THE MECHANICAL EQUIPMENT OF IRRIGATION WORKS.

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The great developments that have taken place in Irrigation Engineering of recent years have presented many new problems of a mechanical character that have had to be solved; and it is my purpose in this paper to bring before the members of the Congress a few of these problems, and to explain the methods by which I have arrived at their solution.

I propose to limit myself on this occasion to two very important matters connected with Irrigation Works, namely :— weir shutters, and undersluice gates.

Weir Shutters.

Weir shutters, as we understand them, are a species of gate attached to the crest of a masonry weir, usually by hinges, so that when in an erect position they raise the level of the weir sufficiently to pond up the water to the level necessary to feed the canal, and when recumbent the level is reduced to that of the masonry weir so that flood waters may have free passage. Until recent years the type of shutter adopted in the Punjab, was that originally placed on the Rupar weir. The same type slightly modified was used on the Khanki and Rasul weirs. At Rupar the shutters are 6 feet high and 4 feet wide, hinged to the masonry crest and supported by tension rods with a hook shaped end. When in an erect position the hooked end of the tension rod penetrates a slot cut in the shutter so that it may engage a catch or trigger placed on the down stream side. In order to release the shutter, the trigger has to be moved so that it may become disengaged from the hook, which is so shaped that it can pass through the slot without catching. The trigger of the Rupar shutter is formed with lever arms extending to the sides of the shutter, so that when it is to be released a man standing behind the erect shutter can strike the lever to knock the catch out of position. In the case of the Khanki and Rasul shutters the arrangement for the release was modified, so that instead of the levers extending to the sides of the shutters, they were curved round above the trigger, and united above with sufficient length to extend vertically to the top of the

shutter, thus the latch and lever as bent round presented a banjo like appearance. The purpose of this peculiar shape was to admit of a special method of release, by the aid of a flexible cord with a ball at its end. Each lever at the top end was forked in shape, and when all the shutters had been lifted the cord was laid along between the prongs of the forks on the levers. The method of release was to wind the cord on to a winch situated at the side of the weir bay, so that the ball at the end of the cord should engage each lever successively and draw it over to effect release. An unexpected factor however came into play which rendered this device uncertain in use, namely, the violence with which the shutters were thrown over by the impounded water, which caused the ball to be flung back and thus the cord or ball frequently became entangled or trapped by a falling shutter, in which case not only was the device out of action for the time being, but the remaining shutters could not be released because the wire cord was in the way. The arrangement being unreliable has been abandoned.

With purely hand operated shutters there is always the danger that an unexpected rise in river level will cause the water to overtop the shutters so that it becomes impossible for men to pass behind them, in which case they cannot be released. Should this happen with a rising flood the effect is likely to be disastrous.

Sir John Benton, K. C. I. E., as Inspector-General of Irrigation, drew special attention to this danger in an Inspection Note on the Khanki weir, and directed that I should be ordered to endeavour to either make the cord and ball arrangement a success, or else design a shutter that should be free from the danger indicated. This led me to take up the subject, and although I reviewed a number of possibilities it was not until I seized upon the idea of utilising the energy of a falling shutter to release the fastening of its neighbour that the elements of success were found. Even then the design of the shutter had to go through an evolutionary process, for three different designs were worked out and practically tested, before all objectionable points were eliminated and a satisfactory shutter was produced.

The problem in design as it presented itself to me contained the following requirements:—

(*a*) The shutters were to release automatically, or so nearly so, that after the release of the first shutter the whole of a series should fall.

ASHFORD'S PATENT WEIR SHUTTERS.

