PAPER No. 144.

RECENT PRACTICE IN GIRDER ERECTION ON THE NORTH WESTERN RAILWAY.

BY MAJOR C. F. CARSON, M.C., R.E.

1. The bridge work being carried out on the North Western Railway embraces the reconstruction and strengthening of bridges on the existing main and branch lines and the building of new bridges on lines under construction. Occasionally in cases of reconstruction it may be economical to divert the track around the bridge site, but this is not always possible. Generally speaking in the reconstruction of major bridges, the work is complicated by the necessity of having to keep the line over the bridge open for the passage of trains.

2. In this paper it is proposed to describe a number of works which have been carried out in the past few years or are now in hand merely to the extent necessary to illustrate the methods adopted in girder erection and some of the devices that have been designed to meet particular situations.

Features affecting the Method of Erection.

3. The following are some of the more common considerations which affect and control the method of erection :—

1. The length and weight of spans.
2. The number of spans.
3. The height of piers.
4. The condition of the river bed :—Dry or partly dry.
5. The depth and speed of water in the river and the liability of the river to spates or flood.
6. The conditions on the approaches, *viz*:—(*a*) High or low banks, (*b*) Cuttings.
7. The width of piers.
   Where wide enough to work on, use may be made of this facility.
8. Number of tracks.
9. The type and amount of plant available.
10. Density of traffic.

Facilities for Girder Erection work on the North Western Railway.

The bridge organization of the North Western Railway has been built up to meet the heavy volume of bridge work of all descriptions. We have now a large equipment of plant—travelling steam and hand cranes, stationary and portable compressors, interchangeable staging specially designed to meet varying conditions, gantries, etc., which, as previously stated, is a factor in considering methods of erection. In our workshops too, we have the necessary facilities for manufacturing special gantries and other devices that may be required. Though well equipped, our plant is in constant use and our work has to be carefully programmed to ensure that the necessary plant is available. Incidentally it follows that our plant charges for any work are comparatively low.

RECONSTRUCTION POLICY.

Just a word on the policy of the Railway with regard to reconstructions. There have been from time to time various standards of loading, which have been modified to meet the increasing loads for which the Railway has to provide. The present standards are:—

(1) **Heavy mineral or H.M.**—A future loading for the main line including a 28-ton axle locomotive.

(2) **M. L.—the present main line loading.**—This covers the heaviest loads at present running or designed over Indian Railways, including the 22½-ton axle locomotive.

(3) **B. L. loading.**—The Branch Line Standard, including 17-ton axle loads.

The practice in force at the time of writing is to strengthen the main line bridges up to M.L. and the Branch Line bridges up to B.L. standards. When this cannot be satisfactorily and economically done, the main line bridges are renewed to H.M. and the branch line to M.L. loading, since it is possible that the increased loads provided for in these standards may be applied during the normal life of the new bridges, and the additional cost, when renewal is to be made, is comparatively small and fully justified by this possibility. In the descriptions, which follow, H.M., M.L. and B.L. Loadings will be mentioned without further explanation.

Particulars of weights, dimensions, etc., of the spans of bridges described herein and illustrations will be found in the Appendix.

NOTE.—The Author wishes to express his thanks to Mr. R. B. Holmes of Peshawar for permission to reproduce his photographs.

RECONSTRUCTION OF THE ALEXANDRA BRIDGE.

Description.—The Alexandra Bridge spanning the Chenab River near Wazirabad carries the Main Line of the N. W. Railway from Lahore to the North West Frontier. The original bridge built in 1876, at a cost of 53·4 lakhs, had 64 spans of 134 ft. each. It had wrought iron main girders of the single inter-section Warren type made up into single track pony truss spans with the flooring on the bottom boom. In 1891 the bridge was shortened to 28 spans and in 1918 it was again shortened to 17 spans, and strengthened by duplicating the main girders.

Being too weak for the increased loads, the complete bridge of 17 spans was renewed in 1927 with single track spans of through type Pratt Trusses on the existing piers at a cost of 8½ lakhs. The structure can now take H. M. loads at unrestricted speeds. The bridge has been so designed that an extra girder and extra floor can be added when the traffic warrants duplication of the line.

Conditions at site.—The piers are comparatively low and the river, although subject to seasonal floods in the winter months, is dry except for a slow flowing and shallow stream about two hundred yards wide. The erection of staging in the river bed, therefore, presented no great difficulty.

Alternative methods.—Three methods were considered which are described briefly below:

Method 1 consisted of a temporary diversion on staging to permit the renewal of the spans free of traffic complications.

Method 2 consisted in the replacement of the old spans one by one by a service span to enable the new span to be built in situ, similar to the scheme adopted for the Krishna bridge on the Madras and Southern Mahratta Railway.

Method 3 consisted in the erection of the spans on staging alongside the existing spans for replacement by "slewing" or "rolling."

Regarding method (1), the amount of staging and the cost of its erection and removal would have been very much out of proportion to the advantage gained and in consequence the idea of a diversion was not seriously entertained.

Method (2) could not be adopted owing to the restricted horizontal clearances available for a service span.

Space does not permit of details being given regarding this method but any one interested may read a very good description of the renewal of the Krishna bridge in the proceedings of the Institution of Civil Engineers, Volume 227, 1928-29. While quite an intriguing method to meet a difficult situation, it had nothing to commend it over method (3) for the reconstruction of the Alexandra Bridge even had it been possible to adopt it.

Method adopted.—Method (3) which entailed the assembly of the girders clear of the bridge, their transport to site, the erection of the new spans on staging, alongside the spans to be replaced, the removal of the old spans and the rolling in of the new, was the method adopted and the method that will be described in detail in these pages.

ERECTION SCHEME DESCRIBED.

Girder assembly.—The new girders were assembled and rivetted on a dump situated near the bridge where work could be carried on continuously without interruption from traffic. The extension of an existing siding into the dump made a convenient erection siding on which a ten ton crane could operate to place the various members of the girders in position. Two girders were assembled at the same time and temporarily braced together for support, and when completed, were moved on rollers on prepared platforms across the dump to a position alongside and parallel to the main track. From here the single girders were lifted bodily by two 25-ton cranes and placed on a rail bogie truck for transport to site *vide* plate I photo No. 1.

Staging.—For receiving the new girders and building them into spans, staging was required on both sides of the piers; on one side to receive the old spans after replacement and on the other side for supporting the new girders and erecting them into spans. This was effected by erecting through staging across the line of the bridge in a position to support the first panel point of the new girders.

The staging was constructed of N.W.R. type interchangeable staging founded on piles round the piers and on timber cribs at the abutments. Old 40 feet girders (44 feet overall) with 12 feet cross girders were used to provide a platform on the staging.

Span Erection.—The girders after they had been assembled, were transported to the site singly on rail bogie trucks *vide* plate I photos Nos. 1 & 2.

The whole weight of the girder was taken by the truck and as a provision against accidents, and to keep the girders in position, the crane chains were kept tight.

To lift the girders at the dump on to the rail bogie trucks and from the rail bogie trucks on to the staging, flexible steel wire slings were attached round the gussets, connecting the end raker and the first vertical strut, shaped hardwood timber blocks being inserted between the gussets to prevent distortion of the plates and damage to the ropes. In the operation of the train transporting girders to the site great care had to be taken to ensure smooth and gentle starting and on arrival at site equal care in braking to avoid undue strain on the girders. The final adjustment of the girders in position on the staging was obtained by the cranes operating under their own power, the material train having been removed. The final rail level was 12 inches higher than the existing rail level. This difference in height was adjusted during the early stages of the work by fixing the track on temporary cross timbers. Such precautions and adjustments are required in carrying out all erection schemes but they will not be referred to again in subsequent descriptions, for want of space.

On arrival at site, the girder was lifted by the two cranes over the old girders and placed on the staging on the upstream side of the bridge. As the crane jibs were not sufficiently long to place the outer girder in its correct position for erection, it was received on specially designed cradles shown in plate I photograph No. 2 which were moved out on rollers to a position the girder would have to take up in the span. The second girder was then similarly transported and placed on the staging in a position to give the correct centre to centre distance betwen the girders. The floor system, the portal and sway bracings, were then fixed and the whole span completed by rivetting and adding the track. The span was then jacked up (using 100 and 50 ton hydraulic jacks and frames of 4 inch rollers were inserted to operate between 8″× 10″ R.S. Joists. Rollers were similarly inserted under the old span and the necessary adjustment made.

Since the longest block that was available was $2\frac{1}{2}$ hours, it was of the utmost importance before beginning operations, to have all the tackle ready and in its place, the spans completed and the track fitted, and to waste as little time as possible once the block was imposed. During the block period the old span had to be pulled out and the new span rolled into the position vacated.

Slewing.—Man-power haulage was employed and it was found that for the new span weighing 133 tons a pull on the fall at each end of 500 to 600 lbs. was sufficient to start the rolling operation. The pull on the block hook would be approximately 3,000 to 3,300 lbs. No difficulty was experienced in slewing but a check had to be kept on the tendency of the span to creep in the alignment of the bridge. When the new span was in position it was jacked up, the rollers removed, wooden packings inserted as temporary bearings, adjustments quickly made and the track linked up at both ends to permit the passing of the next train. The cast steel bearings were fixed later as the time available during one block was too limited to allow this work to be done at the same time as the slewing.

Incidental points.—It is obvious, of course, that the track could only be occupied during block periods and therefore the time available for the transport to site by material train of complete girders and other steelwork was severely limited. The same remarks apply equally to the dismantling and removal of the old spans briefly described below. Work had to be programmed accordingly. The method of imposing and removing blocks, however, protects both trains and workmen from accident and although the time allowed was occasionally exceeded, the blocks were generally removed in the time allowed.

Dismantling and removal of old spans.—The removal of the old spans from their position on the staging, where they rested after being rolled out of the bridge was not without its difficulties as a reference to photographs will show. This dismantling was effected in two ways :—

(i) By cutting up the old girders in situ and lowering the parts to the river bed for removal.

(ii) By floating the girders away bodily to a convenient site for removal by cranes to a dismantling dump.

In method (i) the cross girders and stringers were first removed and lowered to the river bed on to trollies, or where water intervened, on to boats. The outer pair of girders were next hauled up alongside the inner pair, and supported by tackle suspended from R. S. Joists temporarily fixed to and projecting from the top booms of the new spans. So supported, the girders were cut up into sections of two panel lengths and removed by crane where accessible, there being just sufficient room between the two end rakers of adjacent spans to permit this. The remaining suspended sections were then lowered by tackle to boats or trollies and finally lifted into trucks by a 10-ton hand crane operating from a temporary jetty.

In method (ii) pontoons were constructed from river boats braced together in sets of three on which staging was erected to take a single girder and float it to a position alongside a portion of the existing bridge where it could be lifted clear of the structure and carried away for cutting up and dismantling.

JHELUM BRIDGE.

Description.—This bridge consisting of 50 spans 94′-6″ and 1 span 25′ crosses the Jhelum river just south of Jhelum railway station on the main line from Lahore to Peshawar. This note refers to the fifty longer spans which having been found weak were renewed to H.M. standard in 1928. Each span of the old bridge consisted of two triangulated girders with flooring of transverse troughing carried directly on the top chords. An investigation of the various methods of strengthening and renewing these spans resulted in a three girder design capable of carrying H.M. loads and in it the existing girders when strengthened were used as outer girders in combination with a new central girder.

Conditions at site.—While there is more water in the Jhelum than in the Chenab, the general site conditions were similar to those at the Alexandra bridge. On the same piers as the railway bridge and on the downstream side of it is a road bridge with a clearance between the two of 3′-4″.

Alternative methods.—The strength of the road bridge precluded the suggestion of running trains across it and a diversion by this or any other method not being feasible, the work of renewal had to be carried out under traffic. The traffic blocks, again as in the Alexandra bridge, were neither numerous nor of long duration, the longest that could be obtained here being 2½ hours.

A diversion being ruled out there were two alternative methods that could be employed :—

Method (1) consisted in the direct insertion of the new central girder between two existing girders and the strengthening of the latter in situ.

Method (2) consisted in the removal of the existing spans and their reconstruction as three girders spans for further replacement.

With the best preliminary arrangements including the replacement of rivets in the cross bracings by bolts, the preparation of the floor to be lifted off in sections, etc., it would be exceedingly difficult to insert the central girder with even reasonably good temporary bracings, and re-make the track to pass a train in the block period. Moreover, the new cross bracings would have to be fitted and drilled at site, a method to be avoided if possible owing to its costly nature and slowness in execution. It was, therefore, decided that the old spans should be removed from the line one by one and re-constructed into 3-girder spans ; and after completion brought to site as single girders and re-erected on staging, and finally slewed into position in a manner similar to that employed on the Alexandra bridge reconstruction, *vide* plate II.

Erection scheme described.—To enable the work to be started two old spans were replaced by entirely new spans. Later to speed up the process a third span was similarly renewed. The Jhelum workshop, being in close proximity, was a particularly convenient place for carrying out all the incidental and preliminary work. This involved

(*a*) the strengthening of the old girders, and

(*b*) their assembly into 3-girder spans with one new central girder.

As has already been mentioned, there was only a clearance of 3′-4″ between the road and railway bridges and this rendered the slewing out of the old spans impossible otherwise the schemes adopted for both the Jhelum and the Alexandra bridges were identical.

To effect the removal of the old spans they had to be partially dismantled as shown in the photo No. 4, plate II. Prior to the block period, rivets fixing the cross bracings were replaced by bolts and the flooring cut into sections and freed from the booms. As soon as the block was imposed the sections of flooring were lifted off and together with the cross bracings were removed and lowered to the river bed where it was dry or left hanging to the girders by bolts where there was water. Cranes then lifted the inner or upstream old girder and held it aloft while the new span was rolled in half way. This girder was then carried over and placed on the staging vacated by the new span. The second old girder was similarly dealt with while the new span was drawn into its final position—see plate II. The new span was then jacked up, rollers removed and hardwood packings inserted in place of the bearings which owing to the limited time during the block had to be put in later. The complete operation including the linking up of the track over the new span was completed each time in the block period of 2½ hours.

Removal of the released girders.—The released girders were loaded on to rail bogie trucks by crane and taken to the Jhelum Workshop for re-construction and a repetition of the process described above.

NEW BRIDGE OVER THE JHELUM BETWEEN SARGODHA AND KHUSHAB.

Description.—The New Jhelum bridge is now (June 1930) under construction over the Jhelum river on the new branch line connecting Sargodha and Khushab. It consists of 15 through type spans, 153 feet of clear water-way in each span. The spans consist of duplicated girders, designed to carry a single line (M. L. Loading) broad gauge railway and a roadway 10 feet wide, cantilevered out on each side. In its construction the old girders recovered from the Kaiser-i-Hind bridge are being used. The outer girders of 3 spans are new. The whole of the fabrication except for the six new girders is being carried out in the Jhelum Workshop.

