PAPER No. 156.

GIRDER ERECTION OF THE de MONTOMORENCY BRIDGE ACROSS THE JHELUM RIVER AT KHUSHAB.

By Captain J. R. Simpson, R.E., Asstt. Executive Engineer, North Western Railway.

The de Montmorency Bridge which was opened by the Governor of the Punjab, Sir Geoffrey de Montmorency on April 25th, 1931, forms a combined railway and road connection across the Jhelum river on the Sargodha-Khushab Branch line of the N. W. Railway. On the completion of the rail cum-road bridge across the Chenab river at Chiniot (which is expected to be ready in March 1932) and with the railway bridge at Kalabagh (opened to traffic on 10th August 1931) an alternative route from Lahore to Waziristan will be available. Photograph No. 1 shows a general view of the completed bridge.

The bridge is briefly referred to in Paper No. 144 by Major Carson, R.E., entitled "Recent Practice in Girder Erection on the N. W. Railway" which was read before the Punjab Engineering Congress during the 1931 session.

There are one or two novel features referred to in the present paper relating to the design and methods of erection which are described in detail in the body of the paper. The provison of overtaking stations on the cantilever roadways and the methods of obtaining the correct camber in the various lengths of roadway cantilever girders ; the moving out into position of the inner and outer main girders, and connecting together the pairs of main girders at close spacing by means of specially designed pneumatic tools.

The bridge consists of 15 spans, each 159′ centre to centre of piers, with a clear span of 144 ft., see fig. 1, Sheet 1.

Standard of loading.

The de Montmorency Bridge is designed to carry a single line of broad-gauge railway to M. L. Standard Loading of 1926, which is equivalent to a trian hauled by two locomotives of $22\frac{1}{2}$ ton axle load, and for the roadways British Engineering Standard 10 unit highway load, which is equivalent to a ten ton axle load followed by $4\frac{1}{2}$ ton axle loads, spaced 10 feet apart.

Foundation of piers.

The piers and wells are brick in cement mortar. Twin octagonal well foundations were employed and they were sunk to an average depth of 90 feet.

The wells, piers, guide bunds, and approach banks were built by the Construction Branch, N. W. Railway, Mr. A. Latif Sheikh, B.A., B.Sc., being the Executive Engineer, and are not dealt with in this paper.

Discharge of river.

The discharge of the river varied from a minimum of 300 cusecs in the cold weather to a maximum of about 5,50,000 cusecs during the monsoon.

Girders.

The spans are made up of half through type truss duplicated trusses and were designed and erected by the bridge division of the North Western Railway. The details of design were approved by the Consulting Engineers, Messrs. Rendel Palmer & Tritten, Westminster, London.

The steel work has been largely made up from railway spans released from the Kaiser-i-Hind bridge across the Sutlej river at Ferozepore.

In all, 6752 tons have been used in the superstructure, 27 per cent. of this being of new material which includes 6 new trusses manufactured by a constructional firm in India. The work entailed closing over half a million rivets in the field.

The second hand material was dealt with in the bridge department workshop at Jhelum, the girders being strengthened and remodelled there as required. Each span was assembled in the yard at Jhelum to ensure correct fabrication before being sent to site for erection.

As the main girders are duplicated, separate arrangements were necessary for the erection of inner and outer girders.

The weight of each pair of inner girders without flooring was 130 tons.

Girder erection.

The girders were erected on the approach banks and rolled forward into position, this method being chosen in preference to either floating out on pontoons or erecting in position from temporary staging. The method adopted was certainly the most economical, while it afforded independence of river conditions. The velocity reaches 10 ft. per second during the summer months and sudden rises amounting to as much as $9\frac{1}{2}$ ft. in one day have been recorded.

The first pair of inner girders was assembled and riveted without cross girders and stringers, on the main approach bank.

The girders were then launched across the staging and lowered by jacks to their normal position, see fig. 1, Sheet 2, and Photo No. 2, after which cross girders and stringers were fitted and riveted.

The inner girders of No. 2 span were then assembled and riveted on the main approach bank, and launched through the girders of No. 1 span, into their position on No. 2 span.

To permit of the inner girders of No. 2 span passing freely through the inner girders of No. 1 span, the girders of No. 2 span were assembled at 11 ft. 6 inches centres, and on arrival at their position on No. 2 span, were respaced to their normal 18 ft. 6 inches centres, see fig. 5, Sheet 2.

While cross girders and stringers were being fitted on No. 2 span, the inner girders of No. 3 span were being assembled and riveted on No. 1 span, and were subsequently launched between the inner girders of No. 2 span on to No. 3 span.

Similarly the inner girders of No. 4 span were assembled on No. 2 span and then launched through No. 3 span on to No. 4 span.

Photo No. 2 shows the inner girders of No. 4 span being launched.

Special spring borne trollies were designed for running out the girders. They were fitted under the lower booms of the inner girders, to run along two tracks along the staging.

Each trolly having one 3 inch axle, was capable of taking 10 tons, the wheels being double flanged to keep direction. The weight of each trolly was $\frac{1}{2}$ ton.

