PAPER No. 223.

REFLOORING THE SUKKUR CHANNEL BRIDGE.

By S.L. Kumar, Assistant Bridge Engineer, N.W.R.

This Paper on the reflooring of the busy rail-cum-road bridge at Sukkur describes the work, how it was carried out with a minimum of inconvenience to traffic and how improvements have been introduced to facilitate maintenance.

The Sukkur Channel Bridge, three through-type spans of 90, 230 and 270 feet respectively, carries a single line of broad gauge railway, a roadway and two footways (outside the main girders) across the north-western channel of the Indus at Sukkur. Together with the more famous Lansdowne cantilever bridge over the south-eastern or the Rohri channel, it was opened in 1889 and provided the closing link in the first chain of all-rail communication between Karachi and the north-west of India.

The road and railway share the same deck and traffic is worked in the "level-crossing" fashion. About two dozen daily trains, about two thousand pedestrains, three hundred animals, fifty carts, a hundred tongas and about a dozen cars and lorries use the bridge daily.

The floor system on the bridge followed the practice of the last century, the rails being spiked to longitudinal timbers wedged in the bosom of built-up channel or trough section stringers. The roadway, level with the top of the rails, was of 2½ inch thick kikar timbers laid diagonally across and nailed to other timbers bolted into the "valleys" of "7lb. corrugated iron sheeting" (really an early form of iron troughing—3 inches deep, 3/16 inch thick and 4 inch pitch) spanning transversely the gaps between the rail stringers and supplementary road stringers, adjacent to the main girders. (See Plate I). This type of flooring did not lend itself to easy maintenance. Neither the insides of the rail stringers nor the top of the "corrugated iron sheeting" could be examined and painted without wholesale removal of the timbers. And as animals form by far the major part of the road traffic it is not surprising that corrosion was considerable.

In 1936, it was found that much of the roadway troughing had corroded very badly and had reached the end of its useful life. The rail stringers were also badly corroded on their inside, but a second series of intermediate cross girders had been added in 1926 when the bridge had been strengthened, and so it was found unnecessary to renew the stringers. Many of the longitudinal timbers required to be changed and as still more were damaged in their removal, it was decided to seek some method of improving the facilities for maintaining the inside of the stringers. Besides, longitudinal rail-bearing timbers have never been really satisfactory on bridges because the line of spike holes, falling in the line of the grain, leads to early splitting, attended with subsequent difficulties in maintaining the gauge.

It was therefore decided to remove all timbers from the deck of the bridge. And in the reconstruction, the iron-and-wood floor of the roadway has been replaced with a reinforced concrete decking, four inches thick, cast in situ. Steel stools bolted to the bottom of the stringers have taken the place of the longitudinal rail-bearing timbers.

The reinforced concrete decking, vide Plate I, has been designed to carry 2 units of B. S. I. loading with impact of $\frac{1}{2}$ of $65/(45+L)$, where L is the span in feet. The depth of the slabs has been designed to be $3\frac{1}{2}$ inches and an additional $\frac{1}{2}$ inch has been provided on the top to allow for wear. The main reinforcement consists of two layers of B. R. C. Fabric No. 7 with a single layer of Fabric No. 9 at the central supports where allowance has to be made for a negative bending moment. The use of two layers of fabric for the main reinforcement was necessitated as the required single Fabric No. 3 was not available in this country. The mix was 1:2:4 and rapid hardening cement was used. A thickness of $\frac{1}{2}$ inch has been provided as cover below the bottom of the reinforcement. The coarse aggregate for this portion of the concrete was limited to 3/8 inch. For the remainder of the slabs, an aggregate of $\frac{1}{2}$ to $\frac{3}{4}$ inch has been used. Both the sand and the shingle were brought by special train from Pathankot. Mixing was done in a half cubic yard power driven mixer. The field mix was based on the fineness moduli of the sand and shingle and due allowance was made for the bulking of the aggregate and shrinkage consequent on the mixing. The aggregate was thoroughly washed and dried before casting of slabs started and frequent tests were made to ensure a concrete of uniform consistency. The slump was not allowed to exceed $2\frac{1}{2}$ inches. Two test cylinders, four inches in diameter and eight inches long, were cast simultaneously with the slabs. These cylinders, cured under conditions as nearly as possible identical with those of the slabs, were tested after 28 days. A list of these results is given in Appendix B.

With two dozen trains crossing the Sukkur Channel Bridge in the twenty-four hours and, during the hours of daylight very considerable road traffic, the renewal of the decking presented a ticklish problem, demanding careful planning to avoid more than the minimum of inconvenience to the public. The replacement of the wood-and-iron deck with precast concrete slabs was at first considered ; but, the girder

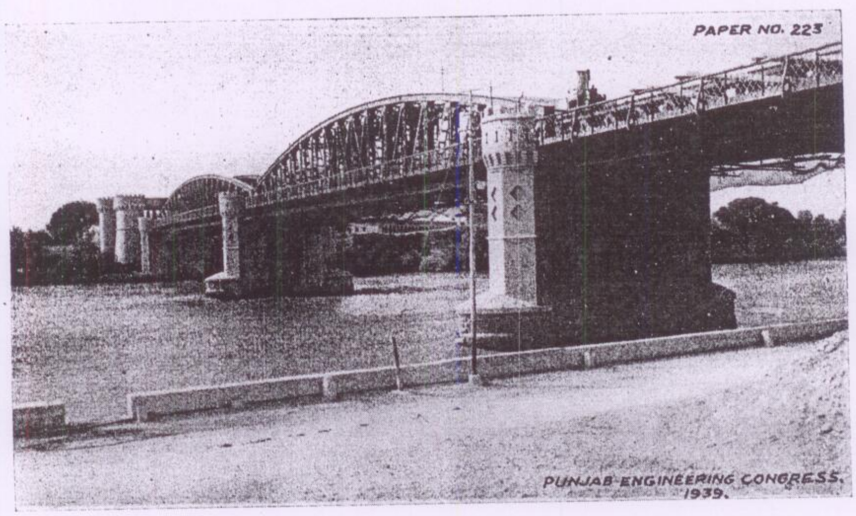


Photo No. 1. The Sukkur Channel Bridge on Indus.

work contained many irregularities and it was felt that the fitting of pre-cast slabs would not be satisfactory. So it was decided to cast all the slabs in situ. The bridge had to be kept open to trains throughout the twenty-four hours except for certain pre-arranged blocks when the track was "killed" for $1\frac{1}{2}$ to 2 hours at a time. And, except during the night when the road is closed, the bridge had to be kept open to vehicular traffic. One-way traffic was introduced and the casting of the side slabs, that is the slabs between the rails and the main girders, pesented no difficulty but the casting of the central slabs between the rails was more difficult as there was not enough room for even a single traffic lane at the sides. The problem was solved by the use of a temporary timber "drawbridge", designed on medieval lines. This consisted of three lengths of fifteen feet spanning the central part of the deck and hinged in one of the side gutters. This "drawbridge" lifted transversely up against one of the main girders to which it was automatically hooked to ensure safety when a train was due to pass. The three sections of the "drawbridge" were moved along the bridge as the work of casting the central slabs progressed. Raising and lowering was controlled by hand-operated winches, placed on one of the footways behind the girder against which the "drawbridge" was lifted. Details of this "drawbridge" are shown in Plate II and it is also illustrated in one of the photographs.

Steel shuttering was used for casting the R. C. slab. Plate III shows how it was fixed. The progress in casting the concrete slabs was governed by the length of shuttering available, the time taken between casting and the removal of the shuttering and also the length of the drawbridge. A start was made with sufficient shuttering to cast six side and six central slabs, each slab being seven feet long. The shuttering was to be removed after every fourth day; but, fortunately, with the experience gained, it was found quite satisfactory to remove the shuttering after 36 hours. This permitted six slabs to be cast every evening and the whole of the concrete decking was completed in twelve weeks.

The joints between the slabs were filled with a mixture of sawdust, bitumen and sand. This bitumen paste was also used in the joints between the steel guard plates alongside the rails, and the concrete slabs.

After casting, each slab was thoroughly cured for fourteen days and allowed to dry for another two, after which the top surface was treated with three coats of a solution of P84 grade sodium silicate to improve its wearing properties. Details of applying this solution are given in Appendix C. A sheet of expanded metal was pressed on to the top of the green concrete to render the surface proof against skidding.

On reference to the details of stools in Plate IV, it will be clear that before the rails can be taken out and the insides of the stringers painted, the angle cleats which support the longitudinal guard plates have to be removed. These cleats are bolted to runner angles on the tops of the stringers. So to ensure that these cleats can, at any time, be removed, the nuts have been spot-welded to the side of the runner angles in contact with the concrete and the bolts have been cut flush with the nuts. Before casting the slabs, the ends of the bolts were greased and while the concrete was taking up its set, the bolts were occasionally loosened to prevent their setting with the concrete. In order to avoid transmission of vibration from the running rail to the concrete, a clearance of 1/8 inch was maintained between the rails and the longitudinal guard plates.

The spans of the Sukkur Channel Bridge are provided with expansion bearings on the pier between the 90 and 230 feet spans, vide Plate V, and on the Bhukkur Island abutment. At each of these points, special comb expansion joints have been provided across the concrete decking. These comb joints consist of twin sets of alternate long and short steel plates arranged like the teeth of a comb so that the longer ones on one span come opposite the shorter ones on the other. The teeth are shaped so that the joints are self-cleaning with the movements of the spans under changes of temperature. The combs have been set in the concrete slabs to which they are permanently attached and special care has been taken to ensure that the surfaces of the concrete and steel are exactly level. A simpler and less costly expansion joint would have been an angle sliding on an angle as shown in the alternative arrangement in Plate V; but such a joint would impart a slight bump to vehicles passing over the edge of the angle. Such a bump might accelerate wear in the surface of the adjacent concrete. The comb joint precludes all chances of imparting vertical motion to wheels crossing it and it is mainly for this reason that it has been chosen.

The maximum time allowed for occupation of the track between trains was two hours and so the replacement of the rail bearing timbers with steel stools was a lengthy undertaking, involving the following five operations:—

(*a*) The guard plates, and angle and the cleats were removed. The bolts securing them were so badly corroded that each had to be cut with a hammer and chisel. Similarly the track fastenings had to be cut. The old rails were removed and replaced with new.

(*b*) The rails were removed and the old timber rail-bearers wedged out of the stringers. Temporary timber blocks were inserted and the track re-linked.

(*c*) The rails were removed and the insides of the stringers thoroughly scraped. The track, still on temporary timber blocks, was re-linked.