Conditions at site.—The river bed is of sand about 25 feet to 30 feet deep overlying hard clay. During the winter 1929-30 (October to March) there was water varying in depths from 1 feet to 15 feet under 7 spans and the flow was approximately 3 miles an hour. After March, the water increased to 13 spans with depths up to 25 feet and a current of 6 to 10 miles an hour. Like most Punjab rivers, the Jhelum is subject to sudden and rapid rises of water. On April the 9th, 1930, it rose to within 3 feet of the highest recorded flood level. During this spring the water has been considerably in excess of normal.

Alternative methods.—Three feasible alternative methods of erection are briefly described below, all pre-supposing the erection of spans of inner girders in the first place, the outer girders and roadways being added afterwards :

Method (1) The erection of service staging for the assembly of girders at site.

,, (2) The assembly of inner girders on pontoons for floating into position over deep water combined with (1) above for the spans over shallow water or dry land.

,, (3) The assembly of the girders on staging or stallages on the approach banks for launching forward into their final position.

Method (1) requires a large amount of staging the cost of which would be prohibitive. Difficulties would also attend its erection in the deeper channels.

Method (2). This method to be effective would require pontoons or boats far in excess of those that are available.

Method (3) involves—(*a*) Staging for approximately the centre third of a span in the dry and shallow spans and (*b*) pontoons for partially supporting the girders in the deep water spans. This method requires only about $\frac{1}{3}$rd of the staging and not more than $\frac{1}{4}$th of the floating devices required by methods (1) and (2) assuming of course in method (2) sufficient pontoons, etc., to permit of continuous work. Method (3) also has the further advantage that the assembly of girders can proceed on the bank even when launching for one reason or another may have to be delayed. This method was, therefore, adopted for the construction of the inner girders of the bridge, *vide* Plate III.

Erection of the outer girders.—At the moment of writing it is proposed to attempt the erection of the outer girders by suspending the two girders of each span from outrigged steel frames carried on Rail bogie trucks. The girders themselves will be assembled and rivetted on each side of the track on the approach bank so that when completed, the lifting and suspending device may be brought into position and operated. Both girders will be lifted simultaneously and propelled forward by winch gear.

On the completion of each duplicated span, the roadway cantilevers will be lowered into position by means of a crane with a special form of bent jib to give facilities for operating without fouling the girders.

ERECTION SCHEME DESCRIBED.

(a) Bridge of Inner girders.—The inner girders are being assembled in pairs on the approach banks and also on spans already erected. The first span with single girders was completely erected with the cross girders, stringers and bracings and then launched over central staging similar to that shown in photographs 3 and 4 of plate III. The inner girders for the second, third, and fourth spans were braced together by temporary cross bracings at 11 feet centres to permit their passage through the erected spans *vide* plate III. Subsequent spans will be similarly dealt with. Sleeper stacks, which can also be seen in plate III, were erected on the piers to receive the girders. From this position the girders were opened out to their correct spacing and lowered on to their bearings. The difficulty of obtaining anything approaching an equal distribution of weight over a system of rollers in booming out spans of this size can readily be imagined. To overcome this difficulty special sprung trollies were designed and manufactured in the Jhelum Workshop. These trollies which were fixed to the bottom booms of the girders can be seen in photographs 3 and 4 of plate III. Rails at 11 feet centres are fixed on the spans over which a pair of girders is being launched and also on the centre block of staging.

Staging.—The staging requires no particular description. It consists of the N. W. R. type interchangeable staging founded on piles, as shown in the photographs.

Pontoons.—To launch the spans over deep water it is intended to support the forward end of the girders on specially made pontoons. At the time of writing, girders have not been launched in this manner but a similar method was employed in the dismantlement of the Kaiser-i-Hind bridge. Only in this case the girders were floated back on to adjacent spans instead of being launched forward. See plate IV.

The pontoon measures $32' \times 32' \times 5'$ deep and consists of 6 watertight tanks each measuring $16' \times 8' \times 5'$ braced together. In the preliminary work use was made of this pontoon mounted with a derrick for driving piles as foundations for the staging.

FEROZEPUR WEIR.

Description.—The new railway bridge over Ferozepur Weir consists of 36 plate girder spans 66 '-9" overall of which 29 spans are square and 7 skew. Each span consists of two plate girders at 6 '-2" centres suitably braced together.

The girders were supplied by the firm in two sections and the problem was, therefore, to complete the field rivetting and erect the spans in position as cheaply and quickly as possible. The bridge alignment is over the water covered apron of the weir. There were no traffic complications, the bridge being an entirely new construction.

Alternative methods.—Ordinarily the erection of a 60 feet span presents no great difficulty and can be effected either by the use of staging and cranes or by derricks, but when dealing with a bridge consisting of a large number of spans the delay and cost of dismantling and re-erecting staging or derricks will be readily apparent. This consideration with the coupled difficulty of founding staging or derricks on a water-covered apron led to the adoption of a booming out device capable of being operated from the track.

The adopted method.—This consisted of a " Traveller " which was made up of a light service span erected on a rail bogie truck and carrying a large projecting arm capable of spanning the gap between two piers. When in position the projecting portion of the service span was propped up from the pier to provide a bridge over which the girders of the new spans could be rolled.

The " Traveller. "—The traveller is illustrated in plate IX. It consisted of two light lattice girders braced together at 4 feet centres (called above a service span) fixed on a rail bogie truck and projecting 70 feet beyond the end of the truck.

On top of the service span a light track of 41 lbs. rails at 4 feet centres was laid. Two bogies of heavy material trolly wheels were made to run on this track. Across each was a 12 inch-plate girder 11 feet long with traversing **10** ton differential pulley block at each end.

Sequence of operations.—The operations were carried out in the following sequence :—

The plate girders were received from the firm each in two pieces. An erecting and rivetting dump was made near the bridge approach. All left hand girders were unloaded and rivetted upon the left side of the track and right hand girders on the right. The two girders of a span having been rivetted were moved close to the track. The Traveller was brought in between them and the girders were then lifted by the differential tackles high enough to be placed on the truck, and when this had been done, the truck moved out on the bridge to the end of the last completed span. The end of the projecting service girder was then over the next pier and the end prop was placed under it, so that the service girder was supported on the O. R. T. B. and the pier. The two main girders were then picked up off the truck and moved forward along the service span by means of the trollies till they were vertically above their piers. The girders were then lowered on to the piers and adjusted to correct position after which cross bracings were fitted and rivetted. The Traveller went back to the dump yard to repeat the operation.

THE BARAN BRIDGE.

The method first described for the erection of the Ferozepur Weir bridge was also employed on the Baran bridge, a double line bridge of 48 spans 60 feet clear—24 down line spans and 24 up line spans—on the Karachi-Kotri Section built on a diversion alignment in 1929-30 to replace an old bridge of masonry arches.

The Traveller was used for placing the girders of the up line while steam cranes operating on this line placed the girders of the down line. When this work was in full progress, spans were erected at the rate of one per day. In December 1929, 26 spans were erected and completed in this way.

In this bridge it was considered convenient to take the assembled girders to a position two spans behind the gap to be bridged and place them by steam cranes one on each side of the existing span. The Traveller from this position picked up two girders one on each side just sufficiently high to clear the piers and in this position moved forward till the rail bogie truck was over the last span. The girders were then rolled out and lowered the necessary few inches to their final position.

EMPRESS BRIDGE.

The Empress bridge is a single track bridge (in the process of reconstruction to a double track bridge) crossing the Sutlej river on the main Lahore to Karachi line between Adamwahan and Bahawalpur. Since it is in a double track section, the problem of altering it to a double track bridge had been before the Railway for some time. Investigation showed that the original bridge of 16 spans (257′ centres of bearings) could be halved in length. It was decided that this should be done and that the remaining spans which were weak should be replaced by double track spans. The shortening was carried out in 1926-27 and the remaining spans were strengthened as a temporary measure pending the time of their complete replacement. The replacement of the 8 single line spans by double line spans was started in the spring of 1929.

Conditions at site.—The river is subject to seasonal floods, but in the winter season the river bed is for the most part dry, the stream being confined to two spans.

There is an up grade to the bridge from each side. After being satisfied that the clearance between high flood level and the underside of the bridge would be ample it was decided to take the opportunity when renewing the spans to improve the grade. In the double track span design the track is 4′-10″ lower than the existing track.

The existing piers were of brick 42 feet long by 14 feet wide with semicircular ends. Each pier rested directly on a plinth 52′ × 16′ capping three circular wells.

Design.—A double track span 258 feet, 0¼″ centre to centre of bearings was designed to be built on the same piers after re-modelling, with the top of the cap 5′-8¼″ lower than the existing cap as shown in the attached plates.

The problem in re-construction principally concerned :—

(*a*) The remodelling of the piers and abutments—

(i) by increasing their lengths

(ii) by reducing their heights, and

(iii) by casting new reinforced concrete caps.

(*b*) The erection of a double track span and removal of the existing single track span.

(*c*) The regrading of the approaches and the fixing of two tracks at the new reduced level.

Alternative methods of erection.—The only methods which could be effectively considered were—

(1) The construction of a diversion to permit erection without traffic complications.

(2) The construction of the new spans around the old and the subsequent removal of the latter maintaining traffic throughout the process.

The first is a feasible method but limited to one working season. For this reason it could not be seriously entertained.

The second alternative was, therefore, adopted and the work is being carried out under traffic.

Description of the work.—*Remodelling of piers and abutments.*—The preliminary dismantlement of brickwork was carried out as far as possible without disturbing the bearings. The girders were then jacked up off their bearings and supported on staging, *vide* plate X figures 1 and 2. This permitted the further dismantlement of the brick-work and finally its re-construction. A crescent of new brickwork was added to the ends of the piers to increase the length to 50 feet. A reinforced concrete cap was then cast with quick-hardening cement and a steel stool designed to take the combined dead and live load was inserted under each bearing to keep the girders at their former level, see plate X, figu es 4 and 5.

(*b*) *Erection of new spans.*—Service staging was erected on piles on which the new girders were assembled. A special gantry, *vide* plate V photos 1 and 2, was used to place the members. Over the water spans in place of pile staging a system of service girders supported on piles and on temporary wells, as shown in plate No. V photo 3 was used.

There was no difficulty in erecting the new spans round the old up to the point of fixing the cross girders and stringers and the main members of the portal and sway bracings.

The end cross girders could not be put in till the bearings of the old girders and the temporary stools were removed.

Temporary knee bracings had to be fixed in the portal and sway bracings until the dismantling of the old girders permitted the designed members being fitted.

It was necessary to take the weight of the old span on to the new without the help of the end cross girders. This was done by—

(*a*) packing between the intermediate new cross girders and the old span ;

(*b*) Fixing special diaphragms between the ends of the new and old girders, designed to transfer the load of the end bay of the old span to the bearings of the new.

This part of the work having been completed, the temporary stools and the bearings of the old girders were removed and the new end cross girders fixed and packings inserted. The weight of the old span now having been transferred to the new the dismantling of the former could be taken in hand. This may be followed in figures 5, 6, 7, 8 and 9 plate X.

In dismantling the old girders the members were handled by travelling steam cranes from the track.

When all the old girders had been dismantled down to the floor on which the track was still carried, (Figures 8 and 9 of plate X) the floor with track was replaced by 40 feet spans placed centrally over the new cross girders. Track was added to these spans and linked up on the approaches to the main line. When this was completed, the 40 feet pans were slewed to one side of the bridge to provide space for laying one of the new tracks at final rail level. This is the position of the work at the time of writing. The track is now being laid at the new level and when completed, traffic will be diverted across it so that the 40 feet spans can be removed and the second track laid.

General.—Prior to the floods in 1929 it was only possible to unload material. Work was again started in September, the intervening time having been taken up in working out details and the manufacture of special plant. It was necessary to have everything ready as far as possible to permit the work being completed and false work removed from the river bed before the flood season of 1930. Actually this was effected before the end of May. It is expected to open the double line across the bridge in September, 1930.

BANGANGA BRIDGE.

General description.—The Banganga bridge consisting of one span of 257 feet and four spans of 60 feet is built on a gradient of 1 in 500 and on 14° and 11° reverse curves. It is situated on the Kangra Valley Railway, north of Pathankote, and spans the river Banganga at a point where it runs in a deep gorge.

At the time of construction of the Railway the shortening of the Empress bridge at Adamwahan was in progress and it was found particularly convenient to utilize one of the released spans provided with a new floor system for the Banganga bridge. The bridge carries a single 2′-6″ gauge track.

Conditions at site.—The approaches of the bridge are in deep cuttings and at the time of construction provided no ground at all for dumps. A small area at the bridge head, however, was levelled by blasting but this only gave sufficient room for the compressor plant, important stores and about two days' supply of steelwork. A second and main dump had, therefore, to be arranged seven miles in rear of the bridge where the nearest suitable ground was available. As a result of this all the steelwork for the staging and service girders had to be unloaded by hand, as cranes were not available and stacked in readiness for despatch to site to meet the demands of the erection gangs.

To facilitate erection a broad gauge steam crane of 5 tons lifting capacity was used after having been dismantled and taken to site on a narrow gauge truck.

Methods of erection.—

(1). Four 60 feet spans.

(2). One 250 feet span.

1. 60 *feet spans.*—Three methods were possible :

(*a*) Erection in situ on staging.

(*b*) Lowering parts of the gi-ders on to the river bed, assembling and then lifting with derricks.

(*c*) Assembling at rail level and launching.

Methods (*a*) and (*b*) were expensive and slow.

Method (*c*) was quicker and cheaper than methods (*a*) and (*b*) and was, therefore, adopted.

The photographs, plate VI will give a general idea how the 60 feet spans were launched. One derrick was erected projecting about 30 feet above the pier at the farther end of the gap to be spanned. The girders were assembled at rail level near one approach abutment. Skids were provided under the bottom flanges and each girder in turn was hauled to a position where tackle suspended from the derrick could be attached and utilized for launching. Hold-back tackle controlled the forward movement of the girder and a winch crab located in the river bed provided the necessary motive force for projecting the girder forward. The girder on reaching its final position was supported by shear legs and then lowered on to the bed stones. When both girders were in position, the bracings and bridge timbers were added and the track laid.

250 *feet span*.—Method of erection :

(1) on staging only.

(2) on service girders.