This arrangement ensured that alignment was maintained and provided a more rapid method requiring less labour than by using rollers. Using these trollies a pair of inner girders weighing 135 tons was moved 477 feet in 20 minutes.

Fig. No. 2, sheet 2. gives the trolly details and they can be seen in position in Photo No. 2 and on fig 1, Sheet 2.

The object of assembling No. 3 span inner girders on No. 1 span and No. 4 span inner girders on No. 2 span, etc., was to save length and cost of laying trolly track.

The outer girders were assembled and riveted at their normal centres, 24′—10″, on the main approach bank, and were then picked up by a special traveller consisting of frames mounted on 3 bogie trucks and wheeled forward to their respective spans, lowered on to their bearings and connected to the inner girders.

The traveller frames, made from angles and channels, were subsequently dismantled and the material used for bracings on small spans elsewhere.

These frames on the bogie trucks are in the form of a "T", the outer girders being suspended by slings from the ends of the arms of the "T". There were 2 frames to each bogie truck making 6 frames in all for lifting a pair of girders, see fig 3, Sheet 2, and Photo No. 4.

The arrangement was simple to operate as the bogie trucks worked on the permanent way track.

As outer girder erection started with the centre spans and worked back towards both ends of the bridge, wheeling forward of the outer girders could not take place until all inner girders were complete. While the inner girders were in course of erection, it was possible to assemble

6 outer girders on each approach bank. The number of outer girders being assembled on the approach bank was only limited by length of straight and width of bank, and number of men and tools available.

On completion of the inner girders, the outer girders were carried forward, one pair of outer girders being dealt with every two days. The great advantage of the frames was their ability to pick up the girders at any distance from the bridge and wheel forward, the same frames and bogie trucks being used from both ends of the bridge alternately.

As an alternative means of carrying the outer girders forward, gantries running on tracks on the top booms of the inner girders was considered. This method, however, would have meant providing a track on the top booms of the inner girders, spanning the gaps between the inner girders, and providing trollies for the outer girders on the approach bank.

The built or shop camber of both the outer and inner girders was 2·75". After riveting and launching the outer girders the camber was on an average 2·20".

After launching inner girders, and fitting flooring and bracing their camber was on an average 2·07".

To distribute the weight of the flooring equally between both pairs of main girders, stress were introduced at each panel point equal to a total of 16 tons load per girder. This was carried out as follows :—

The span consisting of inner girders and flooring was raised on jacks until the holes in the diaphragms connected to the main girders at the central panels coincided with the holes in the outer girders at that point when drifts and bolts were inserted. The span was then lowered until the two panels on each side of the centre coincided when drifts and bolts were inserted. The lowering was continued and connections similarly made until the final central camber in each girder was 2·14."

During the official tests before opening the bridge a deflection of ·44 inches was recorded under a double-headed test rain drawn by HG/S class locomotives at low speed equivalent to a uniform load of 308 tons per span. Owing to the stiffness of the floor system which acts as a relief to the main girders, the deflection of the complete span is about 31% less than for the trusses alone.

The riveting of the connections between inner and outer main girders was carried out by Bohler pneumatic hammers. These tools were specially obtained for working in confined spaces and successfully closed rivets put to one inch diameter, thus enabling the girders to be spaced much closer together than would otherwise have been possible. A view showing this type of hammer in use is illustrated on Photo No. 3-A.

Roadways.

The two roadways carried on cantilevers outside the main girders are provided with overtaking stations at every second pier to permit

fast moving vehicles to pass bullock carts, draft animals, etc. The width of the roadways is ten feet and is increased to eighteen feet for a distance of thirty-two feet at each overtaking station. This form of construction is an entirely new feature as far as the writer is aware, and is illustrated in photograph No. 5 and on fig. 2, Sheet 1. Cantilever girders 6 feet 6 inches deep resting directly on the piers, form the main support to the widened roadway.

In order to obtain a level surface for the roadway, the initial camber necessary for each of the three lengths of cantilever girders was determined for the first overtaking station by stressing the girder with known weights attached at various points, the resulting deflection being noted and corrected for in all overtaking stations, by making adjustments at the connections to the main steelwork.

The channel, connections between roadway cantilever brackets and railway cross girders, carry the tension component of the bending moment. These are subject to a maximum unit tensile stress of 4·8 tons per square inch under dead plus live and impact loads and were initially stressed to about 3 tons per square inch before rivet holes were filled by means of a 25 ton calibrated hydraulic jack, this obviated tension in the rivets forming the web connection between the brackets and the main structure.

The surface of the roadways consists of a $3\frac{3}{4}$" thickness of cement concrete on steel troughing.

Air compressor.

Motive power for riveting hammers, drilling machines, and pile driving, etc., was supplied by one Ingersoll Rand X.P. V. compound air compressor with a capacity of 1000 c.ft. of free discharge per minute, steamed by stationary locomotive type boilers

Piling for service staging.

For pile driving for temporary staging, a double action steam pile driver weighing 4,000 lbs, was used, suspended from a 40 feet timber derrick carried on a pontoon, see Photo No. 3.

The pontoon consisted of 8 steel water tanks each measuring 16′×8′×5′ bolted together to form a 32′ square. Niwar (coarse tape) soaked in white lead was used for caulking the points.