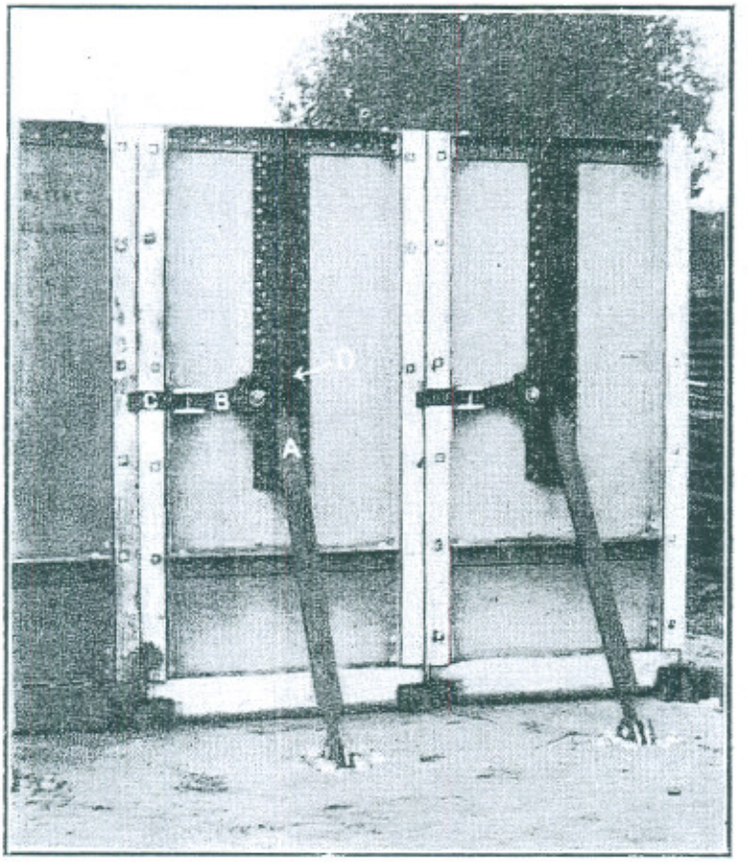
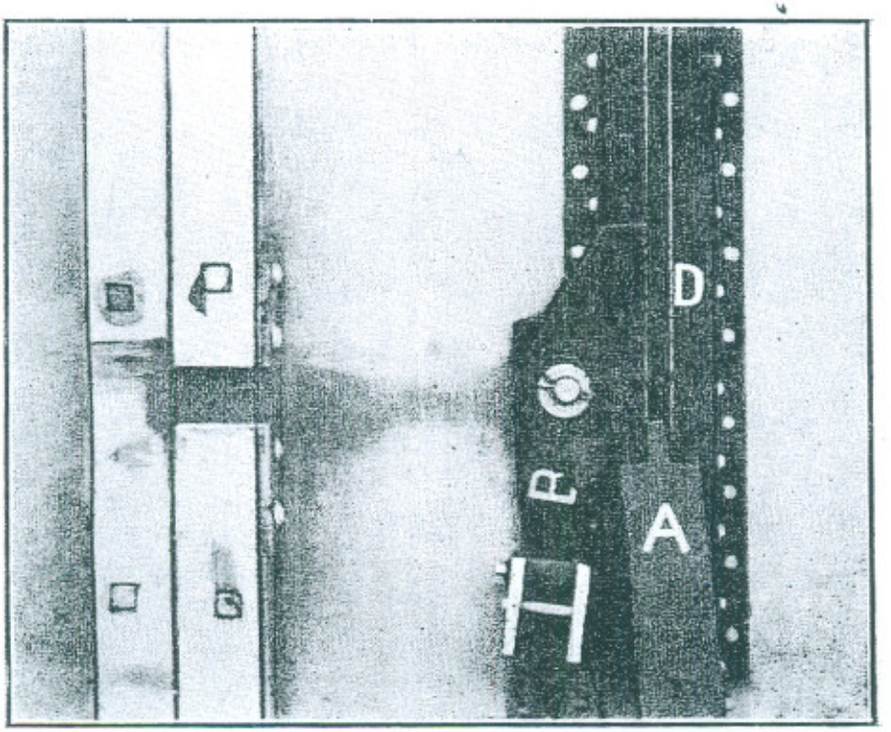


Fig. 1.—Shutter Erect—Lever Locked.



(*b*) In addition to the necessity for releasing the whole of the shutters in time of emergency, it should be possible to release any smaller number for the purpose of river regulation or for scouring purposes.

(*c*) It should be possible to fasten each shutter in an erect position immediately it was raised, and without reliance upon the neighbouring shutter.

(*d*) The fastening should be sufficiently positive and secure to be proof against the action of wind and wave.

(*e*) Such mechanism as is necessary should be simple and not likely to get out of order.

(*f*) The mechanism should be open to inspection when the shutter is erect.

(*g*) The mechanism should be fully protected when the shutter is prone to avoid injury from logs or boulders.

(*h*) The whole should be such that even though the shutters are overtopped with water, control would not be lost.

(*i*) The mechanism should be cheap and easy to manufacture, and for preference such as could be easily fitted to existing shutters.

(*j*) The arrangement for release should be such that one man could successfully release the whole of the shutters without assistance.

(*k*) The shutters should have a safety device by which they could be automatically released should the river reach a dangerous height.

The list of requirements is somewhat formidable, at least it seemed so when I first tackled the problem although after the final solution it seemed simple enough.

Without troubling you with the successive steps which led to final success, I will now describe the shutters of which 1,296 have been fitted to the Marala Weir, and 672 to the Rasul Weir. The description has more particular reference to Figs. 1 and 2. The shutters are strut supported, the strut reaching to approximately half the height of the shutter. The strut A (Fig. 1) is of Tee iron and its top end is constrained to slide within a groove formed upon the shutter by rivetting thereto two Z-like pieces of iron. (D Fig. 1). The flanges of the Tee iron strut are cut away

