Discussion.

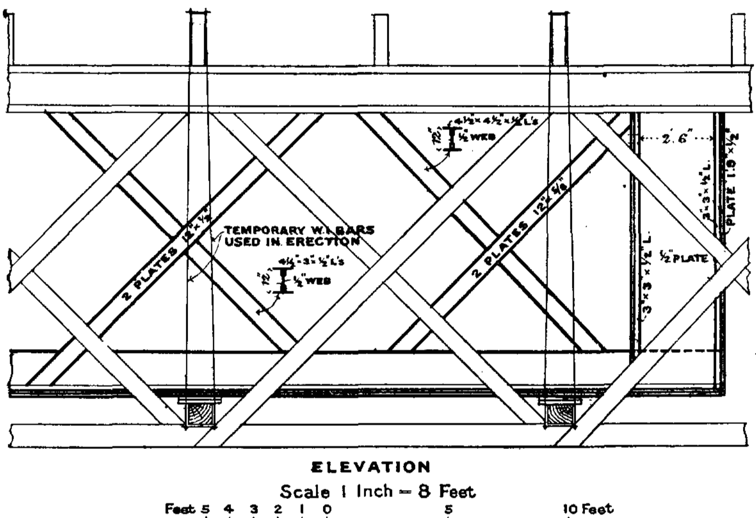
The PRESIDENT moved a vote of thanks to the Author for his interesting Paper. The President.

The AUTHOR exhibited a number of lantern-slides illustrative of the work described in the Paper. The Author.

Mr. W. J. CUDWORTH remarked that the subject was of much interest and importance, and one which afforded a wide scope for that "ingenuity" from which the profession derived its name. On the strengthening of early iron bridges it was hardly possible to generalize, and the Author had acted wisely in not attempting to do so, but in giving detailed descriptions of two successful instances in which the process had been carried out. On the question of maintenance, however, it was possible to generalize to a certain extent, and this the Author had done in a very interesting manner. Referring first to Fig. 15, Plate 5, Mr. Cudworth had not been so daring as the Author in that respect. Many years ago he noticed that the bridges under the care of the Durham County Council were treated with concrete on all the bottom flanges, in much the same way as the Author described, and he had treated road-bridges thus for several years; but he had never ventured to apply that treatment to a bridge carrying a railway, having always been afraid that the vibration would render it impossible to maintain a tight joint between the concrete and the steelwork of the girder. If water got in at slight cracks between the concrete and the steelwork, there would be mischief going on behind the concrete which could not be seen or dealt with in any way. He would like to know whether the Author had experienced that difficulty. With regard to the use of protective coatings on parts of a bridge which were sheltered from the sun, and exposed to the steam of locomotives, such as the lower sides of overbridges, nothing was so good as ordinary tar. The Author mentioned tar and lime, but the practice on the North Eastern Railway was to use tar slightly thinned with paraffin for the first coat, and ordinary tar without any thinning for the second coat. That treatment had given very good results. The corrosion going on in those places was very serious, and in bridges of that class, steel floors, when not absolutely necessary, were strongly to be condemned. Of course, it was not always possible to do without them; but on the ordinary road- Mr. Cudworth.

Mr. Cudworth. bridges of the North Eastern Railway the floors had been constructed of late with rolled joists of ample section and with timber decking running longitudinally. That formed a very satisfactory floor, which he thought would not give the trouble in maintenance that had been experienced with some of the iron-decked floors of the older bridges. He had tried the use of rolled joists embedded in concrete for a comparatively short time, and he was watching with interest to see whether perfect adherence was secured between the concrete and the joists, because if that result were attained, the form of construction would be excellent for small bridges; but it was always a little doubtful whether there would be sufficient adherence on a bridge subjected to the vibration caused by railway-traffic. Many of the older bridges had certain faults which were easily cured. One fault common to nearly all bridges, whether old or modern, was that the ends of the girders were enclosed in pilasters of brickwork or masonry with neat stone caps, which looked nice but were objectionable from the point of view of maintenance. He could not help thinking that the American plan of finishing the masonry at the bedstones, without any pilaster above them, was, from the point of view of maintenance, far better than the ordinary English practice. It gave freer circulation of fresh air, it rendered every part of the girder accessible for inspection and painting, and it prevented the corrosion which was almost inevitable when part of a girder was covered up as it often was. Another fault of the older iron bridges was that the amount of cross bracing between the two girders was generally insufficient. If the cross bracing were examined, it would nearly always be found that the riveting was loose; indeed, that was often the only part of the bridge at which there was bad or loose riveting: showing clearly that the structure at those points was not equal to its work. In several cases he had had to introduce additional cross bracing between existing girders, with very good effect. Turning to the question of strengthening, innumerable circumstances were presented by the conditions of the structure to be strengthened, and also by those of the traffic, so that it was impossible to generalize effectively. There were, however, three principal methods upon which such work might proceed. First, fresh girders or fresh cross girders might be introduced, relieving the existing girders of a portion of their strain, but leaving them in their old positions. Secondly, the existing girders might be added to and strengthened as described in the Paper —a thing which often had to be done. It was always a little unsatisfactory to patch an old garment with a new piece of cloth, and if circumstances permitted he would always pursue the first method in preference to patching the existing members of a structure. The third plan, which was not always possible and not frequently desirable, was the reduction of the span by the introduction of intermediate supports. His predecessor, Mr. Joseph Cabry, had had occasion in 1886 to strengthen the viaduct across the River Tees at Barnard Castle, built about 1858. It was a high viaduct, of four spans of 120 feet, across a deep valley; the two main girders were below the rails, with cross girders on the top of them carrying a double-line road. In that case it had been possible without much difficulty to insert Mr Cudworth

