

Correspondence.

Mr. P. C. TEMPEST remarked that the strengthening of the bridge Mr. Tempest. was one of the problems with which he had had to deal in connection with the bringing up to date of the whole of the bridges on the South Eastern and Chatham Railway. It was a problem of a special character, inasmuch as it was necessary not to disturb the traffic which passed over the bridge during ordinary week-days; this consisted of 400 trains going in and out of Cannon Street station each day. When extensive works of such a character had to be done on a bridge which at the same time had to carry out its ordinary functions, the problem was more difficult and complicated than that of the construction of an entirely new bridge, especially in the case when an important river ran below. At Cannon Street there was an existing structure which was in good condition, and the columns and foundations were equal to supporting a stronger superstructure. Although the difficulties to be overcome were very great, it was decided that the best thing to do was to carry out the strengthening which has been described in the Paper. It would be noticed from the Figures that the maximum load on the foundations when the bridge was fully loaded was about $5\frac{1}{2}$ tons per square foot. That was a point that had been very carefully looked into before proceeding with the work. The pressure mentioned was the maximum figure on two columns only, each at a different pier, and was arrived at without taking into account any distributing effect of the diaphragms which undoubtedly took place to a great extent. The foundation was London clay and was known to be of excellent character, which had been seen when the widening of the western side of the bridge was carried out in the early nineties. At Charing Cross bridge the foundations were, and had been for many years, stressed to an appreciably greater extent than at Cannon Street, without any deleterious effects having been experienced, and that enabled the designers to come to the conclusion that they would be quite safe in proceeding with the work in the manner described. Very careful observations taken over a period of years had shown that no settlement had taken place. He wished to say a word about the limit of stress for which the strengthening was designed, namely, 5 tons per square inch. When the calculations for the strengthening were got out it was anticipated that there would be increases in the

Mr. Tempest weight of locomotives as they then existed, and that anticipation had been borne out. Further, the stress of 5 tons per square inch made no allowance for impact, and taking those two factors into consideration he had concluded that if the material for the new girder work were steel the unit of stress at 5 tons per square inch would be a suitable one. He added that in 1918 a series of experiments had been carried out on Charing Cross bridge main girders by means of an instrument designed by Mr. F. Palmer and Mr. Fereday, and he had found that on the girders of Charing Cross bridge, with the speed of trains at the maximum which could be attained so close to a terminal station, the maximum percentage of impact was 15·5 per cent.

Mr. F. TIFFANY considered that the method of comparing the effects of the weights of engines on bridges by dividing the weight of the engine by the length, either over the buffers or the wheel base, might be very misleading, and that the comparison should be made by calculating the equivalent distributed live load due to bending. He would like to ask the Author whether he could supply a diagram of the loading which produced 3·2 tons per linear foot of track for a length of 75 feet. The statement that the new main girders were to be capable of taking one half the live load was vague. He wondered whether the designers had known that, and if so, how, or whether it was just an assumption. The difference in Young's modulus in the case of wrought-iron and steel would throw a greater proportion of the load on the steelwork; that, possibly, was all to the good. The distribution of the loads in the design adopted was almost indeterminate. Remembering that with one girder loaded and its neighbour not loaded, the diaphragms acted as cantilevers, incidentally throwing the rivets through the webs of the main girders and the diaphragms alternately into tension and compression according to which girder was loaded. That effect was particularly noticeable at the centres of the spans where the deflection would be a maximum, the diaphragms doing less work towards the piers. Trouble might occur with loose rivets at those places. Altogether the advantage of the diaphragms was doubtful, however carefully the calculations might have been gone into, and would be emphasized by the connection of old wrought-iron and new steel. The necessity for the new girder on the Middlesex intermediate span to the east of the water crane was not apparent. The necessity for the sag given to the two outer spans of the continuous girders (Fig. 9. Plate 4,) owing to the difficulties which would arise in the connections of the new diaphragms was not obvious, as, by the cross sections, the

diaphragm angles seemed well clear of the main angles of the old Mr. Tiffany. girders. He asked whether that was done to simplify the floor plate connections ; also, whether in launching the continuous girders over the last span, when there was apparently an overhang at one time of about 100 feet, there was not, with those shallow girders, a danger of over-stressing them. The ideal to be aimed at in such a type of bridge was to get, as far as possible, one girder under each rail on a plain road, so that the two girders were loaded equally and deflected equally, a light bracing between the girders under each pair of rails only could then be used which would have very little stress in it. In the parts where the crossover roads occurred, cross-girders could have been inserted. On the Middlesex intermediate span, new girders could have been placed approximately under the rails of the road which connected to Nos. 5, 6, and 7 roads, at an angle to the centre line of the bridge.

