

Nov. 6, 1962

E. M. HUNNEBECK

3,062,340

GIRDER UNITS AND CONNECTING MEMBERS

Filed April 12, 1957

16 Sheets-Sheet 1

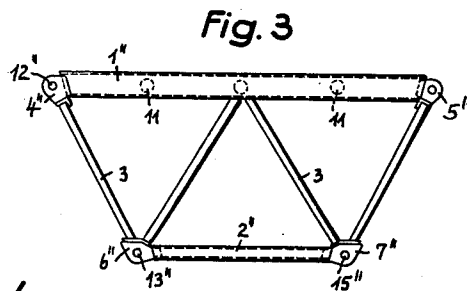
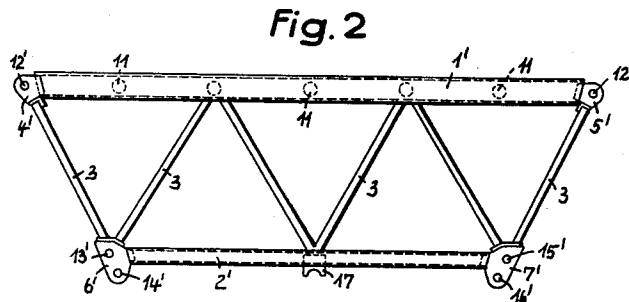
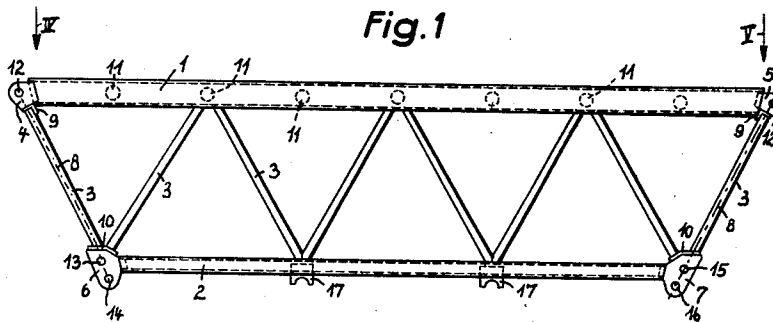


Fig. 4

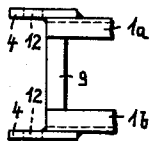
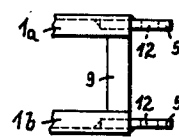


Fig. 5



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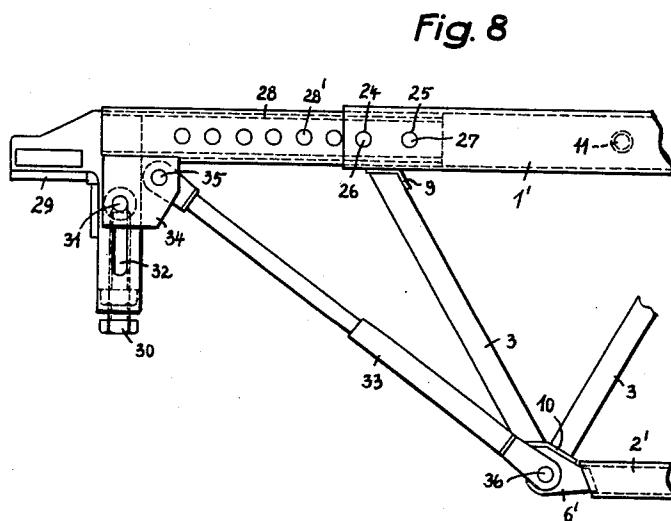
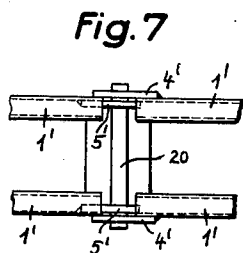
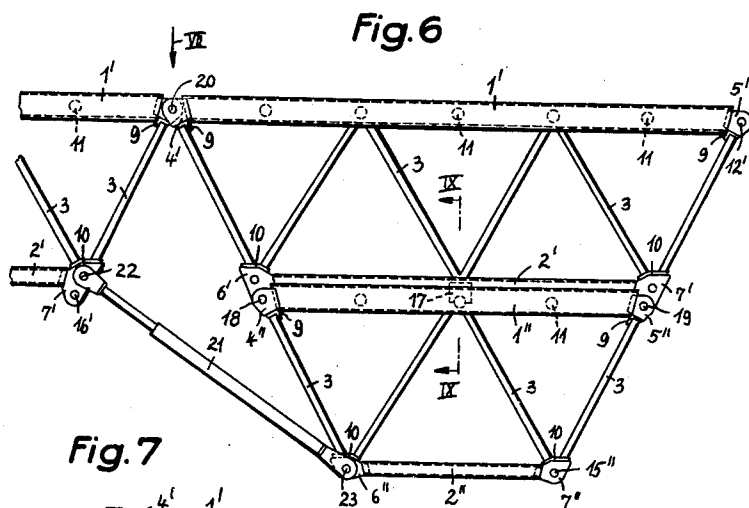
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GIRDER UNITS AND CONNECTING MEMBERS

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16 Sheets-Sheet 2



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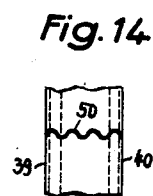
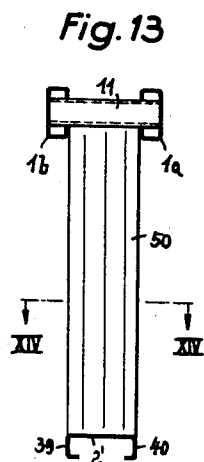
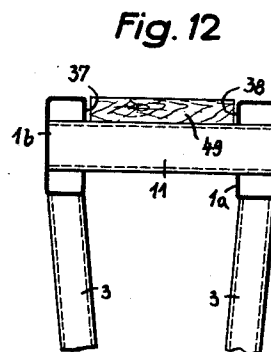
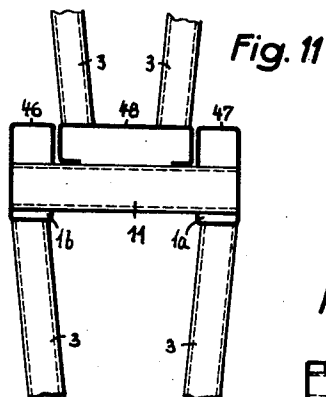
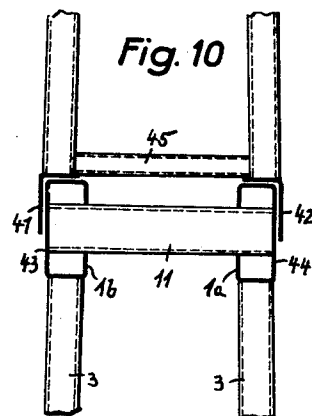
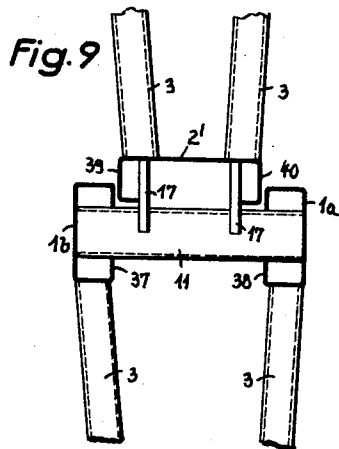
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GIRDER UNITS AND CONNECTING MEMBERS

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16 Sheets-Sheet 3



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GIRDER UNITS AND CONNECTING MEMBERS

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Fig. 15

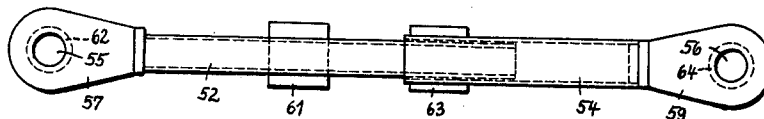


Fig. 16

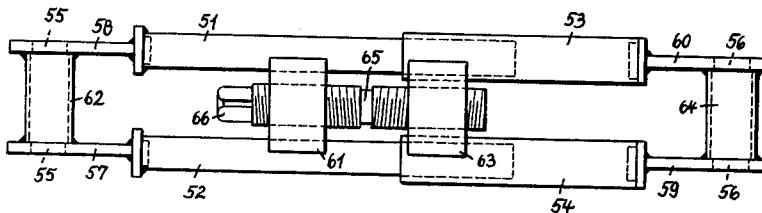


Fig. 17

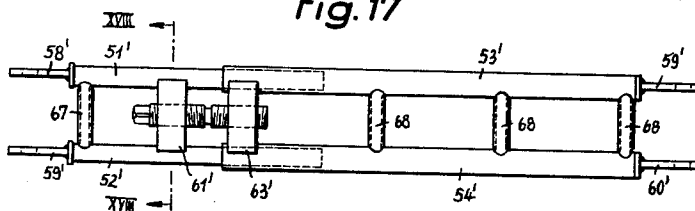
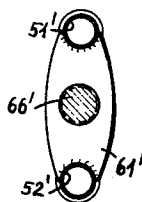


