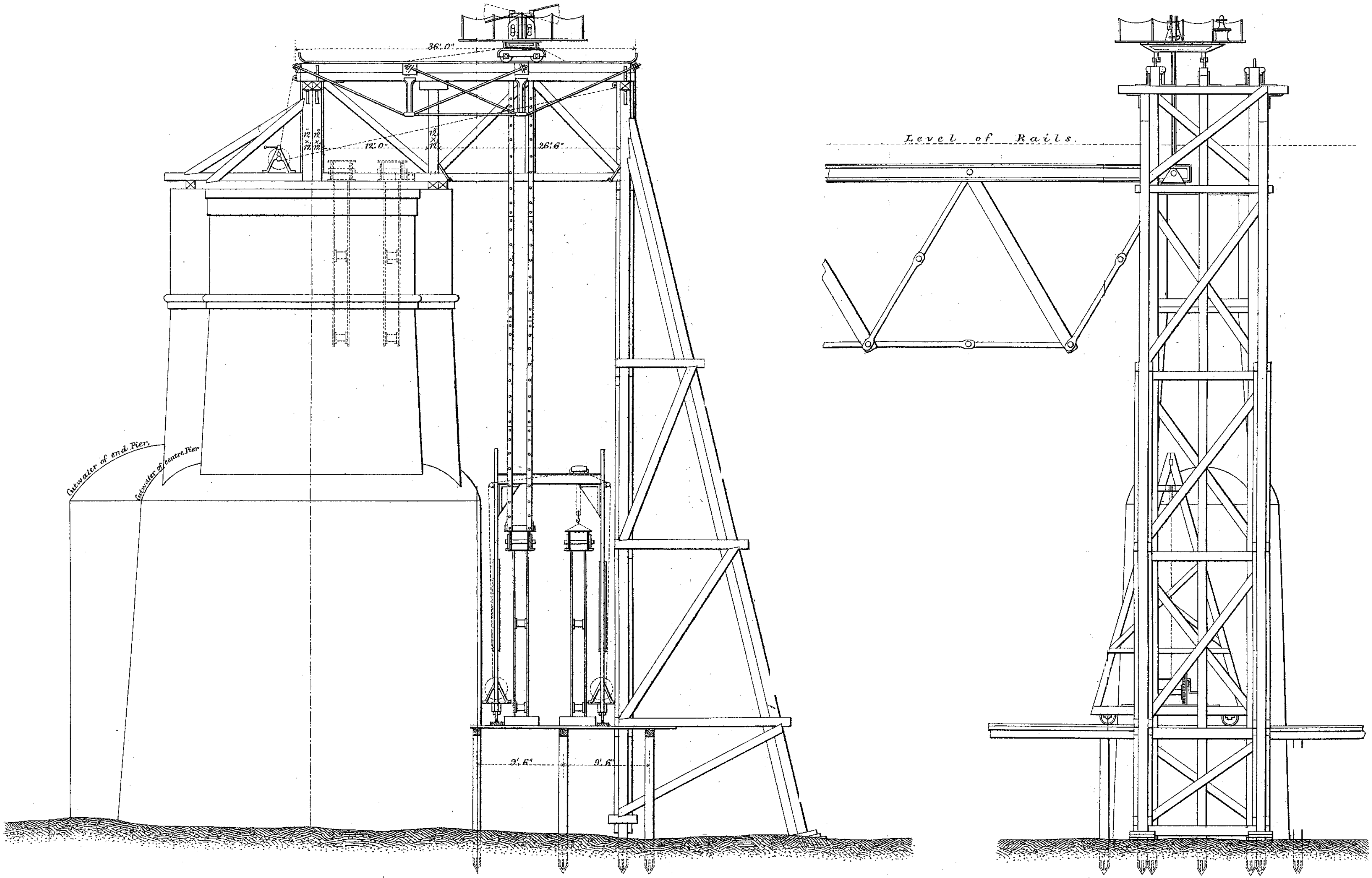
Mr. W. Parsey said, the apparatus described as having been used for the erection of the girders of the Mhow-ke-Mullee viaduct was designed by him for a different and, in many respects, a more favourable site. The principal requirements were that the apparatus should be capable of being quickly erected and arranged in place, that it should be simple and readily struck, and that the whole process of the erection of the apparatus and of the girders might be effected in one season. The piers of the viaduct for which it was intended were from 80 feet to 90 feet in height to the level of the girders; and it was a matter for consideration, whether an apparatus of this description would be more economical than the employment of wooden staging. The process of rolling girders described in the Paper on the Pennair bridge was not applicable to the Warren truss, the lower flange, or member, of which was a chain: it was therefore only a question whether a timber platform or an apparatus of this description should be employed. Three or four years previously he had designed an arrangement for lifting some girders of 80-feet span, by means of a staging on the top of each pier, and by lifting the girders from the tops of the piers. In that case there were eleven openings, and the contractors found it answered so well, that they determined to adopt a similar arrangement. Another consideration in favour of this apparatus was, that good timber, of sufficient length for large scaffolding, was expensive in India. It was estimated that the timber would cost from 10*s.* to 12*s.* per cubic foot by the time it was erected. Therefore, to fill up a gap, 200 feet wide and from 70 feet to 80 feet high, even with timber of small scantling, would have been costly. This apparatus, including the travelling Goliah and duplicates, cost about £1,000, or £1 per ton upon the whole of the iron-work erected. A further reason for the adoption of this apparatus was the small number of labourers required in the process of erection and of lifting. Iron piles had been used in forming the staging, owing to the fact that the piles were obtainable near Bombay; and he imagined the engineers there considered it could be more quickly erected by that means; but in the apparatus as originally designed, timber staging was intended to have been employed. In erecting the girders on two stages, it appeared that the top flanges, or booms, were put together in the first instance, and were then dropped on to the lower stage. The way in which these girders were erected for testing in England was first to lay down the bottom flange, then to put the struts and ties in their places, passing temporary wooden pins into them, allowing the triangles to support themselves, and next to drop on the top box, or member. He thought there was an unnecessary expenditure of labour and of materials in using two platforms instead of one, as one platform had been found to answer. The reason why it had taken some hours to drive

