PAPER NO. 210.

REMODELLING UPPER CHENAB CANAL HEAD REGULATOR 1936—37.

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Introductory.

This paper relates to the Head Regulator of the Upper Chenab Canal which takes off at Marala (Sialkot District), the site of the first weir on the Chenab river. The Upper Chenab Canal forms an important link in the Triple Canal Project and carries the Chenab waters to the Ravi at Balloki for irrigation of the Bari Doab area. The capacity of the canal is approximately 13,000 cusecs and it is the biggest irrigation canal in India. This paper briefly describes the work of remodelling the Head Regulator completed early in 1937 at a cost of Rs. 2,95,000.

The Regulator consists of 12 spans of 24½ feet each and the full supply discharge per foot run is 44 cusecs. The Remodelling work comprised the replacement of the entire steel work of gates and gearing, construction of a reinforced concrete breast-wall and some alterations to the ashlar cill to accommodate redesigned gates. The breast-wall which is 10½ feet high was constructed with a high pond level upstream. The entire civil engineering work was done with the canal in flow the whole time, excepting cutting of the ashlar cill and fitting in of grooves which were done in an ordinary rotational closure of 20 days. The work, thus embodies a technique of construction, which, it is hoped will be of interest to the members of this Congress.

Brief History of the Regulator, Original gates with travellers.

It is necessary to state here a few historical facts regarding the arrangements of gates and gearing of the Marala Regulator. The original design was based on the Rupar Head Regulator, viz., rising cill gates and upper gates only to be used for closing of the canal. Originally two 7-ton travellers were employed for lifting the gates. This arrangement involved great trouble, when small supplies had to be regulated against a high river as the points of suspension of the gates being ouside the grooves, no easy slinging arrangements were possible except when the gates were fully open. For intermediate positions, the gates were supported by a temporary arrangement of wooden blocks, which were placed at the bottom of the grooves. This process was dangerous for the regulation establishment as these blocks had often to be changed at night by beldars descending into the Regulator. On one occasion a beldar was washed into the canal between the two gates, while

interposing a wooden block. Independent gearing was therefore fitted for the upper gates in the year 1915—16 and the travellers removed. The system consisted of counter-balance boxes and a worm driving the wire rope suspension drum.

Remodelling of Upper gates, 1926—27.

The next remodelling of the Regulator was done after the raising of the weir crest by 2·0 feet in the year 1924—25. Increased supply had then to be fed into the canal with a high pond, and the upper gates were converted into rising cill gates to prevent the large amount of silt that was passing into the canal. Thus the lowermost single groove was replaced with a double groove. Photograph No. 1, taken by the author in 1927, shows a view of the Regulator from the nose of the upstream divide-groyne.

Original Rollers.

The rollers originally fitted to both the cill and the upper gates were Mr. Ashford's design, and of the cage type (see plate I). Each roller unit was housed in a box of size 10" x 7" studded on to the downstream side of the gates. The roller had a central steel pin, around which there was a brass cage containing 8 small cylindrical rollers, which served as bearings for the main roller. These rollers gave satisfactory service for over 15 years, but as described further, they suffered from the disadvantage of being inaccessible for inspection and greasing purposes unless the gates were taken out of the grooves, which process involved dismantling of the entire lifting machines and a cumbersome arrangement of crib work, screw jacks and pulley blocks.

Replacement of Rollers.

In the year 1932-33 the rollers were thoroughly examined and 80 % of those on the upper gates were found to have worn flat. These were therefore removed and replaced by new rollers of the pin type. These were designed by Mr. Charles the then Superintendent, Central Workshops, Amritsar, and consisted of a hollow roller fitted internally with a gunmetal bush, which revolved round a steel pin 2" in diameter. This pin was to take all the pressure amounting to over 100 lb. per sq. inch. These new rollers proved less satisfactory than those which were replaced, and the upper gates had frequently to be worked undershot, from 1930 to 1935.

Defects of existing Gates and Rollers (1935.)

The chief defect of the new rollers was that they used to get stuck due to silt collecting in the clearance round the pin, and also due to the

corrosion of the pin. To summarize, the existing arrangements (1935) had the following defects :—

(1) The lower gates operating on screw gear, were extremely slow to work, and caused loss of control over the supplies entering into the canal.

(2) The fixed rollers frequently got jammed and made the working of the upper gates very difficult. During the flood season 8 men had sometimes to be employed to operate a winch, which should ordinarily be handled by two men, thus throwing an enormous strain on the winches.

(3) It was not possible to lift the gates clear of the grooves for examination and repairs without the crude and risky method of dismantling the whole of the machinery, and resting the gates on crib work after lifting.

(4) The skin plates of the gates were worn out.

Remodelling Scheme. Alternative Proposals.

The scheme of gates, rollers, gearing and superstructure now constructed was prepared in the summer of 1935 by Mr. W. G. Wheatley, I. S. E., Superintendent, Central Workshops, Amritsar. Two alternative proposals were got out by him :—

(1) Double gates working in separate grooves on free roller system with superstructure.

(2) Single gates working on free roller system with superstructure.

Disadvantages of Single Gates.

Although the estimated cost for single gates was about Rs. 80,000 less than the cost of double gates, it was decided to adopt double gates for the following reasons :—

(*a*) During high pond in summer, the supply would have passed into the canal, between the top of the gates and the bottom of the breast-wall under orifice conditions and with greater velocity.

(*b*) In case the canal got silted up, it would not be possible to meet the canal indents without raising the head across the weir to above 10 feet in the latter half of September, and beginning of October. This would cause unnecessary strain on the weir.

(*c*) It would be necessary to raise the permanent cill by 2·7 feet to avoid unsuitably high single gates (over 10 feet). During winter, supplies would have to be passed over the permanent crest with gates

lifted clear. The pond level would therefore be permanently pushed up during winter by 2·7 feet. A constant high pond would require laborious tamping of weir shutters to prevent leakage.

Features of the new work.

In view of the reasons given above, it was decided that double gates of the solid girder type, but of the same dimensions as the old gates should be used. This required no alteration to the level of the permanent cill. As both the gates were to work on winches, two sets of counterbalances were necessary.

Breastwall.

The existing false arch and upstream parapet wall left no room for the travel of the counter-balance of the upper gate and were therefore required to be dismantled altogether. In substitution of the false arch a breastwall was necessary on the upstream face of theRegulator in order to enable a complete closure of the canal during floods. The general arrangement as it existed before and as now modified is given in plate No. II, attached.

Cutting of Ashlar Cill.

The old cill gates consisted of a built up section and were bowed or convex on the upstream side. Correspondingly, the permanent cill was concave on the downstream side to enable a close fit of the gate. The new cill gates are of the solid girder type with both upstream and downstream faces vertical and for their installation the existing ashlar cill required trimming at the ends (see plate No. II.)

The cutting of this ashlar was one of the stiffest items, on the successful tackling of which depended the timely completion of the rush job of the erection of grooves and gates during a 24-day closure.

Work before the closure.

In order to complete the entire work of remodelling the Head Regulator within the scheduled closures in one season it was essential that as much of the work as possible should be completed while the canal was in flow. Also no work could be possible when due to excessive supplies in the river, the pond level rose above R. L. 805·0. This normally happens about the middle of May.

Hence the only alternative was to start work in the month of March, 1936. Fortunately, this was granted under a special sanction and the operations for the breastwall were started on 16-3-36.

Programme.

Since it was essential not to cause any dislocation in the normal

regulation of the canal the programme of construction had to be split up into suitable stages. In Appendix No. 1 of this paper, diagrams are given showing how the construction of the civil portion of the job was effected in time to suit the schedule of the Central Workshops for erection of the superstructure and gates. A brief description of the order in which the successive items of work were undertaken will not be out of place here, as it will enable a proper understanding of the expedients resorted to for the various portions of the job.

Main Divisions of the Work.

The work was split up into the following periods :

1936

(1) 15th March to 15th May.

Construction of R. C. breastwall up to R. L. 815·0, i.e., to a height of 7·5 feet, and rebuilding of pier masonry.

(2) August to September.

Completion of breastwall up to R. L. 818·0, i.e., full height of 10·5 feet, and construction of footings for oloumns of superstructure.

(3) 15th September to 19th November.

(a) Erection of columns, grouting of holding-down bolts, fitting of new winches, removal of old machines, switching of old gates to new winches.

(*b*) Construction of needle dam in front of bays 8 to 12, putting of ring bunds in canal for enclosing bays 8 to 12, unwatering and cutting of ashlar crest and gullets in piers for installation of gates and grooves.

(4) 19th November to 12th December.

(Rotational closure of the canal.)

Continuation of work as per (3) above and grouting of grooves, cill and breast-wall staunchings and of counter-balance guides.

In what follows, no attempt will be made to describe the operations of erection of steel work. This job was entirely done under the direction of Mr. W. G. Wheatley, I. S. E., Superintendent, Central Workshops, Amritsar, who, the Author understands, is writing a paper on the subject for the Institution of Civil Engineers.

As seen later the sub-division of the work into the stages mentioned above proved to be a success. Both the Marala and Central

Workshops Divisions were able to finish the civil and the mechanical jobs respectively hand in hand, well within the scheduled time.

Construction of Breastwall.

A reference is invited to plate No. II. Before the breastwall could be constructed the stone masonry of piers had to be dismantled from R. L. 818·0 to R. L. 805·0. This involved a complete removal of the lifting machinery, thus temporarily putting the bay out of action.

Both the gates were lifted to closing position prior to the removal of the winches and kept supported in this position by means of rails inserted under them in grooves. For additional safety the gates were also slung by means of chains attached to short pieces of rails which were placed crosswise on the grooves.

This was done in four bays at a time, as the canal supply being about 8,000 cusecs could be passed through eight bays without causing undue strain on the Regulator floor.

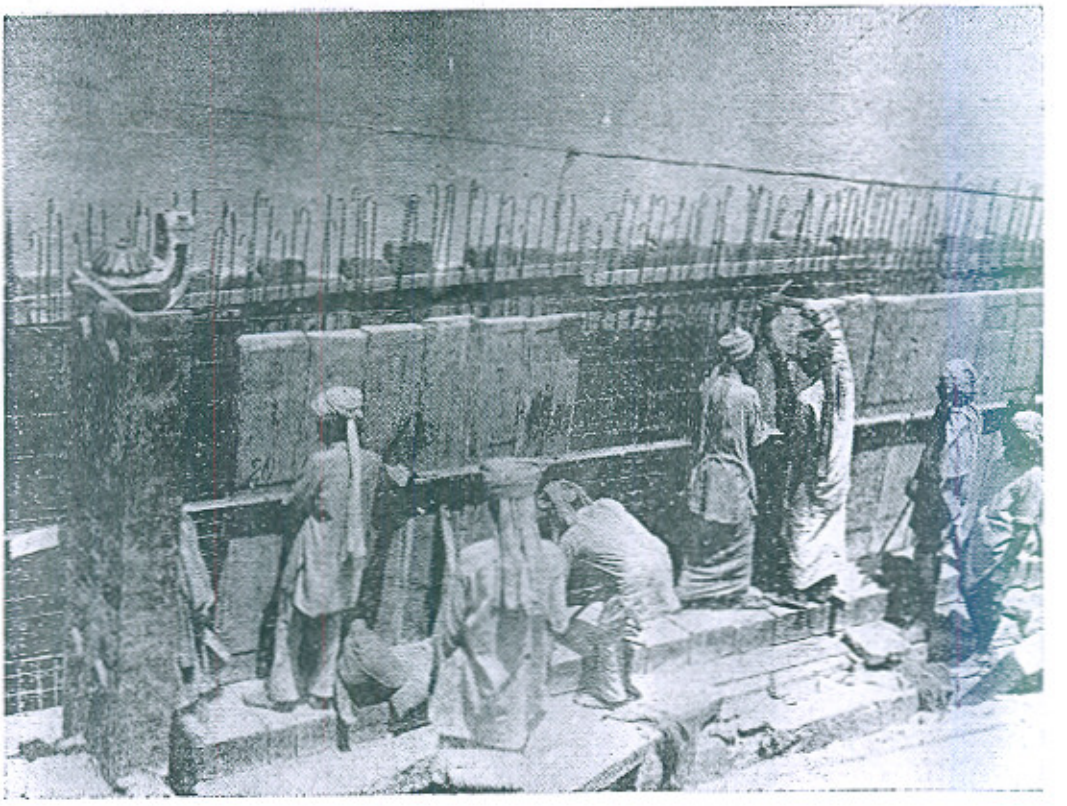
False Work.

The arrangement adopted for falsework is shown in plate No. III and photographs Nos. 3 and 4. Steel girders obtained from dismantling the machinery, were employed to act as main supports for the bottom shuttering. In view of the long span (24·5 feet clear) three girders 14"×6", were placed side by side. To facilitate easing of the centering, the girders were supported at the ends on wooden blocks resting in boxes of sheet iron filled with sand.

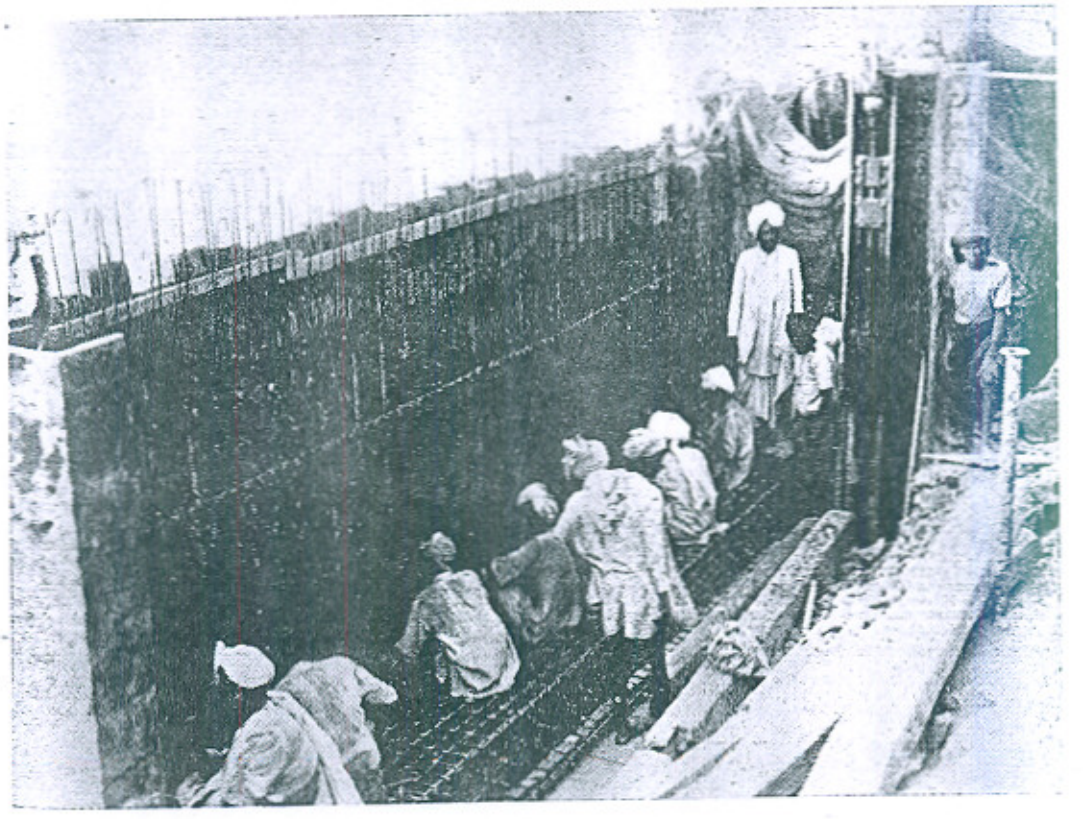
For lowering the centering, sand was made to flow out of the boxes by pouring in water and stirring the sand.

The concreting of the breastwall up to R. L. 815·0 was done in two stages. The horizontal portion marked *A* on plan was concreted first. As rapid hardening cement was employed this portion set to a suitable hardness in 24 hours to bear the weight of the inside shuttering. The vertical portion marked *B* was then concreted.