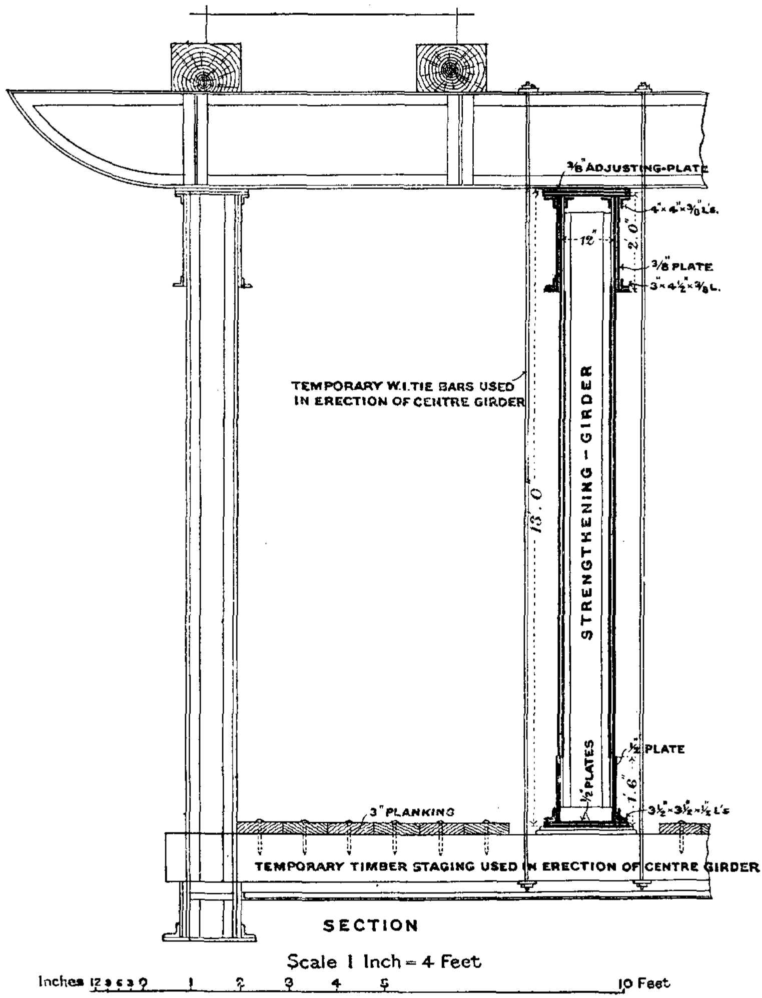
Fig. 16.



STRENGTHENING OF THE TEES VIADUCT, BARNARD CASTLE.

centre girders on all the spans, which relieved the existing girders of a large part of their work (*Figs. 16* and *17*). Care had, of course, to be taken to adjust the load properly between the new central girder and the side girders by means of adjusting-plates under the cross girders. When tested, it was found that the adjustment had been accurately done; when both roads were loaded all three girders deflected alike; and when one road only was loaded a less deflection was obtained on the central girder than on the outside girders. That was a successful piece of work, which had cost about £3,000 for four spans of 120 feet. Another case with which he had dealt was a viaduct at East Row, Mr. Cudworth. near Whitby, where the cross bracing of the girders was very defective (*Figs. 18*). It was a shallow viaduct of no great height, and it had been possible in that case to take out the old girders from

Fig. 17.



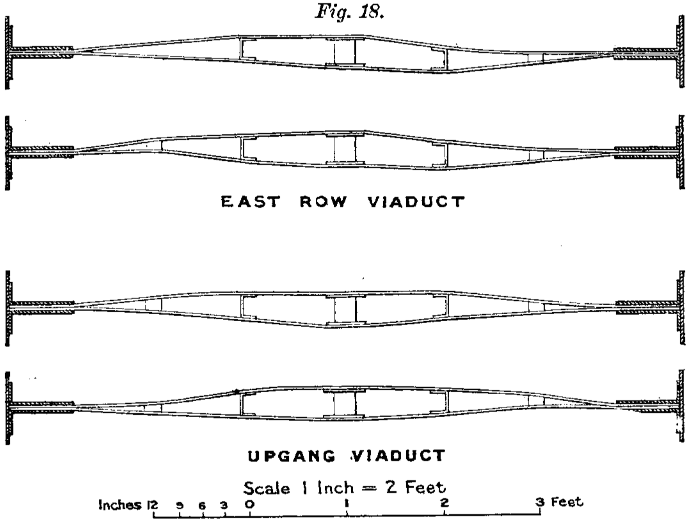
STRENGTHENING OF THE TEES VIADUCT, BARNARD CASTLE.

under the floor, leaving the old flooring, and to put new girders under the latter, so that the upper part of the bridge remained as it was, but with new girders. The work had been executed

Mr. Cudworth.

successfully at a cost of £2,600 for five spans of 60 feet. A similar viaduct over a very deep ravine at Upgang, near Whitby, had required strengthening where it was not possible to get even temporary support from below. In that case, while the girder was of the same type as the girders of the West Lynn Bridge, it had been the bracing which was at fault, and not the flanges, the former having been badly designed and much crippled. Fresh bracing was put in without removing the old (*Figs. 19*). Verticals were put in at the centre of each panel; end bracing was then put in connecting the panels, and that bracing had to be carried round the old bracing. It had rather a singular appearance, but it had been

Fig. 18.

