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, Mr. Archbutt.

and it must be of such a consistency as not to flow after it was put on. To ensure this, the mixture should weigh 30 lbs. to 40 lbs. per gallon. Two coats of this mixture were desirable, applied at intervals of a few days, and afterwards any other paint could be applied to produce the desired tint. He had adopted, in conjunction with Mr. H. Fowler, the following method of testing paints for steelwork or ironwork:—Flat steel plates measuring 2 feet by 1 foot were thoroughly cleaned by sand-blasting and were then painted with two coats of the paint it was desired to test. Similar plates were painted with red-lead and boiled oil. All the plates were then fastened to the sides of a gasholder in such a position that they were sometimes immersed in water and at other times suspended in the air. In order that substances dissolved in the water of the gasholder might not affect the plates, a trough of clean water was fixed in the gasholder trough for the plates to dip into. He had been conducting some trials in this way for the last 15 months, and had compared several well-known paints with red-lead. Steel plates carefully painted with two coats of red-lead remained quite free from rust for nearly 9 months and then began to pit slowly. A graphite paint behaved nearly as well as the red-lead. The next best results were given by paints composed of natural oxide of iron, in coarse particles working harshly under the brush and of very little covering-power. Highly pure and finely levigated oxide of iron prepared from copperas did not give nearly such good results as the native oxides. He had not tried any of the tar-varnishes in this manner, but hoped to do so in the future.

Mr. Bache.

Mr. ALFRED BACHE asked whether the Author had had any experience of using a jet of paint blown by an air-blast; and if so, whether this ensured complete protection from rust in a tangential joint where a brush could not penetrate; or was there risk of air getting trapped in with the paint, and so conducing to blisters?

Mr. Barker.

Mr. JOHN BARKER pointed out that in strengthening wrought-iron bridges by the addition of strips of steel it was important to bear in mind that the superior strength of steel could not be utilized for this purpose without overstressing the wrought iron to which it had to be attached. There was no economy in using steel to strengthen wrought-iron bridges unless it could be bought at a less price than wrought iron. In deciding whether it was advisable to repair or renew a bridge, each particular case must be considered on its merits, with full knowledge of all circumstances and conditions involved. The difficulty of making such a

Mr. Barker. thorough examination of an old structure as to enable its exact breaking-load to be calculated would no doubt always give a bias in favour of renewal, except where the existence of a large number of spans of one kind justified the expense of testing one span to destruction, in order to ascertain the exact amount of strengthening required to bring them all up to standard. While generally agreeing with the Author in regard to maintenance, he wished to point out that it was an error to suppose that the Admiralty was the only public department alive to the importance of rustless plates. Mr. Barker had carried out 20 years ago a series of experiments with a view to ascertain the effect of applying linseed-oil to wrought-iron plates in preventing the commencement of rusting. The plates had been placed on the top of a flat roof in Trafalgar Square, London, and exposed for 12 months to the full force of east and west winds, in addition to the impurities of a London atmosphere during a severe winter. The results had clearly shown the strong preservative effect of genuine boiled linseed-oil when applied to clean iron immediately after rolling; they had also shown that paint applied over a coat of linseed-oil after the latter had dried was much less likely to scale off than when the paint was applied to iron on which rust had set in, even to a very small extent. At that time the late Sir George Berkley inserted the following clause in his specifications of bridge-, boiler-, and wagon-plates :—

"Wherever practicable the material must be dipped in genuine boiled linseed-oil immediately after being rolled, before it has cooled below 212° F. When dipping is not practicable, the material must be painted with hot boiled linseed-oil immediately after the material has been sheared, and before the slightest rust has set in."

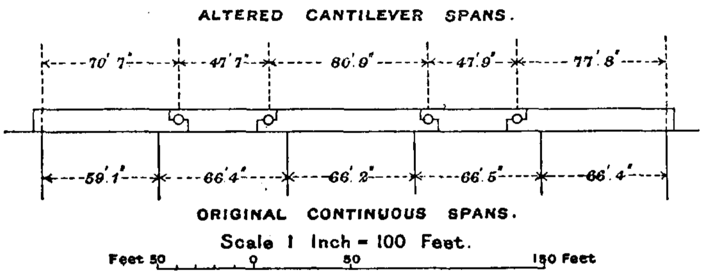
Sir George Bruce had continued to use that specification, and notwithstanding opposition from steel-manufacturers and others it had since been followed in the work for the Great Indian Peninsula Railway Company. Mr. Barker fully endorsed the Author's conclusions that rusting should not be allowed to begin. Patches of scale were formed on plates during the process of rolling, and it was next to impossible to detach it; this scale prevented the oil and paint first put on from adhering to the solid iron, and it frequently fell off after lapse of time, leaving the bare iron exposed to the atmosphere. Such patches should be oiled after scaling, and after the oil had dried, they should be painted. Some engineers had adopted the policy of doing nothing after rolling to prevent plates from getting very rusty and afterwards systematically scraping the rust off with wire brushes before painting. The chances were greatly in favour of such scraping being very imperfectly done, with the result that an oxide-of-iron powder intervened to prevent adherence of the paint to the solid plate. Anyone who had watched the careful preparation of wire and wrought-iron sheets for galvanizing would realize the importance attached by the manufacturers to securing clean surfaces for the zinc coating to adhere to. It was to be hoped that a fuller appreciation of this subject would result in the application of boiled linseed-oil or other preservative agents to iron and steel immediately after rolling, thus not only preventing rust from beginning, but also forming a glutinous film between the paint and the iron. Mr. Barker.

