A. VIERENDEEL.
GIRDER OR BEAM FOR BRIDGES.
(Application filed Dec. 31, 1897.)

Fig. 2.

Inventor
Arthur Vierendeel
By
William A. Appleton

Oscar M. Kromer

Witness

The Kurz Photo Co., Photo Litho., Washington, D.C.
GIRDER OR BEAM FOR BRIDGES.


Application filed December 21, 1897. Serial No. 864,823. (No model.)

To all whom it may concern:

Be it known that I, ARTHUR VIERENDEEL, a Belgian subject, residing at Bruges, Belgium, have invented new and useful improvements in Girders or Beams Having Arched Openings for Bridges, Framings, and other Metal-Work, (for which I have obtained patents in Belgium, No. 122,018, bearing date June 29, 1896, and No. 128,573, bearing date May 29, 1897; in France, No. 261,686, bearing date November 28, 1896; in Great Britain, No. 20,214, bearing date September 12, 1896, and in Austria, No. 47/2,618, bearing date June 24, 1897,) of which the following is a specification.

My invention relates to a new system of girders or beams for bridges and other metal constructions designed to be used in the place of the lattice-work girders employed at present.

The said invention has for its object to dispense with the use in lattice-work beams or girders of diagonal bars—that is to say, of triangulated bracing—and thus to simplify the lattice-work by reducing it to a rectangular truss.

In triangulated lattice-work with pin-joints as employed in America the diagonal is an indispensable stay; but in lattice-work having rigid joints of the type in general use in Europe the diagonal becomes superfluous and therefore useless, for which reason I have dispensed with it by reducing the lattice-work to the verticles alone, whereby I have been led to the girders having arched openings, which constitute my invention.

Triangulated lattice-work with pin-joints of the American type has the advantage of being capable of being calculated with absolute accuracy, which is not the case with triangulated lattice-work having rigid joints of the European type, which are calculated solely according to the formula of statics by assuming the joints to be pinned; but this is a hypothesis which experience has proved to be incorrect. The bars which are rigidly held at the joints are thus subjected by the deformations of the girder to bending strain, which produce stresses that are added to those which are due to the direct strains and act to increase the same very considerably; but if the American type has the advantage of absolute accuracy of calculation it also possesses numerous disadvantages—great complexity in the construction of the joints and in the rigid connection of the cross-girders of the flooring and of the wind-bracing to the pin-joints, which connection must be made without interfering with the movement of the latter, thus causing considerable expense for labor, want of safety due to the necessary inclusion of forged parts, wear of the joints after a certain time, and consequent mobility in the general connections of the framework, which produces on the passage of trains dynamical effects, shock, and very powerful hammering or jarring.

I have sought to produce a type of girder which shall be capable of replacing to advantage not only the lattice-work with rigid joints used in Europe, but also the American pin-jointed lattice-work, while possessing the same absolute accuracy of calculation as the pin-jointed type, avoiding the practical inconveniences of pin-jointing, reducing the surface exposed to rusting, causing a saving in labor in the workshop and in erecting, and in most cases a saving in material. With this object I have invented a system of open-work girders or beams composed solely of verticles and verticles without any diagonal connecting the foot of one vertical to the top of another vertical, and I have discovered an exact method of calculating for this kind of construction.

The accompanying drawings illustrate the construction of the beams or girders of my system and also various types of said girders.

Figure 1 is a perspective view showing the application to the construction of a railway-bridge of girders having parallel and horizontal booms connected together by vertical members rigidly fixed thereto. Fig. 2 is a perspective view showing the application to the construction of a railway-bridge of girders having booms which are not parallel and not symmetrical. Fig. 3 is a diagram illustrating a girder having non-parallel symmetrical booms. Fig. 4 illustrates a portion of a girder having parallel booms with pin-joints in the upper and lower booms. Fig. 5 shows a portion of a similar girder with pin-joints in...
the lower boom only. In these figures, B is the lower boom of the girders, C the upper boom, and D D the vertical members. E E, Figs. 4 and 5, indicate the pin-joints. Figs. 6 and 7 show the method which I employ for calculating the constructions according to my invention, and the theory of which I shall set forth in a concise and clear manner, while repeating the statement that the possibility of exact calculation constitutes one of the most important advantages of my invention. The method of calculation is based on the following principle: Taking a girder of any shape, Fig. 6 or 7, let it be cut into two parts on the line M M at any height, but in such a manner as to intersect all the vertical members. At each section thus made there are at each vertical which is cut through three unknown forces—viz., a direct strain X, a transverse strain Y, a couple or moment Z—and therefore there are as many times three unknown forces as there are vertical members. Now after deformation of the girder by the action of the load carried by it the section A of the vertical member is shifted by exactly the same amount, whether it be considered to belong to the upper part S of the girder or to the lower part I of the same. I take the section indicated at A in Figs. 6 and 7 and I consider it as belonging to the upper part S, and I designate it by A'. I estimate its displacement in a horizontal sense and represent it by A'$. I then estimate its displacement in a vertical sense and call it A'$. and, finally, I estimate its angular displacement and call it A'$. These three displacements are readily represented as functions of the several unknown forces X Y Z acting upon each vertical member. I then take the same section A, and I consider it as belonging to the lower part I of the girder and I call it A". I represent its three displacements by A"$, A"$, and A"$, as above, and by virtue of the equality of the displacements above stated I get the three equations—

