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# TWO NOTES ON GROUTING APPLIED TO BRIDGE WORK.

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## (1) BISHENDORE BRIDGE AT MILE 474/5-10 ON LALAMUSA-RAWALPINDI SECTION, NORTH WESTERN RAILWAY.

### General.

Bishendore Bridge consists of three spans of deck type triangulated girders, 120 feet overall, on very high piers. Rail level is 82 feet above the bed of the Nullah. The original girders were strengthened in 1914, but in 1930 it was decided to renew them altogether. At the same time it was known that the masonry, of which the piers were built, was of inferior quality and was showing signs of distress. After considering the alternative of rebuilding the piers altogether, it was finally decided to strengthen them by injecting cement grout. This work was carried on simultaneously with the renewal of the girders.

### Object.

The object was to inject as much grout as possible into the piers, with a view to filling all cracks and voids with cement paste. It was also expected that the old and porous lime mortar would absorb a proportion of cement paste and so would be reinforced.

### Short description of method.

Holes $1\frac{1}{4}$" diam spaced approximately 3' were drilled into the faces of the piers at the joints with the type of pneumatic rock drill known as a "jack-hammer." The depth of these holes varied from 3' to 8'. Six to eight inch lengths of 1" G. I. pipe, threaded at the outer end, were then inserted in these holes, and were fixed with rich mortar made from Swasticrete cement. Cement was then injected into the holes, working from the foundation upwards.

### Detailed description of procedure.

**Drilling the holes.**—For the purpose of renewing the girders, North Western Railway pattern of interchangeable staging had been erected on each side of the piers and thus afforded a safe and suitable staging for the workmen. A supply of compressed air was available from a steam compressor plant installed at the site. Holes were drilled some normal to the pier, some inclined to the left or right and some inclined downwards. Evidence of voids was afforded by the fact that the drill, after offering considerable resistance, would suddenly penetrate from 1 to 2 feet. Some holes, which offered great resistance and jamming

to the drill, had to be abandoned. In some cases dust was seen blowing out of adjacent holes while drilling, thus proving that the hole communicated with each other inside the pier through voids in the masonry. Orders were received that no excavation was to be done to drill holes in the bottom of the piers, but the lowest line of holes at ground level were inclined downwards and pains were taken to get these holes as far into the masonry as possible. After drilling the holes the short lengths of pipe were fixed as already described.

**Plant.**—A grouting machine, manufactured by Messrs. Consolidated Pneumatic Tool Company was used. Its general arrangement is shown in the plate.

**Use of neat grout.**—Experiments were made with grout containing various grades and proportions of sand. In all cases this was found to be unsatisfactory. The sand could not be kept in suspension with the water and cement, but invariably settled and caused a stoppage in the flexible delivery pipe of the grout injector. As the result of these experiments the Author is convinced that neat cement grout should always be used for this class of work and no admixture of sand should be permitted.

**Sluicing the grout holes with water.**—A day's work consisted of about 9 feet height of pier, *i.e.*, three layers of holes. On the evening of the previous day, pure water was injected into the holes that were to be grouted on the following day. About 32 gallons were injected into each hole. Water would frequently ooze out between the joints in the masonry.

**Injecting grout.**—Next morning the work of injecting grout into these holes would be taken in hand. Sixteen gallons of water was placed in the drum and one bag of cement was added slowly, while the handle of the machine was turned to prevent lumps forming. Before closing the drum the operator ascertained by inserting his hand into the drum, that there were no lumps. The flexible pipe had already been connected to the appropriate grout hole by its union nut. The drum was then closed, and keeping the handle of the agitator turning the air inlet valve was opened and the air pressure on the top of the grout was increased to 10 to 15 lbs. per square inch. If the grout hole was in communication with voids, the drum would be emptied in about 10 seconds, or even less, and the fact of the drum being emptied was indicated by a peculiar noise which was soon learnt and easily recognized by the operators. On hearing this, the air was at once closed and the pressure remaining in the drum was released by opening a cock provided for the purpose. If the grout hole was impervious, or possibly sealed by previous injections of grout into other holes, no grout would flow, and this state of affairs was readily recognised by the operators as there would be no noise. In some cases pressure was increased to 20 to 25 lbs. per square inch, but usually this was ineffective. The maximum number of bags of cement injected into any hole was 32. In such cases cement grout would usually start to

escape from adjacent holes and from joints in the masonry. This was stopped by plugging the pipes with wooden plugs and stoping the cracks with wooden wedges. In many cases grout would escape from holes on the far side of the pier. Such holes as were plugged in this stage were invariably found to be sealed when it came to their turn to be grouted. The flexible pipe was, however, applied to all holes in turn to make sure.