Dr. FRANCIS ELGAR observed that the steel used in shipbuilding appeared to corrode more rapidly than iron whenever it was exposed to attack by corrosive agents; but the hull of a steel ship could be protected so well by paint and cement that deterioration by corrosion was practically non-existent when the surfaces of the steel were first of all properly prepared for painting and afterwards kept coated with good paint and oil. In the early days of steel shipbuilding the complaints about unexpected and rapid corrosion and pitting had been as strong as any in the Paper. But it had soon been discovered to be a *sine quâ non*, whatever paints or protective compositions might be applied to the steel hull of a ship, that the surfaces of the plates should be thoroughly cleaned from mill-scale, and when quite clean should receive a coat of good paint, which should be allowed to harden well before having a second coat put upon it. The great difficulty was to get quite rid of all mill-scale. In Admiralty practice that was done by immersing all plates, before they were worked, for a few hours in a bath of dilute hydrochloric acid (19 parts of water to 1 of acid), and afterwards thoroughly washing them and cleaning off the scale. As the work progressed upon a ship, each portion of the steel structure received a coat of good linseed-oil or thin red-lead paint, the surface having been first well scraped and cleaned. The same treatment was employed occasionally, though very seldom, in mercantile work, and sometimes in yachts; but the general practice in mercantile shipbuilding was thoroughly to scrape and chip off the mill-scale after it had been exposed to the weather for a sufficient time to cause it to rust and become easily detachable. After the mill-scale had thus been completely removed and the surface of the plating had been well scraped and cleaned, the first coat of paint was applied; or, sometimes, a coat of good boiled oil Dr. Elgar.

Dr. Elgar. was put on before painting. The whole of the steelwork inside and outside received while quite dry two or three coats of the best oil-paint, generally red-lead, and each coat was allowed to harden thoroughly before the next was applied. This was the general treatment of steel in shipbuilding, which, when properly carried out, was an effective preventive of deterioration from corrosion; and it was difficult to see why similar treatment should not be equally effective in steel structures like bridges, or in those parts of them where protection was required only against exposure to the weather. It went without saying that every part of such a structure should be open for inspection and repainting. There were parts of a ship, however, where, as in bridges, more than mere exposure to water, damp air, or weather had to be provided against. For covering the inside of the bottoms of ships Portland cement was used, which formed an excellent and reliable protection of the plating. The chief reason for this practice related especially to the requirements of a ship. It was impossible to keep water from collecting in a ship's bottom. This required to be pumped out when it was sufficient in quantity; and, so long as any loose water was there, it moved from side to side of the bottom compartments as the ship rolled, carrying dirt with it, and operating injuriously upon exposed surfaces, especially rivet-heads, by friction and abrasion. Hence it was necessary to make a raised surface of cement which would cover all landings of plating, rivet-heads, and other unevennesses of the plating of the bottom, and allow water to drain freely off it to the pump-suctions. The cement used for this purpose was often mixed with clean sharp river-sand, and it formed an excellent protection to the bottom plating. The upper parts of water-ballast compartments were washed with two or three coats of cement wash, after being thoroughly scaled and cleaned. The flush surface of Portland cement over the inside of the bottom plating, from bilge to bilge, was not peculiar to steel ships, but had been the practice in the days of iron ships, for the reasons already stated. Bitumastic cement was sometimes used instead of Portland cement, where weight was very important, and there was no difficulty in getting the bituminous cement to adhere to the steel when proper care was taken to have the surface of the plating quite dry. Portland cement was, however, preferred where the question of weight was not important. The extreme ends of a vessel, where the sides of the plating approached each other at too acute an angle to be properly cleaned and painted, were filled in solid with a mixture of cement and crushed coke. Another difficulty in steel ships was the action upon the parts which were exposed to the heat of the boilers. Special care was there required to keep down corrosion. The plating immediately under the boilers was made of extra thickness, in order to provide a larger margin for corrosion, which sometimes started and went on very rapidly under the combined influences of damp and heat; and occasionally this plating was of iron, because of the better resistance of iron to corrosion. The boiler-bearers were frequently of iron. It was the action of heat in this case which rendered generally unreliable the ordinary means of protection and made frequent inspection and constant care necessary. The lower parts of steel girders which were exposed to heated gases from the funnels of locomotives were in like or probably worse case, as regarded the necessity of special treatment and frequent examination. Dr. Elgar.

Mr. J. HUSBAND contributed the following account of the alteration and strengthening of a road-bridge over the River Canche Mr. Husband.

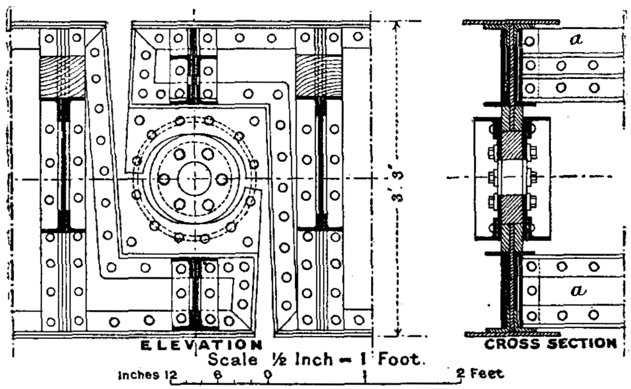
Fig. 25.