where it enters the groove and a cross pin is fixed in the web of the Tee, so that when in position the end of the strut cannot get free from the groove, thus, when the shutter is lifted the strut must come with it. The lower end of the strut is suitably hinged to a foot plate and the latter is fixed to a foundation plate by four bolts in elongated holes. This permits of such adjustment as is necessary to set the shutters truly vertical when initially setting them in position. When the shutter is in recumbent position the web of the Tee iron strut lies snugly in the groove on the shutter, and is entirely covered by the shutter. When the shutter is erect and subject to water pressure the overturning force is resisted by the strut. The reacting force may be considered as resolved, at the top of the strut, into horizontal and vertical components. The horizontal one holds up the shutter, and the vertical one is received upon a locking-lever B (Fig 1). This latter is fulcrummed on a pin placed on one side of the Z iron, and cut into the latter is a slot through which the short end of the lever may pass to take its bearing upon the top end of the strut. When the locking-lever is secured in a horizontal position the shutter is fixed in a vertical position. To secure the locking-lever and to fit it for its other functions it is joined with a special form of joint, as may be seen in Fig. 1. The joint allows the long end of the lever to move in a horizontal plane, so that for locking purposes it can be moved into, and engage, a notch cut in the shutter frame. Conversely the action of release is to push the jointed end C of the lever out of the notch, from which it thus becomes disengaged, and it falls into the position shewn in Fig. 2. This leaves the strut free to slide up the groove, which it does as the shutter falls over. The jointed end of the lever projects beyond the side of the shutter sufficiently for the adjacent shutter in falling to push it out of the notch and so disengage it. It is obvious that when each shutter is so arranged, and a suitable arrangement is provided at the pier to release the lever of the first shutter, this in falling will disengage the lever of the second shutter by pushing the overlapping jointed end out of the retaining notch. The second shutter as it falls, disengages the lever of the third shutter, and so on throughout any number of a series.

The releasing gear on the flanking wall or pier normally consists of a vertical spindle, placed in a groove cut in the masonry, which has a lever placed to act upon the locking-lever of the first shutter. The spindle extends to the top of the pier, where there is a handle that may be used to give the

MARALA WEIR.

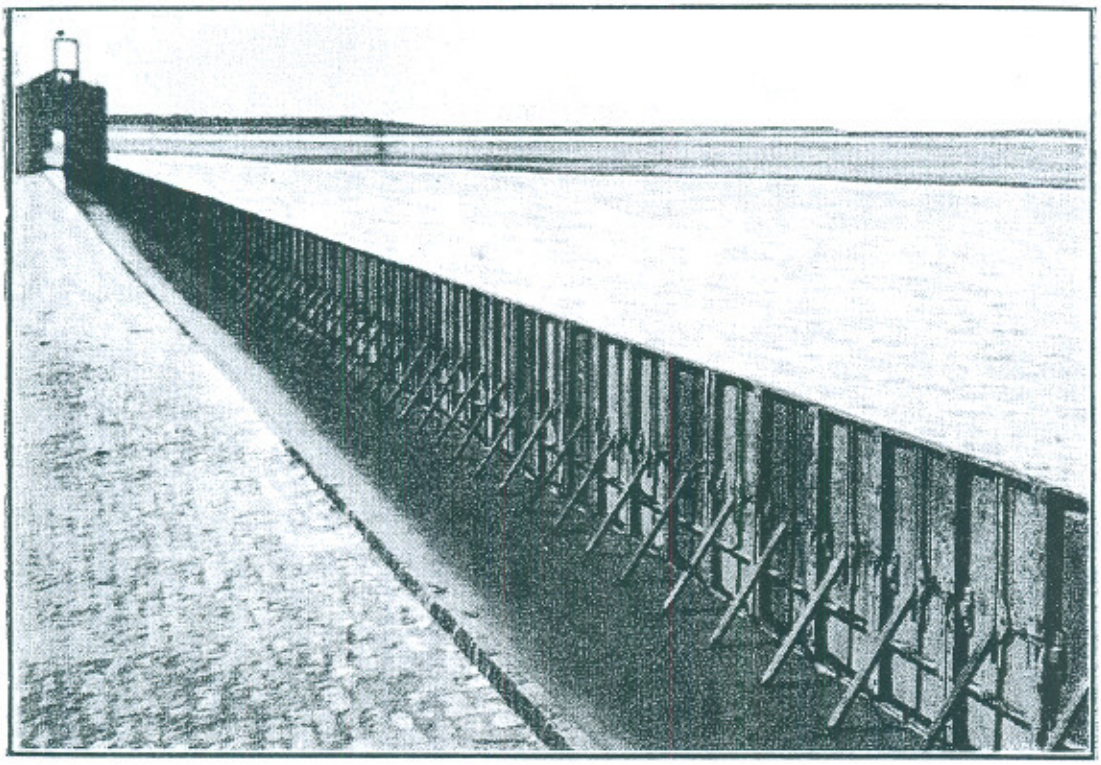


Fig. 3.—Bay of Weir with Shutters Erect.

