PAPER No. 232

SIDHNAI DAM BRIDGE.

BY

MESSRS. C.L. HANDA, I.S.E. AND MADAN LAL, C.E.

1. Introductory.

The Remodelling and Reconstruction of the Sidhnai Headworks embraced the construction of an Arterial Road Bridge across the Ravi which forms the subject of this paper.

The bridge lies on Arterial Road No. 41 of the Public Works Department linking the towns of Jhang and Khanewal. Previous to this, there used to be an 8 ft. wide timber bridge which was essentially meant for the use of Irrigation Regulation Staff at Sidhnai Dam. In the reconditioning scheme of the Dam, a bridge of the same type and dimensions would have met the needs of the Irrigation Branch but the necessity of combining an Arterial Road Bridge with the Dam was stressed by Government. The additional cost involved was estimated to be Rs. 86,000 which the Buildings and Roads Branch readily agreed to pay.

In this paper it is proposed to give brief details of the design of this bridge, the assumptions made in respect of loading, and a detailed description of the practical execution of what will be seen to be at once a simple and original design combining with itself the great merit of economy.

The cost of decking of this bridge is Rs. 42 per linear foot which compares favourably with costs of decking of similar bridges. The cost is exclusive of the cost of parapet.

2. Loading of the Bridge.

Before getting on to the selection of the type of the bridge and its design the question of live loading for which the bridge has been designed might be gone into. The Arterial and District Road Bridges are specified by the Punjab Public Works Department to be designed for 10 units B. E. S. A. loading up to a span of 80 ft. and from spans of 80 ft. to 300 ft. a straight line reduction from 10 to 6 units in addition to impact according to the formula :—

$$I = \frac{1}{2} \times \frac{65}{45 + L}$$

which is to be allowed in all cases, but subject to a maximum of 50%, where I is the percentage increase in the loading to allow for impact and L is the length in feet of the portion of the span which is loaded to produce the maximum stress in the member considered. The details of this loading are given in Appendix A.

As against this loading the Indian Roads Congress has specified two distinct loadings as given below :—

The Indian Roads Congress Heavy Loading. 0·58 ton per linear foot of each traffic lane, 10 ft. wide, plus a knife edge load of 7 tons for computing bending moments or of 10 tons for computing shears, with the limitation, that for computing bending moments the total distributed load on loaded lengths of 20 ft. and under, shall never be less than 11·6 tons per lane of traffic over the whole loaded length.

The Indian Roads Congress Standard Loading. 0·34 ton per linear foot of each traffic lane, 10 ft. wide, plus a knife edge load of 6 tons for computing bending moments or of 9 tons for computing shears, with the limitation that for computing bending moments the total distributed load on loaded lengths of 20 ft. and under, shall never be less than 6·8 tons per lane of traffic over the whole loaded length.

On these loadings the percentage increase due to impact has been specified by the Indian Roads Congress to be worked-out according to the formula :—

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On these loadings the percentage increase due to impact has been specified by the Indian Roads Congress to be worked-out according to the formula :—

$$I = \frac{1}{2} \times \frac{65}{45 + \frac{L(n+1)}{2}}$$

where L = Loaded length of the span.

n = number of traffic lanes.

Excluding the effects of impact, the 10 units B. E. S. A. loading for spans ranging from 10 ft. to 80 ft. is equivalent to a uniformly distributed load 100 lbs. per sq. ft. on the decking area and a knife edge load 1230 lbs. per foot width of the lane applied at the worst position. It stands to reason that for spans less than 10. ft. which is the axle spacing, the intensity of equivalent uniformly distributed load as explained in Appendix A would be much greater, and for spans greater than 80 ft. the intensity of loading would decrease with the increase in span length, as the possibility of the whole length being loaded with specified train loads would be less.

The corresponding figures in the Standard and Heavy Loading, for uniformly distributed load are 76 lbs./sq. ft. and 133 lbs/sq. ft. and for the knife edge load are 1340 and 1570 lbs. respectively for all spans greater than 20 ft. In specifying these loadings the Indian Roads Congress has attempted, what has been done in Appendix A. These loadings as specified do not afford a picture of what is to pass across a bridge. That can be best done by specifying the maximum axle loads and their spacings as has been done by the British Engineering Standards Association by their specifying a unit loading train. Depending on the nature and volume of traffic, the loading for any road bridge can be specified as a multiple of the unit loading and an equivalent loading curve for different spans can be worked out as has been done in Appendix A. The Sidhnai Bridge as such has been designed for 10 units B. E. S. A. loading. Bending moments engendered in different spans by the Indian Roads Congress loading and the 10 units B. E. S. A. loading have been plotted in Plates No. 6 and 7. It is evident from the bending moment curves that in case of spans upto 7 ft. the 10 units

B. E. S. A. loading is almost as severe as the Indian Roads Congress Heavy loading and for spans greater than 200 ft. it is lighter than even the Indian Roads Congress Standard loading. It would consequently appear that the loadings as adopted by the Indian Roads Congress require modification.

The formulæ for impact as specified above apply best in case of steel bridges. The impact effects on reinforced concrete bridges should be determined differently, due to their mass and rigidity. A general discussion on the Impact for R. C. Bridges would be outside the scope of the Paper but the general conclusions as arrived at in the Paper on Impact for R. C. Bridges by Korni, Institution of Engineers, India, might be given as a useful guide :—

Bridges without metalled-road :—

Span.	Percentage increase in Impact.
30 ft. and less	40 %
30 ft. „ 40 ft.	30 %
40 ft. „ 60 ft.	25 %
60 ft. „ 80 ft.	20 %
80 ft. „ 100 ft.	15 %
100 ft, „ 120 ft.	10 %
120 ft. „ above with 3" asphalt road.	0 %

The reduction in impact effects due to the damping caused by road metal has been plotted on Plate No. 6 for various thicknesses.

The conclusions referred to above, however, were not applied in the design of Sidhnai Bridge since the span was very small, and it was essential to keep to the loading specified by the Punjab Public Works Department.

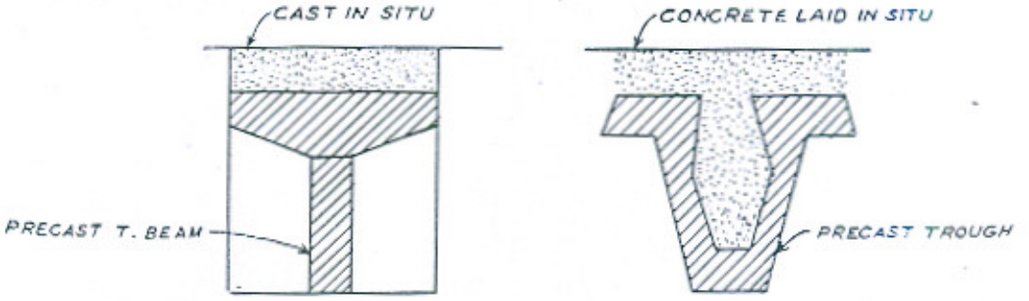
3. Selection of the Type of the Bridge.

A steel bridge was considered to be definitely uneconomical and as such various alternative designs of reinforced concrete decking as given below were worked out in detail and estimated to a fair degree of approximation.

(*a*) Cast-in-situ construction,
  (*i*) T-beams Bridge.
  (*ii*) Slab Bridge.

(*b*) Precast Construction,
  (*i*) T-beams Units.
  (*ii*) Trough Units.

FIG. NO. 1 (*a*, *b*)



(*a*) (*b*)

The time factor alone in the remodelling of Sidhnai Dam ruled the cast-in-situ construction out of consideration, since after the dam section had been completed and the piers built, the bridge could be finished earliest by using precast units only. Compared to the trough units the precast T-beam units were found a better proposition in soundness of design as well as cost. As a matter of fact the precast T-beam units bridge worked out to be the cheapest of all the types considered as mentioned above and as such it was considered to be the right type to be adopted. The details of cost of the various types of bridges have been analysed and a comparative cost statement is given in Appendix C.

4. Description of the Bridge and Details of Design.

The bridge as constructed consists of 31 spans each 19 ft. clear, the piers being 4 ft. thick ; each span is made up of ten reinforced concrete precast T-beam units laid side by side (Plate 1A). The T-beams are overlaid with a R. C. decking slab 6" thick. This decking slab is tied to T-beams by means of reinforcement which passes through hooks projecting out of the T-beams. Monolithic with the decking slab is a light wheel guard on either side in which U-bolts have been

embedded to facilitate the fixation of a galvanised iron railing. The design of the railing meets the requirements of the Buildings and Roads Branch and ensures complete protection to every kind of traffic across the bridge. The galvanising entails some extra initial cost but it is economical in the long run as it eliminates the necessity of periodical painting to afford protection against rusting.

The details of design and calculations are set forth in Appendix 'B' but the salient features have been outlined below.

It has been assumed that the live load is uniformly distributed through the decking slab on to each of the precast T-beam units. As such each precast unit 23 feet long is designed as a T-beam to carry its proportionate load which aggregates to

Dead load = 5,940 lbs.

Uniform live load = 5,000 lbs.

Knife edge load = 3,080 lbs.

The action of the decking slab consists in affecting as uniform a distribution as possible over all beams in the transverse direction, the distribution in the longitudinal direction having been unaffected by the use of precast units instead of cast-in-situ T-beam construction. By the use of precast units, the transverse distribution above is destroyed. Once it is restored the longitudinal distribution will come into play.

The slab deflects more under the wheels than elsewhere, *i.e.*, the pressure on the slab under the wheels is greater. That means that the distribution of load over the beams is not exactly uniform but uniformity is assumed to simplify the calculations. In working out the maximum bending moments and shearing force for the design of the slab the assumption of uniform load distribution is on the safe side. However the flanges of precast T-beams are designed to take the load dispersed at an angle of 45° through the surfacing slab. This conservative estimate of loading in the design of T-beam flanges is to cater for secondary stresses caused in the longitudinal as well as transverse direction.

5. Construction Organization.

One of the main objects of this Paper is to bring out the technique of simple and economical construction of this River bridge. Unlike other Irrigation Headworks in the Punjab, Sidhnai Dam is a small affair and nothing very much was available at the spot by way of tackle machinery or mechanical hoists. Both in the manufacture of the precast units and their erection, the labour employed was of the ordinary unskilled type. From a perusal of what follows, the members of the profession will be convinced that a precast T-Beam bridge can well be made a universal rule in case rapidity of construction is to be secured along with a sound design and reasonable economy.

The construction organization sub-divides itself into the following sections :—

(*a*) Moulding of reinforced concrete T-beams and their removal from the concreting yard.

(*b*) Curing operations which were carried out by means of a pumped supply and a water jet which kept the beams continuously moist through a cover of wet sand.

(*c*) Transporting of the precast T-beam units each weighing just over two tons.

(*d*) Hoisting of the precast units into position across piers of the Dam.

(*e*) Construction of the decking slab and wheel guards into which U-bolts were grouted for fixation of the railing.

Some of the above operations are vividly illustrated by photographs as given below :—

Photographs Nos. 1, 2 ... Operation (*a*)
Photograph No. 3 ... Operation (*c*)
Photographs Nos. 4, 5, 6 ... Operation (*e*)

Photograph No. 7 shows a section of the completed bridge.

Detailed working drawings of the bridge are appended to this Paper. A dimensioned drawing of the special

timber moulds employed for the manufacture of T-beams has also been included.

A brief description of the operations enumerated above will not be out of place. Only the special points involved in the construction and execution of the job have been brought out.

(*a*) *Moulding operations.* The moulding operations were carried out on a simple special type platform. This consisted of a dry brick floor of flat bricks laid on 3″ of sand. It was perfectly level, having been finished off with 1 : 3 cement plaster $\frac{1}{2}$″ thick. In this platform 3″ wide transverse grooves were kept in order to hold the "bottomless" moulds into position. The use of bottomless moulds made possible a quick out-turn of precast concrete units as with a mould consisting only of side members many castings can be obtained without having to lift the green product. In this particular case during the winter months as many as three beams were out-turned per mould per day, thus leading to a considerable economy in the one item which as every concrete engineer knows is the bogey of reinforced concrete work. Grooves in the floor housed angle iron transverse cleats fixed to the sides of moulds which prevented the entire beam getting out of shape during concreting and tamping operations.

(*b*) *Curing.* For efficient curing, a very cheap device was employed. It consisted enclosing each beam as it was made with half a brick thick dry wall and filling the space round the beam with ordinary sand which was kept moist for a period of three weeks. Since these bricks and the sand could be used over and over again, the cost of curing was very little.

(*c*) *Transporting of the beams.* The most complicated part of the job was the transport of the beams to the Dam. Various alternatives were considered but the device of loading the beams with a pair of shear legs on to an M. G. Truck frame and transporting it to the site on Tramway track proved to be the best. This procedure can be adopted at any odd site, provided the necessary length of tramway track and a few M. G. frames can be made available. When the work was once organised a

gang of 6 *Khalasis* could transport 6 beams over a distance of 1000 feet conveniently in one shift of 8 hours.

(*d*) *Hoisting of the beams.* Hoisting of the beams into position across piers was affected in two operations. In the first instance a derrick made of sal ballies was installed in the bridge span by means of suitable guys. Two timber beams of length 23 feet each made available from the dismantling of the old regulating bridge were first hoisted on to the piers. Over these the tramway track was laid and the loaded M. G. frames were hand shunted on to the span; the same derrick with an easy swing of the pulley block picked up the precast T-beam which was gently lowered into position over the finished piers. In this manner all the T-beams were erected in one span. As soon as two T-beams were put in position the tramway track could be shifted on to the concrete beams and the wooden beams became spare for a similar operation in the next span. A reference is invited to Appendix 'C' from which it will be seen that the cost of hoisting amounted to just over a rupee per ton.

At this place it is necessary to bring out with emphasis the great suitability of the design for providing a roadway for traffic even before the decking slab is laid in position. The nature of the work of reconstruction of Sidhnai Dam demanded that even in the contingency of a flood in the river, traffic across the Dam must be maintained over the portion which was to be opened for seepage of water. As soon as the T-beams were erected across one span they were covered with a three inch thickness of sand which was kept moist and which served the purpose of a flawless track for traffic in addition to further curing of the beams. During the construction as soon as 16 spans of the Headworks had been completed, an unprecedented freshet caused by abnormal rains in the hills attacked the Headworks. During this contingency the following features of the bridge proved to be of special utility :—

1. No centring or shuttering was required on account of the use of the precast units; hence full waterway was available in each of the spans which had just been "bridged."

2. Each precast T-beam had been designed to bear a greater part of the load that was expected to come on the bridge when it was built to its complete section; hence transport of the traffic and the machinery across the number of spans bridged with these T-beams could take place in an entirely satisfactory manner.