Fig. 18



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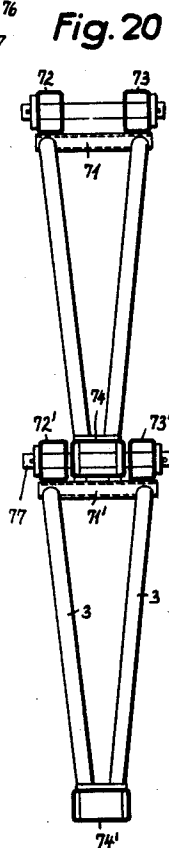
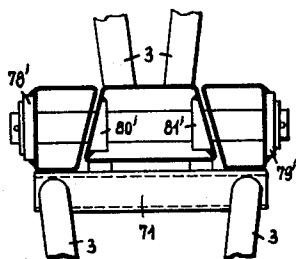
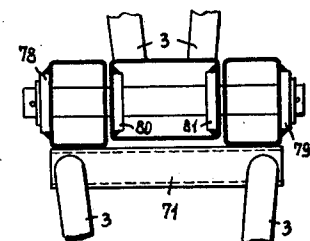
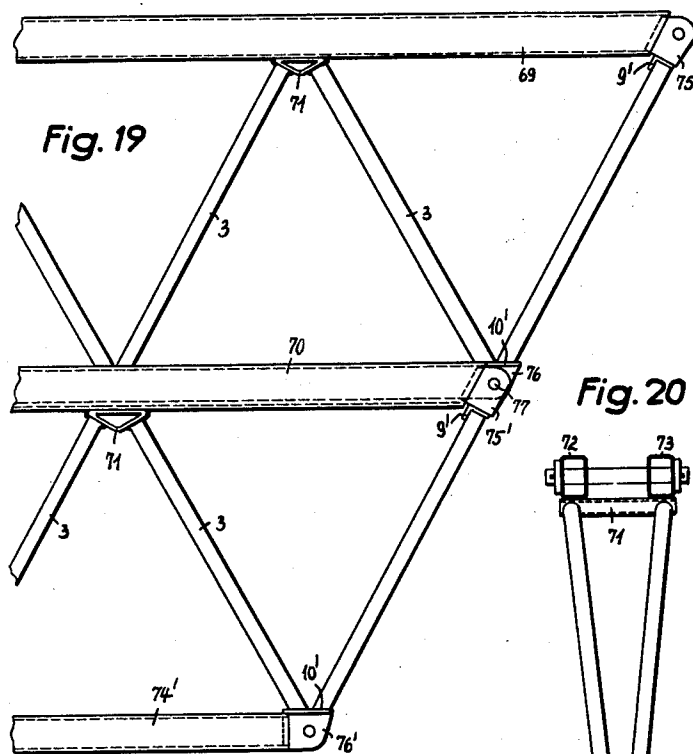
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GIRDER UNITS AND CONNECTING MEMBERS

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Fig. 23

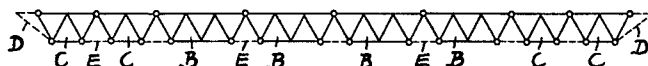


Fig. 24

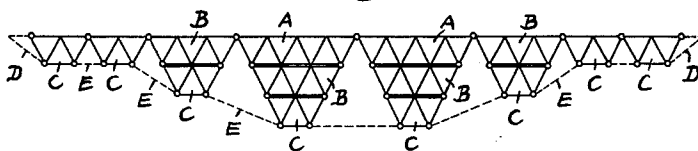


Fig. 25

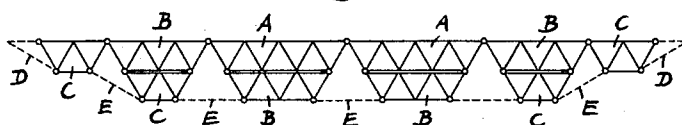


Fig. 26

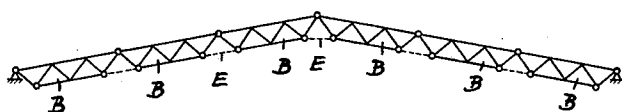
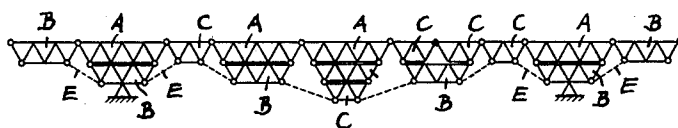


Fig. 27



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Fig. 28

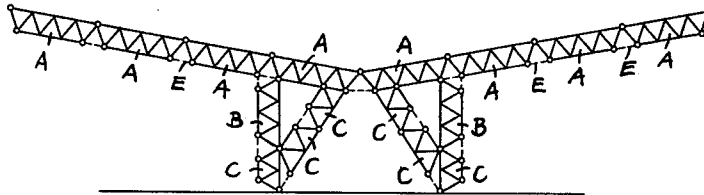


Fig. 29

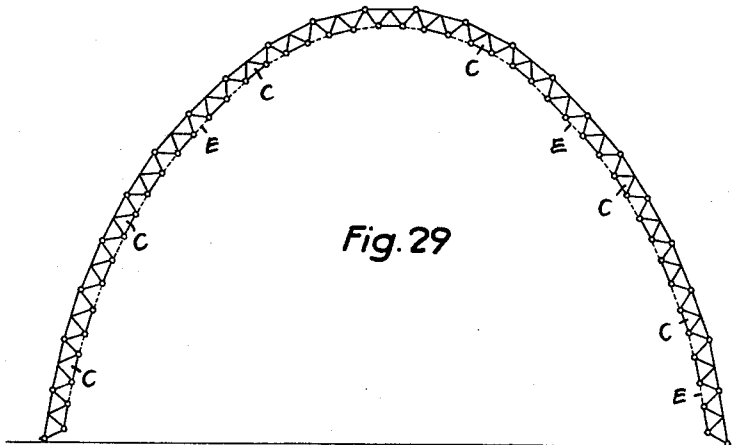
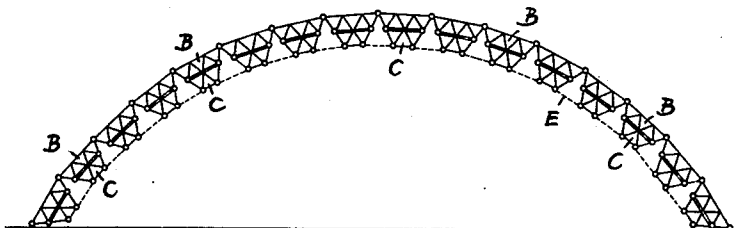


Fig. 30



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Fig. 31

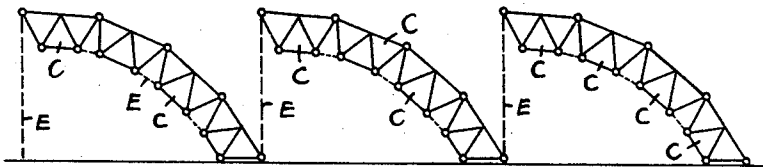


Fig. 32

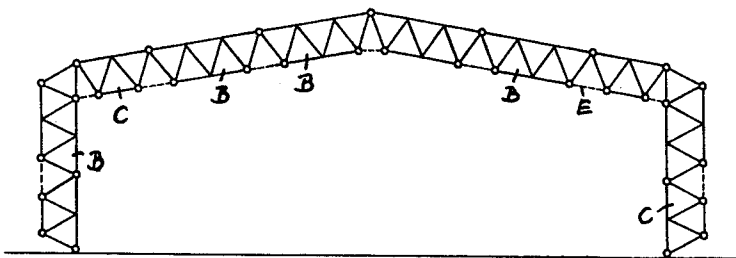
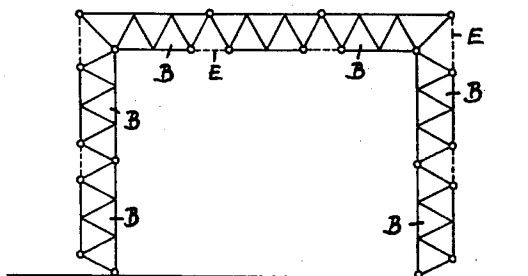


Fig. 33



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GIRDER UNITS AND CONNECTING MEMBERS