at Etaples. The original structure consisted of a continuous plate-girder bridge of five spans as illustrated in *Fig. 25.* The loads provided for in the original calculations were much less than those obtaining at the present time, and in addition the distribution of stresses in the structure had been considerably modified by reason of very unequal settlement of the piers, which rendered the effective strengthening of the bridge an urgent matter. The liability to further subsidence of the piers rendered desirable the breaking of the continuity of the girders, to avoid the abnormal stresses which would be caused by a recurrence of this contingency; while the maintenance of the continuity would have necessitated reinforcing the flanges to enable the girders to carry the existing loads safely. Severing the girders immediately over the three intermediate piers, besides duplicating the bearings on each pier—a difficult matter on account of their small width of 4 feet 3 inches—

Mr. Husband. was also open to the objection of badly utilizing the material of the old structure, since it annulled the bending-moment at those points where the girders were already provided with a liberal sectional area, and caused very little stress in the heavy parts of the flanges adjacent to the piers. In order, therefore, to ensure as nearly as possible future constancy of stress in the event of slight further subsidence of the piers, and to utilize to the best advantage the large sectional area of the old girders near the piers, it was decided to convert the bridge into a cantilever structure. Articulations were introduced at the points indicated in *Fig. 25.* The reduction in length of the severed spans, between the hinges, diminished the moments and consequently the necessity for

Figs. 26.



strengthening the supported girders. The position of the hinges was so fixed that the moment due to the combined weights of the overhanging end and the semi-supported span was equal to the moment of resistance of the original girder section over the pier. The slight discrepancy in the spacing was necessary to fall in with the positions of the existing stiffeners and floor-beams. The details of the hinges were shown in *Figs. 26*, which gave an elevation of and a cross section through one of the articulated joints. A hollow steel disk, $2\frac{3}{8}$ inches thick and $11\frac{3}{16}$ inches in outside diameter, constituted the pin. A slightly elliptical hole was cut in the web which allowed a little play for expansion and deflection. The reduced depths of web above and below the pin were reinforced by $\frac{3}{8}$-inch plates on either side, and the bearing-surface on the pin was increased by riveting 1-inch plates on either side. The pin was prevented from moving laterally by angle collars, while the hole through it assisted the alignment. Two additional cross beams *a*, *a*, were inserted to further stiffen the free ends of the girders. The platform and parapet were also interrupted to ensure independence of action of the supported spans. The order of the operations involved in effecting the changes was the following: The additional cross beams *a*, *a*, and the stiffening-plates of the web were first fitted, after which the elliptical openings for receiving the pins were cut. The bearing-plates were next riveted on and the pins inserted. The girders were then cut through by commencing at the pins and working outwards. The work was executed without experiencing any special difficulty and without interrupting traffic; and the altered structure had given entire satisfaction. This appeared to be a cheap and efficient method of dealing with continuous plate-girders over several spans, especially where unequal subsidence of piers might have dangerously augmented the stress in certain parts of the girders. Mr. Husband.

Mr. E. W. Stoney observed that there were on the Madras Railway a large number of plate-girder bridges, as shown by the following Table I., aggregating a length of over 6 miles; also three hundred and ten 6-foot openings, spanned by rail-girders; besides the large bridges enumerated in Table II., having through N-girders of modern design. The rail-girder spans were Mr. Stoney.

Table I.—Plate-Girder Bridges, Madras Railway.

Clear Span.	No. of Spans.	Aggregate Lengths.	No. of Types.	Clear Span.	No. of Spans.	Aggregate Lengths.	No. of Types.
Feet.		Feet.		Feet.		Feet.	
9	240	2,160	4	Brought forward .		10,714	
12	264	3,168	5	30	149	4,470	8
15	38	570	3	34	5	170	1
18	9	162	1	39	12	468	1
20	185	3,700	13	43½	7	304	1
22	39	858	6	50	18	900	3
24	4	96	1	64	230	14,720	8
Carried forward .		10,714		Total length . .		31,746	

strengthened by duplication, a pair of rail-girders being put under each rail, making four in all where there were but two before (*Fig. 27*). Each of these 6-foot openings was originally spanned by two girders, formed of a pair of 75-lb. double-headed iron rails fixed side by side in cast-iron chairs; on these were laid teak sleepers, 12 feet by 12 inches by 6 inches, 2 feet 10 inches

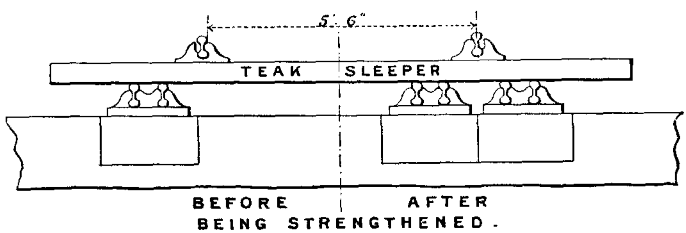
Mr. Stoney.

TABLE II.—LARGE GIRDER BRIDGES, MADRAS RAILWAY.

Bridge.	No. of Spans.	Span. Centre to Centre of Pier.	Total Length.
		Feet.	Feet.
Ferok	6	130	780
Kallai	3	130	390
Papaghni	15	140	2,100
Chittravati	19	140	2,660
Penner	13	140	1,820

apart, secured to the rail-girders by hook-bolts, the permanent-way rails being supported by chairs spiked to these sleepers. The plate girders were placed 8 feet apart between centres, and to the top flanges of these, teak sleepers, 12 feet by 12 inches by 6 inches, carrying the road as described for rail-girders, were fixed by four hook-bolts, two at each end. The 64-foot spans were 139 feet 10 inches long, continuous over two spans, and in one instance (the Palar Bridge) they were continuous over five openings. Most of the girders included in Table I. had been made in England, and sent to Madras between the years 1855 and 1869; they were designed under then existing Board-of-Trade rules for much lighter loads

Fig. 27.