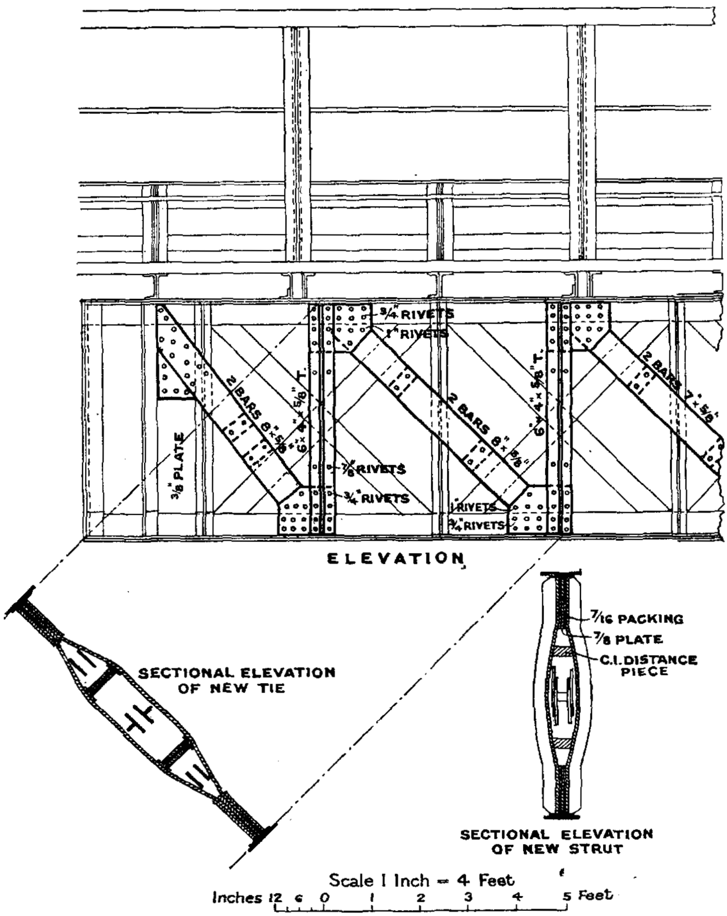


Deformed Struts removed in Course of Strengthening.

very successful, and not at all costly. About £800 was spent on the viaduct, which consisted of five spans of 60 feet, and no trouble whatever had been experienced since. The Author had referred to the great difficulty of adding to the flanges of the West Lynn Bridge. Mr. Cudworth remembered one case on the North Eastern Railway where the flanges of a bridge had to be added to, although not to so large an extent as on the West Lynn Bridge. The bridge, which crossed the River Eden at Musgrave, near Kirkby Stephen, consisted of three spans of 66 feet, the width of the flange being just the same as that of the West Lynn Bridge, namely 2 feet. The method adopted (*Fig. 20*) was much the same as in the work carried out at the West Lynn Bridge, rivets being cut out and

Mr. Cudworth. bolts substituted, but the work was done half at a time. The old cover-plates were cut down the middle of the girder and one-half was removed first; then new plates were added, which were secured by bolts, and riveted up during the week, the plates being

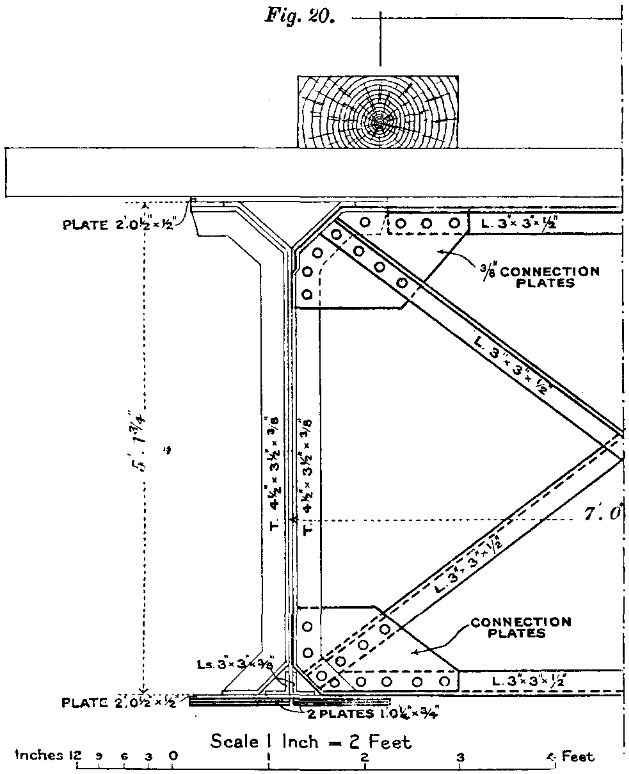
Figs. 19.



