MODULAR BUILDING UNIT

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ABSTRACT

A modular building unit including a moment resistant space frame. The space frame includes an elongate lower frame assembly and an elongate upper frame assembly overlying and spaced above the lower assembly. A pair of upright support posts adjacent one set of ends of the frame assemblies and another pair of upright support posts adjacent the other set of ends of the frame assemblies provide the sole vertical support for the upper frame assembly above the lower frame assembly. The upper and lower sets of ends of the support posts are secured to the frame assemblies in such a manner as to provide moment resistant connections therebetween. Further, the support posts at one set of ends of the frame assemblies are of a different cross section than the support posts at the opposite ends of the frame assemblies to minimize effects of vibrations on the structure.

4 Claims, 10 Drawing Figures
MODULAR BUILDING UNIT

BACKGROUND AND SUMMARY OF THE INVENTION

This invention relates to modular building units, and more particularly to a space frame which provides the structural support in such a modular building unit.

Various modular building designs have been developed in the past, however for the most part, such prior designs have required that wall panels in the structure provide structural support in the building unit. With such previous designs, there was a great sacrifice in flexibility in the uses to which such a modular building could be put. For example, if wall panels must bear structural loads, there is no opportunity to provide totally open spaces, or use glass curtain walls.

A general object of the present invention is to provide a novel moment resistant space frame for a modular building unit which is relatively inexpensive to construct, yet which has sufficient structural strength that there is no need for wall panels to bear vertical structural loads in the unit.

More specifically, an object is to provide a space frame for a modular building unit which includes an elongate lower frame assembly, an elongate upper frame assembly spaced thereabove, and which requires only a pair of support posts adjacent one set of ends of the frame assemblies and another pair of posts adjacent the opposite set of ends of the frame assemblies for providing the sole vertical support between the upper and lower frame assemblies. With such structure, wherein the four support posts adjacent opposite ends of the structure provide virtually all of the support in the structure, there is no need for relying upon the structural characteristics of wall panels for providing structural integrity in the unit. With such a building unit, there is almost unlimited flexibility in use, allowing free, open spaces to be provided, or allowing glass or solid wall panels to be used to enclose a space.

Another object is to provide a novel modular building unit having a self-supporting moment resistant space frame permitting the use of nonload bearing wall panels which may be easily attached to the space frame or detached therefrom for reuse at another location. Modular building units generally are trucked from the point of assembly to point of use. This may be accomplished either by carrying them on the bed of a conventional truck, or by connecting wheeled trucks thereunder with a towbar connected to an end of the frame of the unit. During towing of such units vibrations often occur. When vibrations occurred in previously designed structures, harmonic vibrations often developed which increased the intensity of the vibrations and caused damage to such structures. Earthquakes also may produce harmonic vibrations in previous structures which may be destructive to the unit.

Another object of the present invention is to provide a novel modular building unit which minimizes the likelihood that harmonic vibrations will be produced in the structure.

More specifically, in the structure of the present invention, the upright support posts adjacent opposite ends of the structure have differing cross sections. With such differing cross sections, should vibrations occur, they will not produce a harmonic effect and thus will not be amplifying in their destructive characteristics.

Yet another object is to provide a novel space frame for a modular building unit which includes means for simply and efficiently connecting a pair of such units together in side by side relationship.

More specifically, an object of the invention is to provide a modular building unit which may be set in an approximate position adjacent another such unit, and providing such units with connecting means whereby a unit approximately positioned adjacent another unit may be drawn into abutting relationship therewith and locked into such abutting relationship.

DRAWINGS

These and other objects and advantages will become more fully apparent as the following description is read in conjunction with the drawings, wherein:

FIG. 1 is a perspective view of a space frame for a modular building unit constructed according to an embodiment of the invention;

FIG. 2 is an enlarged view taken generally along line 2—2 in FIG. 1 with portions broken away;

FIG. 3 is a view taken generally along the line 3—3 in FIG. 2;

FIG. 4 is an enlarged view taken generally along the line 4—4 in FIG. 1 and additionally showing the interconnection of an upper portion of the space frame with an adjacent disposed space frame;

FIG. 5 is an enlarged cross-sectional view taken generally along the line 5—5 in FIG. 1 and additionally illustrating the interconnection between the lower portion of a space frame and an adjacent disposed space frame;

FIG. 6 is a cross-sectional view of a support post at one end of the space frame taken generally along the line 6—6 in FIG. 2;

FIG. 7 is a cross-sectional view of a support post at the opposite end of the space frame taken generally along the line 7—7 in FIG. 5;

FIG. 8 is a perspective view of a plurality of modular building units incorporating the space frame of the invention connected in side by side relationship to form a building;

FIG. 9 is an enlarged cross-sectional view, with portions broken away, taken generally along the line 9—9 in FIG. 8; and

FIG. 10 is an enlarged cross-sectional view taken generally along the line 10—10 in FIG. 8 with portions broken away.