The tanks were strutted with timber to withstand water pressure an 18″×6″ R. S. joists 32′ long and 12″×6″ R. S. channels were laid longitudinally and transversely to strengthen the pontoon and distribute the weight of derrick.

The advantage of the pontoon was that the daily variations in the river level, averaging 1 ft., did not affect pile driving.

In cases where scour was excessive and it was not possible to drive piles for erection of temporary staging, it was intended to float out the

nose of the inner girder on the pontoon but this was not found to be necessary as there was no excessive scour and staging was used throughout.

Temporary staging in all cases was founded on salwood piles 35 feet long. Sixteen piles being used for the staging, grouped under the centre of each span.

Most of the piles were extracted by inverting the pile driver and suspending it from the main girders above, the pile driver driving against a yoke attached to the piles.

During the monsoon some of the piles were extracted by making fast one end of a rope to the pile and the other end to the main girders and allowing the next flood to scour out the bed and free the pile.

Labour.

With the method of girder erection described, assembling and riveting of each pair of girders occupied 7 days ; launching, fitting and riveting cross girders another 7 days, each pair of inner girders being completed in a fortnight.

About 350 men were employed in the ordinary way and 100 of these were semi-skilled men.

With double the above labour, and working from both ends of the bridge, it was found possible to double this output. Work proceeded through the monsoon of 1930, the highest flood experienced being within 1·5 feet of the maximum flood for the last 40 years.

Climate.

With high temperature which reached a maximum of 119° cases of sickness were not uncommon, being as much as 1 per cent. of labour per day. With 350 men there were 105 fresh cases of malaria per month during the months of August and September, 1930.

Cost.

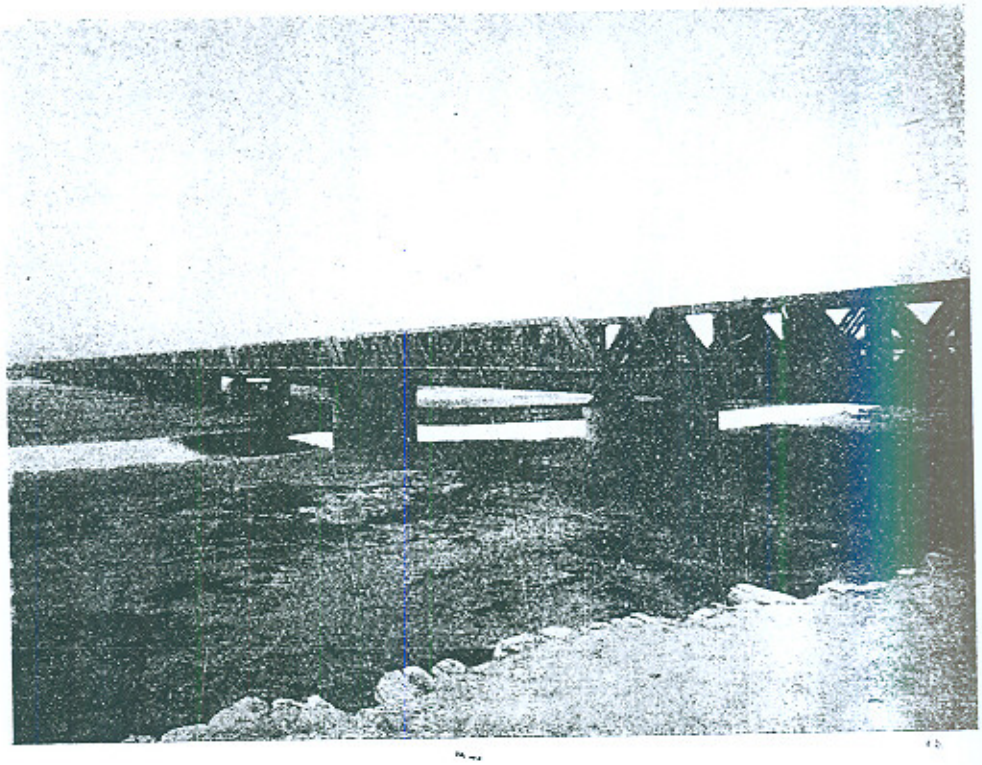
Work was completed at Rs. 200 a ton. With new steelwork, the cost would not have been less than Rs. 350 per ton.

Staff.

