MARALA UNDERSLUICES.
GROOVE SECTION.

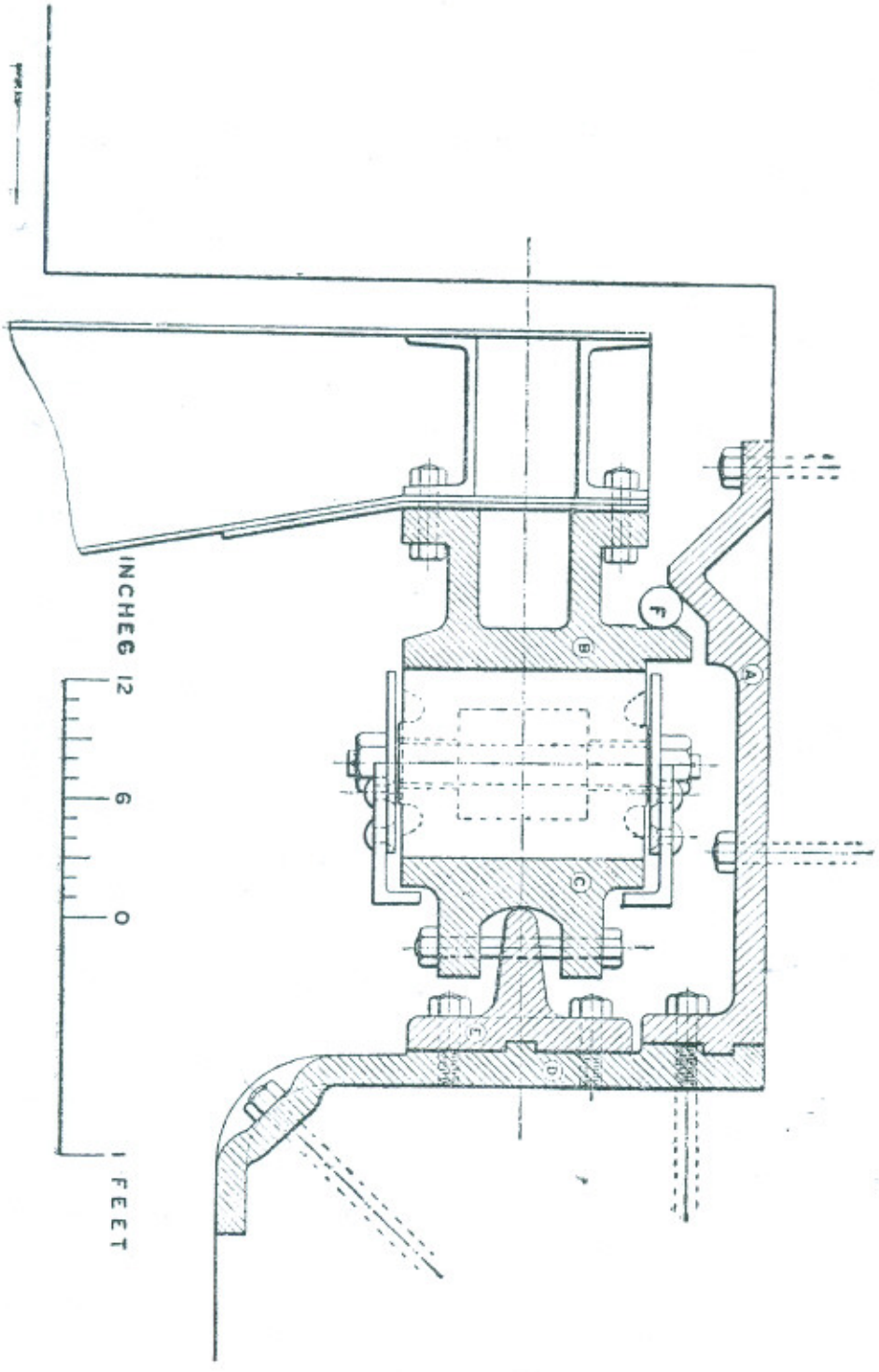


FIG 16

On working out designs it was found that the most economical method was to support the plates with lattice girders of light construction placed sufficiently close together to support the plates without any other auxiliaries. (See Plate II.)