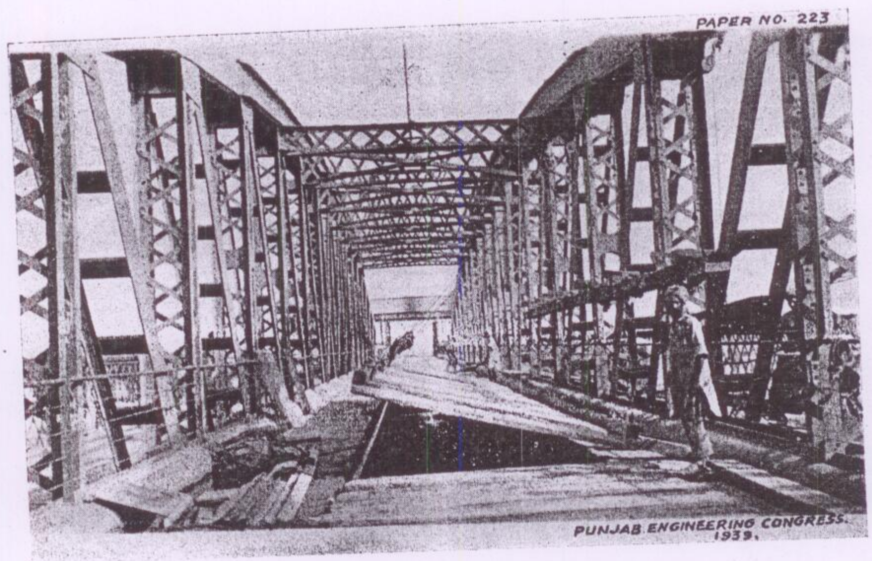


Photo No. 2. Lowering of the Draw Bridge.

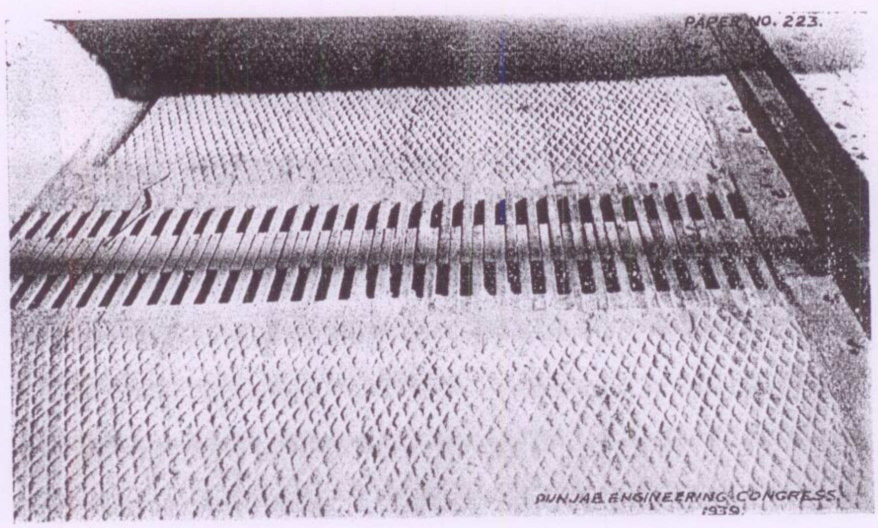


Photo No. 3.=Expansion Arrangement (part) on Pier.

(*d*) The rails were removed. Snap-headed rivets interfering with the steel stools were cut and replaced with counter-sunk rivets. The inside of the stringers was given one coat of red oxide paint. The position of the holes was scribed on the stools. The track, still on temporary timbers, was re-linked.

(*e*) The rails were removed. The stools together with any necessary packings were bolted in position. Finally, the stools were adjusted to any irregularities in the cross levels. The inside of the stringers was given a second coat of red oxide paint. The track was finally linked and the gauge adjusted.

The spaces between the stools in no place exceed 2 feet 8 inches, and at the rail joints this is reduced to about 18 inches. The rails are secured to the stools with jaws, one of which is welded to the stool, and the other is a standard removable jaw as used in steel sleeper tracks. The rail is held between these jaws by a tapered wedge, also a standard part of the track equipment, and shims are inserted in the jaws to adjust the gauge.

The labour employed on the reflooring of this bridge was divided into two shifts and work was carried on day and night. The first shift, employed on dismantling the old floor, rivetting, cleaning and painting the girderwork, fitting the stools and placing the shuttering in position, worked from 6-30 to 12-00 and again from 15-30 to 19-00 hours. At first, the second shift worked from 12-00 to 16-30 and from 19-30 to midnight; but, later, they worked only at night when the concrete was being laid. The second shift was engaged on work which could not be got at during the time the bridge was open to road traffic.

The bridge was fully illuminated for night work. Normally, there are a certain number of electric lights about the bridge and these were supplemented with additional bulbs slung from the girders. Current was taken from the railway mains.

Elaborate precautions were taken to safeguard not only the rail and road traffic but also the workmen employed on the bridge. Trains were stopped at the approaches and speed was restricted to 3 miles an hour. Animal and vehicular traffic was carefully controlled. One-way traffic was strictly enforced and notice boards, displayed at each end of the bridge, warned the public of the need to exercise caution. Men were stationed at the approaches to see that the drivers of all animal-drawn vehicles got down and led their animals across the bridge. Whenever a portion of the floor had been opened up, timber kerbs, clipped to the rails and strutted from the girders, were used to prevent traffic from straying into danger. One of the footways outside the main girders was kept open for pedestrians.

As a precaution against workmen falling from the bridge safety nets were slung below the spans. In addition, a row-boat, equipped with a supply of life-belts, was stationed in the stream below the bridge. It is a testimony to the effectiveness of these safety measures that no accident occurred either to the public or to the labour. One day, when the river was in flood and the stream was running swiftly, a country boat floating downstream got out of control and crashed into the pier in mid-stream. The boat capsized throwing the occupants into the water. The men manning the railway safety boat acted promptly and it was through their exertions that the crew of the country boat were rescued and a tragedy averted.

The reflooring of the Sukkur Channel Bridge was carried out during the latter half of the summer of 1938 by labour directly employed by the Bridge Branch of the North Western Railway, at a total cost of about Rs. 39000. Appendix A gives an analysis of the cost of reinforced concrete slabs and of steel stools.

Mr. Sahib Singh, Bridge Inspector, was in charge of the labour at the site. The Author was stationed as resident engineer and Mr. P.S.A. Berridge was Executive Bridge Engineer. The whole scheme was carried out and the drawings prepared under the guidance of Mr. H. Wood Robinson, Deputy Chief Engineer, Bridges, to whom the Author desires to express his thanks for permission to present this Paper. The Author is also thankful to Mr. Berridge for his help in writing this Paper.

APPENDIX A.

Analyses of the cost of R.C. slab and steel stools.

(*A*) *Analysis of cost of the reinforced concrete slab* :—

Quantity of concrete done =3375 cubic feet.

Cost of Bajri, shingle and sand	Rs. 256
Cost of binding wire	.. 38
Cost of B.R.C. Fabric	.. 4,600
Cost of Rapid Hardening Cement	.. 1,578
Cost of sodium silicate	.. 77
Cost of coal tar, other consumable stores	.. 314
Cost of shuttering after deducting credit for released material	1,029
	7,893
Labour Charges	3,384
Total	..11,277

Rate per cubic foot =3·34 Rs.
i.e., Rs. 3-6-0

(*B*) *Analysis of cost of steel stools.*

Cost of 548 stools	Rs 2,392
Cost of packings under stools	.. 121
Cost of keys and jaws	.. 266
Cost of bolts and washers and rivets	.. 330
Cost of other consumable stores	.. 92
Labour charges	1,951
Total	5,152

Cost of fitting each stool=Rs. 9-6-0.

APPENDIX B—*Table A.*

28 days ultimate strength of Concrete test cylinders 8″ by 4″ dia.

(*a*) Maximum size of coarse aggregate 3/8″

No. Marked on cylinder.	Date of casting.	Breaking load in tons.	No. Marked on cylinder.	Date of casting.	Breaking load in tons.
1	8-6-38	17·6	43	20-7-38	14·9
2	9-6-38	16·0	46	22-7-38	14·7
3	11-6-38	16·1	48	24-7-38	16·2
5	13-6-38	21·0	50	26-7-38	18·2
7	14-6-38	17·9	51	27-7-38	13·2
8	16-6-38	18·7	53	29-7-38	10·8
10	20-6-38	11·0	55	30-7-38	12·5
12	23-6-38	16·9	57	2-8-38	13·7
14	26-6-38	16·4	59	4-8-38	13·9
16	29-6-38	15·2	61	5-8-38	16·3
17	30-6-38	18·5	63	6-8-38	7·0
18	30-6-38	19·1	65	8-8-38	13·3
19	1-7-38	14·8	67	10-8-38	10·7
20	2-7-38	13·5	69	12-8-38	9·8
21	3-7-38	18·0	71	15-8-38	11·0
24	5-7-38	10·0	73	17-8-38	14·4
27	7-7-38	10·4	75	19-8-38	8·5
32	10-7-38	14·7	77	22-8-38	16·8
34	12-7-38	9·2	79	25-8-38	9·4
37	14-7-38	12·5	81	29-8-38	17·7
39	16-7-38	16·6	83	1-9-38	13·9
41	18-7-38	12·8	86	4-9-38	12·5

APPENDIX B—*Table B.*

28 *days ultimate strength of Concrete test cylinders* 8″ *by* 4″ *dia :*

(*b*) Maximum size of coarse aggregate $\frac{3}{4}$″

No. marked on cylinder.	Date of casting.	Breaking load in tons.	No. Marked, on cylinder.	Date of casting.	Breaking load in tons.
4	13-6-38	16·8	47	24-7-38	18·2
6	13-63-8	14·6	49	26-7-38	17·6
9	17-6-38	8·5	52	27-7-38	9·3
11	21-6-38	11·0	54	29-7-38	11·7
13	24-6-38	13·2	56	30-7-38	8.6
15	27-6-38	15·3	58	2-8-38	12·4
22	4-7-38	17·0	60	4-8-38	11·9
23	4-7-38	14·7	62	5-8-38	17·5
25	5-7-38	14·9	64	6-8-38	13·1
26	5-7-38	16·5	66	8-8-38	12·8
28	7-7-38	9·2	68	10-8-38	9·7
29	8-7-38	12·7	70	12-8-38	12·2
30	8-7-38	13·6	72	15-8-38	12·5
31	9-7-38	19·6	74	17-8-38	13·3
33	11-7-38	17·9	76	19-8-38	15·2
35	12-7-38	20·0	78	22-8-38	13·2
36	13-7-38	13·4	80	25-8-38	14·4
38	14-7-38	14·5	82	29-8-38	18·9
40	17-7-38	16·5	84	1-9-38	15·5
42	18-7-38	20·7	85	1-9-38	9·5
44	20-7-38	14·7	87	4-9-38	12·8
45	22-7-38	10·7			

APPENDIX C.

