May 2, 1933. W. H. WEISKOPF ET AL 1,906,683

PLATE GIRDER

Filed May 26, 1931

Fig. 1

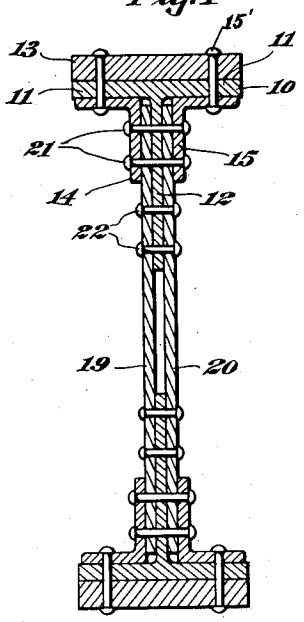


Fig. 2

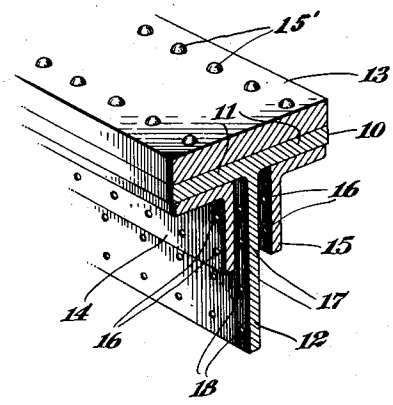
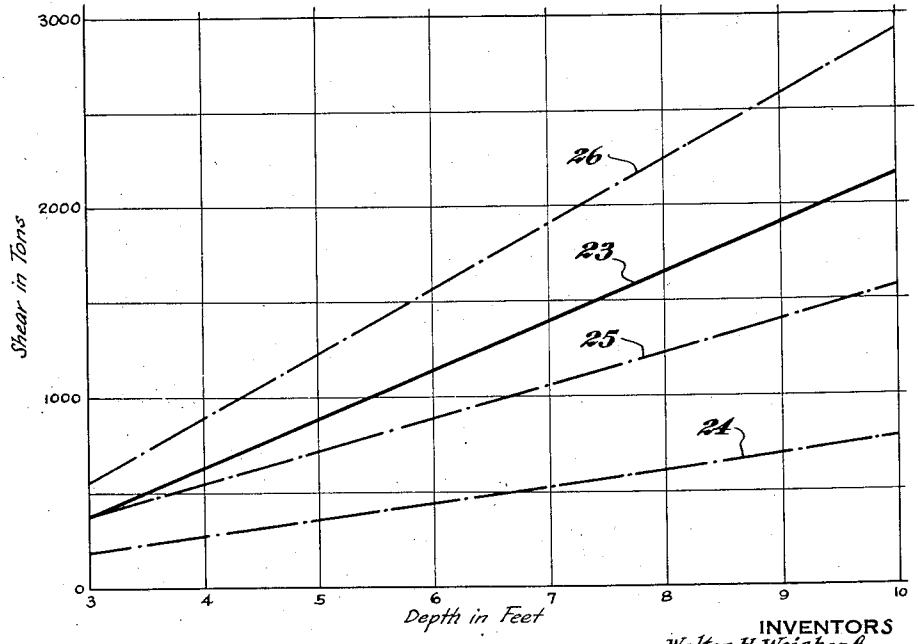


Fig. 3



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UNITED STATES PATENT OFFICE

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PLATE GIRDER

Application filed May 26, 1931. Serial No. 540,094.

Our present invention relates generally to structural elements, and has particular reference to plate girders.

The design of beams is, of course, predicated primarily upon the maximum load which is to be supported, and the general objective of the structural engineer is to provide a beam having strength characteristics sufficient to carry the predetermined load and having a structural arrangement which is as economical as possible. Economical design requires more than merely keeping the total weight of material to a minimum, since the designer is restricted, from a practical standpoint, to the employment of I-beams, angles, and other structural elements of a character which are readily and inexpensively available on the market.

In steel structures of the present skyscraper variety, a further limitation of economic importance is imposed upon the designer by virtue of the fact that free and available space in present-day buildings of this character is so extremely valuable. Whether a beam is an inch or more deeper or less deep than another beam might appear to be a trivial consideration, but in present-day structures, of mammoth proportions not only in height but also in ground area, a saving of as little as one inch in beam depth represents a total saving throughout an entire floor or floors of many thousands of dollars.