STRENGTHENING OF THE UPGANG VIADUCT, NEAR WHITBY.

put in on the Sunday when there was no traffic. Such treatment had been much more feasible in the Musgrave Bridge than in the West Lynn Bridge, because the dead load did not bear nearly such a high ratio to the total load; so that while the rivets were all out, and the bottom plate was being added, what was left of the bridge was quite sufficient to carry it during the operation. The effect of the work had been to reduce the deflection of the bridge from a little more than ½ inch to about ⅜ inch. The bridge had stood very satisfactorily ever since, and the cost of the work had been only £350. The Paper did not refer to the renewal of wrought-iron bridges, but he would like to say a word in favour of what might be called the flat-floor type of bridge. The Author, in referring Mr. Cudworth.

Fig. 20.



STRENGTHENING OF THE MUSGRAVE BRIDGE, NEAR KIRKBY STEPHEN.

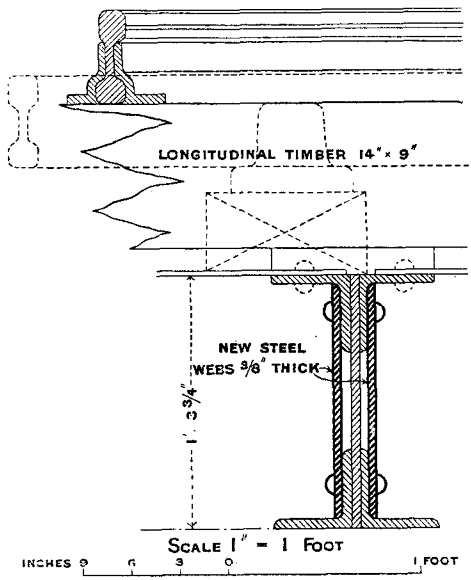
to Figs. 14, Plate 5, spoke of the floor as being "tied," no doubt meaning thereby a road not resting on sleepers, and which could not readily be adjusted to suit the superelevation or curvature of the rails. There could be no doubt that a good stiff floor covered with flat plates and a layer of good asphalt, on which ballast and ordinary sleepers and permanent way were laid, was the ideal floor for railway-bridges. It could not always be got, but, wherever possible, he strongly advocated the use of a floor of that type.

Mr. Sadler. Mr. H. W. SADLER thought there were three principal reasons why old bridges required strengthening; first, on account of improper or bad design, which was a cause of the weakness of many bridges; secondly, the increase in the weight of locomotives; and, thirdly, corrosion. Some old bridges were very badly designed; the girders were too shallow, some being only one-thirtieth of the span in depth. A very common defect was that the webs were too thin, a usual practice having been to make webs of cross girders only ¼ inch thick throughout. There was a want of sufficient rivet- and bearing-area, and the connections were weak. The girders were seldom deficient in flange-area. The increase in the weight of locomotives was becoming a serious matter, and had necessitated the strengthening of many bridges. In 1870 engines weighed 40 tons; now they weighed over 78 tons. In those days engineers took 1½ ton per lineal foot as the usual weight for an engine measured over buffers, and 2 tons per lineal foot measured on the wheel-base; at the present time the corresponding loads were 1·82 ton and nearly 4 tons. Of course many of the old girders were incapable of standing such an increase. The Author's statement that no iron bridge, however old, rusted so quickly as new steel bridges did, was a very serious one, in view of the fact that so many steel bridges had been built; and it was certainly well worthy of discussion. Text-books gave the coefficient of corrosion for wrought iron in pure air as 0·0123, and that of steel as 0·0125; while in towns and manufacturing districts it was 0·1254 for wrought iron and 0·1252 for steel. If those figures were correct, steel should not corrode more than wrought iron. He did not wish to assert that steel did not corrode, but he thought it was questionable whether it corroded more than wrought iron, and his experience did not agree with the Author's. Certain steel bridges which he had examined had been in work more than 18 years and were in good condition, whereas some wrought-iron bridges had corroded all to pieces in 23 years. Corrosion was largely a question of maintenance and situation. He would like to ask whether the mill-scale was taken off the plates to which the Author referred; because if it were not removed, rust would result. Mill-scale could not at first be brushed off with wire brushes; it was impossible even to hammer it off; and until it was removed rust was sure to occur. The Author stated that no plate should ever be allowed to rust; whereas, many leading engineers at the present time were purposely leaving their girders to rust so that the mill-scale should be taken off. He would be glad to hear the Author's opinion on that point, because both contentions could not be right. On the Great Northern Railway the present practice was to oil the girder at the works, but to defer painting until the bridge was erected complete; it was then brushed with wire brushes, and all particles of scale were taken off as far as possible. A former Paper [1] read at the Institution in 1881 referred in strong terms to the liability of steel to corrosion, but the consensus of opinion of those who took part in the discussion upon that Paper—men of wide scientific knowledge and practical ability—was that steel did not corrode more than iron. For instance, Dr. (afterwards Sir William) Siemens stated that steel under proper conditions lasted as long as iron; Mr. Martell expressed the opinion that steel could be protected as much as iron; Sir Nathaniel Barnaby remarked that the Admiralty had come to the conclusion that there was no difference between iron and steel in the rate of corrosion; Sir Henry Bessemer, Professor Abel and other speakers concurred; while Mr. Weston, the Admiralty Chemist, stated that experiments showed the corrosion of the two metals to be not very different, and any advantage to be on the side of steel. When a bridge was found to be weak there were two ways of dealing with it; first, to replace it with a new structure, which was easy and efficacious but somewhat expensive, and, secondly, to strengthen it, as in the examples the Author had shown, which often yielded a satisfactory result, but involved more thought and trouble. At the Author's request he had prepared a few diagrams showing what had been done at four different bridges. *Fig. 21* related to a wrought-iron overbridge, built in 1874 and strengthened in 1900. The webs of the cross girders were only $\frac{1}{4}$ inch thick throughout, and had corroded very badly. They had been strengthened by putting two new webs on the outside of the old webs. The cross girders were 2 feet 6 inches apart throughout the whole of the bridge—quite unnecessarily close—and therefore only the alternate cross girders had been dealt with. The ballast had been removed, and longitudinals had been fixed over the bridge and wedged up on to those girders which were not to be repaired. The others had then been taken out one by one, the new webs riveted on, and the girders put back again. The longitudinals remained and the ballast had not been replaced, thus reducing the dead load and keeping down the stresses. *Figs. 22* referred to the repair of a bridge which had, he thought, almost all the faults a design could have. It was a Mr. Sadler.