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Fig. 34

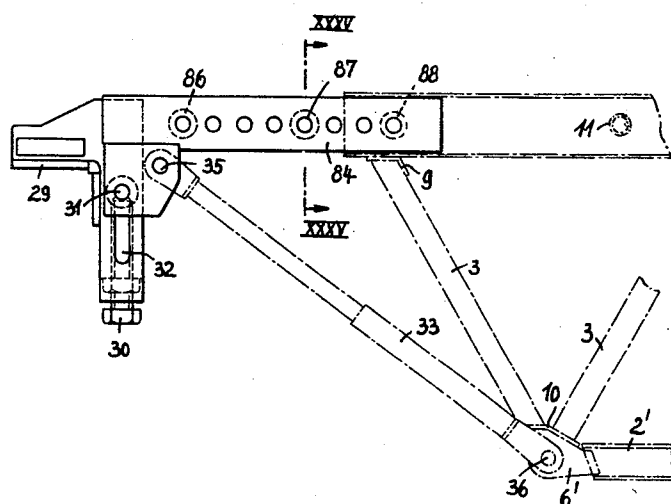
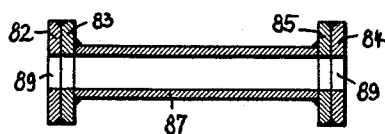


Fig. 35



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GIRDER UNITS AND CONNECTING MEMBERS

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Fig. 36

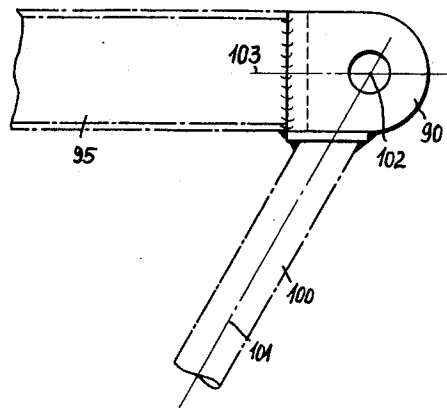
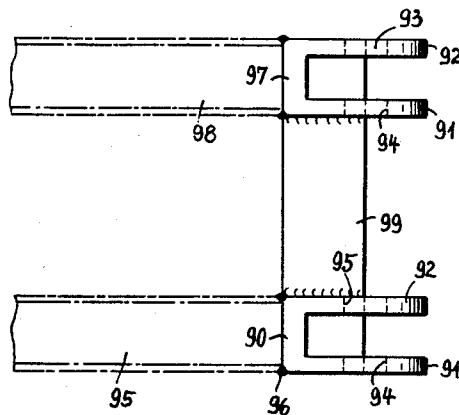


Fig. 37



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Fig. 38

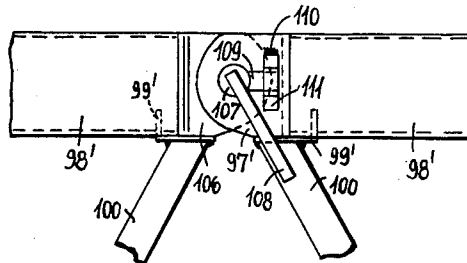


Fig. 40

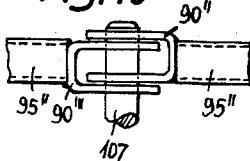


Fig. 41

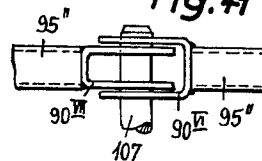


Fig. 39

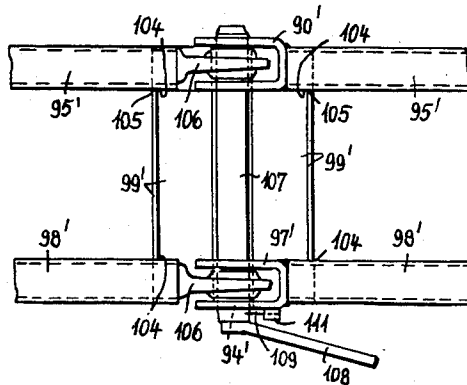
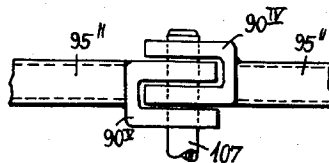


Fig. 42



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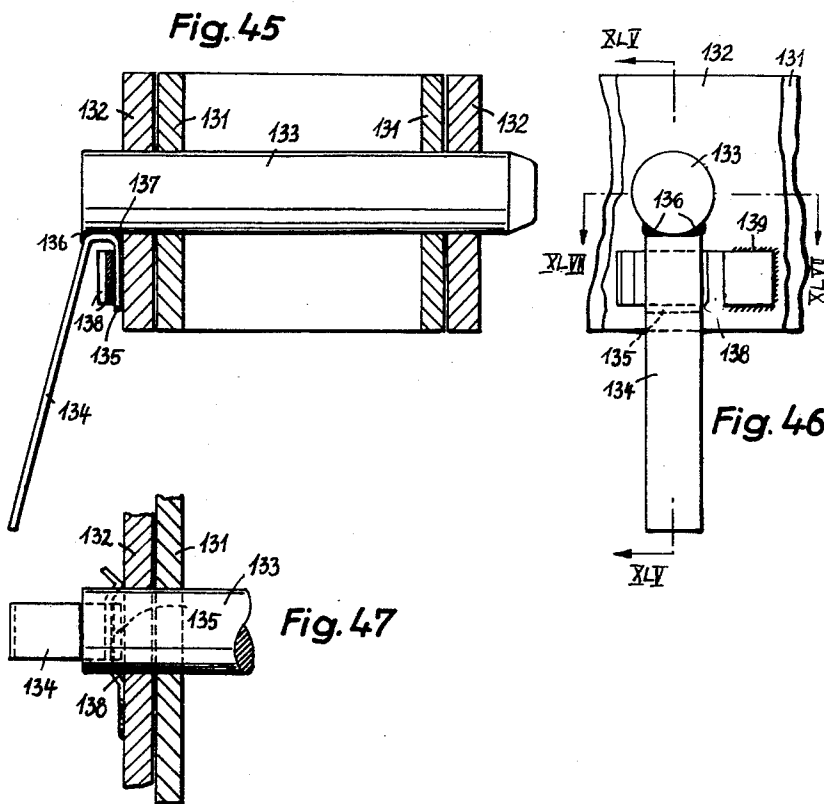
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GIRDER UNITS AND CONNECTING MEMBERS

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Fig. 48

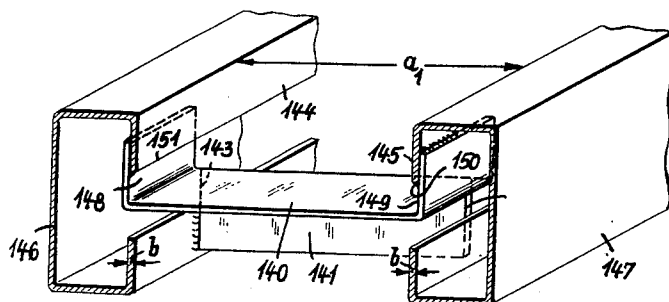
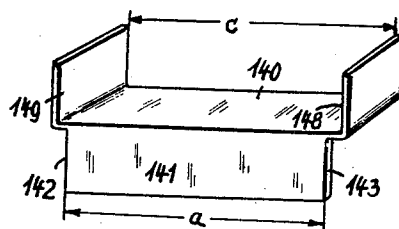


Fig. 49



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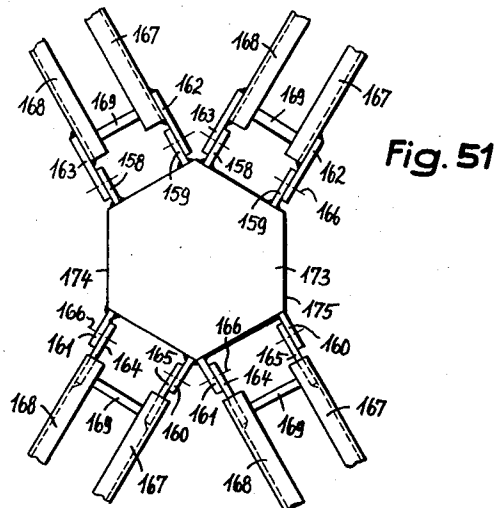
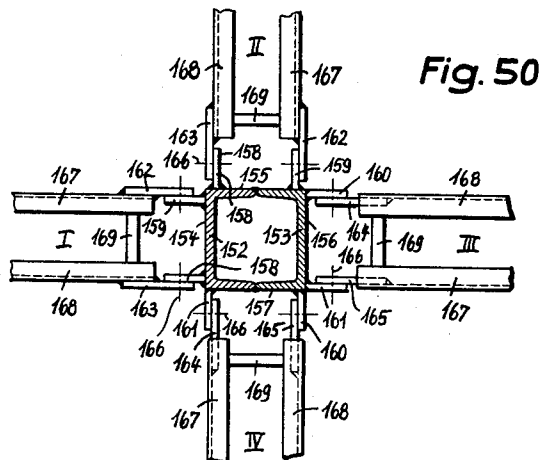
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3,062,340

