

[54] BUILDING STRUCTURAL SYSTEM

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[51] Int. Cl. E04b 1/41, E04b 7/02

[58] Field of Search ... 52/90, 93, 73, 309, 584, 405, 52/406, 615, 463, 467

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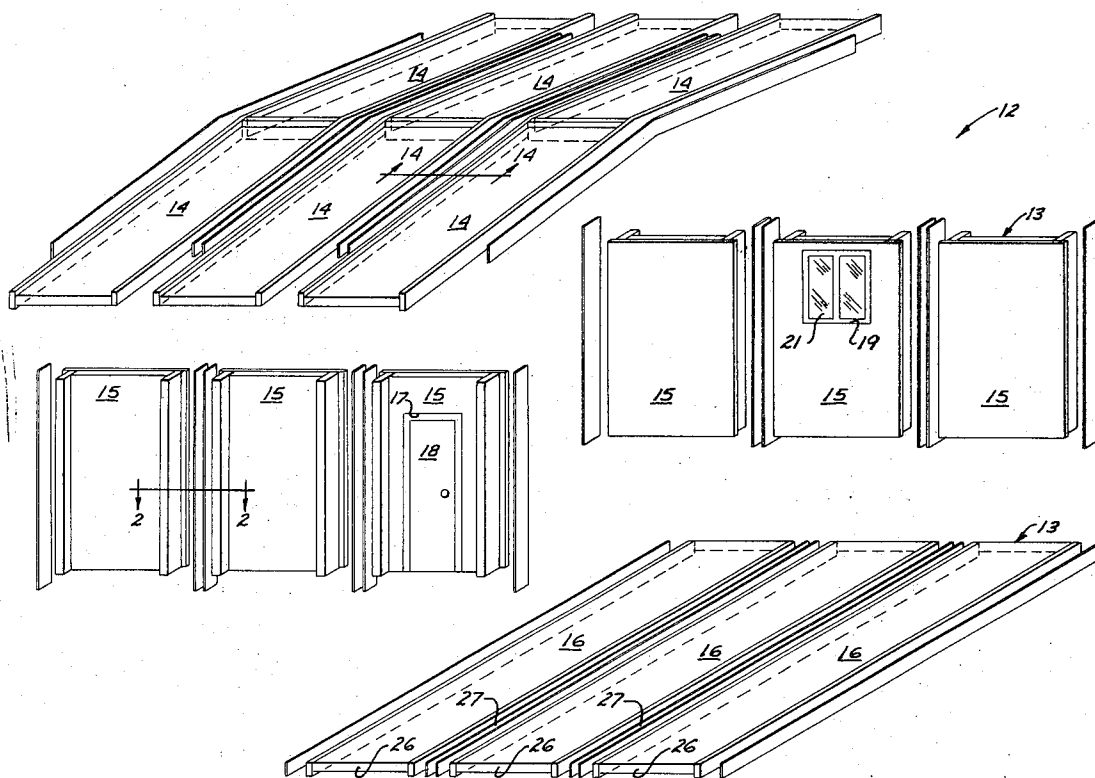
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[57] ABSTRACT

Structural units comprising laminated, skin-stressed, panels and attendant components are joined in various combinations by connecting members so as to form frameless, load-carrying structures affording a clear span desirable not only in commercial, industrial and institutional applications but in residential construction as well. The structural system especially lends itself to factory manufacture and assembly in maximum size transportable sections completely finished for job-site installation on pre-arranged foundations.

The term panel is used herein in its broadest sense and denotes a structural member substantially greater in the dimensions of length and width than in thickness. The term structural unit is more comprehensive than the term panel and includes not only a panel but also various components associated with a panel.