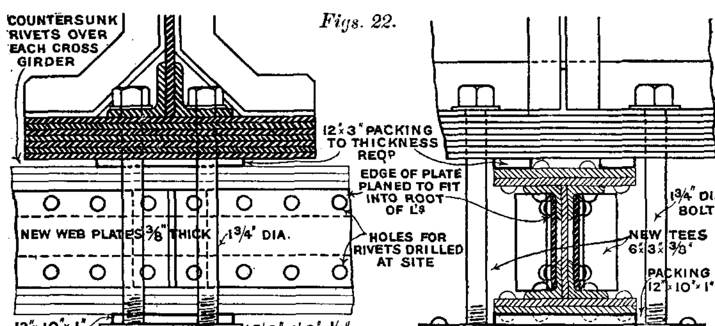
[1] D. Phillips, "The Comparative Endurance of Iron and Mild Steel when exposed to Corrosive Influences," Minutes of Proceedings Inst. C.E., vol. lxv. p. 73.

Mr. Sadler. wrought-iron structure built in 1879, and strengthened in 1904. The cross girders, which carried two roads, were 26 feet 6 inches

Fig. 21.



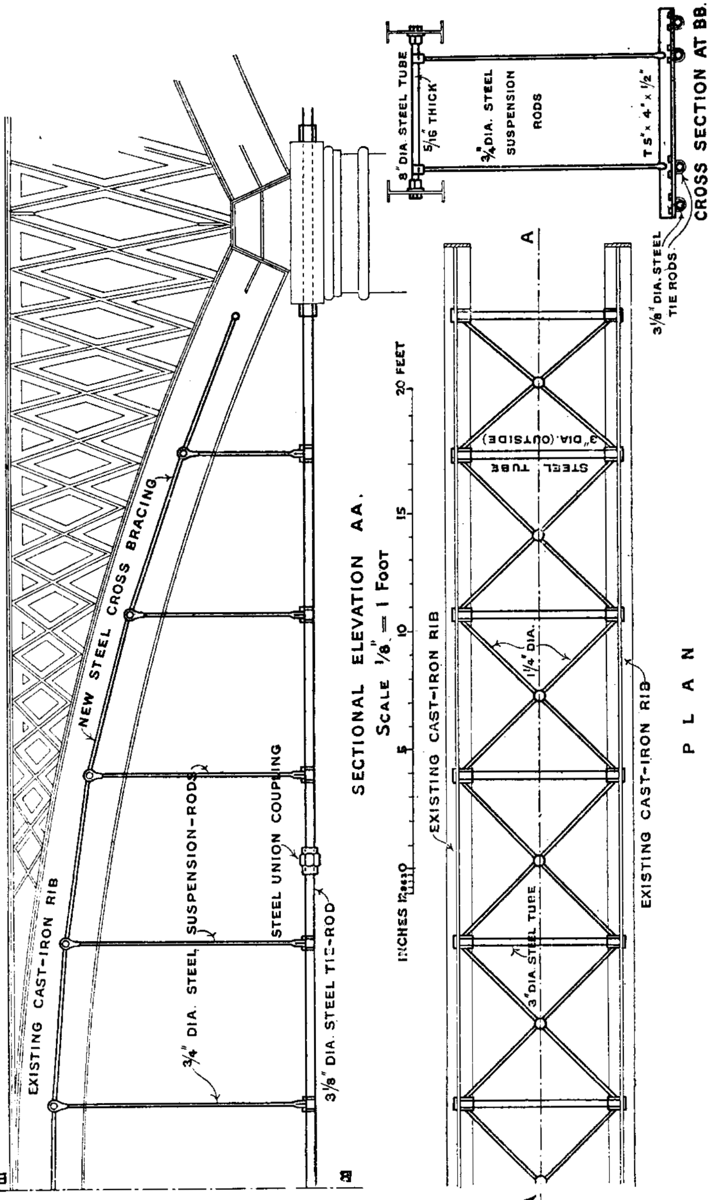
Figs. 22.



long and only 10 inches deep in the web, giving a ratio of depth to span of about 1 : 32. A new centre girder had been

Mr. Sadler.