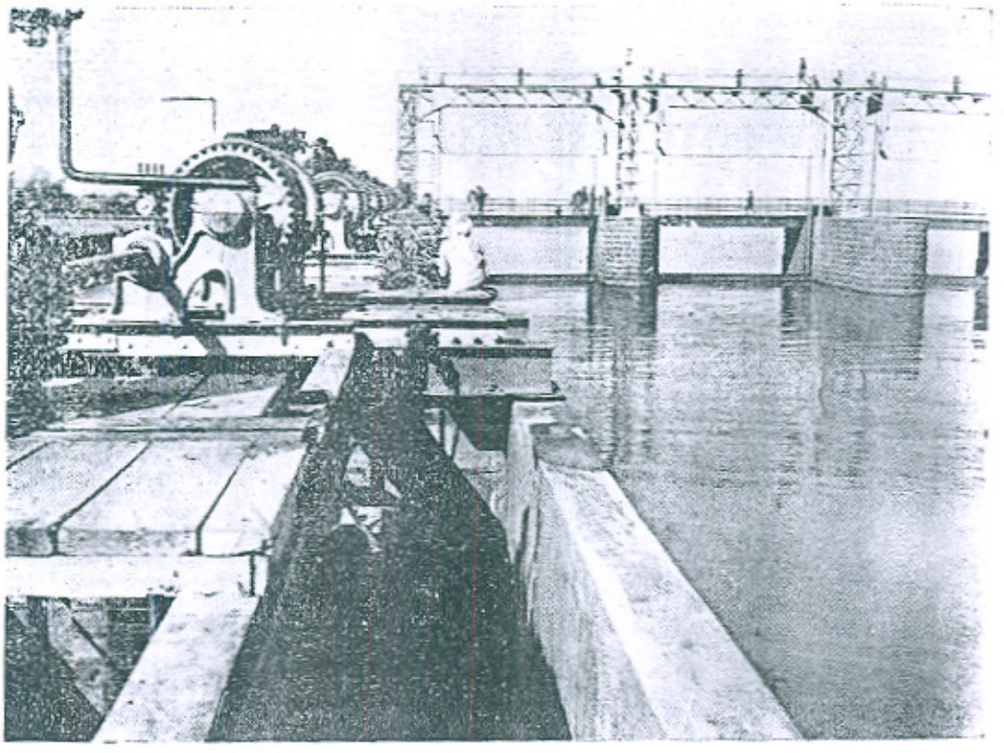
The tying of reinforcement for a thin wall of this height presented a good deal of difficulty which was heightened by lack of room. To secure correct placing of reinforcement advantage was taken of the vertical stirrups which were made out of single bars long enough to cover the entire upstream face and the downstream face up to more than half the height. These stirrups were bent to shape by means of a template specially made for the purpose. A full size natural scale section of the breastwall was drawn on a platform on the ground to enable these stirrups to be actually tested for correctness of the various bends.



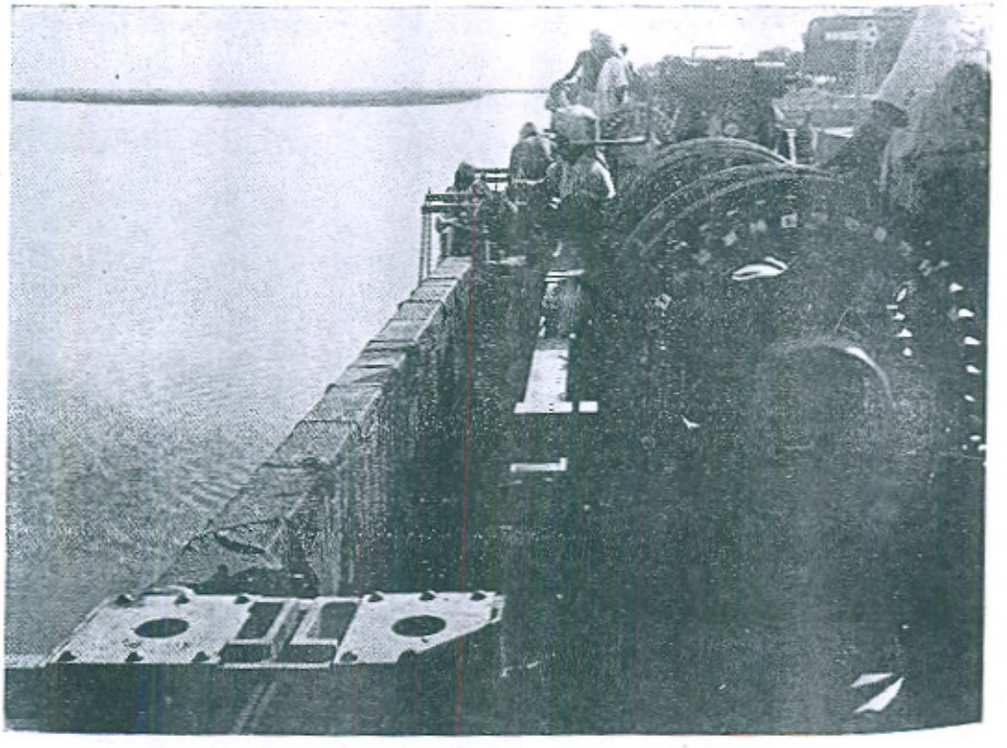
Inside Shuttering.



Bottom Beam Reinforcement.



Interim arrangements for Regulating Old winches fitted on temporary brickwood footings.



Final raising of Breast Wall.

To complete the cycle for the construction of the breastwall in one bay took 72 hours. Three sets of shuttering were made for the bottom and two for the sides. To avoid wastage of timber, full size deodar sleepers were used for the upstream face as well as for the bottom. The process of construction took the following order :—

1st day. Erection of bottom and river face shuttering and tying of reinforcement.

2nd day. Concreting of bottom (portion *A*).

3rd day. Erection of inside shuttering and tying of reinforcement concreting in vertical portion (*B* marked in plate.) Work could go on simultaneously in three out of the four bays of which the gates were closed. It was possible to remove the side-shuttering after 24 hours, the bottom shuttering was however left in position for at least one week before it was struck.

By 15th May, 1936, the breastwall was completed in all the bays up to R. L. 815·0, and the pier masonry rebuilt up to R. L. 816·0. During this period the shaft required for fitting in new grooves was also cut into the piers up to R. L. 809·0, i.e., to the bottom of the topmost length of the groove. The old grooves were in 3 pieces each 9 ft. long. These gaps were filled with brickwork laid in lean mortar to enable temporary installation of the winches. Similarly footings for machinery were also made in brickwork in lean mortar.

Design of the Breastwall.

The design of the breastwall follows the usual lines. The vertical part has been designed both as a cantilever fixed in the horizontal part and as a slab supported at the piers against the water pressure. The horizontal portion is designed as a freely supported beam carrying its own weight as well as of the vertical part. Additional reinforcement has also been provided for the contingency of a loaded counter-balance box resting on the breastwall beam.

Interim Regulation Arrangements.

When the breastwall was completed up to R. L. 815·0 the machinery in each bay was reinstalled by using an additional set of girders which served as supports in place of the downstream parapet wall which had been dismantled (see plate II). On the upstream side, the girders carrying the gangway were erected on piers as supports. This step was necessary because normal regulation conditions had to be restored on about the 15th May, 1936, when canal supplies at head had to be increased for feeding the *kharif* branches at Bambanwala. The indent of the canal at head goes up to 12,800 cusecs in the *kharif*, and therefore all the twelve bays were required to function.

Final Completion of Breastwall, Extension Pieces and Shuttering.

On reconsidering the position in July, it was decided that the breastwall should be raised to the final level of 818·0 as quickly as possible to enable the Superintendent, Central Workshops, to start the work of erection of columns for superstructure. In the position in which the upstream girders supporting the counterbalances and the gangway were lying, they would have fouled the completed breastwall and the holding-down bolts of the upstream footing (see photographs 5 and 6). The only solution was therefore to remove these girders. This required a modification of the suspension arrangement, involving extension of the built up cross-girders supporting the counterbalances. Mr. W. G. Wheatley proposed an extension made of channel iron which could easily be bolted to the existing section (see plate No. III). Commencing from the middle of July the work of raising the breastwall to R. L. 818·0 was completed in 24 days without upsetting the regulation of the canal. This was really a crucial stage of the job and without its completion at the time the erection of the superstructure would have been seriously set back.

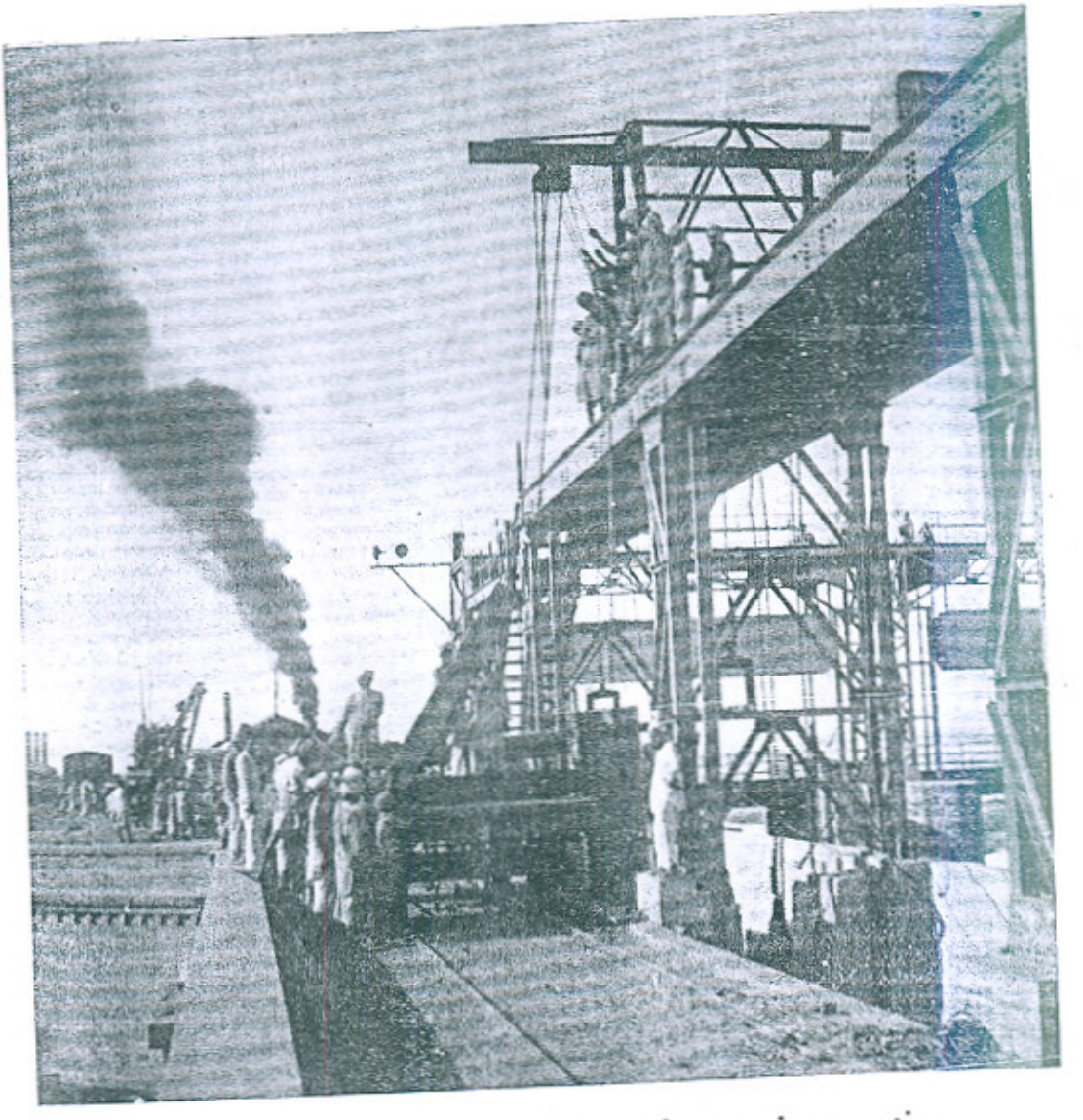
Plate No. III and photographs 5 and 6 show details of the extension pieces and the shuttering employed. Particular attention is invited to the shuttering which was simple to erect, perfectly rigid and easy to strike, in addition it turned out a true vertical face of concrete and not a patch of plaster had to be put for the so-called finish.

Column Footings.

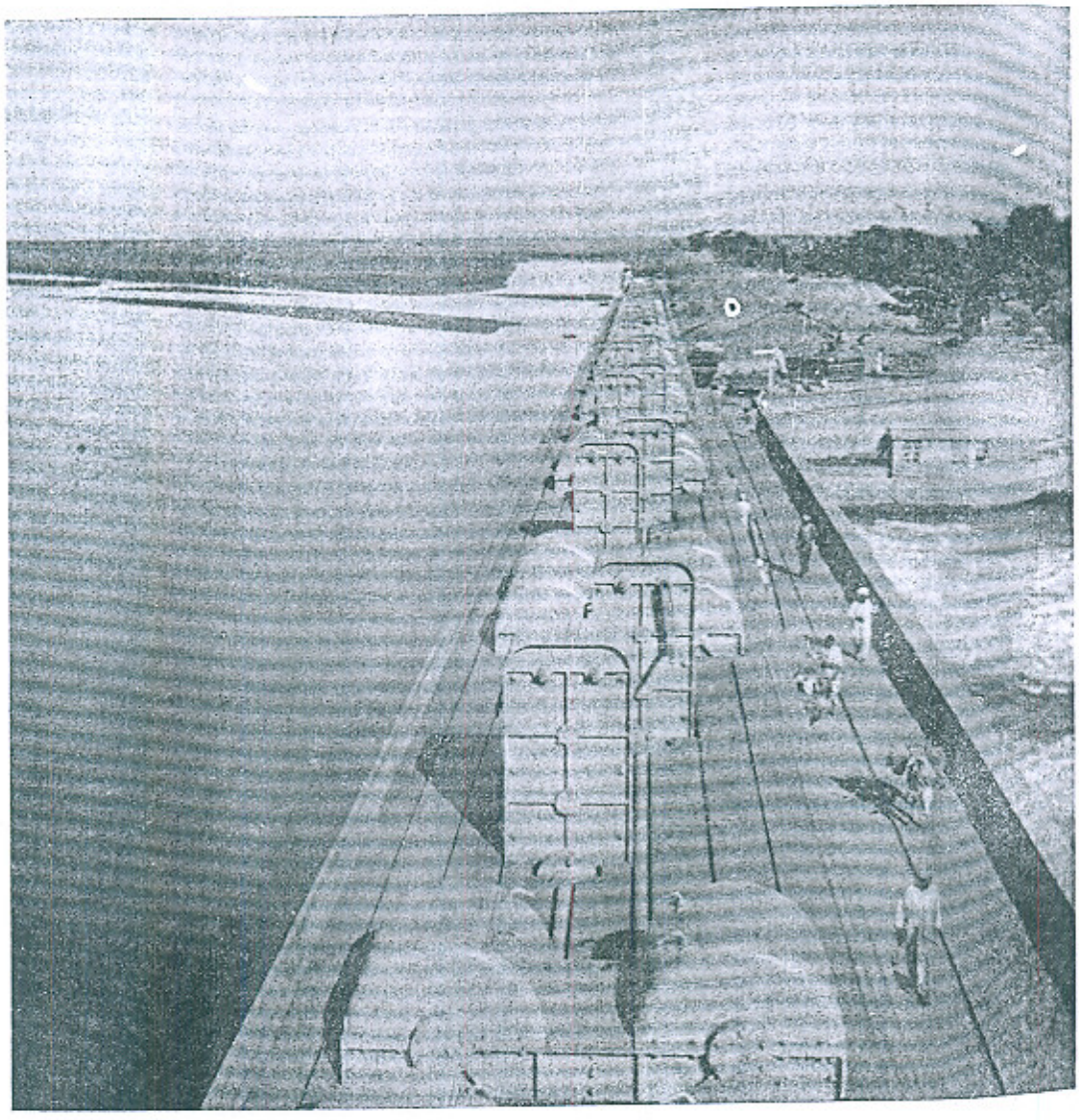
As the masonry of the piers was progressing, the channels and the plates of the holding-down bolts were embedded at suitable places. Square holes roughly 9″ wide were left around every bolt to enable adequate play to secure correct alignment. Some of the bolts had to be placed in the breastwall also and here the reinforcement was locally bent away to make room for the bolts. At this stage the final alignment for the position of bolts was carried out by means of theodolites fixed on permanent pillars on both ends of the Regulator. The footings were then completed to one *soot* (1/8th of an inch) of their final level and the play of the bolts were also limited to about one inch of round as this was considered sufficient to accommodate the foot plates of the columns truly. This was secured by inserting 4″ diameter pipes round the bolts which were 6 feet deep. Rapid hardening cement and very fine bajri were used for grouting around the pipes which were given an occasional twist to prevent sticking. They were withdrawn after 6 hours and left true holes.

Erection of Superstructure.

The tops of piers having been concreted nearly to the finished levels and the bolts having been aligned, the scene was now ready for the erection of columns, grooves and gates. These involved the lifting



Erection of superstructure : Special gantry in operation lifting a groove.



New winches in position. The winches are fitted with the operating lever in a longitudinal direction. This does not obstruct the over-bridge and is an improvement on old designs.

nd fitting of a total weight of 500 tons. Originally it was proposed o do the erection with the help of a derrick. It was however suggested y the Author that a crane would be extremely handy for the job proided a broad gauge track was linked across the Regulator. This suggesion was accepted and accordingly the ten-ton crane available at Khanki vas requisitioned and put on rails on the Regulator on 1.9.36. As experienced later, erection work was greatly expedited by this arrangement. The various members for the superstructure, counterbalances, winches, grooves and gates were loaded on a flat truck without sides, by the crane or by a special over-head gantry travelling on the superstructure girders. This gantry was obtained from England specially for this job. (Photograph 7).

Work immediately before the long Closure.

The bulk of the superstructure (see photograph No. 8) was in position by the middle of October 1936. In view of the uncertainty of the time required for fitting new grooves and gates and their final adjustment, Mr. Wheatley was of opinion that he should get at least two weeks in advance of the closure wherein he could try the entire operations. This would enable him to have his organization in full swing when the closure actually started, also any practical difficulties that would arise in the actual execution of the job would have been provided for in time, thus ensuring the completion of the programme within the closure.

It was therefore decided that arrangements should be made for the installation of new grooves and gates in at least three of the Regulator bays before closure started. This required the obtaining of closure conditions in five bays of the Regulator whilst the canal was running with a supply of 7,000 cusecs and a depth of about 10 feet.

