June 25, 1940. C. J. KAVANAGH 2,205,725

BEAM STRUCTURE

Filed Oct. 6, 1936 3 Sheets-Sheet 1

Fig. 1

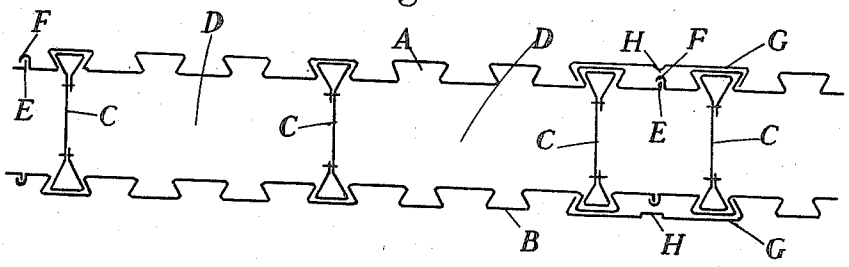


Fig. 2.

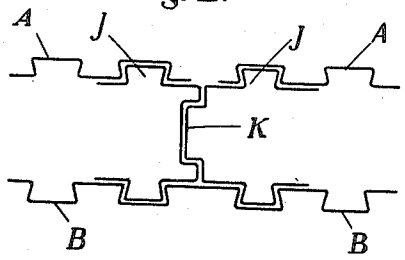


Fig. 3.

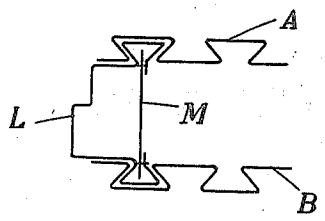


Fig. 4.

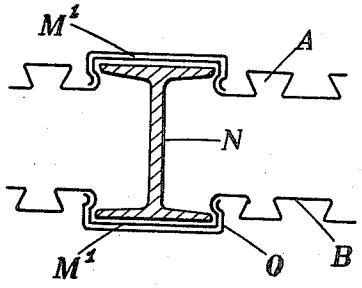


Fig. 5

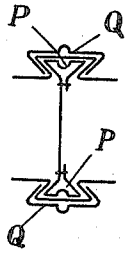


Fig. 6.

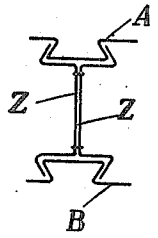
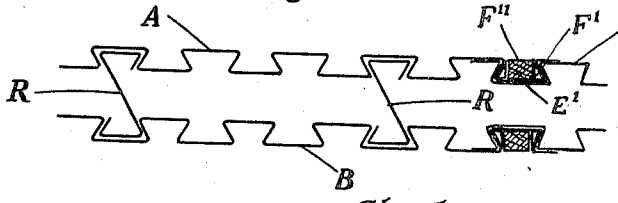


Fig. 7.



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June 25, 1940. C. J. KAVANAGH 2,205,725

BEAM STRUCTURE

Filed Oct. 6, 1936 3 Sheets-Sheet 2

Fig. 8.

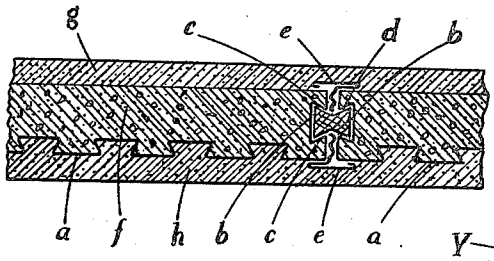


Fig. 9.

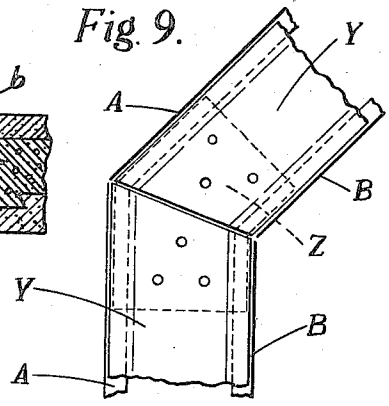


Fig. 10.