TOWAH VIADUCT.

GREAT INDIAN PENINSULA RAILWAY.



SCAFFOLDING, AS ORIGINALLY DESIGNED FOR LIFTING GIRDERS OF 202 FEET SPAN.

Scale of Feet.

0 5 10 20 30 40 50 60 Feet

W. PARSEY, DELT.

KELL, BROS LITHRS CASTLE ST HOLBORN.

in the connecting pins probably resulted from their being painted to protect them during the voyage out, and from their not being properly cleaned after arrival. The apparatus was not intended to lift so great a weight as 112 tons. The estimated weight of one girder was 80 tons, and the apparatus was arranged to carry that weight. He thought it was straining it too much to put the cross girders on and the roadway as well, for there was not only the additional weight, but there must have been cross strain from the centre of gravity being displaced. He had intended to test all the links with a strain of 10 tons to the square inch, and he began by testing every bar; but after he had tested a great number, without the failure of a single link, he contented himself with testing every other link, although he examined every one, and could not imagine how the link that failed escaped scrutiny. The fracture was not through a weld, as the links were made of the best Staffordshire bar-iron, planed off at the ends and not cut roughly. There must have been a slight crack or flaw in the bar which was overlooked, and it must have been one of those he did not test. He could not understand how it was that one of the force-pumps had given way. Every one of them had been tested up to 3 tons' pressure to the square inch; and the working strain of 40 tons' weight would only have given 1 ton to the inch; therefore with 112 tons the strain ought not to have been more than about $1\frac{1}{2}$ ton to the inch.

Mr. G. Berkley said he would make a few remarks upon the reconstructed work, and, if permitted, refer to the failure of the masonry of the former structure, on which subject he knew some degree of interest was felt. The design of this viaduct was partly accidental. The girders were originally intended for a viaduct of 202 feet span, the early completion of which was not required. They were therefore used for this purpose, and had been so far applicable that a fine work had been constructed. If those girders had not been ready, spans 20 feet longer might have been adopted, and some masonry at the abutments saved; or the viaduct might have been designed with three spans each of 150 feet. Mr. Rushton, the late chief Resident Engineer of the Great Indian Peninsula railway, took great interest in this work, and an examination of the masonry showed that Mr. Rushton was a good mason, and an able engineer. Mr. Dewar superintended the execution of this work, which did him great credit. He also made the arrangements for carrying the goods traffic across the ravine, during the reconstruction of the viaduct, by means of the tramway. The only points of interest he would mention in connection with the tramway were, that it was worked for the whole period without serious accident, though the rope broke several times; and that the resistance of the wagons descending from the top of the incline, where they were started at a velocity of about 10 miles an hour, to the bottom, where a velocity of 40 miles an hour was attained, had been ascertained by Mr. Dewar to be 18 lbs. per ton when the rails were dry; when they were wet this resistance was slightly exceeded. Warren girders were found to be convenient for use in India, inasmuch as they could be easily put together, and, the pieces being comparatively small and light, could be carried inland with facility. He did not think it necessary, after Mr. Parsey's remarks, to dwell on the question of raising the girders. A staging of some kind was essential to provide a level platform on which to put the girders together, before they were lifted into their places. The iron piles were purchased from the Bombay and Baroda Railway Company, and their use materially expedited the execution of the work, as a large quantity of suitable timber would have been scarcely procurable in that part of India, and, if procurable, would have been very costly. He would only remark, in conclusion, that he believed this work, and many others that had been accomplished by those engineers who had gone to India, were highly creditable; and he would venture to say, that his acquaintance with civil engineers in all parts of India led him to entertain a high appreciation of the energy and ability they had displayed, in overcoming difficulties which were probably not generally known and understood in this country.