Method (1) was impracticable at the time of construction owing to the close proximity of the rains and the resistance that a mass of staging would have offered to floods in the river. Plate VI shows the method of construction adopted which is method (2). It necessitated the sinking of two concrete wells about 15 feet below water level. A greater depth was believed necessary but as time did not permit of sinking operations being carried further (it was already June) two units of staging forming a central pier for the service girders were built up on the wells as they then stood. As was proved later, 15 feet was insufficient to withstand the heaviest floods but at the time of construction it was hoped that the 257 feet span would be fully erected on bolts and drifts before the monsoon broke. This unfortunately was not so, as will be described later.

Staging.—All material had to be lowered on to the river bed (some 60 feet below Rail Level) and erected by means of derricks. See photos, plate VI.

Service spans.—The heaviest girder section was about $4\frac{1}{2}$ tons. Each section was lowered on to the river bed, hauled into position on rails, assembled on drifts and bolts and then raised with two derricks to the top of the staging. The pier-ends of the girders were supported in recesses built into the masonry of the piers and the staging-ends on cross girders secured to the tops of the staging units. Before damage was caused by flood that is during the first attempt at erection, the service spans were in two separate units of three girders each. In the second and successful attempt the spans were erected as before, that is as two units, but special members were added over the staging supports after erection to make the girders continuous. It was thought that this would prevent distortion of the main 250 feet span if any displacement occurred to the staging during erection.

After the erection of the near service span, cross girders carrying 40 feet spans longitudinally were bolted to the top booms. These 40 feet spans (placed end to end) carried the broad gauge track for the steam erection crane. The 2nd system of service girders spanned the water channel which necessitated the building of a temporary rail bridge on which the service girders could be assembled before erection. The girder sections were lowered piece by piece from the staging end of the first service span and erected in a similar manner to that of the first span, each girder in turn being lifted and placed in position by derricks.

Erection of 250 feet span.—Each member of this span was brought up from the dump seven miles in rear of the bridge by material train, the members on arrival being taken by crane to site and placed in position on the service girders. The bottom booms were first laid and then the floor system and afterwards the other members in the following sequence, the joints being made with bolts and drifts.

(1) Vertical struts.
(2) Diagonals.
(3) Top booms.
(4) Portal, sway and lateral bracings.

The process is clearly shown in plate VI.

Rivetting was then taken in hand.

Dismantling.—The service girders were first removed and lowered bodily on to the river bed, cut up into short sections and raised to rail level by the crane and loaded into trucks. The staging was next dismantled, lowered to the river bed and dealt with similarly.

Damage caused by floods.—The erection of the staging and service girders was begun on June 9th, 1927, the date on which the temporary piers were completed. During the ensuing three weeks work was carried on by night as well as by day in an effort to complete erection from the river bed before the occurrence of floods. Unfortunately the monsoon broke early and on the morning of the 6th July heavy rain fell and worked such serious damage to the cuttings and embankments between the steelwork dumps and the river that all further work became impossible. Trains could not bring up material and as there was still a part of the main 257 ft. span lying seven miles in rear of the bridge, all work had necessarily to stop.

On 25th July the river rose 20 feet and scoured out and tilted the temporary piers damaging the superstructure. After careful inspection it was decided to dismantle all the erected work and save as much material as possible before floods of a more formidable character could cause worse damage. On 1st August, 1927, when about 50 per cent. of the floor system of the 257 feet span had been salvaged the river rose 40 feet and carried everything before it. This put a stop to all further work until after the rains.

In October, 1927 the erection was started again and completed in three months.

The Reond Arch on the Kangra Valley Railway.—The Reond steel arch bridges a deep precipitous nallah with almost vertical sides rising to about 200 feet above the river bed, and spans, with the two forty-feet approach spans, an opening of 260 feet.

The arch is of the three pin spandrel braced type, 180 feet centre to centre of bearings, having a rise of 31 feet to the crown and is designed for a single line metre gauge loading although the floor system is arranged at present to suit the 2′-6″ gauge of the line.

An interesting and notable feature is that this arch is believed to be the first of its type to be constructed in India.

Alternative methods of dealing with the problem of bridging the Nallah.—Five methods of dealing with this problem are immediately evident:

(1) Filling in the gorge and providing an opening for the maximum flow in the Nallah which was comparatively small.
(2) Spanning with plate girders supported by steel trestles.
(3) Spanning with triangulated girders.
(4) Spanning with a steel arch.
(5) Spanning with a reinforced concrete arch.

Method (1) was ruled out probably on account of the amount of earthwork and the time required to consolidate and render it safe in the rains.

Method (2) The cost of the steelwork exceeded that of method (4) described below.

Method (3) The cost of the erection of falsework was considerable on account of high transport charges to site and the weight of permanent steelwork was double that of method (4).

Method (4) This called for the least weight of steelwork and had the advantage of rapid erection and general suitability for the site.

Method (5) This was ruled out owing to the long time required for erection.

Method (4) was adopted and a three-pin type of arch designed in preference to other types on account of the large annual temperature variation and also because the bridge is situated within an area subject to earthquake disturbances.

The steelwork which was fabricated in India had to be delivered at short notice. The design included many sections which were not being rolled in India and could not be obtained quickly from England on account of the Coal Strike. Other sections, therefore, had to be accepted, which resulted in an increase in weight and a less economical distribution of steel in the compression members.

In order to save the cost of temporary foundations or scaffolding and to make use of the contractor's existing cranes, the span was completely erected in the contractor's yard with the arch ribs lying in a horizontal plane. Main dimensions were then taken with an invar tape at known temperatures for reference during final erection which was carried out by cantilevering from each abutment using temporary bars as tie-backs which incorporated a toggle joint for final adjustment during closure of the arch.

A temporary ropeway and traveller were used for carrying out and placing the members, the power required for both traversing and lifting being provided by hand winches. The weight of the heaviest member to be lifted in each main girder was 3 tons. See plates VII and XI.

Special methods were used to set the end bearings to the correct centres as given by shop measurements and calculations. The bearings were mounted on adjustable frames embedded in the partly finished reinforced concrete anchor blocks and after the necessary adjustments had been made, the reinforcement was placed and the anchor blocks finally concreted.

When all main members had been erected, the central pins were placed and the winches working the toggle gear were operated to lower the two cantilever arms until the total dead load horizontal thrust was being taken through the central pin. The floor system and 40 feet approach spans were then erected and the bridge completed.

The calculations on which the various adjustments for camber and deflection were based and a description of the methods of carrying out the adjustments are given in Selected Engineering Paper No. 82 of 1929 published by the Institution of Civil Engineers.

ATTOCK BRIDGE.

This bridge originally consisted of five spans having parallel chords and double web systems as shown in figure 1, plate XII, the original trestle piers being of wrought iron. The girders were twenty-six feet in depth and carried the railway track on a flooring system attached to the top boom and the highway twenty-two feet below the railway track. The clearance below the girders was one hundred feet above low water level.

In 1921, following the policy laid down by the Railway Board for increasing the capacity of important bridges on the system, this bridge came under investigation. From analysis, and test, overstresses were found to exist, the most serious being in the main girders of the river spans and it was found to be un-economical to strengthen these spans satisfactorily to enable them to carry the proposed heavier loading. The following temporary relief measures were carried out :—

(1) The speed of all trains was limited to five miles an hour and to single engines of specified types followed by rolling stock not exceeding 1·4 tons per foot run.

(2) Heavy road traffic and trains were not allowed on the bridge at the same time.

(3) The dead load of the metalling on the roadway was reduced by substituting timber blocks.

(4) The L/r (slenderness ratio) of the vertical web member struts in the plane of their least radius of gyration was halved by providing continuous horizontal members extending from one end of the girder to the other in the plane of the span and located midway on the struts, to which the horizontal members were securely rivetted.

(5) . The diagonal web ties near the centre of the girders were converted into stiff compression members by rivetting angles and lacings to the existing flat bars, the latter being bowed out sufficiently to take out all distortions.

This enabled the bridge to carry the loads mentioned until a definite scheme of re-construction had been decided on.

Four alternative schemes for the renewal and strengthening of the bridge were prepared and considered. General outlines of these schemes are as follows :—

Scheme "A".—This consisted of strengthening the existing bridge by the addition of new main girders outside the existing spans ; retaining the old materials and encasing the existing iron trestles in concrete piers. This scheme provided for a single track and for retaining the present 14 feet width of highway. The scheme had the demerit of limiting the bridge to single track working as it would not be feasible eventually to provide a double track and retain the old material.

The estimated cost of this scheme was Rs. 24 lakhs and the approximate weight of new steelwork 3,000 tons.

Scheme "B".—This consisted of entire renewal of the existing bridge by erecting new steel main girders outside the existing spans ; the new girders were to be supported on piers similar to those in Scheme "A" and spaced 31′-6″ centres so as to provide sufficient width for a double track bridge. A new roadway was included with a clear width of 19 feet. This scheme necessitated tying up capital for an indefinite period for which there was no justification as a double track would not be required for many years. The estimated cost of the scheme was Rs. 39·5 lakhs and the approximate weight of steelwork 6,500 tons.

Scheme "C".—Consisted of a cantilever double track bridge with a centre span of 648 feet, centres of piers, and two anchor spans of 216 feet each and a land span of 150 feet at the Attock end giving a total length of 1,230 feet and sited 250 feet downstream of the existing bridge, the latter being retained for highway traffic only.

The estimated amount of steelwork required was 7,500 tons. The piers were to be of concrete founded on rock which exists on the site selected.

The estimated cost of this scheme was Rs. 49 lakhs.

Scheme "D".—(The scheme actually adopted). See plate XII.

This consisted of the renewal of the two existing 308 feet spans over the main water channel by erecting new steel main girders outside the existing spans and supported on concrete piers built up round the existing trestles, the girders spaced at 28 feet centres and, although only proposed for a single track in the first instance, the clearances are such that a double track can be provided at a future date by duplicating the girders and re-arranging the flooring system.

The three smaller spans each of 257 feet were retained and converted to continuous girders by the erection of a central pier, reinforcing the main members where necessary and remodelling the flooring system. All the new piers were designed to be suitable to accommodate double track spans.

The total weight of steelwork is 3,100 tons excluding the weight of the service gear for which credits are allowed. The total cost of the scheme was estimated as 24·89 lakhs.

Scheme "D" was accepted by the Railway authorities and the Consulting Engineers as being the most suitable one on financial grounds and providing for immediate single track requirements, with facilities for conversion to double track when that is justified.

The re-construction work falls under three distinct heads :—

(1) Pier and Foundation work.
(2) Remodelling of three 257 feet land spans.
(3) Erection of two new 304 feet river spans.

Pier and Foundation work.—A start was made on the temporary works during the autumn of 1925. Block yards with siding and crane equipment were erected on both river banks. A workshop and compressor plant were also erected on the left bank and these served the whole works.

Material for pier work was delivered at site by rail, the sand and shingle being received in hopper wagons discharging through special chutes erected at each abutment.

The pier work included the construction of new main piers Nos. 1, 2, 3 and 4 around the existing trestles and three intermediate piers A, B and C under each of the 257 feet spans, *vide* plate No. VIII, photo No. 1.

The main piers Nos. 2, 3 and 4 were provided with reinforced caps to accommodate the new river spans. The excavation of the pier foundations was carried down well into the rock, and filled with cement concrete of 1 : 2½ : 5 mixture with 15 per cent. boulder plums.

A cofferdam of steel sheet piling was constructed for founding the tail water end of pier No. 3 on rock situated below water level in mid stream.

All piers were built up with a core of mass concrete faced with pre-cast block work in one ton units. Air operated hoists on special jib cranes attached to the girders were employed throughout for lifting mixed concrete and blocks. Material for the island pier was supplied by means of a boat bridge during the winter months and by ropeway during the flood season.

Remodelling of three 257 feet land spans.—The main girders were strengthened by converting them to continuous spans by the addition of a central pier. By this means the chord stresses were reduced to the permissible value under the increased loading. The web system was remodelled to suit the re-distribution of stress. Direct staging of standard interchangeable type was erected under the spans in order to relieve the main girders of dead load deflection and live load stress in the bays where the strengthening was carried out.

A service frame was used during the changing of vertical members designed to provide temporary support to the chords and to transmit live load from the Railway floor system direct to the staging.

During operations on the main girders, the rail bearers were replaced by duplicated R. S. J. type stringers and each intermediate rail cross girder was strengthened by the addition of an auxiliary girder below it. Upper and lower lateral bracings were also added and the highway was re-surfaced with bonded concrete 4½ inches thick above the top of the trough plates.

Erection of new 304 feet spans Nos. 3 and 4.—These spans were erected by building out as cantilevers from the piers towards the centres of the spans. The anchor arms for the left half of new span No. 3 and the right half of new span No. 4 were provided by existing spans No. 2 and 5 respectively while the right half of span No. 3 and the left half of span 4 were erected so that one half balanced the other as far as possible during erection.

The new girders are spaced at 28 feet centres and were erected outside the old girders which were spaced at 18 feet centres. The new panel lengths were so arranged to enable the new top floor beams to be threaded in between the old work. In this way the new main girders were completely erected as a framed structure before the existing spans were interfered with.

The two cantilevers of each span were joined up as follows :—

The cantilevers were erected so that the noses were at a higher level than required for camber and the initial settings were such that a small gap remained at mid span when the closing bottom chord member had been placed in position. Span No. 3 was closed first as follows :—

Span No. 2 together with the left half of span No. 3 being entirely supported on roller bearings was jacked forward towards pier No. 3 until the small gap referred to above had been taken up and a few drifts and bolts were inserted in the holes of the open lower chord joint. The screw gears were operated in the struts in pier No. 3 (figure 10, plate XIII). This caused small rotation in the plane of the girders of all new work erected from pier 3, the right half of span No. 3 being depressed and the left half of span No. 4 being raised. Simultaneously with the operation of the screw gears, the effective length of the struts in pier No. 2 was shortened by operating mechanical jacks incorporated in these struts. When the two cantilevers of span No. 3 had been lowered sufficiently by these means, all holes in the closing bottom boom joint were filled.

The closing top chord member was then inserted and at this stage a small gap remained at the closing joint. The steelwork built out from pier No. 3 was then given a degree of freedom by releasing the location gears (figure 11, plate XIII) in the tunnels in pier No. 3 to allow the steelwork to rotate freely in the plane of the girders. The jacks in struts of pier No. 2 were then lowered until they became free thus causing the small gap at the centre of the top chord of span No. 3 to be taken up. The closing joint was then bolted up making span No. 3 a complete structure acting as an anchor arm for the left half of span No. 4.