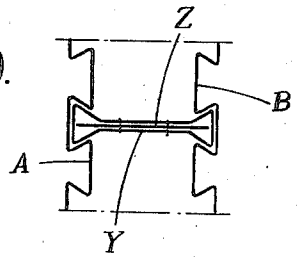
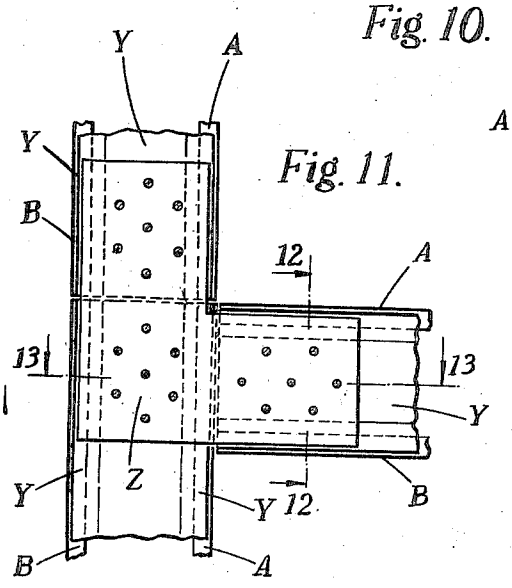


Fig. 11.



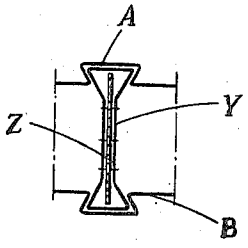


Fig. 12.

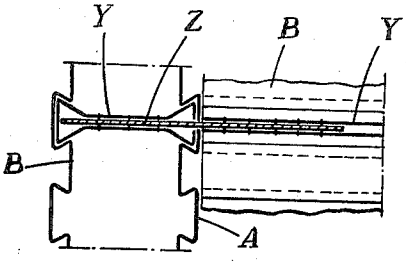


Fig. 13.

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June 25, 1940. C. J. KAVANAGH 2,205,725

BEAM STRUCTURE

Filed Oct. 6, 1936 3 Sheets-Sheet 3

Fig. 14.

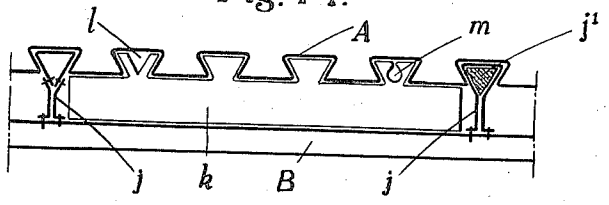


Fig. 15.

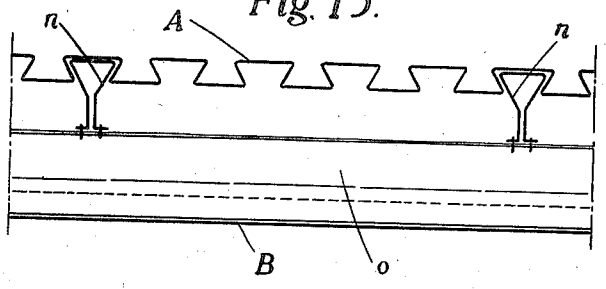


Fig. 16.

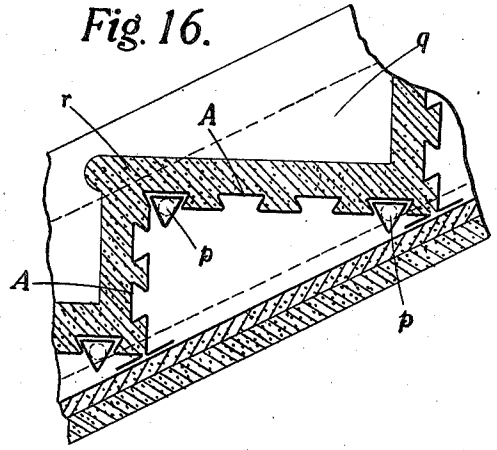


Fig. 17.

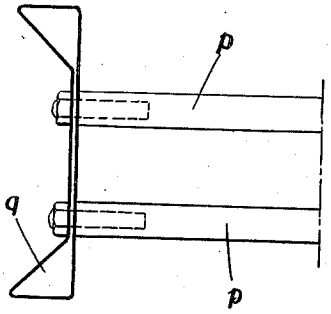
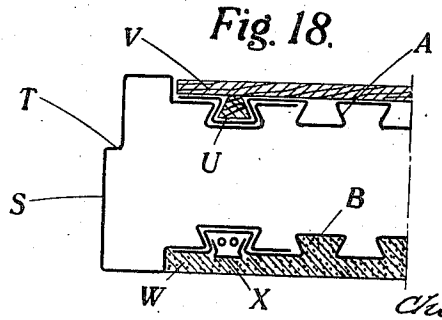


Fig. 18.