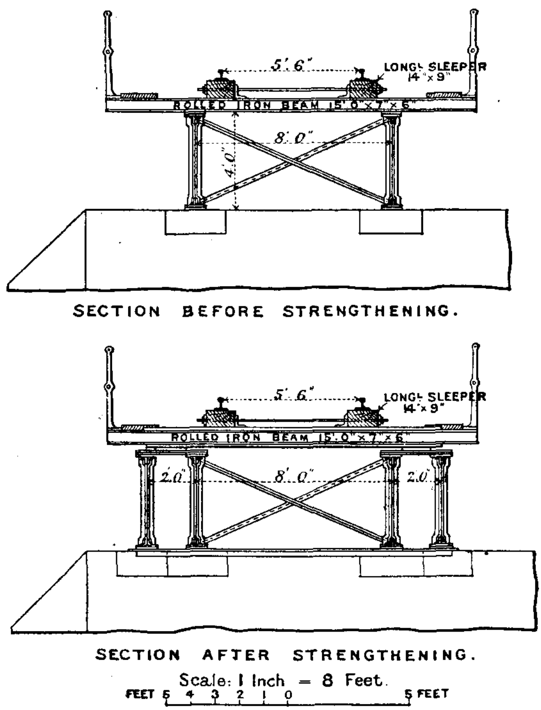


than now obtained, and most probably from uniform-load bending-moment diagrams, the much more severe stresses produced by concentrated moving axle-loads, especially on small spans, not being at that time, it was believed, provided for. In 1890 Mr. Stoney was deputed by the late Mr. H. R. P. Carter, M. Inst. C.E., then Chief Engineer of the Madras Railway, to go thoroughly into the girder question, and then prepare a scheme for strengthening, and where necessary replacing, all weak girders. Accurate measurements and drawings of all those then in use had first to be made: these were classified into types for each span, according to flange-area, etc.; and, as girders of increased strength had been sent out from England from time to time, many types were found. The engine which imposed the severest stresses—a six-coupled one, weighing $41\frac{1}{2}$ tons, and 14 tons 10 cwt. on the heaviest axle—was adopted for calculations; and bending-moment diagrams were prepared for the positions of these axles which produced maximum moments as they moved across each span: from these, the sectional areas of flanges required by Board-of-Trade and Government-of-India rules were calculated and compared with those existing. The area of many of the older girders was then found to be so deficient, according to Government-of-India rules, that it could not be made up by the addition of extra plates; and these girders were therefore replaced in small spans by new girders of modern design, of ample area for contemporary conditions. Those with webs strong enough to take the shearing-stresses, and whose flanges could easily be brought up to the requisite area, were taken out bridge by bridge, the necessary plates were added, and they were then put back. As trains were not numerous, there was time enough between them to remove the weak girders of spans up to and including 30 feet, and replace them by previously strengthened girders. In a few cases, where there was sufficient headway to pass floods—or at road overbridges for carts—and the foundations were favourable, the weak girders were replaced by masonry arches. This Mr. Stoney considered far the best method, where practicable, as masonry arches could carry any loads and were cheaply maintained with but little trouble, while girder-bridges needed constant careful supervision to keep them and the road over them in good running-order, and, as engine-loads increased, they had to be strengthened or replaced. Nine spans of 50-foot girders were strengthened by building a light masonry pier in the centre of each span, thus converting each girder into one continuous over two openings. Thirty-four spans of 64-foot girders were dealt with in a similar manner, converting these girders, 139 feet 10 inches long and already continuous over two spans, into one continuous over four openings. Where there was sufficient waterway and good foundations this was a cheap and expeditious method of providing considerable increase of strength without any interruption to traffic. For other 64-foot spans whose girders were deficient in area, two methods were used for duplicating the existing girders with others of the same type and flange-area, as shown in *Figs. 28* and *29*. In the first, used at the Cheyair Bridge, the work was done while trains ran over the bridge, their speed being limited to 5 miles per hour. The extra girders were placed one on each side outside the existing

Mr. Stoney.

Mr. Stoney. girders at a distance of 2 feet, to allow of painting; these were connected on top by plates 4 feet apart. On the centre of each of these was riveted a plate shorter than the distance between the inner sides of the top flanges of the pair of main girders. To these plates were fixed the bed-plates of each cross girder, so as to ensure the load on these being equally divided between each pair of main girders; these were connected below by strong horizontal

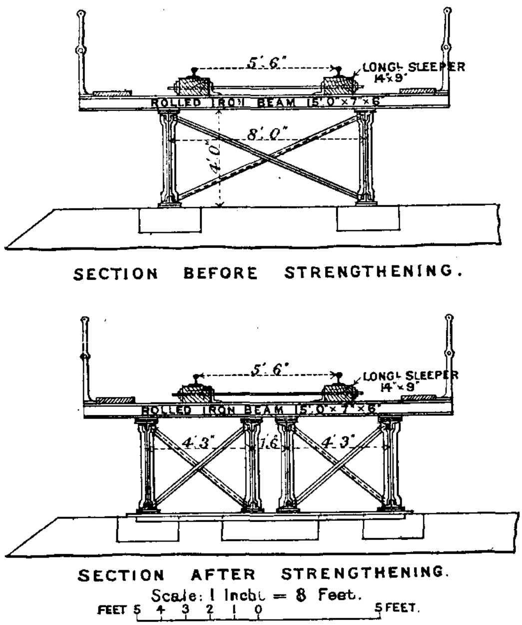
Figs. 28.