Needle Dam.

The arrangements necessary for closing off five bays and subsequent removal of old gates and machinery from these bays are detailed in plate No. IV and photographs 9 and 10.

The two main items were the needle dam on the upstream side and the ring bund on the downstream side. Originally it had been decided to employ fir beams of section 14" x 7" for the needle dam. These were to be clamped at the top to steel girders temporarily erected in the bays from pier to pier. A serious complication arose at this stage. The normal pond level which during October is seldom more than R. L. 802·5 had at this particular occasion to be maintained at R.L. 805·0 on account of the work of the ring bunds that was intensively going on in connection with reconditioning operations on the weir. With a lower pond and canal open, the current towards the left became too dangerous

for safe negotiation of boats carrying earth. In addition, the faster current retarded the progress of bunds due to extra wastage of earth by erosion. The needle dam had therefore to be constructed under conditions very much different from those anticipated. To get over the difficulty of putting girders and fixing clamps under water it was decided to make a trial needle dam with Ransome sheet piles which were already at site for the weir sheet piling. These required no separate clamps on account of the interlocks and could be lowered in position by means of the over-head gantry. Accordingly starting from the right abutment a cofferdam of these interlocked piles was built in position in front of three bays.

A reference is invited to plate No. IV. The portion of the pocket immediately upstream of the permanent cill was found to have lot of debris and stones so that the foot of the cofferdam could not be bedded evenly thus causing an excessive amount of leakage into the canal.

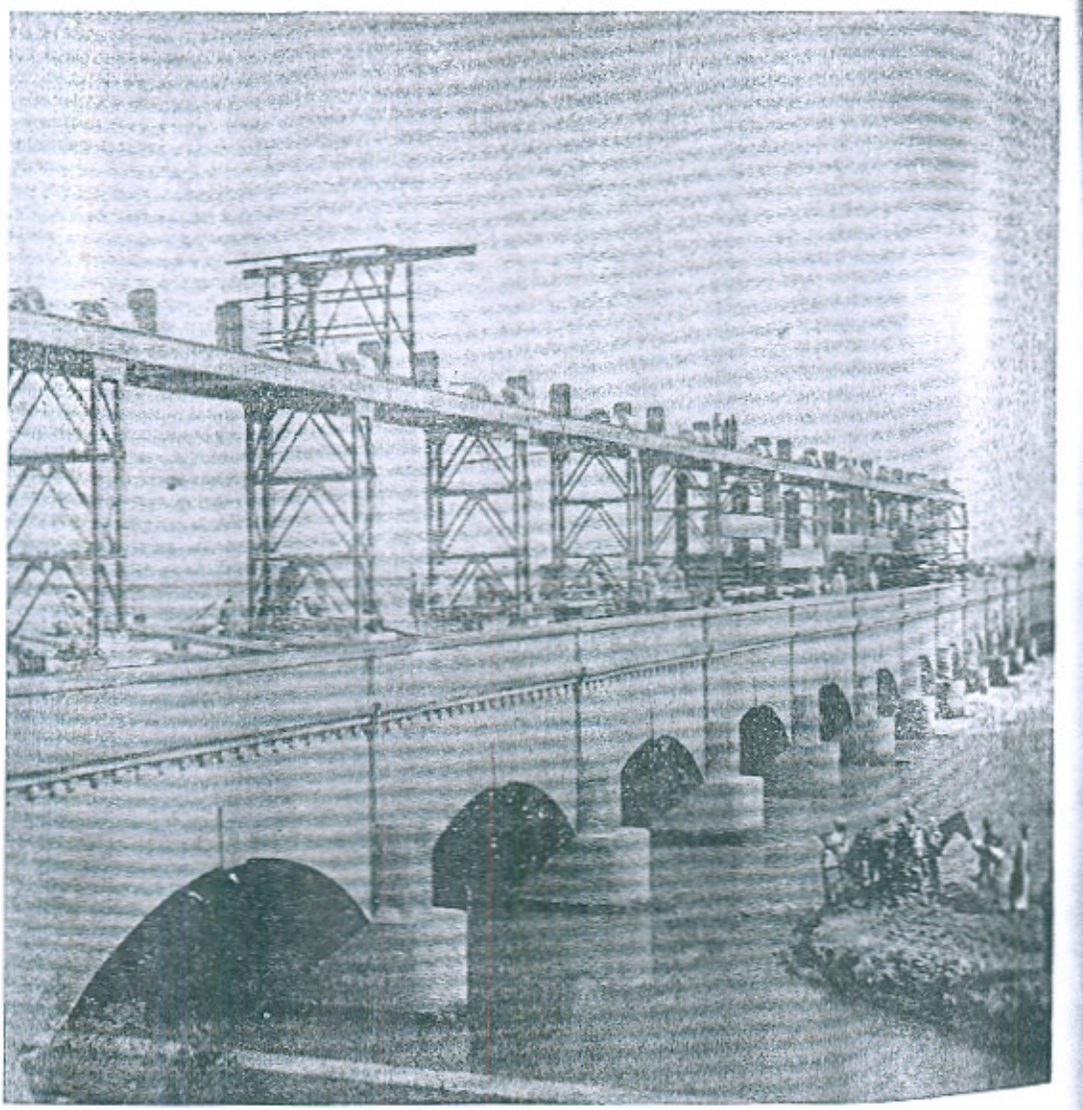
Various expedients were tried to make the cofferdam watertight. A great quantity of earth was dumped by boats immediately upstream of the cofferdam and a bund of gunny bags filled with sand was raised on the pucca cill and the space in between was packed with puddle.

The leakage however still persisted and the timber needle dam sketched on plate No. IV had to be finally restored to. Since this had to be installed under water by divers, appreciable slits and gaps were left between the needles. Initial tamping was satisfactorily secured by laying a large sheet (60 feet x 40 feet) of tarred gunny bags on the upstream face and loading the same with earth. The gunny bag tarpaulin was given an over-lap of 15 feet over the foot of the needles so as to seal the cavities caused by the debris and stones lying unevenly in front of the cill.

Ring Bund.

On the downstream side of the Regulator, a ring bund of sand was advanced from the right flank, after closing gates Nos. 12 to 8 (numbering from the left). This bund had to be made in water 10 feet deep and against considerable wave action (photograph II). To protect the outside toe and nose of the advancing bund, *pilchhi* revetment was used in the form of a mattress. Simultaneously a solid bund of gunny bags filled with sand started from pier No. 8 where the velocity of the current was 4·0 feet per second. The needle dam and the ring bund were completed for three bays a fortnight in advance of the closure. Due to the efficient tamping, unwatering was easily done by means of an 8" direct coupled electric pump which was fitted with a sluice valve to allow reduction of discharge after the initial pumping had been done

In the absence of gates, the canal was closed off with a needle dam. (View from downstream).



Ring bund being made for enclosing bays 12-8.
Depth of water in canal 10 ft.

Work during closure.

For the further completion of the work in each bay the following jobs had to be done in the order in which they are given (reference plate No. II).

(*A*) Demolition :—

1. Removal of old machinery.
2. Removal of old gates; (upper gate 7·6 tons, cill gate 4·5 tons).
3. Cutting of ashlar cill.
4. Removal of old grooves.
5. Cutting of shafts in abutment and piers for new grooves.

(*B*) Construction and Erection :— (see plates II and V).

1. Erection of grooves and counterbalance guides and their grouting.
2. Fitting of cill staunching and its grouting.
3. Fitting of Breastwall and its grouting.
4. Installation of gates.

From a perusal of the items as per (*A*) and (*B*) above it will be seen that a great number of operations had to be arranged in a very limited room and an extremely limited time. Another difficulty was that while the erection of heavy steel members was going on in any bay, it was unsafe for any labour to work underneath and none was allowed. To add to the difficulty, passage had to be given to long lines of unwieldy camels which were carrying shingle across the Regulator for use on the Weir works. Careful precautions had therefore to be taken and though human life was saved, two camels had to pay the toll with their lives by falling over the Regulator. Reference is here invited to the detailed programme given in Appendix No. I. Each step in this programme was a determining factor on which the timely completion of the work hinged. By far the major part consisted of difficult dismantling of large ashlar (Hasanabdal stone). For this, special stone-masons were engaged for day and night shifts but still the progress was not up to the mark. Mechanical drills and pavement breakers worked by an air compressor were then used. These gave the desired success.

The taking out of the old grooves required dismantling of large stone all along the sides and to a depth of two feet at the back to enable putting in of the chain slings with which the entire groove was pulled out by means of the gantry. Some of the stones which had to be manhandled were as much as two cubic feet in volume and after levering down, had to be carried out by parties of coolies on bamboos. For

grouting of grooves timber shuttering was at first used but was later dispensed with as it was found more convenient to do the face work with specially cut stone, and then fill at the back by fine cement concrete poured from the top by coolies with the help of ladders (see photograph). The shafts above groove level were filled with concrete *in situ* with special shuttering. The entire civil portion of the work was completed on the 3rd December thus leaving a clear week for the Central Workshops Division to complete their erection and final adjustments. They were also able to finish their erection well in time and actually tested the working of the new gates before the opening of the canal.

Staunching arrangements.

Particular attention is invited to the staunching devices adopted on the new gates. These are given on plate No. V on an enlarged scale.

These have been found to be singularly water-tight; so much so, that during the short closure of April 1937 there was practically no water on the pacca floor downstream of the Regulator, a condition which was impossible at Marala (and also at Khanki Headworks) without elaborate tamping for days. This is a useful feature in so far as it facilitates the early start of any closure works that may have to be undertaken on the Main Line. Another advantage is that water-tight gates do not allow harmful silt to go into the canal. With the old gates at Marala, it was observed that during a 14-day closure of the canal an average of of 1·5 feet of silt found its way into the canal in its first mile with leakage from the bottom and the sides of the gates.

Silt problem at Marala.

One of the most important functions of a Regulator is the prevention of the entry of harmful silt into the canal and it is felt that this paper will not be complete without a brief reference to this feature in respect of the Regulator which is the subject of this paper.

Like other canals, silt trouble on the Upper Chenab Canal has always been a menace and at times conditions have been really bad and various remedial measures have been undertaken to combat and control excessive silt entry. The more important of these have been :—

(*a*) the conversion of the upper gates into rising cill gates to avoid "undershot" regulation in full supply conditions;

(*b*) the change in the method of regulation from "Partial flow" to "Still-pond"; and

(*c*) preventing fluctuations in pond level during summer and keeping it as high as possible.

In 1929-30 when the " Open Flow" system of regulation was in vogue and high velocities were allowed in the Pocket, the head reach of this canal got silted up by over 5 feet in 48 hours and prominently exposed the unsuitability of this system of regulation. The conditions, then, were so bad that the station area had to be saved from inundation by means of a special dowel. After this, the " Still-pond" system of regulation has been enforced and the conditions now are so good that the Regulator protection in the canal has to be watched for scour. It has been observed that the following factors are conducive to silt exclusion at Marala :—

(1) The maintenance of a rigid Still-pond;

(2) Watching the approach channel for turbulence and boils.

(3) Raising the pond gradually to its maximum limit and maintaining it steady in summer.

(4) Suitable manipulation of shutter bays to keep the main stream of the river on the right, so that supplies in the canal run parallel to the weir, allowing decantation opposite each open bay.

(5) Extension of the Virtual Pocket by having weir bays Nos. 1 and 2 almost always closed while the canal is running.

It might be observed here that the conditions of this Headworks are peculiar due to the Jammu Tawi tailing in almost directly opposite the undersluice channel.

This stream comes suddenly in flood even before the telegraphic warning from Jammu is received and the slightest mistake in regulation or delay in manipulation of gates can cause a disaster. It is therefore most important that the Regulator should be capable of quick and efficient working.

This end has now been achieved and in the last summer the Tawi spates were controlled without silt or excessive supply entering the canal.

Acknowledgements.

Acknowledgements are due to Mr. E. O. Cox, I. S. E., M. B. E., Superintending Engineer and Rai Bahadur Ganpat Rai, I. S. E., Executive Engineer, Marala for their guidance in the execution of the work.

The construction of the breastwall up to R. L. 815 was done by Mr. A. C. Malhotra, I. S. E., Executive Engineer, as S. D. O. Headworks Sub-division. S. B. S. Raghbir Singh as S. D. O., Special Works, besides giving valuable help and suggestions on all details of construction

was responsible for the successful arrangements which made the work in bays Nos. 12 to 8 possible.

The Author's thanks are due to Mr. W. G. Wheatley, I. S. E., Superintendent, Central Workshops, for the helpful suggestions he gave on various constructional details of the civil portion of the job. He was also very kind to take an interest in this paper during its preparation.

Acknowledgement is also due to Mr. F. E. J. Connolly, Assistant Superintendent, Central Workshops Division, for the co-operation given in the execution of the job.

APPENDIX I.

Remodelling Canal Head Regulator Marala 1936-37.
Detailed programme of work of Marala and Central Workshops Division.

No.	Items of work in order of their occurrence.	Bay No.	Dates. From	Dates. To	Remarks
	Civil Portion.				
1	Needle Dam	12 to 1	16.10	27.11	1936
2	Downstream Bund ..	12 to 1	16.10	27.11	
3	Removal of gates, machinery and two upper lengths of grooves	12 to 1	16.10	27.11	
4	Unwatering	12 to 8	1.11	12.11	
5	Removal of bottom of grooves, cutting of shaft in piers and cutting cill	12 to 1	4.11	4.12	
6	Fitting gates and grooves by Central Workshops ..	12 to 1	9.11	8.12	
	Mechanical Portion.				
1	Superstructure columns ..	13a to 1	10.9	5.10	
2	Do. Overbridge	12 to 1	14.9	6.10	
3	Do. Alignment	12 to 1	..25.9	9.10	
4	Lifting Machinery ..	12 to 1	27.9	19.10	
5	Removing old machinery and counter-balance ..	7 to 1	8.10	28.10	
6	Rivetting new lower gates ..	7 to 1	9.10	27.10	
7	Installing new lower gates & counter-balance.	7 to 1	11.10	29.10	
8	Slinging old upper gates and new counter-balance for new machinery	7 to 1	12.10	30.10	
9	Rivetting new lower gates ..	12 to 8	28.10	6.11	
10	Rivetting new upper gates ..	12 to 1	8.11	5.12	
11	Erecting new grooves ..	12 to 1	9.11	7.12	
12	Installing new lower gates and counter-balance	12 to 8	17.11	26.11	
13	Installing new upper gates ..	12 to 1	8.11	10.12	
14	Hand railing and planking was erected in position as was convenient to fit in with rest of the programme.				

NOTES.

1. *Dismantling existing machinery and gates* :—Bays 12,11,10, 9, 8 to be done entirely by Marala Division. Bays 7 to 1, machinery and counterbalance to be removed by Central Workshops and upper gates slung from new machinery. Removal of gates and removing details to be done by Marala Division.

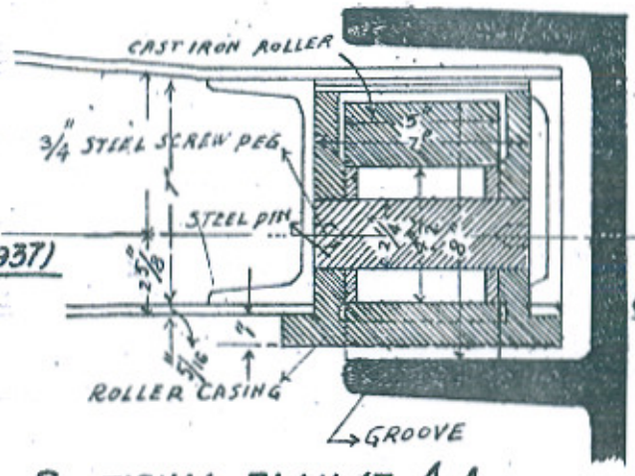
2. Existing grooves in all spans to be removed by Marala sion. Erection of new grooves to be done by Central Workshops Div Grouting of new grooves and superstructure columns to be done by M Division as required.

3. In Bays 1-7. In order to remove existing machinery pr closure to permit of installing new lower gates, the existing upper will be slung from and operated by the new machinery, and count anced by the new counterbalance for the upper gates.