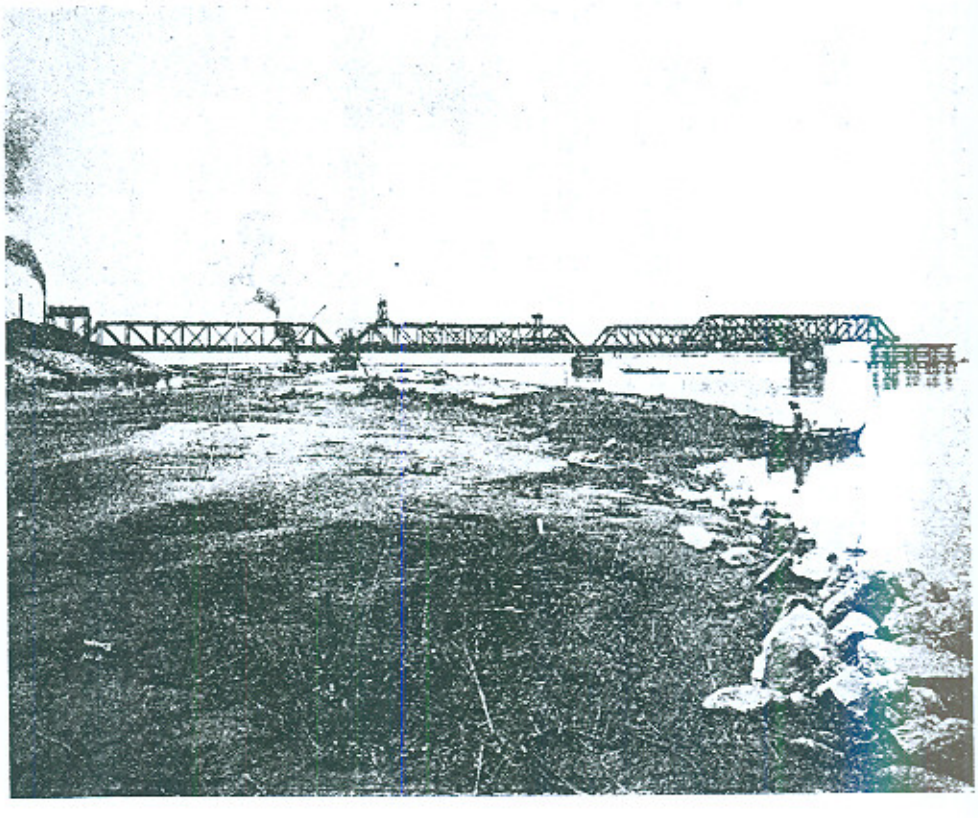
The design, fabrication of girders at Jhelum, and girder erection in the field, was carried out under the supervision of Mr. W. T. Everall, O.B.E., M. Inst., C.E., Deputy Chief Engineer, Bridges. Mr. A.S. Hay, Executive Engineer, Bridges, was responsible for the fabrication of girders in Jhelum, girder erection in the field, and for several of the interesting features employed on the work.

The writer in the capacity of Asstt. Bridge Engineer, and Bridge Inspector, Khan Sahib Farman Ali were resident at the site of girder erection.

The author wishes to thank Mr. C. A. H. Edwards, the Chief Engineer, Surveys & Constructions, North Western Railway, for permission to present this Paper.

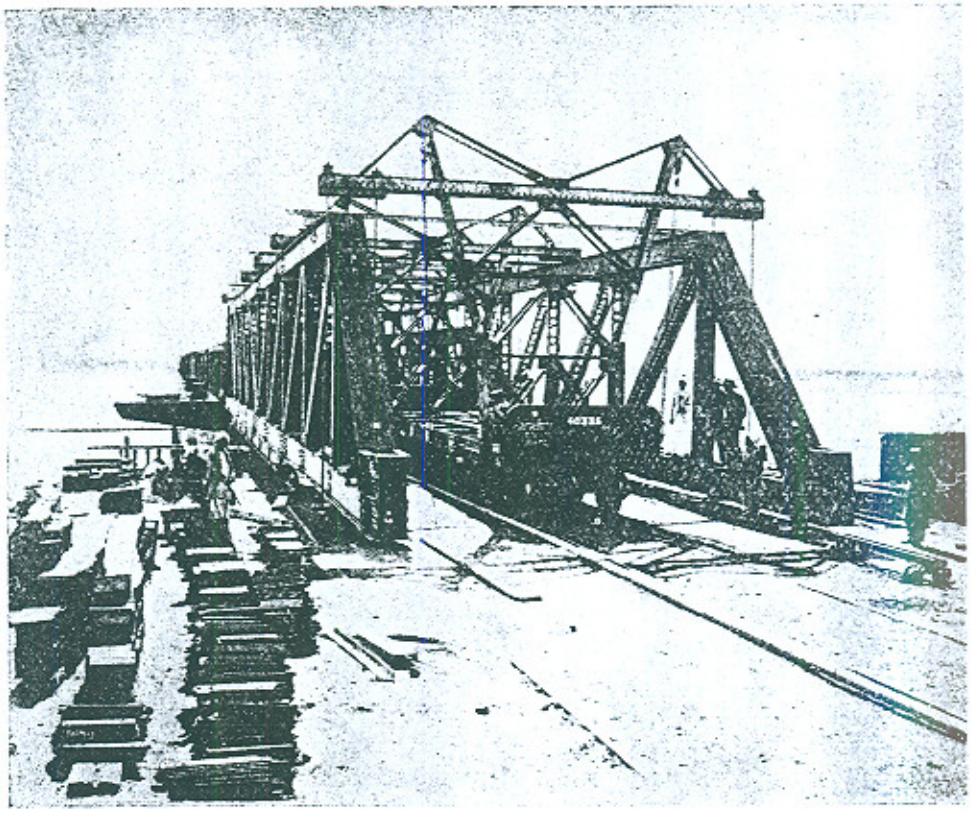


General view of completed Bridge from the Shahpur end.