GIRDER UNITS AND CONNECTING MEMBERS

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3,062,340

GIRDER UNITS AND CONNECTING MEMBERS

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Fig. 52

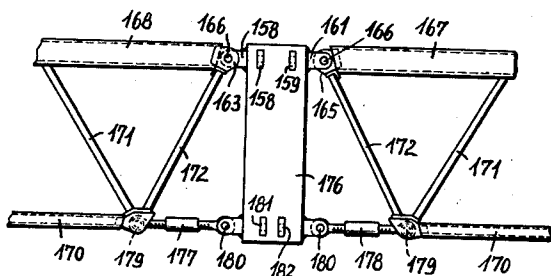


Fig. 53

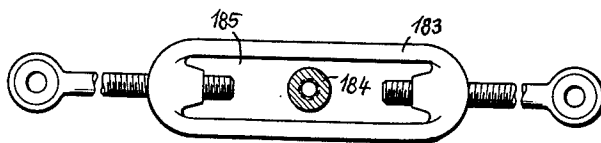
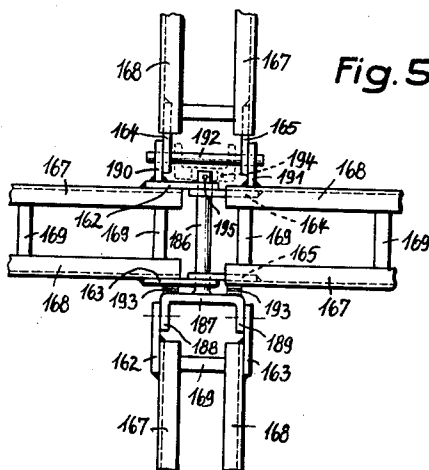


Fig. 54



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GIRDER UNITS AND CONNECTING MEMBERS

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Filed Apr. 12, 1957, Ser. No. 652,422

Claims priority, application Germany Apr. 18, 1956

7 Claims. (Cl. 189—37)

The present invention relates to new improvements in structural elements for erecting and supporting walls, floors, and roofs of buildings, including hangars, bridges, scaffolds, and similar structures, and especially such structures which are intended for temporary use only and should be designed so as to be easily assembled and to be dismantled after use.

The structural elements hereinafter called "girder units," known for similar purposes prior to this invention are generally of two different types, namely, those that may be connected to each other only in an end-to-end position, and those that may be connected to each other both end-to-end, as well as one above the other. The individual units of the first-mentioned type are generally connected to each other by a positive pivotal connection of the adjacent upper booms thereof by means of bolts or the like, and by adjustable means such as turnbuckles or the like connecting the adjacent lower booms to each other. The known girder units of the second type, on the other hand, are directly combined with each other by means of clamps and fishplates or the like to form a single rigid unit in which the upper and lower booms of adjacent units directly abut against each other.

Supporting structures consisting of girder units of the above-mentioned types have the great disadvantage that they can only be used for spanning relatively short distances, even though the individual units might be reinforced by stiffening girders or tension cables.

It is the principal object of the present invention to provide such girder units which are designed and may be connected to one another so as to span very large distances, and also to have any desired load-carrying capacity.

A preferred feature of the present invention for attaining the above-mentioned object consists in the provision of girder units, each of which, when seen in a side view, forms a regular quadrangle and consists of an upper boom and a lower boom which are connected by a plurality of diagonal brace bars. Each of these girder units may be combined with others of the same type in a longitudinal direction of the booms at the four corners of each unit by suitable connecting means, such as bolts or the like which are inserted into apertures or bores within these corners. According to the invention, these bores are preferably so disposed relative to each other that their axes coincide with the points of intersection of the neutral axes of the parts which form the outer contours of each girder unit.

Another preferred feature of the present invention, applicable when two or more girder units are superimposed upon each other, consists in designing the girder units in such a shape that the neutral axis of the upper boom of a lower girder unit coincides with the neutral axis of the lower boom of an upper girder unit, and that the neutral axes of the superimposed girder units which extend at an angle to the first-mentioned neutral-axes lie within the same straight line. In such event, the upper and lower booms of two or more superimposed girder units are designed so as to enterengage with each other, for example, by partly embracing each other.

Another preferred feature of the invention consists in providing the individual superimposed girder units of different lengths so that the distance between the points of connection of each lower boom of an upper girder unit is equal to the distance between the points of connection of each upper boom of a lower girder unit. In such a case,

the endwise adjacent girder units may be connected to each other in a manner known in the art, that is, by connecting the adjacent upper booms directly to each other, while the adjacent lower booms may be connected indirectly to each other by means which are adjustable in length, such as turnbuckles.

Further objects, features, and advantages of the present invention will be apparent from the following detailed description thereof, particularly when read with reference to the accompanying drawings, in which—

FIG. 1 shows a side view of a girder unit of trapezoidal outer shape with connections for securing such unit to other girder units of a similar shape either in an end-to-end relation, or superimposed to each other;

FIG. 2 shows a side view of a girder unit similar to FIG. 1 which is adapted to be connected to the latter either end-to-end or underneath the same;

FIG. 3 shows a side view of a girder unit similar in shape to those shown in FIGS. 1 and 2 and adapted to be connected to a girder unit according to FIG. 2 either end-to-end or underneath the same;

FIG. 4 shows a plan view of the left end of any girder unit according to FIGS. 1 to 3, as seen in the direction of arrow IV in FIG. 1;

FIG. 5 shows a plan view of the right end of any girder unit according to FIGS. 1 to 3, as seen in the direction of arrow V in FIG. 1;

FIG. 6 shows a partial side view of a girder assembly composed of a plurality of girder units according to FIGS. 1 to 3;

FIG. 7 shows a plan view of the connection between the upper booms of two adjacent girder units, as seen in the direction of arrow VII in FIG. 6;

FIG. 8 shows a partial side view of a terminal girder unit, the upper boom of which is directly connected to an adjustable end support forming a bearing bracket which, in turn, is indirectly connected to the lower boom by means of an adjustable truss bar;

FIG. 9 shows a cross section taken along line IX—IX of FIG. 6 and illustrates the connection of two superimposed girder units;

FIG. 10 shows a similar sectional view of a modification of the connection shown in FIG. 9;

FIG. 11 shows a sectional view of a further modification of the connection of two superimposed girder units;

FIG. 12 shows an end view of an upper boom carrying an inserted catwalk;

FIG. 13 shows an end view of a girder unit, the upper boom of which is connected to the lower boom by corrugated sheet metal bars;

FIG. 14 shows a cross section taken along line XIV—XIV of FIG. 13;

FIG. 15 shows a side view of an adjustable truss bar;

FIG. 16 shows a plan view of the truss bar of FIG. 15;

FIG. 17 shows a plan view of a modification of the truss bar of FIGS. 15 and 16;

FIG. 18 shows a cross section taken along line XVIII—XVIII of FIG. 17;

FIG. 19 shows a partial side view of two superimposed girder units;

FIG. 20 shows an end view of the superimposed girder units of FIG. 19;

FIG. 21 shows an end view of the point of connection of the lower boom with the upper boom of two superimposed girder units as shown in FIGS. 19 and 20, wherein these booms consist of tubular members of substantially rectangular cross section which are connected by other tubular members extending transversely thereto;

FIG. 22 shows an end view similar to FIG. 21 of a modification, in which the booms are of trapezoidal cross section;

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FIG. 23 shows a side view of a girder assembly consisting of a plurality of girder units of different lengths;

FIG. 24 shows a side view of another girder assembly likewise consisting of a plurality of girder units of different lengths and supported by a substructure of several individual and superimposed girder units;

FIG. 25 shows a side view of another girder assembly consisting of a plurality of girder units of different lengths and supported by a substructure of several individual girder units of different lengths;

FIG. 26 shows a side view of a girder assembly similar to that of FIG. 23 for forming a roof;

FIG. 27 shows a side view of a girder assembly consisting of a plurality of endwise-adjacent and superimposed girder units, and extending beyond the bearing pads;

FIG. 28 shows a side view of a girder assembly composed of a pair of underpinnings formed of vertical and diagonal girder units and centrally supporting a plurality of interconnected, slightly inclined upper girder units forming self-supporting arms;

FIG. 29 shows a side view of a girder assembly consisting of girder units of equal length which may be used, for example, during the construction of self-supporting hangar structures;

FIG. 30 shows a side view of a girder assembly composed of a plurality of superimposed girder units interconnected to form a low arch;

FIG. 31 shows a side view of a girder assembly forming a saw-tooth roof and composed of girder units of equal length;