Instructions for application of P 84 grade of silicate of soda to roads and floors.

(1) Take one gallon of P84 silicate of soda and stir well into four gallons of water. This will usually suffice to give one coat to 1000 square feet of concrete.

(2) Take precautions to ensure that the surface of the concrete is clean, free from grease and reasonably dry.

(3) Apply the solution by means of a spraying machine or watering can and brush it over the surface with a soft broom or mop. Allow to dry thoroughly.

(4) Repeat when dry as often as may be necessary, i. e., until the concrete will take no more solution. Three coats are usually sufficient.

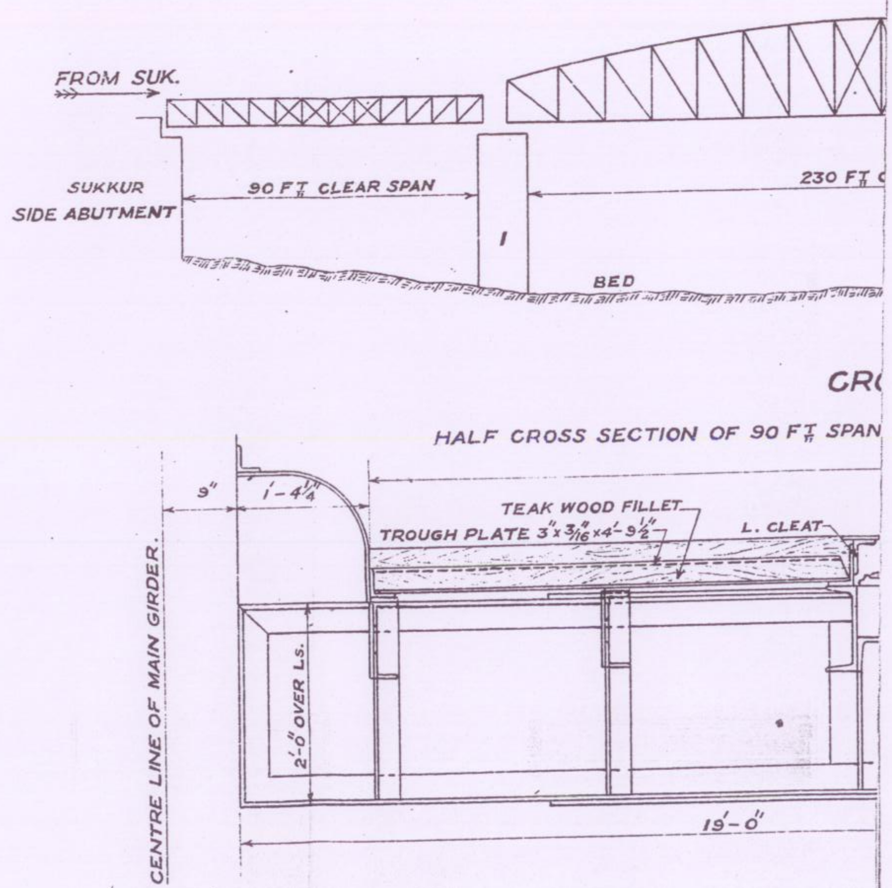
(5) After a final interval of twenty-four hours any surplus solution may be removed with a damp brush or mop.

(6) P84 silicate of soda can be used on new or old concrete, provided it has a clean surface, at any time after the concrete has set.

(7) The silicate will keep indefinitely if the stopper of the container is replaced to prevent evaporation.

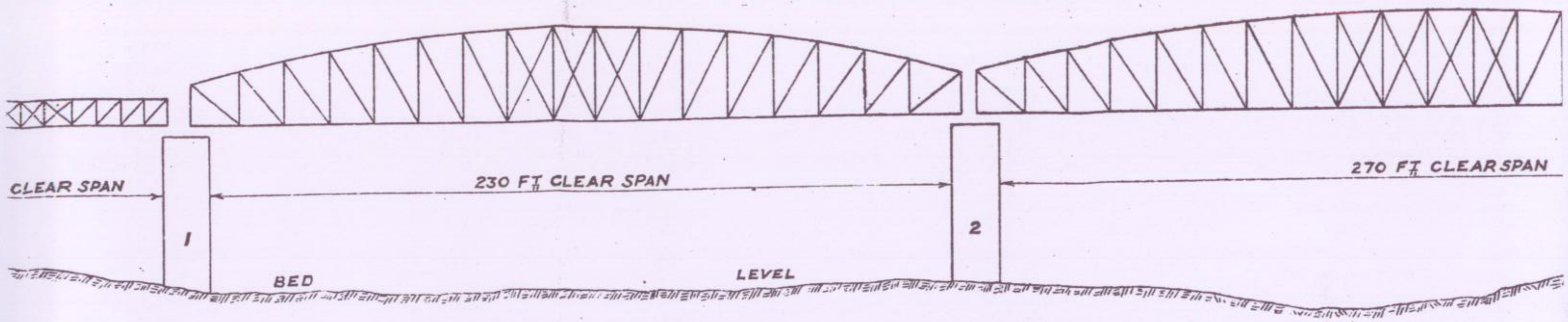
(8) In hot dry climates silicate of soda should be diluted with six to eight times its volume of water before it is applied, as the evaporation from the hot surface of the concrete may be so rapid that the 1 in 4 solution will dry out before it can penetrate to the required depth.

(9) Take care when using silicate of soda not to splash it on to paint work or clothes. On drying it becomes glass hard and is then difficult to remove.


FROM SUK.
SUKKUR
SIDE ABUTMENT
90 FT. CLEAR SPAN
230 FT.
1
BED
CR
HALF CROSS SECTION OF 90 FT. SPAN
9"
1'-4¼"
TEAK WOOD FILLET
TROUGH PLATE 3"x3/16"x4'-9½"
L. CLEAT
2'-0" OVER Ls.
CENTRE LINE OF MAIN GIRDER.
19'-0"

GENERAL ELEVATION OF SUKKUR CHANNEL BRIDGE

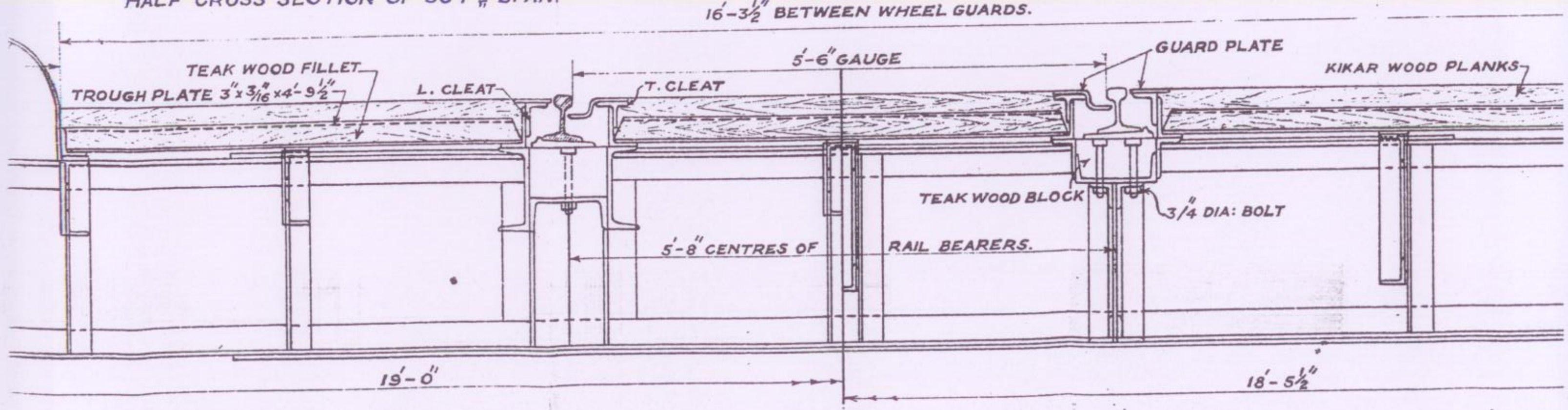
SCALE 40' = ONE INCH



CROSS SECTION OF OLD ROADWAY

HALF CROSS SECTION OF 90 FT. SPAN.