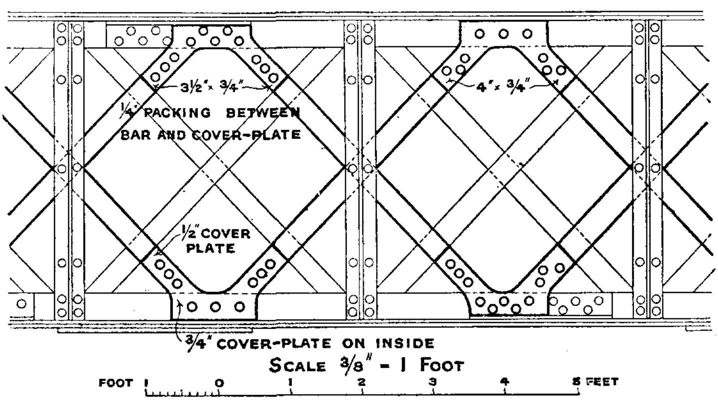
Figs. 23.



STRENGTHENING OF BRIDGE OVER RIVER OUSE, HUNTINGDON.

Mr. Sadler. put in, as shown, and the cross girders had been hung from it by four $1\frac{3}{4}$-inch bolts carrying supports underneath the girders. The cross girders had thereby been made into continuous girders, and although the flanges had been strong enough for this the webs had not, and two new webs had been riveted on each side of the old webs as shown in the diagram. *Figs. 23* referred to a cast-iron arched bridge, of three spans of 77 feet each, over the River Ouse just outside Huntingdon. The drivers had complained that the arch moved under the train, and on the bridge being examined, it had been found that the arches had no struts at all. Struts and cross bracing had been put in as shown in plan, and tie-rods had been fastened from springing to springing,

Fig. 24.



and supported from the arches to prevent sagging. This work had been done 10 years ago and had proved very satisfactory. *Fig. 24* was an example of a lattice-girder bridge deficient in shearing- and rivet-area, which had been strengthened by putting in fresh lattices in the manner shown.

Mr. Johnson. Mr. T. R. Johnson was sorry he could not altogether agree with his colleague, Mr. Sadler, in regard to the tendency of steel to rust. It had been his lot, between 1890 and 1900, to have charge of a somewhat important section of main-line railway; and although he admitted it was difficult to account for the fact, his experience showed that steel rusted more rapidly than wrought iron. And that fact had been discovered by others also. A valuable book by an American writer, Mr. M. P. Wood, entitled "Rustless Coatings[1]," went into the subject thoroughly. Under the heading of "Corrosion of Iron and Steel" Mr. Wood said— Mr. Johnson.

> "Experiments conducted by the Admiralty, Board of Trade, and Lloyd's prove that steel corrodes much more rapidly than iron when exposed to the action of salt water; also that the commoner brands of iron corrode less rapidly than the better brands when exposed to the same influences. With steel and iron both unprotected and exposed to the same action of the weather and sea-water corrosion advanced at the rate of 1 inch in depth in 82 years for the steel and 190 years for the iron. When always immersed in sea-water the periods are one inch in 130 years for the steel and 310 years for the iron. When always immersed in fresh water the periods became 600 years for the steel and 700 years for the iron."

Mr. Thomas Andrews, M. Inst. C.E., carried out some very interesting experiments in 1897 on wrought-iron and steel plates immersed in sea-water which was changed monthly; and it was found that the best wrought iron had corroded less than any of the steels, at any stage of their exposure during the 110 weeks of the test. Of course it might be said that plates immersed in salt water did not occupy altogether the same position as ordinary plates in bridgework exposed to the effects of the English climate; but the fact remained that, notwithstanding careful maintenance, steel plates would rust more rapidly than wrought-iron. He had in mind the case of a top boom of a steel girder of 240 feet span, which used to give constant trouble. Two patches on the top boom had had to be treated over and over again with red-lead and boiled oil—which, in his opinion, were the best materials for the protection of almost any metal work; and at last the defect had been cured. He would be sorry to be understood to mean that because of that tendency steel would fall out of use: such was not his opinion. The facts simply pointed to the conclusion that engineers must be much more careful in the maintenance of steel structures, even under ordinary circumstances; while in respect of the undersides of steel bridges exposed to the influence of the sulphur from the chimneys of engines and of the steam-blast, still greater care was necessary, in order to protect the metal work from serious deterioration. He wished to emphasize the desirability of using the best of red-lead and boiled oil for painting bridges. The difficulty nowadays was to get either material that was to be depended on; but, given the best red-lead, nothing better could be found for ordinary circumstances. To a considerable extent he agreed with Mr. Cudworth in regard to the underside of bridges; but he had been much impressed with Mr. Inglis's recent statement[2] in the Institution in regard to the use of carbon-

[1] New York and London, 1904.