FIG. 32 shows a side view of a girder assembly composed of a plurality of composite girders of different lengths;

FIG. 33 shows a side view of a girder assembly formed of a plurality of girders of equal length which may be used, for example, as a crane bridge;

FIG. 34 shows a partial side view of a terminal girder unit similar to that shown in FIG. 8;

FIG. 35 shows a cross section taken along line XXXV—XXXV of FIG. 34;

FIG. 36 shows a side view of the connecting end of an upper boom of a girder unit;

FIG. 37 shows a plan view of FIG. 36, in which the two yokelike connecting members are directly connected to each other;

FIG. 38 shows a side view of a modification of the manner of connecting two adjacent upper booms with each other;

FIG. 39 shows a plan view of FIG. 38;

FIG. 40 shows a plan view of the manner of connecting two yoke members on adjacent upper booms to each other;

FIG. 41 shows a plan view of a modification of FIG. 40;

FIG. 42 shows a plan view of a further modification of FIG. 40;

FIG. 43 shows a side view of a modified connecting element of a lower boom;

FIG. 44 shows a plan view of FIG. 43;

FIG. 45 shows a cross section taken along line XLV—XLV of FIG. 46 through a modified connection between two adjacent girder units;

FIG. 46 shows a plan view of FIG. 45;

FIG. 47 shows a cross section taken along line XLVII—XLVII of FIG. 46;

FIG. 48 shows a vertical cross section through two parallel stringers of C-shaped cross section which are interconnected by a spacing member of special design to form a boom;

FIG. 49 shows a perspective view of the spacing member according to FIG. 48, but seen from the opposite direction;

FIG. 50 shows a plan view, partly in cross section, of

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the connection of several girder units, wherein the girder units which are connected end-to-end are disposed at substantially right angles to the other girder units;

FIG. 51 shows a plan view of the connection of several girder units wherein two girder units extending within a straight line are disposed at an acute angle to the other two girder units;

FIG. 52 shows a side view of the connection of several girder units as shown in FIG. 50, with a connecting member extending from the upper booms to the lower booms;

FIG. 53 shows two turnbuckles crossing each other at right angles for a girder assembly in which the girder units extend at right angles to each other and the connecting member between the upper booms has a relatively low height and does not extend up to the lower boom; while

FIG. 54 shows a plan view of a modified connection of several girder units similar to FIG. 50.

Referring to the drawings, and first particularly to FIGS. 1 to 3, the girder units according to the invention comprise upper booms 1, lower booms 2, and diagonal brace bars 3 connecting the upper and lower booms. The cross-sectional shape of the upper and lower booms may be of different designs and, for example, of the designs as illustrated in FIGS. 9 to 11, and 20 to 22. The outer ends of both types of booms are provided with parallel flat connecting plates 4, 5, 6, and 7, respectively, which are secured thereto, for example, by welding. As shown in FIGS. 4 and 5, connecting plates 4 are secured to the outer surfaces of, for example, the left ends 1a and 1b of the upper boom 1, while plate 5 of, for example, the right ends of the upper boom 1, and also plates 6 and 7 of the lower boom are secured to the inner surfaces of the respective boom ends. Similar to the girder unit as shown in FIG. 1, the upper booms 1' and 1'' of the girder units according to FIGS. 2 and 3 have plates 4', 5', and 4'' and 5'', respectively, at their outer ends. The two stringers of each boom are interconnected at their ends by angle bars 9 and 10 which may, for example, also be welded thereto. The diagonal bars 3 may be, for example, of tubular construction, and the upper ends of the outer bars 3 of each girder unit are secured to angle bars 9 on upper booms 1, while the lower ends of these outer bars 3, as well as the lower ends of the next adjacent bars 3 are secured to angle bars 10 on lower booms 2. The upper ends of these next adjacent bars 3 and both ends of all other diagonal bars are secured directly to the upper and lower booms. The two stringers of upper boom 1 are spaced apart in parallel relation and rigidly connected to each other by tubular members 11. Each of plates 4 and 5 of the upper booms has a transverse hole 12, and each plate 6 and 7 of the lower booms of the girder units according to FIGS. 1 and 2 has two transverse holes 13, 14 and 15, 16, and 13', 14', and 15', 16', respectively, while each of plates 6'' and 7'' of the lower boom of the girder unit according to FIG. 3 only has one hole 13'' and 15'', respectively. Holes 12 serve for connecting together two abutting girder units of either the same or different lengths, and holes 14 and 16 for connecting the upper boom or upper booms of one or several lower girder units to the respective lower boom of an upper girder unit. Since plates 4' are likewise mounted on the outer surfaces of the left end of upper boom 1', and plates 5', 6', and 7' on the inner surfaces of the right end of boom 1' and on both ends of lower boom 2', respectively, the girder units may be simply connected to each other by aligning the axes of holes 14 and 16 with those of the corresponding holes 12', and by then inserting a bolt (not shown) into each of the then remaining two holes. The distance between the lower holes of the lower boom of an upper girder unit equals the distance between the holes of the upper boom of a lower girder unit. Therefore, if the distance between holes 14' and 16' of a lower boom 2' equals, for example, a value 2f, the distance between holes 12' of the upper boom 1' of the same girder unit and also

the distance between holes 14 and 16 of the lower boom 2 of a superimposed girder unit will be equal to a value 3f, and the distance between holes 12 of the upper boom of this upper girder unit will be equal to 4f, while the distance between holes 13' and 15' of the lowest girder unit does not necessarily have to equal a value of 1f.

In the same manner as above described in which the girder unit according to FIG. 2 is connected to the girder unit according to FIG. 1, it is also possible to connect the upper boom 1' of a girder unit according to FIG. 3 to the lower boom 2' of a girder unit according to FIG. 2. The lower booms 2 and 2' fit between the two stringers 1a and 1b of upper booms 1' and 1'' and are provided underneath the junction points of bars 3 with one or two suitably shaped bearing lugs 17 which then rest upon the tubular mounting members 11 of the upper booms 1' and 1''. The particular manner in which the respective lower boom of one girder unit may be engaged with the upper boom of the unit underneath will be described in detail further below.

If only two girder units according to FIGS. 1 and 2 are to be connected to each other in a superimposed position, and if similar girder units are to be connected to each other end-to-end, the lower booms of the joined girder units must be secured to each other by suitable connecting means which are adjustable in length so as to resist tension and compression stresses. Thus, for example, in this case, the connecting or bracing means, which will be later described in detail, would be connected to the girder unit according to FIG. 2 by means of bolts fitted into the holes 13' and 15''. If three girder units according to FIGS. 1, 2, and 3 are to be connected together above each other, the lower booms of adjacently connected girder units would be rigidly connected to each other by suitable truss members and bolts fitted into holes 13' and 15''.

These constructions will now be further explained with reference to FIG. 6 in which two girder units according to FIGS. 2 and 3 are connected one above the other, and a girder unit according to FIG. 2 is connected to another of the same kind at the adjacent ends of the upper booms thereof. The lower boom 2' is connected to the upper boom 1 of the lower girder unit by bolts 18 and 19. As shown in FIGS. 6 and 7, the two plates 4' of the upper boom 1' are slipped over the outside of plates 5' of upper boom 1' of the adjacent girder unit at the left which may, for example, form one terminal unit of the entire girder assembly. A bolt 20 is inserted through the four plates 4' and 5' and thus connects the upper booms of the two girder units with each other. The lower boom 2'' is connected to the lower boom 2' of the adjacent upper girder unit by means of an adjustable truss bar 21 which is resistant to tension and compression and may be of the type as shown in FIGS. 15 to 18. The two ends of truss bar 21 are brought into registry with holes 15' and 13' of plates 7' and 6'', respectively, into which bolts 22 and 23 are then inserted. Holes 16 of the two parallel plates 7' are therefore not needed in this arrangement.

If the girder unit shown at the left of the two superimposed girder units is intended to serve as a terminal unit of the girder, the left part of such girder unit would preferably be constructed as shown in FIG. 8. In this modification, the upper boom 1' does not have any connecting plates but has at its left end two holes 24 and 25. The free end of the adjustable boom extension 28 is adapted to be slipped between stringers 1' and has a series of holes 28' which are spaced from one another, for example, at one-half of the distance as the distance between holes 24 and 25 so that one pair of alternate holes 28' may at each time be brought into alignment with holes 24 and 25 for the insertion of two bolts 26 and 27.

At the other end of extension 28 a bearing bracket 29 is attached which can be adjusted vertically by means of a screw 30 or the like. A pair of connecting plates 34 are also secured to extension 28 and carry a bolt 21

which engages in a slot 32 formed in bearing bracket 29 so that bolt 31 and slot 32 limit the vertical adjustment of bracket 29. Screw 30 can bear either against the face of extension 28 or, as shown in FIG. 8, directly upon bolt 31.