HALF CROSS SECTION OF 230 FT. AND 270 F



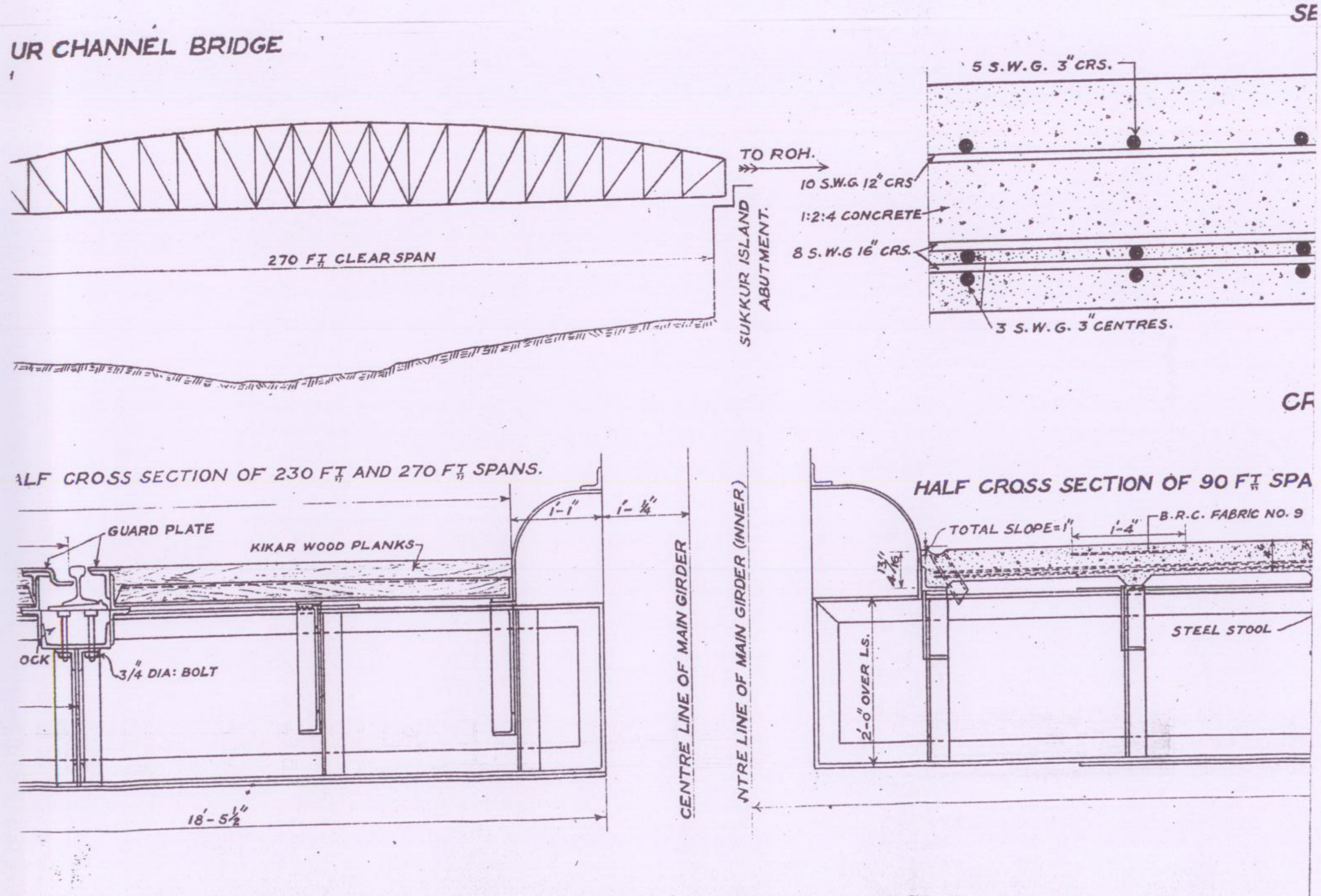

UR CHANNEL BRIDGE
TO ROH.
270 FT. CLEAR SPAN
SUKKUR ISLAND ABUTMENT.
SE
5 S.W.G. 3" CRS.
10 S.W.G. 12" CRS
1:2:4 CONCRETE
8 S.W.G 16" CRS.
3 S.W.G. 3" CENTRES.
CF
ALF CROSS SECTION OF 230 FT. AND 270 FT. SPANS.
GUARD PLATE
KIKAR WOOD PLANKS
OCK
3/4 DIA: BOLT
1'-1"
1'-¼"
18'-5½"
CENTRE LINE OF MAIN GIRDER
NTRE LINE OF MAIN GIRDER (INNER)
HALF CROSS SECTION OF 90 FT. SPA
TOTAL SLOPE=1"
1'-4"
B.R.C. FABRIC NO. 9
STEEL STOOL
2'-0" OVER L.S.

PLATE I
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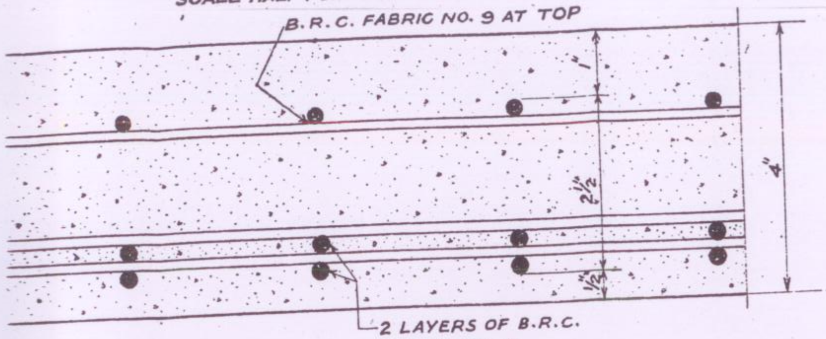
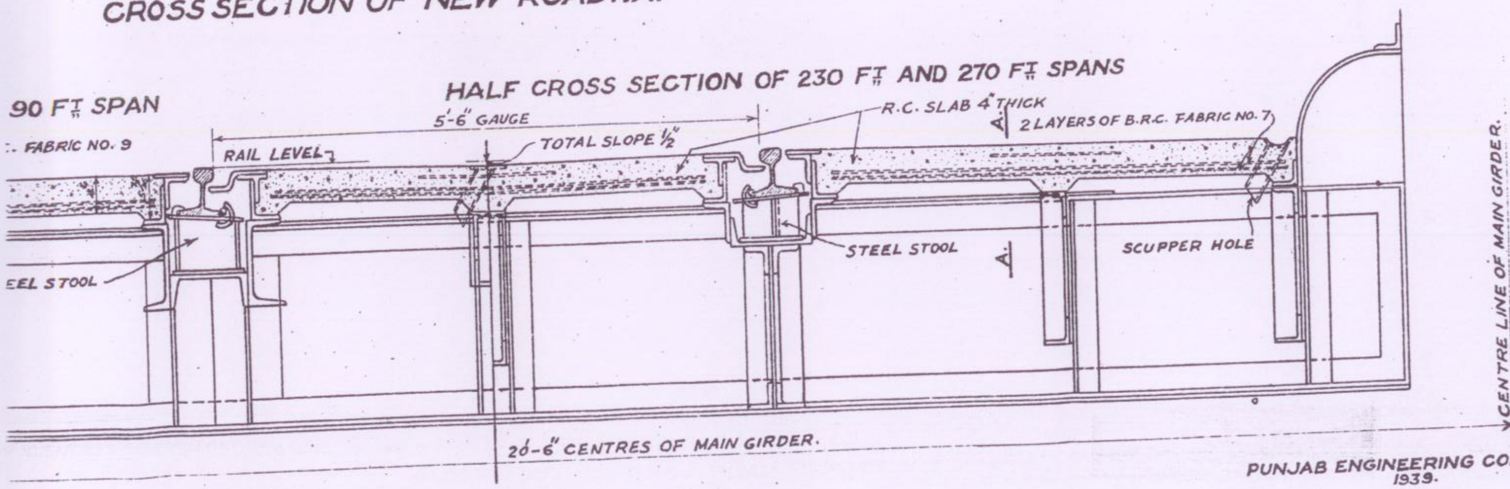
SUKKUR CHANNEL BRIDGE
CROSS SECTIONS OF OLD AND NEW ROADWAYS
SCALE 3/4" = ONE FOOT

SECTION OF SLAB ON A.A.
SCALE HALF FULL SIZE



CROSS SECTION OF NEW ROADWAY



PUNJAB ENGINEERING CONGRESS
1939.

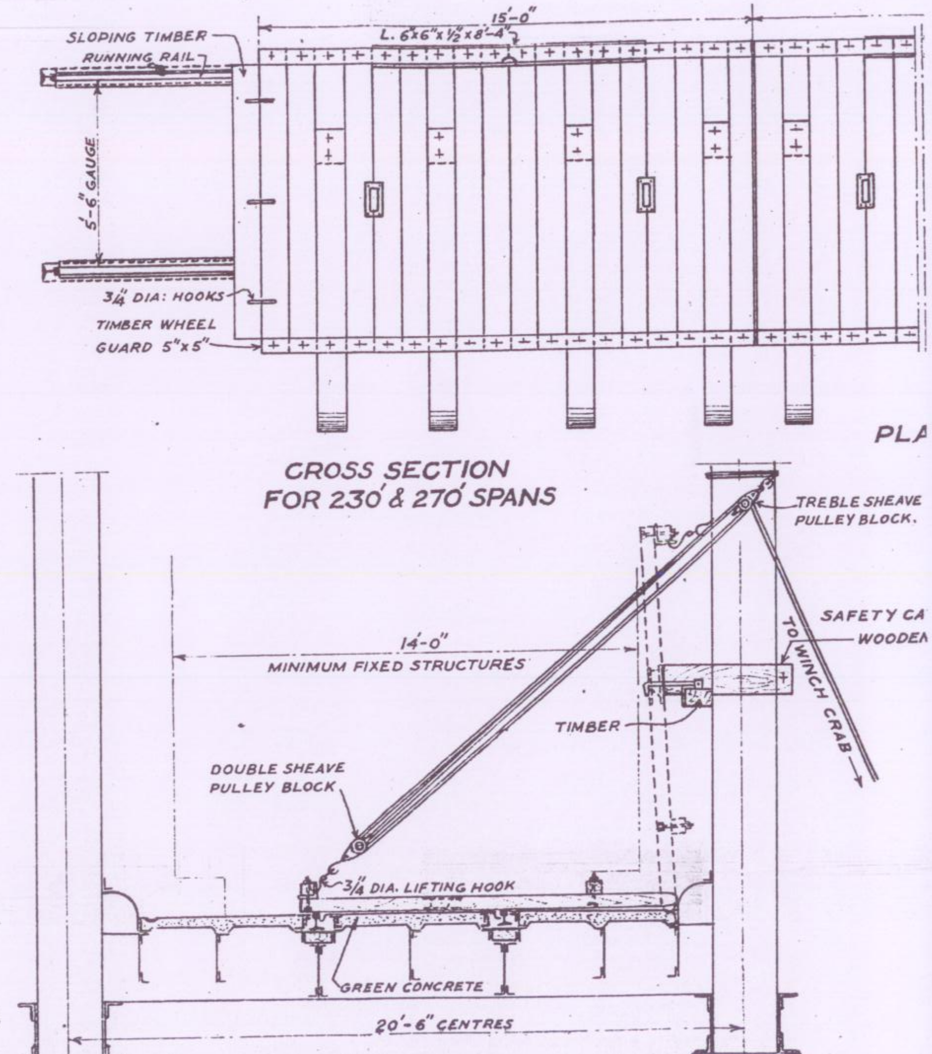

SLOPING TIMBER
RUNNING RAIL
5'-6" GAUGE
3/4" DIA: HOOKS
TIMBER WHEEL
GUARD 5"x5"
15'-0"
L. 6"x6"x1/2"x8'-4"
PLA
CROSS SECTION
FOR 230' & 270' SPANS
TREBLE SHEAVE
PULLEY BLOCK.
SAFETY CA
WOODEN
TO WINCH CRAB
14'-0"
MINIMUM FIXED STRUCTURES
TIMBER
DOUBLE SHEAVE
PULLEY BLOCK
3/4" DIA. LIFTING HOOK
GREEN CONCRETE
20'-6" CENTRES