With nine roads and a siding which could easily have been temporarily converted into a running-road, it should not have been impossible to obtain possession of one road at a time, putting in temporary connections as required, or if the old continuous girders were suitable to act as simple girders temporarily, the road could have been kept open during weekdays, and light-weight engines run over it at a reduced speed. The continuous girders could have been cut over the piers, the rivets of the flooring cut out during the week. On a Sunday with two 35-ton steam travelling cranes, the old girders could have been taken out and the new girders lowered on to their bearings. If such cranes were not available, they would have saved their cost on the job. Such a plan would have saved the cost of the staging (about £10,000 at least, presuming the item " wages," £34,757 16s. 6d., included labour in erecting and dismantling the staging). The girder work, riveting, and field work would have been greatly simplified, and the cost per ton of steelwork would have been very much reduced. The sill girders could have been erected from barges. A very considerable credit would have been obtained from the girder work taken out, and the undesirable practice (besides being very expensive where many attachments to old work have to be made) of joining old and new work would have been avoided and the loads on the piers reduced. The girders would be freely supported, thus doing away with any ambiguity as to the distribution, and amount of reactions and stresses, and the costly and doubtful expedients adopted. The Author had not stated whether headway in the riyer was limited ; if not, Mr. Tiffany wondered why he had not encroached on that and used deeper

Mr. Tiffany. girders. Continuous sill girders over the piers were of doubtful advantage, and to facilitate the erection outlined above, it would have been better to have made the sills free girders, inserted under the existing sill girders, the old sill girders being removed as found convenient during the work ; on large piers like those, a considerable amount of packing and other arrangements could be made, hard to determine on the small scale plates supplied. Any difference in level between the new sill and the new girders could be made up by suitable stools. He asked whether any arrangements had been made for expansion on the continuous girders. He considered that the usefulness of the summary of cost would be augmented by the addition of the dates when the work was started and completed.

Mr. Ellson. Mr. G. ELLSON, in reply to the points raised by Mr. Tiffany, remarked that, as a rule, it was desirable to use for the basis of loading the equivalent uniformly distributed load per linear foot obtained by the bending moments given by the locomotives, etc., in the calculations for girders working parallel to the running roads, and that was done where possible. The proportion of the live load to be taken on the new main girders was based upon the conclusion arrived at after a careful investigation of the strength of the existing members of the bridge, and their capacity to carry and distribute load. Regarding the distribution of the load through the diaphragms, during the 7 years the new work had been in use, no loose rivets had been found in their connections to the main girders. The new girder on the Middlesex intermediate span to the east of the water-crane was necessary to give the bridge a uniform strength in case of any alterations to the lay-out of the lines which had been under consideration, and, further, its provision kept the character of all the girders connected together uniform, that was, continuous over three spans. In launching the continuous girders over the last span with an overhang of 100 feet, calculations showed that there was no danger of over-stressing them.

With regard to the method of arranging the girders under the running-roads, alluded to by Mr. Tiffany, since the bridge was built the running-roads had been rearranged, and for the strengthening work it had been impossible to do as he suggested. The suggestion to fix the girders from the top was considered before commencement, but was found impracticable. The volume of traffic over the bridge was exceptionally heavy, especially during the morning and evening peak hours, and it would have been impossible to work it without very serious curtailment if the running-roads had been interfered with. Apart from that fact, there would have been no saving in

the cost, as the constant alterations to the permanent way, disconnecting and reconnecting cross-connections and providing new temporary cross-overs and signal-appliances, would have more than balanced the cost of the staging. The sill girders could not have been erected from barges, as suggested by Mr. Tiffany, as the river conditions would not permit of this, and it was also not possible to encroach on the headway in the three middle spans of the bridge. The removal of the old sill girders would have meant the entire renewal of the bridge and its being out of use for a prolonged period.
