THE "SCHWEDLER" BRIDGE: A COMPARISON OF THE VARIOUS FORMS OF GIRDER BRIDGES

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Trieste

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"SCHWEDLER" BRIDGE.

A COMPARISON OF

THE VARIOUS FORMS OF GIRDER BRIDGES,

SHOWING THE

ADVANTAGES OF THE "SCHWEDLER" BRIDGE;

TOGETHER WITH

AN ELUCIDATION OF THE THEORETICAL PRINCIPLES OF THE SAME.

BEING A PAPER READ AT THE INSTITUTION OF CIVIL ENGINEERS, AND TO WHICH THE COUNCIL AWARDED A MILLER PRIZE.

BY

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THE "SCHWEDLER" BRIDGE.

The subject of the present paper being a comparison of the various systems of iron girder bridges, with particular reference to those constructed on the principle suggested by Herr Baurath Schwedler, it will be necessary to mention what other systems have been carried out or suggested. This will, perhaps, be most effectually done in an historical form, which will best illustrate the development of the theory of their construction.

Between 1830 and 1840 iron was first used in the form of beams, mostly for smaller bridges. This was found to be the shortest and cheapest way of putting up such bridges, a result very important in consequence of the immense development of railways at this time. Many girders of this sort were cast for the York, Midland Counties, Northern, and Eastern Railway Companies. They were composed of long castings held together by wrought-iron bands. Common sections are shown in Figs. 1 and 2, Plate 1. The second form was used where the admissible height of girder was very small. These bridges were copied both in Germany and France for the railways which began to spring up in those countries. Among the most important and largest of these was the cast-iron girder bridge over the Schelde at Ghent (1). It was erected by the engineers Marcellis and Duval, and consisted of two girders 60 feet long, which supported the road and at the same time served as parapet. Each girder consisted of two pieces, bolted together in the middle.

At about the same time appeared a kind of bridge on the Continent, the shape of which is exactly the opposite of that which theory would indicate as the proper form. The top flange is horizontal, the under one in the form of an arch, as shown in Fig. 3. These were constructed without any abutments capable of resisting horizontal thrust, and cannot be considered as arches, but must be regarded as girders. The strains are therefore the greatest in the middle, where the moment of resistance is the smallest. These were soon found to be unserviceable and expensive, and were followed by a girder of the form of Fig. 4, in which the moment of strain is opposed approximately at every point of the girder by a moment of resistance equal to it; in other words, the beam is of equal strength throughout its length. Although these beams fulfil theoretical requirements, they were found, when employed for larger spans, not to last long, in consequence of the small resistance of cast iron to tension, especially when accompanied by continually repeated shocks, such as those caused by the frequent passage of railway trains. This gave rise to the idea of employing both cast and wrought iron in the construction of bridges, in such a manner that those parts exposed to tension should be made of wrought iron, and those exposed to pressure, of cast iron. A form of small span bridge is given in Fig. 5. One of the oldest of the larger bridges on this system is that designed by Stephenson in the year 1846. It is a road bridge over the North-Western Railway at Camden (2), as sketched in Fig. 6.

After the year 1846, the cast-iron parts in these and similar bridges were almost entirely replaced in the newer constructions by wrought iron, owing to the greater capability of resisting tension, and the much longer endurance of the latter under concussion, as shown by experience, and by the experiments made by Stephenson on the erection of the Britannia bridge. Notwithstanding this, in the bridges built on the principle suggested by Neville, and afterwards improved by Captain Warren, cast iron was employed for some time longer. A detailed description of these bridges will be unnecessary, as they are well known in England. It need only be remarked that, although the form of the Neville girder may be deduced from correct theoretical principles, the faults in its construction were numerous. Warren corrected many of these, and formed the upper member of his girder out of cast-iron tubes, the lower of wrought-iron bands. The struts between them were cast iron, the ties wrought iron. As an example may be cited the bridge over the Trent for the Great Northern Railway line (3).

In Germany, the system invented by Shifkorn followed the Neville system. His girder consisted of three long rails, one at the top and bottom, and one in the middle. These were bolted together at suitable distances, the four-cornered spaces between the bolts and rails being filled up with cross-formed iron castings. The latter were laid between the bands or rails, then the bolts tightened up till the whole became firm. These iron castings were all of one pattern, notwithstanding the various strains to which they are subject, and owing to the above-mentioned manner of bolting the parts together, an accurate calculation of the strains is impossible. This bridge was entirely condemned by the Austrian Society of Engineers.