The upper part 28 of the terminal support is connected to plate 6' of the lower boom 2' of the girder unit which is only partly shown in FIG. 8, by means of an adjustable truss bar 33 and bolts 35 and 36 which are inserted through coinciding holes in the bar and in connecting plates 34 and 6', respectively, after truss bar 33 has been adjusted to the proper length.

FIG. 9 illustrates how the lugs 17 of the lower boom of an upper girder unit engage and bear against the tubular cross members 11 of the upper boom of a lower girder unit. The lower boom 2' consists of a bar having a C-shaped cross section with its opening facing downwardly. Lugs 17 are welded to webs 39 and 40 of boom 2' and have semicircular cutouts which enable them partly to embrace the tubular connecting members 11 of the upper boom of the lower girder unit which consists of two bars or stringers 1a and 1b, each of a C-shaped cross section with the open sides thereof facing each other and rigidly connected to one another by members 11. The two opposite surfaces 37 and 38 of stringers 1a and 1b partly overlap the exterior webs 39 and 40 of the lower boom 2'. The diagonal bars 3 of the lower girder unit are welded to the two stringers 1a and 1b.

As shown in FIG. 10, the lower boom 2' may also be formed of L-shaped bars or stringers, the inwardly facing webs 41 and 42 of which bear against the exterior sides 43 and 44 of stringers 1b and 1a of the upper boom of the lower girder unit. In this construction, the L-shaped stringers should be interconnected by connecting members 45 of any desired cross-sectional shape, while the C-shaped stringers 1a and 1b are interconnected by tubular members 11 similarly as shown in FIG. 9.

The C-shaped stringers of an upper boom may, however, also be designed as shown in FIG. 11, in which case the upper webs 46 and 47 of stringers 1a and 1b are flush with the upper surface 48 of the C-shaped lower boom 2' of the superimposed girder unit, and in which the inwardly facing webs of each stringer 1a and 1b are of unequal length.

As shown in FIG. 12, the space between the inwardly facing webs 37 and 38 of stringers 1a and 1b may hold a plank 49 which rests upon the transverse members 11 and may serve as a catwalk on the uppermost girder units. Instead of the diagonals 3 consisting of tubular members, they may also consist of corrugated sheet metal braces 50 which connect either the upper boom stringers 1a and 1b or connecting members 11 to the upper surface of lower boom 2', as shown in FIGS. 13 and 14. The advantage in using corrugated sheet-metal braces is that they can be manufactured at a lower cost than rigid tubular members.

The construction of bracing truss members which are resistant to tension and compression is illustrated in FIGS. 15 to 18. A comparatively short bracing member consists of two parts 51, 52 and 53, 54, respectively, extending parallel to each other, each end of which is provided with a connecting plate 57, 58 and 59, 60, respectively, each having at least one transverse hole or bore 55, 56. Parts 51 and 52 are connected to each other by a bridge 61 provided with a threaded bore, while plates 57 and 58 are connected by a tubular member 62 which extends coaxially to bores 55. The tubular parts 53 and 54 are secured to each other by a bridge 63 which is provided with a threaded bore, while connecting plates 59 and 60 are connected similarly as plates 57 and 58, namely, by a tubular member 64. The two bridges 61 and 63 are interconnected by means of a threaded rod 65 provided with right-hand and left-hand threads, which may be turned by means of a suitable tool fitted on a square end 66.

If the truss member has to have a greater length than the one illustrated in FIGS. 15 and 16, parts 51', 52' and 53', 54' may be connected by a plurality of bridges at least at one of the two relatively movable parts. Thus, as shown in FIG. 17, parts 51' and 52' are interconnected by a bridge 61' and a tube 67, while parts 53' and 54' are interconnected by a bridge 63' and several tubes 68. If desired, connecting plates 57', 58' and 59', 60', respectively, may also be interconnected by tubular members. Instead of providing one hole in each plate, several holes may also be provided in the two plates of at least one part in order to permit a greater amount of adjustment of the relatively movable parts.

The modification as shown in FIGS. 19 and 20 illustrates how girder units mounted adjacent and above each other may be combined without the need of two holes in the lower booms or their connecting plates. In this case, each upper boom 69 and 70 of two superimposed girder units consists of two parallel tubular stringers 72, 73 and 72', 73', respectively, of substantially rectangular closed cross section which are connected with each other by means of tubular members 71 of substantially triangular cross section. The two ends of the two stringers 72 and 73 of the upper boom and the two ends of the lower boom 74 or 74', respectively, which likewise consists of a tubular member of a closed rectangular cross section, are provided with connecting plates 75, 76 and 75', 76', respectively, which are arranged in exactly the same manner as plates 4, 5, 6, and 7 of the girder units shown in FIGS. 1 to 3, and are also connected to each other by means of angle irons 9' and flat bars 10'. The diagonal bars 3 are welded to the angle irons 9' disposed on the connecting plates of the upper boom, and to the flat irons 10' which interconnect the plates of the respective lower booms, and also to the surfaces of the triangular tubular connecting members 71. Accordingly, superimposed girder units are joined together by connecting the two plates of the lower boom with the respective plates of the upper boom of the lower girder unit by means of a bolt 77 which also extends through the tubular stringers 72 and 73 of the upper boom and through the tubular member 74 of the respectively lower boom.

A lower boom of an upper girder unit may also be connected to the upper boom of a lower unit if the connecting plates 75, 76, or 75', 76' are entirely omitted. In that case, a hole may be provided in each end of the booms and the portions around these holes may be reinforced by annular disks 78, 79 and 80, 81, as shown in FIG. 21. The connection between the tubular stringers forming the upper boom may also consist of tubular members similar to members 71.

While in the girder units shown in FIG. 21, the upper boom parts and the lower boom parts have a closed substantially rectangular cross-sectional shape so as to permit a lower boom of an upper girder unit to be inserted from above into the upper boom of a lower girder unit, it is also possible to make the tubular members forming the booms of a substantially trapezoidal cross section, as shown in FIG. 22, so that a lower boom of an upper girder unit can be inserted into the upper boom of a lower girder unit only by slipping it from the side into such upper boom. In this case, it is also advisable to reinforce the individual boom parts by reinforcing rings 78' to 81', particularly if these parts are made of light metal.

FIGS. 23 to 33 illustrate a few examples of the manner in which the girder units according to the invention may be assembled so as to form girder assemblies of different shapes and for different purposes. In these drawings, the girder units according to FIG. 1 are identified by "A," girder units according to FIG. 2 by "B," and girder units according to FIG. 3 by "C." Naturally, the individual girder units may also be arranged in a different relation to each other, and they may also consist of units of a size and shape as shown, for example, in FIGS. 19 and 20. The terminal supports of a girder assembly are desig-

nated by "D," the bracing means, regardless of what length, by "E." These drawings are self-illustrative and need no further explanation. They show that, apart from the adjustable brace bars and terminals, only three different lengths of substantially similar girder units according to the invention need to be provided for easily assembling into various kinds of structures of any desired length or height, with the girder units disposed end-to-end, side-by-side, and one above the other.

While in the embodiment according to FIG. 8 the parts of the adjustable boom extension 28 on the bearing bracket 29 engaging into the opening between the two stringers of the upper boom of the terminal girder unit are spaced apart by means of flat bars, the two bars of the adjustable boom extension which are provided with a series of adjusting holes may also be combined with each other by means of at least two tubular members having an inner diameter substantially equal to the diameter of the adjusting holes in the bars, and by arranging each tubular spacing member so that its longitudinal axis coincides with the axes of two corresponding bores in the opposite bars. Such arrangement not only reduces the number of points to be welded but also results in a more rigid construction. This is illustrated in FIG. 34 which substantially corresponds to FIG. 8 and shows that the two parallel bars of the adjustable boom extension terminating in the bearing brackets 29 each consist of two flat bars 82, 83 and 84, 85, respectively. They are rigidly connected to each other by means of three tubular members 86, 87, and 88. The boom extension in this case also engages for a certain distance into the upper boom of the terminal girder unit and is secured thereto by a bolt (not shown). Although in FIG. 35 the inner diameter of the tubular members 86, 87, and 88 is equal to the diameter of holes 89 in bars 82, 83 and 84, 85, such inner diameter may also be made larger than the diameters of holes 89.

While the girder units as previously described and illustrated are provided with connecting plates 4, 5, 4', 5', 4'', 5'', etc., the girder units as shown in FIGS. 36 to 44 illustrate that, instead of such connecting plates, the booms may also be provided with bifurcated connecting members or yokes.