3. Due to abnormal floods more waterway was required for the free and safe passage of the discharge than was available in the left section of the Headworks, which had been sub-divided into two compartments for the purpose of completing the sheetpiling work and the concreting of the foundation raft. Since the provision for passage of floods has been envisaged in the programme, the work in the right compartment had also sufficiently advanced to permit of the deliberate breaching of the right ring bund. This was done and the remaining construction of the bridge had to be carried out in the open river. But for the special design of the bridge as described heretofore, it would have been impossible to construct any other form of bridge in these difficult conditions except at a much heavier cost. This detailed explanation of the suitability of the design for river and canal works has been given in order to explain that this work permits of a very wide application whenever bridges of small spans are required to be constructed for the type and magnitude of loading as described in the earlier part of the paper.

(*e*) *Decking slab.* Next we come to the final operation in the construction of the bridge, *i.e.*, the concreting of the decking slab and wheel guards. It was the simplest operation since it consisted in laying concrete over precast beams lying side by side. Concreting of the entire decking of a seven hundred feet long bridge was completed with a small roll of labour during the short period of a fortnight. A quarter cubic yard mixer was employed on the job. The machine could travel ahead of the finished slab, thus enabling a continuous operation.

The only shuttering that was necessary on this job was that required for the concreting of the wheel guards. This shuttering was fixed to the side beams by a few bolts that had been judiciously grouted in there earlier. The details of this shuttering are brought out in Photograph No. 5.

Even before the laying of the decking slab the precast T-beams had to undergo a severe full scale test as loaded lorries belonging to the Central Workshops, Amritsar, had to be emergently transported across the bridge. Each of these lorries was loaded with a steel gate and other heavy gear, a load of over seven tons. The beams were closely inspected after the passage of this load and were found to have come out of the test without even a hair crack.

6. Aesthetic Considerations.

Judged from architectural standard this cheap river bridge will stand out as a distinct success. The beams have a longitudinal tapering panel which is made to stand out in elevation due to the widening of the web towards the ends, thus simultaneously securing a better end bearing. The finish of precast work is admittedly much better than that of an *in-situ* construction in the matter of uniform surface texture. As a matter of fact this type of construction can always be advantageously employed when conditions permit as in the case of this particular bridge.

7. Acknowledgements.

The tables and diagrams of loading appended to this Paper were compiled in the Central Designs Office of the Punjab Irrigation Branch, which office also took out the design of this bridge.

APPENDIX A.

10 Units B. E. S. A. Loading.

In the diagram of British Standard unit loading, there is one engine of one ton axle and three trailors of 0·45 tons axles. Total length of train is 70 ft. Such trains are assumed to follow each other with 10 ft. distance between them. The width of track covered by the train = 10 ft. In case of 10 units B.E.S.A. loading the axle loads of unit loading train become ten times.

FIG. NO. 2

(EACH 10 FT. WIDTH OF CARRIAGE WAY OF THE BRIDGE IS TO BE ASSUMED AS COMPLETELY OCCUPIED BY SUCCESSION OF STANDARD TRAINS)

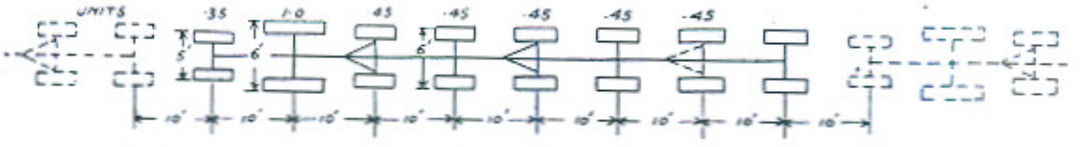


DIAGRAM OF UNIT LOADING

Application of the Loading Curve. For an easy and correct application of the 10 units B.E.S.A. loading an equivalent loading curve has been worked out.

The equivalent loading curve is shown in Plate No. 9 and the live load to be applied to bridge member is explained below :—

1. The uniformly distributed load applicable to "loaded length" of the bridge or members in question is selected from the curve.

2. The "loaded length" is the length of member loaded in order to produce the most severe stresses. In a freely supported span the "loaded length" would thus be (*a*) for bending moment ; the full span. (*b*) For shear at the support; the full span. (*c*) For shear at intermediate points ; from this point to the farther support.

3. In arches and continuous spans the "loaded length" can be taken from the influence line curve.

4. The live load to be used consists of two items (*i*) the uniformly distributed load which varies with the loaded length, and which represents the ordinary axle loads of the train, perfectly distributed. (*ii*) An invariable knife-edge load applied at the section where it will, when

combined with the uniformly distributed load, be most effective, *i.e.*, in a freely supported span: (*a*) for bending moment midspan, at midspan point. (*b*) For shear at the support, at the support. (*c*) For shear at any section, at the section.

5. This knife-edge load represents the excess in the train of the heavy axle over the other axles, this excess being undistributed (except laterally as already assumed).

6. In spans of less than 10 ft. (*i.e.*, less than the axle spacing) the concentration serves to counteract the over-dispersion of the distributed load.

7. In slabs the knife-edge load is taken as acting parallel to the supporting members, irrespective of the direction in which the slab spans.

8. In longitudinal girders, stringers, etc., this concentrated loading is taken as acting transversely to them (*i.e.*, parallel with their supports).

9. In transverse beams the concentrated loading is taken as acting in line with them.

10. If longitudinal or transverse members are spaced more closely than at 5 ft. centres, the live load allocated to them shall be that calculated on a 5 ft. wide strip. With wider spacing this strip will be equal to the girder spacing.

11. In all cases, irrespective of span length, one knife-edge load is taken as acting in conjunction with the uniform distributed load appropriate to the span or "loaded length."

In the standard train the loading is distributed fairly evenly throughout the full length except for the excess which occurs at the heavy axle. The uniform load as given in the curve is assumed to be evenly spread over the area under consideration.

Average axle spacing = 10′
Train width = 10′

Axle load corresponding to 10 units B.E.S.A.
$= 0{\cdot}45 \times 10 = 4{\cdot}5$ tons.

$$\text{Uniform load} = \frac{4{\cdot}5 \times 2240}{10 \times 10} = 101 \text{ lbs./sq. ft. say } 100 \text{ lbs./sq. ft.}$$

The excess which occurs at the heavy axle = 10−4·5 = 5·5 tons. It is applied as knife-edge load and per foot width = $\frac{5{\cdot}5 \times 2240}{10}$ = 1230 lbs./ft.

These figures of 100 lbs./sq. ft. and 1230 lbs./ft. are for spans ranging from 10 ft. to 80 ft. and do not allow for impact.

The corresponding figures for 6 units would be

Uniform load = $\frac{0{\cdot}45 \times 6 \times 2240}{10 \times 10}$ = 60 lbs/sq. ft.

Knife-edge load = $\frac{0{\cdot}55 \times 6 \times 2240}{10}$ = 740 lbs./ ft.

The Punjab Public Works Department specifies 10 unit B.E.S.A. upto a span of 80 ft. and from spans of 80 ft. to 300 ft. a straight line reduction from 10 to 6 units in addition to the impact.

It would be rational not to vary the knife-edge load as its effect in long spans is relatively less important and does not warrant the additional complication of its variation. The uniform load intensity has been reduced as shown in Plate No. 9.

Impact allowance is made according to the formula

$$I = \tfrac{1}{2} \times \frac{65}{45 + L}$$

in the case of the uniform load intensity. In case of the knife-edge load 50% impact allowance has been allowed for all the spans so that the knife edge load inclusive of impact equals 1850 lbs. In case of reinforced concrete bridges the impact allowance should be as explained in the text of the Paper.

Below 10 ft. account has to be taken of the fact that the full effect of the heaviest wheels is experienced although the span is less than the average axle spacing and this is done by increasing the intensity of the uniformly distributed load and keeping the knife-edge load with or without impact constant. The load for spans less than 10 ft. is derived from the bending moments worked out by Peigeaud's method for the two following cases in case of slabs spanning transversely

over longitudinal girders as well as slabs spanning longitudinally over cross girders:—

(1) The two 5 tons wheels 12″ apart of two 10 units trains running parallel to each other.

Contact area of wheels being 18″×3″.

(2) One 9 tons wheel of contact area 24″ ×3″.

Both (1) and (2) do not make allowance for impact, (2) will provide for the passage of an exceptionally heavy single vehicle which might reasonably occur. Single concentrated load corresponding to 10 units loading exclusive of impact has been allowed on the slab, from the considerations of affording the same factor of safety to all the structural members of a bridge. Consider a T-beam bridge designed for a specific train of vehicles ; the longitudinal girders of that bridge would very well negotiate a single vehicle of very much heavier axle load but not a slab unless it has been designed for it.

The B.M. curves for these two cases in case of slabs spanning transversely as well as longitudinally have been plotted in Plate No. 7. A design moment curve, the same for transverse and longitudinal directions has been drawn as a mean curve. From this curve of bending moment, after deducting the bending moments due to the knife-edge load, the required unit loading has been obtained.

Tables 3 and 4 detailing out steel in case of freely supported and rigidly fixed slabs across different spans will be useful for ready reference.

Plate No.10 relates to simply supported R. C. slabs designed for 10 units B.E.S.A. loading in case of spans ranging upto 20 ft.

TABLE No. 1

Bending Moments for 10 B. E. S. A. Units Loading.

(PEIGEAUD'S METHOD)

Effective span.	SLAB SPANNING ALONG THE LINE OF TRAFFIC.		SLAB SPANNING AT RIGHT ANGLES TO THE LINE OF TRAFFIC.		Design moments from the curve (without impact).
	Two 5 tons wheels 12″ apart 18″ × 3″ contact area.	One 9 tons wheel 24″ × 3″ contact area.	Two 5 tons wheels 12″ apart 18″ × 3″ contact area.	One 9 tons wheel 24″ × 3″ contact area.	
4′	33,140	41,000	...	31,000	33,460
5′	39,920	45,700	22,250	35,600	39,470
6′	44,560	48,500	26,950	39,200	43,730
7′	48,260	51,600	30,050	42,000	46,930
8′	51,280	54,400	33,650	44,600	49,200
9′	54,200	57,200	36,450	47,000	50,670
10′	58,100	59,000	39,850	49,000	52,100

TABLE No. 2.

Uniform Loading for 10 B. E. S. A. Units Loading.

Effective span *l*.	Design bending moments as taken from the curve.	Knife-edge load (1,230 lbs.) bending moments $1,230 \times 3l$.	Uniform load bending moment *M* Col. 2 — Col. 3.	Uniform load per square ft. *W* (without impact) $1{\cdot}5\ wl^2 = M$.	Uniform load per sq. ft. with 50% impact $3/2 \times$ Col. 5.
1	2	3	4	5	6
4	33,460	14,800	18,660	777	1,165
4·5	36,730	16,670	20,060	659	988
5·0	39,470	18,460	21,010	560	840
5·5	41,800	20,320	19,480	430	644
6·0	43,730	23,000	20,730	383	572
6·5	45,400	24,100	21,300	336	504
7·0	46,930	25,320	21,610	294	442
7·5	48,000	27,530	20,470	243	364
8·0	49,200	29,600	19,600	204	306
8·5	49,870	31,400	18,470	171	256
9·0	50,700	33,300	17,400	143	214
9·5	51,500	35,140	16,300	120	180
10·0	52,100	37,000	15,100	101	151

TABLE NO. 3.

Details of Slabs in Monolithic Construction.

(1 : 2 : 4 cement concrete f_c =750 lbs. per sq. in. ; f_s =16,000 lbs. per sq. in.)

Span in ft.	Effective thickness in inches.	Total thickness of slab in inches.	Dead load (3″ concrete surfacing).	Dead load moments.	Design moments as taken from curve × 1·5* × 0·8†	Tota moments *M*.	Main steel *M*	DISTRIBUTION STEEL.		PROVISION OF STEEL.	
							16,000 × ·862 × *t*.	Percentage.	Quantity.	Main.	Distribution.
4	5·75	7	120	1,920	40,160	42,080	0·53	40%	·212	½″ Ø @ 4·5″	3/8″ Ø @ 6″
4·5	5·75	7	120	2,420	44,080	46,500	0·587	40%	·234	½″ Ø @ 4·0″	3/8″ Ø @ 5·5″
5·0	5·75	7	120	3,000	47,360	50,300	0·635	45%	·286	½″ Ø @ 3·75″	½″ Ø @ 8·25″
5·5	5·75	7	120	3,620	50,160	53,780	0·68	45%	·306	½″ Ø @ 3·5″	½″ Ø @ 7·5″
6·0	6·0	7.25	123	4,440	52,480	56,920	0·687	50%	0·343	½″ Ø @ 3·50″	½″ Ø @ 7″
6·5	6·25	7·5	126	5,320	54,480	59,800	0·694	50%	0·347	½″ Ø @ 3·5″	½″ Ø @ 6·75″
7·0	6·25	7·5	126	6,160	56,320	62,480	0·725	50%	0 362	½″ Ø @ 3·25″	½″ Ø @ 6·5″
7·5	6·5	7·75	129	7,250	57,600	64,850	0·722	50%	0·361	½″ Ø @ 3·25″	½″ Ø @ 6·5″
8·0	6·5	7·75	129	8,280	59,040	67,320	0·750	55%	0·413	½″ Ø @ 3″	½″ Ø @ 5·75″
8·5	6·50	7·75	129	9,330	59,840	69,170	0·770	55%	0·424	½″ Ø @ 3″	½″ Ø @ 5·5″
9·0	6·69	8·0	132	10,700	60,800	71,500	0·775	55%	0·426	5/8″ Ø @ 4·75″	5/8″ Ø @ 8·5″
9·5	6·69	8·0	132	11,900	61,840	72,740	0·790	55%	0·435	5/8″ Ø @ 4·5″	5/8″ Ø @ 8·5″
10·0	6·94	8·25	135	13,500	62,520	76,020	0·793	60%	0·475	5/8″ Ø @ 4·5″	5/8″ Ø @ 7·75″

* Impact factor † Continuity. *Note* :—Effective span = clear span in case of T.-beam or monolithic construction.