Span No. 4 was closed in a similar way. The right half was lowered by operating the jacks in the struts in pier 4 and the left half was lowered by operating the wedge gears (figure 12, plate XIII) which caused a shortening of the main struts in the tunnels in pier No. 3. The sub-structure and other temporary material was designed in such a way that it could be readily used up as 20, 30 and 40 feet standard spans after fulfilling its temporary function.

Upon completion of the new main girders, the existing spans were raised by jacks operating from the new girders sufficiently to remove about half their dead load deflection. Working from the ends of the spans towards the centres, the existing rail stringers were removed and new ones were erected on the new girders. After the Railway floors had been dealt with, the old top chords and web systems were removed.

Changing the roadway floor was carried out as follows :—

The existing roadway complete with bottom booms was raised about 4 feet (in sections) and a ramp was provided at each end to pass traffic. The steelwork including troughing was then erected and a 14 feet width of new road concreted underneath the existing roadway. The existing roadway was then removed and the concreting of the new roadway completed.

For a complete description of the erection of this bridge, reference may be made to the proceedings of the Institution of Civil Engineers, Volume 229, dated 1930.

PARTICULARS OF THE BRIDGES MENTIONED IN THE PAPER.

Alexandra Bridge—Lahore-Rawalpindi Line, 17 Spans.

138′-9″ centres of bearings.

Weight of one span=142·67 tons.

Maximum lift by two cranes during erection=Weight of one girder =40.10 tons.

Total weight of steelwork in bridge = 2425·39 tons.

Jhelum Bridge—Lahore-Rawalpindi Line.

50 spans 94′-6″ centres of bearings.

Weight of one span=87·84 tons.

Maximum lift by two cranes during erection=
Weight of new central girder=23·9 tons.
Weight of one old girder after strengthening=22·1 tons.

Total weight of steelwork in bridge of 50 spans = 4392·00 tons.

New Jhelum Bridge—On Chiniot-Khushab Line.

15 spans 153′-0″ centres of bearings.

Weight of one span = 440·00 tons.

Weight of one girder = 59·50 tons.

Weight of steelwork in bridge of 15 spans = 6600·00 tons.

Ferozepur Weir—On Raewind-Bhatinda Line.

36 spans 65′-2″ centres of bearings.

Weight of one span = 30·75 tons.

Weight of one girder = 12·83 tons.

Weight of steelwork in bridge of 36 spans = 1107·00 tons.

Baran Bridge—On Karachi-Kotri Line.

24 Up and 24 Down spans 63′-6½″ centres of bearings.

Weight of one span = 31·94 tons.

Weight of one girder = 14·38 tons.

Weight of steelwork in bridge of 48 spans = 1533·12 tons.

Empress Bridge—On Samasata-Lodhran Line.

Eight double track spans 258′-0¼″ centres of bearings.

Weight of one complete new span = 709·2 tons.

Weight of steelwork in complete new double track bridge = 5673·6 tons.

Banganga Bridge—On Kangra Valley Railway.

Four spans 62′-4″ centres of bearings and one span 257′-0″ centres of bearings.

Weight of one span 62′-4″	=	22·70 tons.
Weight of one 257′-0″ span	=	323·00 tons.

Reond Arch Bridge—On Kangra Valley Railway.

Rise 31′-0″ and span of steel arch = 180′-0″

Weight of steelwork in arch	=	259·00 tons.
Maximum lift required by ropeway	=	3 tons.

Attock Bridge—On Rawalpindi-Peshawar Line.

Three spans 257′-0″ centres of bearings.

Weight of one girder	=	138·88 tons.
Weight of one span	=	469·60 tons.

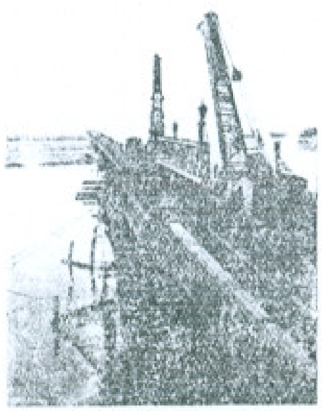
2 spans 304 feet centres of bearings.

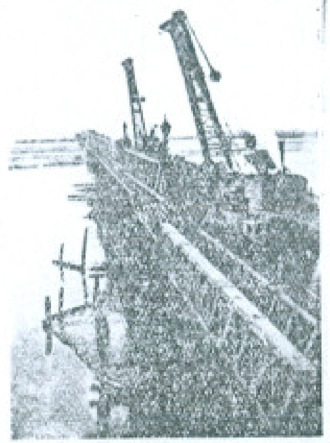
Weight of one girder	=	321·57 tons.
Weight of one span	=	1151·50 tons.

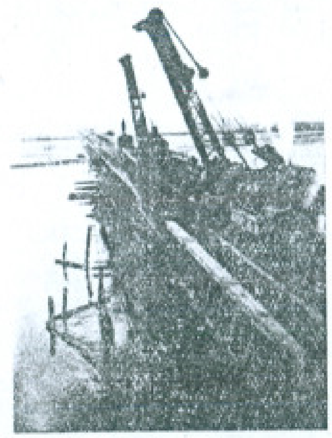
PAPER Nº 144.

JHELUM BRIDGE – ROLLING IN A NEW SPAN

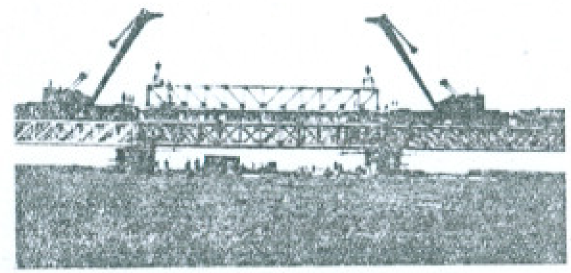
PLATE II



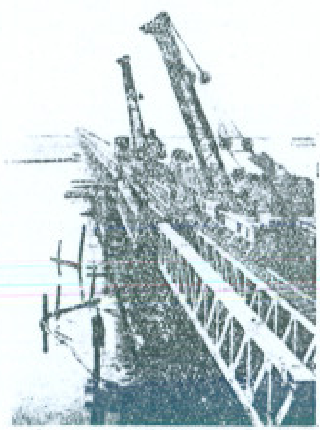




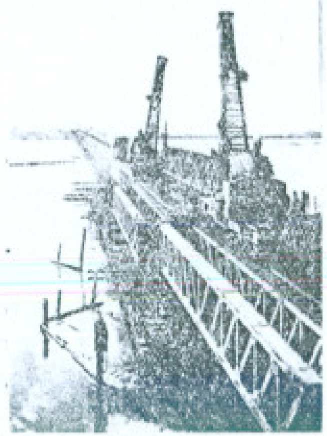
1, 2, & 3 OLD UPSTREAM GIRDER BEING LIFTED AND NEW SPAN BEING ROLLED IN HALF WAY



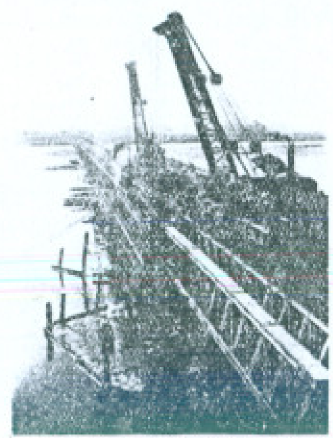
GIRDERS, BROUGHT TO SITE ON TRUCKS BEING UNLOADED ON TO STAGING



4. OLD UPSTREAM GIRDER SET ON STAGING.



5. CRANES LIFTING OLD DOWNSTREAM GIRDER.



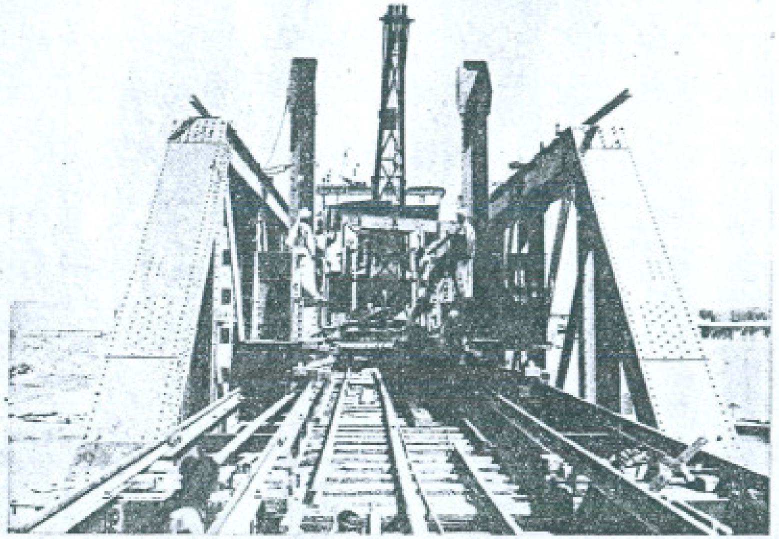
6. NEW SPAN ROLLED IN AND BEING JACKED DOWN ON TO BEARINGS.

HANDLING THE TROUGH DECKING

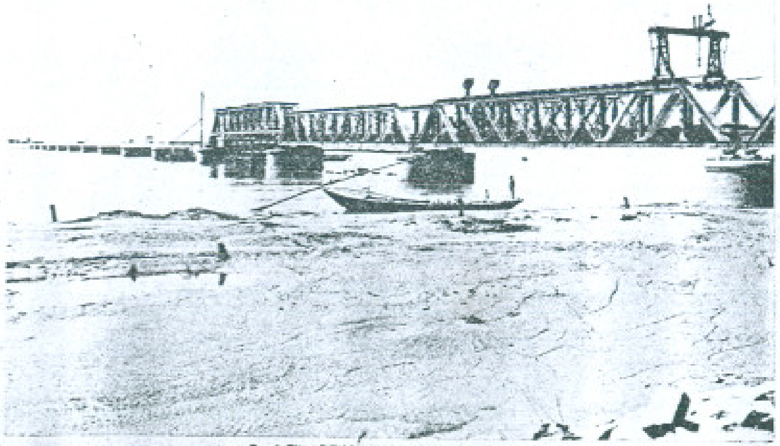
PAPER No 144.

NEW JHELUM BRIDGE ON C.K. RAILWAY

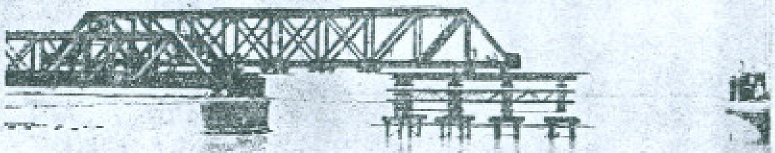
PLATE III



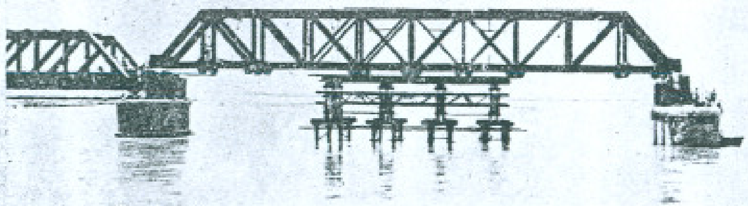
1. ERECTING 4TH SPAN ON FLOOR OF 3RD SPAN