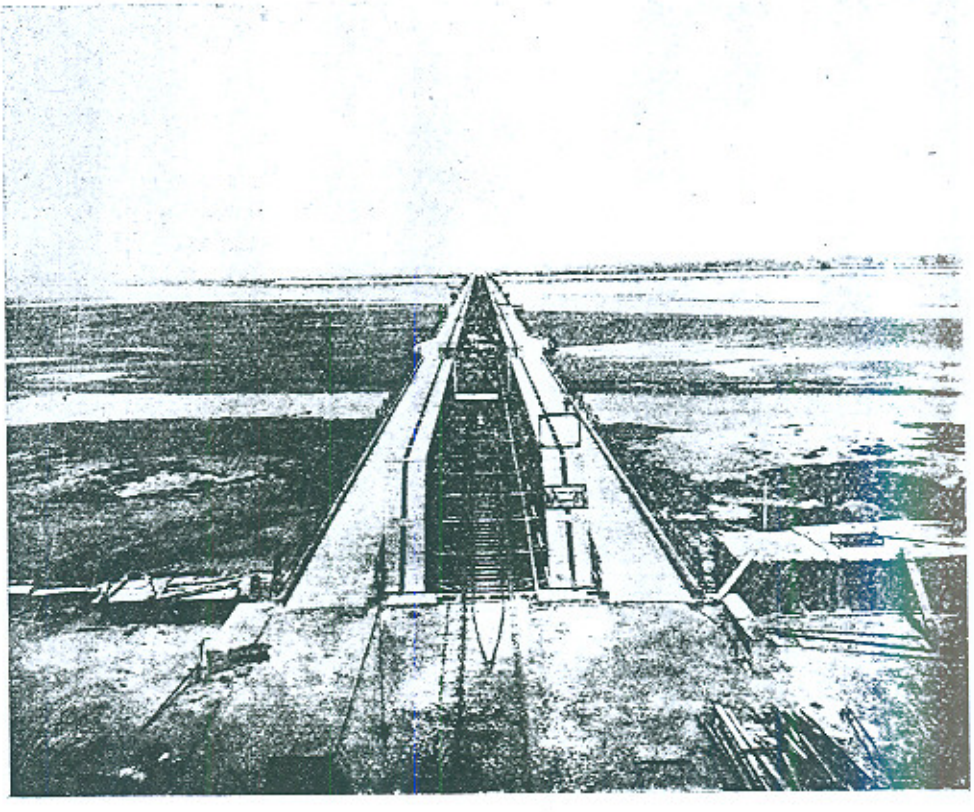


Showing the inner girder of span No. 4 being launched.

De Montmorency Bridge Construction.

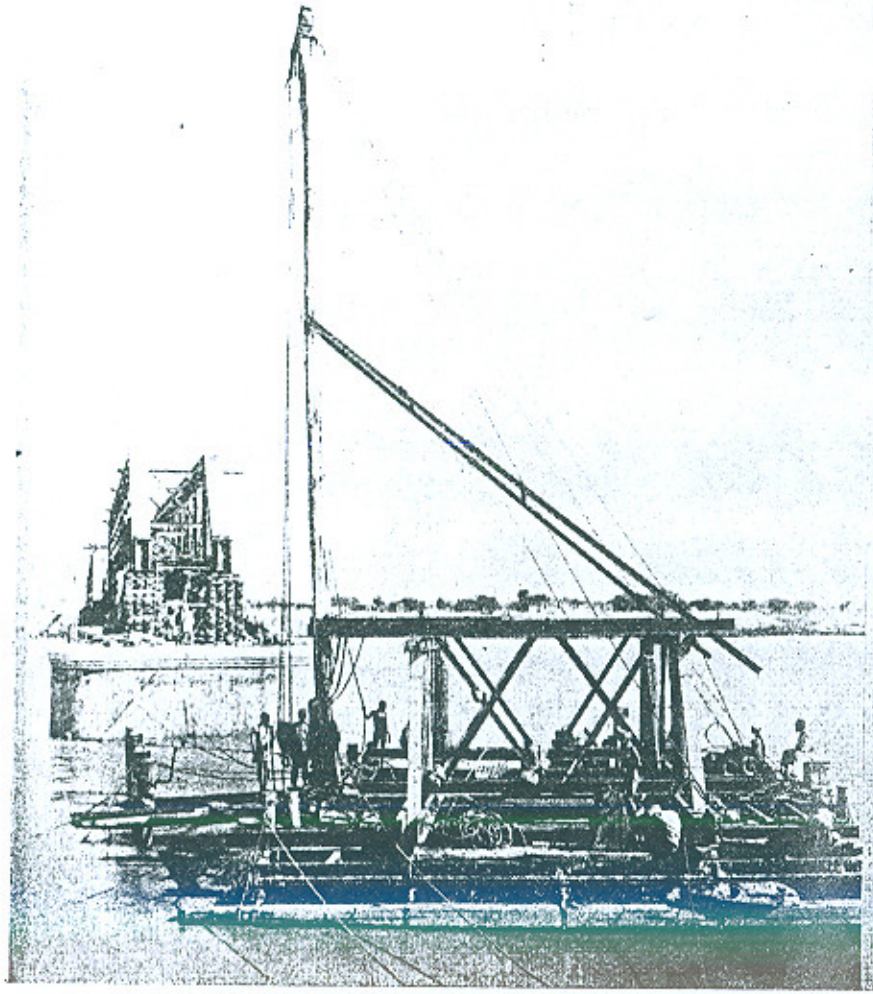


View showing traveller on abutment ready for moving the outer girder into position.