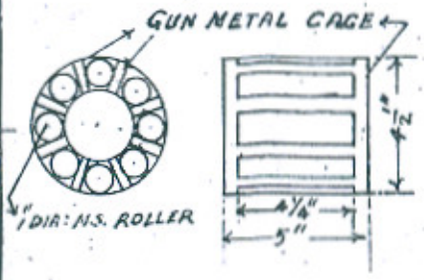
Procedure for carrying out change over will be as follows :—

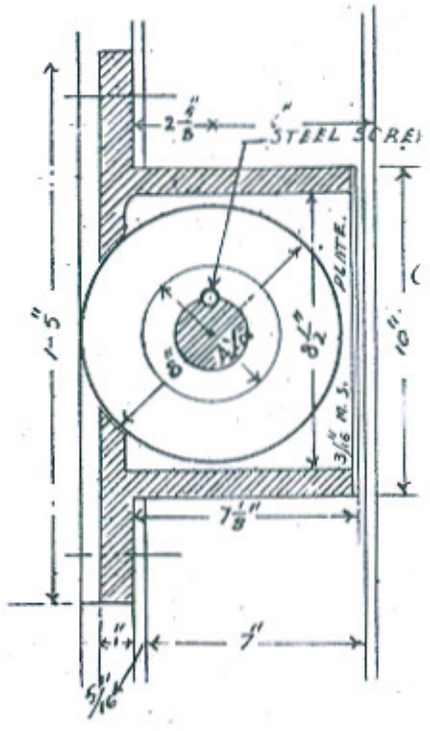
1st stage	..	Raise and clamp existing upper gates.
2nd stage	..	Free, empty and remove existing counterba and remove existing machinery.
3rd stage	..	Put into position new counterbalance for new gates.
4th stage	..	Instal new lower gates.
5th stage	..	Suspend existing upper gate from new machi

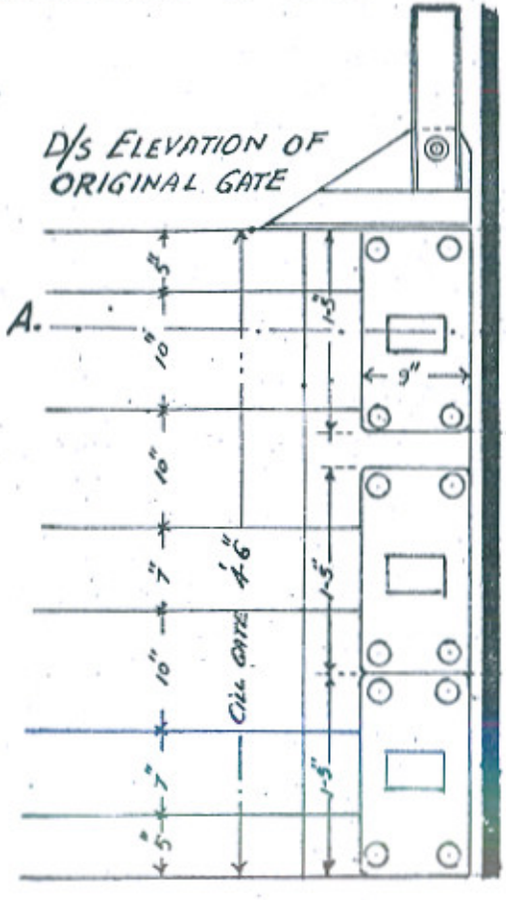
REMODELLING
MARALA HEAD REGULATOR (1937)
ROLLER ARRANGEMENTS
SCALE 3/4" = 1 FT & 2" = 1 FOOT

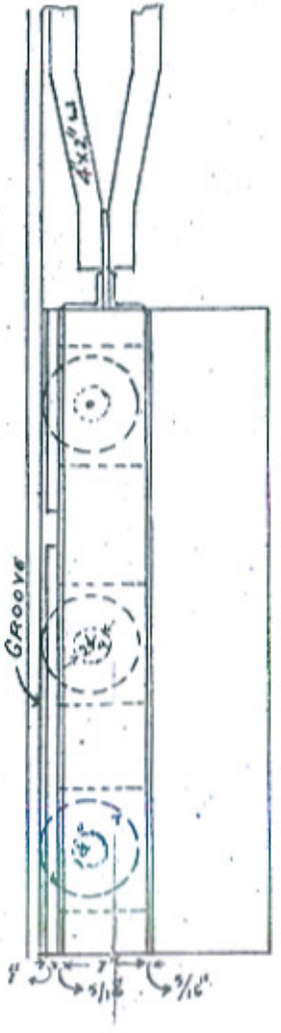


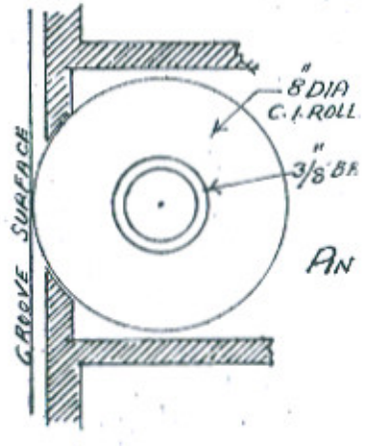
SECTIONAL PLAN AT A.A.



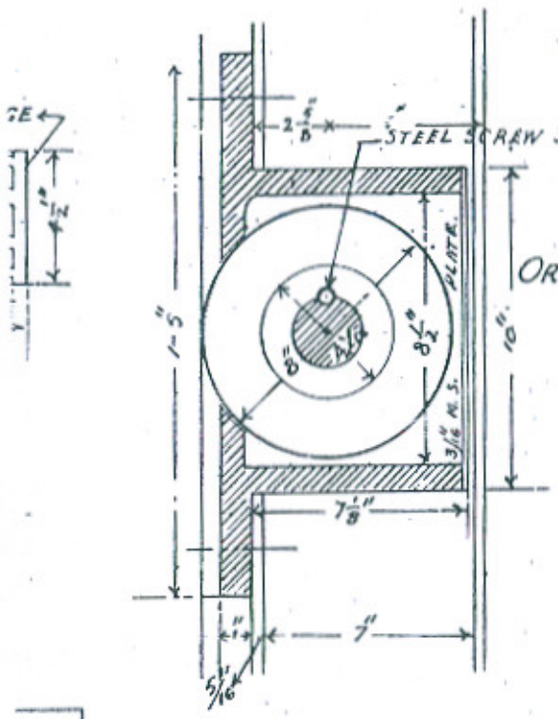


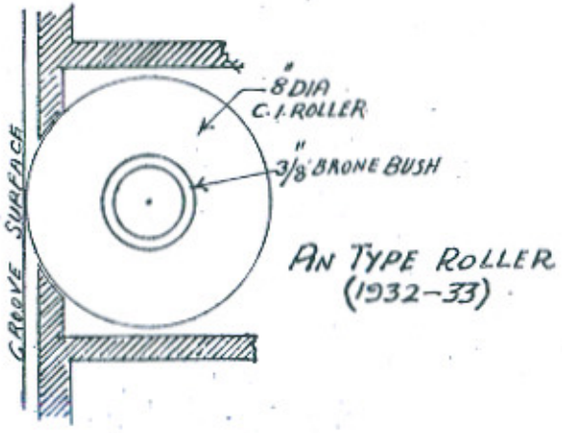


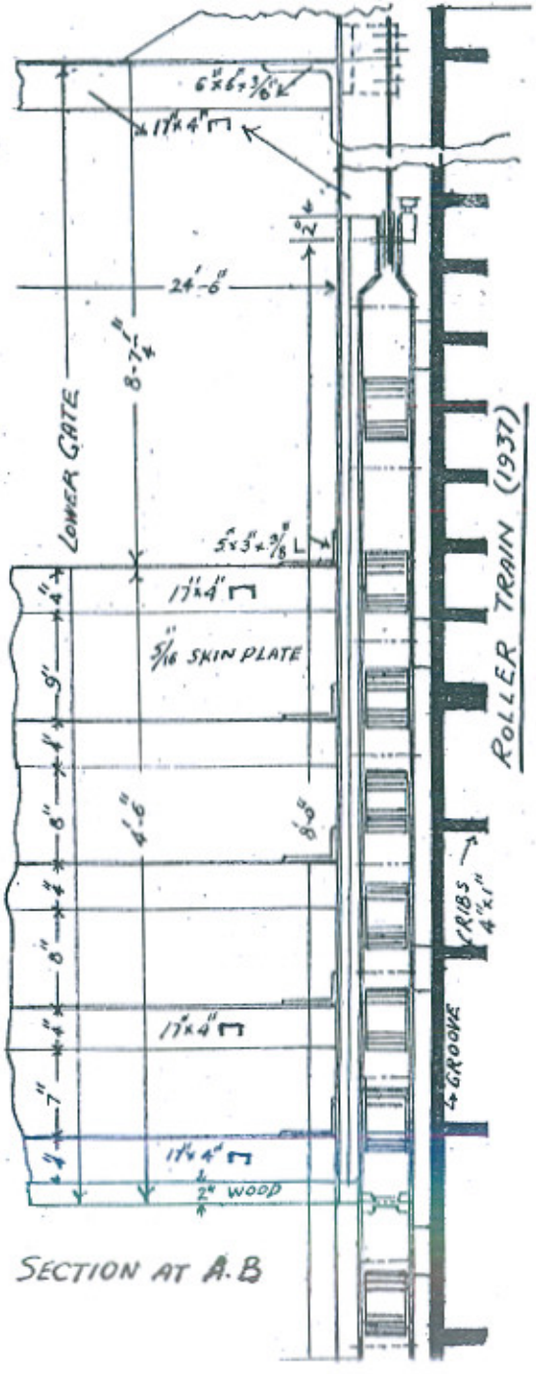


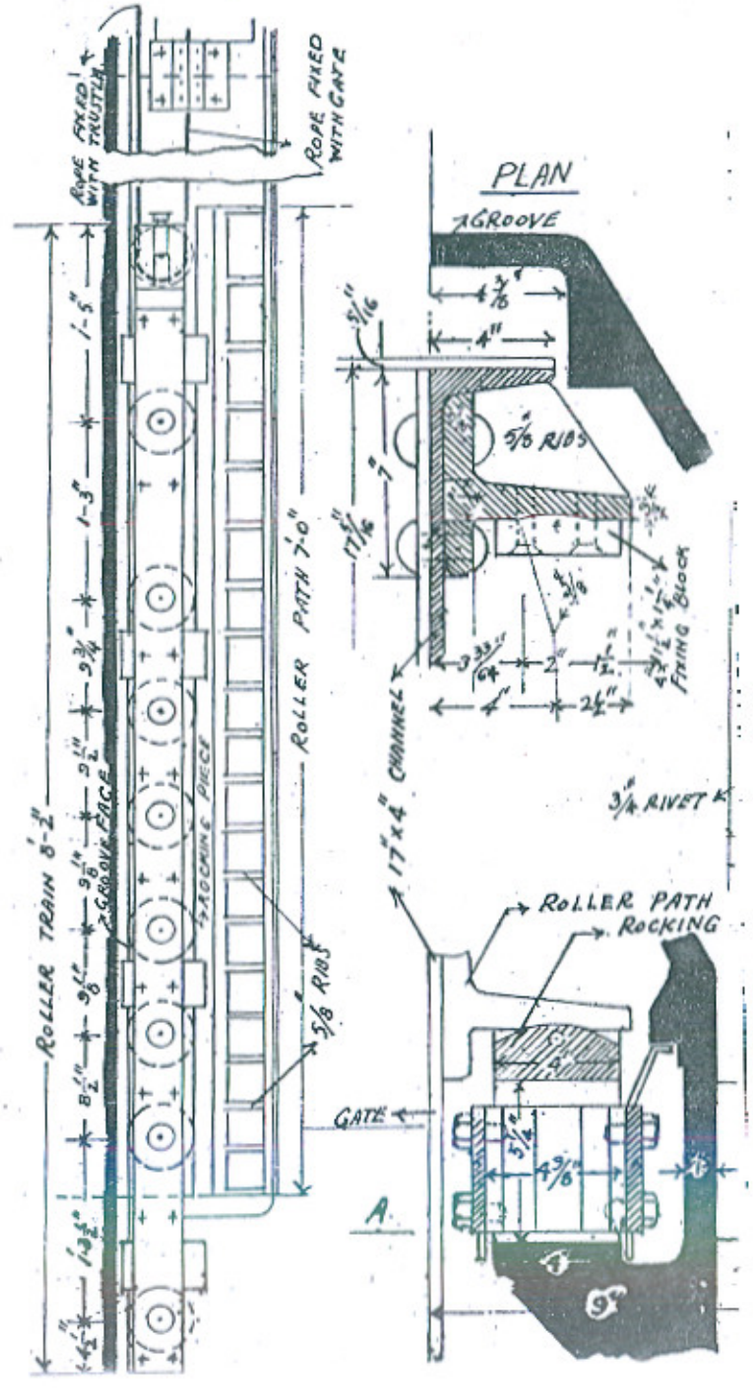


DRAWN BY
'Kwankiah'
DRAFTSMAN

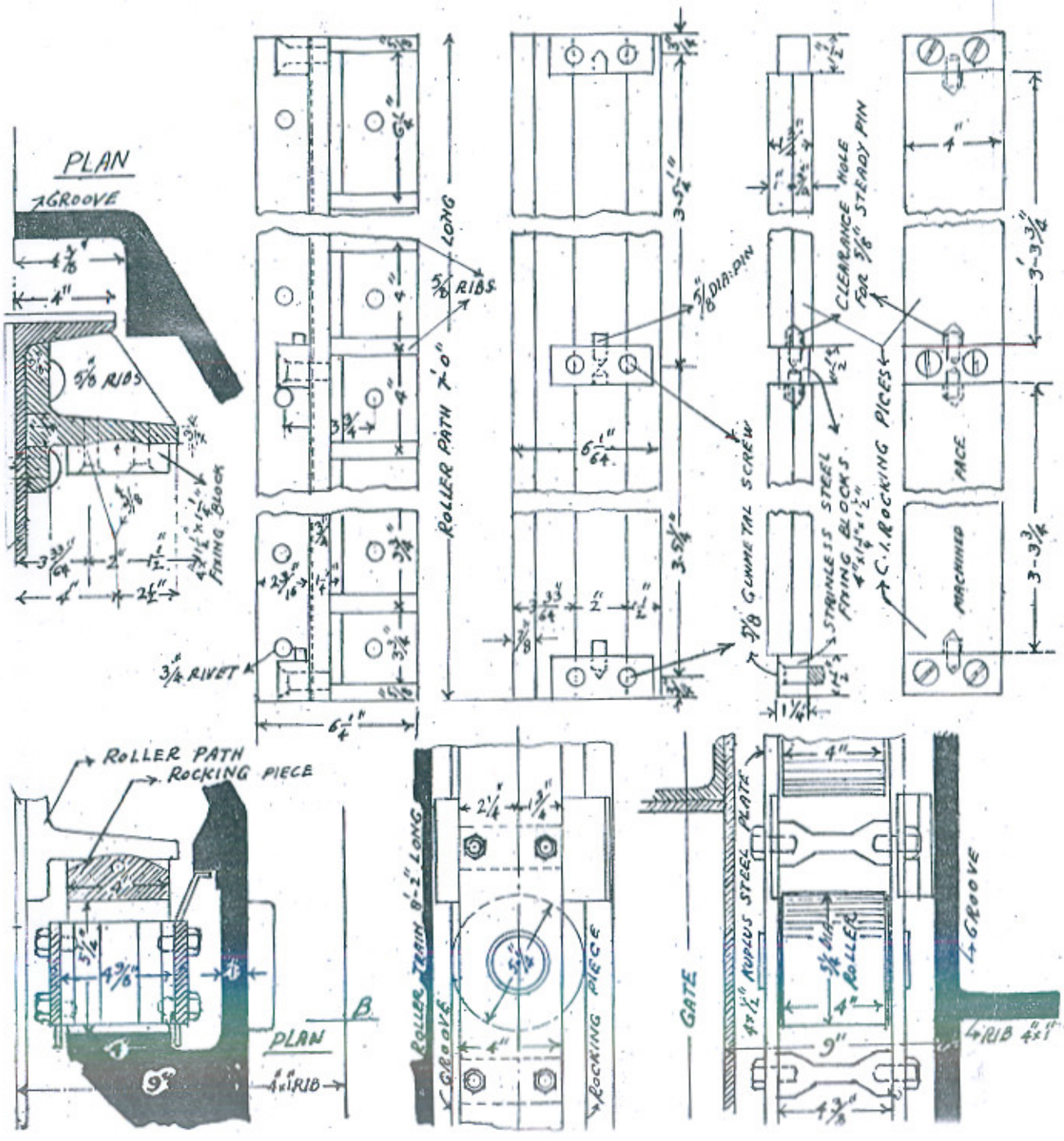

STEEL SCREW STUD.
PLATE.
ORIGINAL ROLLER
(1912)


8 DIA
C.I. ROLLER
3/8 BRONE BUSH
GROOVE SURFACE
AN TYPE ROLLER
(1932-33)


LOWER GATE
ROLLER TRAIN (1937)
5/16 SKIN PLATE
GROOVE
RIBS
SECTION AT A.B

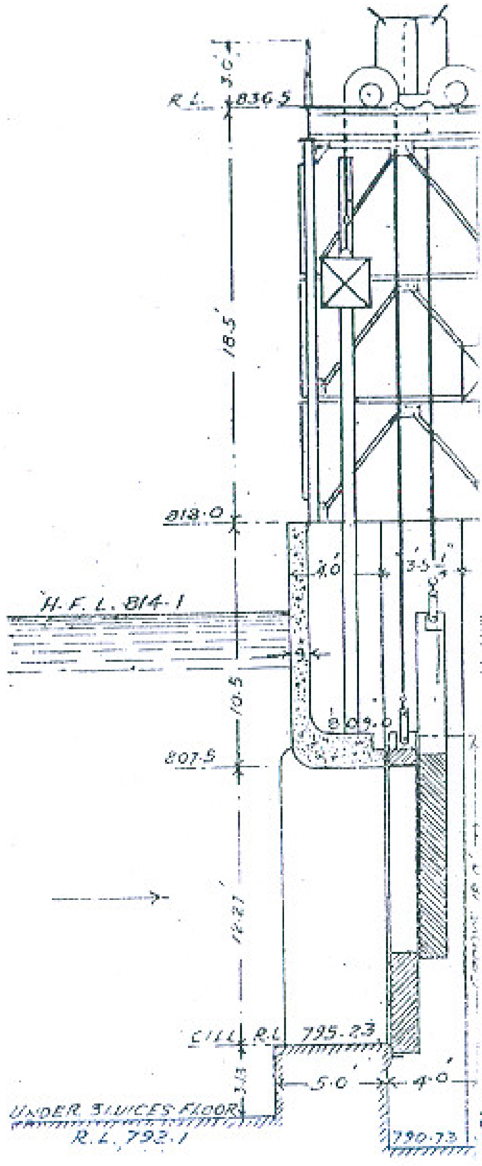

ROPE FIXED WITH TRUSTLE
ROPE FIXED WITH GATE
ROLLER TRAIN
ROLLER PATH
GROOVE FACE
FACING PIECE
5/8 RIBS
GATE
PLAN
GROOVE
5/8 RIBS
FIXING BLOCK
17"x4" CHANNEL
3/4 RIVET
ROLLER PATH
ROCKING