FIG. NO. 3

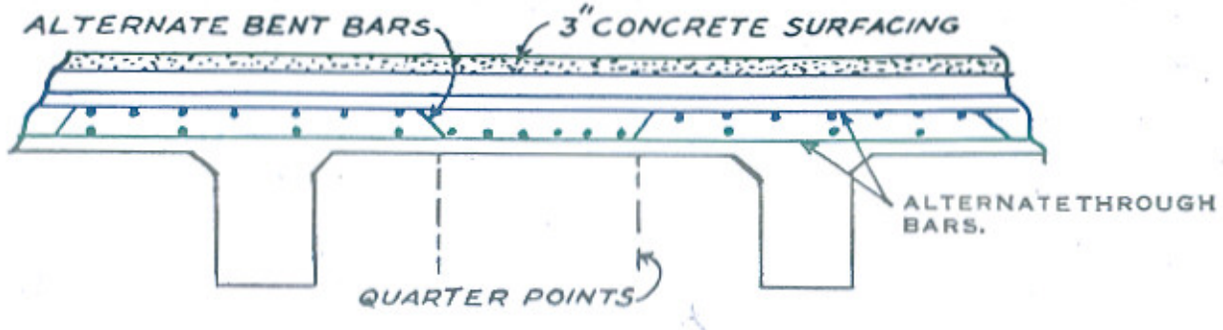
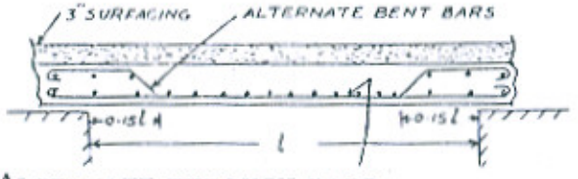


FIG. NO. 4



ALTERNATE THROUGH BARS

TABLE No. 4.

Details of Simply Supported Slabs.

(1 : 2 : 4 cement concrete f_c = 750 lbs. per sq. in.;
f = 16,000 lbs. per sq. in.)

Effective span in feet.	Thickness of slab in inches.	Effective thickness in inches.	Dead load 3" concrete surfacing.	Dead load bending moments	Live load bending moments	Total moments	MAIN STEEL		DISTRIBUTION STEEL		
							Quantity in sq. in.	Provision.	Percentage of main steel.	Quantity.	Provision.
4·0	7	5·75	120	2,880	50,200	53,080	0·669	1/2" Ø @ 3·5"	40	0·268	1/2" Ø @ 8·75"
4·5	7·25	6·00	123	3,750	55,100	58,850	0·710	1/2" Ø @ 3·25"	40	0·284	1/2" Ø @ 8·25"
5·0	7·5	6·25	126	4,720	59,200	63,920	0·742	1/2" Ø @ 3"	45	0·334	1/2" Ø @ 7·0"
5·5	7·75	6·5	129	5,890	62,700	68,590	0·765	1/2" Ø @ 3"	45	0·334	1/2" Ø @ 6·75"
6·0	8	6·69	132	7,130	65,600	72,730	0·789	5/8" Ø @ 4·5"	50	0·394	1/2" Ø @ 6"
6·5	8·25	6·94	135	8,560	68,100	76,660	0·804	5/8" Ø @ 4·5"	50	0·402	1/2" Ø @ 5·75"
7·0	8·5	7·19	138	10,150	70,400	80,550	0·812	5/8" Ø @ 4·5"	50	0·406	1/2" Ø @ 5·75"
7·5	8·5	7·19	138	11,600	72,000	83,600	0·844	5/8" Ø @ 4·25"	50	0·422	1/2" Ø @ 5·5"
8·0	8·75	7·44	141	13,500	73,800	87,300	0·851	5/8" Ø @ 4·25"	55	0·469	5/8" Ø @ 8"
8·5	8·75	7·44	141	15,250	74,800	90,050	0·878	5/8" Ø @ 4·25"	55	0·482	5/8" Ø @ 7·5"
9·0	9·0	7·69	144	17,500	76,000	93,500	0·884	5/8" Ø @ 4·00"	55	0·485	5/8" Ø @ 7·5"
9·5	9·25	7·94	147	19,850	77,300	97,150	0·887	5/8" Ø @ 4·00"	55	0·488	5/8" Ø @ 7·5"
10·0	9·25	7·94	147	22,000	78,150	100,150	0·914	5/8" Ø @ 4·00"	60	0·54	5/8" Ø @ 6·75"

Note :—1. Shearing and bond stresses work out to be safe.
Max : safe shearing stress = 75 lbs per sq. in.
Max : safe bond stress in flexure = Twice safe bond stress in direct pull = 2 × 100 = 200 lbs per sq. in.
2. Effective pan = clear span + thickness of the slab.

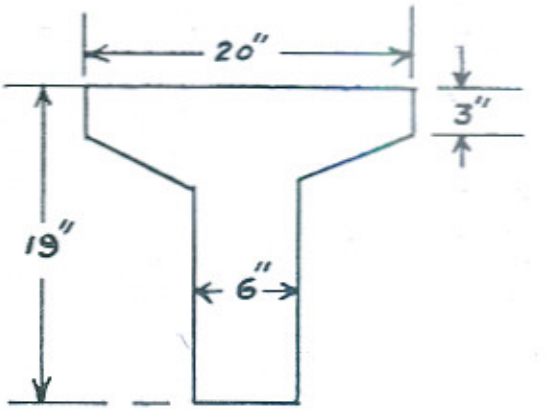
APPENDIX B.

Details of Design and Calculations.

1. *Loading.* 10 units B. E. S. A. From the loading curve it is equivalent to uniformly distributed load of 150 lbs/sq. ft. and a knife-edge load of 1850 lbs. inclusive of impact.

2. *Precast T-beam Unit* :

FIG. NO. 5



Clear span = 19′

Effective span = 20′

Dead load.

6″ surfacing = $6 \times 20 = 120$

Beam $= 19 \times 6 + 9 \times 7 = \frac{177}{297}$ lbs.

Dead load moments $= 297 \times \frac{20^2}{8} \times 12 = 17{,}800$ lbs. in.

Knife-edge moments $= 1850 \times \frac{20}{12} = 3{,}080$ lbs.

∴ Moments due to knife-edge load $= 3080 \times \frac{20}{4} \times 12$
$= 184{,}800$ lbs. in.

Uniform live load $= 150 \times \frac{20}{12} = 250$ lbs.

∴ Moments due to uniform load $= 250 \times 20^2 \times 1{\cdot}5$
$= 150{,}000$ lbs. in.

Total moments $= 178{,}000 + 184{,}800 + 150{,}000$
$= 512{,}800$ lbs. in.

The economical depth of T-beam is given by

$$d^2 = \frac{M}{if\left\{\frac{xb}{z} + \frac{2y}{z}\right\}}$$

x=cost per c. ft. of concrete=0·75 $\therefore \frac{x}{z}=\frac{0{\cdot}75}{45{\cdot}5}$
$=0{\cdot}0165$

z=cost per c. ft. steel $=45{\cdot}5 \therefore \frac{y}{z}=\frac{0{\cdot}125}{45{\cdot}5}=0{\cdot}00275$

y=cost of shuttering per sq. ft. $=0{\cdot}125$
b=width of rib $=6''$

$$d^2=\frac{512{,}800}{0{\cdot}9\times 16{,}000\times(0{\cdot}099+0{\cdot}055)}=342$$

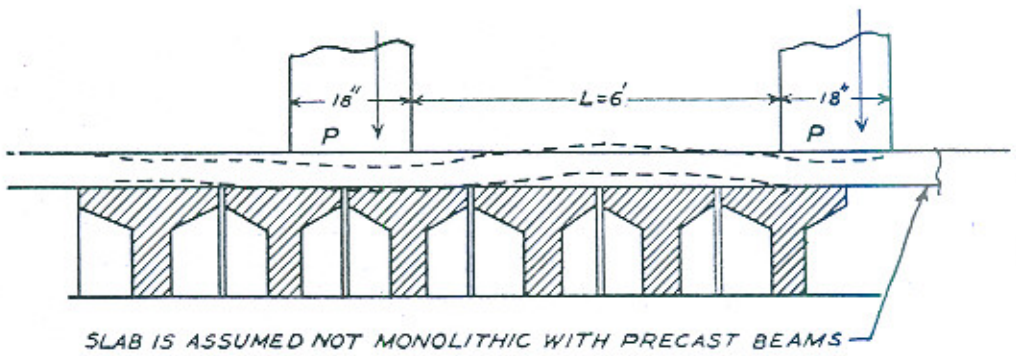
$\therefore\ d=18{\cdot}5$

Keep total depth of beam $=19''$ so that effective depth $=16{\cdot}72.''$

Main reinforcement in the beam. $2-1''\phi$ and $2-5/8''\phi$. Provision of $\frac{1}{4}''\phi$ – vertical stirrups and bending of bars are in accordance with the instructions contained in the "Concrete Code of Practice" as regards shearing and bond stresses.

3. *Surfacing slab.* Each precast T-beam has been designed to carry the equivalent uniformly distributed load and knife-edge load over its flange area. To effect an uniform distribution of axle loads of the 10 units B.E.S.A. train as assumed in working out the equivalent loading on beams it is essential that a reinforced concrete slab should over-lay the precast T-beam units. The load on precast T-beams due to a concentrated live load on the bridge will be in proportion to the deflections of the slab. And the slab deflects more under the wheel than elsewhere. That means that uniform distribution of load on beams does not obtain though assumed to simplify the calculations.

FIG. NO. 6



To design the surfacing slab safe against the maximum moments and the maximum shearing force it will be on the safe side to assume uniform distribution of load.

Maximum wheel load $=7{\cdot}5$ tons each inclusive of 50% impact.

Maximum wheel width $=18''$

Roadway width $=14'$

$$\therefore \text{ Load/sq. ft.} = \frac{7{\cdot}5 \times 2 \times 2240}{14 \times 10} = 240 \text{ lbs.}$$

$$\text{Maximum negative moments} = \frac{240 \times 6^2 \times 12}{12}$$

$$= 8640 \text{ lbs. in.}$$

Maximum positive moments $=4320$ lbs. in.

Steel:—

Total thickness $=4''$

Clear cover $=\frac{3}{4}''$

Effective thickness $=4-3/4-3/16=3{\cdot}06''$

$$\therefore \text{ Negative steel} = \frac{8640}{16{,}000 \times 0{\cdot}88 \times 3{\cdot}06}$$

$$= 0{\cdot}201 \text{ sq. in.}$$

Use $3/8''$ ø @ $6''$

Steel provided $=2 \times 0{\cdot}11 = 0{\cdot}22$ sq. in. O. K.

This steel is to be provided at the bottom throughout the width of road.

Positive steel:—

Steel required $=\frac{1}{2}'' \times 0{\cdot}201 = 0{\cdot}1$ sq. in.

Use $\frac{1}{4}''$ ø @ $6''$

Steel provided $=0{\cdot}0982$ sq. in. O. K.

This steel is to be provided at the top throughout the width of the road.

Distribution steel.—Take about 40% of the main steel, *i.e.*, equal to about $0{\cdot}4 \times 0{\cdot}201 = 0{\cdot}08$ sq. in. Provide $\frac{1}{4}''$ ø @ $9''$ at bottom and $\frac{1}{4}''$ ø @ $18''$ at top.

Maximum shearing force $= 240 \times 3 = 720$ lbs.

$$\therefore \quad V = \frac{720}{12 \times 0{\cdot}88 \times 3{\cdot}06}$$

$$= 22 \text{ lbs/sq. in.}$$

$$U = \frac{720}{2 \times 1{\cdot}18 \times 0{\cdot}88 \times 3{\cdot}06}$$

$$= 113 \text{ lbs./sq. in.}$$

It is as well safe against punching shear.

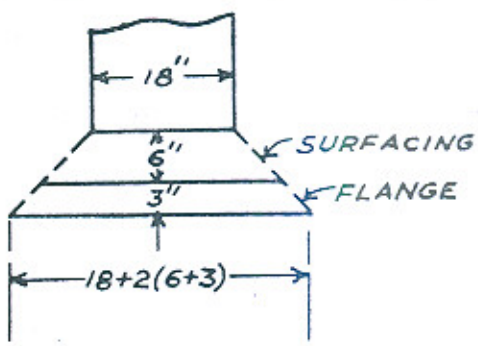
4. *Flange of T-beam.* It would not do to take the same figure as that of uniform distribution of load for designing flange. It will be reasonable to neglect impact and allow 45° dispersion through the surfacing slab and the flange.

FIG. NO. 7

Maximum wheel load = 5 tons.

Width wheel load = 18″

Contact width = 3″



Allowing 45° dispersion,

$$\text{Load/sq. ft.} = \frac{5 \times 2240 \times 144}{(18+18)\{3+2(6+3)\}}$$

$$= \frac{5 \times 2240 \times 144}{36 \times 21} = 2140 \text{ lbs.}$$

$$\therefore \quad \text{Load over } 7'' \text{ width} = \frac{2140 \times 7}{12} = 1250 \text{ lbs.}$$

$$\therefore \quad \text{Maximum cantilever moments} = 1250 \times 3{\cdot}5 = 4375 \text{ lbs. in.}$$

Allow 1″ clear cover.

$$\therefore \quad \text{Effective depth} = 6 - \left(1 + \frac{1}{8}\right) = 4{\cdot}88 \text{ lbs. in.}$$

$$\therefore \quad \text{Steel} = \frac{4375}{16{,}000 \times 0{\cdot}9 \times 4{\cdot}88} = 0{\cdot}062 \text{ sq. in}$$

Use $\frac{1}{4}''$ ϕ @ 8″

Maximum shearing force=1250 lbs.

The dead load of flange is negligible

$$\therefore \quad V = \frac{1250}{12 \times 0{\cdot}9 \times 4{\cdot}85} = 24 \text{ lbs/sq. in.}$$

$$U = \frac{1250}{1{\cdot}50 \times 0{\cdot}785 \times 0{\cdot}9 \times 4{\cdot}88} = 240 \text{ lbs/sq. in.}$$

In precast work bond stress upto 240 lbs/sq. in. may be allowed if 1:2: 4 nomial mix is used since it is always possible to obtain High Grade Concrete. This figure is recommended by the Concrete Code of Practice, Explanatory Handbook by Scott and Glanville page 75, Clause 604 (*a*). Actually bond stress would be considerably less than 240 lbs/sq. in. as the shearing force has been worked out on the most conservative method of dispersion and distribution of loads in reinforced concrete members.

To ensure full T-beam action the flange must be safe against maximum longitudinal shear.

$$V = \frac{V}{j\,t\,d} \times \frac{b - b'}{b} \times \frac{K}{2K - \frac{t}{d}}$$

(Ref.—Taylor & Thompson Vol. 1, page 146)

$$= \frac{8550}{5 \times 0{\cdot}885 \times 16{\cdot}72} \times \frac{20 - 6}{20} \times \frac{0{\cdot}36}{0{\cdot}72 - 0{\cdot}299}$$

$$= 69 \text{ lbs/ sq. in.} \qquad \text{O. K.}$$

5. *Wearing surface.* It is proposed to allow 2″ thick wearing coat laid monolithic with the surfacing slab 4″ thickness. Thus the total thickness of the top slab to be laid *in situ* over precast units would be 6″.

The wearing of the concrete slab due to the abrasion caused by the steel tyred traffic though small would be greater near the expansion joints which will be on the piers. To indicate the thickness of the wearing coat, iron strips are embedded in concrete in each span at the ends exactly 2″ below the top of the 6″ slab.