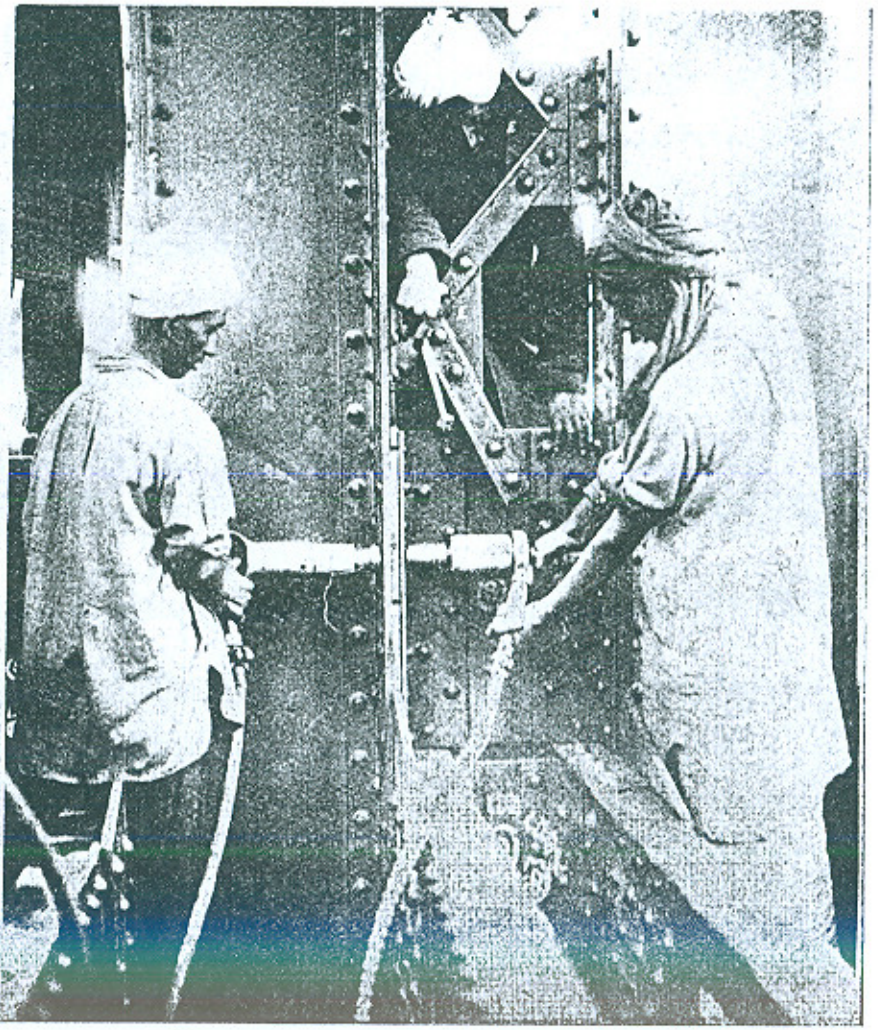


General view from the Shahpur end of the completed bridge showing the cantilevered roadways with crossing stations.

De Montmorency Bridge Construction.



Piling hammer on pontoon.

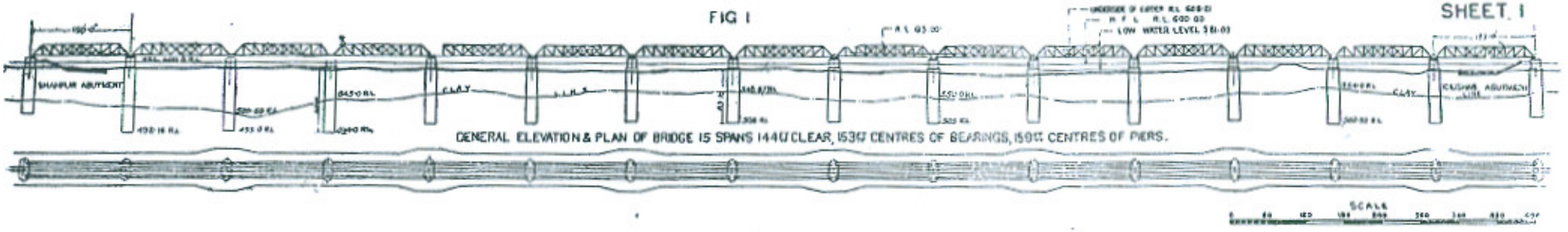


Closequarter rivetting with special short pneumatic hammer.