It is a general object of our present invention to provide a structural composite beam of the "plate girder" variety whereby an increased load carrying capacity is provided within a prescribed depth, and whereby, conversely, a given load can be provided for within a lesser depth.

Stated in terms of structural engineering, wherein the formula

$$M=\frac{SI}{C}$$

prescribes that for a given bending moment (M) (bending moment being a function of the external load) and a given maximum allowable fiber stress (S), a certain minimum section modulus

$$\left(\frac{I}{C}\right)$$

is required, wherein I is the moment of inertia of a beam structure and C is proportional to the depth of the beam, it is an object of our present invention to provide a novel and improved type of plate girder wherein a larger section modulus is attained per given depth.

Before proceeding to describe the details of our present invention, we will premise that a structural beam of the present character is composed of a pair of opposite flanges connected by a relatively thin web. The flanges are designed to withstand the maximum bending movement which any particular load imposes upon the beam, and the web is designed primarily to resist the maximum shearing stresses. The flanges are tied to the web by means of rivets, and the rivets must be so designed as to withstand the maximum shearing stresses which are imposed upon them during the fulfillment of their function to transmit the stresses from the flanges into the web. One of the limitations confronting the beam designer who is aiming for economy of depth is due to the fact that the resisting capabilities of a given number of rivets is almost directly proportional to the distance of the rivets from the neutral axis of the beam; and, therefore, where the depth is to be kept at a predetermined amount, increased carrying capacity may be provided only by increasing the number of rivets or by designing the beam in such a way that the rivets are subjected to multiple shear along two or more planes. Increasing the number of rivets is not always feasible, and, in many cases, entirely

impossible due to the limitations imposed by the available sizes of structural elements; and a similar difficulty frequently arises in endeavoring to design the structure so that the rivets are subjected to multiple shear of a higher order.

For example, in the conventional type of plate girder composed of a single web plate and a pair of angles tying one edge of the plate to the flange, the number of rivets that may be employed is, from a practical standpoint, limited to the sizes of angles which are commercially available, and usually only two rows of rivets may be provided form. In endeavoring to support heavier loads without increasing depth of beam, efforts have been made by designers to provide for a multiple shear of higher order in the rivets, as, for example, by employing two additional web plates arranged respectively on the outsides of the angles referred to.

Our present invention provides in a simple, efficient, and economical manner for a plate girder which has even greater load carrying capacities, per given depth, than the last-mentioned type of conventional multiple web plate girder.

It is a more particular object of our present invention to provide a plate girder which is so designed that, for a given depth, more rivets may be employed, and more of the rivets may be efficiently employed under multiple shear. Furthermore, our invention provides simultaneously and in a uniquely efficient manner for enlarging the flange area. All of these advantageous characteristics are attained without any material sacrifice of total weight or of any of the other factors entering into economical design. As a result, our present plate girder is enabled to support a greater load per given depth, or, conversely, to withstand a given load in a lesser depth and with no increase, and possibly even a decrease, in total cost of building construction.

We achieve the foregoing objects and advantages, and such other objects and advantages as may hereinafter appear or be pointed out, in the manner illustratively exemplified in the accompanying drawing, wherein—

Figure 1 is a cross-sectional view of a plate girder constructed in accordance with our present invention;

Figure 2 is a fragmentary perspective view of one of the flanges; and

Figure 3 is a graph illustrating the advantageous characteristics of our present beam as compared with conventional plate girders of the character mentioned.

One of the main features of our present invention lies in providing a structure wherein the flange is a substantially T-shaped, preferably composite, member wherein the cross bar of the T is provided with at least three depending stems. In the drawing, we have illustrated a preferred construction wherein the T has three stems, and it is a particular and essential feature of our invention to construct the middle stem integrally with the cross bar of the T. In Figure 2, for example, it will be noted that the flange is composed of the integral T-shaped member 10 having the cross bar 11 and the main depending stem 12. A cover plate 13 is preferably arranged upon the outer surface of the cross bar 11. To the under surface of the cross bar 11, and on opposite sides of and spaced from the main stem 12, we provide a pair of auxiliary stems 14 and 15 which may conveniently be provided by the employment of angles of the character shown, these angles being made part of the flange construction by means of rivets 15′.

Rivet holes 16 are provided in the auxiliary stems, and we have illustratively shown two parallel rows of these holes. Two rows of rivet holes 17 aligned with the holes 16 are provided in the main stem 12. In accordance with our invention, the main stem 12 is appreciably longer than the outer stems of the T, and we provide at least one additional row of rivet holes, such as the two rows 18, in this main stem.