APPENDIX C

A.—Analysis of costs for the Sidhnai Dam Bridge.

1. Cost of one span of the precast T-beam unit bridge :—

	Rs.
8 T-beam @ Rs. 66/4/- each	= 530
2 side T-beam units @ Rs. 63/- each	= 126
196 c. ft. 1 : 2 : 4 surfacing slab and wheel guards concrete @ Rs. 71/-%	= 139
4·95 cwts. surfacing slab and wheel guard steel @ 10/10 cwt.	= 53
Total	Rs. 848
Work charged establishment @ 2%	= 17·0
Contingencies @ 3%	= 25·5
Total cost one span	= Rs. 890·5

$$\text{Cost per ft.} = \frac{891{\cdot}5}{23} = \text{Rs. } 39$$

Cost 2 ft. special type railing = Rs. 12/10

∴ Total cost per ft. length of bridge = Rs. 51/10

say = Rs 52/-

2. Cost of one precast T-beam :—

(*a*) *Materials* :—

(1) Cement concrete :—

Rapid hardening cement 6 bags @ 2/6 each	= Rs. 14/4
Sand 14·0 c.ft. @ 2/-%	= Rs. -/5
Bajri 29·8 c.ft. @ 22/6%	= Rs. 6/8
Total	Rs. 21/1
(2) Steel 2·75 cwts. @ Rs. 10/10	= Rs. 29/4
Total	Rs. 50/5

(*b*) *Labour* :—

(1) Mixing laying, wriggling and curing. Cement concrete 33·11 c.ft. @16/-%	= Rs. 5/4

(2) Bending, binding and placing reinforcement 2·75 cwts. @ Rs. 2/4 cwt. = Rs. 6/3

Total Rs. 11/7

(c) *Average cost of moulds for one T-beam including greasing charges* = Rs. 3/-

(d) *Transporting of T-beams and erection* :—

For 12 T-beams :—

1 No. Erector @ 1/6 daily for 2 days = 2/12

12 No. Tackleman @ -/10/- daily for 2 days = 15/-

Total Rs. 17/12

∴ Cost per T-beam = Rs. 1/8/-

Abstract of cost of one T-beam :—

		Rs.	A.	P.
(a)	Materials	= 50	5	0
(b)	Labour	= 11	7	0
(c)	Mould	= 3	0	0
(d)	Erection	= 1	8	0
	Total Rs.	66	4	0

3. Cost of one precast side beam :—

(a) *Materials* :—

(i) Cement concrete.

Rapid hardening cement 5·25 bags @ 2/6 each = Rs. 12/8

Sand 13 c.ft. @ 2/- % = Rs. -/4

Bajri 26 c.ft. @ 22/6% = Rs. 5/13

Total Rs. 18/9

(ii) Steel

2·75 cwt. @ Rs. 10/10 cwt. = Rs. 29/4

Total Rs. 47/13

(*b*) *Labour* :—

(*i*) Mixing, laying, wriggling and curing cement concrete 29·11 c.ft. @ Rs. 16/-% = Rs. 4/7

(*ii*) Bending, binding and placing reinforcement 2·75 cwt. @ 2/4 cwt. = Rs. 6/3

Total Rs. 10/10

(*c*) *Average cost of moulds for one T-beam including greasing charges* = Rs. 3/-

(*d*) *Transporting of T-beams and erection* = Rs. 1/8

Abstract of cost of one T-beam :—

			Rs.	A.	P.
(*a*)	Materials	=	47	13	0
(*b*)	Labour	=	10	10	0
(*c*)	Mould	=	3	0	0
(*d*)	Erection	=	1	8	0

Total Rs. 62 15 0
say Rs. 63/-

4. Cost of the T-beam mould :—

(*a*) *Material* :—

(*i*) Deodar sleepers 6 No. @ Rs. 5/10 = Rs. 33/12

(*ii*) Channel iron :—

12 No.	2′ 3″	= 27′
8 No.	2′ 4″	= 19′
4 No.	1′ 7″	= 7′
6 No.	1′ 2″	= 7′

60 ft. or 158 lbs.
@ 12/1 cwt. = Rs. 16/14

(*iii*) G. I. sheets 5 No. @ 33 lbs. each = 165 lbs. @ 15/- cwt. Rs. 22/8

(*iv*) Fastenings :—

Iron screw $1\frac{1}{2}''$ = 2 gross
@ -/6/- gross = Re. -/12/-
do $3''$ = 1 gross
@ 1/4/- gross = Rs. 1/14/-
Wire nails 3" & 4" = 3 lbs.
@ -/3/- lbs. = Re. -/9/-
do 1" = 5 lbs. @
-/3/- lbs. = Re. -/15/-
Iron bolts 3" × 3/8" = 12 No.
@ -/6/- doz. = Re. -/6/-
do 1" × 3/8" = 28 No.
@-/6/- doz. = Re. -/14/ = Rs. 4/12

Total Rs. 77/14

(*b*) *Labour* :—

Two carpenters worked for 6 days

∴ 12 days of 1 carpenter @
1/4/- per day = Rs. 15/-
Total cost = Rs. 92/14
say Rs. 93/-

No. of times each mould is used = 31

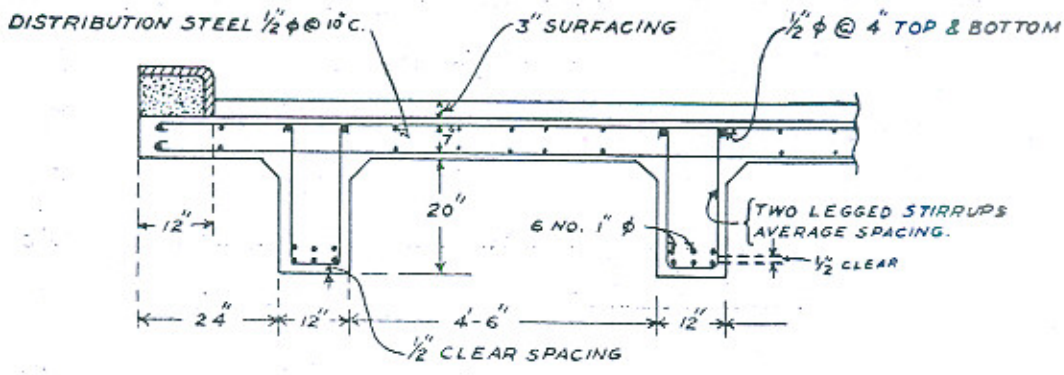
∵ Average cost of one T-beam mould $= \frac{93}{31} =$ Rs. 3

B.—Comparative costs of the various types of R. C. Bridges.

The various types, besides the precast T-beam units analysed above, considered for the Sidhnai Dam Bridge were :—

(*i*) *R. C. T-beam Bridge (cast-in-situ.)*

FIG. NO. 8

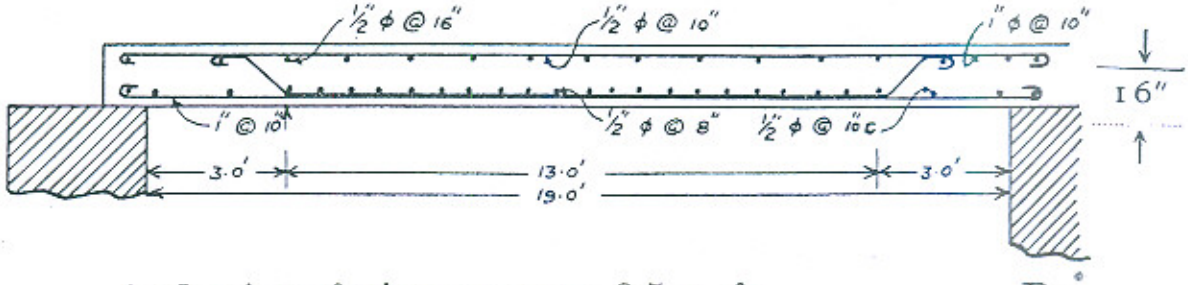


	Rs.
1 : 2 : 4 surfacing cement concrete 3·5 c. ft. @ 71·0% c. ft.	= 2·5
Colas cold emulsion 14 sq. ft. @ 6/-% sq. ft.	= 0·8
1 : 2 : 4 R. C. concrete 16·6 c. ft. @ 76·0% c. ft.	= 12·6
Shuttering for R. C. slab horizontal 16 sq. ft. @ -/4/- sq. ft.	= 4·0
Vertical 14·5 sq. ft. @ -/6/- sq. ft.	= 5·5
Steel reinforcement 1·5 cwt. @ 13/-	= 19·5
Total	44·9
Work charged establishment @ 2%	0·9
Contingencies @ 3%	1·4
Total ...	47·2

say Rs. 47/- per foot.

(*ii*) *R. C. slab bridge* :—

FIG. NO. 9



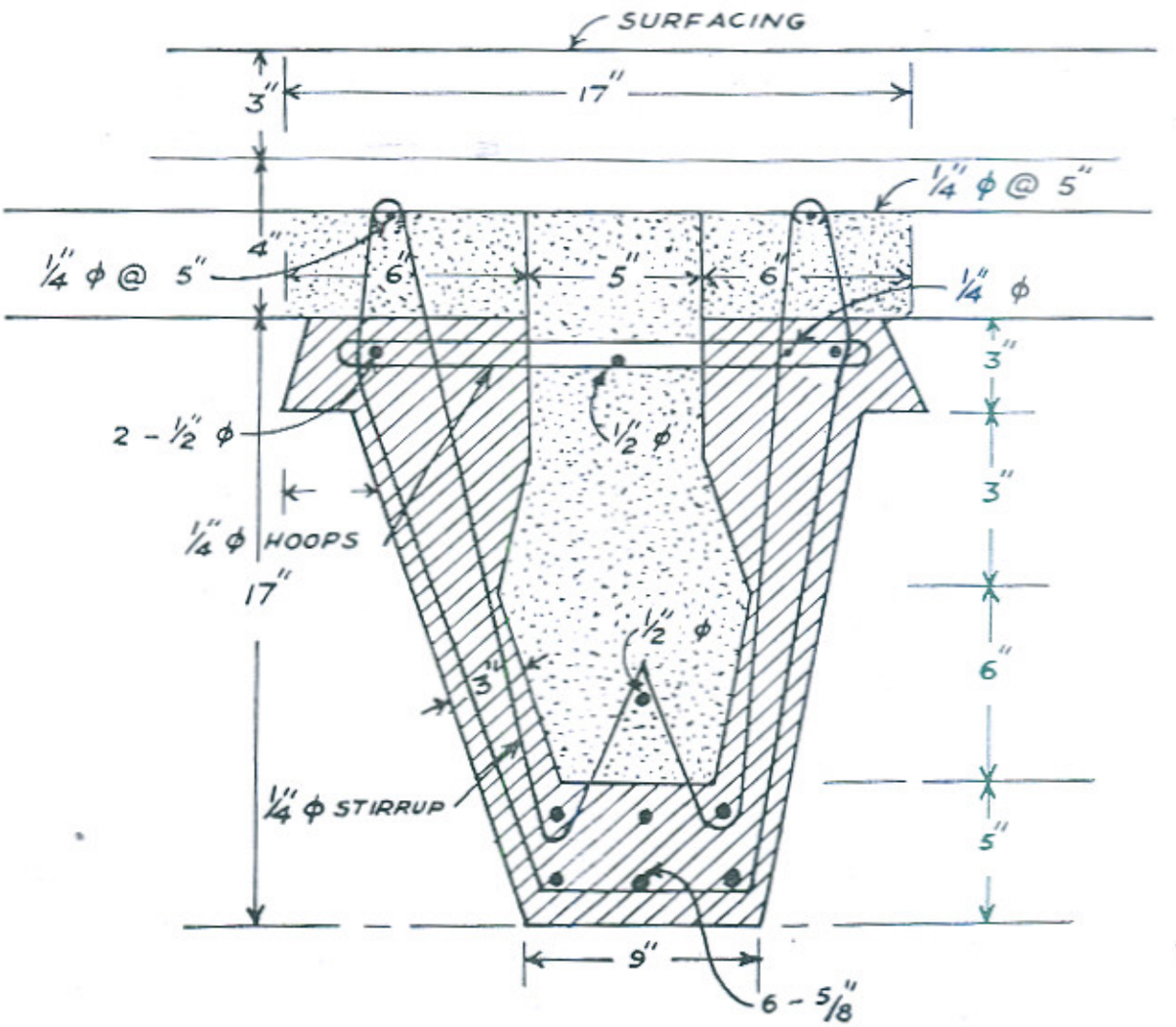
	Rs.
1 : 2 : 4 surfacing concrete 3·5 c. ft. @ Rs. 71/- % c. ft.	= 2·5
Colas cold emulsion 14 sq. ft. @ Rs. 6/- % sq. ft.	= 0·8

	Rs.
1 : 2 : 4 reinforced concrete 23 c. ft. @ Rs. 76/- % c. ft	= 17·5
Shuttering (horizontal) 16 sq. ft. @ -/4/- sq. ft.	= 4·0
Vertical 4·2 sq. ft. @ Re. -/6/- sq. ft.	= 1·6
Reinforcement steel 1·3 cwt. @ Rs. 14/- cwt.	= 18·2
Total	44·6
Work charged establishment @ 2%	= 0·9
Contingencies @ 3%	= 1·3
Total ...	46·8

say Rs. 47/- per foot.

(iii) Troughs as used at Khanki :—

FIG. NO. 10



11 troughs placed side by side with ½" joints will give 14 ft. wide road and 12 in. wide wheel guards on either side.

	Rs.
1 : 2 : 4 surfacing concrete 3·5 c. ft. @ Rs. 71/- % c. ft.	= 2·5
Colas cold emulsion 14 sq. ft. @ 6/- % sq. ft.	= 0·8
1 : 2 : 4 reinforced concrete *in situ* 12·0 c. ft. @ 77/- % c. ft.	= 9·2
1 : 2 : 4 reinforced concrete precast 10·5 c. ft. @ 130/- % c. ft.	= 15·0
Reinforcement steel 1·55 cwt. @ 14/- cwt.	= 21·6
Work charged establishment @ 2 %	= 1·0
Contingencies @ 3 %	= 1·5
Total ...	51·6

say Rs. 52/- per foot.

Comparative statement of the Types of R. C. bridges.