2. 4TH SPAN LAUNCHED

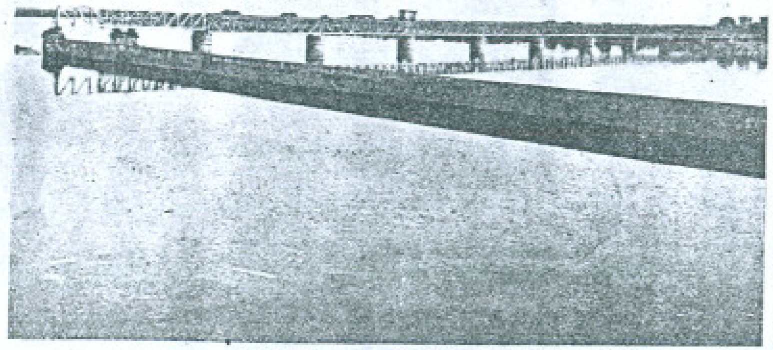


3. 1ST STAGE IN LAUNCHING

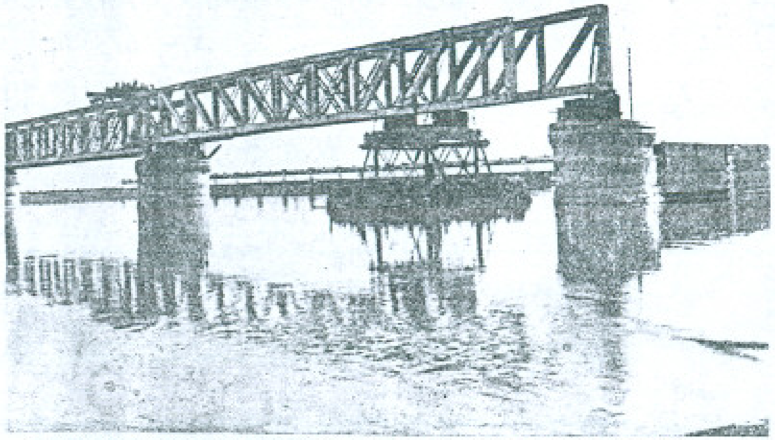


4. FINAL STAGE IN LAUNCHING

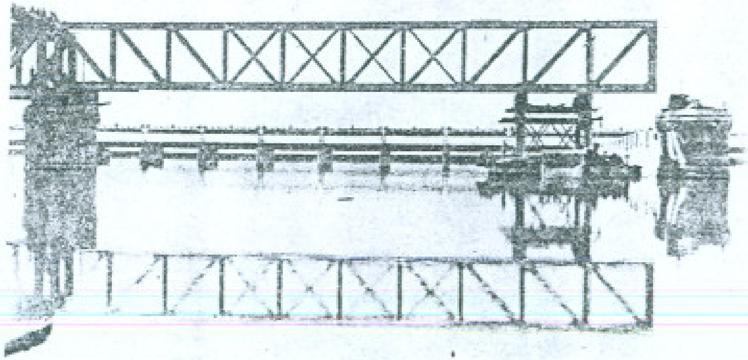
KAISER-I-HIND BRIDGE



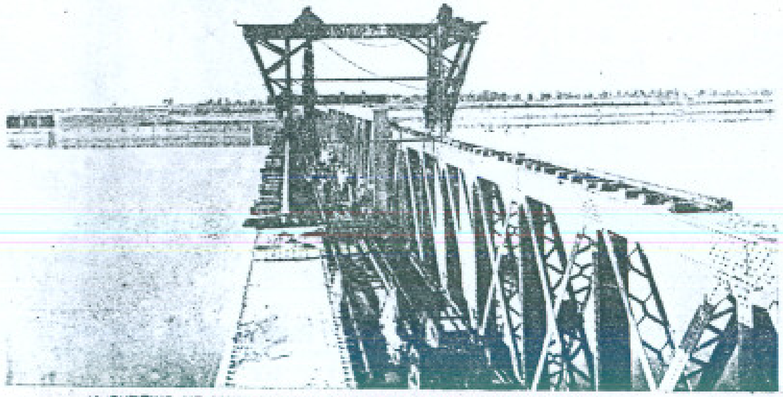
1. DISMANTLING KAISER-I-HIND BRIDGE



2. SUPPORTING GIRDERS OF DISMANTLED SPAN ON PONTOONS FOR FLOATING BACK

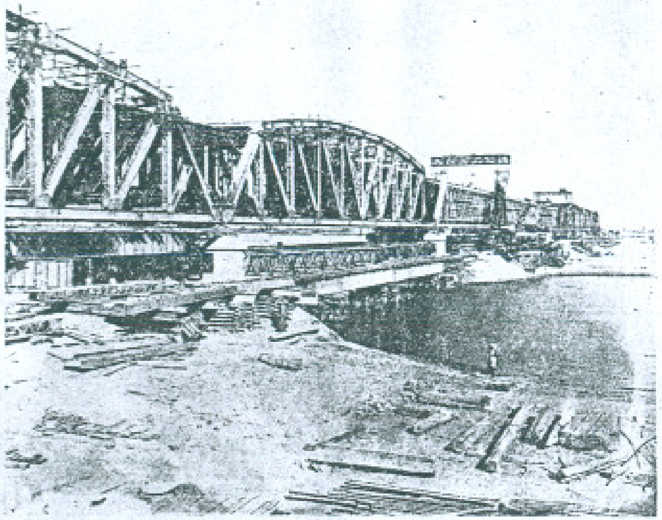


3. FLOATING GIRDERS BACK ONTO FLOOR OF ADJACENT SPAN FOR DISMANTLING

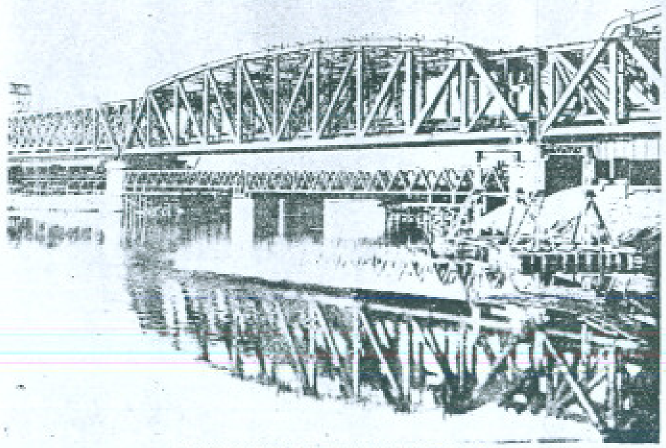


4. CUTTING UP MAIN GIRDERS. SHOWING GANTRY FOR LOADING

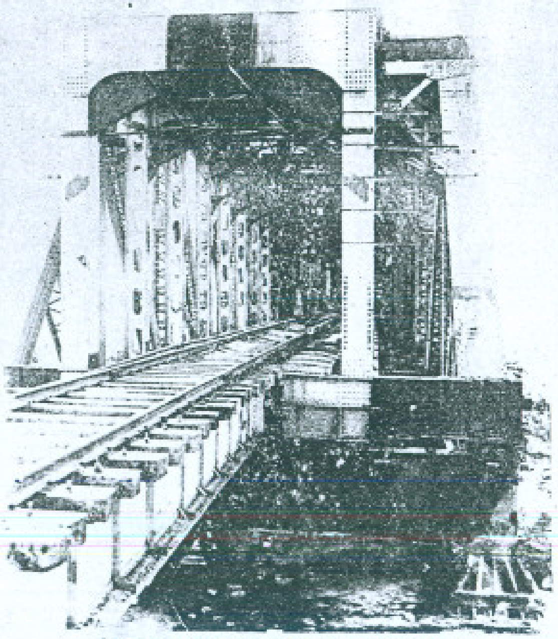
1. GENERAL VIEW OF ERECTION OF SPANS FROM BOTH ENDS OF THE BRIDGE



2. VIEW SHOWING STAGING & SERVICE GIRDERS

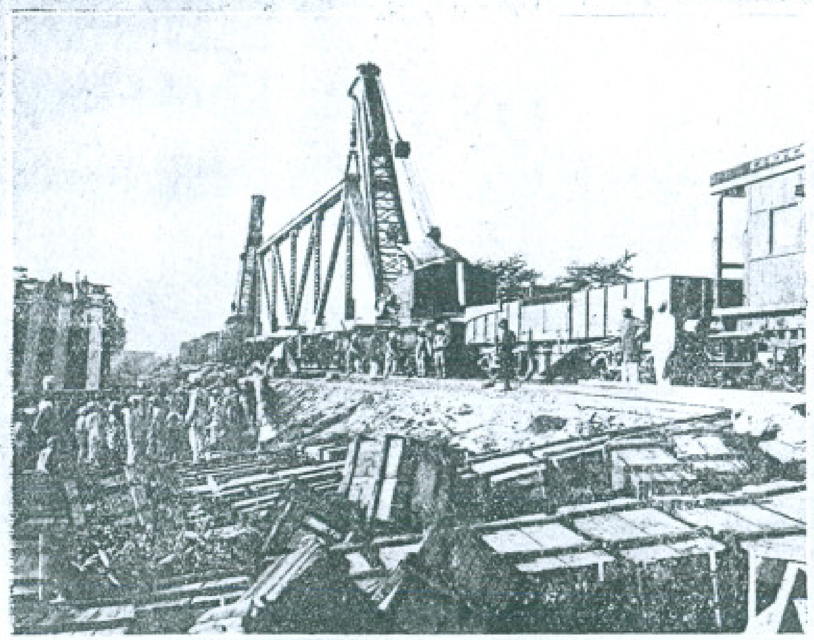


3. DISMANTLING OLD SPANS INSIDE THE NEW

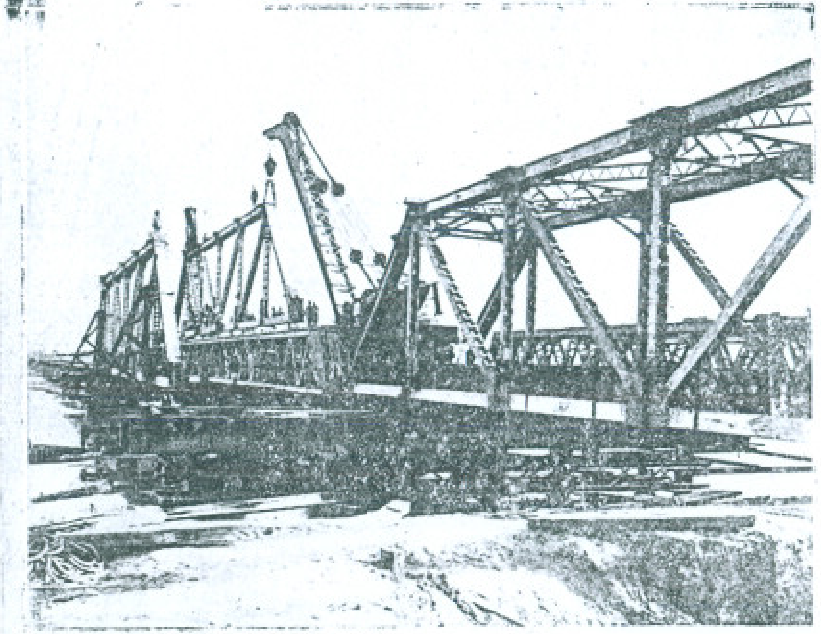


4. NEW SPAN ERECTED AROUND THE OLD STRUCTURE

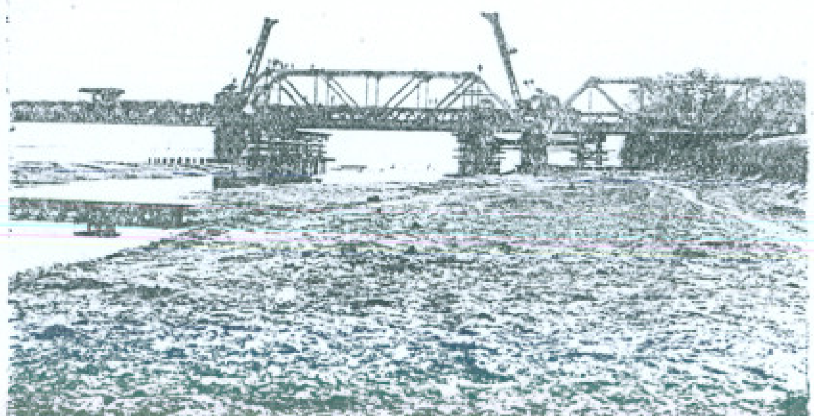
ALEXANDRA BRIDGE



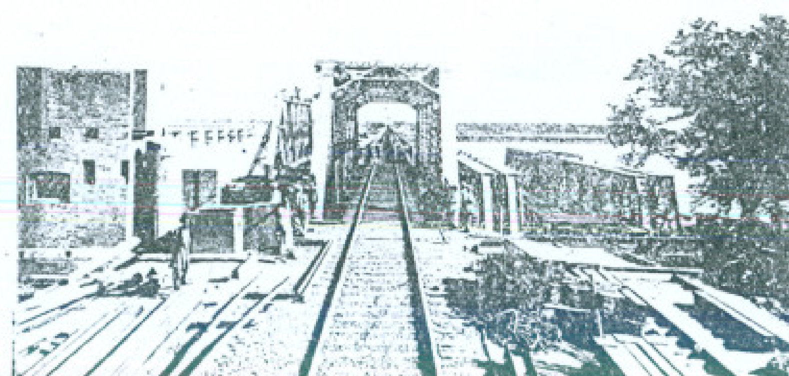
1. CARRYING NEW GIRDER FROM ASSEMBLING DUMP TO SITE.



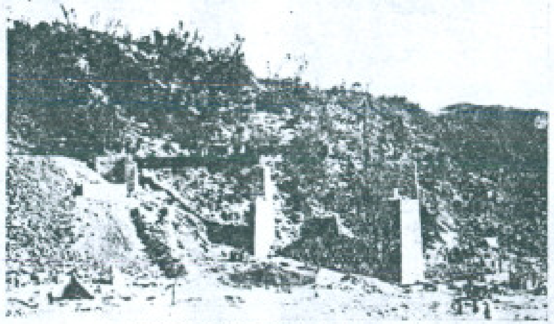
2. PLACING NEW GIRDER IN POSITION ON STAGING.



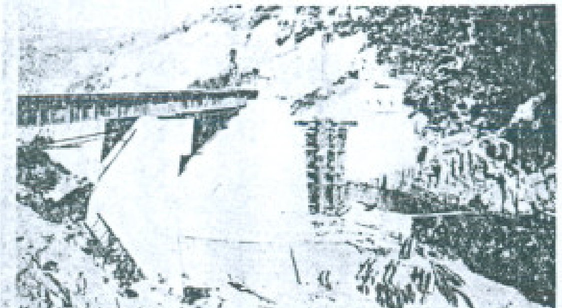
3. GENERAL VIEW SHOWING NEW & EXISTING SPANS & STAGING.



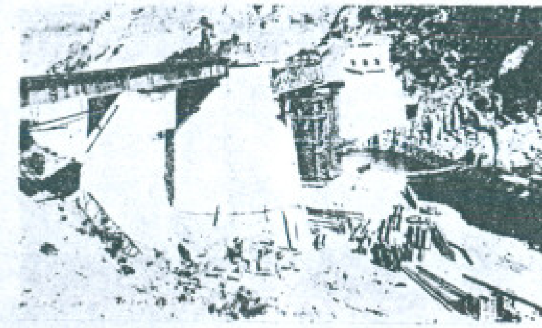
4. FIRST NEW SPAN IN POSITION AFTER SLEWING.



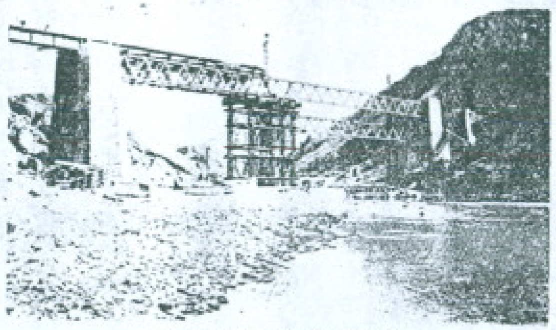
1 LAUNCHING ONE GIRDER OF 60 FT. SPAN



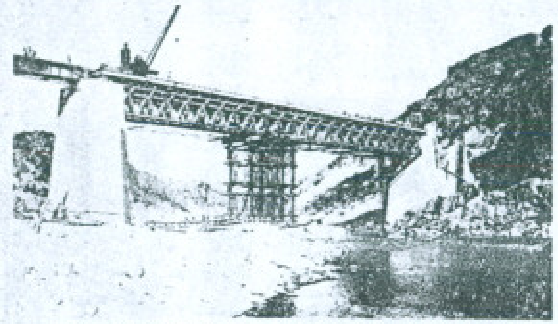
2. ERECTING STAGING FOR SERVICE GIRDERS



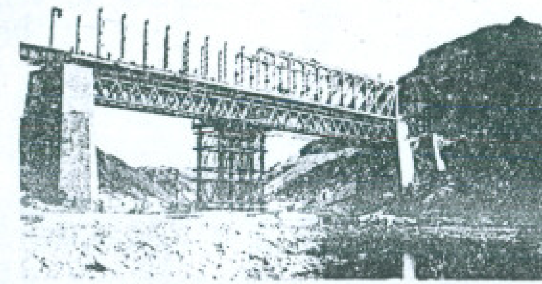
3. ERECTING SERVICE GIRDERS



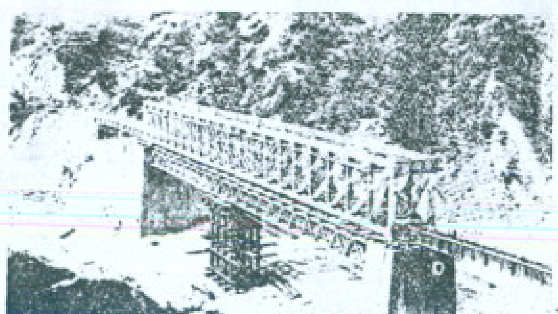
4. LIFTING SERVICE GIRDER



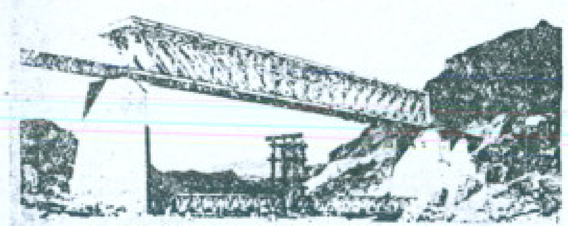
5. PLACING FLOOR AND BOTTOM BOOM OF 250 FT. SPAN