12 Claims, 19 Drawing Figures



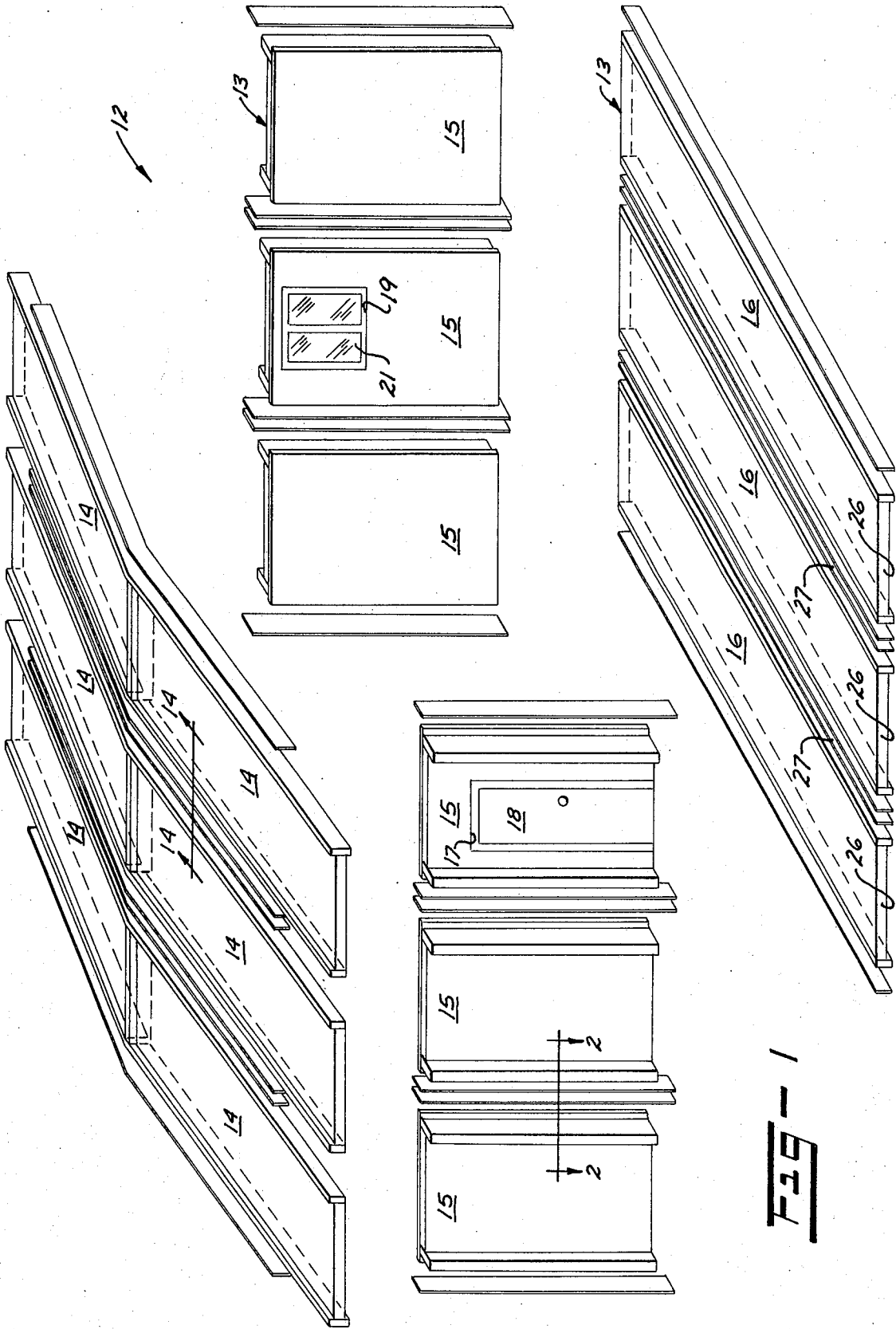


FIG - 1

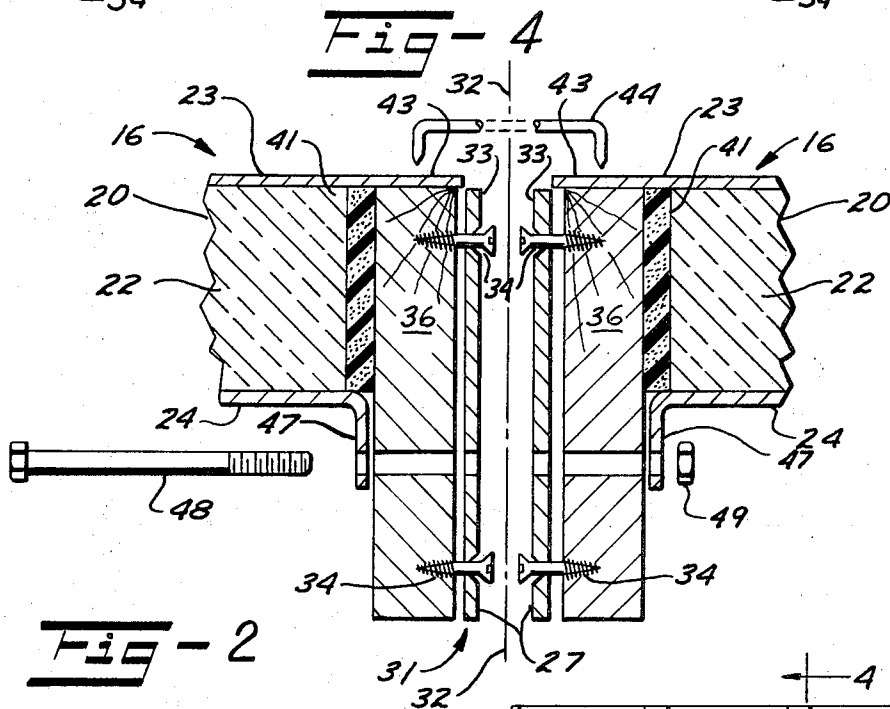
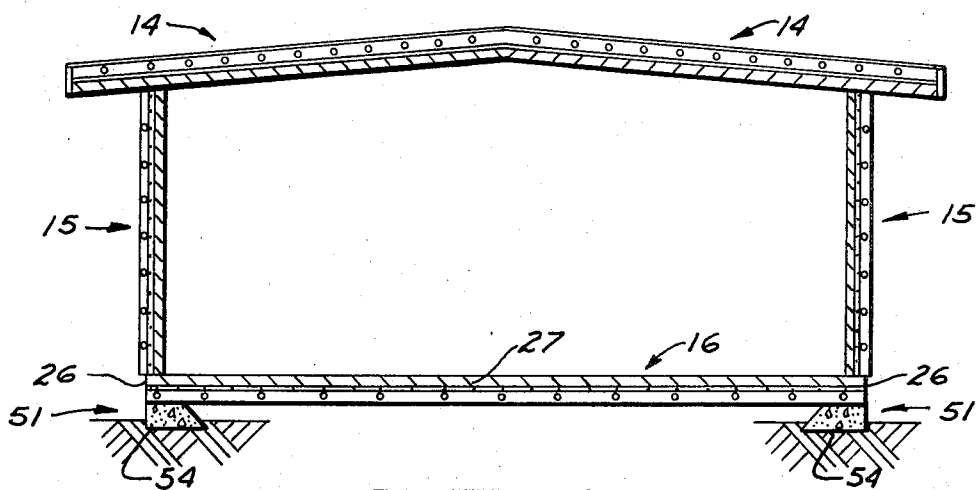
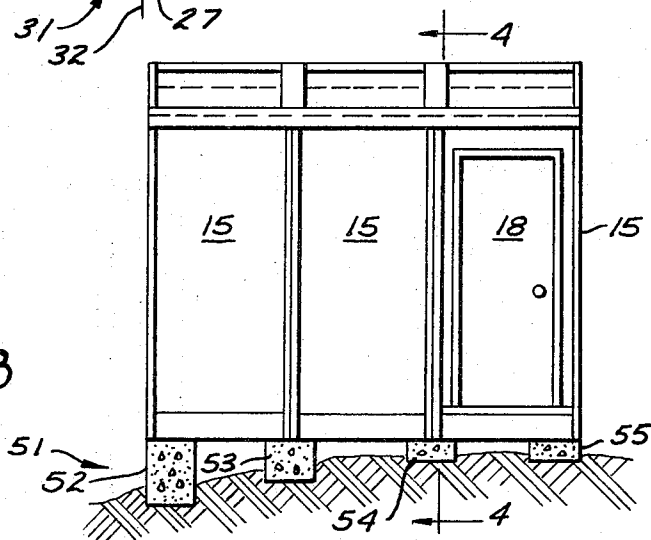