Type of bridge.	T-beam type *in-situ*	Slab.	Precast troughs	Precast T-beam units.
Cost per foot of the decking excluding Railing	Rs. 47	Rs. 47	Rs. 52	Rs. 39

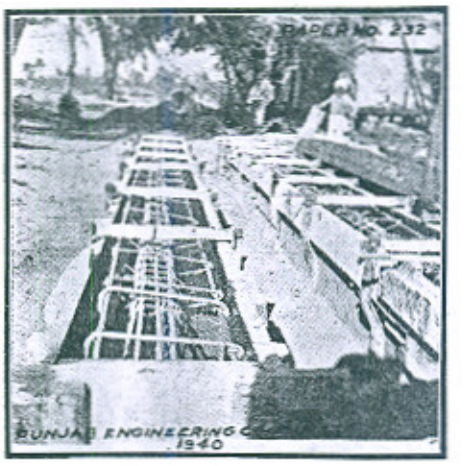


Photo No. 1.
Precasting of T. Beams.
Reinforcement in position within the timber mould.



Photo No. 2.
Typing of Reinforcement for T. Beams.



Photo No. 3.
Transport of T. Beams.

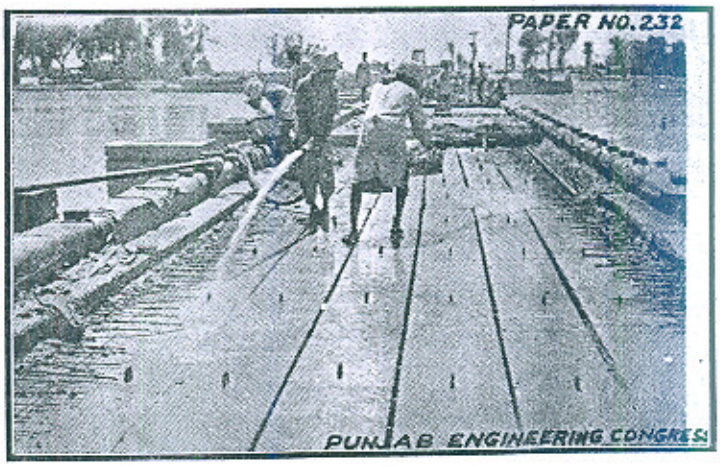


Photo No. 4.
T. Beams being washed before concreting of distribution slab.



Photo No. 5.
Shuttering for wheel guards.



Photo No. 6.
Concreting of Distribution Slab.

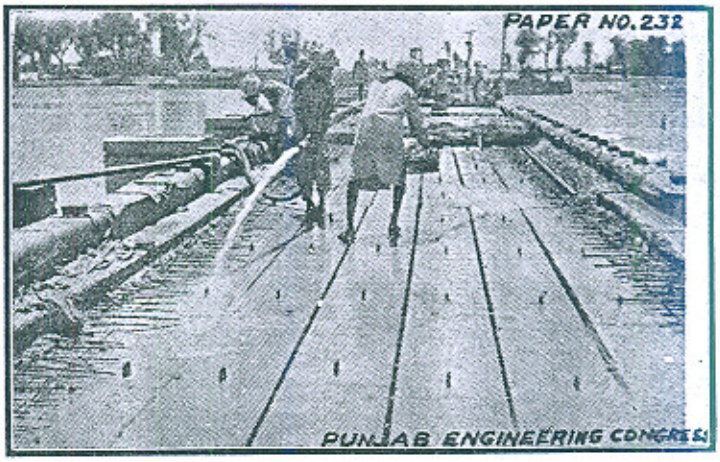


Photo No. 4.
T. Beams being washed before concreting of distribution slab.



Photo No. 5.
Shuttering for wheel guards.

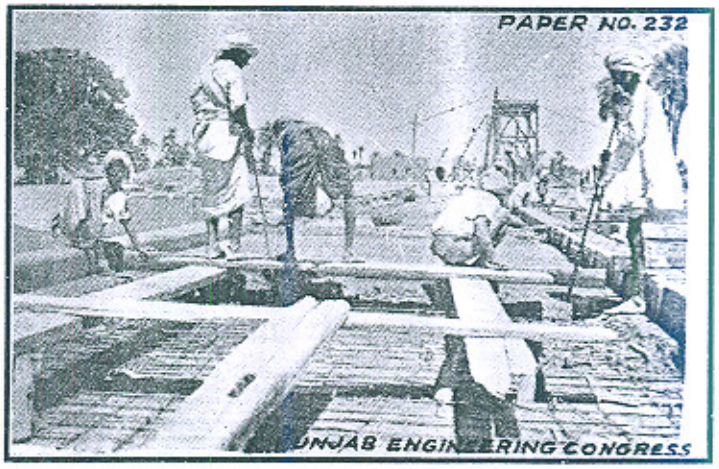


Photo No. 6.
Concreting of Distribution Slab.

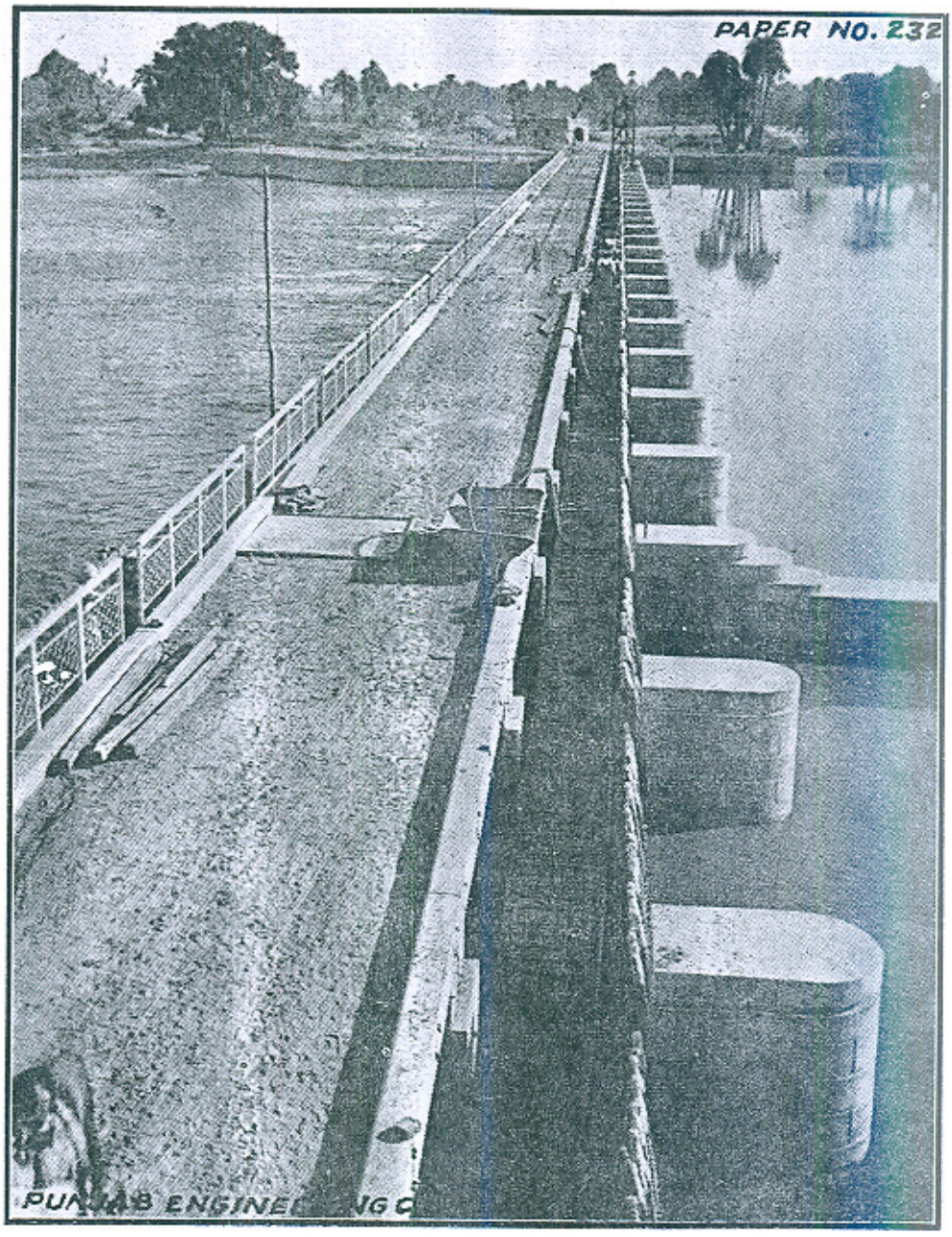
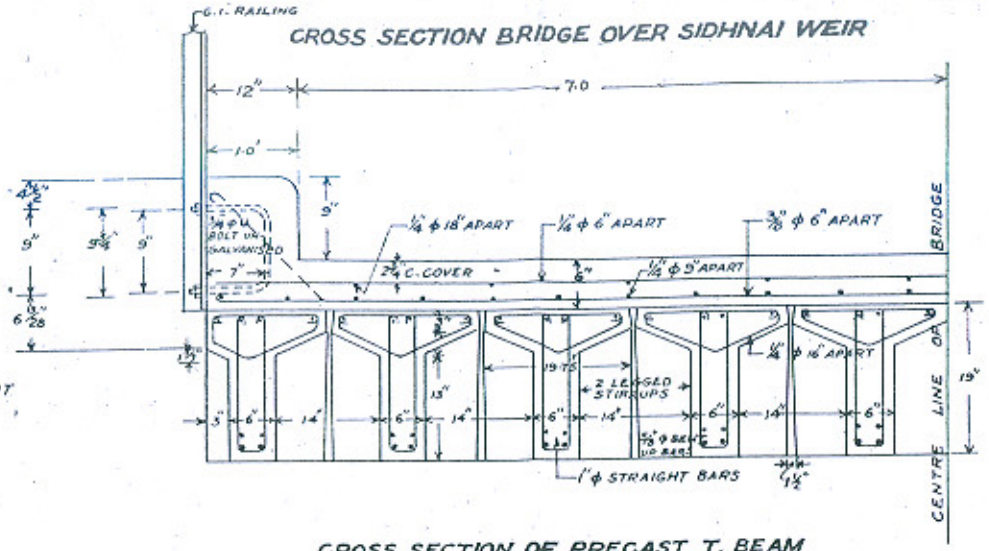


Photo No. 7.
A view of the bridge from the left flank. Road way covered with wet sand for curing.

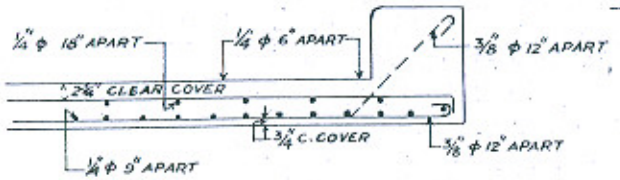
ARTERIAL ROAD BRIDGE SIDHNAI HEADWORKS

PLATE I A
PAPER NO. 232

CROSS SECTION BRIDGE OVER SIDHNAI WEIR

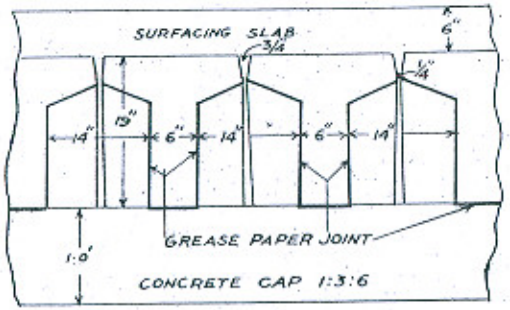


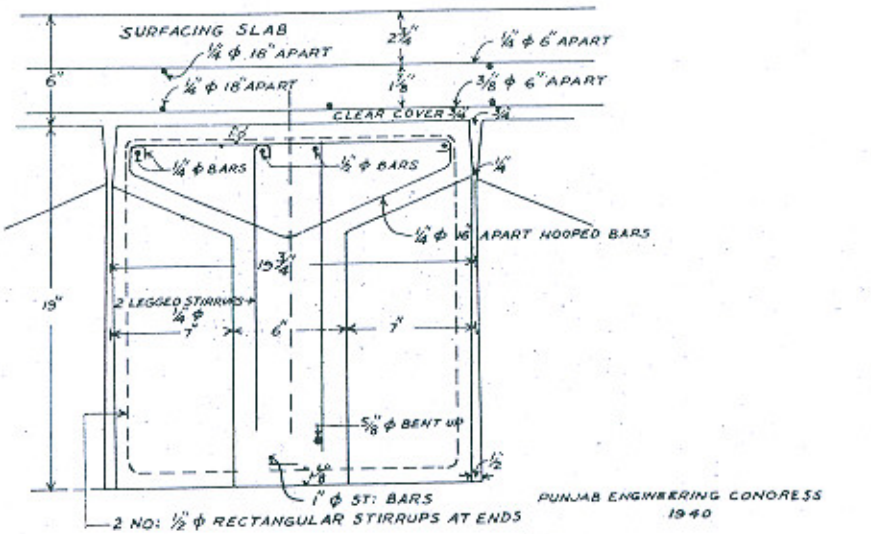
CROSS SECTION OF SURFACING SLAB



CROSS SECTION OF PRECAST T. BEAM

SCALE 12/100





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ARTERIAL ROAD BRIDGE SIDHNAI HEADWORKS

