Correspondence.

Dr. Linden-thal.

Dr. GUSTAV LINDENTHAL observed that when the bridge was built it was deservedly considered a masterpiece in bridge engineering and a bold undertaking. The manufacturing and shop facilities for such ironwork, also the science of statics, were then still of a primitive order, and it required more than ordinary courage to attempt a structure of this kind, for which the designer was entitled to lasting distinction and honour. The recent examination recorded by the Authors gave many valuable facts on the behaviour and condition of metal exposed for 100 years to strain and wear in a damp climate. The defects of the bridge would hardly warrant thoroughgoing repairs, which would be quite expensive, and, after all, only of a temporary nature. The account reported the stonework in the piers and stone arches to be in excellent condition. It would be true economy to replace the old suspension part of the bridge with steel arches abutting in two ribs against the solid stone towers, which were founded on rock. If the form of such steel arch followed the lines of the Hell Gate bridge over the East River, New York City, its architectural appearance would harmonize with the old stone towers of the suspension bridge. The haunches of the arch bridge would reduce somewhat the height at each end above the water, which would not interfere with navigation. A concrete arch with two ribs reinforced with steel on the Melan system would probably cost a little more than steel arches, but the extra cost would be justified by the saving in the cost of painting. The architecture would also be harmonious with the existing masonry arches of the approaches. It would result in a very durable handsome bridge, with a low cost of maintenance.

Mr. Pratley.

Mr. P. L. PRATLEY found a number of interesting points in this investigation of Telford's great work at the Menai Straits. Taken with the Paper by Messrs. Rivers and Morris, it formed a valuable addition, alike to the knowledge of this famous structure, and to information regarding the general subject of bridge materials and maintenance. Cold fact seemed almost to touch with warm romance when a suspension bridge built 100 years ago, but yet in service, was inspected and reviewed. It would indeed be regrettable if no means were found to permit the retention of this

Mr. Pratley. historic structure; and he felt that all bridge-engineers with interests beyond the merely utilitarian would experience a sensation akin to bereavement were it determined to replace it by another span. Generally the comment of the Authors of the earlier Paper as to the material in the bars was substantiated by the present evidence. The condition of the iron was remarkable, considering age, exposure, and the limited facilities for its manufacture. The tests given in Appendix A showed a notable uniformity in physical properties. The Kirkaldy tests given in the former Paper for similar bars exhibited independent figures, all of which, however, lay between similar limits of 22·3 to 24·4 tons per square inch. The elastic limits and the modulus were equally consistent, and the ductility uniformly good, which testified to what must really have been excellent production under the methods then available. It was a fact that to-day the physical properties of a series of specimens from the same melt would not be more consistent. Apparently, no chemical analyses had been made, and there was no mention of the metallurgical features. These latter would probably assist in the study of corrosion. The actual loss by corrosion had been wonderfully small, all influences considered; and the high local losses referred to by the National Physical Laboratory as probably due to faulty welding or low-temperature rolling might be more definitely explained by a metallurgical examination. A large portion of corrosion was electric in its origin, and in the chemical and metallurgical properties were often found the causes of small potential-differences, which, given the proper medium, air or water, set up electrolytic exchanges. In his experience, the old English wrought-iron bridges of 1850–75 very often showed marked superiority, in their resistance to corroding agencies, over the steels, principally American, of 1900–10. During his detailed examination of the 1,100 bridges on the Grand Trunk system, incidental to the arbitration proceedings, he frequently found such old iron girders in distinctly good condition. The Authors' observation regarding small clearances, timber contacts, and pockets for the accumulation of rubbish, served to illustrate and emphasize the urgent need of laying out work so as to be easily accessible for inspection, cleaning, and painting, or, as an alternative in special cases, definite protection of inaccessible parts by bitumastic or other preparations, capable of long life under all weather-conditions. This was a practical point, the importance of which could not be overestimated; and it should therefore be steadily present in the minds of designers and builders of bridgework.

These old wrought-iron chains had evidently been carrying

Mr. Pratley.