To connect the two flanges thus constructed, we employ at least two web plates arranged in parallel, spaced relationship on opposite sides of the main stem 12. In the drawing, for example, we have shown two web plates 19 and 20, these plates being arranged in alternate lapped relationship with the three depending stem portions of the substantially T-shaped flanges. Suitable rivet holes having been provided in these web plates, the assembly is completed by the rivets 21 and 22, and it will be noted that the rivets 21 of the two rows closest to the flange are each in multiple shear along four planes, while the rivets 22 of the two rows which are relatively farther from the flange are each in double shear.

By means of this simple and compact and obviously inexpensive construction, a plate girder is provided which has greatly increased capabilities per given depth. In Figure 3, for example, we have chartered the depth in feet which is necessary in a plate girder to permit the rivets, regardless of how they may be arranged, to withstand the shear imposed upon them by a given load. The line 23 represents the characteristics of the present beam as illustrated in Figures 1 and 2, and it will be noted that for a given shear of, say, 1,000 tons, the present construction requires a depth of only 5½ feet or slightly less in order that the rivets may be capable of withstanding the shear imposed upon them by this load. The

dot-and-dash line 24 has been shown for comparative purposes and represents the capabilities and characteristics of the conventional type of plate girder having a single web and two angles connecting one edge of the web to a flange. Regardless of the amount of material that may be embodied in the flange of this conventional construction, or in the web thereof, the structural arrangement of parts is such that a depth of at least 10 feet, and, in fact, considerably greater than this, would be necessary to permit the rivets to withstand the shear imposed upon them by the illustrative load of 1,000 tons.

The dot-and-dash line 25 represents the capabilities of the conventional plate girder referred to wherein two additional web plates have been mounted alongside of the original plate for the purpose of subjecting the rivets to multiple shear of a higher order. This line, which to our knowledge represents the maximum capabilities of constructions of this character up to the present time, indicates that a depth of at least 6⅔ feet would be required to enable the rivets, regardless of how they might be arranged, to sustain the same given load.

It is to be noted that our present invention, even in its simplest form as illustrated in Figures 1 and 2, has greater load carrying capacities than the multiple web arrangement of the conventional type of plate girder. By adding two additional web plates to the construction of our present invention (thereby making a total of four web plates), we are enabled to provide a construction whose characteristics are designated by the dot-and-dash line 26 of Figure 3, from which it will be seen that the sheer of 1000 tons chosen for purposes of comparison could be sustained within a depth as low as 4¼ feet.

The graph of Figure 3 is the result of mathematical computation based upon the use of one-inch rivets aligned vertically on all gauge lines and with the minimum allowable rivet pitch of three inches. The formula employed is the well known formula for rivet pitch:—

$$P=\frac{nRd}{S}$$

where—P is the spacing in inches between successive rivet lines; R is the maximum allowable single shear on each rivet, in tons; n is the number of instances of single shear on a vertical line; d is the distance in inches between the center of gravity of the rivets at one flange and the center of gravity of the rivets at the opposite flange; S is the total shear on the girder, in tons.

According to some authorities, d in the above formula is more correctly stated as being the distance in inches between the center of gravity of one flange and the center of gravity of the opposite flange. The d value employed usually makes little difference in computations involving ordinary conventional plate girders, but it may make some difference in girders of the present type, and a graph of the character illustrated in Figure 3, if plotted on the basis of the d value between the centers of gravity of the two opposite flanges, results in demonstrating even more markedly the advantages of the present construction.

In charting the lines shown in Figure 3, the ordinates represent values of S, and the abscissæ represent the distance in inches between the backs of the flange angles in the conventional type of construction and the backs of the T-shaped flanges of the present construction. The distances represented by the abscissæ of the chart of Figure 3 can be readily computed from d of the formula.

We attribute the advantages of the present construction to the provision of a substantially T-shaped flange having at least three spaced stem portions with the middle stem or stems integral with the cross bar of the T. Where four stem portions are employed, both middle portions are made longer than the outer stems, and correspondingly greater load capabilities may be provided for.

Obviously, our construction is susceptible to a variety of modifications. The cover plate 13 may be entirely omitted, or it may be augmented by additional cover plates. Spacing plates may be inserted between the angles and the under surface of the cross bar 11. The sizes of the respective parts may be altered to suit differing requirements.