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Patented June 25, 1940 2,205,725

UNITED STATES PATENT OFFICE

2,205,725

BEAM STRUCTURE

Charles Joseph Kavanagh, London, England

Application October 6, 1936, Serial No. 104,321
In Great Britain October 17, 1935

12 Claims. (Cl. 72—70)

This invention relates to constructional means and more especially to constructional beam units employing steel or other sheets in such a manner as to give a cellular form of construction or a single sheet form of construction with simplified connections.

The object of the invention is to provide a form of metal beam construction employing metal sheets with undercut corrugations in which the web members and flanges act as a composite beam unit resisting bending stresses and so provide a construction of great strength and light in weight. It is well known, for example, that a light beam section subject to bending stresses generally fails by local buckling at the point of maximum moment, but in my construction, in which the beam or web stiffening members are securely interlocked with the flange sheet or sheets, a lateral restraint is provided which hinders such local buckling as well as considerably increasing the moment of resistance of the composite section in relation to that of the separate sheets and by the proper disposition of such members leads to a form of stressed skin construction which is highly efficient.

Similarly, in the case of vertical beam members the flanges provide restraint against the local buckling of the interlocked internal web members, when under compressive stress, thus leading to an exceptionally strong form of box column construction.

In all cases, whether as horizontal or vertical members, the invention provides a form of construction whose weight efficiency ratio is very high, the strength of which is not dependent upon concrete surfacings.

From another aspect the invention provides a form of undercut corrugated sheet metal construction which comprises its own framing and thus enables walls, floors and roofs to be compositively constructed without additional framing members. Thus, for example, the vertical stiffening web elements of wall units and the horizontal stiffening web elements of floor or roof units are easily connected together at their junctions. The invention enables forms of construction to be carried out in which the flange and interlocked web members provide a structural continuity, such as, for example, in curved building constructions such as roofs.

In the carrying out of the invention the dovetail corrugations in the sheets and the interlocking web stiffeners are preferably rolled so that the constituent parts can be manufactured to tolerances which insure a gripping fit when it will be found that additional means of securing the constituent elements to one another will be reduced to a minimum. Where, however, in order to transmit high local stresses, such as, for example, the shear stresses in beam units, additional means of attachment are necessary, this is provided by welding, or other suitable means.

In my invention the web members are best formed with triangular flanges symmetrical with the web, and such triangular flanged web members may be of sheet metal or solid rolled sections, but in certain cases, such as in the construction of walls, the member may have open triangular flanges.

The metal sheets may be perforated or expanded between undercut corrugations.

Other objects and advantages of the present invention will be apparent from the following description and the accompanying drawings forming a part of this specification, the new or improved features, arrangements and combinations of which form parts of the invention.

In the drawings:

Fig. 1 shows a cross-section through a constructional unit,

Figs. 2 and 3 show forms of end enclosure elements,

Figs. 4, 5, 6, 7 and 8 show modified forms of end supports or intermediate stiffeners,

Figs. 9 and 11 show elevations and Figs. 10, 12 and 13 plans respectively, of connections for mutually inclined stiffeners.

Figs. 14 and 15 show two similar forms of construction employing spaced dovetailed sheets with their dovetails running in directions at right angles to one another,

Figs. 16 and 17 show a sectional elevation and a detail respectively of the application of the constructional beam units of the invention to stair units, and

Fig. 18 shows a form of constructional beam having an end stiffener which serves as a door frame.

Referring to the drawings, in which like references refer to similar parts throughout all the figures, Fig. 1 shows a cellular unit, comprising an upper dovetailed corrugated metal sheet A spaced from a similarly formed lower metal sheet B by sheet metal stiffeners C having straight web portions and hollow triangular section flanges. These stiffeners C divide the unit into a series of hollow beams D.