In FIGS. 36 and 37, yoke 90, the two webs 91 and 92 of which have coaxial holes 93 and 94, is butt-welded to one end of a stringer 95 of, for example, C-shaped cross section. The same is true for yoke 97 which is secured to stringer 98. The two webs 91 and 92 of each yoke 90 and 97 are preferably combined with each other at their lower sides by means of a flat bar 99 which is welded to the webs of the yokes and also to the cross-pieces thereof. The two yokes connected by a flat bar may also be manufactured as a single unit. The diagonal bars 100 connecting the two stringers 95 and 98 of the upper boom with the stringers of the lower boom, after being properly tapered at the ends, are preferably welded to the respective flat bar 99 so that the axis 101 of the respective diagonal bar intersects with the axis 102 of holes 94 and 95. The neutral axis 103 of stringers 95 and 98 should likewise intersect with the axis 102 of the holes. If the webs of the two yokes 90 and 97 are then connected by a flat bar 99, the upper booms will not be required to have any spacing means at their connections to adjacent booms.

Referring to FIGS. 38 and 39, the force-transmitting means provided at the other end of the upper boom consisting of stringers 95' and 98' may be designed either so as to engage between the two webs 91 and 92 of the two yokes or, if they have the same shape as yokes 90 and 97, so as to engage with one web into a similar yoke, while the other web rests on the outside of one of the two webs of the other yoke. FIGS. 40 and 42 show yokes 90'', 90''', 90''', 90'' of this kind which are secured to the ends of two adjacent girder units. Bolt 107 in FIG. 40 is acted upon by double-shear stresses, while in FIG. 42 it is acted upon by triple-shear stresses. In the latter case,

the web of yoke 90^V of one girder unit 95'' which engages between the webs of yoke 90^{IV} of the other girder unit 95'', fills out the space between the two webs almost completely. It is then merely necessary to mount the yokes on the respective girder units in the properly offset relation. The yokes may, however, also be disposed as shown in FIG. 41 so that one yoke 90^{IV} laterally embraces the other yoke 90^{VI}.

If yokes 90' and 97' are connected with each other by an angle iron 99', as shown in FIGS. 38 and 39, it is advisable to notch such angle iron so as to have surfaces 104, 105 which will abut against the corresponding surfaces of stringers 95' and 98' of the upper boom and may, if desired, be welded thereto. FIG. 39 shows that one end of each stringer 95' and 98' has a yoke 90' and 97', respectively, rigidly secured thereto, while the other end carries an angle iron 106 which is reinforced at both sides around its holes 94' and 95'. Angle irons 106 are preferably secured to the stringers of the upper boom by welding. A bolt 107 passes through the bores in yokes 90' and 97' and in angle irons 106, and this bolt is provided at one end with a handle bar 108 and a lug 109 which is adapted to be inserted into a resilient strap 111 mounted at 110 so as to lock bolt 107 against accidental removal.

The connecting means, whereby the lower booms of adjacent girder units may be connected with each other by means of bolts and elements which are adjustable in length, may also be of a bifurcated shape. A preferred construction of such yoke members to be mounted on the lower booms of girder units is illustrated in FIGS. 43 and 44. Each yoke member which is welded to the two ends of the stringers of a lower boom of a girder unit consists of two heads 112 and 113 which are interconnected by a crosspiece 114 to form a single unit. The upper surface of each head 112 and 113 forms two surfaces 115 and 116 which are inclined relative to each other so as to permit diagonal bars 117 and 118 to be secured to each surface 115 and 116, preferably by welding.

The crosspiece 114 is designed so that its lower lateral surface 119 may be placed upon two webs of two angle irons 120 and 121 forming the lower boom, which webs are disposed within the same horizontal plane. Surface 119 is further disposed, as shown in FIG. 43, so that the neutral axes 122 of the two angle irons 120 and 121 intersect with the axis 123 of the two bores 124 and 125 provided in heads 112 and 113. Diagonal bars 117 and 118 are preferably likewise welded to heads 112 and 113 so that their neutral axes likewise intersect the axis 123 of bores 124 and 125. The lower surfaces of yoke heads 112 and 113 are provided with at least one reinforcing bulge, preferably two bulges 126 and 127, so that the thickness of the walls of the heads may be reduced around the bores, while the heads themselves will still be of adequate strength. After the two yokes on the ends of the same lower boom have been arranged so that their axes 123 are at the proper distance from another, each yoke is welded to the stringers forming the lower boom along several edges thereof, for example, along edges 128, 129, and 130, whereupon the diagonal bars 117 and 118 are also welded upon surfaces 115 and 116. Obviously, the same yoke member may also be used for lower booms which consist of a single member, for example, of a U-shaped section.

The bolts to be used for connecting the end plates, yoke members, and the like of adjacent or superimposed girder units to each other may also be secured in a simple manner to one of these units as illustrated in FIGS. 45 to 47. One end of bolt 133 is provided with a lever 134, the longer end of which serves as a handle, while its shorter end 135 is bent into U-shape at points 136 and 137 relative to lever 134 and serves as a lock member. Lever 134 may form a single flat strip of metal which is welded to bolt 133 at the bent points 136 and 137. One

of the boom parts to be connected, for example, part 132, carries a lock strap, in this case a bent leaf spring 138, which is welded to part 132 along three edges, as shown at 139.

If two or more parts, which are to be connected by a bolt or the like, are in their proper relative position, it is merely necessary by holding the bolt in handle 134 to insert the bolt into the bores of the respective parts 134 until the lock member 135 engages against the outer surface of part 132, and then to turn the bolt about its axis so that the lock member 135 engages between the lock strap, i.e. in this case spring 138, and the outer surface of part 132. Bolt 133 may again be unlocked for possible removal by proceeding in the reverse order.

The stringers forming the upper and lower booms of the girder units as previously described and illustrated are connected to each other by means of flat iron bars, bars of hollow cross section or tubular elements, wherein it is immaterial whether such sectional bars are of open or closed cross section.

According to a modification as shown in FIGS. 48 and 49, each member between the two stringers of each boom consists of an angle iron, the two main webs 140 and 141 of which are disposed vertically to each other. The two ends of web 141 are shortened so that this web has a length a between the two end surfaces 142 and 143 which is substantially equal to the distance a_1 between the opposite surfaces 144 and 145 of the C-shaped stringers 146 and 147. The two ends of the other web 140 of the angle iron 140, 141 are bent at an angle of 90° to web 140 and in the opposite direction to web 141, and so that the distance c between the opposite surfaces 148 and 149 of the two upwardly-bent ends is substantially equal to the distance a_1 plus twice the thickness b of the wall of one of the two stringers 146 or 147. This distance c is therefore equal to $a_1 + 2b$. These spacing members are then welded to stringers 146 and 147 so that each end of one spacing member is rigidly secured to one of the two stringers at least along two surfaces 142 and 150 or 143 and 151, respectively, which are vertically disposed to each other.

By designing the spacing member in such a manner, the advantage will be attained that, if the upper boom of a trapezoidal girder unit is formed of two sectional stringers, the spacing members can be used not only for supporting a string of a lower boom of one girder unit upon the upper boom of a lower girder unit, but also for supporting planks to serve as catwalks, if the respective girder unit provided with such spacing members forms the uppermost girder unit of a substantially level girder assembly.

If a plurality of girder units according to any of the embodiments as previously described are to be combined into a girder assembly which is capable of transmitting the forces acting thereon in several directions extending at an angle to each other, this may be done by providing the points of connection of adjacent girder units extending within the same plane with connecting means for similar girder units which extend in a plane at an angle to the plane of the other girder units.

In order to simplify the illustration, FIGS. 50 to 54 only show girder units which are adapted to be connected to each other, although it is to be understood that these instructions are not restricted to such girder units but are also applicable to such girder assemblies, the girder units of which are connected end-to-end or one above the other. If, for example, the four girder units I, II, III, and IV, as shown in FIG. 50, are to be combined into a girder assembly, the ends of each unit may be connected to a connecting element which consists, for example, of two U-irons which are welded together to form a single unit. The connecting element formed of the two U-irons 152 and 153 is provided with a connecting plate or the like 158, 159, 160, and 161, on each of its four surfaces 154, 155, 156, and 157, respectively. The distance between

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the connecting plates 158 and 159 is smaller than the distance between the opposite connecting plates 160 and 161 since the connecting plates 162, 163, 164, and 165 on each of the two ends of girder units I to IV are also differently spaced from each other. Each plate 158 to 161 and also each plate 162 to 165 is provided with a bore through which a bolt may be inserted. The axes of the bores or bolts are designated by 166. It is to be understood that, instead of connecting plates, connecting yokes or other equivalent members may be provided which should then preferably be welded to the stringers 167 and 168 forming the upper booms. These stringers 167 and 168 may be sectional irons of an open or closed cross-sectional shape, and each pair of parallel stringers 167 and 168 may be combined by several spacing members 169 and be connected to the lower boom or booms 170 by means of diagonal bars 171 and 172, as shown in FIG. 52.