PAPER N.º 210
PLATE Nº I



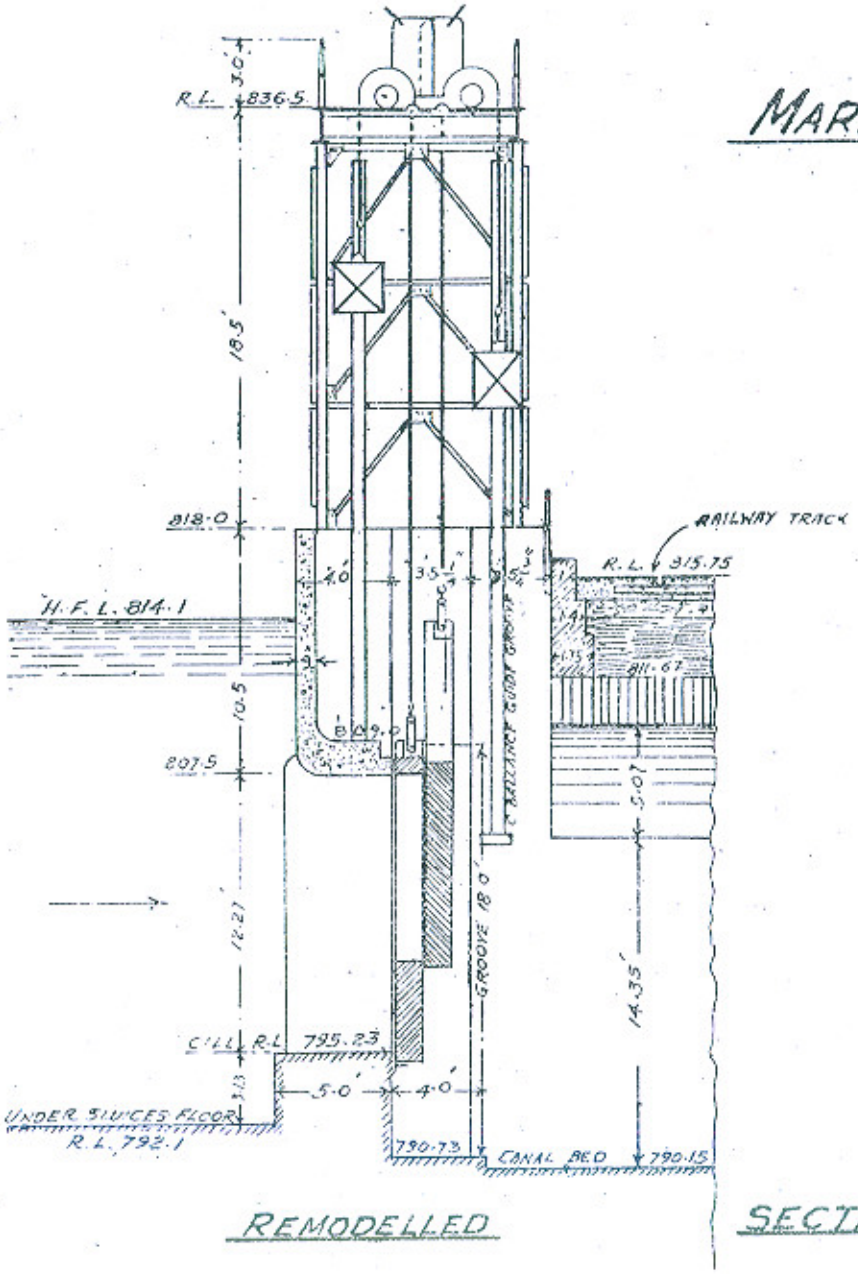
C. Nanda. 18/9/37
I.S.E.,
S.D.O. HEAD WORKS
MARALA.

PUNJAB ENGINEERING CONGRESS
1938

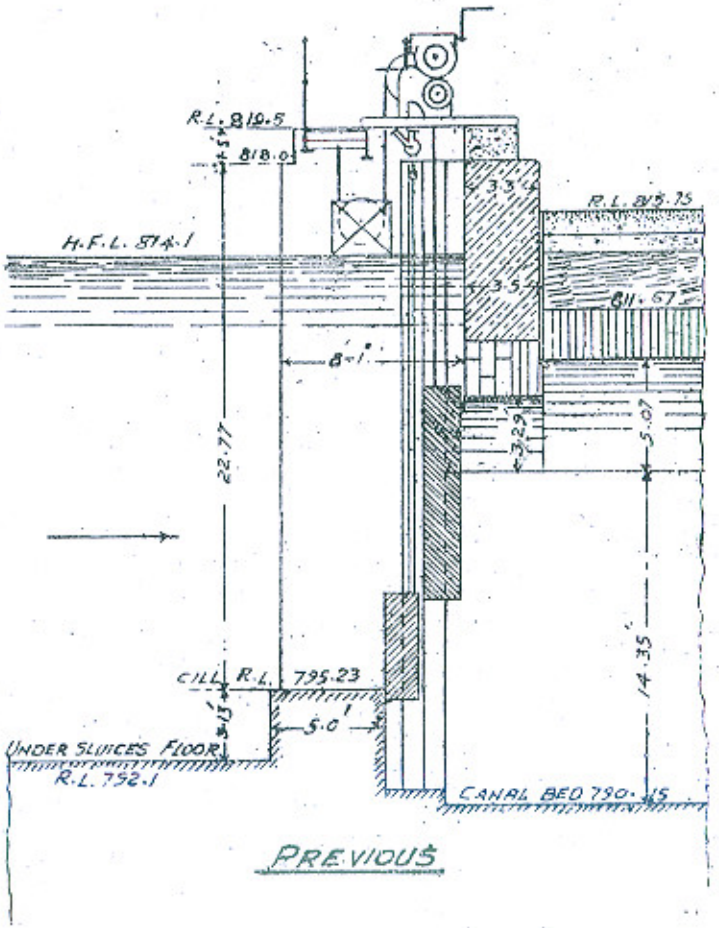

R.L. 836.5
3.0
18.5
818.0
4.0
3.5
H.F.L. 814.1
10.5
809.0
807.5
12.27
CILL R.L 795.23
3.13
5.0
4.0
UNDER SLUICES FLOOR
R.L. 792.1
790.73

REMODELLEL

REMODELLING
MARALA HEAD REGULATOR (1937)
SCALE 1/100



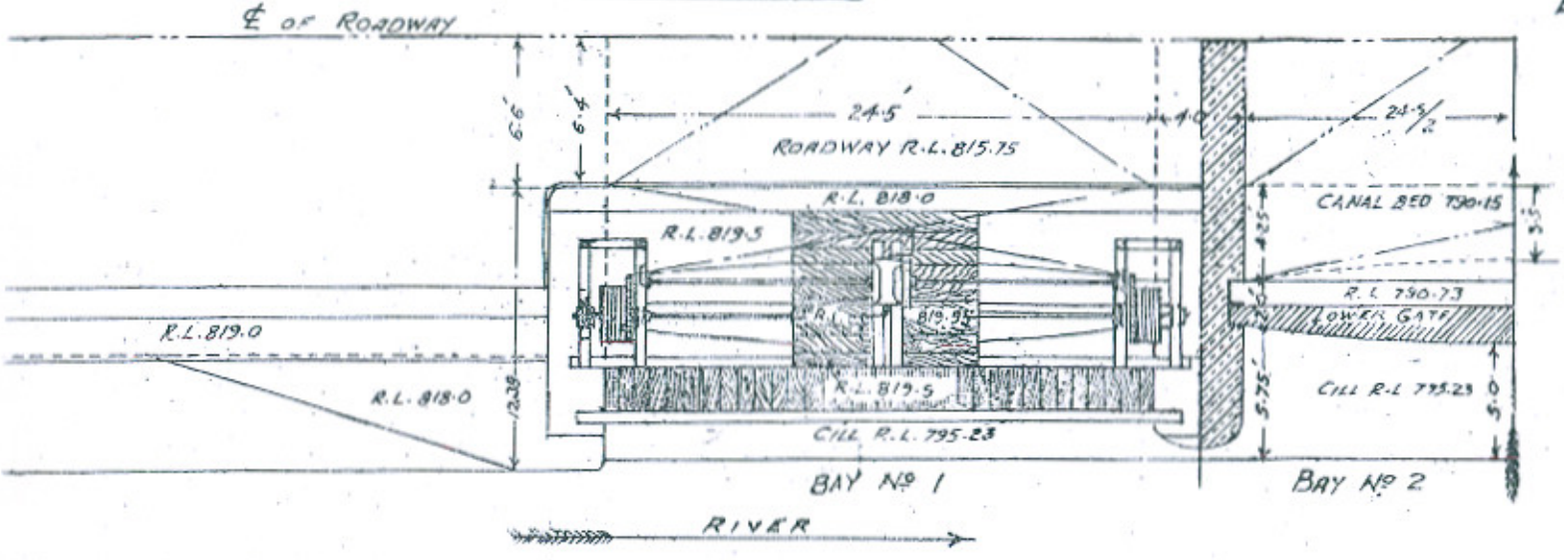
REMODELLED SECTIONS



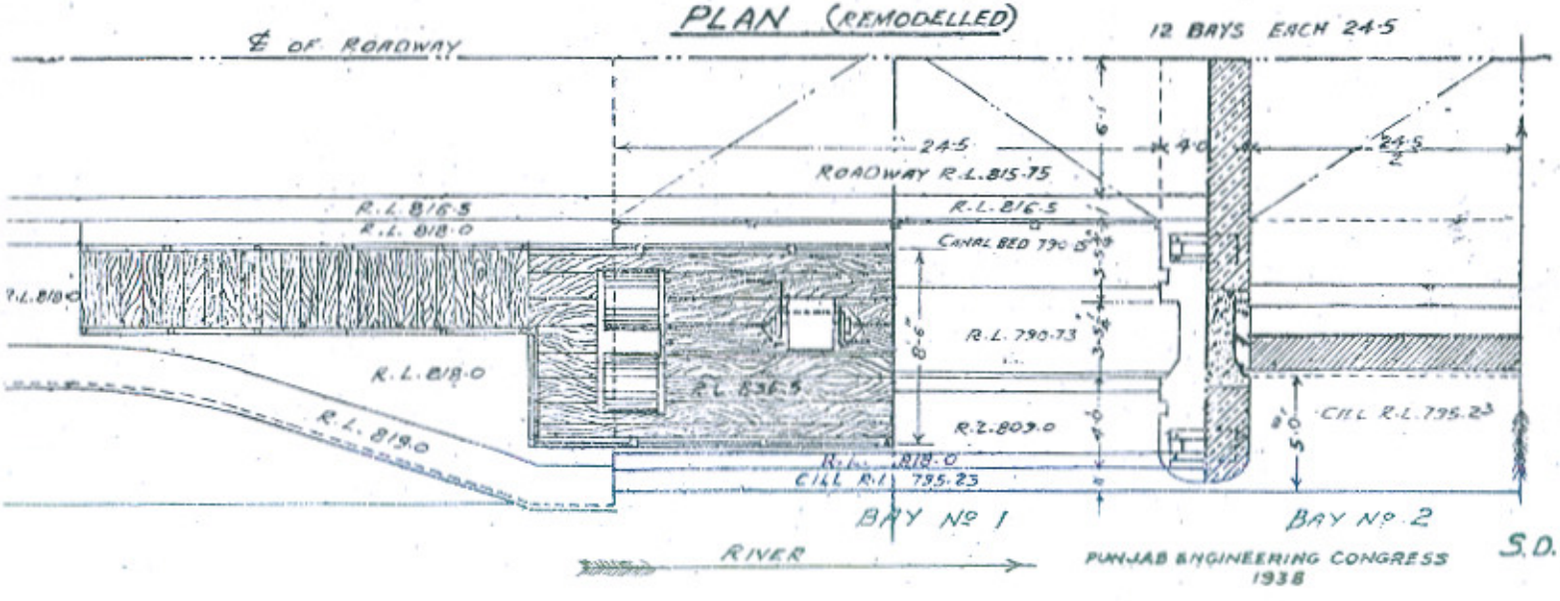
PREVIOUS

PAPER No 210
PLATE No II

PLAN (PREVIOUS)



PLAN (REMODELLED)



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1938

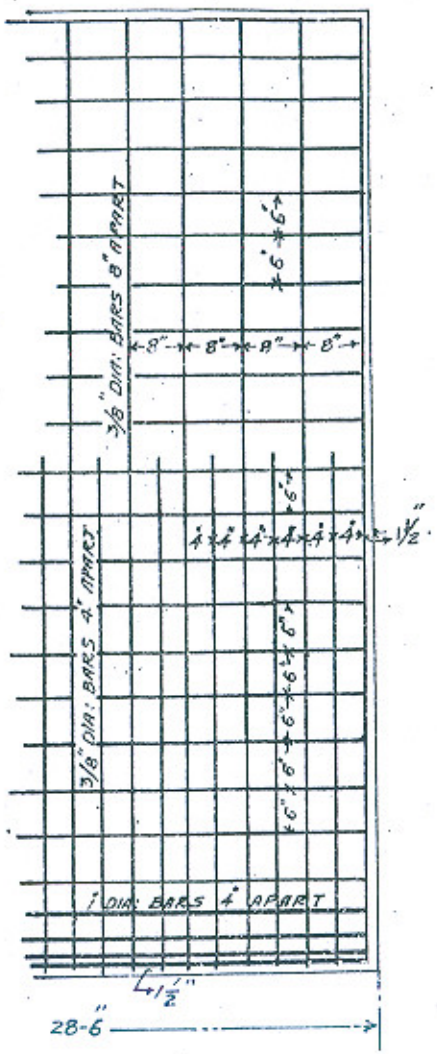
C.A. Banda 18/9/37
I.S.E.,
S.D.O. HEAD WORKS,
MARALA.

REMODE

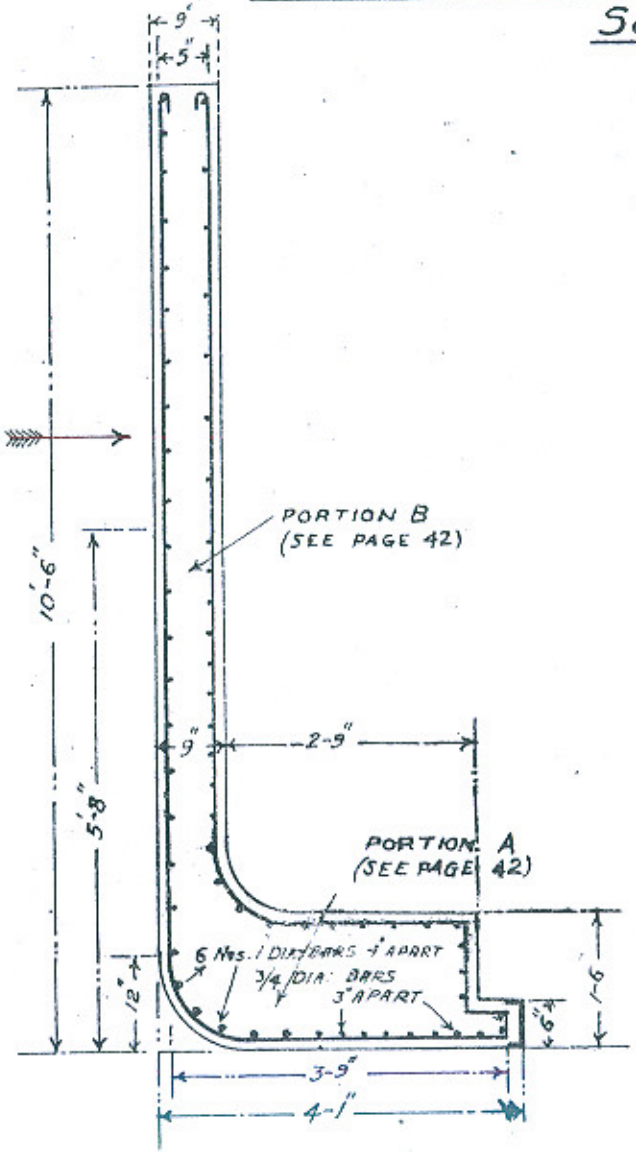
MARALA HEAD R

BREAST WALL DETAILS,

SCALE 1/2"