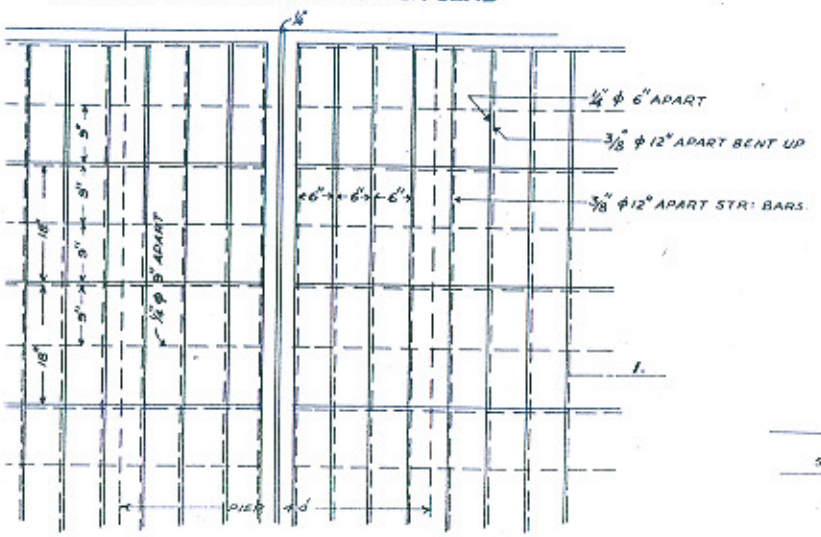
LONG: SECTION OF PRECAST T. BEAM SHOWING BEAM REINFORCEMENT

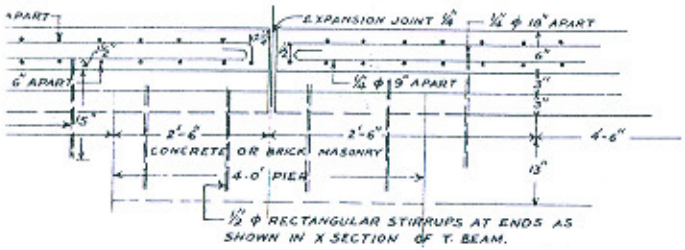
SCALE = 1/20

PLATE I.B

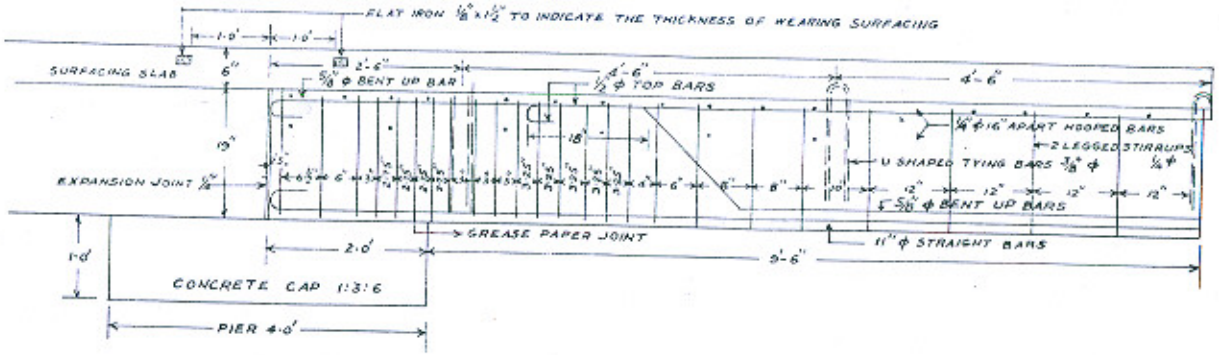
PAPER NO. 232

PLAN OF REINFORCEMENT FOR SLAB





SECTION NO. I

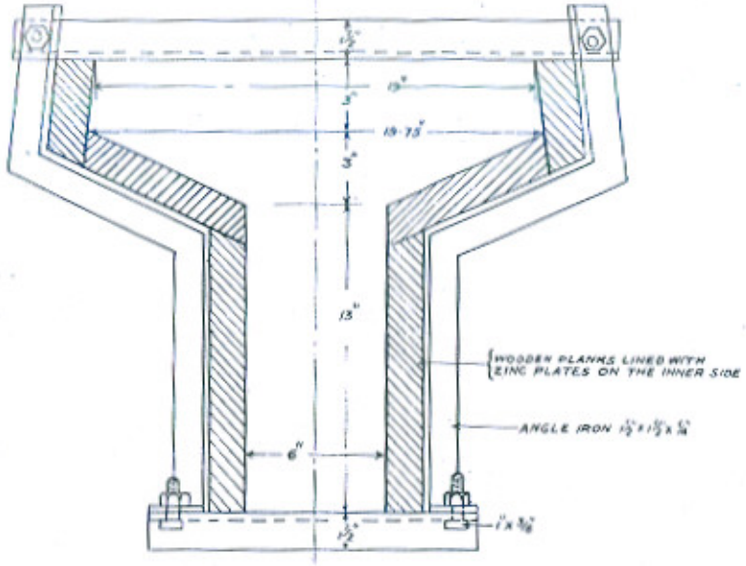


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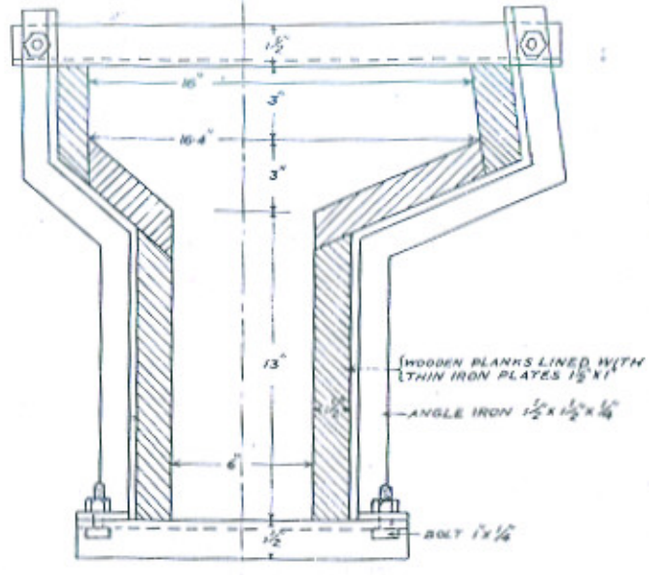
ARTERIAL ROAD BRIDGE SIDHNAI HEADWORKS

PLATE 2
PAPER NO. 232

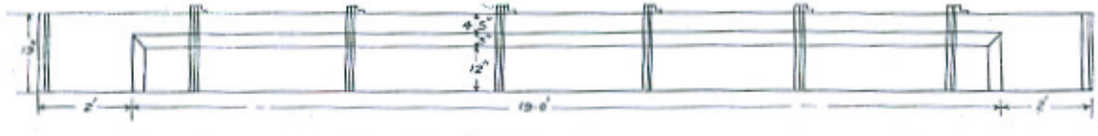
SECTION OF THE MOULD



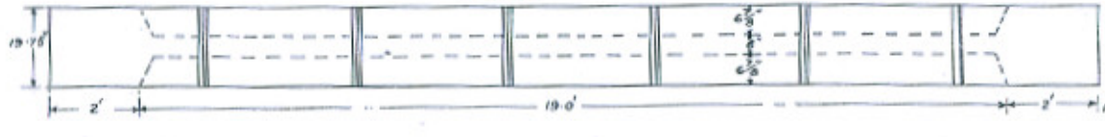
SECTION OF THE END T MOULD



WOODEN MOULDS ELEVATION



PLAN



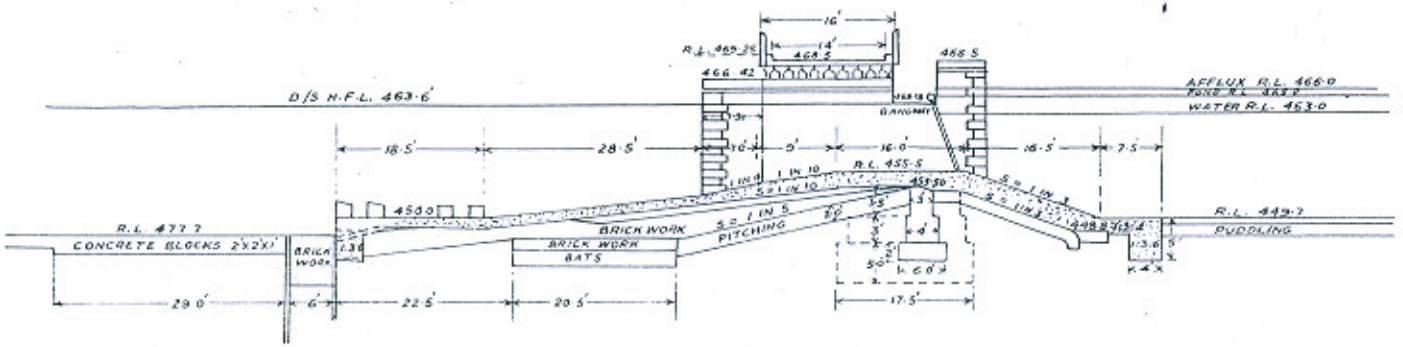
PUNJAB ENGINEERING CONGRESS 1940

ARTERIAL ROAD BRIDGE SIDHNAI HEADWORKS

CROSS SECTION OF SIDHNAI WEIR

SCALE = 1/200

PLATE 3
PAPER NO. 232

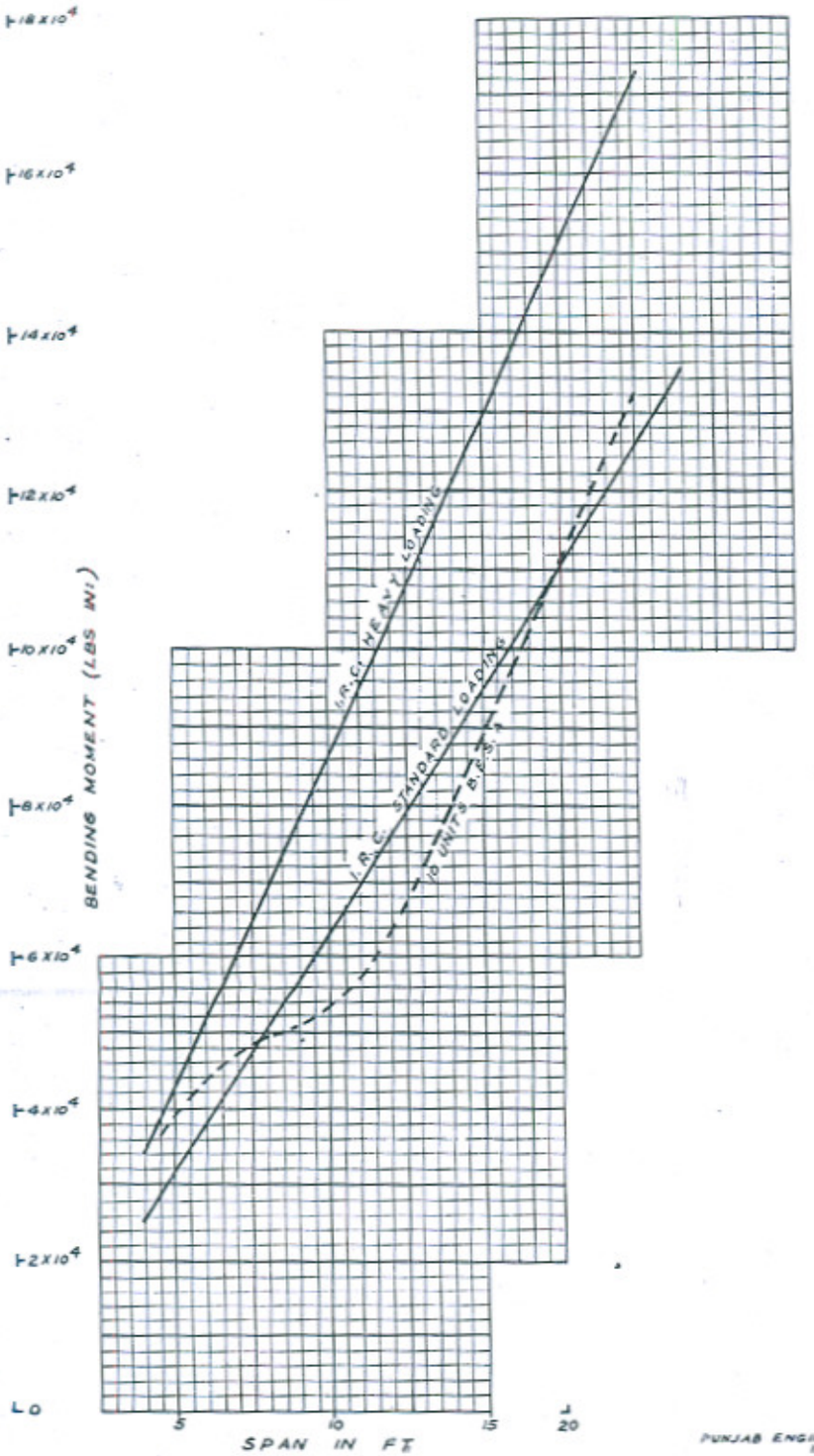


PUNJAB ENGINEERING CONGRESS
1940

PLATE 4
PAPER NO. 232

SIDHNAI DAM BRIDGE

BENDING MOMENT CURVES.
(EXCLUDING THE EFFECT OF IMPACT)

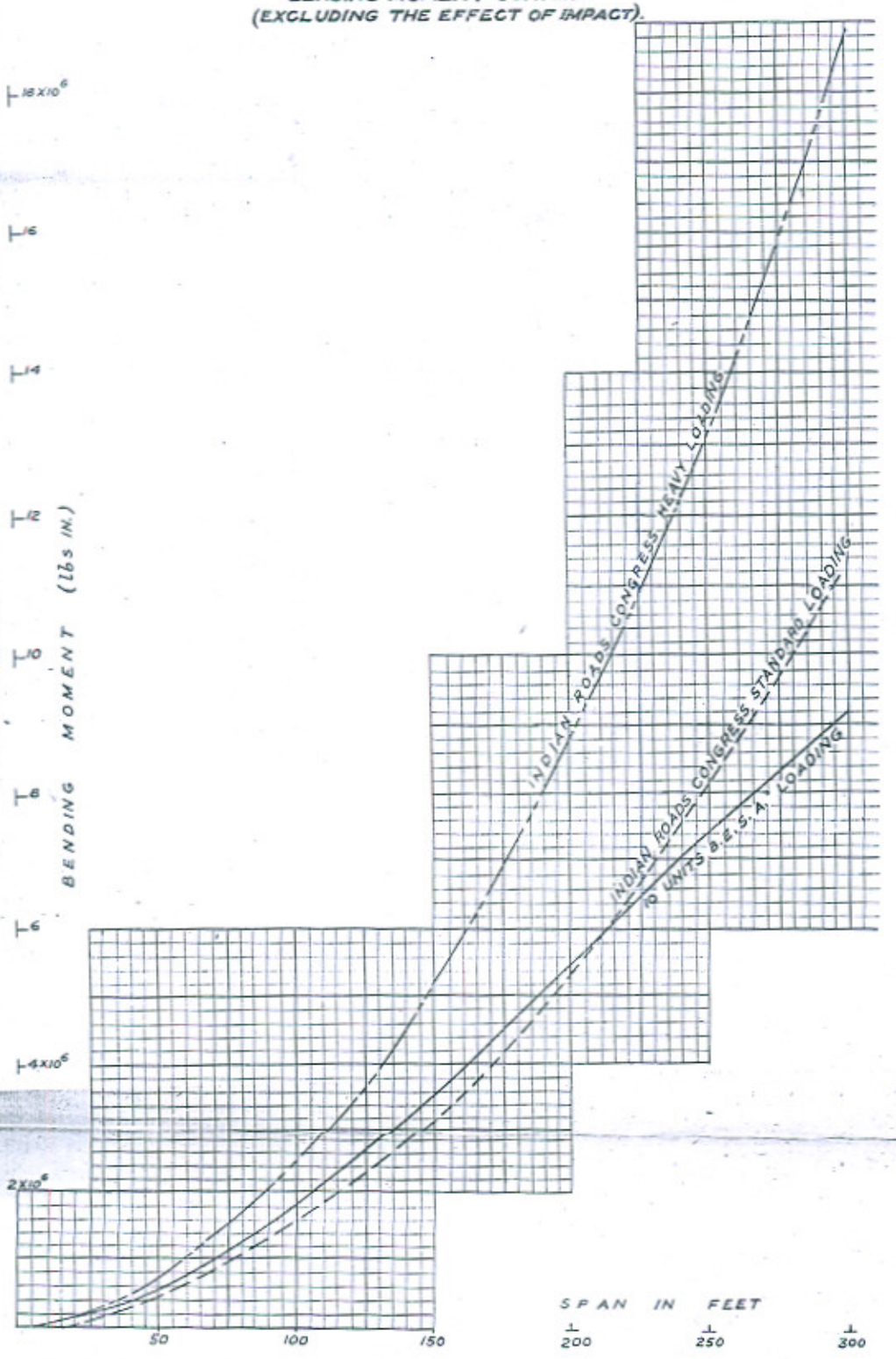


PUNJAB ENGINEERING CONGRESS
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SIDHNAI DAM BRIDGE

BENDING MOMENT CURVES.
(EXCLUDING THE EFFECT OF IMPACT).