If two substantially level girder units or girder assemblies are to intersect at an acute angle, the connecting element must be designed accordingly, as shown, for example, by the connecting element 173 in FIG. 51, in which the parts which are similar to those in FIG. 50 are identified by the same reference numerals. If more than two level girder units or girder assemblies are to cross at the point of one connecting point, the connecting element 173 may be provided with additional connecting plates or the like on surfaces 174 or 175, or the connecting element may be made of a different shape in accordance with the angle at which the girder units are to cross each other.

Each connecting element according to FIGS. 50 or 51 may be made of such height that its upper and lower surfaces terminate within the limits of the upper booms. The connecting element may, however, as shown, for example, in FIG. 52 also be made of such height that its upper surface lies within the level of the upper booms, while its lower surface lies within the level of the lower booms of the adjacent girder units. In this case, only two girder units extending within the same plane are connected to the connecting element 176 at the level of the upper booms by adjustable connecting means, such as turnbuckles 177 and 178. Each turnbuckle 177 and 178 is secured at one end by a bolt 179 to lower boom 170 of one of the adjacent girder units, and by a bolt 180 to the connecting plates 181 or 182 on element 176. By turning the turnbuckle in one direction or the other it will be possible to incline the position of the individual girder units or their upper booms relative to each other so that the entire girder assembly can thus be given the desired shape.

If a connecting element is merely provided on the upper booms, the lower booms of the intersecting girder units may be connected with each other by two turnbuckles which must pass through each other if the neutral axes of the four intersecting girder units are to extend within the same plane. It is then advisable to design one turnbuckle 183 as shown in FIG. 53 so that the other turnbuckle 184 can extend through the central aperture 185 in turnbuckle 183. If the neutral axes of the four girder units do not extend within the same plane, but, for example, the two neutral axes of two girder units which are disposed within the same vertical plane extend within one straight line, while the neutral axes of the other girder units which are disposed at an angle of 90° to the first units extend within two intersecting straight lines, then it will not be necessary that the turnbuckles connecting the lower booms of the four girder units pass through each other since in that case they will be disposed above each other, so that the same type of turnbuckles may then be used on all girder units.

As shown in FIG. 54, bolt 186, which pivotally connects the connecting plates 162 and 163 on the upper boom of an adjacent girders unit, may be provided with a yoke member 187, the two heads 188 and 189 of which may be secured to the connecting plates 162 and 163 of a

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third girder unit. The stringers 167 and 168 of the two upper booms of two connected girder units which extend within a vertical plane are each provided with a connecting plate or the like 190 or 191 which also has a bore so that a bolt 192 may be inserted through the bores of connecting plates 190, 191 and 164, 165 and be suitably locked from falling out. It is also advisable to provide spacing plates 193 between the yoke member 187 and stringer 167, on the one hand, and connecting plate 163, on the other hand, and preferably to secure them to yoke member 187, so that the forces to be transmitted through yoke member 187 will be directly transmitted to the girder units extending transverse to the yoke member. Instead of providing connecting plates 190 and 191, bolt 186 may also be provided with another yoke member 194, indicated in FIG. 54 in dotted lines, which may be removably secured to the bolt by a pin 195 which is needed in any event for preventing bolt 186 from falling out. Bolt 186 may therefore be of almost symmetrical shape, except for the fact that one of the two yokes 187 and 194 is wider than the other and that one of them, for example, yoke 194, is removably secured to bolt 186.

Obviously, the connecting elements may also be of a different design than illustrated and above described, and they may, for example be of hollow cylindrical shape.

Although my invention has been illustrated and described with reference to the preferred embodiments thereof, I wish to have it understood that it is in no way limited to the details of such embodiments, but is capable of numerous modifications within the scope of the appended claims.

I claim:

1. A structural supporting member comprising at least two girder units; each girder unit comprising an upper boom and a lower boom which is shorter than the upper boom, two diagonal bars connecting the end portions of the booms giving the girder unit a trapezoidal shape, a plurality of intermediate diagonal bars alternately extending in different directions connecting the upper boom with the lower boom and forming with the booms and diagonal bars at the ends a plurality of isosceles triangles, said parts of each girder unit are rigidly connected; said upper and lower booms of each girder unit having apertures at the four outer corners for the insertion of connecting elements for connecting one girder unit to other similar girder units in an end-to-end and in superimposed relation; one of said booms of each girder unit at least partly embracing the other boom of another girder unit and attached by two connecting means to said other boom of said second girder unit, said structural member formed of said two girder units having the shape of a trapezoid and connectable at its four corners to similar girder units, whereby every end of the upper boom of said structure member is connectable directly with an upper boom of another girder unit, while each end of the lower boom of said structure is connectable over an adjustable truss bar with a lower boom of another girder unit.

2. A structural supporting member comprising at least two girder units; each girder unit comprising an upper boom and a lower boom which is shorter than the upper boom, two diagonal bars connecting the end portions of the booms giving the girder unit a trapezoidal shape, a plurality of intermediate diagonal bars alternately extending in different directions connecting the upper boom with the lower boom and forming with the booms and diagonal bars at the ends a plurality of isosceles triangles, said parts of each girder unit being rigidly connected; said upper and lower booms of each girder unit having apertures at the four outer corners for the insertion of connecting elements for connecting one girder unit to other similar girder units in an end-to-end and superimposed relation, each diagonal end bar of a girder unit having a neutral axis which coincides with the centers of the apertures and the neutral axis of the engaged upper and lower booms also being coincident with the centers of the apertures,

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one of said booms of each girder unit at least partly embracing the other boom of another girder unit and attached by two connecting means to said other boom of said second girder unit, said structural member formed of said two girder units having the shape of a trapezoid and connectable at its four corners to similar girder units or structural members, whereby every end of the upper boom of said structure member is connectable directly with an upper boom of another girder unit, while each end of the lower boom of said structure is connectable over an adjustable truss bar with a lower boom of girder unit.

3. A structural supporting member comprising at least two girder units; each girder unit comprising an upper boom and a lower boom which is shorter than the upper boom, two diagonal bars connecting the end portions of the booms giving the girder unit a trapezoidal shape, a plurality of intermediate diagonal bars alternately extending in different directions connecting the upper boom with the lower boom and forming with the booms and diagonal bars at the ends a plurality of isosceles triangles, said parts of each girder unit are rigidly connected; said upper and lower booms of each girder unit having apertures at the four outer corners for the insertion of connecting elements for connecting one girder unit to other similar girder units in an end-to-end and superimposed relation; each diagonal end bar of a girder unit having a neutral axis which coincides with the centers of the apertures and the neutral axis of the engaged upper and lower booms also being coincident with the centers of the apertures, one of said girder units being attached by two connecting means to said second girder unit so that the lower boom of one girder unit is in groove and tongue engagement with the upper boom of the other girder unit, said structural member formed of said two girder units having the shape of a trapezoid and connectable at four corners to similar girder units, whereby every end of the upper boom of said structure member is connectable directly with an upper boom of another girder unit, while each end of the lower boom of said structure is connectable over an adjustable truss bar with a lower boom of another girder unit.

4. A structural supporting member comprising at least two girder units; each girder unit comprising an upper boom and a lower boom which is shorter than the upper boom, two diagonal bars connecting the end portions of the booms giving the girder unit a trapezoidal shape, a plurality of intermediate diagonal bars alternately extending in different directions connecting the upper boom with the lower boom and forming with the booms and diagonal bars at the ends a plurality of isosceles triangles, said parts of each girder unit are rigidly connected; said upper and

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lower booms of each girder having apertures at the four outer corners for the insertion of connecting elements for connecting one girder unit to other similar girder units in an end-to-end and superimposed relation; each diagonal end bar of a girder unit having a neutral axis which coincides with the centers of the apertures and the neutral axis of the engaged upper and lower booms also being coincident with the centers of the apertures, said upper boom of each girder unit embraces the lower boom of another girder unit and being attached by two connecting means with the lower boom of said superimposed girder unit so that the lower boom of one girder unit is in groove and tongue engagement with the upper boom of the other girder unit, said structural member formed of said two girder units having the shape of a trapezoid and connectable at its four corners to similar girder units or structural members, whereby every end of the upper boom of said structure member is connectable directly with an upper boom of another girder unit while each end of the lower boom of said structure is connectable over an adjustable truss bar with a lower boom of another girder unit.

5. A structural supporting member as defined in claim 4, wherein the upper boom of each girder unit forms a recess extending along the entire length of said boom for embracing the lower boom of another girder unit.

6. A structural supporting member as defined in claim 5, wherein the upper and lower booms of each girder unit have a closed tubular cross section of rectangular shape.

7. A structural supporting member as defined in claim 5, wherein the upper and lower booms of each girder unit have a closed tubular cross section of a trapezoidal shape.

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