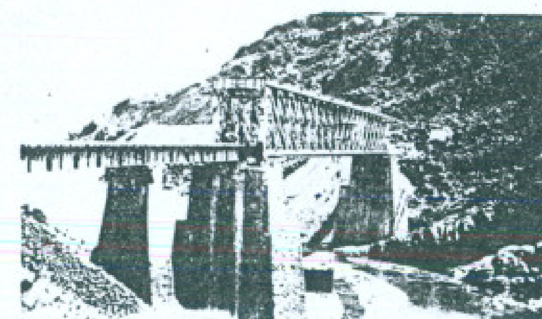
6. ERECTING MAIN MEMBERS OF 250 FT. SPAN



7. ERECTED 250 FT. SPAN

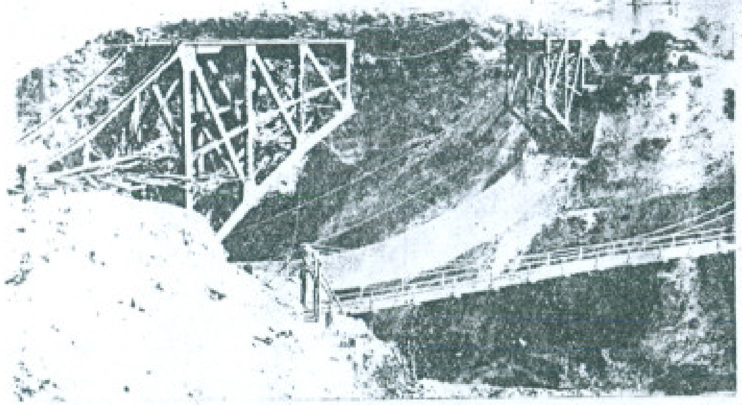


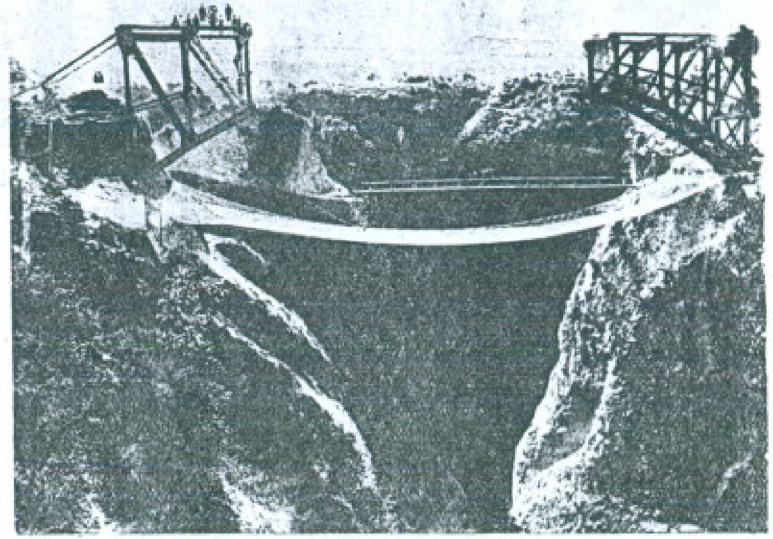
8. DISMANTLING SERVICE GIRDERS & STAGING

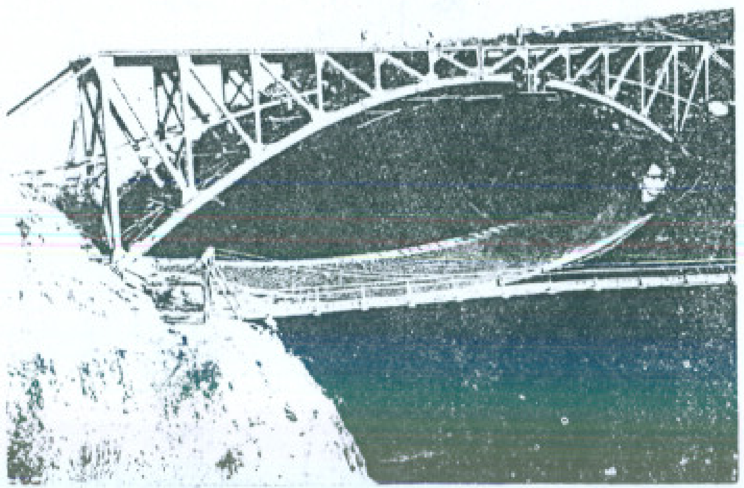


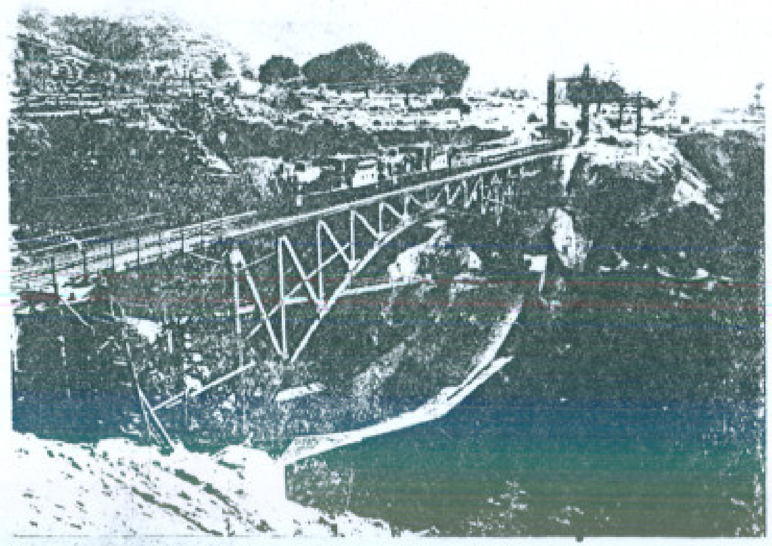
9. COMPLETED BRIDGE

PAPER No144. REOND ARCH PLATE VII


1 PARTLY ERECTED SPAN WITH TIE-BACKS AND TOGGLE JOINT


2 WORK IN PROGRESS

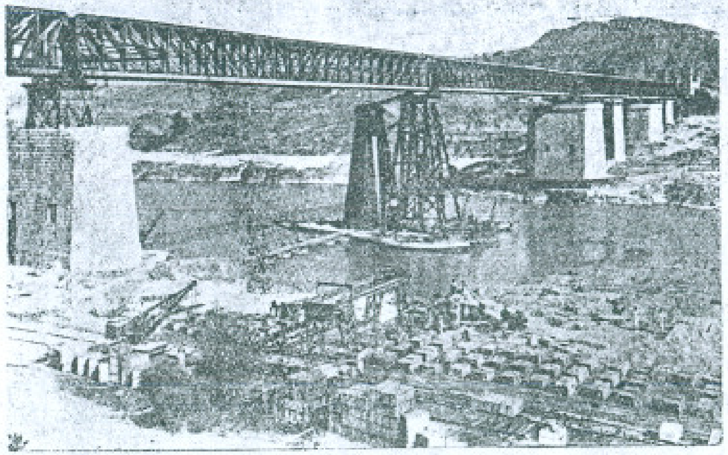

3 ARCH COMPLETED


4. ARCH BEING TESTED

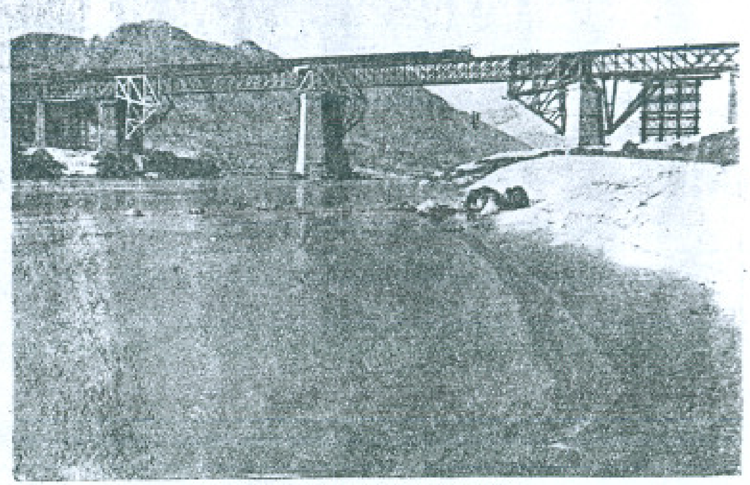
PAPER No 144.

ATTOCK BRIDGE

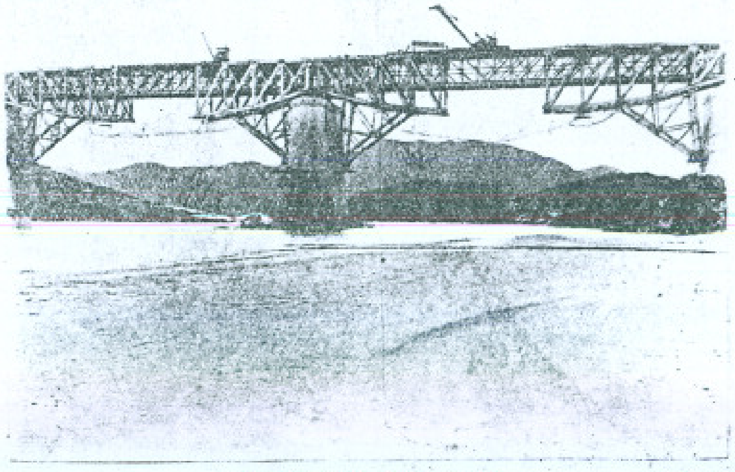
PLATE VIII



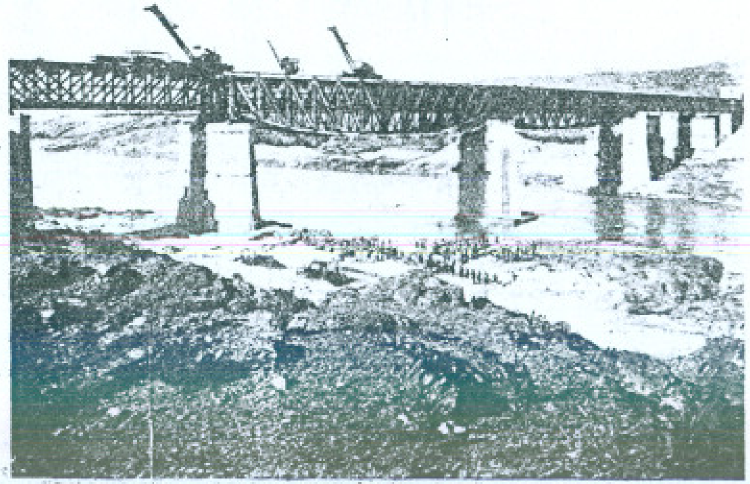
1. BUILDING CONCRETE PIERS AROUND EXISTING STEEL TRESTLES



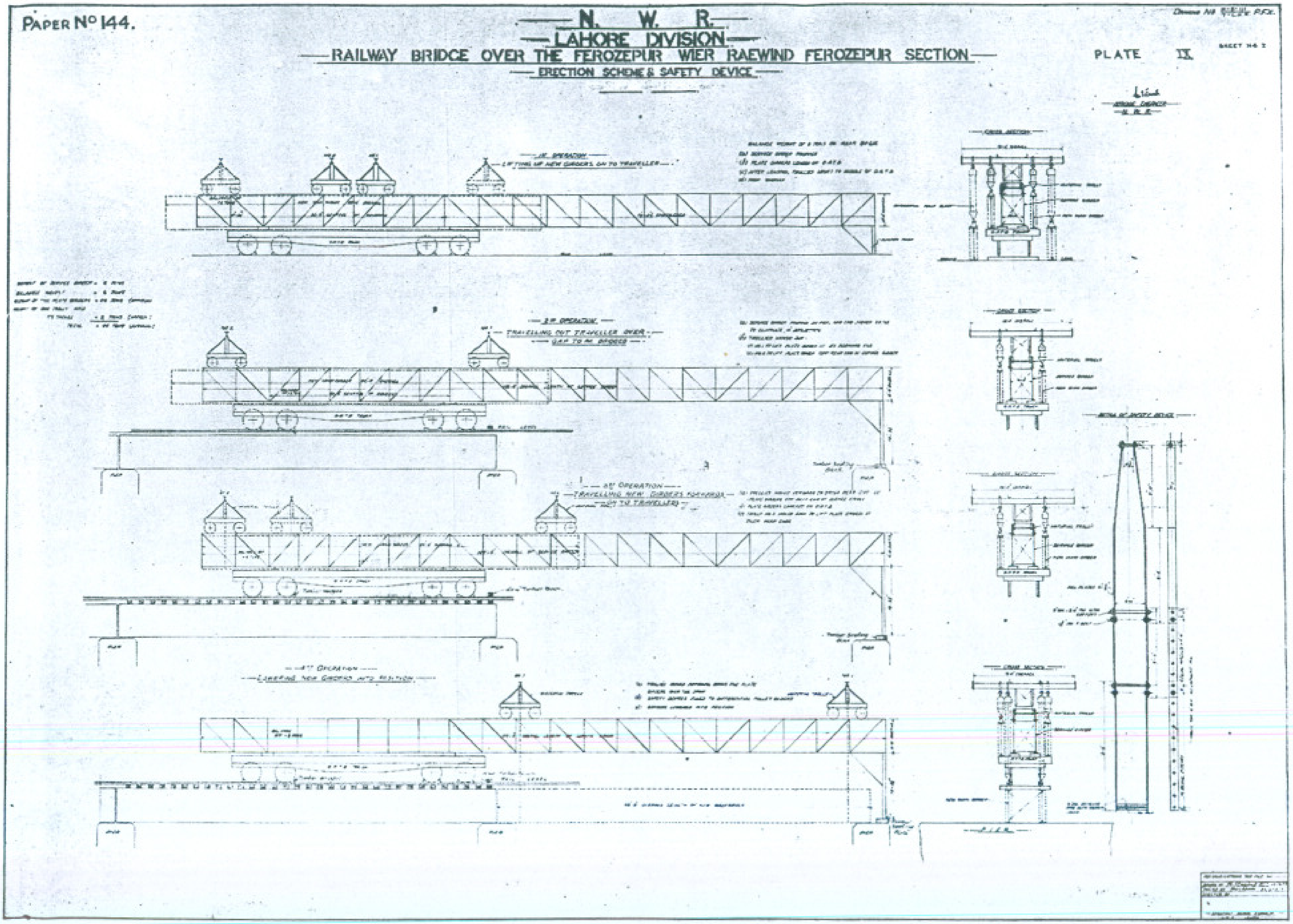
2. ERECTING THE 308 FT SPANS BY CANTILEVERING