Cheyair Bridge, Madras Railway.

diagonal bracing. This method required all the cross girders carrying the permanent way to be strengthened, as their span was increased from 8 to 10 feet, but did not involve sluing, interruption to traffic, or a diversion. The second method, illustrated by the Palar Bridge (*Figs. 29*), had been largely used, as it gave perhaps a better distribution of the load carried by the four girders, and greatly reduced the stresses on the old rolled cross girders used; but to carry this plan out, it was necessary either to divert the line over a temporary road in the river-bed during the dry season, or to slue the existing girders and road on to the unoccupied double-line side of the masonry or other piers, and then build the new superstructure with old girders on the site of those slued over. The Tongabudra Bridge originally consisted of fifty-eight 64-foot openings, with piers 6 feet wide on top, spanned by girders 139 feet 10 inches long, each continuous Mr. Stoney.

Figs. 29.



Palar Bridge, Madras Railway.

over two openings. In order to strengthen them, twenty land-spans had light masonry piers built in the centre of each, thus converting each 64-foot opening into two 30-foot arches, the remaining thirty-eight spans being covered by new steel girders. To allow of this being done, the old girders and road were slued to the double-line half of the masonry piers, and the new girders were put in place over the deep-water spans. When the road over these and the land arches was finished and opened, the old girders of the fifty-eight openings were removed, and they provided a

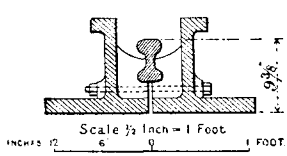
Mr. Stoney. sufficient number of girders to duplicate all of the same type on other bridges, and also to replace those of weaker type. In preparing this scheme, which had been carried out with some slight modifications, his aim had been to utilize as far as possible existing girders and materials, and to ensure their being brought up to the strength necessary to meet the requirements of the new Government-of-India rules, and other existing conditions, as cheaply and expeditiously as possible, with as little interference with trains as practicable. Particulars of the spans then found too weak to comply with the new Government-of-India rules were given in the following Table, from which might be formed an idea of the magnitude of the work to be done, and of the necessity for the most careful consideration as to how it could best be carried out.

Span of Bridge.	Number Weak under New Government-of-India Rules.	Span of Bridge.	Number Weak under New Government-of-India Rules.
Feet. 9	231	Feet. 30	141
12	268	34	6
15	37	39	2
18	10	43½	17
20	177	50	14
22	36	64	243
23¼	1	..	..

There were also two hundred and ninety-seven 6-foot rail-girder spans which were strengthened.

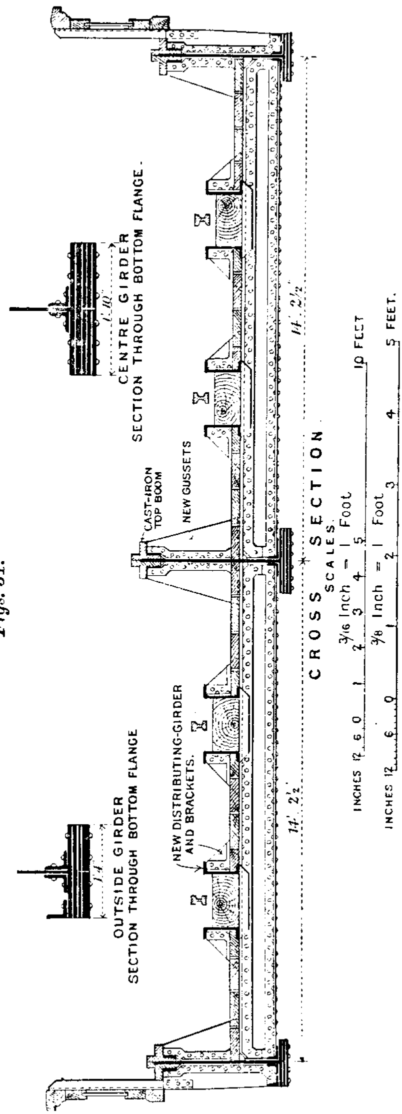
Mr. Tempest. Mr. P. C. Tempest stated that on the South Eastern and Chatham Railway a large number of the bridges were constructed of cast iron, and as these did not allow of strengthening they were being gradually replaced by wrought-iron or steel structures. The old girders being generally of longitudinal trough-section the depth was small; and in two cases the depth from rail-head to the underside of the girders was only $9\frac{3}{8}$ inches for a span of 15 feet, though this was obtained by the rail-seatings being cast on and forming part of the girders as shown in *Fig. 30*. In these shallow floors the new girders had usually to take the form of longitudinal troughs. It was a very usual practice in

Fig. 30.



Mr. Tempest.

the early days of wrought-iron bridges to place the cross girders only 3 to 4 feet apart, and where—as sometimes occurred—they had been found to be weak, and the main girders fairly well up to the strength necessary for the present locomotives, he had found that two or more distributing-girders were effective in distributing the load to more than one cross girder, and thus considerably reducing the internal stresses. He had also had several bridges having wrought-iron webs and bottom flanges and the top booms of cast iron. A bridge of this compound construction, as shown in *Figs. 31*, situated at Lee on the North Kent loop line, had recently been strengthened. It was a three-girder bridge of 46 feet span, carrying two tracks over a public road. The cross girders were 4 feet apart between centres, and the deck was of timber. The cast-iron top booms of the main girders were cruciform in section, cast in halves, with a vertical joint, and double-riveted to the web. The castings were in 8-foot lengths and broke joint with one another, flanges being cast on them, by which the lengths were bolted together. Notwithstanding its peculiar construction, the top boom showed no sign of weakness. In order to bring the main girders up to



Figs. 31.