In the actual details angles were selected varying in section from $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{5}{16}''$ up to $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{1}{2}''$ in the lowest girders, but all had cover strips of the same width. This gave a series of girders of suitable increasing strength to support the greater loads at the lower part, while presenting a regular appearance (See Fig. 6). The depth of the girders was fixed at one-twelfth of the span approximately, and the latticing was divided into comparatively small panels to adequately support the compression member of the girders against the bending tendency of the load, which is evenly distributed along the compression boom. Redundent members are introduced into the bracing especially to provide extra support to the compression side. Towards the ends of the girders, where the shear stress becomes severe, the bracing merges into web plates, and an extra plate is placed on the back to cover all the girders and still further increase the shearing section. Support is given to the girders to resist lateral flexure by bracing them to each other vertically, thus at these parts a vertical section shows a vertical lattice girder. (See Plate II, Fig. 19). The gate is thus stiffened in every direction, and as a whole forms a lightly constructed gate with an ample margin of safety. Throughout the whole work all angles and details have been made of dimensions suitable to receive $\frac{3}{4}''$ diameter rivets. All the angles except those in the tension booms are straight, and without joggling, being merely cropped off in the machines. The joints have all been provided with gussets to give adequate connection to the angles, and they are so arranged that lines through the centres of gravity of the members meet. All the angles used in the work were specially rolled at the Cossipore Gun and Shell Factory to the full length required, and have a strength of from 30 to 34 tons per square inch. The rivet bars were also specially rolled from a ductile steel of 26 to 28 tons strength. All plates and the rolled girders used in the superstructure were obtained through the Director-General of Stores to the usual India Office Specifications.

To ensure that the gates should hang vertically, the shackle links for uniting the lifting-chains to the gates were provided with means for adjustment, and it was found when the

gates were suspended, that this was a very necessary precaution, as it is not a simple matter to accurately determine the centre of gravity of a gate of this description.

The counterbalance (See Plate I, Fig. 8) is a steel plated box extending across the span, and situated up-stream of the gate, to leave the down-stream side free for the road-bridge. The box is divided into several chambers each with a covered manhole for access. It is of sufficient capacity for sand loading to be used.

At each end there is a pulley for the chains to pass around. They are provided with internal roller-bearings working upon fixed pins. The pins project from the ends of the counterbalance, and have small friction pullies to engage a channel-iron guide (Plate I, Fig. 11) which prevents the counterbalance swinging in a strong wind.

Turning now to the machinery for raising and lowering the gates. There is a lifting pulley at each end around which the supporting chains pass and these must work in unison. It was originally intended that the chain-pullies should be provided with sprockets to engage with the links of the chains, so ensuring a positive drive, but when manufacturing them these sprockets had to be omitted because the chain makers would not undertake to manufacture chains with the links sufficiently accurate to engage with the sprockets. There is however ample friction between the chains and the pullies to give the lifting effort necessary. In subsequent designs steel ropes have been introduced instead of chains because of this difficulty. The chain-pullies are fitted with machine cut gear-rings bolted to their sides, with a register to keep them concentric. This facilitates the manufacture of the gears, and is better practice, as it applies the torque directly to the pulley, instead of to the axle and thence through keys to the pulley. As designed there are no keys to work loose.

The machinery as a whole has been most carefully thought out, and designed to be as nearly mechanically perfect as it can be made, and also to be simple in manufacture. I may mention that all parts have been made strictly to gauge, and all holes have been drilled or bored through jigs, so that new parts can be made in the future with the certainty that they will correctly fit into place. The worm and wheel gear has been adopted as a standard design in our work, and it is used not only in the work described but also in travellers and on other works.

MARALA UNDERSLUICES GATE.