\[
\begin{align*}
A'_{S} &= A'_{I} \\
A'_{V} &= A'_{I} \\
A'_{d} &= A'_{I}.
\end{align*}
\]

Each vertical gives me three similar equations. I have therefore as many times three equations as there are vertical members and therefore as many equations as there are unknown quantities. Consequently the problem is solved—that is to say, I can determine all the unknown forces X Y Z which act upon each vertical member. I can therefore determine the exact stresses and dimensions of the several elements of the girders, and the calculation of these is complete. In practice this general method can be greatly simplified. It should be noted that it has no recourse to any hypothesis. It is solely and simply based on the two fundamental equations of flexure—

\[
\begin{align*}
\frac{d^{2}y}{dx^{2}} &= M. \\
E \frac{d^{2}y}{dx^{2}} &= M.
\end{align*}
\]

These equations are not mathematically correct, it is true, but experience has proved their practical exactness. Experiments which I have made upon a bridge of thirty-one to fifty millimeters in length under the super vision of the Belgian government engineers have shown the exactness of results obtained by the calculation above set forth, as well as regards stress in girders, as also as regards the deflection of such girders, and comparison of these results with the official results of tests made by the Swiss government with a lattice-work bridge shows that the type of construction which forms the subject of my present invention gives a strength equal to 95.75 times that of the lattice-work type with equal load, which renders my type in particular much lighter with equal strength.

Now in lattice-work bridges it is necessary that the verticals and diagonals should be fastened at their ends, with the result that the rivets alone carry the bending strains at their maximum; but my system allows of arranging intermediate joints J, Fig. 2, at those places where the bending strains are smaller and even of arranging them at the middle of the height of the vertical members, where the bending strain is equal to 0.

The saving in labor is considerable with my system not only because the construction is more simple, but also because the larger parts can be sent out of the workshops in sections ready riveted together without risk of damage, with the result that the labor of erection is considerably diminished.

My system has the great advantage that the verticals are not subjected to any contingency of collapse, this being a great drawback in all lattice-work bridges and more so in those with pin-joints. Finally, a bridge on my system will offer in the case of a train running off the line a resistance to the impact of a locomotive against the verticals sufficient to prevent its destruction and breaking down or collapse.

Instead of the upper and lower booms being continuous or rigid from one end of the girders to the other they may be made with a hinge or pin joint at the middle of two successive vertical members, as shown in Fig. 4, or even this hinging may only be provided in one only of the two
booms, as shown in Fig. 5. The position of the hinge is much better than in the American pin-jointed type, because, first, each joint or connection consists only of the union of two parts, whereas in the American lattice-work there are at least four parts, and, second, the pin-jointed connections are outside the connections of the cross-girders of the flooring and of the wind-bracing, whence there results great simplicity of construction.

Having fully described my invention, what I claim, and desire to secure by Letters Patent, is—

1. A modified construction of girders or beams for bridges of the type known as "lattice-work," in which the diagonals are removed and the vertical members rigidly connected to the booms by rounded pieces in such manner that the booms and vertical members form practically one piece, substantially as described.

2. A modified construction of girders or beams for bridges of the type known as "lattice-work," consisting solely of booms and vertical members made of rolled iron or steel plates and angle-irons rigidly connected by rounded corner-pieces and rivets, but without any diagonals connecting the foot of one vertical member with the head of another vertical member, substantially as described.

In witness whereof I have hereunto set my hand in presence of two witnesses.

ARTHUR VIERENDEEL.

 Witnesses:
H. J. E. KIRKPATRICK,
J. S. KIRKPATRICK.