Mr. Tempest. standard strength, bars half the width of the flange-plates, two sets to the width, were riveted on to the bottom flanges (*Figs. 31*), two bars $\frac{3}{4}$ inch thick being used in the case of the middle girder, and one bar 1 inch thick to each of the outside girders. The existing flange-covers were not removed, but the flange was made up to their level with longitudinal $\frac{1}{2}$-inch packings half the width of the flange. The object of making the packings and flange-bars only half the width of the flange-plates was that only two of the four rows of flange-riveting might be broken at one time. The girders were further stiffened by the addition of gussets to the stiffeners at every 4 feet. The webs of the outside girders above the bottom flange-angles were badly corroded; these were strengthened by the addition of panel-plates between stiffeners, joggled over the vertical table of the flange-angles. The cross girders were assisted by distributing-girders formed of 12-inch by $3\frac{1}{2}$-inch steel channels 50 feet long, two to each rail, one on each side of the longitudinal rail-timber. As only two rivets could be got in directly through the channel and cross girder, brackets consisting of two $3\frac{1}{2}$-inch by $3\frac{1}{2}$-inch by $\frac{1}{2}$-inch angles and a $\frac{1}{2}$-inch gusset were added to the channel over each cross girder, and carried along the tops of the cross girders, to which they were secured by six rivets. Each pair of channels was further tied together and stiffened by 6-inch by 3-inch by $\frac{1}{2}$-inch tees at 4-foot centres under the channels between the cross girders. These channels, thus firmly secured, distributed the load over at least two cross girders, and reduced their stresses by about 50 per cent. The work had been carried out in the following manner:—First the channels and stiffener brackets were placed in position and riveted to the cross girders during the week; then, during the week-end "possessions," the way-beams were taken out and the brackets were riveted to the channels; next the gussets were added to the main-girder stiffeners; then the panel-plates were fixed to the outside girders, the rivets being cut out of the flange-angles and the plates bolted in position, between trains, and afterwards riveted up. With regard to the flange-plates, the plates for one-half of a girder were got in position below the girder beforehand; the main-girder rivets of that half of the flange were cut out, and bolts and drifts were substituted on Friday and Saturday. The plates were put on and bolted in position during a Sunday and while the traffic was diverted on to one track, the plates being afterwards riveted up, one bolt being removed at a time. In proportioning the new additional flange-plates, it was assumed that the old plates had an initial stress due to the dead load, and that the new plates acted only under live load. The stress produced by the live load was assumed to act simultaneously on both the old and new plates; therefore the permissible stress per square inch on the old plates due to both dead and live load (equal to about 5 tons per square inch) governed the stress on the new plates, which were only strained by the live load. In reference to the question of bridge-painting, it had been proved that Portland cement was one of the best preservatives of iron and steel, and to be able to apply it satisfactorily in the form of a paint would be a great advance on present methods. There was, he understood, an American cement paint already available. Mr. Tempest.

Mr. JOHN WILSON forwarded several drawings (*Figs. 32–35*) illustrative of methods of strengthening which had been applied to railway-bridges on the lines of the Great Eastern Railway and on joint lines of the Great Eastern and the Great Northern Railways. In these Figures the new work was shown by thick lines. Mr. Wilson.

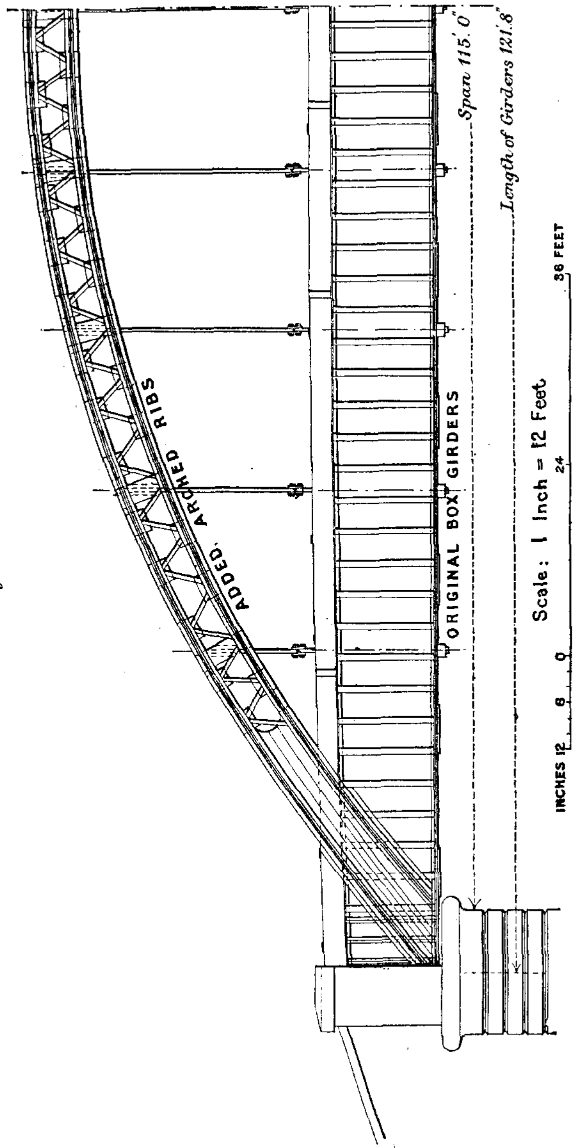
Mr. W. GATHORNE YOUNG, of Doncaster, agreed with the Author that steel rusted more rapidly than iron under the same conditions: this was clearly shown in ships. In his opinion, based upon practical experience as well as theoretical considerations, if oil-paint was to be used, the most satisfactory results were obtained by applying the following:— Mr. Young.