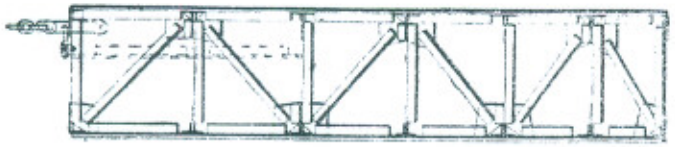


FIG 19

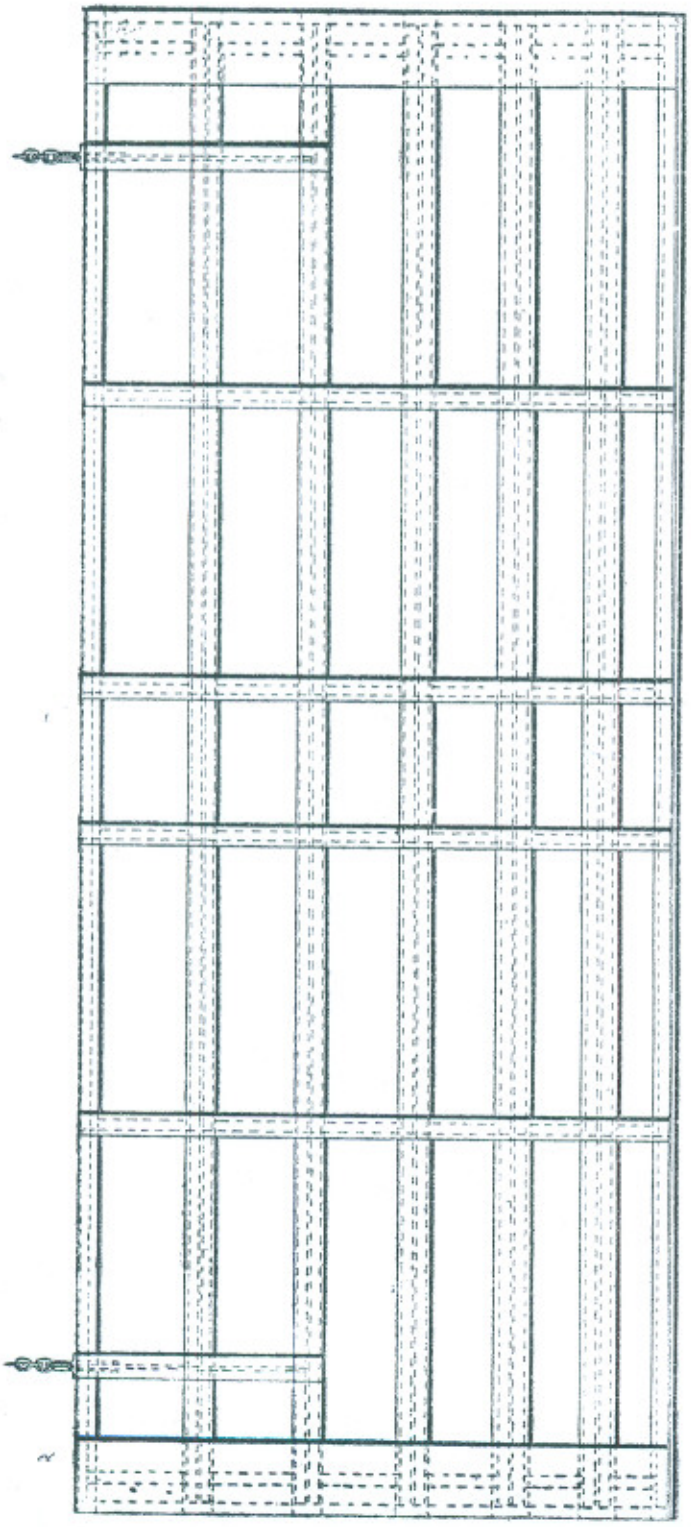


FIG 17

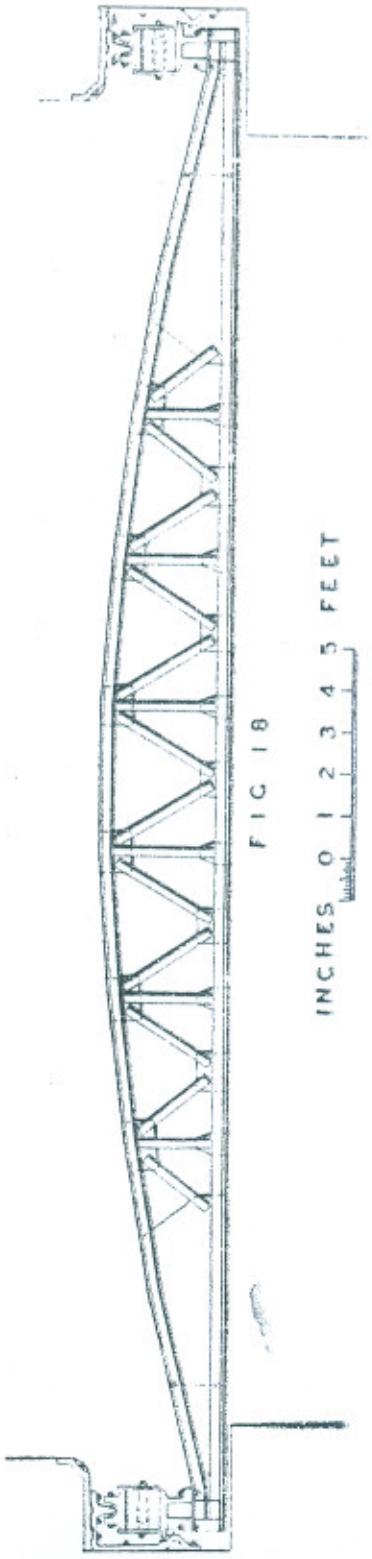


FIG 18

INCHES 0 1 2 3 4 5 FEET

When preparing these and other designs great care has been exercised to adopt and adhere to standards both for immediate manufacturing purposes, and to facilitate repairs and replacements in the future when such become necessary.

DISCUSSION.

MR. COLYER said he had had the advantage of being in personal charge of Mr. Ashford's shutters both at Rasul and Marala Headworks, and would like to say that those shutters, which were the subject of the first part of the paper, seemed to be excellent in their general principles, and in the simplicity of their design. Mr. Ashford had, however, used the term "evolution," and the speaker was of opinion that the shutters were still in the process of evolution, and his remarks were made with the object of assisting in attaining the end in view, which was a perfect shutter. One thing which often happened was that the groove, in which the strut slides, silted up solid or nearly solid. Presumably it was intended that the pressure from the upstream side should be sufficient to cause the strut to clear its own way, and this it usually did, but there were times—as Mr. Colyer had found from experience—when the strut jambed, and all the pushing in the world would not fetch the shuttur down. This might not matter very much if here and there a single shutter remained erect, but what happened was that several remained standing, and caused serious derangement to the general flow of the river, and thus might cause disaster to the Headworks, and, if a catastrophe did occur, it would of course be the Sub-Divisional Officer in charge who would have to bear the brunt of the blame. Another effect of this jambing, which had been observed after the flood-season, was, that a large number of the rivets holding the grooves in position, sheared, and this was a source of weakness. These points were not particularly scientific—they were not intended to be—but they were of great practical importance to the man on the spot. Mr. Colyer would therefore ask, with all due deference to Mr. Ashford, that the practical working details should be gone into; and for this careful observation of the shutters, both under flood conditions, and after, the subsidence of a flood, was essential. During a flood the mechanism was fairly well lubricated by the water itself, but when the flood subsided, the silt referred to deposited and clogged the working parts. It was the weakest link in the chain which betrayed one, and, if a flood were to come down suddenly—(as they sometimes did) and the Jamadar happened to be asleep, and the Sub-Divisional Officer in Lahore at the Engineering Congress, it was necessary to obtain an absolutely reliable shutter to make all safe. The next point was a minor, but still a very practical detail, and it was that the lever had