ELEVATION TOWARDS RIVER

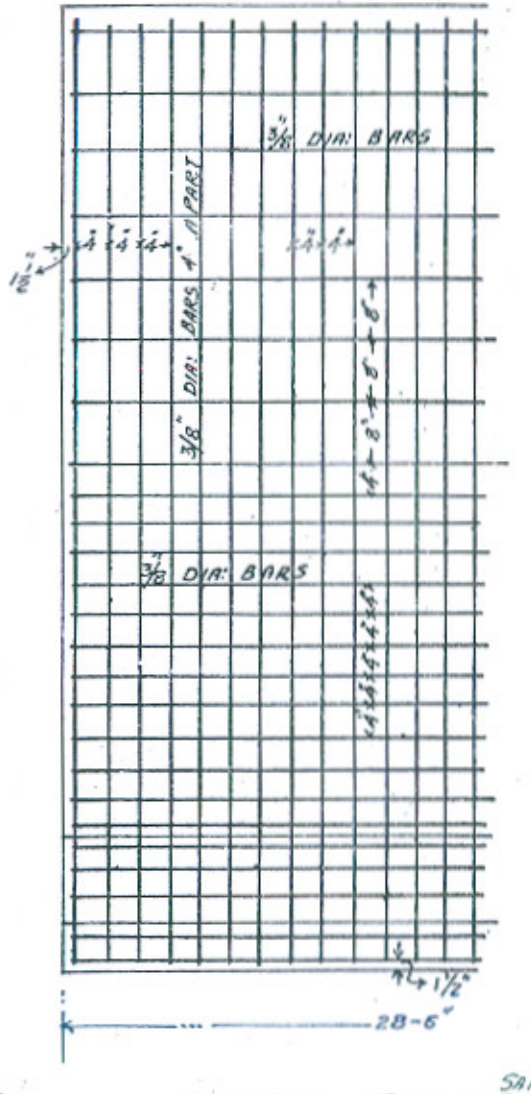


CROSS SECTION

ELEVAT

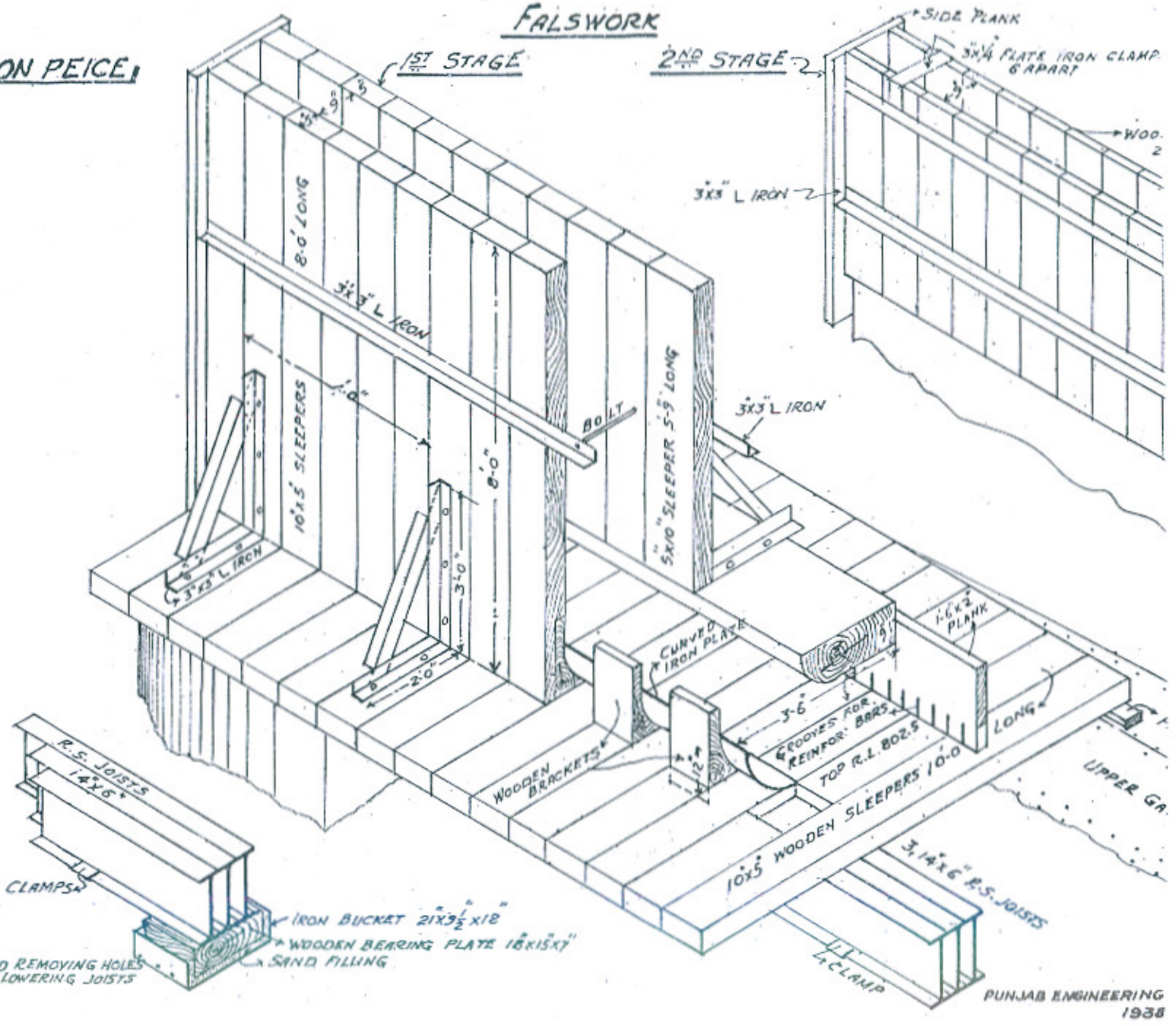
DRAWN BY
KiwaNath
DRAFTSMAN

REMODELLING
HEAD REGULATOR (1937)
DETAILS, FALSWORK & EXTENSION PEICE.
SCALE 1/2" = 1FT & 3/8" = 1FT



ELEVATION TOWARDS REGR

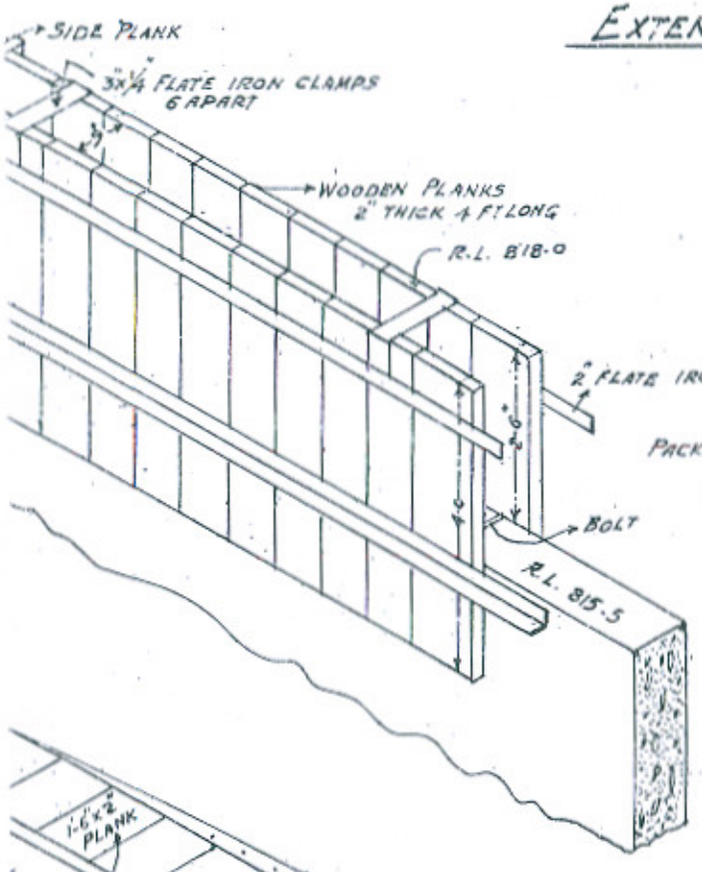
FALSWORK

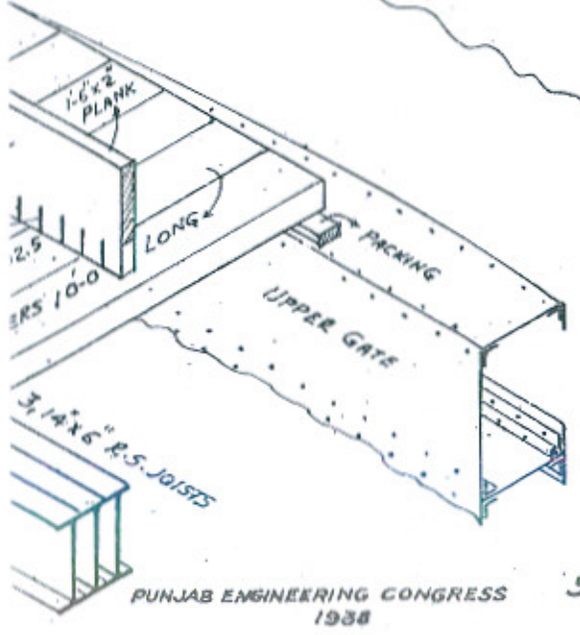


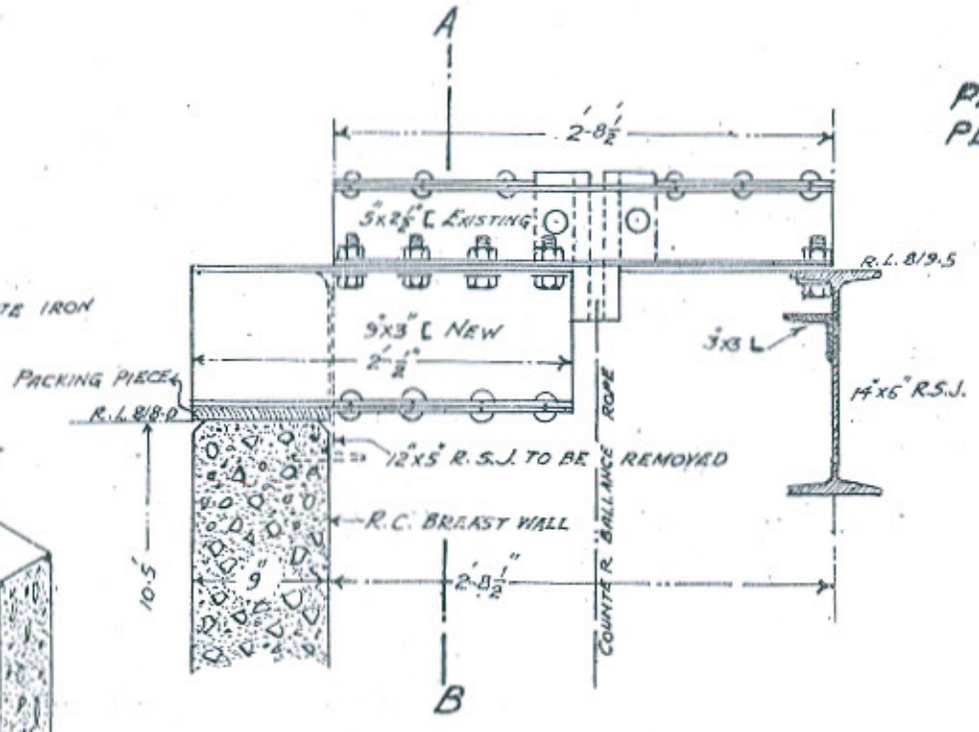
PUNJAB ENGINEERING
1938

EXTENSION PIECE for COUNTER BALLANCE CROSS GIRDERS

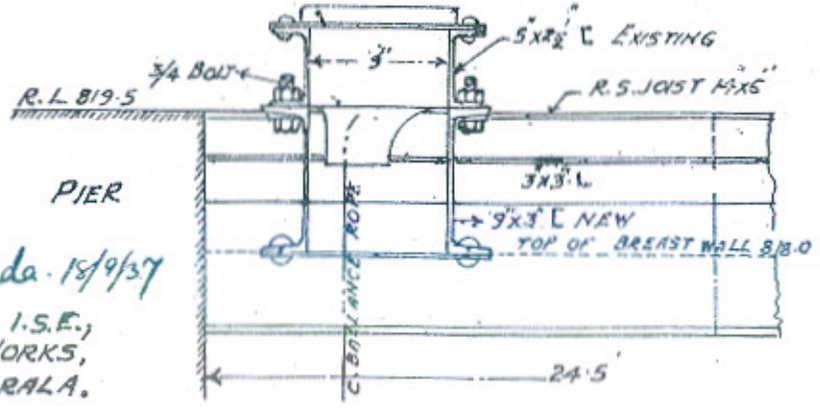
PAPER Nº 210
PLATE Nº III







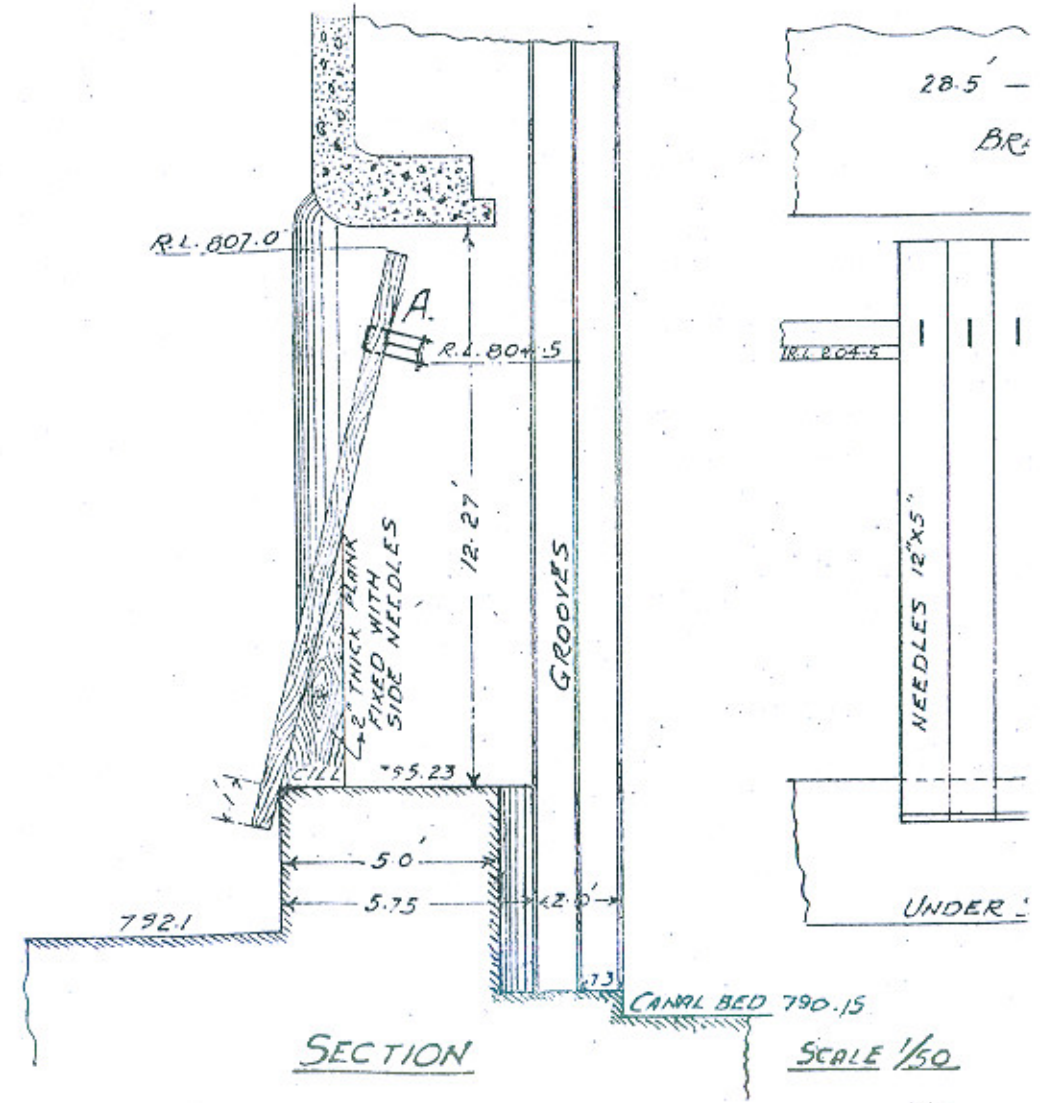
SECTION ON A.B.



PIER

C Manida 18/9/37
I.S.E.,
S.D.O. HEAD WORKS,
MARALA.