PLATE 5
PAPER NO. 232



PUNJAB ENGINEERING CONGRESS
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SIDHNAI DAM BRIDGE

IMPACT ABSORPTION BY METALLED ROAD CONSISTING OF SAND, BALLAST AND STONE SETS.

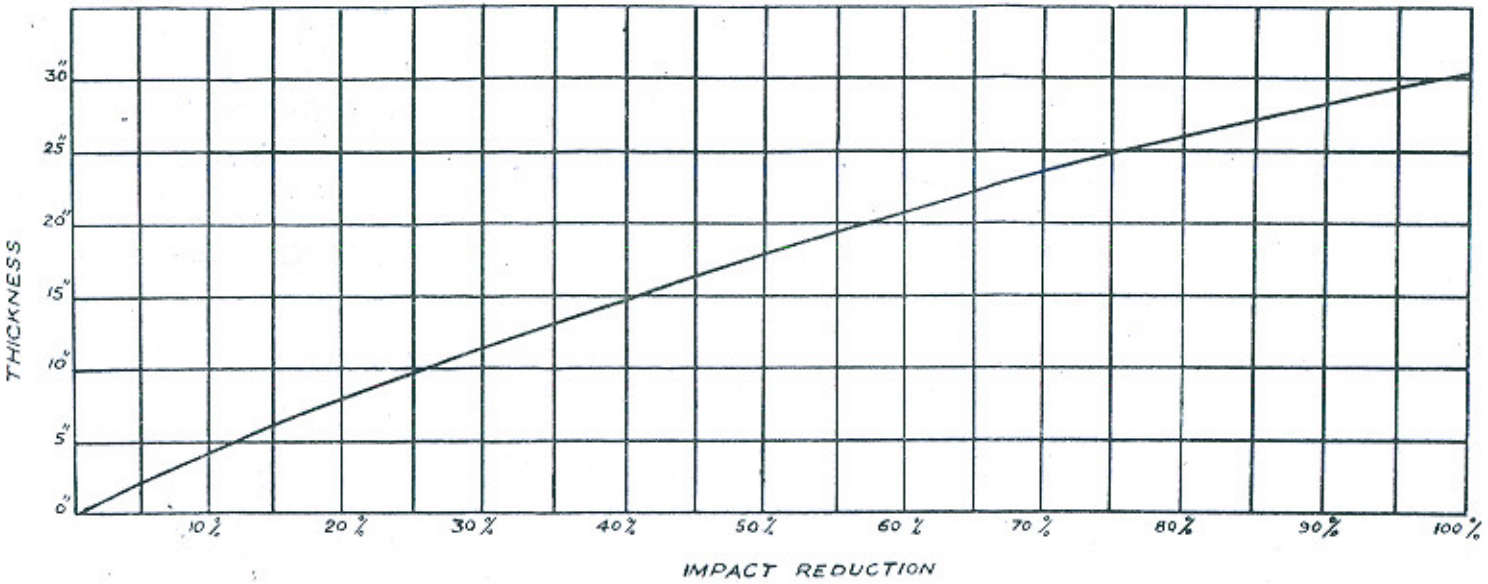
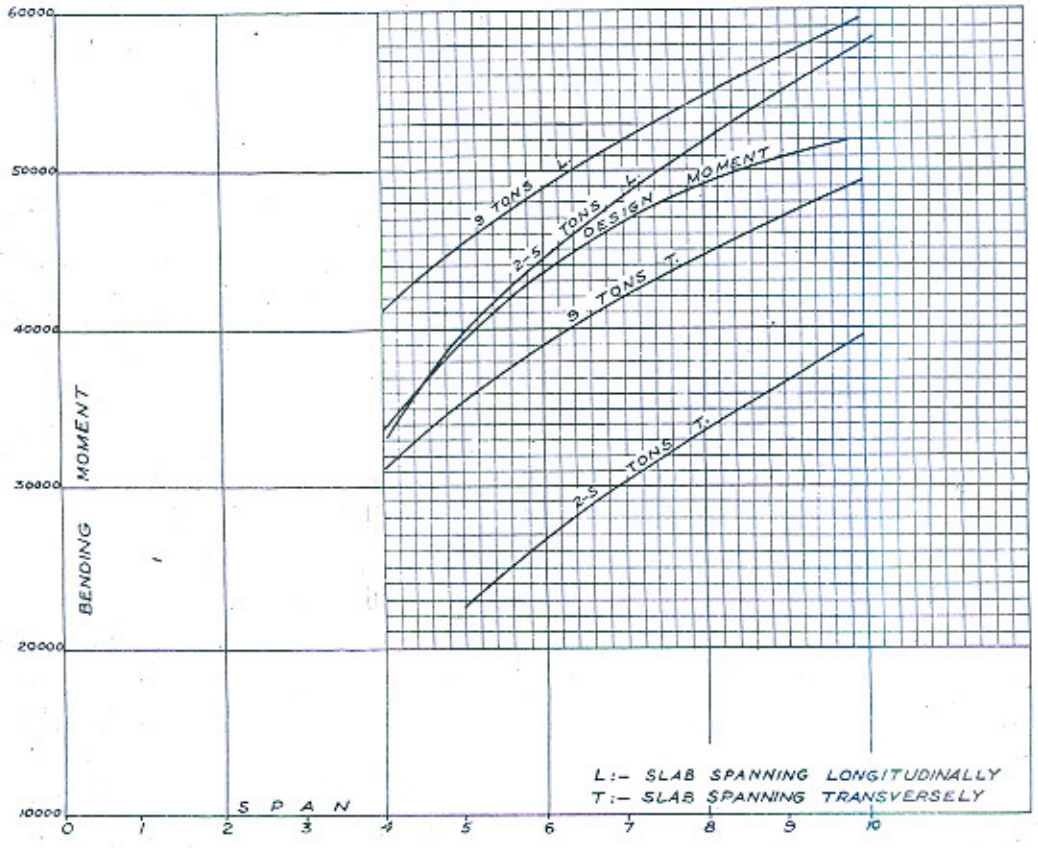


PLATE 7
PAPER NO. 232

SIDHNAI DAM BRIDGE

10 B.E.S. UNITS LOADING
FOR ARTERIAL ROAD BRIDGES
BENDING MOMENT CURVES PIGEAUD'S METHOD
KNIFE EDGE LOAD { 1230 lbs WITHOUT IMPACT
1850 lbs. WITH IMPACT



PUNJAB ENGINEERING CONGRESS
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PLATE 8
PAPER NO 232

SIDHNAI DAM BRIDGE

10 UNITS B.E.S.A. LOADING
SPANS UP TO 10 FT
LOADING & BENDING MOMENT CURVES

KNIFE EDGE LOAD { 1230 lbs. WITHOUT IMPACT
1850 lbs. WITH IMPACT

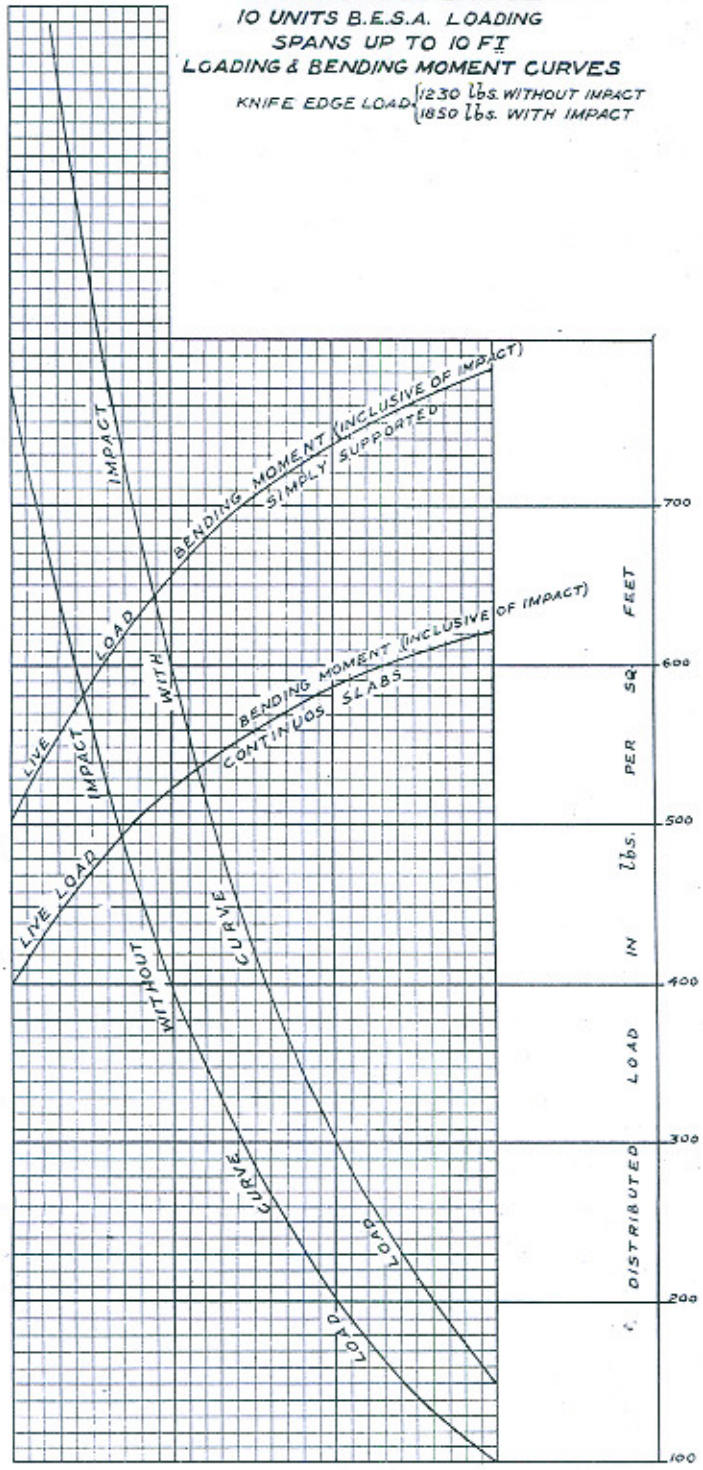


PLATE 9
PAPER NO. 232

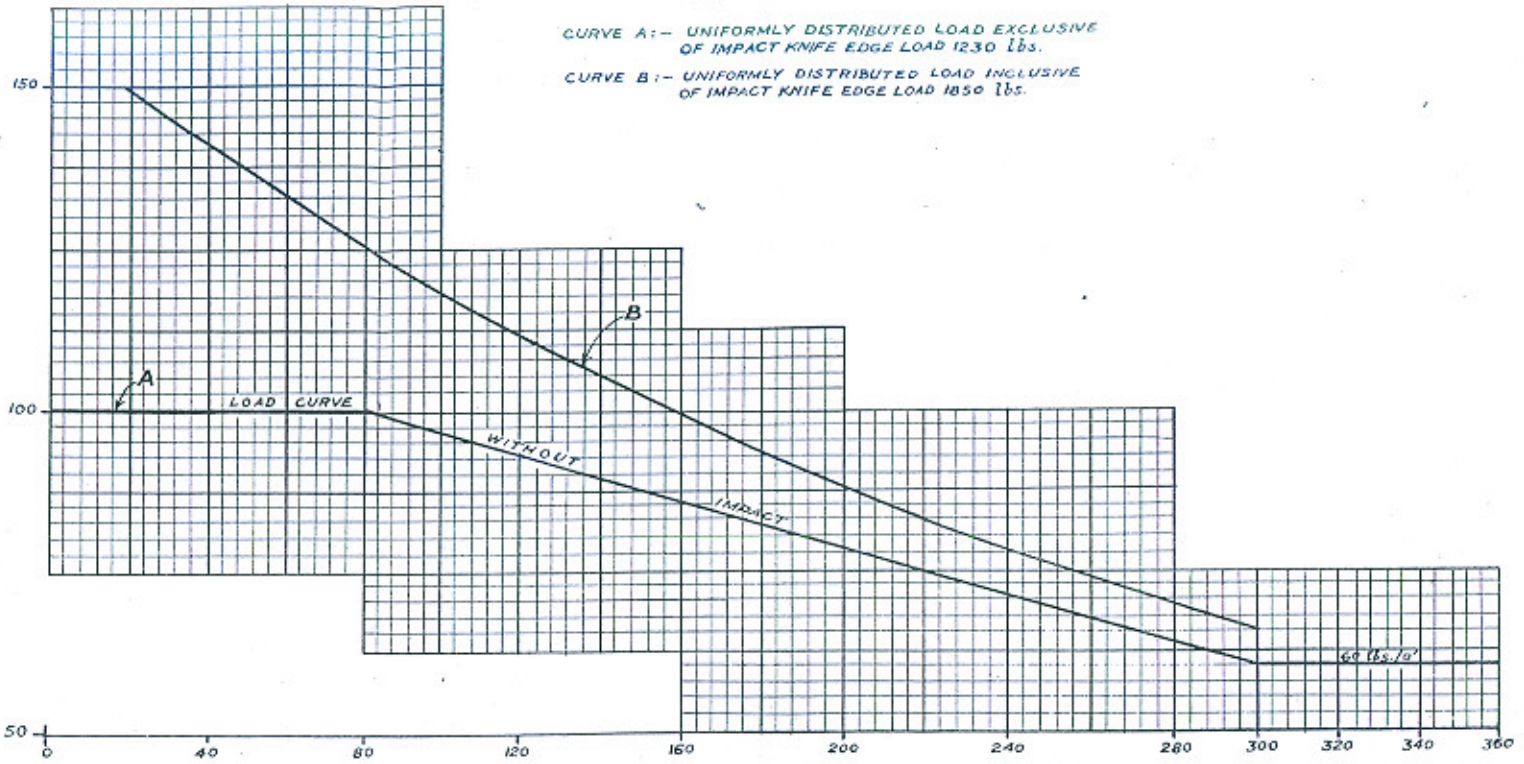
SIDHNAI DAM BRIDGE

10 UNITS B.E.S.A. LOADING CURVES

SPAN 10'–300'

CURVE A :– UNIFORMLY DISTRIBUTED LOAD EXCLUSIVE OF IMPACT KNIFE EDGE LOAD 1230 lbs.