Fig - 2

Fig - 3



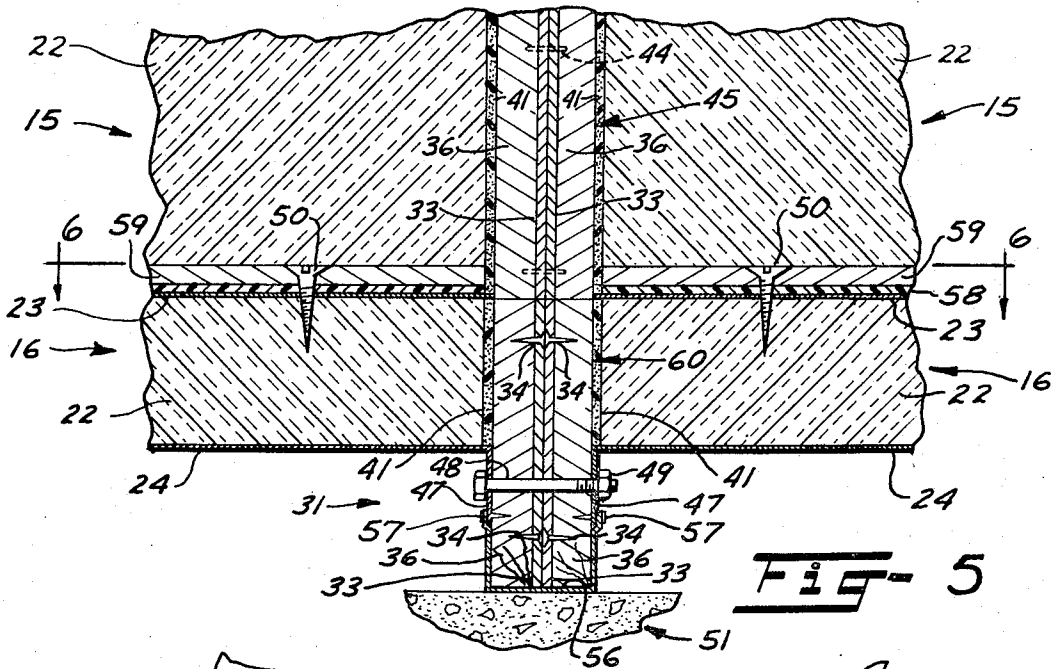


FIG-5

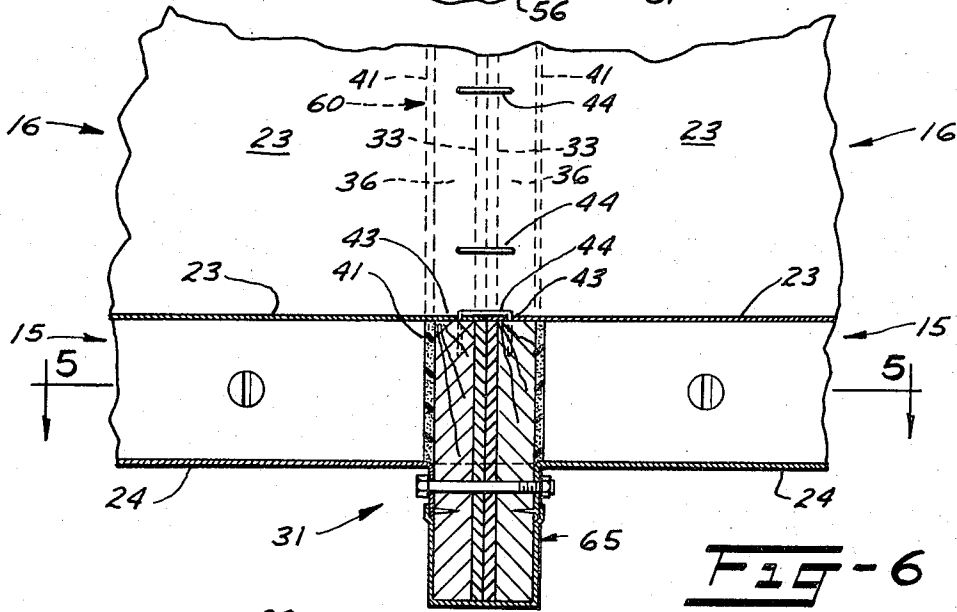


FIG-6

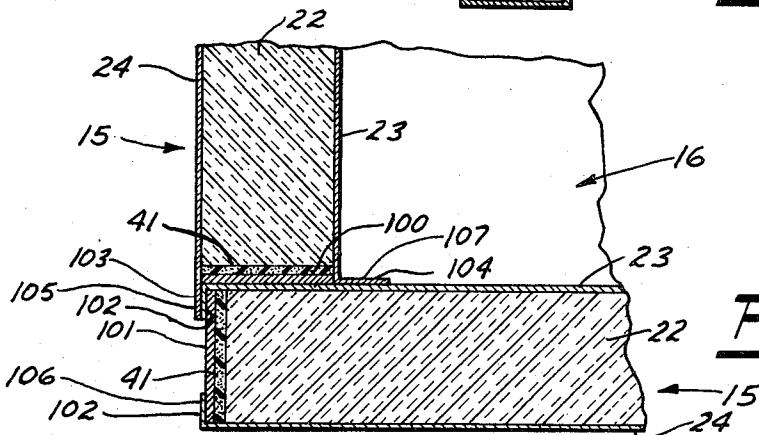


FIG-7

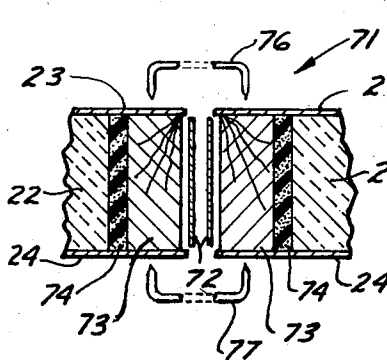
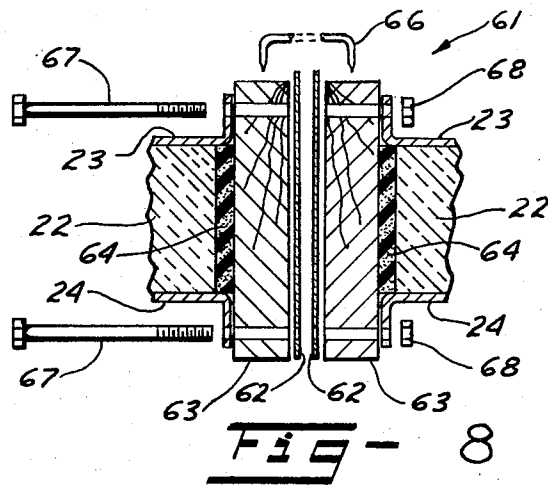