[2] Minutes of Proceedings Inst. C.E., vol. clxi. p. 143.

Mr. Johnson. tar for coating rails in tunnels. He had been making some small experiments with it, and had requested that a considerable quantity should be reserved at the Great Northern Railway Company's gasworks at Holloway, in order that it might be tried on an important bridge near King's Cross, where the deterioration on the underside of the bridge was serious. He thought the preparation was one which, if the ingredients were properly selected, would be most useful in the protection of steel against corrosion.

Mr. Hawksley. Mr. CHARLES HAWKSLEY, Past-President, asked whether, in lieu of covering the steel or iron with cement, the Author had tried asphalt, because if that would adhere properly to the iron it would probably obviate the difficulty referred to by Mr. Cudworth, namely, liability to crack and leave a space between the iron and the cement, in which moisture might accumulate. On railway-bridges the ballast often rested against the ironwork, which appeared to him to be very undesirable, because naturally the ballast retained moisture. It could easily be prevented by putting in an iron fender to keep the ballast away from the ironwork, leaving sufficient room for painting between the two.

Sir Benjamin Baker. Sir BENJAMIN BAKER, K.C.B., Past-President, in reference to Mr. Hawksley's question, mentioned that he had tried asphalt, tar mixtures and cement on top surfaces, and after 6 or 7 years he had generally taken them off, because there were signs of disturbance, and he did not like to be ignorant of what was going on underneath. In some cases he had found that they had cracked off of themselves. Eventually he had stripped them all off, so that he might know the worst. Excluding the undersides of bridges, which he did not know how to deal with effectually, an iron or steel bridge would not rust if it was maintained properly. First of all, the bridge must be painted with good linseed-oil. He did not care whether the mixture was red-lead or pure oxide; he had tried hundreds of mixtures, and, in his opinion, the essential point was to have absolutely pure linseed-oil, so that a continuous and elastic coating—a kind of kid glove—was put over the structure. But even that would not last indefinitely; inside tubes it might last for 20 or 30 years; if it was exposed to the atmosphere and the rain it must be renewed every 3 years: while on the undersides of girders and of steel floors it might have to be renewed every year, whether it was red-lead or oxide paint; and if the work was near the sea, where it was exposed to spray, or in a place where it was exposed to the gases from locomotives, it might have to be touched up every 3 months. In the latter cases his experience showed that some sort of bituminous mixture

Sir Benjamin Baker.

should be used. There were as many fashions in bituminous mixtures as there were in pills; he did not think it made much difference which was used. In a place like the Underground Railway he thought nothing short of actually casing the girders in concrete or cement would answer, and even that casing would have to be renewed from time to time. A good deal was heard at the present time as to reinforced concrete obviating many of the difficulties referred to in the Paper, and the Americans were putting in the whole of the floors of some railway-bridges without cross girders at all, using simply slabs of concrete with steel rods buried in them. He had never adopted that plan, and he certainly would not live long enough to have sufficient experience to do so, because he would not trust anything of the sort which had not been tested for 20 years. Engineers were told that steel rods would not rust if they were cased in concrete, and sometimes rods were put in only about 1 inch from the surface of the concrete. He very much doubted whether these latter would not rust in time. Quite recently he had seen at Alexandria hundreds of what might be called concrete joists; they looked about the size of ordinary wooden joists, 12 inches by 4 inches, but were really made of concrete with 1-inch rods put in. They had been up for about 2 years, but at the bearing end they were quite destroyed. The sea-air had penetrated through the rather weak concrete, made of Portland cement with a matrix of rather weak limestone, which was evidently neither air-tight nor damp-proof. The air had got in and rusted the rods so that at the bearings of the joists the concrete had burst out and the rods were exposed. Homely timber joists and wooden props had been put underneath, which was not a good testimony to the efficacy of a coating of concrete as a preventive of rust. He had tried protecting steel girders also with asphalt, and had found the result was not always better than concrete. It was an old practice of shipbuilders to put concrete between the frames of vessels, because it was found that, notwithstanding the racking and strain going on there, it was the only thing which would keep the rivet-heads from rusting off. When the floor of the Battersea suspension-bridge was renewed he saw the state of the buckle-plates. There was about 3 inches of concrete and some wooden pavement which had been down for 20 years; and when the concrete was taken up the paint was still on the plates, which were as sound as ever: so that no general rule could be laid down. The engineers of an earlier day used reinforced masonry, but they called it "hoop-iron bond," and there were many experiences of injurious effects from oxidization, so that

Sir Benjamin Baker. special care must be taken to exclude both water and air in order to ensure durability. He thought the Paper did not lend itself so much to discussion as to the contribution of written communications illustrated by sketches. He therefore hoped there would be numerous written communications on the subject, which was of the utmost interest not merely to the Institution but to American engineers, who were quite as keen about the subject as English engineers.