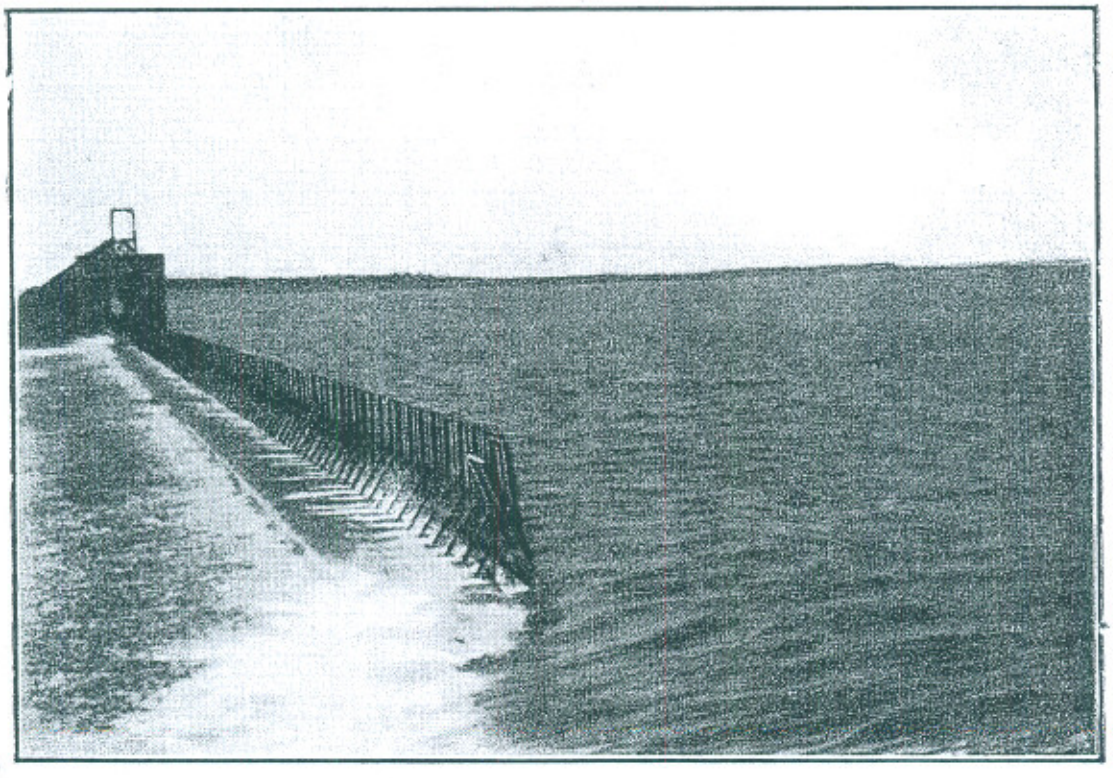


Fig. 4.—Shutters in act of falling.

rotation necessary to release the first shutter. As yet a purely automatic arrangement has not been fitted to release the first shutter, but it would be quite a simple matter to do so by some such means as a balanced tank which would fill with water and tip over, so providing the force to release the first locking lever.

Half of the shutters in each bay are fitted with levers to release from the right hand, and the other half from the left hand, thus half the shutters only are released from either side. When it is desired to release less than half a bay, a shutter at the required distance from the centre of the bay is released by prising up the locking lever out of its retaining notch, whereupon all the shutters from the one opened will be released up to the centre of the bay.

A bay of shutters as fitted to the Marala Weir is illustrated in Fig. 3, and the same shutters are shown in the act of falling in Fig. 4. They fall very rapidly with a full head of water against them, and if allowed to impinge directly upon the masonry something might be damaged. To avoid this a curb of stone is placed on the weir, just out of reach of the shutters when prone, so that the water that leaks through is collected to form a water cushion on which the shutters are received as they fall, and thus damage is avoided. This is clearly seen in Figs. 3 and 4.

I may here quote two paragraphs from a report by the Sub-Divisional Officer of the Rasul Headworks where 672 shutters are fitted :—"The rapidity with which these shutters "fall is astonishing, and with a head against them varying from "two to three feet, the rate of falling is five shutters per "second. I consider the shutters a success, and in my opinion "their great advantage over the existing type with tie-rod "up-stream is that even with a flood passing over the top "of the automatic shutters, it would be quite simple to drop "them, whereas with the tie-rod type nothing could be "done".

Again I may quote from a letter :—"In a flood we had recently the newly fitted bay of automatic shutters "acted perfectly".

The following is an extract from a letter that appeared in the Civil and Military Gazette, dated 21st May 1912 :—

"The row of iron shutters is so devised that when the "end one is released the others fall in quick

> "succession, each with a reverberating slap upon "the water, the whole producing a striking "feu-de-joie effect".

Undersluices.

It has become customary in our Department to designate those sluice-gates which form part of the weir and are placed near the canal regulator "the Undersluices".

In the earlier works these undersluices were limited to spans of about twenty feet, and they were frequently made up of two or three gates arranged to work in as many pairs of grooves, and so that they in the desired combination made up the required height. Apparently the reasons for this arrangement were to keep the gates of such an area that they could be operated with the types of travelling cranes that were then in use, and to enable them to slide by their own weight down the grooves. The last set of undersluice gates made on this principle in the Punjab were for the Rasul Headworks.

The improvements introduced by Mr. Stoney in placing sets of free rollers between the gates and grooves to reduce friction, made it possible to use gates of much larger size. This increase in the size of gates is coupled with several advantages, one of the chief of which is the increased area of waterway for a given length of a series of undersluices, thus there are fewer obstructions in the river and there is less masonry. Until the introduction of friction reducing arrangements, it was impossible to counterbalance the gates because the whole weight of the gate was necessary to overcome the friction in the grooves when lowering it into the closed position. Consequently the whole weight of the gate plus the friction in the grooves had to be overcome when opening an undersluice, whereas, with gates having satisfactory friction reducing appliances, the weight may be wholly or partially counterbalanced, and thus they are far easier to work.