PUNJAB ENGINEERING CONGRESS
1938



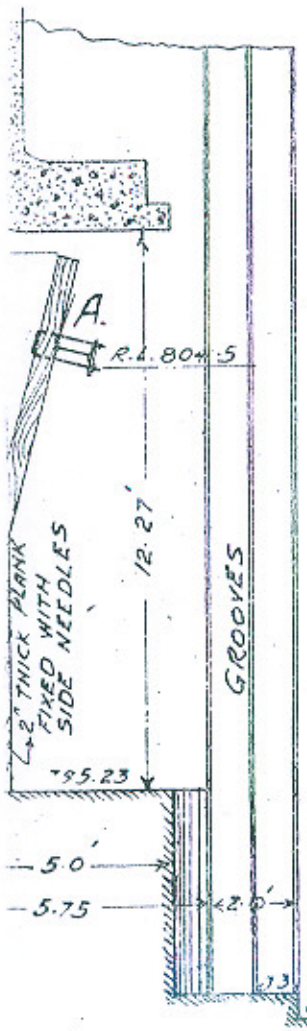
SECTION

SCALE 1/50

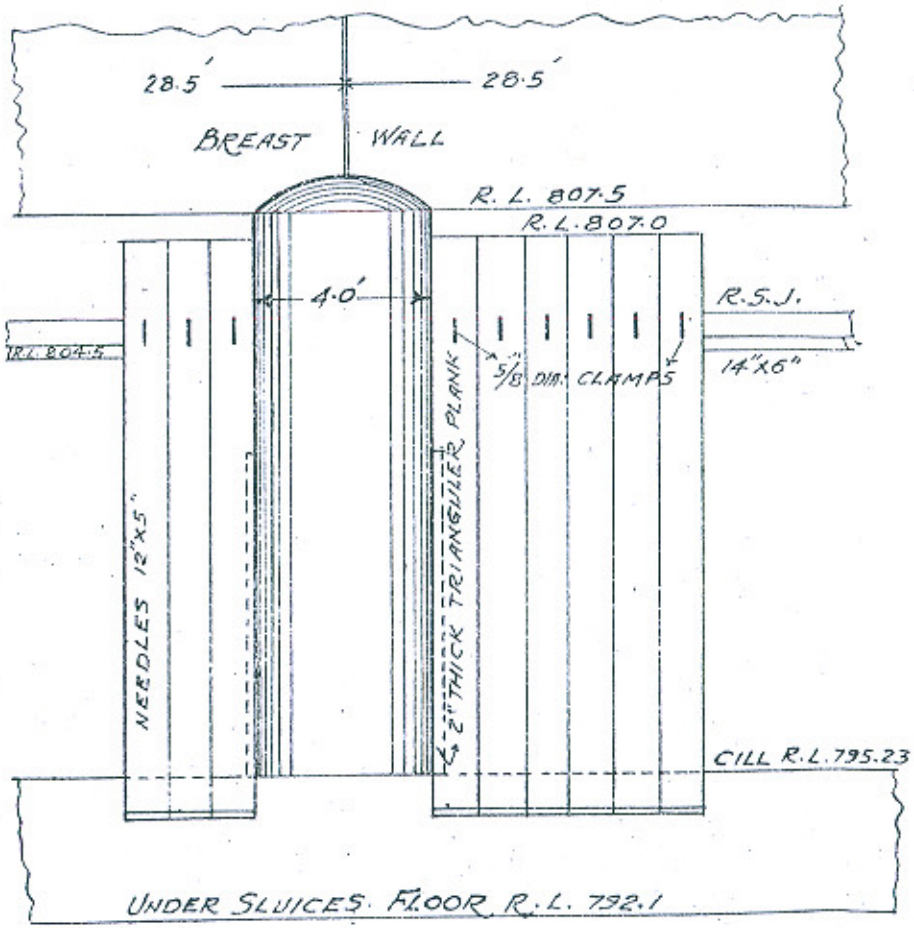
DRAWN BY K. Warnath

DRAFTSMAN

REMODE
MARALA HEAD
NEEDLE DAM

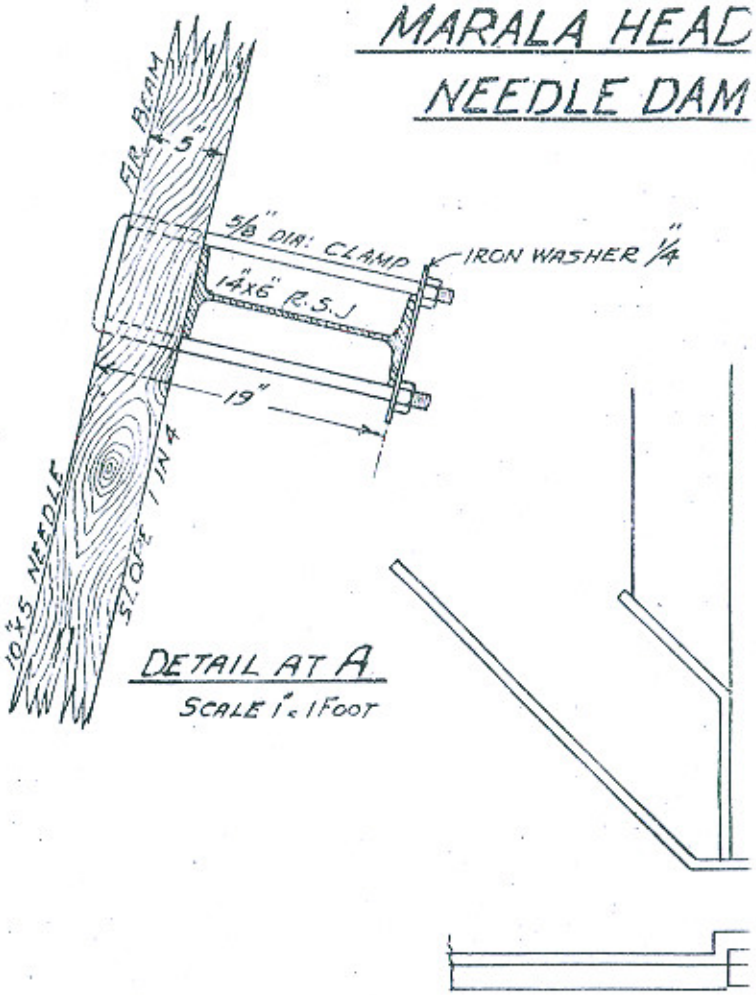


ECTION



SCALE 1/50

ELEVATION



DETAIL AT A

SCALE 1" = 1 FOOT

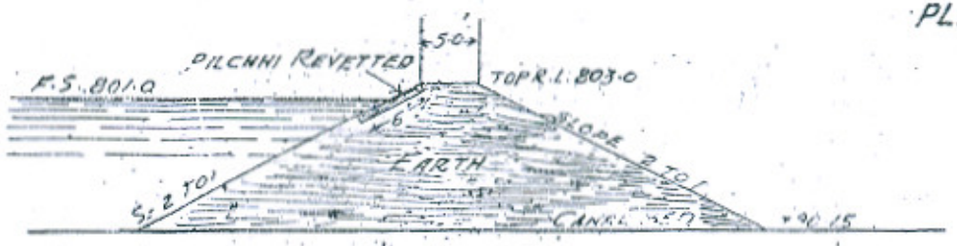
NG

GULATOR (1937)

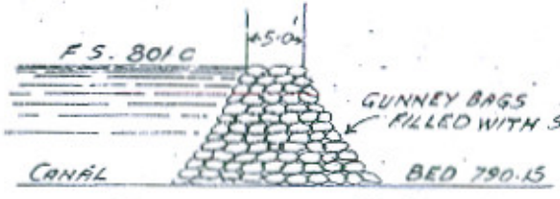
SITE PLAN

PAPER Nº 210

PLATE Nº IV.



SECTION ON A.B.
SCALE 1/200



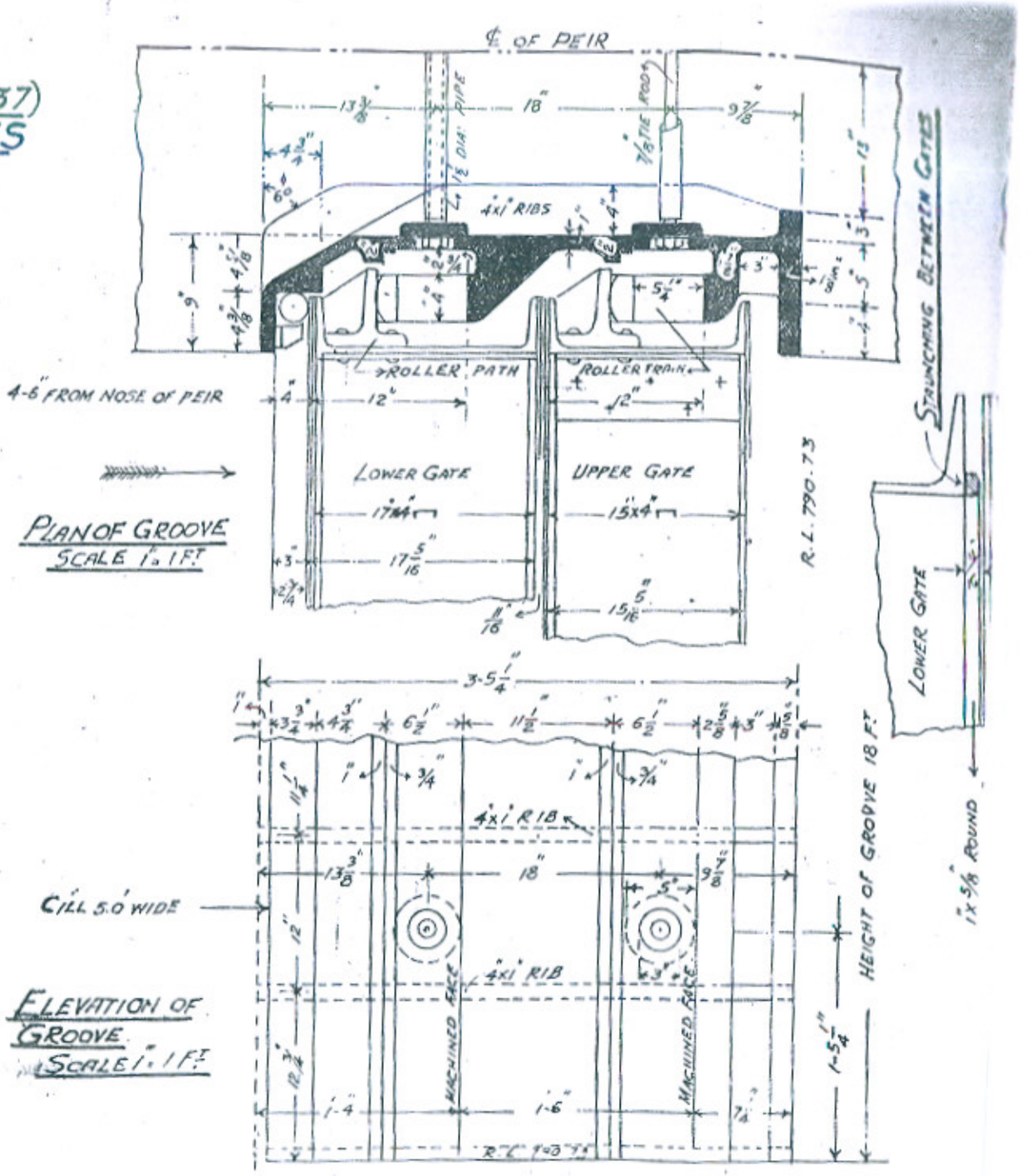
SECTION ON C.D.
SCALE 1/200

REGULATOR
SCALE 1/300

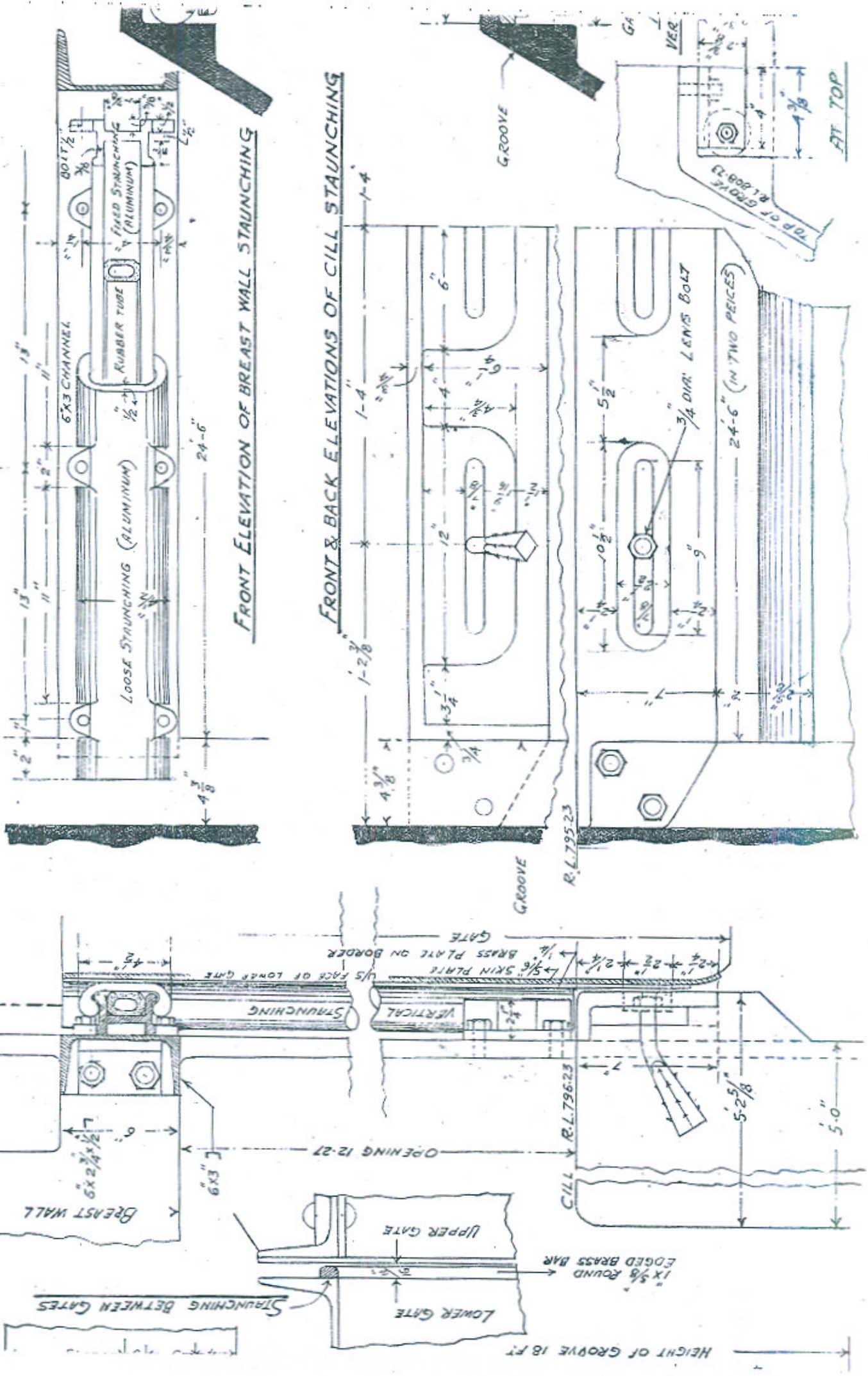
Sharda. 18/9/37
I.S.E.,
S.D.O. HEADWORKS
MARALA.

PUNJAB ENGINEERING CONGRESS
1938

REMODELLING
MARALA HEAD REGULATOR (1937)
STAUNCHING ARRANGEMENTS
SCALE 2" = 1 FT



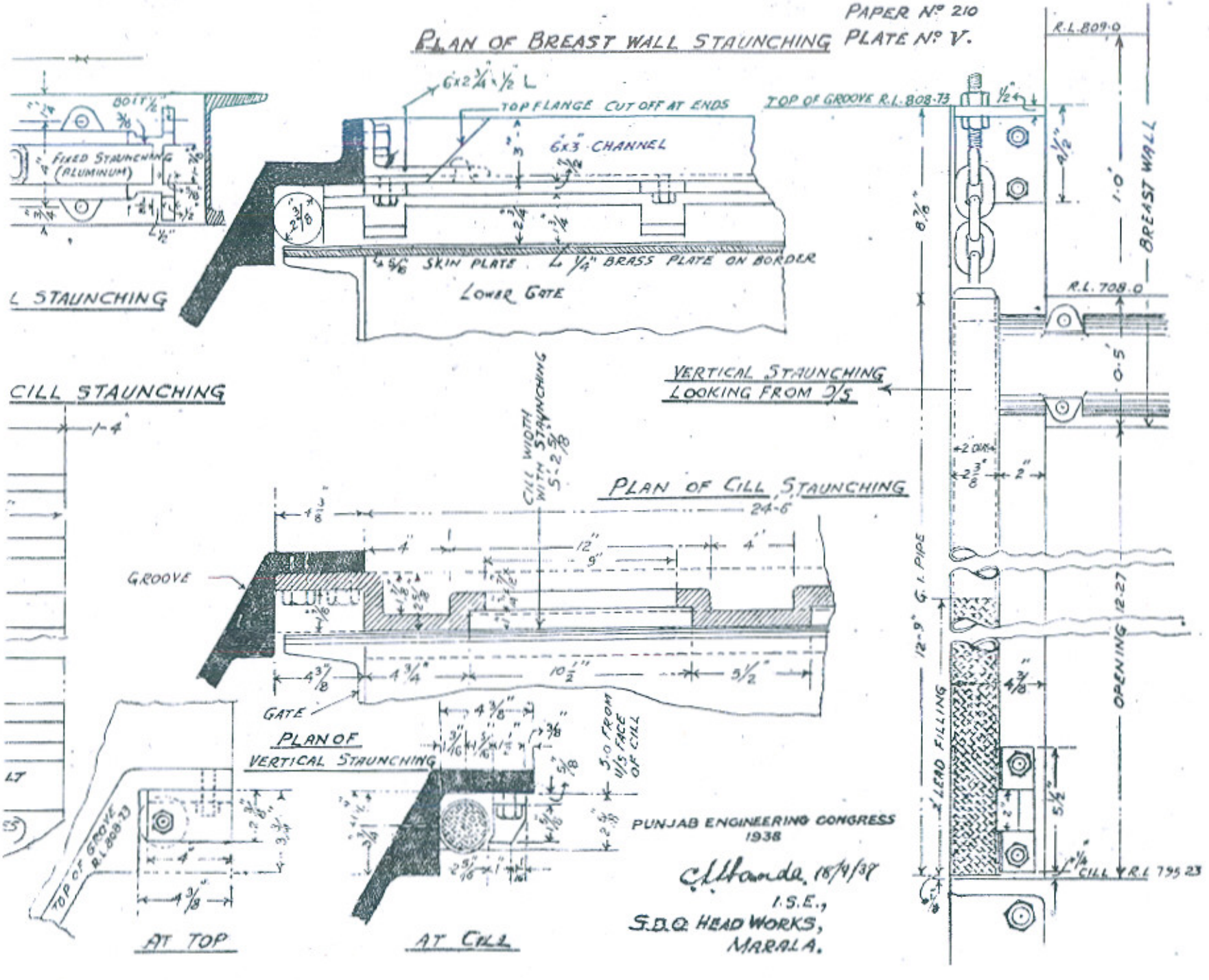
DRAWN BY
Liaqat Nath
DRAFTSMAN


FRONT ELEVATION OF BREAST WALL STAUNCHING
FRONT & BACK ELEVATIONS OF CILL STAUNCHING
6"X3 CHANNEL
RUBBER TUBE
FIXED STAUNCHING (ALUMINUM)
LOOSE STAUNCHING (ALUMINUM)
BOLT
GROOVE
3/4 DIA. LENS BOLT
24'-6" (IN TWO PIECES)
R.L.795.23
R.L.796.23
BRASS PLATE ON BORDER
SKIN PLATE
U/S FACE OF LOWER GATE
STAUNCHING
VERTICAL
GATE
OPENING 12-27
CILL
BREAST WALL
UPPER GATE
LOWER GATE
1X 5/8 ROUND EDGED BRASS BAR
STAUNCHING BETWEEN GATES
HEIGHT OF GROOVE 18 FT

PAPER No. 210

PLATE No. V.