The Author. The AUTHOR, in reply, remarked that it was through noting shipbuilders' practice on the Tyne many years ago that he first thought of using concrete on certain bridges which had given trouble through rusting. Contrary to his expectation he had not found any difficulty from vibration. In one bridge the concrete on the top flange of a girder had not been put on thickly enough, and consequently it had peeled off; but underneath the structure had remained perfectly good. In no other case had he had any failure. He generally coated the concrete with tar, so that if a slight crack developed through vibration, the heat on a hot summer's day allowed the tar to run down the crack, and the water did not get in. On taking down some bridges built by him 20 years ago, he had found that the concrete had preserved the iron perfectly. He had recently heard from Mr. L. G. Mouchel that on breaking open some stumps of ferro-concrete, which, after being cut from the tops of ferro-concrete piles in course of construction at Woolston, near Southampton, had lain on the foreshore exposed to the tide for 7 years, the metal bars inside the concrete had been found to be as blue as when they left the maker's mill. There was much difference of opinion with regard to the relative durability of iron and steel, as had been amply evidenced by the discussion. He had not read Mr. Wood's excellent book, "Rustless Coatings," until after he had written his Paper, otherwise it might have been thought he had copied from it. On many points Mr. Wood held the same opinions as were advanced in the Paper with regard to the rusting of steel. Like other members, the Author could only give the result of his own experience. He had had iron and steel bridges under his observation side by side, and he had had iron bridges patched with steel; so that he had had some opportunity of comparing the behaviour of the two materials. In his opinion maintenance was not a remedy for corrosion: he was acquainted with one bridge at the seaside which, after being carefully scraped and painted by the trusted men of his own staff, with the best materials, had been almost as bad as ever within 6 months. In an interesting letter

Mr. John Wilson, M. Inst. C.E., had communicated to the Author his views on the question of iron versus steel. Mr. Wilson infinitely preferred iron to steel for girders, as giving a more durable and reliable structure; and although he had recently had to agree to the substitution of steel owing to the difficulty sometimes experienced by makers in obtaining the necessary iron for pressing work, he had held this opinion ever since the use of steel girders became recognized, and he had found no reason to alter it. The question of steel for boilers was also an important one, although it was not referred to in the Paper. The Author had both iron and steel boilers under his charge, and while some of the iron boilers needed renewing only after 20 years of life, the steel boilers often needed renewal after 6 or 7 years. Some years ago he coated the inside of certain steel boilers, with which trouble had been experienced, with a coating of cement. Of course it took a considerable time to obtain experimental results which were of any value, and he was still awaiting the result of this experiment; but he expected to find the insides of those boilers in a much better condition than that of an uncoated boiler. He had found nothing better for an inside coating than tar-varnish—which, he presumed, might be considered to be a kind of bituminous coating—if it was made properly, so that it dried quickly. Girders over important public roads could not be coated with tar-varnish, but he believed that, properly applied in fairly warm weather, it was as good a coating as could be obtained. Asphalt cracked in the hot weather and let the water through, and moreover it needed special gangs of men to lay it. His former chief, Mr. Richard Johnson, M. Inst. C.E., had told him many years ago that in all his experience he had not found anything better than red-lead. He believed that if red-lead was properly mixed with pure linseed-oil, and two coats were applied, nothing better could be obtained. There were many nostrums in the market—most of them being only tar-varnish under another name, for which the public had the privilege of paying about four times their proper value compared with a good tar-varnish made from selected tar. He was informed that the tar should contain very little uncombined carbon (some tars having as much as 50 per cent.), so that the pitch which was one of the chief constituents of tar-varnish should have little or no free carbon in it; otherwise the varnish would not present a glazed face. It should also be made with the lighter oils, so as to dry in about ½ hour. There was a great difference between the rusting of iron and steel bridges, and although it was practically impossible to distinguish a piece of The Author.

The Author. iron from a piece of steel by the mere appearance and without looking at the fracture, yet it was comparatively easy to tell of what material a bridge was built if there was any rust. It was a frequent occurrence to find a bridge-member heavily painted and in perfect order with the exception of certain places where the rust had forced off the protective coating, leaving quite a deep pitting; and it was this which rendered the proper maintenance of steel much more expensive than that of iron. With regard to the application of concrete, neat or nearly neat cement should be placed next the girder, to which it would adhere strongly. No slag or cinders should be used in the concrete.

The President. The PRESIDENT observed that the subject of the Paper was a very interesting one, and he was sorry the time at disposal did not allow of further discussion, as this was the last Ordinary Meeting of the session. He hoped, however, that the subject would be brought up again next session, and he would be glad if some members would be public-minded enough to prepare during the recess one or two Papers on the subject, with an even more extended scope. Traffic-managers were always crying out for an increase of speed and load; the locomotive-superintendent was forced to larger and heavier engines; while the permanent-way and works engineer found that his rails and girders were insufficient to meet these ever-increasing demands.

Correspondence.

Mr. Archbutt. Mr. L. ARCHBUTT, of Derby, considered that in the painting of ironwork the result depended more upon the way in which the work was done than upon the kind of paint that was used. Of all the paints which he had tried, under conditions which gave each a fair chance, he had found nothing better than red-lead and boiled linseed-oil. As the Author pointed out, the iron or steel must in the first instance be perfectly dry and free from rust or oxide, and the red-lead must be ground with the oil in a mill, and not simply stirred up with it in a bucket. Mr. Archbutt had found it a good plan to grind the red-lead with about 10 per cent. of raw linseed-oil and to thin this mixture with boiled linseed-oil just sufficiently to run from the stirrer. The paint must be applied as thinly as possible and be well rubbed in with a brush,