FIG-9

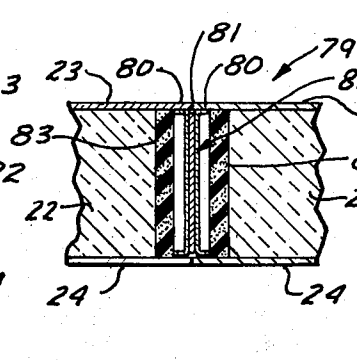


FIG-10

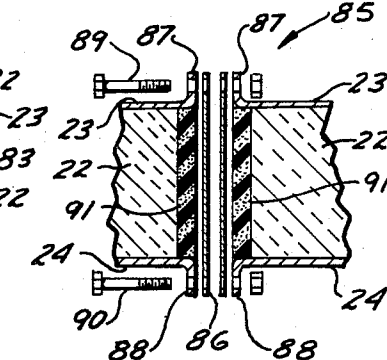


FIG-11

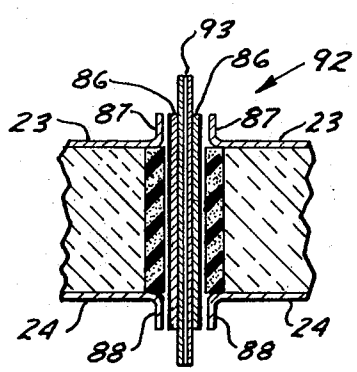


FIG-12

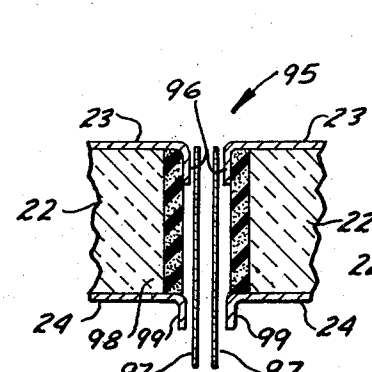


FIG-13

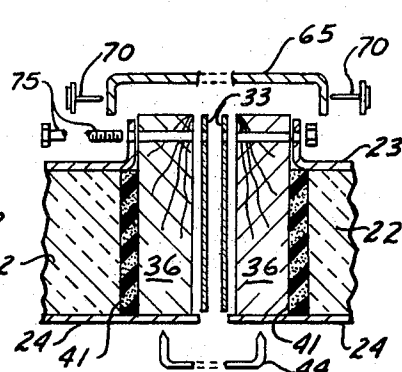


FIG-14

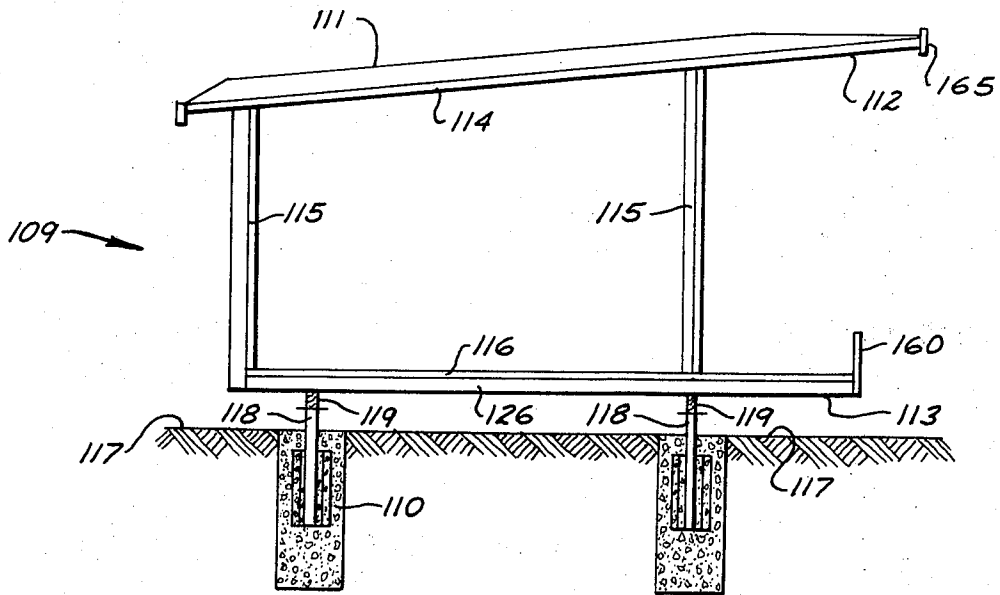


FIG-15

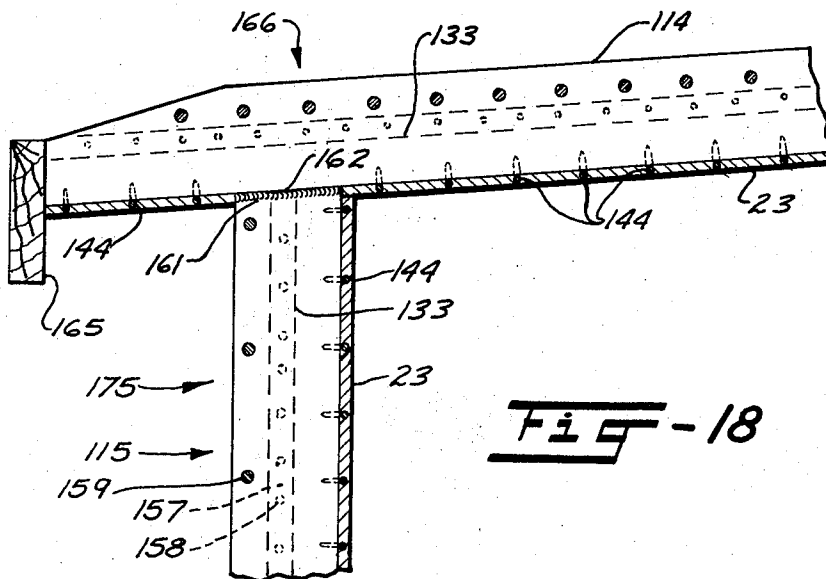


FIG-18

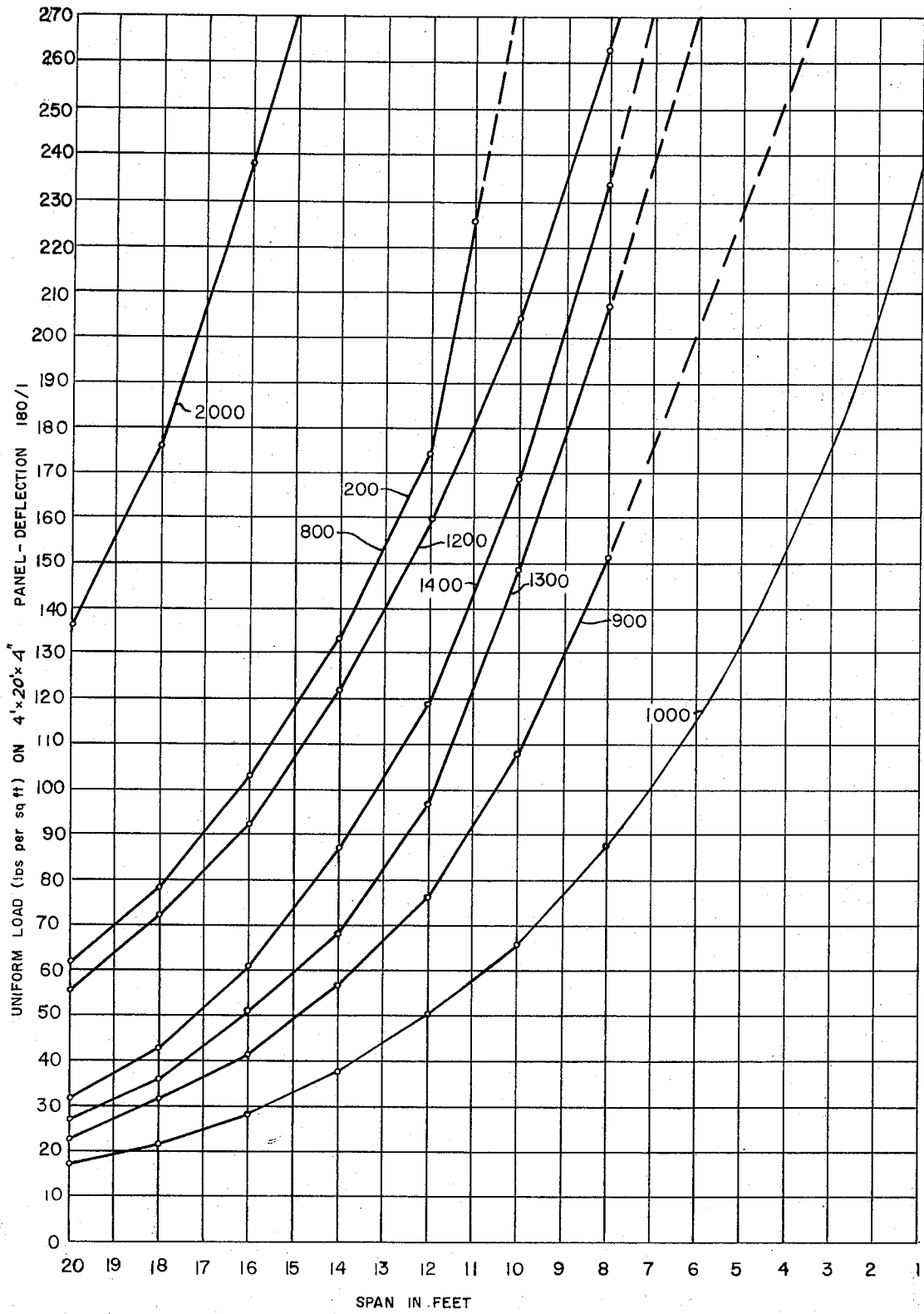


FIG - 19

BUILDING STRUCTURAL SYSTEM

The invention relates to improvements in systems for constructing buildings in which structural units including panels and appropriate additives and connectors serve as floor, bearing walls, roofs and partitions.

The prior art affords numerous disclosures of structures fabricated from structural units serving multiple purposes, but none, so far as is known, provides a combination of structural units and connectors which can be so joined as to fulfill substantially any kind of structural design requirement.

It is therefore an object of the invention to provide a building structural system which is versatile in that it is capable of being used to advantage in constructing buildings of a myriad of different kinds, sizes and styles.

It is another object of the invention to provide a building structural system in which labor at the jobsite is reduced to a minimum owing to the accuracy and degree of completion obtainable at the factory, where better quality control and efficiency can be exercised.