too large a bearing surface on the shutter at the place where it pivotted, and this sometimes resulted in the lever, either from rust or silt, becoming so closely engaged to the bearing surface as to require a sledge hammer to move it. This objection might be overcome by the insertion of a distance-piece or packing washer between the lever and the main shutter. If this washer were made circular in section, it would reduce the working surface to a minimum. Another point, which perhaps was more one of workmanship than of design—(and it was upon local labour and the local Mistry that dependence had to be placed for the execution of the work) was that there were a number of bolts and nuts, washers and pins, etc, which fell off during a working season. This was likely to cause disaster, and, though not a mechanical expert, Mr. Colyer thought that fittings might be devised which would not come off. With regard to the wooden meeting posts, the wood naturally swelled when wet, and, tightening up the joint between the shutters, caused them to stick together. Here it should be feasible to use a material similar in principle to the metallic packing used in stuffing boxes, etc, which, while hard enough to stand the wear and tear, would be sufficiently flexible to obviate jambing. One more point for attention was that the "kick" or stone course, which formed the water cushion upon which the shutters fell, should be kept in a water-tight condition, and thus reduce the amount of damage caused by the impact.

With regard to the undersluices, Mr. Colyer understood that the chain supporting the gates was specially strong, being of admiralty tested material, but the last link was made by the local mistry from ordinary bazar wrought iron or mild steel. A piece of wire rope is fixed so that if the link breaks the gate would be saved from falling, but this would put a severe strain on the superstucture. Could not a link or else a shackle be designed which would be sufficiently strong to do away with the system of tying up with wire rope? A last suggestion was, that it might be advantageous to provide the stirrups in which the counter-balance rested when at the bottom of its run, with buffers of some kind, so that, in the event of the chains failing, the guide lugs might be saved from shearing, and the counterbalance kept from falling into the river.

Mr. Colyer hoped Mr. Ashford would forgive him if he had made some of his remarks in rather a critical spirit, but he felt very keenly on the subject.

MR. NICHOLSON said that, as a brother Sub-Divisional Officer at Headworks at Rupar, he could fully endorse all that Mr. Colyer had said regarding the final responsibility for any untoward accident resting with the Sub-Divisional Officer, and the little interest taken in the actual satisfactory working of the shutters and gates after they had once been erected. The man in charge had a unique opportunity for finding shortcomings of design and workmanship in actual working, yet apparently no inquiries were ever made to see if there were any inprovements that could with advantage be adopted. In lately replacing the needle regulation in the undersluices at Rasul by gates, the design at Rupar had been exactly copied ; but the final arrangement of the Rupar undersluice gates had only been arrived at through the original weir crest being raised 2·23 feet and four foot shutters added, which were subsequently raised to six feet, and these changes had resulted in the three gates. Apparently in duplicating the Rupar gates at Rasul it was felt that every one was freed from responsibility, but it is now intended to remodel the Rupar undersluices, although they have only just been copied as perfect.

Regarding Mr. Ashford's automatic weir shutters, Mr. Nicholson was glad to see from the models that the shutters had been arranged with the upstream tie, as well as the downstream strut to fall automatically. The upstream tie type offered the great advantage, that a line could be laid downstream of the shutters enabling the shutters to be rapidly lifted by a travelling crane. The downstream strut pattern necessitated the shutters being lifted from a boat moored upstream, and this was a method which could only be adopted at Headworks, where there were upstream groynes for mooring the boats. It had a disadvantage which was only apparent to one actually working the shutters, and that was the fact that the men in the boat were out of reach of the officer or subordinate supervising the raising ; and all would agree that it was far more satisfactory to have the men on the weir working a crane within range of peaceful persuasion, as work could thereby be more efficiently controlled. At present there were 586 four feet wide shutters at Rupar and these could only be dropped from the right flank of the weir. A wire ropeway was now being added on piers, dividing the weir into six separate bays, and this would increase the rate of falling six-fold. Although these old shutters were not automatic and the floods rose very rapidly, they had up to the present given no trouble. They had been in use for twenty

years and the fact that a spare shutter had never been required to replace a broken or worn out one, spoke well for the quality ot the work put into them.