Where the width of the structure is greater than that of the unit, such for instance as will be the case in a floor, roof or wall, several units

are employed side by side. In the construction shown in Figure 1 a series of units are employed and the upper and lower sheets have an upturned flange E along one end and a bent over flange F along the other end. The flanges of adjacent sheets interengage and are preferably welded together. The joints are covered and strengthened by sheet metal cover plates G. These have inclined sides to engage with the dovetails of the sheets A and they are provided with grooves H to facilitate placing them in position. Stiffeners C are preferably placed, as shown, in the end dovetailed corrugations of each sheet.

Figure 2 shows a modified form of joint between two units in which, instead of the form of stiffeners C shown in Fig. 1, sheet metal members J are provided. These have dovetailed flanges to engage with the corrugations of the spaced sheets A and B, and web portions of complementary outline to form a spigot and socket joint J between the units.

Figure 3 shows a further form of stiffener, which combines the two forms shown in Figures 1 and 2 respectively. This form comprises a sheet metal member L, with hollow dovetailed flanges and a stepped web, which is secured, preferably by welding, to a metal sheet or strip M which passes into the hollow dovetails. A similar shape of stiffener may alternatively be formed from a sheet metal member similar to the member C shown in Figure 1 secured over its web portion to a wooden block, the free side of which is stepped.

Figure 4 shows a modification in which opposite corrugations M^1 of the upper and lower metal sheets A and B are widened to receive the flanges of a solid I-beam N. These corrugations are undercut by providing a beaded neck, instead of being dovetailed, and cover plates or clips O with beaded rims are preferably also provided.

Figure 5 shows a form of stiffener similar to the stiffener C shown in Figure 1 except that an internal bead P is formed in each hollow flange in order to facilitate inserting the stiffener in position. Beaded cover plates or clips Q are also provided.

In the modification shown in Figure 6 the stiffener comprises two metal sheets 7 welded together over their webs and having open dovetailed section flanges to encircle an inwardly extending dovetail of the upper sheet A.

In the construction shown in Figure 7 the upper and lower sheets A and B are stiffened by sheet metal members R of substantially Z-shaped section with open dovetailed flanges engaged in the corrugations. Instead of open flanges, as shown, closed triangular flanges may be provided, in which case the free ends of the flanges will preferably be welded to the web, thus providing stiffeners similar to the stiffeners C shown in Figure 1, but with inclined webs.

Figure 8 illustrates a modified form of stiffener which is shown used with a single sheet form of construction, but which may similarly be used with spaced sheets. Adjacent ends of dovetailed corrugated metal sheets *a*, *a* are bent up at right angles to the main portions of the beams, as shown, to form portions *b*, *b*. The corrugations of the two portions *b*, *b* respectively are connected by solid or hollow stiffeners *d* having dovetailed flanges *c*, *c* which interlock with the dovetails *b*, *b*. Sealing strips *e*, *e* are placed between the adjacent upturned portions of the sheets *a*, *a*. Each sheet *a* forms a trough which is filled with concrete *f* and this is covered by a screeding or other finish *g* in which the end of the upper strip *e* is embedded. The end of the lower strip *e* is embedded in plaster *h* which forms the ceiling finish. This form of stiffener may be used in a cellular form of construction in which case the concrete fill will be omitted and the upper sealing strips will preferably be interlocked in the corrugations of an upper metal sheet, the corrugations running either in the same direction, or at right angles to, the lower metal sheet *a*.

Figures 9 and 10 show a method of connecting inclined units, for example a roof and wall members. Both the roof and the wall units are made from spaced dovetailed corrugated sheets A, B and they are connected by a hollow webbed stiffening member Y with dovetailed flanges. The web portion is formed of two spaced laps of sheeting and a central gusset plate Z welded or otherwise secured thereto which extends through the hollow flanges of members Y to be joined.

Figures 11 to 13 show a similar construction for connecting units positioned at right angles to each other. In this form the sheet A and flange of the member Y abutting the joint are slotted to permit the leg of the gusset plate Z to pass therethrough.

Figure 14 shows a construction in which the upper and lower sheets A, B respectively have dovetailed corrugations running in directions at right angles to each other and they are connected by stiffeners *j* to form a grid-like structure with interlocking flanges. The stiffeners *j* may, for example, be formed with hollow closed flanges, and hollow webs welded thereto, as shown at the left of Figure 14, or with a hollow flange and web formed from a single blank as shown on the right of Figure 14. This may be provided with a filling of concrete j^1, or of wood or other material. The lower ends of the stiffeners *j* are welded to the lower sheet B.