It will be of interest to describe in some detail the undersluices at the Marala Headworks, see Figs. 5 and 6, as they were the first of the free-roller type to be fitted in the Punjab, and the design as carried out is the type that has since been adopted for other large works.

When it was decided to fit the Marala undersluices with gates of the Stoney free-roller type of thirty feet span, the amount of information available in this country as to their design and

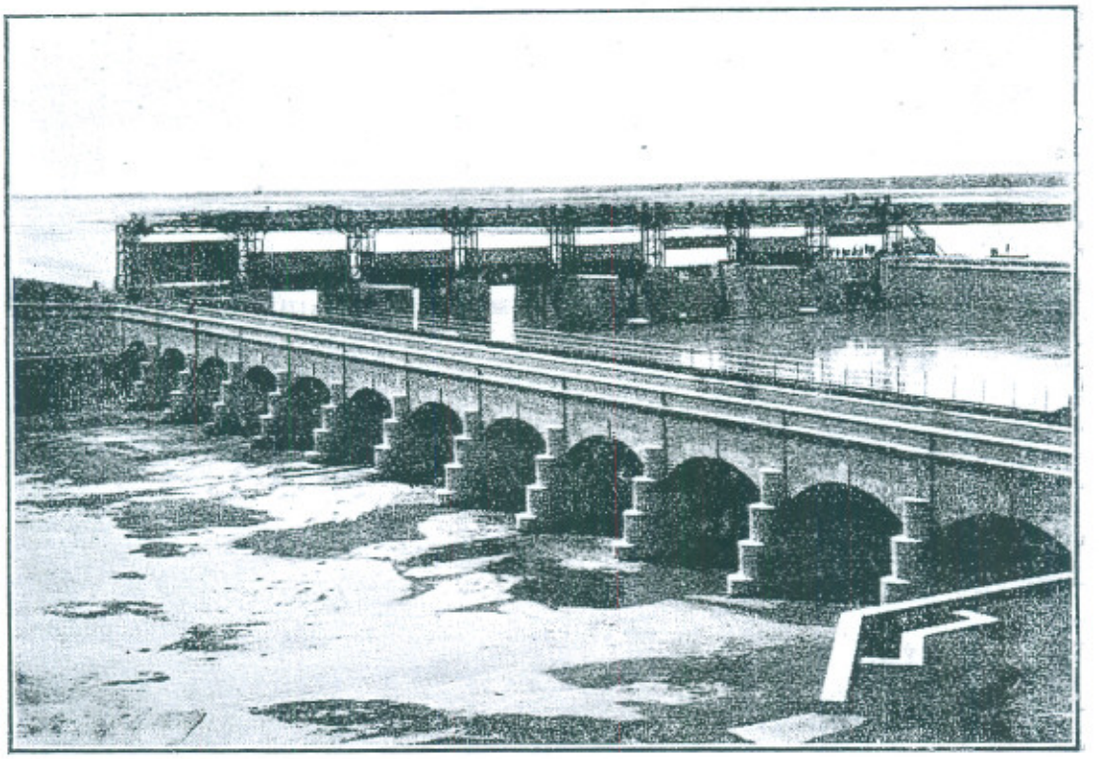


Fig. 5.—Marala Headworks.

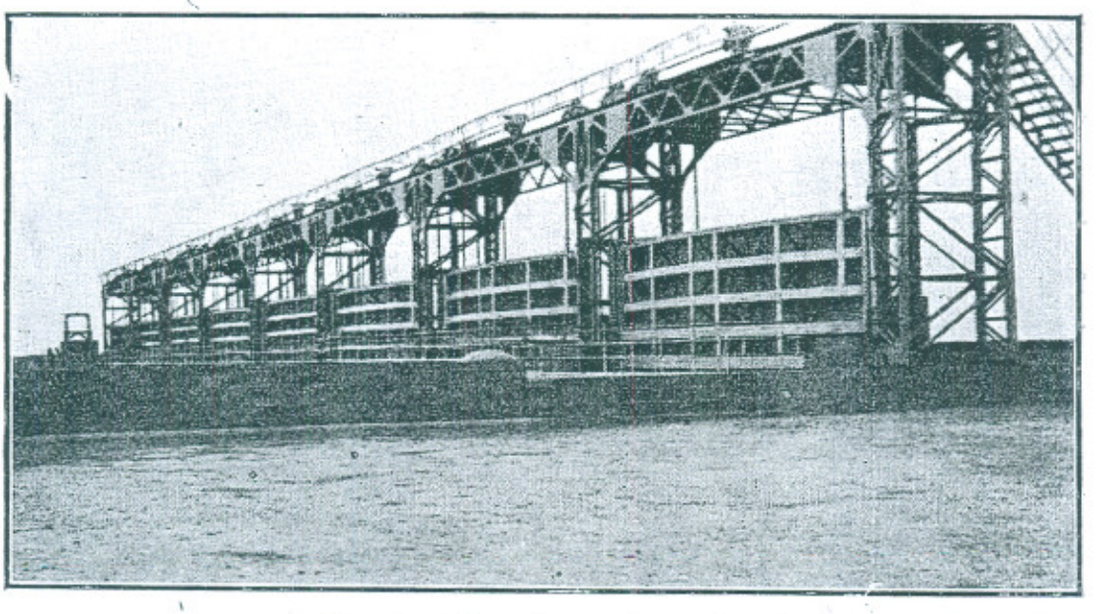


Fig. 6.—Marala Undersluices.

operation was very limited, thus to all intents and purposes the designs had to be worked out "de novo".