PLATE II

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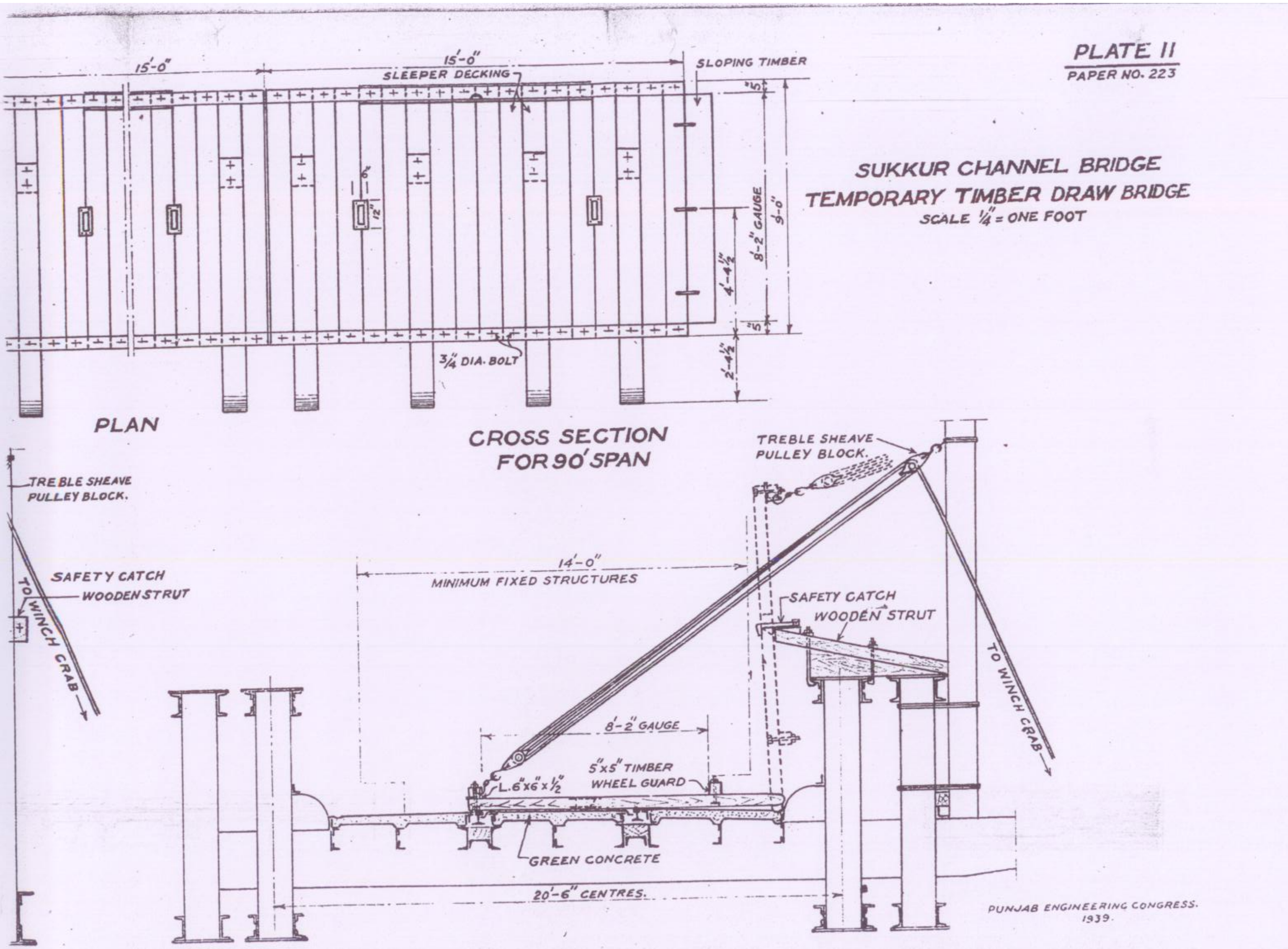
SUKKUR CHANNEL BRIDGE

TEMPORARY TIMBER DRAW BRIDGE

SCALE 1/4" = ONE FOOT



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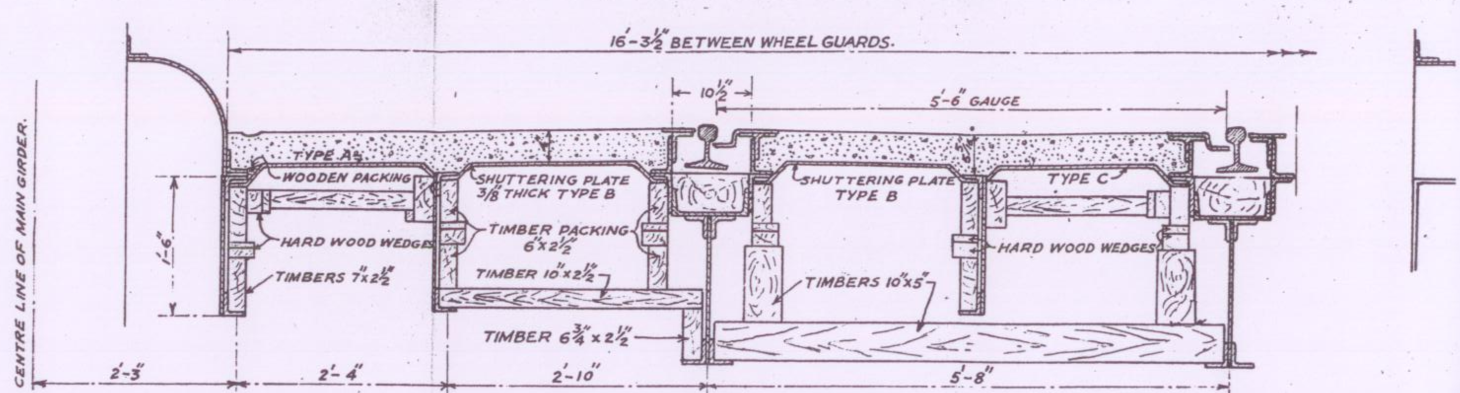
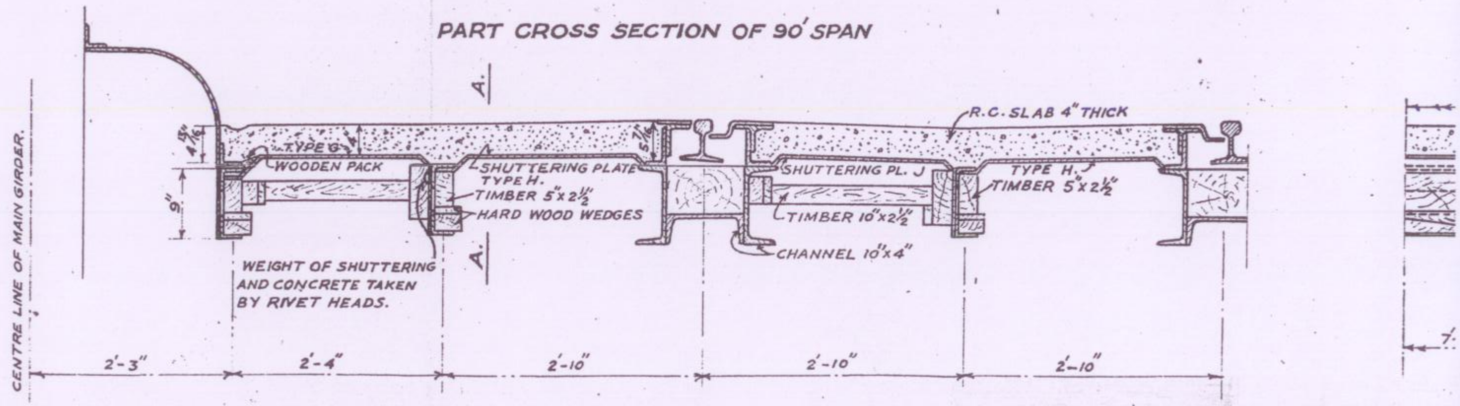
PART CROSS SECTION OF 230' AND 270' SPANS



PART CROSS SECTION OF 90' SPAN



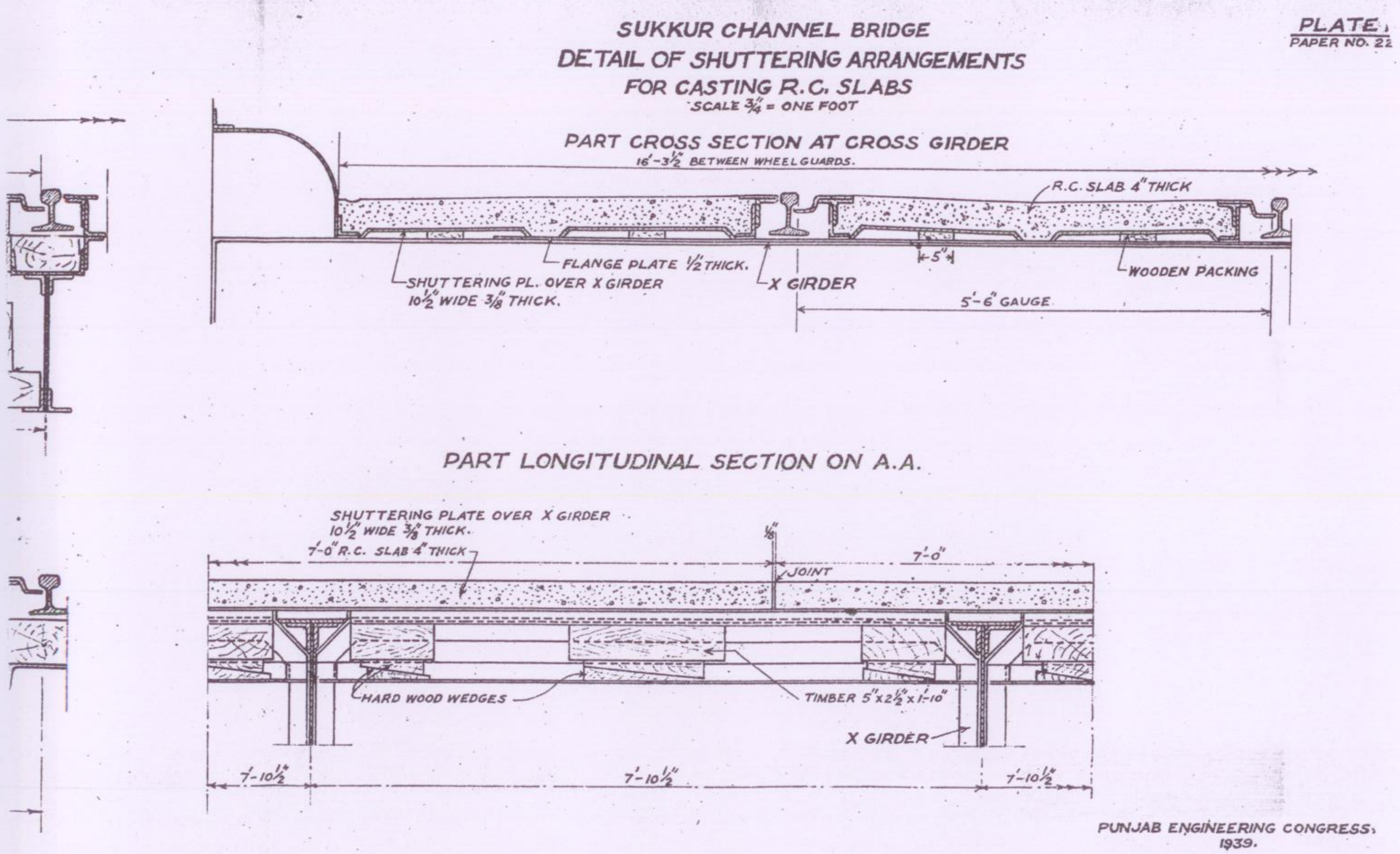
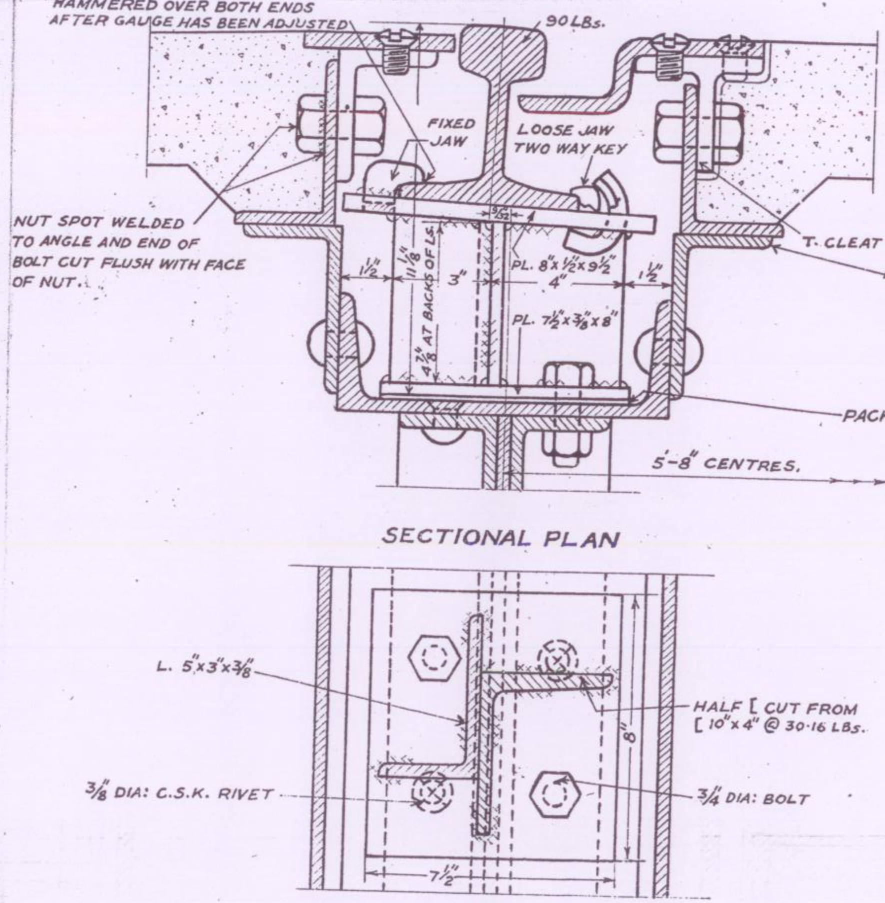