Figure 14 also shows a transverse stiffening plate *k* extending between adjacent stiffeners *j*. The plate *k* has a dovetailed upper edge to engage in the corrugations A and one or more of the dovetailed projections are preferably provided with cut-out portions of shapes, such as *l* or *m*, to give resilience and permit a wedging action. This transverse stiffener may also be employed with other forms of construction in accordance with the invention where this is desirable, but is shown in this figure for sake of convenience.

Figure 15 shows a construction similar to that of Figure 14, but a double set of stiffeners *n*, *o* arranged at right angles respectively are provided. The stiffeners are connected together, preferably by welding, at approximately the neutral axis of the beam.

The constructions shown in Figures 14 and 15 may either form in themselves cellular beam units, or they may be used as one composite sheet where stronger constructions are required.

Figure 16 shows a stair unit in which the dovetailed sheet A is cranked to form the tread and riser of the stair and the sheet A is stiffened by triangular section rods *p* which interlock with the dovetails of the sheet A. The rods *p* are secured to the stringers *q* as shown in Figure 17. A stair surfacing *r* of concrete or other material is shown. In certain cases the sheet A may be used as the tread surface itself, and for a stronger construction a composite sheet comprising

for example two dovetailed sheets with the corrugations running either in the same direction, or at right angles to each other, may be employed.

Figure 18 shows a sheet metal stiffening member S for the members A and B, somewhat similar to the members K shown in Figure 2, but provided with only a single step, shown at T, in the web portion. This member S forms an end enclosure for the unit, and serves as a door frame. Two methods of surface treatment are shown in this figure: wooden supports U of dovetailed section are laid in the corrugations of the sheet A and boarding or plaster board V is laid across the support U and secured thereto. A plaster treatment W is shown on the sheets B, and one or more of the corrugations are preferably closed by caps X before plastering to leave conduits for electric cables and like services.

Instead of the joint between two sheets being of the form shown at E, F in Figure 1, the outermost corrugations of adjacent sheets may be nested together as shown at E^1 in Figure 7 and secured by wedging devices comprising two wedge elements F^1 and a rectangular element F^{11} of width equal to the minimum width of dovetail: this wedging device is not new in itself and could be substituted by other known devices, such as a dovetailed piece formed with a recess to permit a wedge to press the said piece in tight contact with the dovetailed sheet: or a dovetailed piece with a horizontal or vertical slot or with a circular aperture to permit a rectangular or circular wedge element to press the piece into tight contact with the sheet. Such connection pieces may carry a wooden or other fill for the purposes of nailing or screwing thereto and either of the wedging elements or parts thereof may be prolonged sufficiently to serve as connections to another such element or to units to be joined: or a mushroom or truncated cone shaped piece may be inserted in the dovetails and caused to grip by wedges or by screws, bolts and the like. Another form of connection or anchorage for connection is provided by the use of an element which comprises a support which can be introduced into the dovetail on its longitudinal axis and turned at right angles so as to engage into the dovetail transversely such support being then held tightly in place by the use of a screw or bolt and a cover piece seating on the sheet. Such cover pieces may be of sufficient length to be attached to another unit of a construction or to a similar clip or anchorage in another unit. In an alternative form the anchorage may consist of arms mounted on a bolt in such a manner that they can readily be inserted into the dovetail and afterwards wedged to the dovetail by a taper formation on the bolt head which causes the arms to extend when screwed up.

In the application of the invention to a wall composed of a number of cellular units, door and other openings are conveniently formed of end enclosure elements as previously described with the web projections serving for the jambs of window and doors. Alternatively in the case of window openings the construction may comprise a composite jamb and sill element welded or otherwise secured to a vertical dovetailed piece or pieces registering into the dovetails of the wall unit.

I claim:

1. A series of light weight composite constructional beams each including spaced metal sheets having longitudinally ranging outstanding corrugations, stiffening members bridging the space between the sheets and interlocking with the corrugations, and caps bridging the meeting ends of the beams and interlocking with the corrugations adjacent such meeting ends.

2. A series of light weight composite constructional beams each including spaced metal sheets having longitudinally ranging outstanding corrugations, stiffening members bridging the space between the sheets and interlocking with the corrugations, and members interlocking with the final corrugation of each of two adjacent beams, said members bridging the space between the plates of each beam and formed with complementary stepped portions to interengage for a strain resisting connection between adjacent beams.