Mr. J. M. Heppel said, in reference to the second Paper, which described one of a class of bridges designed during the time he had charge of the works of the Madras railway, that its interest had been to some extent anticipated by the account, presented to the Institution five years ago by Mr. Edward Johnston, of the Cheyair bridge,[1] which in its main features was similar to that now under consideration. On that occasion he had given a sketch of the physical geography of the part of the country crossed by the North-western and South-western lines of the Madras railway. The large bridges over all the principal rivers were built much in accordance with the type of that over the Pennair. In the case of the Pennair bridge, however, the sectional area provided for the discharge of the water was in a very different proportion to the drainage area to that which obtained in the case of the Cheyair bridge. Thus, whereas in the former there was, in the highest floods, a sectional area of 22,000 square feet for the discharge of the water from a drainage area of 4,500 square miles, in the case of the Cheyair there were 29,000 square feet of sectional area for the discharge of the water from a drainage area of only 2,270 square miles; so that the Pennair having one-fourth less section drained twice the area of the Cheyair. He would mention a

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[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxiv. p. 184.

circumstance which was to some extent explanatory of this. The Cheyair had a fall in the bed of the river of 11 feet per mile, and for many miles below the bridge it had a free open course, so that there was a free outfall below the bridge, which acted as the main regulator, and whatever floods came down must be rapidly discharged, or a destructive backing up on the upper side would occur. In the case of the Pennair, however, a few miles below the bridge, there occurred a narrow gorge in the mountains, through which the waters had to pass, not only of the Pennair, but also of the Chittranutty, a tributary draining an area about equal to that of the Cheyair. The consequence was that, during heavy floods, a kind of backwater was created, which always kept up a high level on the lower side of the Madras railway embankment; so that in the highest floods there arose an interruption to the free flow from the lower side. The effect would be not to produce an excessive volume of discharge, but to spread it over a considerable interval of time.

This bridge also differed from its analogue, described some years ago, in the method of getting in the foundations. It would be recollected that all the foundations of the Cheyair bridge were got in by excavation within cofferdams; whereas a considerable portion of the foundations of the Pennair bridge were got in by means of wells—a plan which was described by his predecessor, Mr. G. B. Bruce, in a Paper, read in 1857.[1] In the Pennair bridge a solid substratum was reached at depths varying from 11 feet to 12 feet. These wells would therefore, no doubt, form perfectly solid and good foundations. But what he wished to draw attention to was, that these wells followed the old-fashioned Indian plan of construction—being 5 feet in external diameter and 3 feet internal diameter, and they were packed close under the foundation in rows till they made up the requisite area. He thought the progress in recent practice pointed to the advantage for a given area of foundation, whether obtained by wells or by cylinders which were precisely similar, of diminishing the number of the wells, or cylinders, and of increasing the area of each. Any one who examined the condition of stability, or the resistance offered to the lateral force of wind or of currents tending to overturn the structure, would find that, for a given area, the less the number of subdivisions the greater would be the stability. It might be approximately stated as inversely as the square root of the number of separate parts into which the foundation was divided. It would be interesting to know why the practice in Madras was to follow the uniform plan of wells of small diameter. In his own practice in India he had found that wells of larger diameter were preferable; and in the

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xvi., p. 449.

magnificent bridges over some of the large rivers crossed by the East Indian railway, Mr. Rendel's principle had, he believed, been to make the supporting cylinders as few in number, and as large in dimensions, as possible.

With respect to the girders, the Paper was valuable on account of the minuteness with which it entered into the time occupied in erecting them, and the cost of all the parts of the operation. He had at present some girders under construction for a bridge of larger dimensions, which were to be erected in the same way. They were now in course of manufacture at the works of Messrs. Campbell, Johnstone, and Co., and it was intended to go through the whole operation of rolling them over, in order to test the sufficiency of the apparatus for that purpose before it was sent out. Mr. Campbell had desired him to say, that if the operation would be interesting to any members of the Institution, it would give him great pleasure that as many as pleased should witness it.

Mr. Vignoles, President, remarked that there could be no doubt Mr. Heppel was quite right in principle; but when it was considered that the plan of using small wells, of 3 feet internal diameter, was practised by the Indians, many hundred years before the British came into possession of that country, the endeavour should rather be to ascertain, why so long a time had been allowed to elapse in following out a theoretically correct principle, upon the examples set by the natives. No doubt it was on account of greater facilities, and, it might be, of greater economy, in construction.

With respect to the Papers, most of the points had been illustrated before. But with regard to the circumstances attending the failure and destruction of the original Mhow-ke-Mullee viaduct, and other masonry works on the Great Indian Peninsula railway, which had attracted the attention of Engineers in all parts of the Empire, he thought the subject was so important as to be worthy of a separate Paper. He therefore ventured to suggest to Mr. Berkley, that it would be more fitting and proper, if an explanation of the causes of those disasters were given in a distinct communication.