Grouting proceeded from the bottom upwards except in the case of three holes which were drilled vertically downwards in the top of one of the piers just before the new reinforced concrete was cast. Later, however, it was considered incorrect in principle to grout from the top downwards and in the other pier grouting proceeded from the bottom upwards without exception.

**Record of grouting.**—A record of grouting was kept. The information recorded included the position and depth of every hole, the date of grouting and the amount of cement and water injected. The Plate has been prepared from this original record.

**Test Holes.**—The original orders were to drill the holes 6 feet apart. After drilling a few rows of holes to this spacing and grouting them, orders were issued to drill the holes at about 3 feet spacing. Intermediate rows of holes were therefore drilled between the rows of holes drilled originally. In drilling these, the drilling dust showed that the drill was passing through layers of solidified grout, thus showing that even the grout injected through the holes at 6 feet spacing was spreading at least 3 feet in certain cases.

**Pointing.**—After grouting, the faces of the piers were scrubbed with a wire brush, the joints of the masonry were scraped out and were neatly pointed throughout. Such of the grouting pipes that were readily removable were removed, and the remainder were allowed to remain in position where they are practically unnoticeable. The piers were kept damp for about 14 days after grouting.

**Conclusion.**—About 45 tons of cement were absorbed by the two piers. It is difficult to judge to what extent this has strengthened the piers, but judging from the amount of cement absorbed and from the results obtained from the test holes it is considered that the grouting has been effective. The cost, *i.e.*, about Rs. 5,000/- is insignificant compared with the cost of rebuilding the two piers, which was the only alternative.