It is still another object of the invention to provide a building construction system which is economical, not only with respect to initial construction costs but also in connection with repair and maintenance expense.

It is yet another object of the invention to provide a building construction system which provides long span carrying capacities with fewer under-floor supports and internal columns or bearing walls.

It is a further object of the invention to provide a building structural system which is not only light in weight, structurally stable and easy to erect, but which is also substantially impervious to fungus, bacteria or insects, and affords a high degree of thermal insulation and soundproofing.

It is a still further object of the invention to provide a building structural system which is highly resistant to the elements, to attack by fire and to seismic action.

It is yet a further object of the invention to provide a building structural system in which not only electrical services and accessories, but also plumbing, heating and air-conditioning systems are easily installed and well protected.

It is another object of the invention to provide a building structural system which readily lends itself to use with all types of interior and exterior wall and ceiling finishes as well as all kinds of roof and floor coverings of a decorative and protective nature.

It is an additional object to provide a generally improved building structural system.

Other objects, together with the foregoing, are attained in the embodiments described in the following description and shown in the accompanying drawings, in which:

FIG. 1 is a fragmentary exploded isometric view of a stylized structure generally illustrating how the structural units and connecting members are combined to form a one-room building, the end wall units not being shown so as to clarify the disclosure;

FIG. 2 is a fragmentary, exploded, sectional view to a greatly enlarged scale, showing a typical "flush-project" type of connector means, the plane of the section being indicated by the line 2—2 in FIG. 1;

FIG. 3 is a side elevational view of the FIG. 1 structure in assembled position, illustrating in stylized man-

ner one type of foundation utilized in the present system;

FIG. 4 is a transverse sectional view of the FIG. 1 structure in assembled position the plane of the section being indicated by the line 4—4 in FIG. 3;

FIG. 5 is a fragmentary vertical sectional view, to an enlarged scale, showing a typical floor to wall connection, the plane of the section being indicated by the line 5—5 in FIG. 6;

FIG. 6 is a view comparable to FIG. 5, showing a typical floor to wall connection, taken on the horizontal plane 6—6 in FIG. 5;

FIG. 7 is a fragmentary horizontal sectional view to an enlarged scale showing a typical wall to wall corner connection;

FIG. 8 is a fragmentary, exploded, sectional view, to an enlarged scale, showing a typical "project-project" type of connector means;

FIG. 9 is a fragmentary, exploded, sectional view, to an enlarged scale, showing a typical "flush-flush" type of connector means, the plane of the section being indicated by the line 9—9 in FIG. 1;

FIG. 10 is a view comparable to FIG. 9, but showing a modified form of "flush-flush" type of connector;

FIG. 11 is a view comparable to FIG. 9, but showing a modified form of "project-project" type of connector;

FIG. 12 is a view comparable to FIG. 11, but illustrating a further variation of a "project-project" type of connector;

FIG. 13 is a view comparable to FIG. 2, but showing a modified form of a "flush-project" type of connector;

FIG. 14 is a view comparable to FIG. 2, but in inverted attitude and showing a form of "project-flush" connector with closure cap to exclude the elements, the plane of the section being indicated by the line 14—14 in FIG. 1;

FIG. 15 is a transverse sectional view of a simplified building structure having a shed type of roof and a cantilevered deck, the section being taken through two of the concrete piers supporting the structure;

FIG. 16 is a fragmentary sectional view, to a greatly enlarged scale, of one of the concrete pier and pipe supports shown in FIG. 15;

FIG. 17 is a view comparable to FIG. 16 but taken at right angles thereto;

FIG. 18 is a fragmentary sectional view to an enlarged scale of a typical wall to roof, or haunch, connection; and,

FIG. 19 is a graph showing strength characteristics of various types of connectors, showing the uniform load necessary to deflect a connected pair of structural units a predetermined amount for different spans.

While the building structural system of the invention is susceptible of numerous physical embodiments, depending upon the environment and requirements of use, substantial numbers of the herein shown and described embodiments have been made, tested and used, and all have performed in an eminently satisfactory manner.

The structural system of the invention, generally designated by the reference numeral 12, can be used in the construction of buildings of all types, including residential, commercial and institutional, as well as in the field of mobile structures.

In the simplified and somewhat stylized form of building structure shown in FIGS. 1, 3 and 4, only a floor, two side walls and a gable type of roof are illustrated. In the interests of clarifying the disclosure, the end walls are now shown. Each of the structural units, collectively designated by the reference numeral 13, is preferably of modular configuration, with a module base of four feet. Thus, for example, in FIG. 1, 3 and 4, each of the six roof units 14 is four feet wide and twelve feet long; each of the wall units 15 is four feet wide and eight feet high; and each of the floor units 16 is four feet wide and 20 feet long.

Either at the factory or on the jobsite, openings in the structural panel units can readily be made, as by sawing. Thus, a door opening 17 to receive a door 18, and a window opening 19 to receive a window 21, can quickly be formed either by a band saw or circular saw cutting through the unit.

Construction of the panel 20 itself is of the laminated type comprising a planar slab-like core 22 (see FIG. 2) of foamed material having very low thermal conductivity. To each side of the core, a metal skin 23 and 24, or sheath, is bonded, the metal sheath being preferably of aluminum or light gauge steel. The overall thermal conductivity (u) of a typical panel is in the approximate range of 0.03 to 0.07.

The panel core 22 can either be in the form of a pre-cast block of rigid foamed material, such as polystyrene, to which the metal skins are bonded by an appropriate adhesive, or the core can be foamed in place by introducing and combining the necessary ingredients between the parallel metal boundary skins spaced apart the required distance by suitable means. Polyurethane, for example, has been utilized with very considerable effectiveness as a core material, a strong bonding between the core and the metal skins occurring as the core expands into engagement with the inner surfaces of the metal skins and exerts a stress thereon. The prestress, in fact, greatly increases beam and columnar strength. Where appropriate, increased fire resistance is afforded by using foamed vermiculite, perlite, asbestos, or the like, in the core.

As most clearly appears in FIGS. 1, 3 and 4, each of the three floor units 16 (each being, for example, 4 ft. wide and 20 ft. long) includes a pair of opposite end edges 26 and a pair of opposite side edges 27, collectively termed marginal edges; and a building of any desired length can be made merely by adding more units. So also, as will be appreciated, converting the FIG. 1 structure into a building of any desired width is readily accomplished by multiplying the span by the use of multiple rows of interior columns in conventional manner.

With particular reference to FIGS. 1 and 3, it can be seen that in order to form a strong, rigid unitary floor, it is only necessary to join together the longitudinal side edges 27 of the central one of the floor units 16 to the adjacent abutting longitudinal side edges 27 of the two straddling units 16.

The joint must be such as to fulfill the structural design requirements with respect to span and load, and to establish and maintain the dimensions required in a system of building construction using factory made components for the most part.

Meeting all such requirements in an entirely satisfactory manner is the connector 31 shown in FIG. 2 wherein the two adjacent side edges 27 of the floor

units 16, for example, are to be joined. The connector 31 is symmetrical about a central vertical plane 32 and includes on each side of the central plane 32 a sturdy, elongated strap 33, or plate, or web, or metal, preferably extending the entire unit length (20 ft. in the case of the floor unit 16 shown in FIG. 1). Each of the webs 33 is secured by fasteners 34, at appropriate intervals, (or bonded with pressed contact cement, such as adhesive 370, a product of Pittsburgh Plate Glass Co.) to an adjacent beam 36 which can be of wood. As will be seen, the beam 36 serves not only as a spacer and web support but also as a structural additive in substantially increasing the strength and rigidity of the floor.