3. ERECTION OF 308 FT. SPANS IN PROGRESS



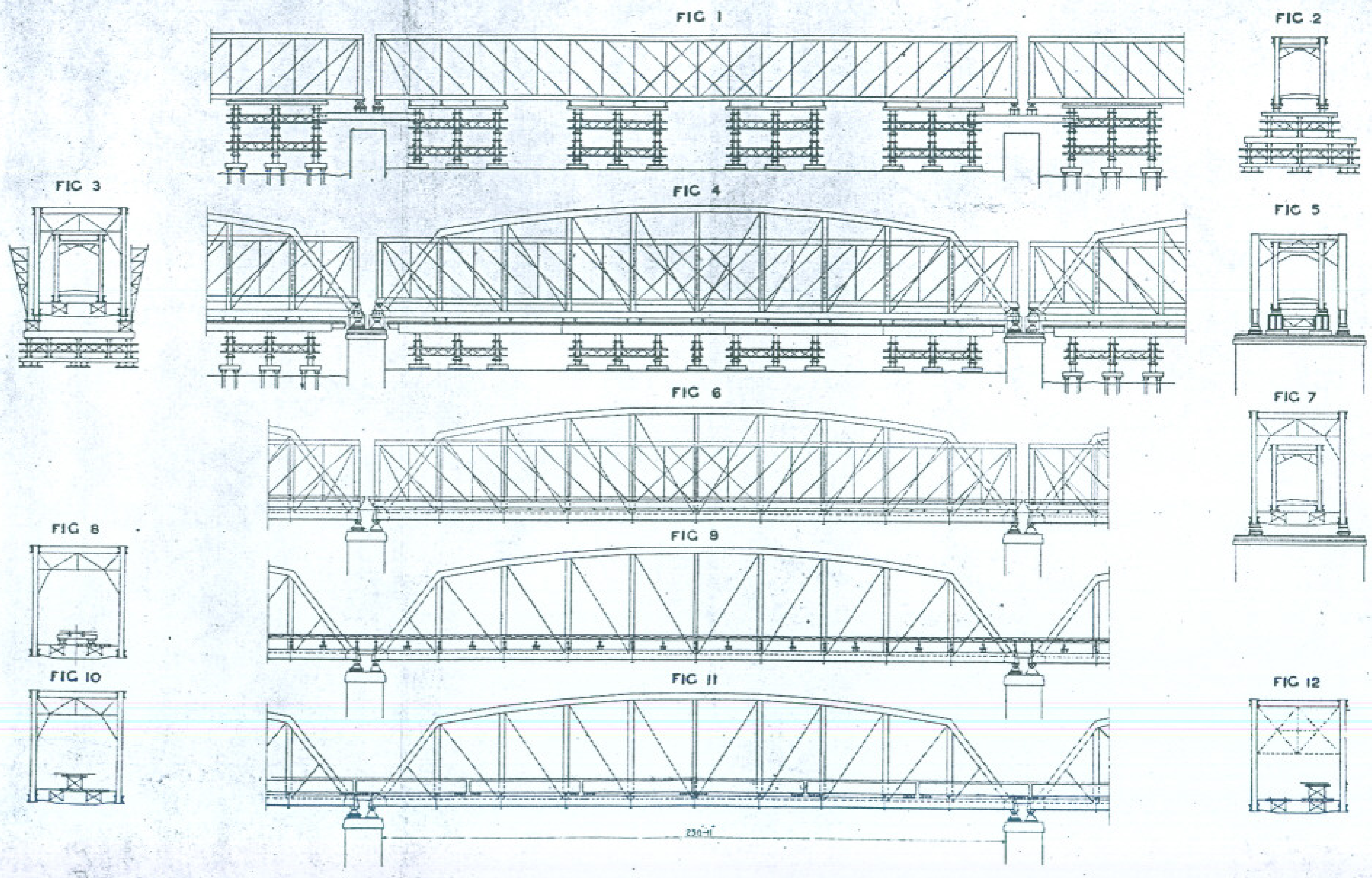
4. ERECTION OF 308 FT. SPANS COMPLETED


PAPER No 144.
N. W. R.
LAHORE DIVISION
RAILWAY BRIDGE OVER THE FEROZEPUR WIER RAEWIND FEROZEPUR SECTION
ERECTION SCHEME & SAFETY DEVICE
PLATE IX
1st OPERATION
LIFTING UP NEW GIRDERS ON TO TRAVELLER
2nd OPERATION
TRAVELLING OUT TRAVELLER OVER GAP TO NEW GIRDER
3rd OPERATION
TRAVELLING NEW GIRDERS FORWARD ON TO TRAVELLERS
4th OPERATION
LOWERING NEW GIRDERS INTO POSITION
DETAIL OF SAFETY DEVICE
CROSS SECTION

PAPER No 144.

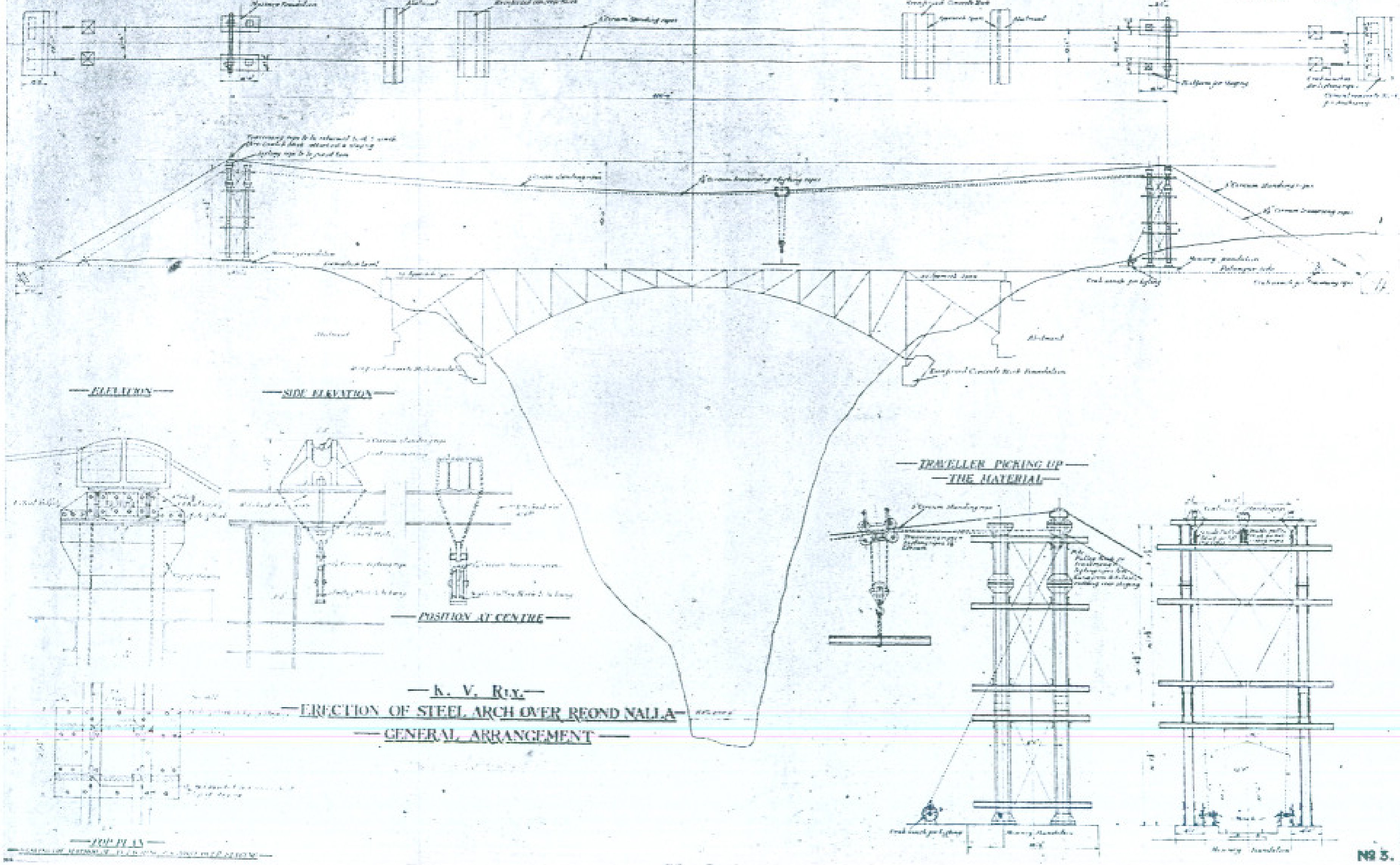
ADAMWAHAN DOUBLE TRACK BRIDGE
ERECTION SCHEME

PLATE X



PAPER No 144.

PLATE XI



— K. V. Rly. —

— ERECTION OF STEEL ARCH OVER REOND NALLA —

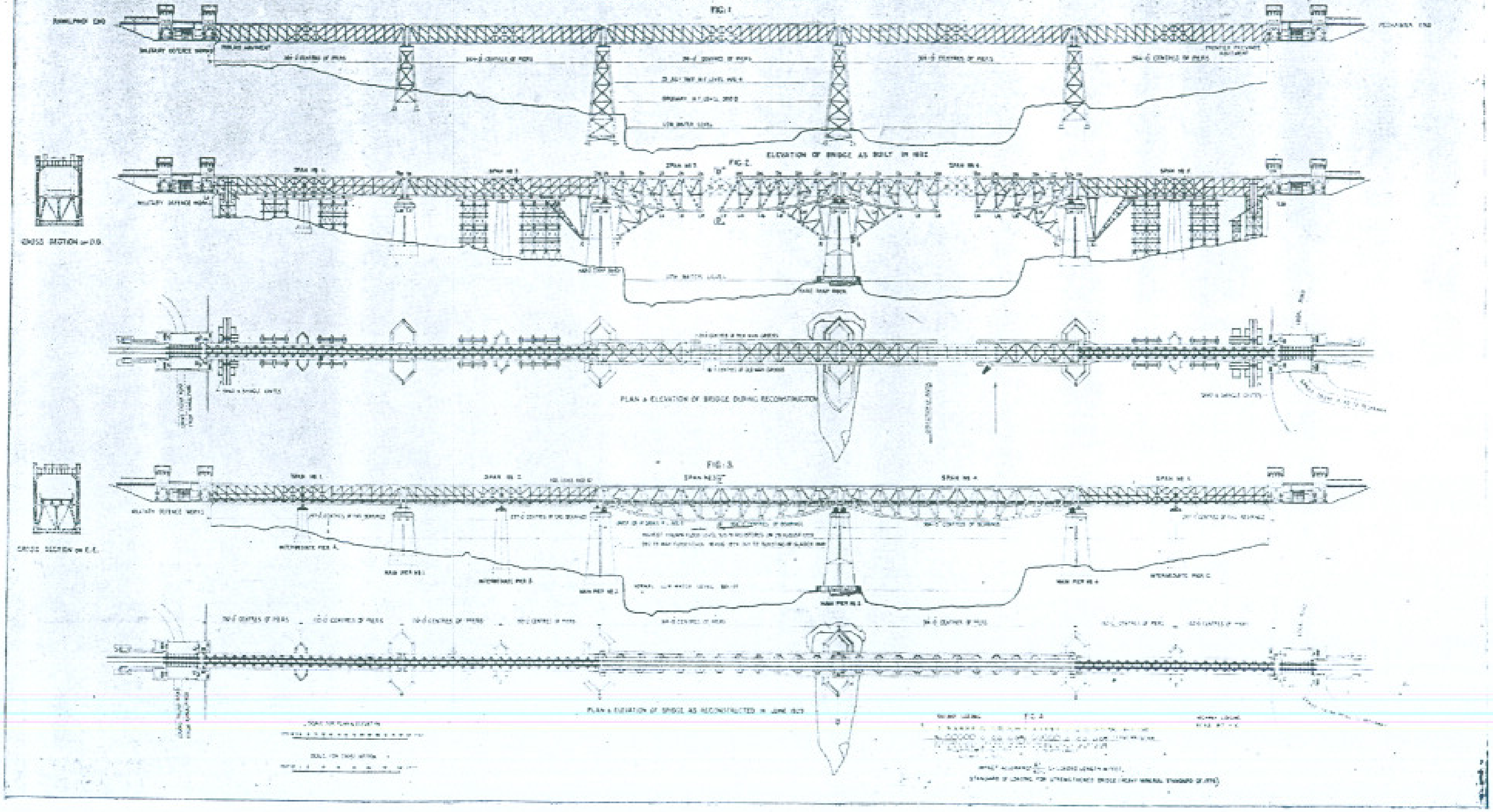
— GENERAL ARRANGEMENT —

No 3.

PAPER No 144.