## (2) CRACKED ABUTMENT OF KOTRI BRIDGE AT MILE 109/1 KARACHI-LAHORE SECTION, NORTH WESTERN RAILWAY.

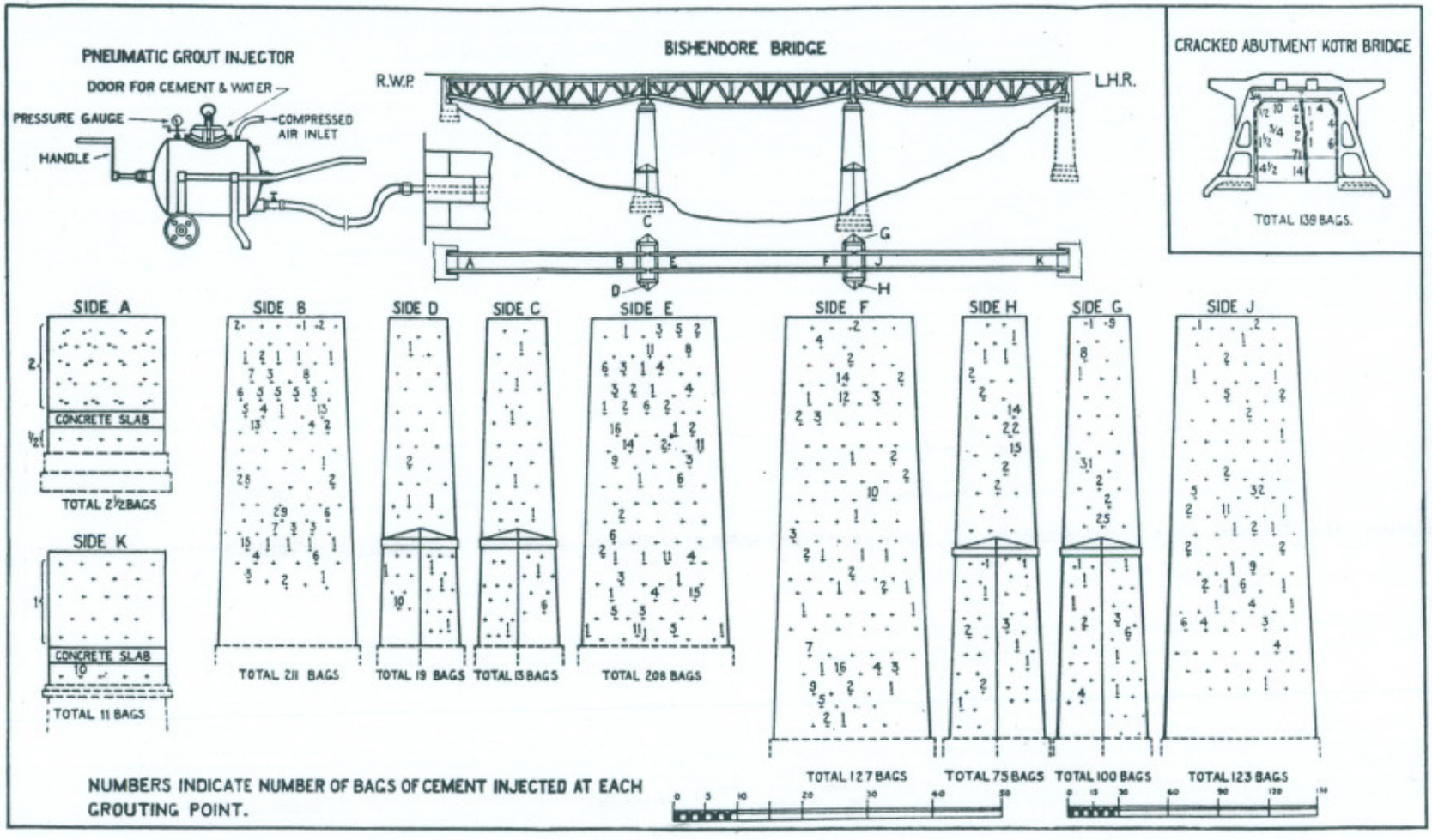
The piers and left bank abutment of Kotri Bridge, 5 spans of 35' feet girders, and 1 span of 100 feet girders are founded on well founda tions, while the right bank abutment is on open foundations. Th brickwork of this abutment had cracked from top to bottom. Durin the recent strengthening of the bridge to carry H. M. standard loadin with two 12 feet cantilever roadways, it was decided to strengthen thi abutment by enclosing it in a frame of reinforced concrete, thus reduc ing the intensity of pressure on the foundations.

A space was deliberately left between the old brickwork and th new reinforced concrete. After maturing, the reinforced concrete wa allowed to take the full train load at reduced speed for a short perio in order to give every opportunity for initial settlement to take place.

The space and the crack were then sealed by cement grout. Th space was first filled with fine dry gravel and pointed on the outer face s as to retain the grout. Grouting pipes were inserted at intervals alon the space and down the crack. The Plate shows their positions and th amount of grout injected at each point.

As with Bishendore, neat grout was used exclusively. Every hol was sluiced with water on the day prior to grouting. This work wa completed by the end of May 1933, and up to the time of writing the ol crack shows no signs of opening up.

The Author is indebted to Lt.-Col. W. Macrae, Chief Engineer North Western Railway, for permission to present this paper and t Mr. W. T. Everall, O.B.E., under whose instruction the work was done for his help and advice. The Note on the Kotri work is based o memoranda kindly supplied by Mr. E. Catley, Assistant Bridg Engineer.


PNEUMATIC GROUT INJECTOR
DOOR FOR CEMENT & WATER
PRESSURE GAUGE
COMPRESSED AIR INLET
HANDLE
BISHENDORE BRIDGE
R.W.P.
L.H.R.
A
B
C
D
E
F
G
H
J
K
CRACKED ABUTMENT KOTRI BRIDGE
TOTAL 139 BAGS.
SIDE A
CONCRETE SLAB
TOTAL 2½ BAGS
SIDE K
CONCRETE SLAB
TOTAL 11 BAGS
SIDE B
TOTAL 211 BAGS
SIDE D
TOTAL 19 BAGS
SIDE C
TOTAL 13 BAGS
SIDE E
TOTAL 208 BAGS
SIDE F
TOTAL 127 BAGS
SIDE H
TOTAL 75 BAGS
SIDE G
TOTAL 100 BAGS
SIDE J
TOTAL 123 BAGS
NUMBERS INDICATE NUMBER OF BAGS OF CEMENT INJECTED AT EACH GROUTING POINT.