Interposed between the beam 36 and the adjacent side edge of the panel core 22 is a cushion 41, or pad, or seal, of resilient material, such as foamed elastomeric material or flexible foamed "plastic," which affords a buffer zone and barrier between the beam 36 and the adjacent side edge of the core 22. Flexible polyurethane has been used to good advantage as cushion material.

The upper metal skin 23 extends over the top of the seal 41 and the beam 36 to form a projection 43 which also overlies the upper end portion of the adjacent one of the webs 33 and thereby abuts the adjacent skin projection 43 when the connector is installed. Thus, after the two adjacent floor units 16 are firmly abutted (with the webs 33 having previously been fastened to the adjacent beams 36) so that the two webs are in close, face to face engagement, the upper ends of the two abutting units are clamped together by a plurality of strong staples 44 driven downwardly by a power-driven staple gun through the metal skin projections 43 and into the subjacent beam edges. The staples 44 are spaced a few inches apart along the entire length of the floor unit joint.

At the same time, the lower ends of the web plates 33, the beams 36 and the downturned flanges 47 of the two lower metal skins 24 are secured together by a plurality of through bolts 48 and power driven nuts 49, or comparable fasteners.

In the form of connecting member 31 illustrated in FIG. 2, both the web plates 33 and the beams 36 extend downwardly beyond the horizontal plane of the bottom surface of the two units whereas the top surface of the joined units is flush, as is of course desirable for a floor surface. For this reason, the FIG. 2 form of connector, indicated by the reference numeral 31, is of the kind termed herein as a "flush-project" type of connector wherein one side is flush and the other side protrudes.

As will subsequently be disclosed, other classes of connectors are of the "flush-flush" type and still others are of the "project-project" variety; and within each of these classes further modifications exist to accommodate varying requirements of design and cost.

Prior to laying the floor, a foundation 51 will have been installed. In the elementary form of structure shown in FIGS. 3 and 4, the foundation can be of a suitable concrete construction, for example, a plurality of piers 52, 53, 54 and 55 on opposite sides of the structure. The piers are located so as to support the corners of all of the three structural units 16 forming the floor.

After the floor is installed with the units spanning the piers 52 - 55 on opposite sides of the building, and the connectors 31 are firmly secured, the walls of the build-

ing are erected. The wall units 15 (each 4 ft. × 8 ft.) are positioned in vertical attitude on opposite sides of the structure, as appears in FIGS. 1, 3 and 4, and joined together by connectors of the appropriate type. A typical wall to floor connection is disclosed in FIGS. 5 and 6.

Should it be desired that the inside surface of the wall be flush and the outside surface be interrupted at intervals, so as to provide an exterior board and batten-like effect, the "flush-project" form of connector shown in FIG. 2, and previously described in detail, would be very appropriate and is therefore shown herein.

Thus, as appears in FIGS. 1, 5 and 6, the joint between the middle one of the three wall units 15 and the right hand one of the wall units 15 on both sides of the building) is provided with a connector 31 of the "flush-project" type, as is shown in detail in exploded form in FIG. 2 and in assembled form in FIGS. 5 and 6.

FIGS. 5 and 6 are vertical and horizontal sectional views, respectively, of a typical floor to wall connection and illustrate, for example, a FIG. 2 form of connector 31 in assembled condition, with the same type of connector 31 for both the horizontal floor and the vertical walls.

In FIGS. 5 and 6, the upper skin 23 of the floor unit 16 comprises the upper surface of the building floor and, as can be seen, the two horizontal adjacent floor units 16 are joined by the connector 31 including the two metal webs 33 and the two beams 36. The webs and beams are each joined together by fasteners 34 and both are joined by fasteners 48 and 49 to the downturned flanges 47 of the floor units 16. The horizontal beams 36 and webs 33 forming a girder 60 are supported on the foundation 51 and, if desired, an elongated U-shaped protector cap 56 can be placed over the bottom and sides of the girder 60 and secured by fasteners 57 as shown in FIG. 5.

Preferably, the floor to wall construction includes not only the customary sealing strips 41 between the cores 22 and adjacent beams 36 along the lateral side edges of the units, but also a sealing strip along the lower end edges of the units. The sealing strip 58 is laid horizontally on top of the floor 16 around the room perimeter, at the foot of the vertical wall units 15, and is slightly less in transverse width than the thickness of the vertical wall unit 15, the thickness of the wall unit 15 being, in the present instance, about four inches. The horizontal sealing strips 58 are preferably of flexible polyurethane material, which is spongy in nature and is compressed by the weight of the superposed vertical wall unit 15 from an uncompressed thickness of about one-half inch to a compressed thickness of approximately one-fourth of an inch or less.

Above the horizontal sealing strips 58 are horizontal retainer strips 59 of wood, such as plywood, five-eighths inch thick and 3 7/8 inch wide, each strip extending between the vertical posts 45, or studs, formed, as before, of face to face metal webs 33 fastened to beams 36 and sealing strips 41 interposed between the beams 36 and the adjacent exposed edges of the solid foam core 22.

Fastenings 50, such as screws, secure the horizontal plywood retainer strips 59 and the seals 58 to the subjacent skin 23 and rigid foam core 22. After the retainer strips are fastened down, the vertical wall units 15 are placed in position, the skins 23 and 24 on the lower ends of the wall units 15 being extended to form aprons

covering the side edges of the horizontal sealing strips 58 and retainer strips 59. As before, suitable fasteners, including staples 44, are utilized to afford a strong, rigid connection.

Depending upon design requirements, variant forms of connectors are used. One of the variant forms is a "project-project" type of connector 61 as appears most clearly in FIG. 8. The full "project-project" connector 61 includes, as before, a facing pair of web plates 62 interposed between a pair of spacer beams 63 separated from the respective pair of cores 22 by a pair of resilient sealing cushions 64, or pads, extending the full length of the structural units. When all parts are abutted in snug relation, fasteners, such as staples 66 and bolts 67 and nuts 68, can be used to connect the units in a strong and rigid manner, registering through bores having been pre-drilled at the factory in the usual case.

FIG. 9 illustrates still another form of connector. This connector is of the "flush-flush" type and is designated by the reference numeral 71. Here again, the connector member 71 is characterized by a facing pair of elongated metal webs 72, or straps, preferably extending the entire length of the structural units. Next to the webs 72 is a pair of beams 73, and interposed between the beams 73 and the respective cores 22 is a resilient strip of cushioning material forming a buffer pad 74. The coplanar ends of the metal skins 23 project over the respective ends of the pad 74, the beam 73 and the web 72, so that the adjacent edges of the skins 23 abut when the connector is installed in final position and secured as by stapling with a plurality of power driven staples 76. The same construction prevails on the opposite side of the panel where the panel skins 24 abut and the connector 71 is secured by staples 77. The connector 71, in other words, affords a smooth, continuous surface on both sides of the wall and lends itself especially well, for example, to the installation of decorative interior plywood paneling or to the application of other decorative and protective exterior or interior coatings, such as paint, stucco or plaster.