Regarding the design of the Stoney gates, Mr. Ashford's solution of the chief difficulty (caused by the heavy bending moment due to the load on the barrels) by having a cantilever superstructure, would seem to be an entirely self-imposed condition. The gates are suspended well towards the middle, thus allowing a possibility of a gate, when overtopped, being loaded with jungle catching in the suspending chain. If the point of suspension were moved into the groove at the end of the gate this objection would be overcome. The loaded barrel would come close to the pier, and, with the trestle made to the full width of the pier, the resulting arm of the bending moment would become nearly as many inches as it was feet in Mr. Ashford's design. The necessity for the cantilever would then vanish and the superstructure could be economically constructed of girders, which would be fitted in the shops, and have all holes for fixing, gearing, &c., drilled to templet. When the girders were erected at site, it would only be necessary to get them absolutely central over the bay and then every fitting would automatically adjust itself to the exact position. This would make erection much easier and more certain. Mr. Nicholson had to erect at Suketar No. II on the Upper Jhelum Canal sixteen Stoney gates, each forty feet span, together with the superstructure. The gates had been made by Messrs. Ransomes and Rapier of Ipswich, and the speaker found that the firm had given a wonderful amount of forethought in their design, to ease and accuracy in erection. The total cost of erection of the sixteen spans was about Rs. 4,800 or Rs. 300 a span. The weight was 504 tons, so erection had cost a little over nine rupees a ton. The only establishment required consisted of three surattis and one blacksmith besides coolies. Mr. Ashford had given no figures of cost, but Mr. Nicholson believed the estimated cost of erecting thirty-three gates at Suketar No. I was about Rs. 1,000 per bay, or just over three times as much as the actual cost at Suketar II, and the actual costs would be figures of interest. The ease in erection of Messrs. Ransomes and Rapiers' design could be judged from the fact that the erection of Suketar II steel work had been actually started early in November 1911, and, including the building of all the masonry piers, was all completed with the gates working by June 1912. The Suketar I or improved Merala type of gate did not appear to lend itself

to the same ease of erection, as this was started in the spring of 1912, and up to date only the supersructure had been completed, and a few gates with gearing placed in position, which, however, the speaker understood, had not yet been worked. This tended to show that erection difficulties had not been fully considered in the design. All the gearing, &c., had to be erected at site on the superstructure, and any slight error had to be adjusted by drifting the bolt holes, or making new ones, as the superstructure could not be shifted, whereas in the Ransomes and Rapier type, the girders which contain all the holes for the gearing of the span could be adjusted on the trestle to the exact position. This appeared to be the great advantage in the girder over the cantilever type, as the erection had to be accurate to one-eighth of an inch, or the gates would jamb.

There was one point which it would be exceedingly interesting if Mr. Ashford would elucidate. He had mentioned that the beauty of his design lay in the fact that, when one gate was lifted, and the weight came on the one side of the cantilever, any overturning effect on the cantilever, which might cause distortion from the bottom of the trestle upwards, was taken by the thrust being transmitted through the lattice girder to the next trestle, where an equal and opposite thrust was induced, but this implied a rigid joint capable of taking a thrust. If this was the case it would be interesting if Mr. Ashford would divulge his method of dealing with expansion, which could not be neglected in a length of approximately three hundred feet. If, as the speaker had been told, Mr. Ashford had adopted elongated holes for connecting the lattice girders to the trestle, it would be interesting to hear how these sliding connections took up the thrust.

MR. ASHFORD, in reply, said he was glad to hear criticisms on his work, because such were helpful in realising the difficulties experienced in the practical use of the shutters and sluices, and also it was good to know the views held by other engineers. Dealing more particularly with Mr. Colyer's remarks, that "if a flood were to come down suddenly, as they sometimes did, and the Jamadar happened to be asleep and the Sub-Divisional Officer absent, it was necessary to obtain an absolutely reliable shutter to make all safe." Mr. Ashford said it was particularly to meet such conditions that he had thought and worked strenuously for years past, and the weir shutter described was the result of his efforts. Mr. Colyer laid particular stress