Many bridges, composed partly of cast, partly of wrought iron, have been also constructed in America, most of the girder bridges being on the system of Long and Howe (which was first executed in wood). The names of Bollman, Whipple, and Fink ought also to be mentioned in connection with American bridges. They are, most of them, girder bridges, with upper and under horizontal flanges, some of them, however, being so trussed that the horizontal under boom may be left out. Those in which the upper member is parabolic, or of other similar form, have all double diagonals in each bay, whereas the Schwedler girder does not require this.

It would then appear that the combination of cast and wrought iron for bridges can be regarded as a period of transition in the European States, the girder bridges being now almost entirely constructed of wrought iron. In North America, on the contrary, such bridges are still very frequently built. The reason is probably not only that the North American cast iron is better able to resist tension, but also that the Americans make smaller requirements with regard to the duration of a bridge, than that it should be lightly, quickly, and cheaply put together.

In these few words on cast and cast and wrought-iron bridges, I have confined myself to girder bridges, that is to say, to such bridges which exercise no horizontal strain on the abutments, either tension or pressure. In the following notes on some of the systems for the construction of wrought-iron bridges which have been carried out, I will also confine your attention to the same class of bridges, inasmuch as the "Schwedler" bridge is one of these.

In the year 1846, some of the foundry owners already began to assert that the upper boom of the girder, made of cast iron, could be much better, and just as cheaply, constructed of wrought iron, where the bridge had to carry heavy movable loads. In consequence of this view of the question, many bridges, more especially movable and drawbridges of all sorts, began to be built entirely of wrought iron. Fairbairn erected several bridges of this sort, also a large floating quay in Liverpool, the upper and under flange of the girder being in the box form. The experiments made on the construction of the Conway bridge, and of the railway bridge over the Menai Straits at Bangor (4), were of considerable importance for the construction of girders of this form, and for a further knowledge of the material used. Brunel suggested girders of a somewhat more convenient form, an example of which is the railway bridge over the Wye at Chepstow. The single vertical rib of Brunel's girder permitted a saving of material in comparison with the double walls of box-formed girder (see Fig. 7). The manner of supporting the cross girders was advantageous, as the height between the rail level and under side of the girder was very small. The observation of bad points, and the keeping in order of the bridge, was also rendered much less difficult by the avoidance of the numerous small hollow spaces of the box girders. This improvement suggested a still further advance; viz. the avoidance of all hollow spaces, the girder thus resulting being of the double T form. The top and bottom plates were united by means of a vertical rib and four angle irons riveted on. Such girders, when small, have since been generally made of one piece.

The top and bottom plates of the wrought-iron girder bridges hitherto noticed were connected by full panels, by means of which the strains of the bridge were conveyed to the flanges. From the experiments made on the Britannia bridge it was already evident that the bending of the vertical walls was the result of pressure, which worked downwards, but the experimenters do not appear to have been quite clear about the way in which these forces worked. Their nature had, however, been practically explained by means of the wooden suspension and lattice bridges of Long and Town. It was already known that these forces could be transmitted by means of single bars, and that therefore the vertical ribs could be replaced by the same. Rider constructed a bridge entirely of iron on this principle, which showed that he had already a considerable insight into the nature of those strains, as he constructed the struts and ties respectively of cast and wrought iron. An example of this construction is the bridge over the Royal Canal, for the railway between Dublin and Drogheda, made in the year 1845 (4). The webs of the girders of this bridge proved to be too weak, in consequence of the want of all stiffening ribs. This fault was corrected by James Barton, in 1855, in the construction of the lattice bridge over the Boyne at Drogheda. The railway was carried by means of four girders over the river, of which two were at one side of the bridge and two at the other. These girder pairs were connected by angle irons, riveted on diagonally, so that they were firmly braced together, and gave the necessary stiffness. Mr. Cubitt erected a similar bridge, with some improvements, over the Thames at Blackfriars, for the London, Chatham, and Dover Railway. The same engineer also constructed a bridge, on the already mentioned Warren system, over the Trent at Newark. This is superior to the lattice bridge. In consequence of greater simplicity, less iron is required.

To these girders with parallel booms succeeded those in which the upper member was in the arch form, viz. the bowstring girder bridges.

In the early part of the century, and up to 1850, Germany followed England, and simply copied its bridges as well as its railways. Among the early lattice bridges there constructed, which shows a considerable acquaintance with the real strains in those bridges, is that over the Saale at Grizena on the Magdeburg and Leipzig Railway. Numerous bridges of this sort were from this time constructed, most of them with very fine meshes, and, in consequence, an immense number of diagonals.