A modified form of the "flush-flush" type of connector appears in FIG. 10 and is designated by the reference numeral 79. A pair of C-shaped channels 80 back up to a central plate 81 and are spot welded thereto to form an I-beam 82 extending the full length of the panel. The overhanging extensions of the skin 23 and 24 are welded to the subjacent flanges of the I-beam 82. This form of connector does not necessarily utilize wooden beams as fillers and stiffeners. It does use, however, a seal 83 on both exposed edges of the foamed core 22 and can include an appropriate filler member, if desired.

Still other exemplary types of connectors which do not employ wooden beams are illustrated in FIGS. 11 to 14.

FIG. 11 shows an elementary "project-project" type of connector 85 comprising an opposed pair of web plates 86 secured to the flanges 87 and 88, respectively, of the metal skins 23 and 24, as by fastenings 89 and 90, or by riveting or welding. Flexible polyurethane pads 91 are interposed, as shown. This type of connection is of especial utility where insect proofness takes precedence over dimensional accuracy.

The connector 92 shown in FIG. 12 illustrates the manner in which the "project-project" FIG. 11 form of device can be strengthened, as by doubling the number

of web plates 86 and by also interposing a plurality of stiffening plates 93 therebetween. Welding affords a reliable method of joining all components, including the plates 86, the plates 93 and the respective upper skin flanges 87 and lower skin flanges 88, into an extremely rigid structural member, although recognizing that conventional, power-driven fasteners or rivets can also be utilized to good effect.

FIG. 13 discloses a modified 11 "flush-project" or "project one-side" type of structure 95 wherein the adjacent flange ends 96 of the metal skins 23 are bent inwardly to lie between the web plates 97 and the flexible pads 98. The bottom flanges 99, however, are outwardly directed to overlie the downwardly projecting portions of the web plates 97. Appropriate securing means, such as welding, bolting, riveting or the like, can be used to effect a firm, rigid connection.

As will be recognized, still other variations of the foregoing arrangements can be used to fulfill differing design requirements.

FIG. 14, in fact, discloses a variant form of "project-flush" or "project one-side" connector somewhat comparable to the connector 31 in FIG. 2 but inverted so that the projecting portion extends upwardly, such as on the roof of the building shown in FIG. 1, and the flush portion is on the ceiling and faces downwardly. To preclude the entry of rain, snow and the like, an elongated protective cap 65, or inverted U-shape in section sheet metal, is mounted over the upwardly projecting beams, being secured by washered nails 70. It will be recognized that cap members can be used wherever desired, for example, as indicated by the numeral 65 in FIG. 6 where the cap 65 covers the exterior projecting portion of the vertical wall stud 45. Fasteners, such as through bolts 75 and staples 44, clamp the components together.

FIG. 7 illustrates a common form of connector used at corners to join two vertical units 15 at an angle, such as the customary 90° corner angle. Covering the usual sealing strips 41 on the exposed ends of the rigid foamed cores 22 of the units 15 are metal plates 100 and 101, of aluminum or steel strip stock (approximately 3 1/8 inch wide with 26 gauge thickness for steel and 0.032 inch thickness for aluminum). Both of the extended flange ends 102 of one of the wall units 15 are bent inwardly to embrace the enclosed plate 101; and the extended flange ends 103 and 104 of the other abutting unit are arranged, as shown in FIG. 7, to overlie one of the flanges 102 and the adjacent panel skin 23, respectively. A strong, rigid corner construction results when the foregoing components are fastened together as by spot-welding or screw fastenings at the locations 105, 106, and 107.

FIGS. 15 through 17 illustrate how a pier-supported structure 109 having a shed type roof 111, for example, with extensive overhang 112 above a cantilevered deck 113 can be built using the structural unit and connector system of the present invention. In the structure 109, the roof units are identified by the reference numeral 114, the floor units by 116 and the wall units by 115.

Anchored in concrete piers 110 in auger holes in the ground 117 are vertical pipes 118 supporting girders 119 fastened by screws 120 to plates 121 welded to the top of the pipes 118. Angle irons 122, fastened by screws 123 to the girders 119, project upwardly and are there secured by fasteners 124 to floor joists oriented

at right angles to and supported by the girders. The floor joists serve to connect adjacent floor units 116 and comprise, as before, a pair of beams 126 with an interposed pair of metal web plates 127 and seals 128 between the cores 22 and beams 126. The beams 126 and the plates 127 are clamped together by bolts 129. Downturned flanges 147 of the floor units 116 are secured to the beams 126 by fasteners 150.

It is particularly to be noted that the extraordinary beam strength of the stressed skin and adhesively-bonded, rigid-core construction of the structural units permits of unusually long spans which need to be supported only at their ends. Thus, relatively few piers or foundation support points are required, thereby reducing construction costs generally and affording additional design capabilities, especially with unusual terrain and with difficult soil conditions.

As before, the inner base perimeter of the vertical walls 115 of the room is characterized by a horizontal sealing strip 135 covered by a wooden retainer strip 140 secured by fasteners 145 located along the retainer strip at appropriate intervals. The bottom edges of the vertical wall units 115 are supported on the retainer strip 140 and the sealing strip 135; and the lower end of the adjacent inner skin 23 of the unit 115 extends downwardly to provide a skirt 155 covering the exposed vertical edges of the strips 135 and 140 (see FIG. 16). The outer skin 24 of the vertical wall unit is bent to provide a pair of flanges 157 secured to opposite sides of the vertical beams 136 by fasteners 158. The two beams 136 and the two interposed webs 133 are themselves clamped together by suitable through bolt type fasteners 159. As before, a pair of vertical sealing strips 141 is interposed between each of the vertical side edges of the core and the adjacent vertical surfaces of the vertical beams 136. Appropriate fasteners are used, such as staples 144, which are power driven into the inner, flush panel surfaces 23 and the underlying connector members.

As appears most clearly in FIGS. 15 and 16, the floor joists 126 and attendant floor units 116 can be extended beyond the right-hand one of the girders 119 so as to provide the cantilevered deck 114, a rail 160 being added to the outer end of the deck as is customary. In comparable fashion, the roof units 114 and attendant connectors can be extended well beyond the supporting upper end of the right-hand wall units 115 so as to afford an overhang 113 suitably sealed and closed by fascia board 165.

As particularly appears in FIG. 15 and in FIG. 18 (which is a fragmentary sectional view taken on the vertical central plane between two adjoining units 114 and two left-hand wall units 115) the uppermost edges 161 of the two central vertical metal webs 133 of the vertical wall connectors 175 are cut at an angle equal to the slope of the roof units 114 and are located so as to abut the corresponding sloping lower edge 162 of the central metal webs 133 of the superposed roof panel connector 166. The two abutting web plates 133 are welded along the joint between the edges 161 and 162 and thereby afford a very strong haunch, or wall to roof, construction. A comparable welded construction is utilized in the gable roof of FIGS. 1, 3 and 4.

Where the gauge of the web material is quite light, the metal webs can be overlapped and secured together as by spot welding rather than by butt welding, as above.

A welded joint construction similar to that described above for the wall to roof junction can advantageously be utilized, if desired, between the horizontal floor connector metal webs and the metal webs of the vertical wall unit connectors.

As appears most clearly in FIG. 19, the structural units themselves (i.e., without connecting members) afford structural integrity of a high order. FIG. 19 is a graph indicating, as an abscissa, the distance in feet, in decreasing order, which a 4 ft. \times 20 ft. unit (of the type heretofore disclosed) can span without deflecting more than the conventional permissible deflection ratio of 180 to 1. The ordinate is the extent of the uniform load in pounds per square feet upon a unit.