The general data upon which the design had to be prepared was as follows :—

(*a*)	Number of gates ...	... 8
(*b*)	Height of gates ...	... 13' 8"
(*c*)	Total lift of gates ...	... 26' 0"
(*d*)	Cill level ...	R. L. 792
(*e*)	High flood level ...	R. L. 813
(*f*)	Clearance required between high flood level and bottom of clearance gates and balance weights ...	5' 0"
(*g*)	Clear span up-stream of gates ...	30' 0"
(*h*)	Clear span down-stream of gates ..	31' 6"
(*i*)	Thickness of piers up-stream of gates	10' 0"
(*j*)	Thickness of piers down-stream of gates ...	... 8' 6"

The usual arrangement of the Stoney gate so far as information was available, was to build masonry piers up to the full required height, and to span from pier to pier with girders to carry the lifting machinery, etc. The balance weight was attached to one end of the supporting ropes or chains, and the gate to the other end. With gates of so great a lift as these under consideration such an arrangement as the foregoing meant an exceedingly high and ugly structure. It therefore was decided at an early stage to arrange the supporting chains, so that one end should be anchored to the top girders, while the balance weight, twice as heavy as the gate, should hang in the bite of the chain. This arrangement reduces the travel of the balance weight to one-half and the height of the superstructure was thereby reduced by about 12'. When considering the arrangement for supporting the gates, balance weights, and lifting machinery, we found that by terminating the masonry at R. L. 818 and mounting thereon a steel latticed superstructure several important points would be gained, namely, a reduction in cost, reduced weight on foundations, and the whole structure could be made of more pleasing appearance. (See plate I).

The determination of the general lines upon which to construct this steel superstructure called for a considerable amount of thought, as we had nothing of a similar nature by way of precedent to guide us, so a variety of possibilities were

considered. It was desirable that the construction should be such, that there would be no great weights to handle in the process of erection calling for cranes or elaborate lifting tackle. Probably the first thought to occur was to provide vertical stanchions upon which to place girders to carry the lifting machinery, and to act as a footbridge, but further consideration showed this to be by no means the best arrangement.

The most suitable method of suspension for gates of large span is near the ends, in which case the load of the gate and counterbalance, if carried by ordinary overhead girders, would produce a constant bending moment throughout the girders between the points where the weights were hung.

The load was estimated at forty tons, consisting of thirteen tons for the gate, twenty-six tons for the counterbalance, and one ton for the machinery. Such a load carried on girders of thirty-seven feet clear span meant heavy girders to be hoisted to the top of the superstructure. A further consideration shewed that heavy top girders could be avoided by carrying the main weights on short cantilevers built on and forming part of the stanchions (Plate I, Fig. 8). The fact that there was a row of eight gates with counterbalances favoured this construction, for, once the whole were assembled in position, the weights upon the intermediate stanchions would balance each other. The greatest condition of out-of-balance would be when one gate had been lowered down to rest upon the cill. Even then its weight would not be wholly taken off the superstructure, as the counterbalance would maintain a full tension upon the supporting chains, thus the actual amount it would be out of balance would be measured by the effort applied to the operating winch, a comparatively small amount. It was therefore decided to build the stanchions with cantilevers to support the weights, and as the overhang is small each stanchion resembles a letter T. The girders spanning the openings having none of the main weight to support, needed to be only of light lattice construction of sufficient strength to carry the winch in the middle, and to serve as a footbridge. This light footbridge is in point of fact a source of strength to the stanchions, for it acts alternatively as a strut or as a tie-rod tending to support the stanchions against overturning moments. This is taken advantage of in the end bays where the extreme stanchions are not balanced, by introducing lateral bracings to connect the two lattice girders of the footbridge together, and make them suitable to act as struts between the stanchions.

MARALA UNDERSLUICES. SUPERSTRUCTURE.