16,000 lbs. per square inch continually for many years, due to dead load alone; while for live load, exclusive of impact, and without wind- or temperature-stresses, the figure had reached 19,000 lbs. Under such conditions, as the Authors pointed out, it would not need much reduction in area by corrosion to induce unit stresses equal to 21,000–24,000 lbs. per square inch, which represented the elastic limit. In fact, it would seem certain that in individual cases the elastic limit must have been reached. However, by some uncanny foresight, excess metal seemed to have been provided alongside such bars as had corroded most, and if any one bar had been stressed to the elastic limit, then it had been automatically relieved of its stress at the expense of its stronger brothers, and its elasticity had probably been partly restored. Nevertheless the situation was undoubtedly critical, and the recommendation to renew the weakest bars was timely. To have carried safely for a long period a dead load 48 per cent. in excess of that originally anticipated was a worthy record. The Authors' figure of 527 tons for the weight of the suspended floor meant 74 lbs. per square foot on the 28 feet between centres of chains A and D. This could be checked by reference to Fig. 2, Plate 2, and seemed unnecessarily heavy for existing traffic. The use of inverted 100-lb. rails had nothing to recommend it save perhaps the thickness of web, and the ease of fitting a strap round the flange; but for floor-panels averaging 4 feet 11 inches, as the previous Paper described them, simple rolled beams about 9 or 10 inches in depth would appear to be more desirable, both as to stiffness and weight. The trough flooring was also out of place on this bridge, in his opinion, and should be abandoned at the earliest opportunity. Some type of light, hollow, pre-cast, rectangular, reinforced-concrete beam, laid longitudinally across the **I** beams, probably in 10- and 15-foot lengths to stagger joints, with the top covered by a wearing surface of $1\frac{1}{2}$-inch asphaltic mixture for smoothness and resilience, would seem to be a more reasonable floor-system. From the data in the Paper he had examined the figures for dead- and live-load unit stresses, with a view to determining what increase, if any, the movement of the test loads produced, as compared with the static effect. It was rather a pity that the Authors had not studied this point while the opportunity offered, or if they did so study it, that they had not mentioned their discoveries. It would appear, from what rough figures could be made with the information available, that of the (*b*) 0·73 ton per square inch live load (p. 227), about 0·61 was static, and the 0·12 additional was due to dynamic increment. The special impact due to running over obstructions was not ordinarily treated as a primary

Mr. Pratley. stress, but should certainly be borne in mind when dealing with structures working on the very verge of safety. The distribution of the stress among the bars of one chain was interesting in the extreme, and considering the importance in this connection of precise measurement, and the means available at the date of manufacture, it was surprising that the variation was not much greater.

With regard to the extensometer, it would be useful to know the length between gauge-points, the nature of these points and of the holes into which they fitted, and the accuracy with which results were obtained. He had used the 10-inch Howard strain-gauge for this purpose, and he was impressed with the need of almost laboratory precision in preparing the holes in the bridge-members. On the Canadian Pacific bridge at Lachine, Que., both in the shop and in the field, he found frequent cases where a reading would not exactly repeat itself, using the same direction of the instrument and the same human touch. The same instrument was used on the Quebec bridge, but with greater care given to the holes, and the accuracy obtained was superior in that respect. At Hell Gate, New York, a 20-inch Howard gauge was used, with good results, but at Niagara, in 1918, a Fuller-West gauge was preferred, the latter reading by dial instead of by micrometer-screw. A more detailed description of the gauge would assist in explaining such references as that on p. 218 to variation due to wind on the rods. A question arose in his mind as to the nature of this variation from vibration. Was it a variation in total tension due to lateral deflection of the chain or the floor, or was it a local bending of the rod ?

Mr. Thorpe. Mr. W. H. THORPE remarked that the imperfect action of the roller bearings was quite consonant with his own observations on rollers under old girders, where the movement of rollers was often less than might be expected, but was accompanied possibly by displacement of some other part—movement of bedstones, or rocking of masonry on its base. Though only ¼ inch of the computed lengthening of the Anglesey land chain due to rise of temperature was accounted for at the saddle, he thought it likely that increase of length in the masonry viaduct might give as much again, which, together with some elastic movement of the pier top, would leave the result less surprising. He suggested that the somewhat high modulus of elasticity of the tested bars was favourable to the view that there had been, by long use at high stress, some increase of that modulus. If the modulus for bar No. 5, Table I, were obtainable, it might be well to see whether for the smaller measured stress of 4·4 tons per square inch that bar showed a lower value of the modulus. Having

Mr. Thorpe.

regard to inequality of stress upon the bars, due to differences in bar-length and other causes, and to the possibility of unknown defects, and bearing in mind the probable effects of wind, he thought the current limitation of moving loads by the responsible authority was a wise precaution.

The Authors

The AUTHORS, in reply, referring to Mr. Pratley's suggestions for a lighter floor, were of opinion that it would not be economical to put in a new floor while the saddles and chains were in their present condition. The floor was subject to longitudinal and transverse wave motion during a wind, and the amplitude of these waves would probably be greater with a lighter floor. While the latter would reduce the stress in the chains, the reduction would be more than equalled by additional dynamic stress due to increased movement of the floor during gales. The dynamic increment from live load in the case of the Menai bridge was partly produced by oscillations set up in the bridge, and varied under different tests. These oscillations continued for a considerable period after the live load had become stationary; and in view of this, and of the fact that the increment proved to be so small compared with the total stress on the main chains, it was not considered practicable to draw theoretical deductions therefrom, and no practical purposes would be fulfilled by pursuing investigations in that direction.

The extensometer used in the examination of the bridge was, in all the cases recorded in the Paper, set with gauge-points 8 feet apart, and was read on a dial. Clips passing around the bars held the points in small deeply punched centre-marks.

The stress referred to on p. 218 was fibre stress produced by oscillation of the long suspension rods when vibrated by the wind.

They agreed with Mr. Thorpe's suggestion that the expansion of the masonry in the approach partly equalized the alteration in stress due to expansion of the main chains on the approach, but they had not had an opportunity of taking observations to verify this. The modulus of elasticity for bar No. 5 had not been taken. While they considered that the elastic limit might have been raised in the case of the more highly stressed bars, they did not think the modulus of elasticity would have been affected thereby.