The bottom curve, designated by the reference numeral 1000, illustrates the relationship between span and load for a plain unit, i.e., a unit 4 ft. \times 20 ft. \times 4 inches, as previously described, without any connecting means joining two units together.

It will be noted from curve 1000 that if a plain 4 ft. \times 20 ft. \times 4 inches unit of this type is placed in a horizontal attitude and is supported at its extreme ends, a uniform load of approximately 17.5 pounds per square foot can be loaded on the entire upper surface of the 4 ft. \times 20 ft. \times 4 inches unit before the deflection exceeds the 180 to 1 limit. If supports are placed only ten feet apart, the permissible load amounts to 65 pounds per square feet, and at a span of five feet the permissible uniform load mounts to 130 pounds per square feet.

The other curves illustrate the substantial increases in span made possible by different kinds of connectors.

In the interests of uniformity of comparison, let it be assumed that the span in all instances is 18 feet. In all cases, it is further assumed that the core 22 is of polystyrene or polyurethane material bonded on both sides either to 26 gauge galvanized iron or to 0.032 inch thickness aluminum skins.

For a 4 inches \times 20 inches \times 4 ft. plain unit, the permissible uniform load for an 18 foot span without exceeding the 180 to 1 limit is about twenty one pounds per square feet.

When two of the 4 ft. \times 20 ft. \times 4 inches are joined together along their two elongated, adjacent, lateral edges with a connector 71 of the "flush-flush" type illustrated in FIG. 9, the uniform permissible load increases from 21 to approximately 31 pounds per square foot for a span of eighteen feet, as can be seen by referring to the curve 900. The cross-section of the beams in this case is 4 $\frac{5}{8}$ inches by 4 inches plywood; one of the plates 72 is 14 gauge galvanized iron, 4 inches wide; the other plate 72 is 26 gauge by 4 inches wide.

The "project one-side" type (with the connector means 95 shown in FIG. 13) appears on the chart as curve 1300. For a span of 18 feet, the connected structural units do not reach the 180 to 1 deflection point until a uniform load of 35 pounds per square foot is imposed. The two web plates 97 in this instance are each 20 gauge galvanized iron, 5 inches in width.

Curve 1400 illustrates the span versus uniform load characteristics of structural units joined by connectors of the "project one-side" type illustrated in FIG. 14 wherein each of the two beams 36 is 4 $\frac{1}{2}$ inches \times 6 inches plywood with the two web-plates 33, each 16 gauge by 6 inches wide galvanized iron. The uniform

load bearing capacity for a span of 18 feet is 42 pounds per square foot.

Curve 1200 relates to a "project-project" type of connecting means, comparable to means 92 in FIG. 12, in which there are no wooden filler members, or additives, but only metallic web plates. In the example shown in cruve 1200 there are two 20 gauge by 6 inches galvanized iron plates and two 16 gauge by 8 inches galvanized iron plates. For a span of eighteen feet the uniform load value is 71 pounds per square foot.

Curve 200 shows the coordinates resulting from the use of a "project one-side" connector 31 as shown in FIG. 2, with each beam 4 $\frac{1}{8}$ inches \times 8 inches in size and each web of 16 gauge galvanized iron, 8 inches in width. For a span of eighteen feet, the permissible uniform loading increases substantially, to a value of 79 pounds per square foot.

It is interesting to note that the same coordinates of 18 feet span and 79 pounds per square foot loading also obtain for the "project-project" or "project both-sides" type of connector 61 as illustrated in FIG. 8. The curve 800 shows the characteristics where the beams 63 are each 4 $\frac{1}{8}$ inches \times 8 inches in cross-section and the web plates 62 are 8 inches in width and are of 16 gauge thickness of galvanized iron. The curves 200 and 800, in other words, are substantially identical.

The building structural system of the present invention is especially characterized by its flexibility and adaptability to meet substantially all design requirement. In some instances, for example, the connecting members comprise only wooden beams, with no metal plates. Curve 2000, for example, shows the load values for 4 inches panels with two 2 inches \times 12 inches Douglas Fir webs. For 18 feet, the load is a very high 178 pounds per square foot.

By varying the number, size and kind of units and connectors, extensive families of curves are worked out. Then, with predetermined design requirements of loading, span, connector shape, size and the customary additional parameters, the most suitable configurations can readily be determined for any type of structure. Cost data and curves are also computed and made available for reference in connection with each design decision.

What is claimed is:

1. A building structural system comprising:

a. a plurality of laminated structural units, each unit including a pair of metal skins, each skin having an outer surface and an inner surface, and a core of material having low thermal conductivity bonded to said inner surfaces of said skins, said laminated units being rectangular and extending longitudinally between opposite ends and transversely between opposite sides, said ends and said sides being defined by marginal edges; and

b. connector means for joining said units along adjacent marginal edges, said unit connector means including a pad comprising a sealing strip of resilient material mounted on each of the adjacent edges of said units, and a metal web located on the exposed face of each of said resilient sealing strips, said metal webs being arranged in abutting relation and fastened together.

2. A building structural system as in claim 1 further including a beam interposed between each of said pads and said metal webs, said beam having a thickness such

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as to provide additional dimensional precision and structural strength to the joint formed by the adjacent marginal edges of said units, and by said webs and said pads when tightly connected together with adjacent surfaces in face to face engagement.

3. A building structural system as in claim 1 wherein one edge of each of said metal webs is substantially flush with the plane of one side surface of adjacent pairs of units, and the other edge of each of said metal webs extends beyond the plane of the other side surface of said adjacent pairs of units to form a projection.

4. A building structural system as in claim 1 wherein both edges of said metal webs extend beyond the corresponding planes of said side surfaces of said units to form a pair of oppositely extending projections.

5. A building structural system as in claim 1 wherein both edges of said metal webs are flush with the planes of said side surfaces of said units.

6. A building structural system as in claim 2 wherein both edges of said webs and said beams are flush with the corresponding planes of said side surfaces of said units.

7. A building structural system as in claim 2 wherein one edge of said webs and said beams are substantially flush with the corresponding planes of one of said side surfaces of said units and the opposite edge of said webs and said beams project from the planes of the other of said side surfaces of said units.

8. A building structural system as in claim 2 wherein both edges of said webs and said beams project from the corresponding planes of said side surfaces of said units.

9. A building structural system as in claim 1 including elongated protective cap means for covering said connector means.

10. A building structural system as in claim 9 wherein said protective cap means comprise an elongated strip of material having an inverted U-shape in transverse section, and means for securing said cap means to the adjacent portions of a pair of abutting units connected by said connector means.

11. A building structural system comprising:

a. a plurality of laminated structural units, each unit including:

1. a pair of skins each having an outer surface and an inner surface; and,

2. a core of material having low thermal conductivity interposed between said pair of skins and bonded to said inner surfaces thereof; said laminated units being defined by marginal edges; and,

b. connector means for joining said units along adjacent marginal edges, said connector means including:

1. a pad comprising a sealing strip of resilient material mounted on each of the adjacent edges of said units; and,

2. a web located on the exposed face of each of said sealing strips, said webs being arranged in abutting relation and fastened together.

12. A building structural system as in claim 11 further including a beam interposed between each of said pads and said webs, said beam having a thickness such as to provide additional dimensional precision and structural strength to the joint formed by the adjacent marginal edges of said units and by said webs and said pads when tightly connected together with adjacent surfaces in face to face engagement.

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