PLATE I

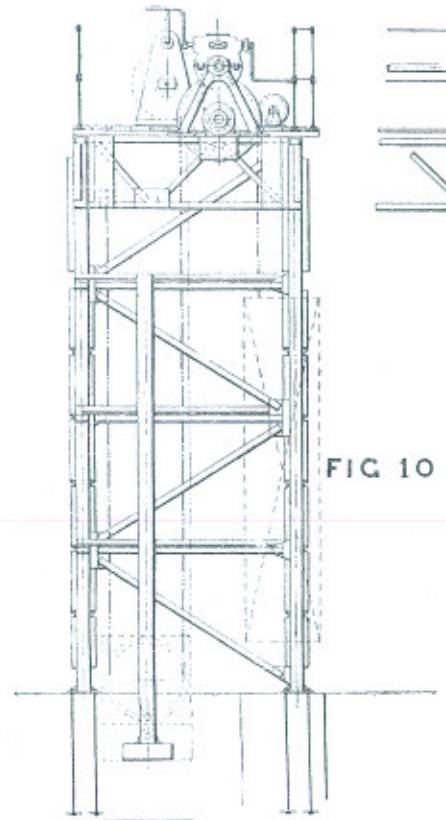


FIG 10

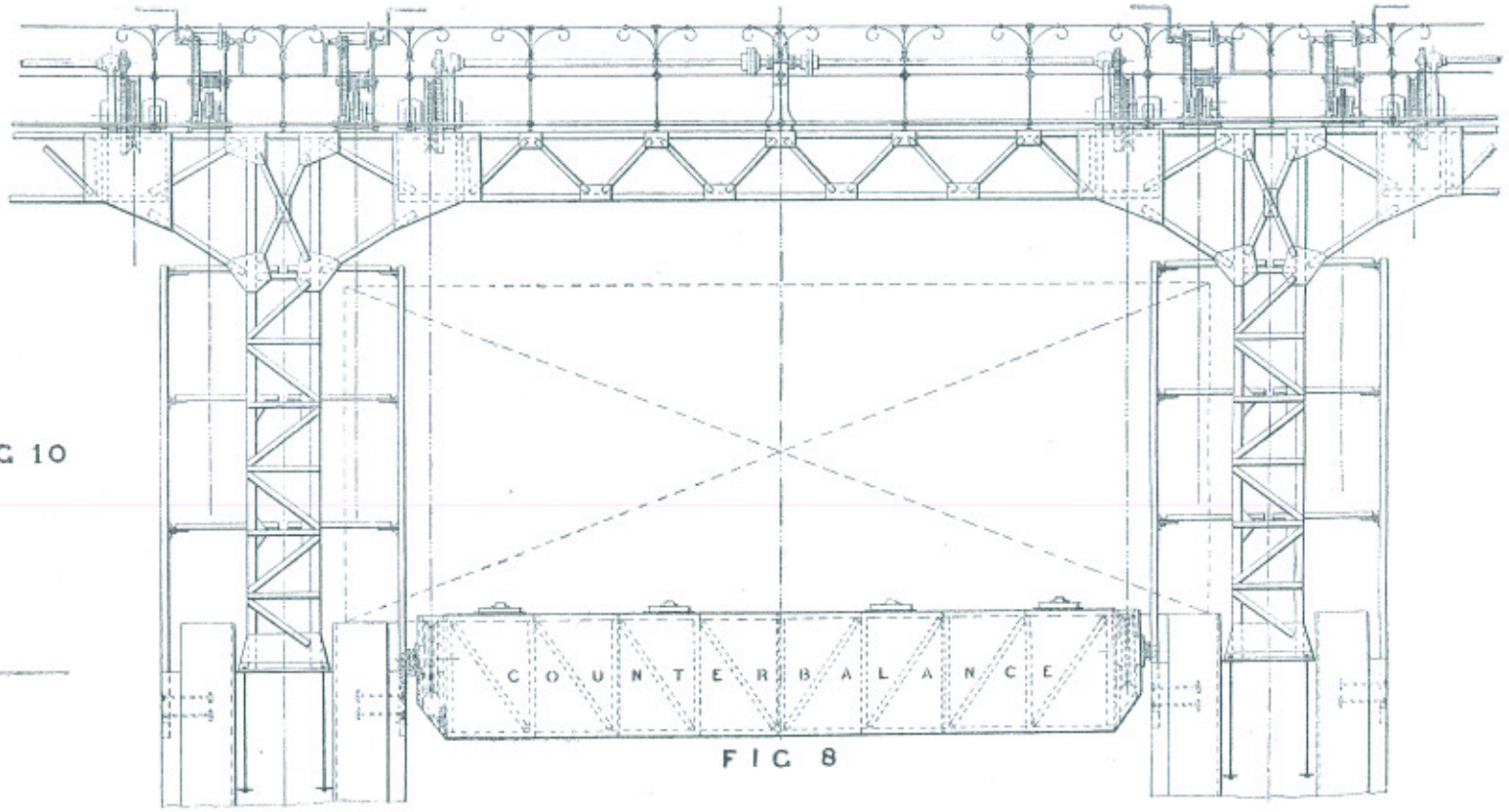


FIG 8

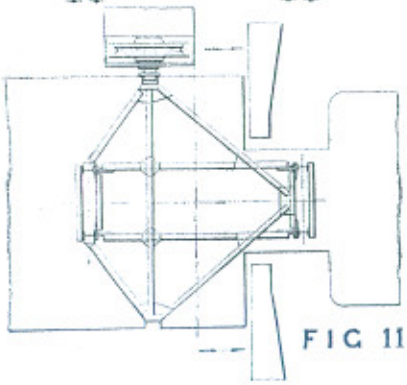


FIG 11

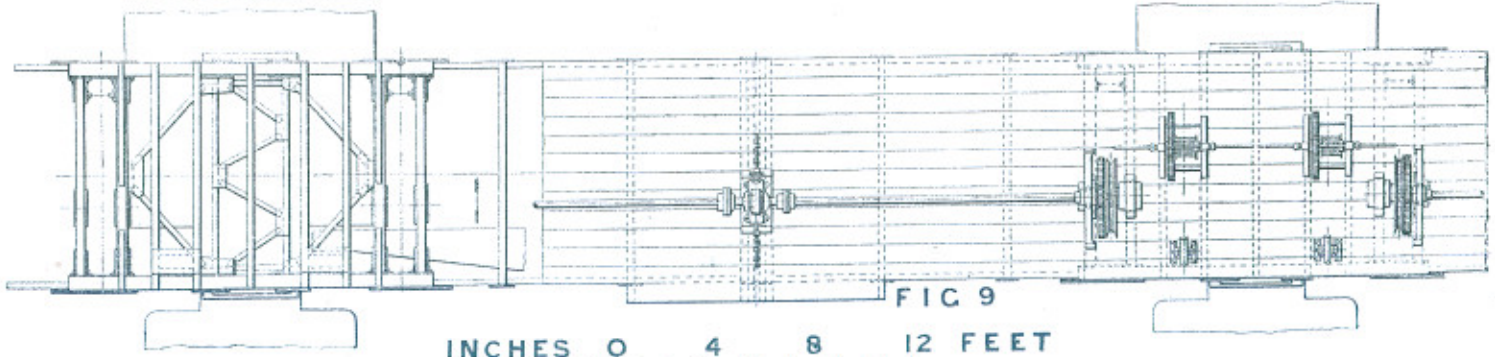


FIG 9

INCHES 0 4 8 12 FEET

When calculating the strength of the details, it was assumed for safety sake that the whole load would at some future time be removed from one of the cantilevers, and the stress diagrams were worked out on this assumption. The stanchions are built up of four rolled H. members situated at the four corners of a rectangle in plan (Plate I, Fig. 11). The bracings introduced are mainly to shorten the free strut lengths, and to tie the structure against wind pressure. It will be observed in the design that hot forged or bent work has been entirely avoided in the members, the various angles and gusset plates being merely cropped off to their required dimensions. Care was taken when designing the joints to see that lines passing through the centres of gravity of sections should meet in a point to avoid bending moments in the members. The outcome of the design was a structure of light and pleasing appearance, no part of which as made, exceeded a ton in weight for erection, and the assembling at site was effected with a single light guyed pole with pulley blocks, a couple of small winches, and ropes.

The undersluice gates were for a clear opening of 30', but at the outset it was ruled that the piers should be 10' wide up-stream of the gates, reducing to 8'·6" behind the gates, so that the grooves would be set behind a projecting portion which would protect the roller-paths from damage by floating logs and the like, thus the span is 31' 6" at the part where the grooves are situated. The grooves were rather deeply sunk into the piers to accommodate the size of rollers and roller-paths that were decided upon, thus the overall length of each gate became 36'. The depth of water held up is 13' above the cill which with freeboard gives a height of 13' 8" for the gates. The total lift of the gates is 26', and this with a suitable margin gives 28' as the length of the grooves.

The groove section received a large amount of consideration, and the final design which is shown in Fig. 16 is very liberal in all its dimensions, much more so than is necessary, but any error of judgment, if error there be, is on the side of safety. It will be seen in the design that the main casting of the groove is of L shape with a large radius outside. The rollers rest against a path C which pivots upon a so-called knife-edge E. The knife-edge casting is separate from the main casting D of the groove to admit of renewal should that be

