“Indian Bridges.”¹

ADDITIONAL CORRESPONDENCE, AND REPLIES OF THE AUTHORS.

Mr. C. O. BURGE remarked that Mr. Stoney's Paper on the New Mr. Burge. Chittravati Bridge was especially interesting to him as describing the reconstruction of one of a series of large bridges on the north-west line of the Madras Railway, of which, with one exception, he had charge when he was Resident Engineer on a maintenance division of that railway, and one of which, that over the Hugri, he partly constructed. They were the Cheyair Bridge (38 openings), the Pápaginí Bridge (20), the Chittravati Bridge (40), the Pennár Bridge (24), the Hugri Bridge (34), and the Tungabhadra Bridge (58 openings). These openings measured 70 feet from centre to centre of the piers, or about 64 feet clear between them. The original bridges were remarkable for having a great number of comparatively small spans, and for the cheapness of their construction, the cost per lineal foot being less than one-third of that of the bridge described in the Paper; the Pennár Bridge for example, only costing R.153, the Chittravati Bridge R.149, and that over the Toongabudra R.168 per lineal foot. The adoption of small spans made it possible to erect the girders at the back of the abutments, and roll them in sets of two continuous spans, over the piers to their respective places, and considerable economy was effected in this manner. The piers were of three types, viz.: (1) masonry built direct in the solid; (2) masonry on a group of small shallow brick wells; (3) screw-piles of wrought-iron. The piers of the Cheyair Bridge were undermined in a terrible flood more than twenty years ago, when the night mail train rushed into the gap with frightful loss of life, the Pápaginí Bridge had been partially or wholly reconstructed, the Chittravati Bridge failed in October 1874, as described in the Paper, and that over the Pennár was carried away on the 16th October 1889, and was now replaced by one very similar to the new Chittravati Bridge. Structures with more substantial piers and fewer of them in the first instance, would have been more durable, and it seemed, from the fact of the girders referred to in the Paper having been safely

¹ Minutes of Proceedings Inst. C.E., vol. ciii. pp. 123-200.

Mr. Burge. erected in the river bed, that little advantage was gained by the original erection on shore of the older bridges; for, as regards floods, all these rivers were of the same character. The failure of the original bridge over the Chittravati was evidently attributed to the insufficiency of the depth of the piers, and not to deficient waterway, as the new bridge was 164 feet shorter, deducting piers in both cases, a difference hardly accounted for by the fact that the old one was slightly skew to the channel. The Author was right in pleading for more latitude with regard to the dimensions of cylinder work, so as to allow for unavoidable divergence in sinking. Mr. Burge had drawn attention to a somewhat similar point in his Paper on the Hawkesbury Bridge, and in the correspondence upon that subject his opinion was supported by Messrs. Bouscaren, Collingwood, and Professor Gaudard.¹ Considering the nature of the strata passed through, the sinking of the cylinders at R.58½ per lineal foot seemed to be remarkably cheap, and reflected great credit on the Author, as it must be inferred from the fact that no contractors were mentioned, that the work was carried out departmentally. It would appear from the Paper that the piers above ground were of iron with masonry inside, and it might fairly be asked why the stonework was not exposed, the Nirgee limestone of which it was composed making very presentable masonry. Mr. Burge had not gone into the question of the quantity of metal provided for the stresses in the girder members, but it would appear from the small deflection of $\frac{1}{3300}$ of the span with a maximum load that the erection of the structure at the maker's works and on the spot had been well carried out.

Mr. Robertson. Mr. ROBERTSON, in reply to the remarks that had been made as to the absence of information regarding the design, loads, and permissible strain, pointed out that the Paper dealt, as its title showed, solely with that part of the work with which he was connected, namely, the erection of the Lansdowne Bridge. The contract for the ironwork had been let before the Author was deputed to consider the erection. The cost of the ironwork was due partly to the fact that most of the members required some special shaping, and partly to the expense of putting it up in England, which might be considered a necessary preliminary in consideration of the locality for which it was designed. There being only a single span to the bridge enhanced the cost of erection, as special appliances, such as the central staging, were

¹ Minutes of Proceedings Inst. C.E., vol. ci., p. 2.

only available for a small tonnage. In reply to Mr. Young, con- Mr. Robertson.
sidering the position of III strut and that its length was 230 feet, and weight 120 tons, it would have been difficult in any case to have lifted it in one piece, and the details of construction rendered it impossible in this particular instance. There was no difficulty in setting the nose of III strut to exactly the right span for the horizontal tie, when once it was completed and the distance measured. The $1\frac{1}{2}$ -inch rope was only a guy to hold the head of each piece after it was raised into its place, so as to prevent any strain on the fastenings; and it was not intended to imply that the rope lifted the piece. With reference to the suggestions that an arch or a girder would be preferable to a cantilever, there was no doubt that the site lent itself to an arch; but in balancing the advantages it must be remembered that each day's work on a cantilever was secured, while in the case of an arch the risk continued till it was closed. As for a girder, it would have been quite impossible to erect false works in the Rori Pass, and such a proposal was never made among the numerous schemes for bridging the Indus. In reply to Mr. Read, the deflection under the test-load (two of the heaviest locomotives and fully loaded wagons placed so as to produce the maximum deflection at the nose of the cantilever) was $2\frac{1}{2}$ inches. Deflections were observed at all the panel points simultaneously by a water-pipe fitted with a gauge-glass at each, the most important being checked by an observer with a level. The oscillation was recorded by a seismograph, and only amounted to $\frac{7}{16}$ inch at a speed of 35 miles per hour, which was the utmost that could be attained by the test train owing to the gradients leading up to the bridge. It was true that there was an oscillation of $1\frac{1}{4}$ inch under a crowd, though the bridge was steady with the train. This was due to the absence of lateral bracing on a part of the cantilever where it only extended between the secondary members. This deficiency having been supplied in those bays, the oscillation was reduced to $\frac{3}{8}$ inch under a crowd marching in step on the footways only—the arrangement which had previously given the greatest oscillation. A larger crowd all over the floor only produced an oscillation of $\frac{1}{8}$ inch, as did also various combinations of train and men. Before this bracing had been added, an opportunity occurred of testing the effect on the bridge of as heavy a storm as had been experienced in those parts, while a goods train was passing; the direction of the wind being inclined at 45° to the bridge. No oscillation was perceptible.