PLATE
PAPER NO. 22
SUKKUR CHANNEL BRIDGE
DETAIL OF SHUTTERING ARRANGEMENTS
FOR CASTING R.C. SLABS
SCALE 3/4" = ONE FOOT
PART CROSS SECTION AT CROSS GIRDER
16'-3 1/2" BETWEEN WHEELGUARDS.
R.C. SLAB 4" THICK
FLANGE PLATE 1/2" THICK.
SHUTTERING PL. OVER X GIRDER
10 1/2" WIDE 3/8" THICK.
X GIRDER
5"
WOODEN PACKING
5'-6" GAUGE
PART LONGITUDINAL SECTION ON A.A.
SHUTTERING PLATE OVER X GIRDER
10 1/2" WIDE 3/8" THICK.
7'-0" R.C. SLAB 4" THICK
1/8"
JOINT
7'-0"
HARD WOOD WEDGES
TIMBER 5"x2 1/2"x1'-10"
X GIRDER
7'-10 1/2"
7'-10 1/2"
7'-10 1/2"
PUNJAB ENGINEERING CONGRESS,
1939.

STEEL STOOLS UNDER RUNNING RAILS OF 270 AND 230 FT SPANS

CROSS SECTION



STEEL STOOLS UN[…] 90[…]

CROSS[…]