1st and 2nd coats.—Pure red-lead in pure boiled linseed-oil, mixed fairly thick, and applied immediately after cleaning the iron surface.

3rd coat.—Any good waterproof paint—for instance, pure iron oxide in pure boiled oil, or vegetable black in pure boiled oil, or barytes tinted as desired in pure boiled oil. The pigment in the third coat should be as nearly chemically inert as possible. Such a pigment seemed calculated to give a better result than white-lead, which formed a chemical compound with the oil and to some extent destroyed its elasticity and waterproofing quality. But it should be remembered that no oil-paint was capable of withstanding atmospheric action in England, the humidity and the rapid temperature-changes causing continual deposition and evaporation of moisture on exposed metallic surfaces, whose rate of cooling was more rapid than that of the surrounding air. Moreover, near centres of industry and railways this moisture contained appreciable quantities of sulphuric acid (derived from the sulphur existing as pyrites in coal); both the moisture and its acid constituents were capable of slow but sure action upon the dried oil, which under favourable circumstances might make it lose its continuity as a surface coating and become permeable to acid

Mr. Young. moisture subsequently deposited upon the structure. Hence it

Fig. 32.



METHOD OF STRENGTHENING GIRDERS OF THE VAUXHALL BRIDGE, GREAT YARMOUTH.

seemed to him that no oil-paint could ever fulfil satisfactorily the requirements of a protective coating for iron or steel structures in England. What was required was a substance Mr. Young. easily applicable, and chemically unaffected under any conditions by either moisture, acids, iron-rust, iron, or oxygen. He believed that the best results were to be anticipated from the use of one of the following substances:—

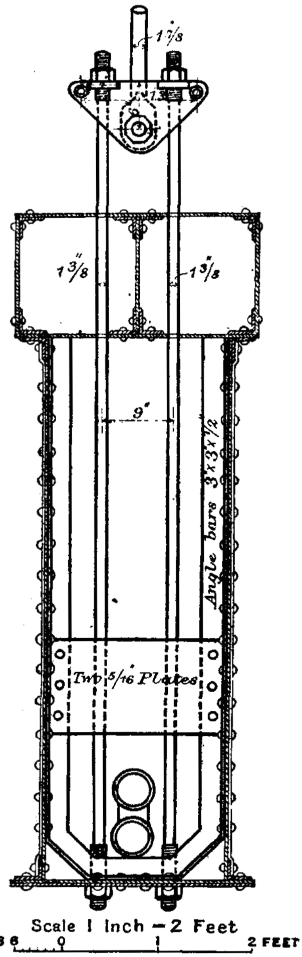
Pure bitumen (dissolved for application in a completely volatile naphtha).

Specially prepared petroleum-tar.

Specially prepared wood-pitch (dissolved in naphtha).

Many difficulties presented themselves. First, practical trials of each substance must be made to discover exactly the necessary consistency to give the requisite elasticity in winter, combined with complete absence of "flow" in summer. Having settled this point, a specification should be framed to ensure the supply of uniform material, and this should be rigidly enforced. A very important point was the proper preparation of the iron surface to receive the protective coating; it was essential to remove every trace of rust, and Mr. Young was confident that it would be economical to spend considerably more time and money over this work than was usually devoted to it. Skilled and well-paid men should do the work, under the close supervision of a foreman known to be conscientious, who had been made to understand the importance of leaving no rust in any corners.

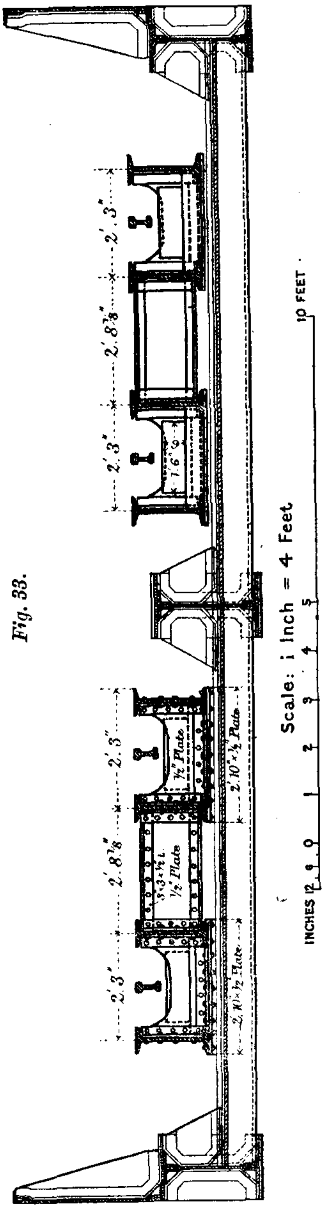
Fig. 32a.



Vauxhall Bridge, Great Yarmouth: Suspension Rod and Lower Connection.