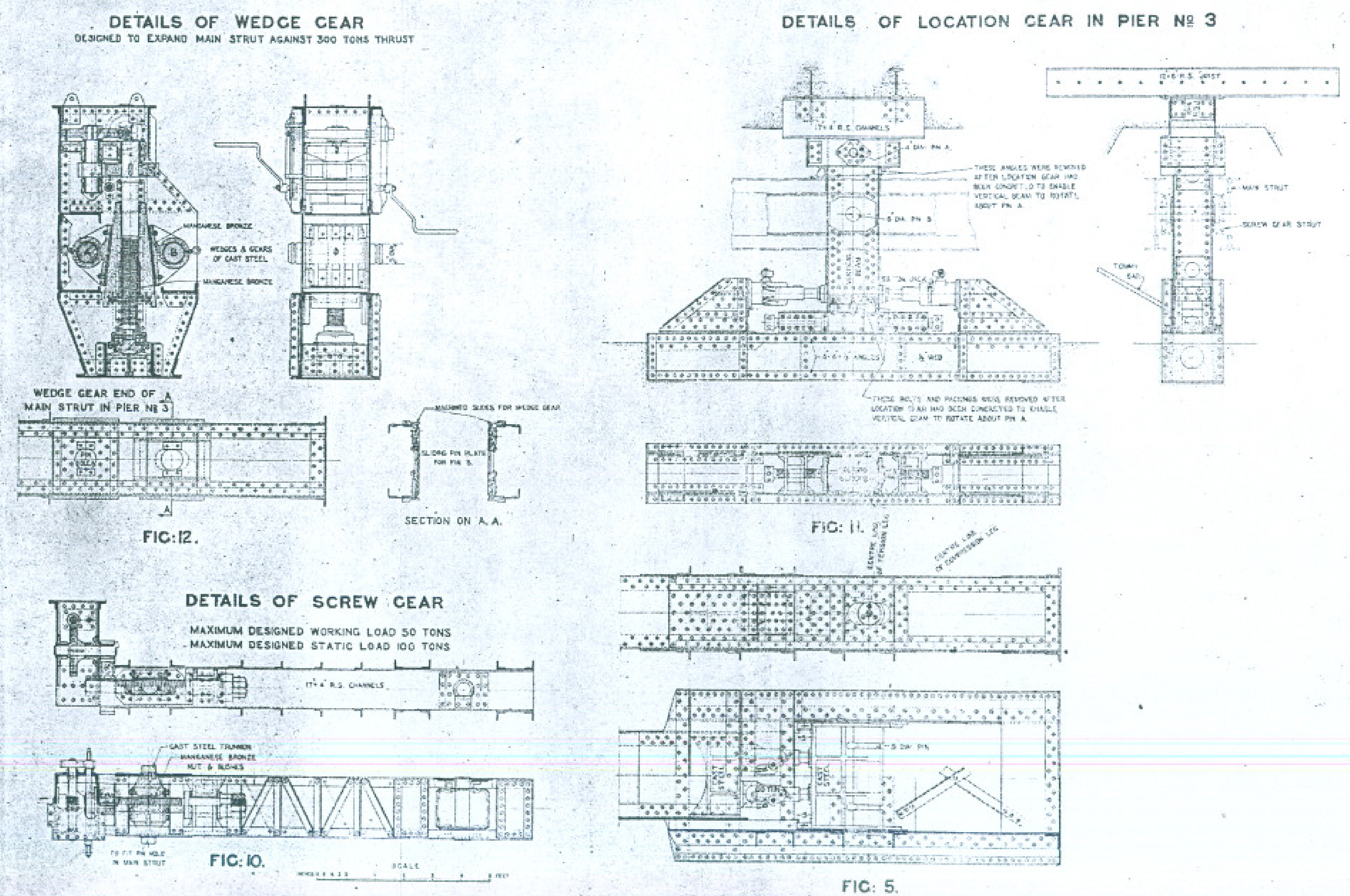
THE RECONSTRUCTION OF THE ATTOCK BRIDGE ACROSS THE RIVER INDUS ON THE NORTH WESTERN RAILWAY INDIA

PLATE XII



PAPER Nº 144.

PLATE XIII



DISCUSSION.

Mr. W. T. Everall in introducing the paper on behalf of Major Carson, remarked that the author of this excellent paper on "Recent Practice in Girder Erection on the North Western Railway" was unfortunately not present with the members and he had asked the speaker to sponsor the paper for him and reply, if possible, to questions raised in the discussion.

The speaker might be able to do so, as he had been associated in one form or another, with all the bridge schemes and their execution, referred to in the paper.

The subject dealt only with the superstructure of bridges and it was only in connection with the requirements for supporting staging and erection facilities that foundation and supporting methods were mentioned.

The paper itself gave an excellent review of some of the methods adopted in recent years for the regirdering of railway bridges or their strengthening, where conditions for the running of trains had to be maintained throughout the work.

The latter condition was primarily the ruling factor which determined the method of erection, and to some extent the design of the superstructure itself. This would be appreciated when it was realised that the erection and changing of important members, or the actual renewal of a whole span had frequently to be accomplished in a matter of two or three hours, the limit of time the section of the line could be blocked for the running of trains, and also the precautionary measures which had to be taken to safeguard the travelling public.

The members would probably have noticed in the illustrations, the steel staging which formed the support for many of the bridges. A brief description of this staging might be of some interest to them.

In connection with an extensive programme of bridge construction and renewals, extending over many years, such as undertaken by the North Western Railway, the need for a standard form of service staging, with its parts all interchangeable, and which could be used over and over again without undue depreciation, was from the commencement, recognised as being an essential part of the equipment.

The staging had to be designed so that it could be adapted to suit a large range of conditions, being simple in construction and capable of being rapidly assembled, and of supporting the dead load of spans up to 350 feet, weighing nearly 1,000 tons; as well as the live load of a moving train hauled by a modern locomotive, weighing 200 tons.

In places this staging had to be erected to heights of 120 feet above the river bed.

The column unit consisted of two 15″×4″ steel channels spaced 2′ to 3′ apart, and laced together; the channels were provided with a group of holes for 7/8″ diameter bolts, to which could be attached either the standard cap or base or the joint covers.

These columns were in lengths of 4 feet, 8 feet and 16 feet and they could be joined together to form any required height.

The units were so arranged that they could be assembled to provide bays of either 8 feet, 12 feet or 16 feet widths, and combined in these multiples, to form any required length and width of staging block.

The connecting cross and lateral bracings consisted of standard lengths of channels and angles, with their holes for 7/8″ diameter bolts, and grouped so as to suit all the connections. These members and their standard connections were used throughout all the combinations.

This staging had now been in use for 8 years and had been thoroughly tested out. The labour was used to its construction and could rapidly handle and erect it at a low cost.

The units had all been fabricated in the bridge workshops at Jhelum and by the use of steel templates and bushed jigs and mass production methods, a high standard of interchangeability had been secured.

Apart from its use for bridge construction purposes, it could be used for emergency measures to replace bridges damaged or destroyed by floods or other causes, and it was an asset of considerable value to the Railway.

The work in connection with the erection of some of the bridges had not always been plain sailing.

Unforeseen difficulties cropped up occasionally and these must be dealt with promptly; the trouble could only be discovered at an advanced stage of the construction, when any appreciable delay meant a serious loss due to labour standing idle, or what was more important, possible damage to the bridge by floods, by holding up staging and erection gear in the river bed and delay in getting traffic over the bridge.

The speaker thought it might be of interest to mention briefly, a few cases where they had encountered such unusual difficulties which were unforeseen, although considerable care had been taken to ensure accurate steel work erection and fabrication.

The 180 feet-3 pin type, steel arch bridge on the Kangra Valley line, was the first of its type to be manufactured in India. When the erection was well advanced, an error in camber was noticed, causing the central pin to be located lower than was intended. This defect was undoubtedly due to errors in the manufacture of the steelwork.

In order to rectify the error, steps were taken at once to remedy matters. A special jig and pneumatic boring machine were hurriedly devised in the workshops at Jhelum. These tools were rigged up at the crown of the arch, and after the two halves of the latter had been adjusted into their correctly cambered position, the holes were re-bored to take a pin half an inch larger in diameter. The existing pins meanwhile were returned to the Depot and machined to take special collars which were shrunk on to give the desired increase in diameter on the bearing surfaces.

The work of rectification was completed within one week and the results were satisfactory.

Another interesting example occurred during the reconstruction of the Attock Bridge.

The erection of the double cantilevers had reached an advanced intermediate stage when certain small fabrication errors in the service structure were detected. These had the effect of producing a greater droop in the cantilevered work than had been provided for in the calculations and design, and there was a considerable element of uncertainty as to whether the spans would close properly at a later stage, unless the discrepancies were adjusted. Dismantling was out of the question and for various reasons it was of the utmost importance that delay should be minimised. Steps were therefore immediately taken to reduce the droop, by lengthening the temporary horizontal struts passing through the Island pier. A reference to the model of the bridge and the diagrams which were before the members, might be of assistance in explaining what was done. Packings in the form of 100 ton mechanical jacks were inserted in the gap L_{24} L_0 between the adjacent ends of the lower boom. The wedge gear in the temporary strut was then operated until the substructure was relieved of the dead load of the cantilevered steelwork, and the portion located at 'R' was further restrained by placing horizontal packings between the service steelwork and the pier, as there was an overbalance of about 5 tons on span No. 3, the compression component of the couple being transferred from the temporary horizontal strut in the pier, to the main lower booms of the new spans, through the packings. The horizontal strut in the pier was then lengthened by providing longer cover plates in one of the field joints. The load was then transferred back into the temporary substructure, by adjusting through the wedge gear and by relieving the mechanical jacks. These operations took about $2\frac{1}{2}$ hours to complete after which the erection proceded to completion. The method, which might be considered bold, was a success, as it enabled the work to proceed after a minimum delay.

A particular case where extreme difficulties were met with in the erection at site, was that of the Kurang Bridge strengthening.

This was a bridge consisting of 2 spans 150 feet and one 90 feet situated on the main line near Rawalpindi, over a deep gorge, 90 feet above the nullah bed.

The work comprised the erection of additional new girders on staging, outside the existing girders.

Owing to delay in the arrival of the new steelwork, the erection was delayed until the month of June and it was only in the early stages of the assembly on the staging already in position, that serious defects were found in many of the members and their connections, so much so that it was considered impossible to develop the required strength of the structure without first rectifying it.

As the work was then in an advanced stage, it was decided to do so.

A very large tonnage of the new steelwork was despatched by train to workshops at Jhelum, and there by concentrating on the work for two weeks, the errors were put to right and the girders sent out to site again by the 3rd July.

On the 14th, the girders were assembled on the camber jacks in their final position on the staging, with all the holes in main chord joints and web member connections, held together by bolts and tight fitted drifts. The riveting was pushed forward with great speed; and "safety" was only attained by a very narrow margin, for on the 23rd July, with only the bottom boom riveted, a heavy flood washed away the supporting staging and a number of men narrowly escaped from drowning.

Another similar instance occurred during the erection of the P. W. D. New Road bridge across the Haro River on the Grand Trunk Road between Rawalpindi and Attock.

In this case the stage had been reached when the bottom booms and some of the web members of the 340 feet span had been erected, and supported on longitudinal service girders carried on interchangeable staging and piling, the latter had been placed in that portion of the channel liable to winter floods of a normal rise of about 5 feet.

A most unexpected flood, rising 13 feet, which was higher than many normal monsoon floods, passed down the river on the 13th March 1926, displacing and tilting several blocks of staging installed on the higher portion of the river bed.

Fortunately, the longitudinal service girders had been bolted together and although they festooned considerably, the new 340 feet girders were saved and more serious damage was averted.

The few instances that the speaker had mentioned gave the members some idea of the emergency measures which the Engineer and his staff on works had occasionally to deal with. The speaker therefore felt that they had been particularly fortunate with their bridges in overcoming unforeseen troubles, and this had been largely due to the spirit of co-operation and unity of purpose which existed throughout the Bridge staff and labour.

The speaker in the end pointed out that there was a correction to be made on page 62 at the end of the Note on the Attock Bridge. This should read that reference might be made to paper No. 4767 in the proceedings of the Institution of Civil Engineers dated 1931.

MR. A. MUSTO apologized beforehand if his remarks were somewhat sketchy, as he had been too busy to make careful notes on the paper. The first thing that impressed him in reading this very interesting and valuable paper was the limited extent to which use was made of the water in the Rivers for transporting and placing the bridge girders in position. Probably there were special reasons in most cases that a greater use was not made of water transportation. Such reasons were probably the existence of plant for land transportation and financial stringency in obtaining floating craft. It was also perhaps natural that Railway Engineers should first of all consider moving their materials by railway. His own experience was that it was almost invariably cheaper, simpler and quicker to move material by water than by land. With a limited amount of staging to form a temporary wharf and a limited amount of staging on a floating platform of pontoons or barges, an unlimited amount of material could be transported and placed in position at various points in the river. One advantage of this method, apart from reduced cost of staging, was the greater mobility and radius of action obtainable. Instead of bridge work being confined to one....or both ends of the bridge, only building out from work already done, as was the procedure in all the cases described by the Author, it would be possible to place girders on other spans out in the river whether connected to the shore or not, and it would seem that it should be possible to place new girders outside old girders by this means with far less interference with traffic than when placing them from the existing bridge.

In the case of new bridges, the advantage would be still greater, as it would enable work to be carried on in a number of spans at once, instead of on only one span, or two spans, from the ends.

Mr. Musto had found no difficulty at Sukkur in placing arch centres weighing up to 50 tons in their spans between piers when heavy floods were running. A rise or fall in water level could often be utilized for landing the girders in position. Especially, if it could be arranged to bring the pontoons, with their girder loads, into position from the *doun stream* side of the piers, there was no danger in working during the flood season, except possibly on extreme floods. The pontoons could either be warped from one pier to the other by suitable bridles round the piers, or could be towed into position by tugs.

MR. H. W. NICHOLSON criticised Mr. Musto's suggestion regarding the transportation of material by water and remarked that the rivers of the Punjab could not be depended upon inasmuch as they were dry during the most of the year and full to overflowing during the monsoon, operations in a river bed after the middle of June being normally out of the question.

He queried the description on page 42 of the past history of the Alexandra Bridge.

Mr. W. T. Everall, in reply to the discussion , said that Mr. Musto had pointed out that in many bridge schemes more use might have been made of the method of moving the girders into position on boats, and also of transporting material to the bridge site.

He had fully realized that in many cases, this method was by far the cheapest one and it was adopted wherever practicable.

As would be seen on plate IV this method was actually used for removing the spans of the Kaiser-i-Hind Bridge across the Sutlej River at Ferozepur in 1928.

In the major bridge across the Jhelum at Khushab now almost complete, considerable use was made of pontoons in floating out the main girders.

The superstructure of the Kalabagh bridge was not dealt with in the paper by Mr. Cruickshank.

The erection of the girders was in course of being carried out by the Bridge Department and in this case, floating out was being adopted for five of the spans.

In many of the North Western Railway works, where conditions were suitable, materials were also moved to the job on flats or barges, but it must not be lost sight of that in many instances there were railway facilities and steam cranes at the disposal of the Bridge Engineer.

The Punjab working season in the river bed usually extended from October to June when the water channel was generally very restricted. Conditions in the Punjab rivers were often unsafe for major erection operations during the monsoon, and it was for this reason that cantilever erection schemes were often adopted where the work had to be pushed on, irrespective of river conditions.

He fully agreed with Mr. Nicholson that conditions must be very exceptional to justify any bridge operations in a Punjab river bed after the middle of June.

Mr. Nicholson correctly queried the statement made on page 42 under the description of the Alexandra bridge, that in 1891 the bridge was shortened to 28 spans and in 1918 was again shortened to 17 spans, and the girders duplicated. The girders were duplicated in 1891 after shortening the bridge from 64 spans to 28.