necessary in the future. The joint between the two parts E and D is machined with tongue and groove to ensure correct alignment. To make castings of the section required, and 28' in length, was rather a formidable undertaking, and to machine them a very large planing machine would be necessary. To simplify manufacture the main grooves were built up in four pieces, the two members A and D of the L shaped section being joined together with tongue and grooved joint, and the joints in the length were made to come in different places, thus the part supporting the roller-path was made in two pieces, one 18' and the other 10', the longer piece being the lower part of the groove. That part of the groove A which receives the staunching rod F was made in similar lengths, but with the longer one at the top, thus the two joints were 8' apart. This construction enabled the parts to be assembled quite accurately. The surface which receives the staunching rod was provided in the groove to ensure that by being machined with one setting in the planing machined, it should be in true alignment with the other parts.

The grooves were easily erected and set at site by first building the masonry piers to a height of ten feet, leaving places for the grooves, and then up-ending the grooves into position. They were then correctly set with templates, grouted in behind with cement, and the balance of the masonry built up to the grooves. This method gave more accurate results than we have obtained in other works where the grooves were first raised in position and subsequently the masonry was built up to them.

The sluice gates must of course initially consist of a flat plate to hold up the water, and suitably supported by girders to transmit the load to the grooves. The thickness of the skin plate depends upon the method of arranging the supports. We had open to us the alternatives of—

(*a*) placing two or three heavy girders longitudinally with several rolled joists placed vertically to support the plates ;

(*b*) placing the girders still closer together and introducing intermediate vertical angles or tee irons ;

(*c*) increasing the thickness of the skin plates to require less frequent supports ;

(*a*) a sufficient number of horizontal longitudinal girders to dispense with auxiliary supports.