DE MONTMORENCY BRIDGE ACROSS RIVER JHELUM AT KHUSHAB FOR COMBINED RAIL & ROAD TRAFFIC

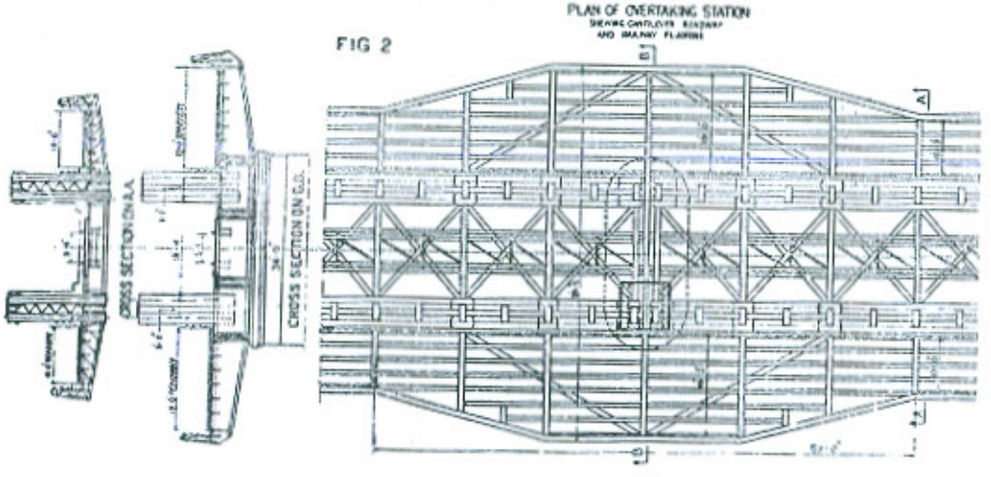
SHEET. 1

FIG 1



GENERAL ELEVATION & PLAN OF BRIDGE 15 SPANS 144'0 CLEAR, 153'0 CENTRES OF BEARINGS, 159'0 CENTRES OF PIERS.

FIG 2



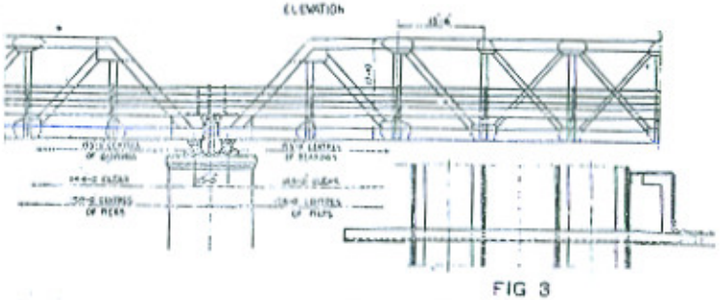
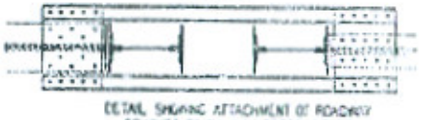


FIG 3



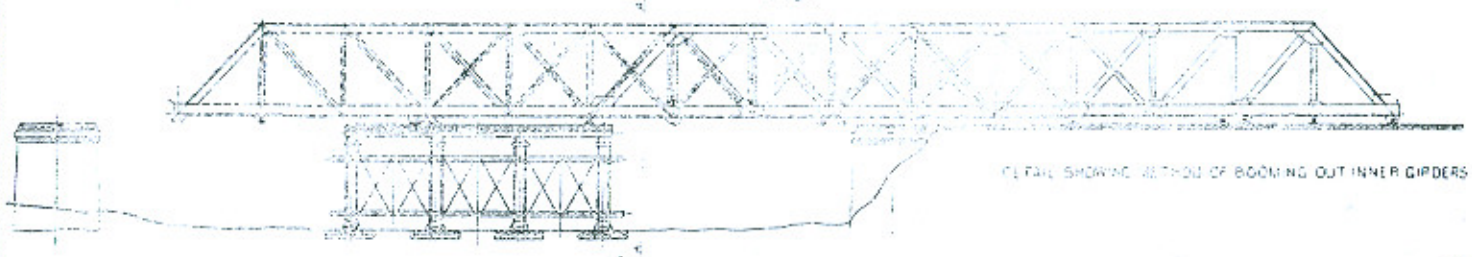
DETAIL SHOWING ATTACHMENT OF ROADWAY BRACKET TO RAILWAY CROSS GIRDER

SCALES

DE MONTMORENCY BRIDGE ACROSS RIVER JHELUM AT KHUSHAB FOR COMBINED RAIL & ROAD TRAFFIC

SHEET 2

FIG 1



THE STAGING IN THE WATER CHANNELS WAS SUPPORTED ON TEMPORARY WOODEN PILES

DETAIL SHOWING METHOD OF BOOMING OUT INNER GIRDERS

CROSS SECTION ON A.A.