## DISCUSSION.

MR. WATSON in introducing his paper, said that as it was the last paper to be taken in the afternoon session, he did not consider that a lengthy introduction was necessary. Strictly speaking, his paper was a record of two actual works. A useful application of grouting existed in dealing with masonry structures damaged by earthquakes. After the earthquake in the Quetta District, grouting was successfully employed to strengthen the pier of a bridge which had been cracked. The Author also considered that grouting might have useful applications in dealing with damage done during the recent earthquake in Bihar and Orissa.

The Author wished to express his thanks to Mr. W. T. Everall but for whose encouragement, he considered, it was probable that his paper would not have been written. He expressed the hope that Members of the Congress, especially those belonging to other Branches of Engineering, would contribute to the discussion, as he considered grouting was a subject of widespread interest to the Engineering Profession.

MR. H. L. SALLY remarked that the profession should be thankful to the Author for giving an account of this method of strengthening old structures without incurring the expense of rebuilding them. The Author, however, had found some difficulty in calculating the strength of his piers and he had only tried to supplement his note in that respect.

The left pier had 13,000 cubic feet of masonry and had consumed 451 cwts. or 540 cubic feet of cement. Grouting could not be done to the full extent in all the holes as the masonry was found sufficiently hard at those places. It was a safe assumption that the cement got mixed with half the masonry, *i.e.*, the ratio of cement to inert material became 540 : 6,500 or 1 : 12·5 which corresponded to a 1 : 4 : 8 concrete, which should give a crushing strength of 500 lbs. per square inch or about 30 tons per square foot.

Looking at the water cement ratio, it was 32 gallons to a hundredweight or 26 gallons to a cubic feet which gave a strength of 45 tons per square foot after six months and 15 tons per square foot after 28 days. These strengths compared very favourably with good brick masonry in lime.

Discussing the procedure adopted he added that 32 gallons of water were injected into each hole on the evening of the day previous to that on which the grouting was to be done. That was evidently meant to clear up the pores of old masonry in order to facilitate passage of grout. That, however, saturated the structure which could not, therefore, absorb water from the cement grout. If five or six days had been allowed between these two operations some of the water in the grout would have been absorbed by the masonry, thereby reducing the strength of the water-cement ratio and definitely increasing the strength. He said that he would like to know from the Author if that suggestion was not likely to improve the resulting strength of such structures.

Referring to an alternative method, he said that these results could have been achieved more easily by Dr. Joosten's chemical consolidation process. With cementation there was no guarantee that cement grout forced under pressure ever reached the fine interstices in a structure. The chemical process, on the contrary, had a very high capacity for penetration. The process consisted in giving an injection of sodium silicate solution through a similar injection pipe, followed by a second injection of sodium chloride. The effect on the structure was instantaneous. As soon as the chemicals meet they combine and solidify. The treatment reached the heart of the wall and was far superior to plastering or cement grouting. These chemicals were easily soluble in water and went wherever water reached and did not require wide passages as the grout necessarily does.

LT.-COL. MACRAE said that he had asked that this paper should be prepared on grouting in the hope that it might lead to some interesting and informative discussion.

From the Railway point of view the Bishandore bridge appeared a particularly suitable case for employing grouting instead of rebuilding under traffic, especially as staging for re-girdering was on the spot simplifying grouting arrangements.

Very little grouting appears to have been done in Northern India apart from the lining of the Hydro-electric tunnel for Uhl water, but this practice has developed greatly of late years for many purposes. The Speaker thought it must be the fact that this is a development since most members completed their technical training that accounts for a tendency to avoid grouting even in suitable cases. In fact he seemed to have noticed a tendency to funk what is really a simple operation, and he put this down largely to want of knowledge.