3. A light weight composite constructional beam comprising in unit combination spaced metal sheets having undercut corrugations running in the direction of the length of the beam and forming tension and compression flanges of the beam, a metal stiffening member adjacent to each end of said metal sheets and at least one metal stiffening member between said end stiffening members, said stiffening members all extending longitudinally of the corrugations, bridging the space between the sheets and interlocking with corrugations in the respective sheets to cause said members to form multiple webs of the composite beam.

4. A light weight composite constructional beam comprising in combination metal sheets arranged in series each having an undercut corrugation running in the direction of the length of the unit constituting a flange of the composite beam, a metal stiffening member terminally provided with a triangular head to fit within and interlock with the said undercut corrugation, said stiffening member extending from the apex of the triangular head, the adjacent sheets having flanged edges which abut and are connected together.

5. A light weight composite constructional beam comprising in combination metal sheets arranged in series each having an undercut corrugation running in the direction of the length of the unit constituting a flange of the composite beam, a metal stiffening member terminally provided with a triangular head to fit within and interlock with the said undercut corrugation, said stiffening member extending from the apex of the triangular head, and caps bridging the meeting ends of the sheets with end walls shaped to interlock with corrugations of the adjacent sheets.

6. A light weight composite constructional beam comprising light weight spaced sheets provided with undercut corrugations running in the direction of the length of the beam, stiffening members which extend longitudinally of the corrugations to serve as the web of the unit, the said stiffening members being terminally provided with triangular-shaped heads which interfit with the corrugations in the sheets and substantially center the members transversely of and with respect to the corrugations, the stiffening members being formed with a stepped portion to interlock with a complementary stepped portion of an adjacent member.

7. A light weight composite constructional beam comprising in unit combination a metal sheet forming the flange of the beam and having a plurality of undercut corrugations running in the direction of the length of the beam, and

a plurality of spaced metal stiffening members separate from one another and from the said metal sheet, the said stiffening members each extending longitudinally of the corrugations and being terminally provided with a head to fit within and interlock with an undercut corrugation in the said sheet to cause the said members to form multiple webs of the composite beam which is complete in itself and resistant to bending stresses.

8. A light weight composite constructional beam comprising in unit combination, a metal sheet forming the flange of the beam and having a series of dovetailed corrugations running in the direction of the length of the beam, and a plurality of spaced metal stiffening members separate from one another and from the said metal sheet, the said stiffening members each extending longitudinally of the corrugations and being terminally provided with a triangular head to fit within and interlock with a dovetailed corrugation of the said sheet to cause the said members to form multiple webs interlocked with but separate from the said flange of the beam.

9. A light weight composite constructional beam comprising in unit combination spaced separate metal sheets each formed with a plurality of undercut corrugations running in the direction of the length of the beam, and a plurality of spaced metal stiffening members separate from one another and from the said spaced metal sheets, the said stiffening members all extending longitudinally of the corrugations, bridging the space between the said sheets and interlocking with undercut corrugations in the respective sheets to cause said members to form multiple webs of the composite beam.

10. A series of light weight composite constructional beams each complete in itself and resistant to bending stresses and comprising a metal sheet forming the flange of the beam and having a portion intermediate its ends formed with a longitudinally ranging undercut corrugation, and a separately formed stiffening member constituting the web of the beam interlocked with the said undercut corrugation, the flanges of adjacent beams being overlapped and held together in operative position.

11. A light weight constructional beam comprising in unit combination a metal sheet forming the flange of the beam and having a plurality of undercut corrugations of uniform size and shape and evenly spaced from edge to edge of the beam to run in the direction of the length of the beam, and a plurality of metal stiffening members separate from one another and from said metal sheet and each being terminally provided with a head to fit within and interlock with a selected corrugation in said sheet to cause the said members to form multiple webs of the composite beam which is complete in itself and resistant to bending stresses.

12. A light weight constructional beam comprising in unit combination a metal sheet forming the flange of the beam and having a plurality of undercut corrugations of uniform size and shape and evenly spaced from edge to edge of the beam to run in the direction of the length of the beam, and a plurality of metal stiffening members separate from one another and from said metal sheet and each being terminally provided with a head to fit within and interlock with a selected corrugation in said sheet to cause the said members to form multiple webs of the composite beam which is complete in itself and resistant to bending stresses, said members being located adjacent each edge of the sheet and intermediate said edges.

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