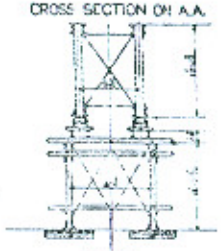
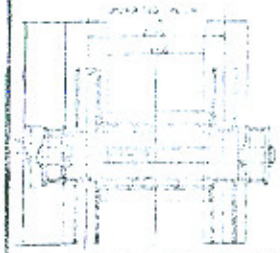


FIG 5

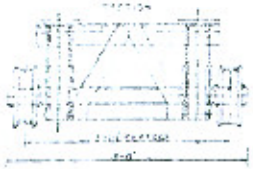
METHOD OF RESPACING THE GIRDERS FROM 11-6 TO 18-6 CENTRES



FIG 2



DETAIL OF SPRING BOGIE TROLLEY FOR LAUNCHING INNER GIRDERS



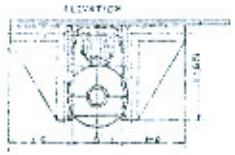


FIG 3

DETAIL OF TRAVELLER FOR MOVING FORWARD OUTER GIRDERS



CROSS SECTION OF TRAVELLER



SCALES



CAPTAIN SIMPSON introducing his paper, pointed out that of the three bridges mentioned in the first para. of his paper, two were built with second-hand material, while the only bridge constructed with the new steel-work was the Mari-Indus Bridge. The other two bridges were one across the river Jhelum at Khushab and the other across the River Chenab at Chiniot.

The Mari-Indus Bridge had new steel-work throughout. The de Montmorency Bridge at Khushab had 27 per cent. of the new steel-work, and the bridge across the Chenab at Chiniot had a very large quantity of second-hand material. The advantage of using the second-hand material, in the opinion of the author was that the work would cost Rs. 200 a ton as against Rs. 350 a ton for new steel-work.

Some of the interesting points on the de Montmorency Bridge, the speaker remarked, were duplicated girders, method of connecting them together, provision of crossing stations on the roadway, which was an entirely new form of construction as far as the author is aware. There were many other interesting features, which the speaker said, the readers could find in the paper.

MR. W. T. EVERALL, congratulated Captain Simpson on his Paper and the excellent work he did in connection with the construction of the girder portion of the bridge.

Mr Everall mentioned that there were one or two points he wished to discuss in connection with this paper as the work came under his charge, both in its design and construction.

A new feature was introduced in this bridge, in the provision of overtaking stations on the cantilever roadways.

The roadways on both sides of the main girders were widened out at alternate piers to 18 feet for a distance of 32'—0", the 10' roads being gradually widened out to 18'—0" over a length of 25'—0" at either end.

The stations occur at intervals of 250 feet and form part of the main structure, they are supported from the piers as well as from the girders ; the latter all rest upon fixed bearings, and there is therefore, no need to cater for expansion movements.

The provision of these stations permit of fast traffic overtaking and passing country carts, camels and other slow moving units, which would otherwise limit the speed of all traffic using the bridge.

The arrangement has many advantages.

The bridge can cope with both fast and slow traffic without incurring serious delays and is suitable for ordinary arterial roads. The system would not of course be suitable for bridges within city areas or on roads carrying dense traffic.

A normal 10′—0″ width of road is provided for 70% of the total length of the bridge and this represents a considerable saving in cost compared with that of a bridge where the roadways are 18′ in width throughout. The saving is estimated at 25%in the roadway portion alone.

There is also a great reduction in the dead loads and this considerably reduces the tresses in the main girders and makes them correspondingly lighter in section.

Eighteen foot width of roadways would not have been justified for this bridge in view of the amount of traffic it is likely to be called upon to accommodate. The Roads and Buildings Engineer in charge of the Division (Mr. Bulwant Singh Shinn) told Mr. Everall that these overtaking stations were functioning very well and that cars were able to pass most of the slow traffic on the cantilever roadways.

There are other features of interest in the bridge, for example in the spacing apart of the twinned girders, which could be spaced much closer together than would otherwise have been possible by bringing into use a short Bohler Pneumatic hammer 13½″ in length which was specially made for this work and could close rivets up to 1″ diameter, an illustration of this tool appears in the paper. Mr. Everall mentioned this feature because the influence of even such a small item as selecting the right form of rivetting hammer, may have considerable bearing on the design of the main details of a structure and one which is sometimes lost sight of.

This bridge is an illustration of successful co-operation between the N. W. Railway and the Punjab Government.

Road accommodation for an important arterial road is provided on this Railway Bridge at a reasonable cost to the Province.

This was made possible by utilizing girder materials surplus from other bridges on the Railway, to the extent of nearly 5,000 out of the total 6,250 tons used, and by making use of the Bridge Workshops and field equipment to fabricate and erect the girder work by the Punjabi skilled labour of the Bridge Branch.

The cost of the steel structure fabricated in the workshop was about Rs. 130 per ton and for its complete erection in the field another Rs. 60—this included all frieght, plant and supervision charges.

These rates are low—they represent a saving of nearly 2½ lakhs on the total steelwork cost of the bridge, as compared with that of providing entirely new girders bought in the open market and capable of carrying the same standard of loading.

The President, MR. SMITH, remarked that he would also like to add his thanks to Captain Simpson, the author, for the presentation of an interesting and valuable paper and said that two distinctive and interesting features of this paper had been brought to light by Mr. Everall. Anyone who happens to pass frequently over the Shahdara Bridge would appreciate the introduction of the overtaking stations on this bridge.

This significant feature, which he was very pleased to note was the co-operation between the North Western Railway and the Punjab Government.

The President thanked the initiators and those who completed the new schemes of the de Montmorency Bridge.