If other branches of engineering will state their experience of grouting, this want of knowledge will tend to disappear.

Grouting, as done in the case of the Bishandore bridge, appears a very suitable method of strengthening defective masonry, particularly where the masonry is entirely or nearly entirely in compression.

For Railway work under traffic there can be great savings, and similarly this may be the case with other engineering works. For instance he suggested its applicability in a case of damaged or defective masonry in a canal fall where closures are short.

A method which has not yet been tried on the Railway, but which he had seen described in Engineering papers is the strengthening of foundations by pumping grout into the soil under the foundations. If any one here has had any experience of this kind of work, he suggested that his contribution to this discussion would be very valuable.

MR. W. T. EVERALL said that Mr. Watson's paper on Grouting dealt with two bridges which he had been connected with. The work described some simple and practical applications of the method to pier and abutment masonry.

The examples give an indication of what can be done by comparatively low pressure grouting up to 20 lbs. per square inch, this pressure was the measurement recorded by the gauge on the Air Compressor plant. There appeared to be a useful field for the use of grouting for such structures, especially where the masonry or concrete was in compression.

In the case of the Bishandore Bridge, the insertion of grout into the piers was facilitated by having staging in position round the piers for the changing of the main girders.

The work carried out in the cracked abutment of the Kotri Bridge had proved satisfactory. After 6 months in service, there were no signs of cracks in the work which was grouted.

An interesting application of grouting has recently been carried out on a large bridge in connection with the concrete slabs forming the roadway surface.

A bottom course of concrete was cast in the troughing and carried 1″ above the top of the troughs, the top surface of the concrete was covered with about 1/16″ of coal tar and sprinkled over with sand.

Slabs were then cast on the top of the tar layer in panels 8′-0″ long by 15′-0″ wide, having a thickness of 4″ at the crown and 3″ at the sides, the roadway being 15′-0″ between curbs.

A space of only 1/16″ to 1/8″ was provided between the faces of adjacent slabs for expansion and contraction. He said that he was not in favour of this system of constructing concrete roadway on bridges.

He preferred the concrete to be formed in one section from the bottom of the troughs to the top of the roadway surface and, where the roadway was carried from the tension booms of the main girders, to have the transverse expansion joints in the concrete not wider than 8′-0″ apart.

Trouble arose in connection with the slabs forming the top layer. It was found that owing to differences in the temperature of the main steel girders and the concrete slabs, (soon after the latter were cast), that the thinner edges of the top slabs had risen and curled up about 1/8″ to 1/4″ over a considerable area. A contributing cause to the trouble was the limited space provided for expansion and contraction between the slabs and the effect of this was very marked at low temperatures when the steel girders were found to contract to a greater extent than the concrete causing the slabs to bear against each other and become curved near their edges.

To remedy these defects, it was decided to increase the width of the expansion joints and to introduce grout into the space between the upper and lower slabs and so prevent their cracking under the loads.

The methods adopted were as follows :—

Alternate joints were opened out by chiselling to a width of 3/8″ and the space filled with a mixture of mexphalte, sand and sawdust.

5/8" diameter holes for the introduction of grout were then chiselled out in the intermediate joints which had previously been sealed with a mexphalte filling, taken to a depth of 3/4". The space to be grouted was first flushed out with water under pressure and then cement grout, in the proportion of 60 lbs. of cement to 50 lbs. of water, was introduced under a maximum pressure of 20 lbs. per square inch.

The penetration of this grout was successful. That was proved by taking a load over the grouted slabs and also by breaking up a slab to see how far the grout had filled up the spaces.

As much as 280 lbs. of cement was forced in under a pair of 8′ × 15′ slabs which meant that an average thickness of grout of about 1/8" was obtained.

The grout was in some cases forced out through holes distant 20 feet to 30 feet away from the grouting holes.

Mr. S. L. Kumar said that thanks were due to the Author for the very interesting and useful data he had provided the profession for cement grouting masonry of bridges under Indian conditions. It appeared to him that the method of strengthening the existing inferior masonry of bridges, was likely to become more popular. The main advantage of the method was that it was very economical as it obviated the necessity of temporary arrangements which were necessary for rebuilding such bridges under traffic. There were quite a large number of bridges on the North-Western Railway which were designed for very much lighter axle loads and which, but for their inferior masonry, would have withstood the heavier loading without inducing excessive stresses. Strengthening by this method was capable of giving them another lease of useful life.