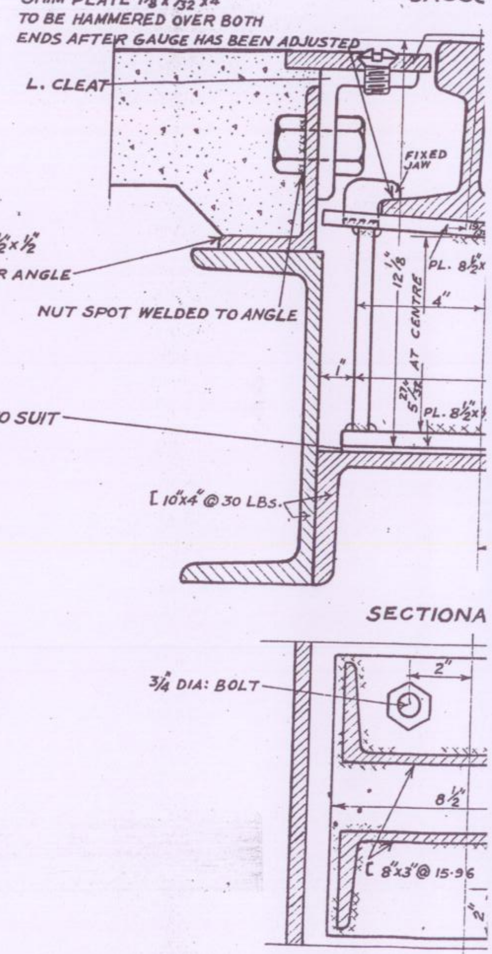


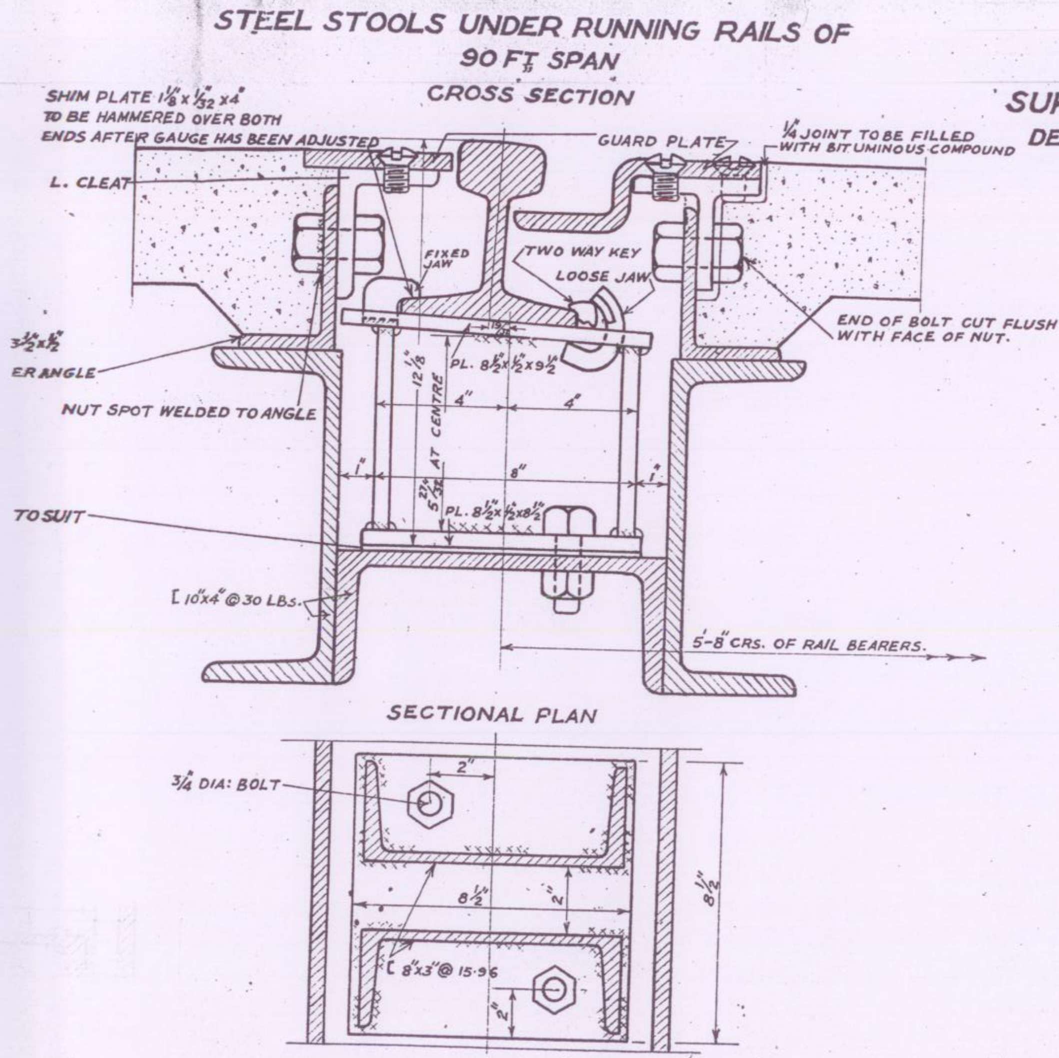
PLATE IV

PAPER NO. 223

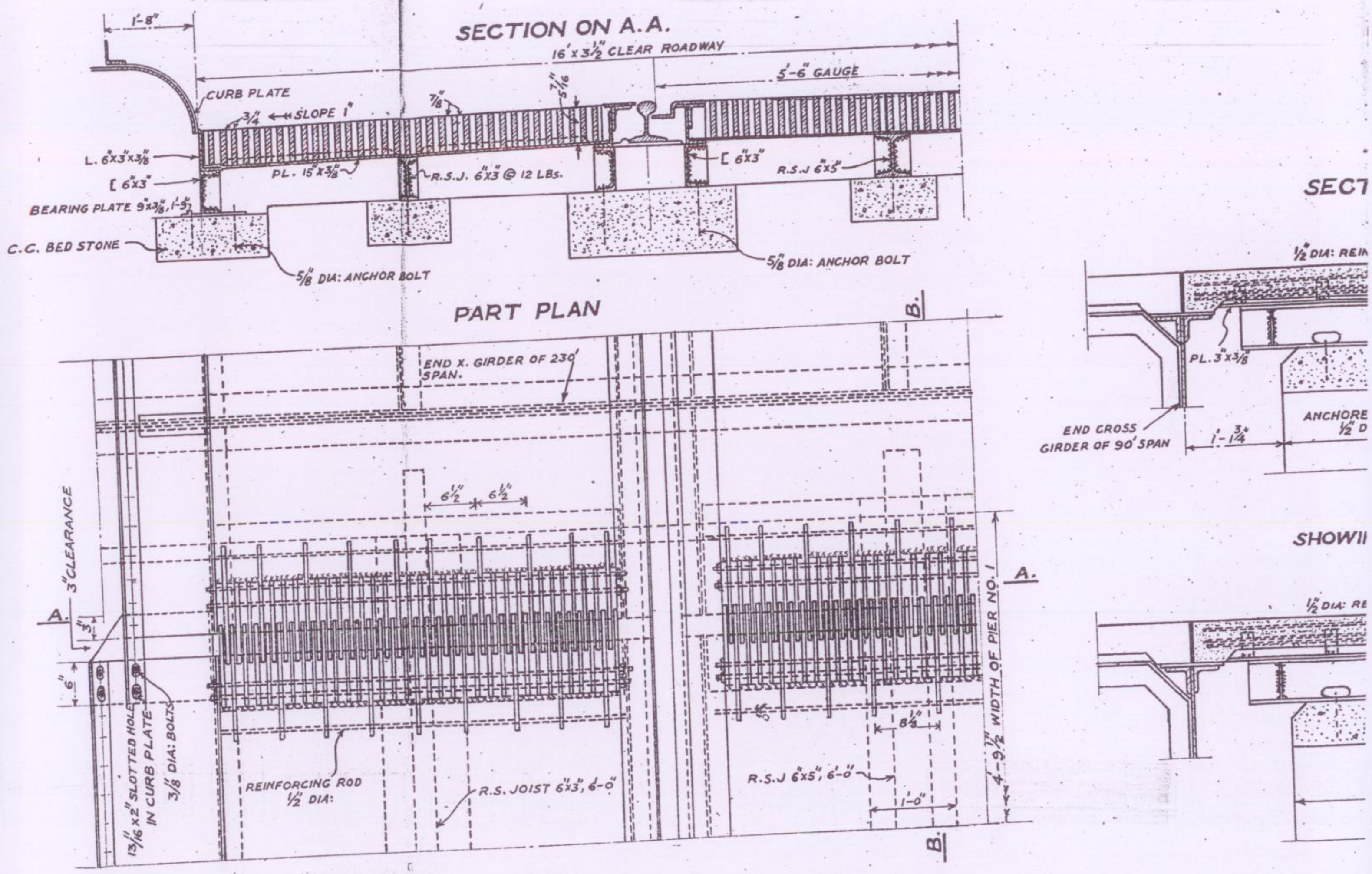
SUKKUR CHANNEL BRIDGE

DETAILS OF STEEL STOOLS

SCALE 3" = ONE FOOT



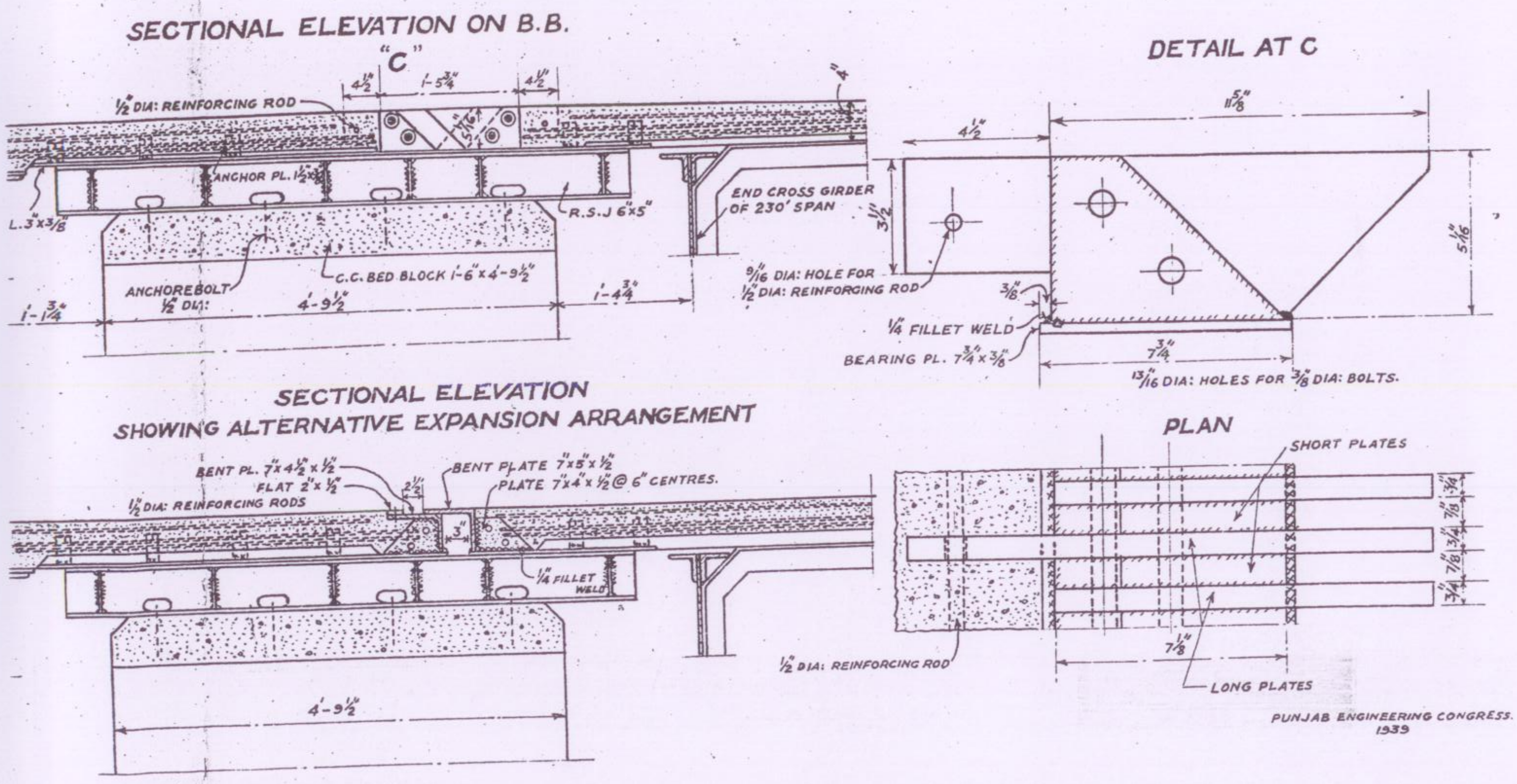
PUNJAB ENGINEERING CONGRESS.
1939.



SECTION ON A.A.
1'-8"
16'x3½" CLEAR ROADWAY
5'-6" GAUGE
CURB PLATE
¾ ← SLOPE 1"
7/8"
5/16"
L. 6"x3"x3/8"
[6"x3"
BEARING PLATE 9"x3/8", 1'-5"
C.C. BED STONE
PL. 15"x3/8"
R.S.J. 6"x3" @ 12 LBs.
[6"x3"
R.S.J 6"x5"
5/8" DIA: ANCHOR BOLT
5/8" DIA: ANCHOR BOLT
PART PLAN
END X. GIRDER OF 230' SPAN.
6½" 6½"
3" CLEARANCE
A.
6"
13/16" x 2" SLOTTED HOLE IN CURB PLATE
3/8" DIA: BOLTS
REINFORCING ROD ½" DIA:
R.S. JOIST 6"x3", 6'-0"
R.S.J 6"x5", 6'-0"
8½"
1'-0"
4'-9½" WIDTH OF PIER NO. 1
A.
B.
B.
SECT
½" DIA: REIN
PL. 3"x3/8"
END CROSS GIRDER OF 90' SPAN
1'-1¾"
ANCHORE
½" D
SHOWI
½" DIA: RE

SUKKUR CHANNEL BRIDGE
EXPANSION ARRANGEMENT
AT PIER NO. I

SCALES 3/4" & 3" = ONE FOOT



PUNJAB ENGINEERING CONGRESS.
1939

DISCUSSION.

While introducing his paper the **Author** said that the main features of the work of reflooring the Sukkur Channel bridge were, in the first place, the improved road surface obtained by the reinforced concrete slab in place of the old roadway of kikar planks laid diagonally over the troughing and secondly the replacement of longitudinal timber blocks under the running rails by steel stools. By these means all factors which had made adequate maintenance of the deck difficult, if not impossible, had been eliminated. The drainage of the deck which was almost non-existent before had been made quite satisfactory thus avoiding corrosion of steelwork. There was hardly any steel surface which was not now get-at-able for periodical painting. The use of all-welded stools in place of timber bedblocks had considerably reduced the first cost and this along with the R.C. roadway had brought down the annual maintenance charges to a negligible amount.

The road traffic using the bridge had to pay toll. The toll contractor paid the Railway about Rs. 25,000 annually. On account of the roadway over the bridge being under repairs, the delays to the road traffic were inevitable and this did adversely affect it. To save, therefore, the contractor making a claim for the loss suffered by him on this account, it was decided to expedite the completion of the work by working night and day. This also enabled the concreting to be done at night and thereby prevented its surface drying too rapidly.

Some Engineers, the author continued, were likely to question the utility of surface treatment of the roadway by P 84 grade of silicate of soda. The firm supplying the silicate clearly says that the substance does not form any skin on the surface of the concrete. The silicate solution penetrates into the concrete to a depth of about $\frac{1}{4}''$ and makes it impervious to water. This was an advantage only in the case of reinforced concrete roads or where the water in the concrete was likely to freeze and cause disintegration. Mr. Nayar had, therefore, clearly misunderstood the use of the silicate when he said in his Paper No. 224 that " whatever thin film the soda silicate may have formed, it has surely been knocked down by the heavy traffic".

Referring to the 28 days' ultimate compressive strength of concrete cylinders tabulated in Appendix B of the paper, it might be mentioned that the standard deviation in strength for the cylinders cast with 3/8" coarse aggregate was 3·3 tons against an average of 14·2 tons per sq. inch and the co-efficient of variation in strength was, therefore, 23%. It would be interesting to know what percentage variation could be allowed in good concrete practice.

A few minor errors had crept in Plate I accompanying the paper. In the general elevation of the bridge, the right abutment should be

"Bhukkur island abutment" and not "Sukkur island abutment" as indicated there. Also the stringers, rail and longitudinal block or stools in the sections of the new and old roadways should be hatched as they were in section and not in elevation as shown on the drawing.