CURVE B :– UNIFORMLY DISTRIBUTED LOAD INCLUSIVE OF IMPACT KNIFE EDGE LOAD 1850 lbs.



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1940.

SIDHNAI DAM BRIDGE

DESIGN CURVES FOR SIMPLY SUPPORTED R.C. SLAB

LOADING:– 10 UNITS B.E.S.A.

STRESSES:– f_c = 750 lbs /a" f_s = 16000 lbs/a"

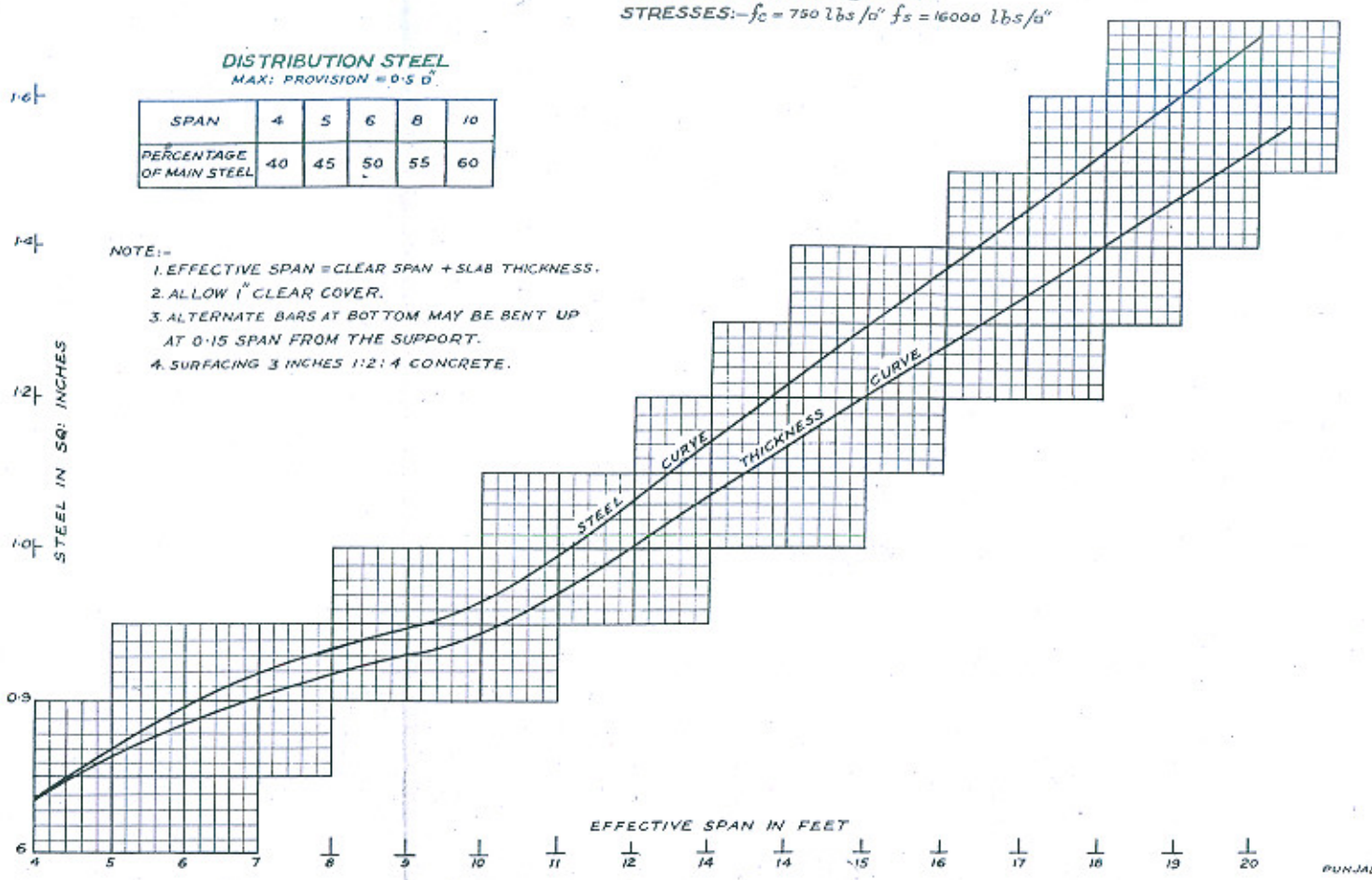
DISTRIBUTION STEEL

MAX: PROVISION = 0·5 D"

SPAN	4	5	6	8	10
PERCENTAGE OF MAIN STEEL	40	45	50	55	60

NOTE:–

1. EFFECTIVE SPAN = CLEAR SPAN + SLAB THICKNESS.
2. ALLOW 1" CLEAR COVER.
3. ALTERNATE BARS AT BOTTOM MAY BE BENT UP AT 0·15 SPAN FROM THE SUPPORT.
4. SURFACING 3 INCHES 1:2:4 CONCRETE.



PUNJAB ENGINEERING CONGRESS 1948

DISCUSSION

Mr. Handa, the Joint Author in introducing his Paper said that "Sidhnai Dam" was the smallest canal Headworks in the Province and the bridge that formed the subject matter of the Paper was a small structure. The design and construction of the bridge had special features which justified the presentation of a Paper.

There were two special advantages in the form of construction with precast units. The first of these was the elimination of centring at site. Centring was by far the most cumbersome and expensive item in the construction of a reinforced concrete bridge and with the absence of skilled assistants the slightest sag or yield in the centring would spoil the appearance and might cause structural defects. The precast bridge of the type described in the Paper required only a few moulds to cast the individual beams, and the manufacture of these precast beams could be arranged under proper supervision and controlled conditions as to mixing, placing and curing. This mode of working ensured good quality coupled with speed and economy.

The second advantage was that the actual construction of the bridge with precast portable units took only a fraction of the time that would be required for *in situ* construction. This would be of special importance in bridge construction on canals, where work has to be completed during short closures. At Sidhnai, there was the risk of being flooded out by a freshet in the Ravi River, so that this form of construction was eminently suited. In case of *in situ* work, with one or more bays blocked with centring, a flood would have caused serious damage to the structure. With these arrangements communications remained uninterrupted across the flooded river during the emergency and the transport of machinery, animals and labour went on without dislocation.

In this connection the T. beam design for the individual units came in specially handy. All that was needed to

produce a satisfactory road way was a three inch cover of sand on the top of the beams. Previously the speaker had an opportunity to take part in the construction of a similar road bridge at Khanki Headworks, where the precast units employed consisted of reinforced concrete hollow troughs. Comparing the two designs it is easier to execute the T. beam design as one can ensure the thorough cleaning of the precast surface before the surfacing slab is laid on. Also the slab reinforcement in this design is very simple.

It would be as well to add a few words for the information of those members who were not familiar with the peculiar situation of the Sidhnai Headworks. The number of bays in the dam was based on the requirements of successful needle regulation. This system of regulation though antiquated had been successfully worked at Sidhnai since the last century and fitted in with the other environment. The setting of the Headworks was unique. The approach to it was a straight stretch of the river Ravi for about nine miles upstream. Whether this canalized river was the work of man or God would remain shrouded in mystery.

Mr. Madan Lal, the Joint Author, stated that with the limited time that was at the disposal of construction engineers to complete the scheme of remodelling of dam and building a bridge, a precast reinforced concrete bridge was pre-eminently suited. A steel girder bridge might have been equally suitable except that it would have cost considerably more and its fabrication might not have been possible in time.

It would be questioned by some members that this type of bridge might not be as sound as a *cast in situ* reinforced concrete bridge. The behaviour of precast T. beams is analogous to that of rolled steel joints laid side by side across a span and over-laid with a reinforced concrete slab. The function of slab consists in distributing the concentrated road load on to joists that are designed strong enough to take an equivalent uniformly distributed load. The slab as such need

not be monolithic with supporting beams. It should be sufficiently strong and rigid enough to affect uniform distribution. That is what has been done in the design of surfacing-cum-distribution slab laid over precast T. Beams on the Sidhnai Bridge.

Low cost of the bridge has been made possible by an elimination of the use of an expensive centring and formwork. Manufacturing of precast T. Beams and their erection have been done at comparatively small cost. Saving has also been affected in cutting away of concrete in tension area just as in an ordinary T. Beam bridge.

Its adoption across running canals where construction can take place only in short closure is strongly advocated. Recently in the Central Designs Office a scheme of building a district road bridge across the Western Jumna Canal in its head reach was examined. Original proposals were to build a steel girder bridge at a cost of about Rs. 50,000. A bridge of this type was estimated to cost about Rs. 20,000 for the same site.

Mr. Madan Lal hoped that members would be interested to review the loading for bridges in light of what has been discussed in the Paper. It affords an average engineer an idea as to what loads should be permitted to pass across a bridge if he knows the axle loads for which the bridge has been designed.

Specifying simply a uniform distributed load for the design of bridges would be erroneous in as much as it would give a wrong impression about the strength of a bridge in accommodating a train of mechanically propelled vehicles of unusual axle loadings and spacing.

Mr. Brij Mohan Lal said that the Authors had done great service to the engineers of the province by bringing out in this Paper designs for a loading of 10 British units. On page 65, in second and third lines from the bottom, Plates Nos. 6 and 7 had been wrongly printed instead of Nos. 4 and 5. The Authors had objected to the Indian Roads Congress loadings because

they did not give a correct picture of the loads likely to pass across the bridge. The main idea of the Indian Roads Congress loadings was to simplify the calculation of bending moments and shears, and this object had been achieved. The differences between the bending moments due to I. R. C. standard loading and 10 British units were not great, and did not appreciably effect the sizes of R. C. slabs. The Indian Roads Congress loading was therefore very handy for designing bridges of short spans.

He requested the Authors to state what bond stress had been used by them in designing the slabs. The British standard code of practice recommended a bond stress of 200 lbs./□" which appeared excessive in face of the usual 80 lbs./□" hitherto used.

Mr. Kanwar Sain stated that the design of the Sidhnai Dam Bridge comprised two essential features, *viz.*, the use of precast units and the method of loading.

He was, personally, in favour of in-situ work. He had been of and still held the opinion that where it was possible to carry out in-situ work, it was preferable to precast work. Monolithic work in reinforced concrete was in his view sounder and had a much greater factor of safety. At Sidhnai, however, the time factor was so important that it was necessary to resort to precast units. His first thought naturally went to the trough bridging with which he had been associated from its earliest stages with Mr. Khosla. He, however, found that it was expensive. After trying various alternatives the design presented by the Authors in the Paper was finally selected. There was one difficulty in the design of this particular type, that was, the assurance of spreading of concentrated loads in accordance with the usual assumptions. This was ensured by providing cross bars in the top layer of concrete.

The other point is the method of loading employed in the design. This method of loading was

evolved in the Central Designs Office and in his view was more rational than that specified by the Indian Roads Congress. He would suggest a critical examination of this method by the Road Authorities.

The bridge as constructed presented an aesthetic appearance.

Mr. Handa thanked the members who participated in the discussion. He regretted that on page 65 in second and third lines from the bottom numbers of plates had been wrongly given as 6 and 7 instead of 4 and 5 as pointed out by Mr. Brij Mohan Lal.

The explanation given by Mr. Brij Mohan Lal of the introduction of Indian Roads Congress loadings as an attempt to simplify calculations of bending moments and shears was not convincing. Ease in calculation should hardly be a consideration in fixing a certain standard of loading. Once a standard of loading has been fixed with reference to axle spacings and loadings of mechanically propelled vehicles designers of bridges can take out equivalent loading curves in light of up-to-date literature available on stress analysis in structures. Equivalent uniformly distributed loads for different spans in case of Indian Roads Congress Loadings and 10 units B. E. S. A. loading have been tabulated below to afford comparison.

STATEMENT SHOWING EQUIVALENT DISTRIBUTED LOADS.

*(Allowing for Impact)**

Effective span in feet.	I. R. C. Standard loading. lbs.	I. R. C. Heavy loading. lbs.	10 Units B. E. S. A. lbs.
4	1579	2150	2090
5	1263	1720	1575
6	1053	1434	1214
7	902	1229	960
8	790	1076	770
9	702	956	625
10	632	860	520
15	416	566	397
20	302	411	335
25	256	356	294
30	226	319	267
40	188	273	231
50	165	245	208
60	150	226	193
70	140	213	181
80	132	202	172
90	125	195	165
100	120	188	159

* Indian Roads Congress impact formula :—

$$\text{Impact factor} = \frac{1}{2} \times \frac{65}{45 + \frac{(n+1)L}{2}}$$ (subject to a maximum of 0·5).

Impact formula for B. E. S. A. loadings :—

$$\text{Impact factor} = \tfrac{1}{2} \times \frac{65}{45+L}$$ (Subject to a maximum of 0·5).

L = effective span and n = number of traffic lanes width of each being taken equal to 10.

For about the shortest spans say 4 ft., 10 units B. E. S. A. loading is almost as severe as Indian Roads Congress Heavy Loading and for spans 8 ft. to 18 ft. even I. R. C. Standard loading is heavier than 10 units B. E. S. A. loading. The latter loading has been specified in terms of certain axle loads and spacings and as such its equivalent loading worked out by up-to-date methods of analysis is quite rational. Obviously Indian Roads Congress Loading would require modifications so that various members of different lengths in a bridge when designed for this loading have the same factor of safety.

Now that designing of concrete mixtures is understood much better than in early days of concrete making, it is quite safe to design mixes for average stresses with a factor of safety of 3·0. Bond stress in direct pull has been found to be $(0{\cdot}1\ f_c+25)$ lbs./□″ were f_c=permissible concrete stress. In case f_c= 750 lbs./sq. inch safe bond stress in direct pull works out to be 100 lbs./sq. inch. Bond stress in bending of beams and slabs varies directly as shearing force. The latter is maximum at support and zero at centre and so also the bond stress, as such the maximum bond stress at support is taken as twice the permissible bond stress in direct pull, *i. e.* $2\times 100=200$ lbs./sq. inch so that average bond stress in bending over the whole span is equal to permissible bond stress of 100 lbs./sq. inch.

Mr. Kanwar Sain having been essentially responsible for the sanctioning of this bridge explained the circumstances that were favourable to its adoption. His suggestion of critical examination of loading as discussed in the Paper would, it is presumed, receive the attention of the Road Authorities in the country.