PLAN OF BREAST WALL STAUNCHING



PUNJAB ENGINEERING CONGRESS
1938

C.L. Handa. 18/4/38
I.S.E.,
S.D.O. HEAD WORKS,
MARALA.

DISCUSSION

The **Author**, in introducing his Paper said that the two Papers on Marala presented at this year's Congress related to works which were carried out simultaneously and in close proximity but the work of remodelling the Head Regulator of the Canal was entirely distinct from the reconstruction of the Weir. It was for this reason that he considered it desirable to send in his Paper and to put on record in a handy manner the various steps that enabled the remodelling of the Regulator to be accomplished within the short space of two scheduled closures of the Upper Chenab Canal. It was hoped that when works of a similar nature had to be undertaken at other Headworks this Paper would be found handy in such matters as the order in which the works should be organized.

The Upper Chenab Canal had peculiar difficulties in regulation on account of the suddenness with which floods in the river, or spates in the Jammu Tawi, reached Marala. It was not unusual to receive the flood warning later than the arrival of the flood and the old and inefficient gates of the Head Regulator were often responsible for huge excesses of supply passing into the canal. After ticking off the evening canal gauges during the months of May to August, the Sub-Divisional Officer would receive a telephone message at night from Khambranwala or Bambanwala that an excess of as much as 400 to 800 cusecs had appeared at these places without any warning. In the subsequent investigations the excesses would be attributed to the change in silt conditions and the velocity of approach; but in the Author's mind, the fault lay with the inefficient gates which could not be closed sufficiently quickly to resist the onslaught of the Tawi. With the new gates that had now been put in, regulation could be done with the degree of nicety that was desired and during the flood season of 1937-38 no trouble was experienced at Marala. In the Paper on Silt Excluders read by Mr. Haigh in the previous day's session, the points affecting silt entry in canals were discussed. The Author said he had mentioned in his Paper that silt exclusion at the Head of the Canal could be very largely secured with suitable regulation at the Headworks without a silt excluder. In this connection it was interesting to compare Marala and Khanki. In the year 1933-34, silt conditions were bad at both these places. He exhibited a diagram to show the head gauges of both these canals for discharges of 11,000 cusecs. It would be noticed, he said, that in a period of four years there had been a drop of about 2 feet in the head gauge of both these canals and yet one of them had a silt ejector at the Head and the other had none. The conditions favourable for effectively dealing with the silt problems had been enumerated by him on page 49 of the Paper and he wished to stress again that the control of the silt was fundamentally allied to the stability of conditions in the virtual pocket. The building of a silt excluder or a silt ejector at the head of the canal resulted in a permanent pushing up of the pond level

and was thus liable to put greater and a more prolonged strain on the weir on account of the heading up that was required to feed the canal. At the same time it did not give the same flexibility as could be had in the absence of a silt excluder when the desired cill level was secured by manipulation of the gates.

Further, he wished to draw attention to two practical details of which mention had been made in the Paper. The first of these was the needle dam whereby the canal was shut off in the absence of gates. This arrangement could well form a standard device whereby channels could be closed off for repairs. In this connection it was to be noted that the downstream bund should be located sufficiently far away from the face of the work to give the necessary working area without the bund sloughing in. The method of making the needle dam water-tight by use of a tarred gunny sheet was also worthy of note as being very cheap and effective.

The other point was the r. c. breastwall. For this the shuttering had to be done in stages and the method adopted worked very well. In the latter stage the surface was left just as it came out of the shutters and little or no rendering had to be done.

He had to thank Mr. Cox for having gone through his Paper and for pointing out certain amendments which were as follows :—

Page 38, *under* ' *Original Rollers.*'

The original design of the rollers emanated from Messrs. Ransomes and Rapier who used phosphor bronze, and not from Mr. Ashford. As stated, Mr. Ashford merely copied the design and adopted steel for phosphor bronze. The change from the original phosphor bronze was an unsatisfactory step as steel could not stand the wear as well as could phosphor bronze.

Page 29, *under* ' *Defects of the existing arrangements,*' *Item No. I.*

It had to be stated that during the monsoon season it was unsafe to use the upper gates as cills as the face plates of the gates had been condemned as unsafe.

Regarding the water tightness of the new gates, the staunching devices provided had been found to be most effective; the downstream protection had become visible in a 24-hour closure. In this connection some precautions might have to be taken at this Headworks with regard to the safety of the regulator, which could not be subjected to a head of 24 feet for which it was not designed. During floods, therefore, a certain amount of escapage might have to be allowed into the canal in order that the head remained safe.

Mr. **Ganpat Rai** said that the Paper served to place on record a number of constructional details which, the Speaker believed, would prove useful to engineers called upon to undertake similar works in future. The description of the difficulties that had to be faced during the execution of the work and of the means adopted to overcome these would also be of considerable interest. Not the smallest of these was the one mentioned by the Author towards the bottom of page 45 where he had stated how the pond level in October 1936, (kept unusually high for the sake of constructing the ring bunds upstream of Bays 1 and 2 of the weir in connection with the work of reconditioning of the latter) had complicated the arrangements for isolating Bays 12 to 8 of the regulator from the rest of the work. Certain items of the work, *viz.*, the removal of the two bottom pieces of the old grooves, cutting of shafts into pieces, cutting of the downstream edge of the permanent ashlar crest and fitting of new grooves and gates could only be done during a canal closure. There was only one long canal closure during the year, *viz.*, a 24-days closure starting generally about the third week of November, and it was realized that no matter how well the work might be organized, considering their nature, these items could not be completed in a period of 24 days. It was therefore decided to form a ring round five bays on the right of the regulator and to start work in them about a fortnight before the long closure started which in effect meant an extension of the closure by this period.

On page 48 the Author had described the effective manner in which the new staunching arrangements were functioning. These had not been tested so far under high flood conditions but there was no ground for supposing that they would be at any time less effective under such conditions. If so, with the *pucca* floor downstream of the regulator dry, the latter might have imposed on it during a high flood a head of anything up to 24 feet (Plate II). This would be more than the maximum safe head of 17 feet to which the regulator could be subjected. To keep the head within safe limits it would be necessary to run the canal with a low discharge for flood discharges of about 3,00,000 cusecs and over. With the old regulator this used to happen automatically as there was a considerable amount of leakage into the canal with the river in flood.

CORRESPONDENCE.

Mr. **W. G. Wheatley** gave the folowing description of the more important features connected with the design and erection of the mechanical portion of the work, at the request of the Author. From the mechanical and structural points of view the remodelling of the regulator was most interesting, both as regards design and erection, on account of the many problems which had to be solved.

2. Once the type and general arrangement of the gate system had been decided upon, the main considerations effecting the design were :—

(*a*) the desirability of utilizing the existing masonry work as far as possible, and

(*b*) the very limited period (*viz.*, 24 days) available for working in the dry.

This latter consideration was by far the most important since, as it was impossible to complete the removal of the existing gates and machinery, etc., and erect the new within the closure period, it meant that a considerable portion of the steel work had to be erected whilst the canal was in flow, and with the old gates and machinery still in position. Moreover, for regulation purposes and in case of possible freshets, it was essential that the gates should not be put out of operation.

3. How far these *desiderata* were obtained in practice might be judged by the fact that the whole of the superstructure and machinery for the new gates were erected with the old gates still in position, and at one stage of the work the latter were being operated from the new superstructure by the machinery for the new gates.

Actually, by the time the closure started, practically the whole of the erection with the exception of the grooves had been completed in six out of the 12 bays.

4. In general, the design of the gates, superstructure and machinery conformed to the usual practice for sluice gates working on the Stoney Roller principle. One or two new features were introduced in the design of certain parts, such as the staunching devices to which the Author had referred in his Paper, and certain features of the design of the remodelled regulator as a whole were unusual and not without interest.

5. A study of the sectional drawings of the regulator reproduced on Plate II of the Paper would show that the main difference between the old and new designs were that in the case of the latter a superstructure had been added and the breast wall rebuilt on the upstream side of the gates. It would be obvious that the positioning of the breast wall upstream of the gates constituted an improvement in many ways, but it was not usually adopted in combination with a double gate system in which both gates could be lowered behind a raised permanent cill on account of the difficulty of providing adequate staunching arrangements. The fact of having to provide means of lowering both gates behind the permanent cill made it necessary to fit the lower gate in the upstream groove which in turn made the design of efficient staunching arrangements difficult owing to the impossibility of sealing the gap between the gate

ends and the grooves when looked at in plan—(see Plate I). Had it it not been necessary to provide for lowering the upper gate behind the cill the relative positions of the two gates in the grooves could have been reversed, and the design of the staunching devices would then have been a simple matter.

6. As it was, the staunching problem was solved by extending the vertical end girders of the lower gate over a length equal to the height of the upper gate and cross-connecting their upper ends by a horizontal member in such a manner as to form a frame or an orifice which could be sealed by the upper gate. A reference to the sectional drawing of the regulator in Plate II would serve to illustrate this in more detail.

7. The Author had referred in his Paper to the effectiveness of the staunching arrangements which, the Writer believed, were of a novel design inasmuch as the underlying principle on which it was based was the use of silt as the staunching medium. Staunching devices for a double gate system similar to that fitted to the reconstructed regulator, were usually of a complicated nature and, from the Writer's experience, usually failed to function properly owing directly or indirectly to the action of silt. In designing the various staunching devices for these particular gates and particularly those between the two gates and between the face of the lower gate and the permanent cill, the Writer's object was to avoid the use of any moving parts or corrodable surfaces and to utilize the silt and small jungle which the river water usually contained as a tamping medium. As would be evident from a reference to the drawings reproduced in Plate V these objects were achieved by reducing the working clearances to a practical minimum and by the fitting of phosphor-bronze strips around the edges of the skinplate of the gates to provide the staunching faces.

8. A point to be noticed in this connection was that due to the provision of these phosphor-bronze strips the gates would only staunch in the fully closed position. A very small movement of either gate from the closed position had the effect of increasing the clearance between the gates, or between the lower gate and the cill as the case might be, to about $\frac{3}{4}$". This increase in clearance was advantageous since it ensured the sluicing away of the tamping silt and, moreover, the thin, and comparatively high velocity jet, which issued from the gap between the face of the lower gate and the edge of the permanent cill served to clear the floor of the regulator immediately below the gates of any silt which might have accumulated and which would otherwise prevent them from being fully lowered.

9. The machinery for operating the gates was shown in the photograph opposite page 45 of the Author's Paper. Separate sets were provided for the upper and lower gate so that each could be independently raised or lowered. Each set of machinery consisted essentially of a

manually operated spur reduction which connected through cross shafts to grooved rope drums from which the gates and counter-balances were suspended.

10. It would be seen from the photograph that the winches and the rope drums were enclosed in cast iron or steel covers to protect the gears, etc., from dust and rain. Lubrication throughout was by the Tecalamet pressure system, separate oiling nipples being provided for every bearing. A feature of the general design was that the cross shafting was all at or below the level of the floor of the over-bridge which was thus unobstructed except for the winches and drum casings.

11. The erection of the steelwork and grooves, etc., was carried out in accordance with the programme given in Appendix No. I and with the aid of the 10-ton hand crane and overhead travelling gantry, referred to by the Author. The crane was used to place in position the heavy parts such as the superstructure columns, the overbridge and the gates, the gantry being subsequently mounted on the overbridge and used to erect the machinery and new grooves, and to remove the old grooves. The Author had stated that the gantry was obtained from England; actually only the travelling pulley block came from England, the gantry frame being designed and manufactured at the Central Workshops.

12. Owing to the limited time available for completing the work and the necessity for interfering with the regulation of the canal supplies (prior to the closure) as little as possible, the methods and procedure adopted for the dismantling of the old work and construction and erection of the new had to be very carefully worked out beforehand.

13. For this reason the programme given in Appendix No. I, which was the outcome of collaboration between the Marala Division and the Central Workshops, was worthy of special attention. The mere preparation of the programme in such detail brought to light many snags and unforeseen difficulties which might otherwise not have been realized until the work was actually in progress, and the Writer was convinced that it was largely on account of these facts that the work was completed without any serious hitch and within the scheduled time.

14. As already mentioned, the superstructure, etc., was erected prior to the grooves and other built in parts; this was contrary to the usual procedure and gave rise to certain difficulties, but the sequence had to be adopted in order to complete the remodelling and have the new gates working by the end of the canal closure. This procedure meant that the grooves had to be set and aligned from the superstructure columns and, as the satisfactory working of the gates entirely depended upon the accuracy with which the grooves were erected, extreme care

had to be taken in erecting the former to ensure that they were correctly aligned and spaced.

On checking up the spacing of the piers previous to starting work it was found that the spans varied slightly but that the overall length between the abutments was approximately correct. It was therefore decided to space the columns and grooves uniformly to the designed span and allow the grooves to project from, or be recessed in, the sides of the piers as might be necessary.

The Author had described how the grooves were erected by cutting slots through the piers; for setting and aligning the grooves two special steel setting jigs were designed which could be fitted between the legs of the columns and centred accurately. Each of these jigs was fitted with a screw mounting to take a theodolite, the mounting being centred over one of the machined faces of the grooves. These jigs or frames were extremely useful and without them, or some such similar device, it would have been difficult if not impossible to have erected the grooves to the required degree of accuracy.

The **Author** in replying, thanked Rai Bahadur Ganpat Rai for his elucidation of the difficulties in the execution of the work. Regarding the point raised by R. B. Ganpat Rai, there was no doubt that some arrangement would be necessary for the security of the regulator during floods, when the head across the weir rose above 17 feet on account of the absence of leakage through the gates. One remedy was to allow some leakage deliberately, so that the regulator floor had a depth of 5 feet or more of water. The other alternative was to drive a line of sheet piles across the weir so that it would be safe for a head of 24 feet. This measure might become necessary for another reason, *viz.*, the danger there was of progressive scour below the regulator. At present the distribution of flow below the regulator had to be carefully watched; even then a scour hole of 12 feet in the *kacha* portion was not unusual. Supposing a concentration of flow through any one bay became necessary for any reason, there ought to be structural provision for the safety of such an important work.

The Author was indebted to Mr. W. G. Wheatley for the note he had contributed regarding the mechanical design of the gates and gearing. His note threw further light on how the change from old gates to new was effected with the minimum of interruption to supplies. The working of the staunching device of the new gates described by the Author in the Paper had been further elucidated and the principle of employing silt as the staunching medium explained. This device became necessary on account of the peculiarity of the arrangement of double gates which involved the seating of the upper gate behind the cill.

In a written communication received from S. B. Raghbir Singh, it

had been suggested that the approximate costs of the gates and gearing should be included in the Paper. This information was intended to be given as an appendix but appeared to have been omitted in the first instance. The figures of cost were reproduced from the completion report of the work.

	Rs.
Grooves	25,200
Staunching	8,340
Overbridge and steel Superstructure	30,720
Lifting gear	67,920
Cill Gates	28,080
Roller paths	11,880
Upper Gates	34,200
Rollers	22,200
Counter-balances	12,600
Constructing Bridge	3,000
Teak-wood Planking	6,600
Transport	5,280
Painting	2,040
Slinging arrangements for Gates ..	1,055
Cost of dismantling old gates ..	2,400
Erection of Grooves	1,800
Other erection	15,000
	Rs. 2,78,300