As Mr. **P.S.A. Berridge** was sick, Mr. **H. Wood Robinson** read out the note prepared by the former. He said that he was particularly grateful to Mr. Kumar for his paper. In it, he had raised several points well worth discussing.

The most important improvements in the new floor related to the facilities for maintaining the track and the iron work of the bridge itself. Firstly, they had got rid of the longitudinal timbers under the rails. Most bridges built at the end of the last century, had these longitudinal timbers tightly wedged into trough-shaped stringers with the result that neither the timbers themselves nor the insides of the stringers could be properly inspected without dismantling the track.

The floor system on the Chenab bridge at Shershah was similar. It carried road traffic on the same deck as the single line of the Railway and when about a year ago, the longitudinal timbers were removed so that the insides of the stringers could be painted, the full disadvantages of the arrangement were fully appreciated. About 25% of the timbers had deteriorated to a texture like cork and the remainder was so badly damaged in getting them out of the stringers that the whole lot across the 17 spans of 200 ft. had to be entirely renewed. That operation cost Rs. 85,000, to say nothing of the inconvenience of having to do the work at night when the bridge was closed to road traffic. Corrosion had taken place up to a depth of more than $\frac{1}{8}$th of an inch on the insides of the stringers.

It was a curious thing that the use of the longitudinal timbers on brdiges had become so widespread before Engineers realized the defects of the design. With the exception of those bridges where a ballasted floor was provided throughout, the majority of the Railway bridges in England had longitudinal timbers under the rails. Even the Forth Bridge itself had this type of flooring.

The use of steel stools instead of longitudinal timbers, as in the case of the Sukkur channel bridge, was certainly a satisfactory solution to this difficulty. But on all such bridges where the road traffic shared the same deck as the Railway, it was always difficult to provide a suitable guard plate to cover up the spaces each side of the rails so that the narrow wheels of the road vehicles would not slip down between the edge of the road and the rails ; and, at the same time, make it easy for the plate-layers to open up the guard rails to get at the track fastenings and in particular to oil the fishplates. The accompanying sketch showed part of a cross section on one of the bridges on the Kalabagh Bannu section. It would be seen that the spaces on each side of the rail were covered by detachable guard plates secured to the steel work by setscrews. The rail is held in position between a fixed jaw welded to the bearing plate and a detachable jaw secured with a setscrew. Shins are inserted between the rails and the jaws to adjust the gauge. Once fixed it is only necessary to inspect the setscrews holding the detachable jaws and to oil the fishplates. Holes were provided in the guard plates over the setscrews securing the rails and the plate-layers were provided with suitable box spanners so that they could tighten up these setscrews without removing the guard plates. But the guard plates had to be removed wherever rail joints occur so that the fishplates could be lubricated. Mr. Berridge thought that this was a case where welded rail joints would be an advantage.

On the Sukkur channel bridge the rails were actually secured by wedges between the jaws on one side of the rail. It is impossible to tighten the track fastenings without the wholesale removal of the guard plates on the side of the rail above the wedges. The attachment of guard plates by countersunk setscrews tapped into the steelwork of the stringers was costly in the first place because of the enormous number of holes to be tapped; and, in the frequent removal of the guard plates by the plate-layers, the threads of the setscrews and the holes rapidly deteriorated. Actually, there were over 1400 holes $\frac{3}{4}''$ dia. tapped on this bridge.

The steel stools on the Sukkur channel bridge weighed 15 lb. less per foot run of track than the old longitudinal timbers. The new concrete decking on the Sukkur channel bridge weighed about 145 lb. more per foot run of the bridge than the old timber and iron troughing. This means an increase of about 38 tons distributed along the whole bridge. Obviously, any increase in the dead weight is a disadvantage; but, the standard of 2 units B.S.I. loading is considered ample for the needs especially as the Sind Government had agreed to the closing of the Lansdowne bridge to all road traffic except pedestrians. Very shortly the road decking on the Lansdowne bridge was to be removed and as a result some 200 tons of dead weight would be removed and heavier engines would be allowed to work trains across the Lansdowne bridge. When the roadway was removed from the bridge over the Rohri channel, all road traffic will be diverted over the Lloyd Barrage and so the traffic crossing the Sukkur channel bridge would be reduced to the requirements of the Military on Bhukkur Island and possibly to a certain amount of wheel traffic which may carry the pedestrians to the Island end of the Lansdowne bridge.

Mr. Kumar had drawn attention to the special comb-expansion joints on the Sukkur channel bridge. These are similar to an improvement on the expansion joints put on the bridge over the river Chenab near Chiniot about six years ago. Those joints were discussed at a previous meeting of this Congress. They were similar to joints used on road bridges in England and as an example they were to be found on the temporary Waterloo bridge over the Thames in London. He was sure that the absence of bump when a vehicle crossed these joints did help to preserve the surface of the concrete adjacent to the combs. On the Indus bridge at Kotri the expansion joints consisted of an angle sliding on the top of a steel plate. The concrete on either side of these expansion joints on the Kotri bridge did show signs of wear and he was of the opinion that the bump which a wheel gets as it rides over the joint had a lot to do with increasing the wear on the concrete adjacent to the joint.

The Sukkur channel bridge was sometimes confused with its much more conspicuous brother, the Lansdowne cantilever bridge over the Rohri channel of the Indus. The Sukkur channel bridge was completed about 4 years before Lord Reay, then Governor of Bombay, opened the Lansdowne bridge on the 25th of March, 1889. The 820′ long span of that bridge was the longest rigid span of that time and as the Lansdowne bridge would be 50 years old that very month, he ventured this slight digression. In his opening speech Lord Reay made it clear that it was to this great cantilever bridge that Lord Lansdowne was giving his name. He thought the following extract from Lord Reay's speech when he was referring to the excellence of the work done by Mr. Robertson, the Engineer-in-charge, would amuse the Members :—

> "This work of exceptional magnitude has been constructed at a cost of four lakhs of rupees below the sanctioned estimate, and it has been finished six months before the time it was expected to be completed. It would not be inappropriate if some percentage of the saving went to make up Mr.Robertson's scanty remuneration."

Such suggestions were seldom heard today ; but, they could take it that the reflooring of the Sukkur channel bridge had been well executed and that Mr. Kumar had most certainly carried on the good traditions of the Engineers who built the bridges over the Sukkur and the Rohri channels.

On finishing Mr. Berridge's note, Mr. Robinson said that he would like to congratulate Mr. Kumar on his paper and to express his appreciation of the way the work was carried out by Mr. Berridge, Mr. Kumar and the rest of the staff.

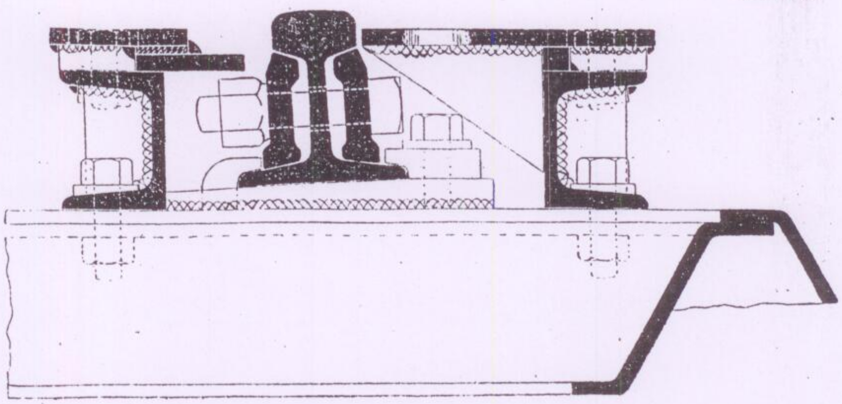
Mr. **D. P. Nayar** said that of particular interest to the concrete man was the table of breaking values of Concrete cylinders attached as Appendix to the Paper. This gave an average of about 14 tons for the breaking load of cylinder which meant a strength of about 2500 lb. per square inch. While he had been engaged on the construction of the concrete road near Shalamar last year, he got samples of concrete cylinders regularly tested at Rasul. The average breaking stress was found to be about 4800 lb. per square inch with a maximum of 6950 lb. He could not account for the huge difference between the two average values, except perhaps it might be ascribed to the difference of water content of the two mixes. The two concretes were required for different types of work, and different degrees of slump had to be worked to. In the case of the road it was a maximum of about ½" while perhaps in this case it was about 2". This disclosed very clearly the value of an effective control on the design of the concrete mix as essential for obtcining proper strength.

One thing that baffled him was how to account for the disparity of 9 and 21 tons in these values. It is not unlikely that this might again be due to difference in the water content, but what he had always wondered at was whether such a concrete did not constitute the weak link of the structure.

The **Author**, while replying to the criticism, said that Mr. Nayar had not stated for what mix of concrete he had obtained an average breaking strength of about 4800 lb. per sq. inch. Also as he was laying his concrete in a road without any reinforcement, he could use a drier mix and therefore could reasonably expect better results. The variation in strength attained by cylinders was probably due to variation in the water content. The author did not place much reliance on the slum tests as he thought that slight variation in water content was not reflected accurately in the slumps obtained. The author thought that as there were only a couple of cases where the 28 days' strength was less than 1800 lb. per sq. inch prescribed by the British Code for work tests with 1 : 2 : 4 nominal mix, there was no fear about the structure as built having in any part less factor of safety than that designed for. The author thanked Mr. Robinson and Mr. Berridge for the kind references made by them regarding his work.

Paper No. 223.

PLATE 1.



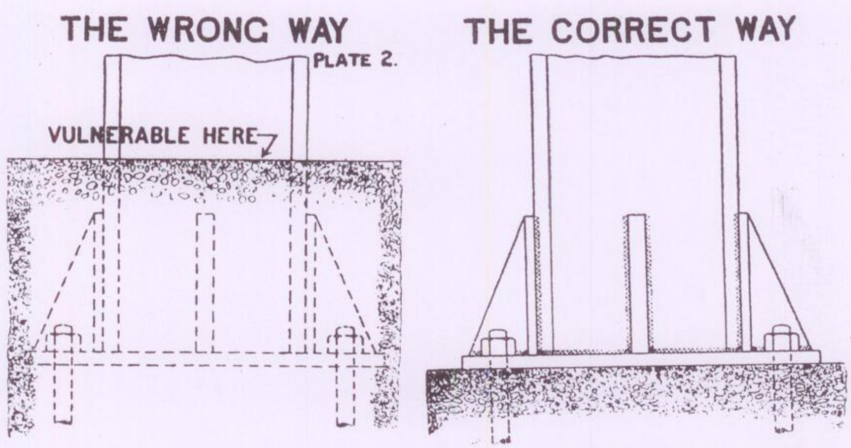


PLATE 2.