upon the sticking of the strut in the groove on the back of the shutter, due to the presence of silt packed "solid or nearly solid," so that the water pressure on the shutter failed to make it fall; wet silt in the groove, however, was not capable of holding up a shutter, such silt must have been deposited with the shutter recumbent and dried hard after it had been raised. It was an elementary precaution to see that the grooves were cleared of silt after the shutters had been lifted and while the silt was still wet, but this could not have done. Again apparently in some cases the levers were in too close contact with the plates of the shutter, as Mr. Colyer had suggested the "insertion of a distance piece or packing-washer between the lever and the main shutter." This actually appeared in the design, and it would seem that in the particular instance noticed, that the lever had been taken out and replaced without the washer. As to the use of wood strips fixed in at the sides with bolts and nuts, and in fact most of the details other than the actual lever and strut arrangement, the design of shutter fitted at Rupar, and mentioned by another speaker as a good one, had been closely followed. Mr. Ashford would have preferred to omit the wooden strips, but when the design was under preparation, and the opinion of superior officers was sought, a preference for the old arrangement was expressed, and hence that feature was retained. Mr. Colyer also referred to a piece of wire rope being fixed to save a gate from falling in the event of a link breaking, but this was not part of the design, and Mr. Ashford disclaimed all responsibility for it. It was a local arrangement which had caused the speaker some amusement. The chains had been supplied by the India Office and there was every reason to believe them to be amply strong for their work. The shackles connecting the chains to the gates had a large margin of safety.

Referring to Mr. Nicholson's opening remarks deploring that more opportunities were not taken for consultation with officers in charge of Head works, Mr. Ashford mentioned that he had not only visited Rupar several times, and discussed various points connected with the design of the weir shutters with the local officers, but had similarly consulted officers in charge of other Headworks with a view to avoiding faults which might be brought to notice.

A reference had been made to the Rasul undersluices, but these did not come within the scope of the paper, and the speaker would merely state that he had officially protested against the design but had been overruled.

Mr. Nicholson apparently considered it a mistake to use a strut support instead of a tension rod for weir shutters, but designs had been worked out for both types so that indenting officers had a choice. Most officers had expressed a preference for the strut supports, noticeably in some cases where the cranes, which had originally been put in for lifting the shutters, had been discarded and taken out and this depite the fact that this was the main argument in favour of tension rods. In designing the Marala weir shutters Mr. Ashford's instructions had been to omit any type of crane.

Referring to the subject of sluice gates, Mr. Nicholson made it clear that he had been engaged in the work of installing sixteen gates made by Messrs. Ransomes and Rapier, and was criticising a type of gate on the erection of which he had not personally been engaged. Had he had any experience with the latter, he would have discovered that all parts of the work had been manufactured to jigs and templates in order to secure interchangeability. Mr. Nicholson assumed there were difficulties in erection which did not exist. The superstructure of the Balloki Barrage, consisting of thirty-five gates each forty feet clear span, was erected in the moonsoon season between May and September 1912, by one mistri and a gang of coolies working from boats. Later, when the time came for putting the gates and machinery into place, the gates were assembled and the machinery placed in position at the rate of one span a day. This large work was manufactured and erected at the same time as the Suketar work mentioned was in progress, and by special orders the latter was given the preference, so that progress made at Balloki had been controlled by the labour and attention that could be spared from Suketar.

The reason for the cantilever construction of the piers had been explained in the paper, but apparently had been overlooked by Mr. Nicholson. By throwing more weight on the skin plating, and spacing the girders further apart, the centre of gravity could be brought within the grooves, but doing so meant increased weight of material and cost. The actual stress in the cantilevers as designed is so low, that there was no particular object in trying to shorten them still further, especially when doing so meant an increase in the weight of the gate. The weight per span of cantelevers plus lattice girders was very low, and much less than the solid girders which appealed to Mr. Nicholson. The latter's efforts to compare costs were wide of the mark, and without actual

figures such efforts were best omitted. Until the completed costs were available, it was sufficient to say that the cost of the finished work was likely to be well within that of the sluices obtained from Messrs. Ransomes and Rapier. A final question was raised as to the arrangements for expansion and contraction combined with the principles of balance mentioned in the paper. The arrangement for expansion and contraction in the superstructure was similar to the provision made in a railway track, namely, elongated holes with the adjacent parts bolted together. The stress due to change of temperature was greater than that from any overturning tendency, so that, while bolting together gave all the support necessary, it still allowed changes of length to be taken up. The Marala superstructure had now been standing for three years, and as it had been through several hot and cold seasons without any sign of distress, it was obvious that the arrangement was satisfactory.