In reply to Mr. Claxton Fidler, the gallows itself had a pro-

Mr. Robertson. jecting arm to work a rope for the heel of raking-pieces as shown in Fig. 8, Plate 6, in plan and front view. A very convenient tool which was much used was a spar or tube furnished with an ordinary jack head at each end and rings to sling it by; these were provided of different lengths and used to boom out pieces. In the event of its being desired to raise a piece from a position on the floor of the bridge where it could not be reached by the overhead rope, an ordinary block and tackle hooked on the traveller on the top was used. A pair of wire-rope tackle sets were provided for this purpose. A good deal of lifting of small pieces was done with ordinary ropes working from the overhead gear. The Paper would hardly be complete without some notice of the accuracy of the work as executed by Messrs. Westwood, Baillie and Co., which enabled the most intricate joints to be brought together without difficulty.

Mr. Stoney. Mr. STONEY thought there could be no doubt that the use of small charges of dynamite facilitated cylinder sinking, and reduced the loads required by perhaps 30 per cent. The same system was used at the Pennár Bridge, having been introduced by Mr. R. E. Ellis, Assoc. M. Inst. C.E., the Author's assistant on that work. With regard to Mr. Wolfe Barry's query, there was no doubt of the fact that in one instance, after 30 feet of concrete had been put in, there was a depth of 8 feet of slurry formed over it; no analysis was made of it, but when taken out and poured on the river-bed it dried like fine mud. It was produced only in the case of one make of cement. Referring to Mr. Robinson's remarks, there was, in the absence of suitable pneumatic plant, no means of getting the large boulders out from under the cutting edge, except by blasting, as they were too large to push out or to chip, and if they were undercut and drawn into the cylinder blows of sand followed, as happened at pier No. 11. The cylinder served merely as a casing to allow of a concrete pillar being carried to the rock bottom, so that its having cracked was of no material consequence. It might be mentioned that the wrought-iron cutting-rings were not cracked by the dynamite, but their lower edges often got crushed by coming forcibly in contact with boulders or rock, when the cylinders ran down under heavy loads. With regard to Mr. Riddell's remarks, the Author had designed an annular plate to carry internal loading, Figs. 12 and 13, Plate 7, and used it very successfully in three cylinders of the north abutment, and he would have liked to adopt this plan all through, but the work had been already commenced, and there was no time to wait for castings from

Madras. The Author was fully alive to the advantages of internal Mr. Stoney. loading, and always advocated it, because, 1st. It kept the centre of gravity of the load low, and saved the great cost of stacking and unstacking rails, which moreover brought the load high above the river-bed, thus increasing the tendency of the cylinder to cant. 2nd. It made use of the permanent filling as a sinking load, and this filling could be built in above water and inspected, instead of having to be put through water by skips. In connection with Mr. Wrightson's remarks, the Author had known cylinders in the Pennár and Cheyair Bridges to sink suddenly without any apparent cause, after resisting the action of a heavy load for days, during which time they had remained untouched.

In answer to Mr. Gillott, 8 per cent. more rivets were used than were actually inserted, including all those that were lost or burned in heating. The number of loose rivets cut out was about 4 per cent. The Author would have been glad to have the furnaces and riveters described by Mr. Gillott instead of the ordinary portable forges which were used. With reference to the remarks of Mr. Macdonald and Mr. Seyrig, it should be explained that the section of the river-bed shown by the original borings was not only often quite wrong in depth, but very misleading as to strata, giving for the most part no indication of the existence of the boulder beds actually met with. For example, at pier No. 11, a depth of 6 inches only of dark boulders was shown by the borings, while 22 feet of them was actually sunk through, without reaching the rock. Piers Nos. 12 to 18 went through layers of boulders varying from 6 to 14 feet in depth over the rock, while the borings indicated none. The working section showed materials suitable for dredging throughout, and it was only when a considerable part of the cylinder-sinking had been done that the existence of the bed of boulders became known. It was then too late to procure suitable pneumatic plant from England, as including the time necessary in order to obtain Government sanction, &c., it could not have been got out in less than nine months at the least. American and English Engineers could not easily realize the peculiar difficulties of working in India, where all plant had to be ordered from England, and machine shops for repairs might be 200 miles or more distant. There was also the greatest difficulty in procuring skilled labour and trained foremen and mechanics, so that the Engineer had to see personally to everything, including minute details, as well as to direct and supervise. The pneumatic work was done with old pumps imported in 1877,

Mr. Stoney. the valves of which were worn and constantly broke down, allowing the cylinders to fill with water, which had to be again forced out; and this had to be done by native labour trained on the spot, without the supervision of a skilled foreman, so that the cost was consequently abnormally high. The Author would like to hear from Mr. Macdonald and Mr. Seyrig what the cost per lineal foot of sinking 12-foot cylinders to a depth of 50 to 60 feet below water-level should be with skilled labour and modern pneumatic plant.