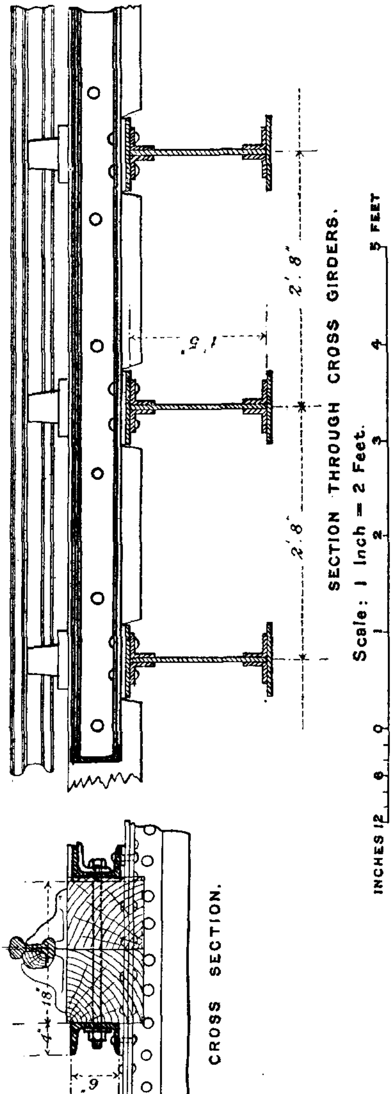
The Author, in reply, stated that he had tried an air The Author. painting-machine, but the result was not satisfactory. The paint

Fig. 33.



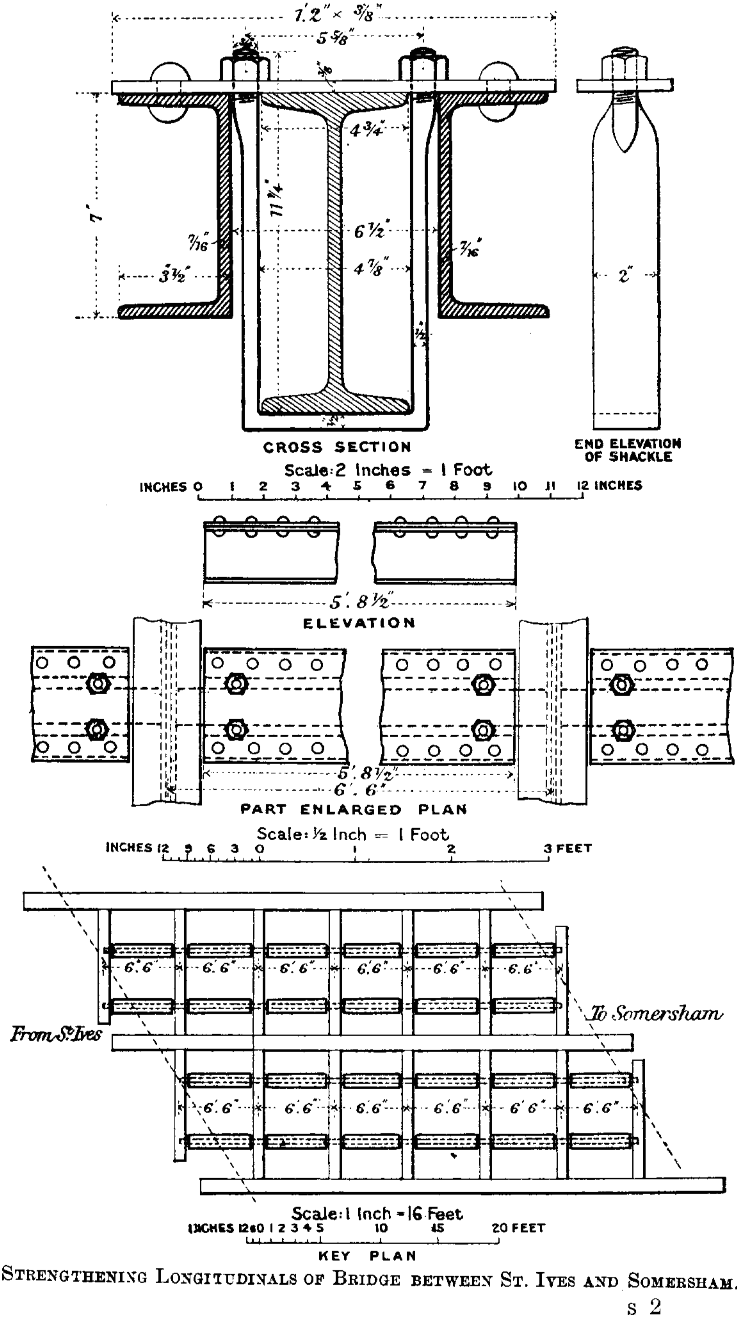
STRENGTHENING BRIDGE AT WILLOW WALK, G.E.R.

Figs. 34.



METHOD OF STRENGTHENING LONGITUDINALS ON BRIDGE BETWEEN MARCH AND SPALDING (G.E. & G.N. JOINT LINES).

Figs. 35.



STRENGTHENING LONGITUDINALS OF BRIDGE BETWEEN ST. IVES AND SOMERSHAM.

The Author. required to be too liquid, and there was apt to be a serious loss of paint, especially in the case of openwork girders. He does not consider the work was nearly so well done as with a brush. The sand-blast was, however, very useful for cleaning plates, and where air was available it might be used. He found that a few seconds' application gave a bright clean and slightly roughened surface. The apparatus was so simple that it only took a few hours to make, and it might with advantage be often used. He was glad to find that Mr. Barker agreed with his view that rusting should not be allowed to begin, as in his experience it was just the places which had been allowed to rust badly that gave all the trouble.