Preferably, though not necessarily, the T-shaped member 10 is provided by splitting a unitary I-beam of commercially available type along a transverse line which passes through the neutral axis where the I-beam is symmetrical. Under certain circumstances, it may be found desirable to leave such I-beam intact.

Obviously, changes in the details herein described and illustrated for the purpose of explaining the nature of our invention may be made by those skilled in the art without departing from the spirit and scope of the invention as expressed in the appended claims. It is therefore intended that these details be interpreted as illustrative, and not in a limiting sense.

Having thus described our invention and illustrated its use, what we claim as new and desire to secure by Letters Patent is—

1. In a plate girder, a substantially T-shaped flange with three spaced, parallel stem portions, the middle portion being appreciably longer than the other two, a web

comprising two parallel, spaced plates arranged respectively within the spaces between said stem portions, and rivets for tying the web to the flange, certain of said rivets extending through all three stem portions and being thereby subjected to multiple shear along four planes, certain other of said rivets extending only through said middle stem portion.

2. In a plate girder, a substantially T-shaped flange with three spaced, parallel stem portions, the middle portion being appreciably longer than the other two, a web comprising two parallel, spaced plates arranged respectively within the spaces between said stem portions, and four rows of rivets for tying the web to the flange, the rivets of two of said rows extending through all three stem portions and being thereby subjected to multiple shear along four planes, the rivets of the other two rows extending only through said middle stem portion and being thereby subjected to double shear.

3. In a plate girder, a composite, substantially T-shaped flange with three spaced, parallel stem portions, the middle stem portion being integral with the cross bar of the T, the outer stem portions being riveted to said cross bar, a web comprising two parallel, spaced plates arranged respectively between said outer stem portions and said middle stem portion, and rivets extending through said stem portions and web plates to tie the web to the flange.

4. In a plate girder, a composite, substantially T-shaped flange with three spaced, parallel stem portions, the middle stem portion being appreciably longer than the others and being integral with the cross bar of the T, the outer stem portions being riveted to said cross bar, a web comprising two parallel, spaced plates arranged respectively between said outer stem portions and said middle stem portion, rivets relatively close to said cross bar and extending through said stem portions and web plates, and other rivets relatively farther from said cross bar and extending through said web plates and only the middle stem portion.

5. A plate girder comprising an I-beam split transversely to provide a pair of opposed T-shaped members, a pair of angles secured to the underside of each T cross bar on opposite sides of and spaced from the main stem of said T so as to provide a pair of auxiliary stems on each cross bar, said auxiliary stems being of appreciably lesser depth than that of said main stem, a pair of spaced, parallel web plates arranged respectively in the spaces on each side of said main stems, and a plurality of rows of rivets, the rivets of at least one row extending through all three stems and both interposed web plates, the rivets of at least one other row extending only through the main stem of each T-shaped member and the web plates on each side thereof.

6. In a plate girder, a composite, substantially T-shaped flange with three spaced, parallel stem portions, the middle stem portion being integral with the cross-bar of the T, a web comprising two parallel, spaced plates arranged, respectively, between said outer stem portions and said middle stem portion, and rivets extending through all three stem portions of the flange and through both web plates, thereby tying the web of the girder to the flange thereof.

7. In a plate girder, a composite, substantially T-shaped flange with three spaced, parallel stem portions, the middle stem portion being integral with the cross-bar of the T and the outer stem portions being riveted to the cross-bar of the T, a web comprising two parallel, spaced plates arranged, respectively, between said outer stem portions and said middle stem portion, and rivets extending through all three stem portions of the flange and through both web plates, thereby tying the web of the girder to the flange thereof.

In witness whereof we have signed this specification this 13th day of May 1931.

WALTER H. WEISKOPF.
JOHN W. PICKWORTH.

CERTIFICATE OF CORRECTION.

Patent No. 1,906,683. May 2, 1933.

WALTER H. WEISKOPF, ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, line 67, for "movement" read "moment"; page 2, line 15, for "form" read "for"; and line 117, for "chartered" read "charted"; page 4, commencing with line 25, strike out all to and through line 35, which comprises present claim 3; same page, lines 36, 51, 69 and 80 respectively, for the claim numbers "4, 5, 6, and 7" read "3, 4, 5, and 6"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 8th day of August, A. D. 1933.

M. J. Moore.

(Seal)

Acting Commissioner of Patents.