The speaker said that there was a 10—40′ girder bridge in his subdivision the masonry of which was of inferior quality. It was at first proposed to rebuild the piers and abutments above the bed level. It was, then estimated that cement grouting would be a cheaper proposition. It was finally decided that a part of the masonry should be cement grouted by power pressure grouting as described in the method and the remaining by hand pressure grouting. The latter method did not require a big initial outlay on pneumatic drills and compressors and did not need much skilled labour.

The object of the scheme was to obtain comparative costs of cement grouting masonry by the two methods under the same conditions and thus be in a position to decide as to which was the cheaper of the two.

The appliance used in hand pressure grouting consisted of an air cylinder, a cylinder to hold the cement grout and an ordinary air pump similar to a motor cycle pump. The above equipment costs Rs. 170/-. The holes were drilled in the masonry by Phillips Spring Hammer.

He added that as the work on that bridge had just started, it was not possible to give detailed information. Preliminary experiments have

however, indicated that sand could not be used with cement in grouting as it tended to choke up the stop cocks and was difficult to keep in suspension. Certain modifications suggested by these experiments had been made to the appliance which may enable the use of a sand and cement mixture.

He further said that he had heard it stated that a good deal of work on hand pressure grouting was done by the Hydro-electric Department, Punjab, while tunnelling in unstable rocky material. He was given to understand that they grouted these rocks before blasting them. He hoped that some engineer of that Department present in the meeting would throw more light on the subject.

He said that it would have been better if the Author of this paper had given some figures of cost—such as cost of drilling holes by pneumatic drills and cost of grouting 100 cubic feet of masonry by power pressure grouting.

MR. NICHOLSON cited the case of a pier which was built by the Railway and said that grouting could only be successful in the Irrigation Branch, and not in Railway where the work was done on contracts and not by daily labour. The Irrigation Branch pays for labour only and the materials belong to Government.

MR. WATSON in reply to the discussion stated that he would have liked to have dealt with Mr. Sally's remarks in detail, but most unfortunately he had been unable to catch all that had been said. He therefore proposed to deal with one or two points only.

With regard to Mr. Sally's suggestion that it might have been better to flush the holes with water and then inject the grout at a considerable time afterwards, it was to be noted that the work was done in the hottest part of the year, *i.e.*, June, it was done at a period when the masonry was, figuratively speaking, red hot. It was, therefore, better to inject the grout while the masonry was saturated with water. If this had not been done, the masonry would have absorbed the water as soon as the grout was injected, with the result that holes would have got plugged up and there would have been unsatisfactory penetration.

Mr. Sally had also advanced a very interesting theory of grout by Sodium Silicate injection. The Author considered that in the case under discussion where voids of considerable volume were known to exist, it was necessary to fill them with the cheapest reliable material, and cement grout answered to this description.

Mr. Kumar had complained that no details of cost were given in the paper. The total cost of the work as given in the paper was Rs. 5,000, for which 45 tons of cement (dry weight) were injected. This worked out to Rs. 111/- per ton of dry cement injected, including labour and materials. Another interesting figure for estimating purposes was that the piers absorbed 4 per cent. of their volume of dry cement.

Mr. Nicholson had given the Author the impression that he under stood the work of grouting the piers had been done by contract. Th Author assured Mr. Nicholson that this was not the case. The wor had actually been done by daily labour and therefore there was no incen tive to enhance the quantities (Mr. Nicholson rose at this stage an stated that he had meant that the original work was done by contract).

Mr. Nicholson's remarks about the grouting work done by certai Irrigation Engineers were very interesting. The Author laid claim t a high barrel-page ratio. He thought Mr. Nicholson would have t admit that.

Colonel Macrae had anticipated his remarks about the washawa that had occurred at Bishendore Bridge.

The Author had had the mortifying experience of watching par of his staging washed away by a flood which considerably topped th previous High Flood Level.