washed down because the wings which had been founded at a much higher level than the abutment were undermined ; and getting completely sheared off from the main abutment fell on the sides, inspite of the fact concrete in this abutment was well made with the cyclopian type of concrete. In his opinion it would have been advisable to cantilever out the wings from abutment or alternately to found them on wells.

The Speaker further remarked that it was time that the P. W. D. should pay more attention to the aesthetics of the highway bridges than they have been doing until now. He added that the bridge was out of all harmony with the road surroundings and in his opinion this form of construction should be abandoned in all circumstances unless the cost makes the construction of other kinds of structure impossible. He wanted to know if when adopting the girder type construction, the question of putting a reinforced concrete Arch Bridge was also examined, and how the costs of the two types of bridges compared ?

Replying to *Mr. Murari Lal's* remarks, the Author said that the Punjab Government had adopted the "Indian Roads Congress Standard Loading" for all bridges on Arterial Roads and that all the slabs of this bridge were designed for this standard loading ; moreover as two traffic lanes of "Indian Roads Congress Standard Loading" are far greater than a single 15-tonner with the possible crowd-loads and that consequently it was, not correct to say that full use had not been made of the available strength of the girders. He further referred *Mr. Murari Lal* to *Mr. Brij Mohan Lal's* Paper on "Design of reinforced concrete bridges of short spans for Indian Roads" read before the Indian Roads Congress.

In his personal opinion it was out-of-date to talk of Standard-Loading in terms of 10 or 15 ton Steam Road Rollers; because the impact factor for such rollers was much lower than for other similar axle-loads. Military Engineer Services Hand Book he said, lays it down at 25 per cent. while they were accustomed to assume it as 50 per cent. The modern heavy vehicles he went on to say had either pneumatic tyres or caterpillar wheels and in both cases the load was spread over a far greater area than was possible with rollers and it was, therefore, a correct lead of the Indian Roads Congress to propose a standard knife-edge live-load in addition to a distributed one.

Turning to actual calculations of *Mr. Murari Lal*, the Author wanted permission to correct him about the width of the back-wheel of a 15-tonner, which was 20 inches and not 18", and remarked that his method of determining the Bending Moment was rather obsolete.

He added that in his calculations the stresses allowed in concrete and steel were 600 lbs. and 16,000 lbs. per sq. inch respectively, whereas 750 lbs. and 18,000 lbs. respectively have been recommended by the Indian Roads Congress.

Calculating for these permissible stresses and even adopting *Mr. Murari Lal's* method, the Author worked out the B. M. as follows :—

l'=length of distribution of load through concrete=20 plus 7 plus 3=30 inches.

$$\text{Live load B. M.} = \frac{5{,}400\ (30 - \frac{30}{2})}{12} = 6{,}750 \text{ ft. lbs. } (i).$$

Taking f_c=750 lbs. per sq. in.

R=160

$\therefore$ Total allowable live load B. M. $= 160 \times 7 \times 7$
$= 7{,}840$ ft. lbs.

or total allowable live load B. M.

$= 7{,}840 - 65 - 243 - 623$

$= 6{,}909$ ft. lbs. (*ii*).

Hence deduced the Author the cantilever slab could even take a 15 tonner with 50 per cent. impact and said that the question of restricting loads did not arise.

Replying to *Mr. G. C. Khanna's* remarks about the level of the sub-soil water the Author said that the bed consisted of sand and shingle and so the Low Water Level shown in Plate IV might be taken as the level of Sub-Soil water.

He further stated that the cheapest method of sinking wells was by open-dredging and that this was particularly suited to the sandy strata encountered. No pumping was necessary he added, except in the case of wells under piers 2 and 4 where they struck rock and here the pumps available failed to cope up with the inrush of water and chiselling (as described elsewhere) proved to be the only solution.

No detailed record for rates of sinking at every particular foot of depth had been maintained by the Author, but from the approximate figures available he said, the rates provided in the contract could not be said to be far wrong.

As regards *Mr. Khanna's* remarks about R. C. Concrete Plugs for wells under piers 3 and 4, the Author again referred *Mr. Khanna* to his introductory speech. The Author was sure that no Bridge Engineer would like to rest his wells on an uneven rock much less on an uneven and unreliable rock, as when scour extends down to the bottom of the wells, the slightest eccentricity in loads coupled with any possible slight yielding of the uneven base might result in disaster and as not to take chances, the best possible alternative had been adopted.

He added that it was impracticable to cut rock under the cutting-edge when there was 3 feet thick steining projecting inside and the chisel had to be worked from outside under 25 feet of water.

About his remarks on the over stressing of members of Span No. 3, the Author related the description of the event again; the bottom booms had been placed and only a few (less than 5 per cent.) half-tight bolts were in position. Under the circumstances, he doubted if there could be any question of overstressing of the members under their own weight.

He also stated that competitive designs had been called for and some of the reputed firms did tender for Reinforced Cement Concrete Designs too but that the design adopted worked out to be cheapest.

The Author further remarked that he was not quite sure if *Mr. Khanna's* figures of cost for a Reinforced Cement Concrete Arch did include all the extra-special stagings which formed a major item in the cost of such a Reinforced Concrete structure.

The Author when replying to *Mr. Brij Mohan Lal* remarked that he was glad that *Mr. Brij Mohan Lal* agrees with the loads adopted for designing the cantilever slab. At the time of designing the slab he said, as local shingle and sand obtained during sinking of wells were proposed to be used and the results of test-cubes were not at hand, so the old conservative value of 600 lbs. per sq. in. for 1 : 2 : 4 cement concrete was adopted and that now that the tests vouch for the soundness of the concrete, it was quite reasonable to assume full values for the permissible stresses.

The Author agreed with *Mr. P. L. Varma* that a bigger free-board would be preferable but his reasons for the same were different. The Author said that he had seen the centrifugal force of water raising its level near the North abutment (as shown in Photograph No. 7) and that though this reduced the clearance between the H. F. L. and the bottom-boom, but it should not be forgotten that the bottom-boom was already 7 feet above the H. F. L.

About the wing walls he remarked that they had been built absolutely separately having a clean vertical joint between their brick-work and that of the abutment and that they rested on shingle bed and had been protected with crate work laid in the form of Bell's Bund. As already stated he said the bridge had been sited on a convenient neck and the main-current flows on the North Bank (where the abutment and wing-walls were founded on rock), and so the South abutment remains high and dry. Even if the wing-walls were washed away he added that the abutment was already designed to stand safely, and that the suggestion of cantilevering wings means enormous eccentric loads which may render the cost exorbitant.

About the design adopted, the Author disagreed with *Mr. Varma's* opinion that steel girders should not be used at all. In his opinion the consideration of appearance was definitely secondary and utility alone could justify the expense. He said, he could not call steel-bridge an "Ugly-Structure" and that if *Mr. Varma* had seen the bridge which had been painted dark grey matching with the grey sandstone banks, he would appreciate the beauty of the structure.