DETAILED DESCRIPTION OF AN EMBODIMENT OF THE INVENTION

Referring to the drawings and first more specifically to FIG. 1, at 10 is indicated generally a ductile, moment resistant, steel space frame constructed according to an embodiment of the invention. In general terms, the space frame comprises a lower frame assembly 12, an upper frame assembly 14, each of which has a substantially rectangular peripheral outline when viewed from above, a pair of upright support posts 16 adjacent one end of the space frame, and another pair of supports 18 adjacent the other end of the space frame. Posts 16, 18 support upper frame assembly 14 over lower frame assembly 12 with peripheral margins of the upper frame assembly disposed substantially directly over peripheral margins of the lower frame assembly.

As is indicated generally in FIG. 1, lower frame assembly 12 is adapted to have a multiple wheel truck as-
assembly 20 and a towbar 22 detachably connected thereto permitting towing of the space frame to a building site, after which the truck assembly and towbar may be removed and the space frame set on a suitable foundation.

Describing lower frame assembly 12, and referring specifically to FIG. 1, it includes a pair of elongate, parallel, laterally spaced I-beams 30, 32. These I-beams extend horizontally and longitudinally of the space frame on opposite sides of the longitudinal axis of the space frame. The I-beams are disposed with their webs extending vertically and their flanges extending horizontally. This may be seen in FIG. 5 also. A plurality of parallel, laterally spaced I-beams 34 extend transversely between I-beams 30, 32 and are secured, as by welding, adjacent their opposite sets of ends to the webs of beams 30, 32.

A plurality of horizontally disposed extension, or outrigger, beams 36 are secured to and project laterally outwardly from opposite sides of beams 30, 32. Secured to opposite ends of beams 30, 32 are formed beams 40 having the general cross section illustrated in FIG. 10, and having a length corresponding to the sum of the lengths of a beam 34 and the pair of beams 36 extending outwardly from opposite ends thereof.

A rectangular angle frame 44 is secured to and supported on the outer ends of beams 36 and extends along the upper surfaces of beams 40 (see FIGS. 1, 2, 3, 9 and 10).

As is best seen in FIGS. 2, 3 and 6, each of posts 16 is an upright channel having a web 16a and flanges 16b. Channel 16 is disposed in the frame with its web substantially paralleling the vertical plane occupied by the longitudinal axis of the frame and its flanges extend normal thereto.

Referring still to FIGS. 2, 3, and 6, a portion of the top flange on one side of the I-beam to which the channel 16 is secured, is cut away, whereby the channel may be inset into the beam with the back of its web 16a resting against the web of its associated beam, as seen in FIG. 6. Channel 16 is secured to the web of its associated beam by being welded thereto. Since, as is seen in FIGS. 2 and 3, the bottom end of channel 16 is closely adjacent the bottom of its associated beam the weld lines securing the channel to its associated beam may be of a length corresponding to the full depth of the I-beam to which it is secured.

Further, a support plate 48 is secured, as by welding, to the upper and lower flanges of the beam to which channel 16 is secured, and is welded along one of its edges to an upright flange of channel 16. This provides further support for the post.

With such securing of the base of a post 16 to its associated beam, a substantially rigid, moment resistant connection is provided therebetween. Further, with channels 16 being disposed with their webs 16a paralleling the longitudinal axis of the space frame, they are able to provide substantial support against movement of the upper ends of the posts and the upper frame assembly in directions extending longitudinally of the frame.

Posts 18 adjacent the opposite end of the frame assemblies are square tubes, as illustrated in cross section in FIG. 5. Whereas posts 16 may be on the order of seven inch channels, tubular posts 18 may be on the order of three to four inches on a side. As is seen in FIG. 7, a post 18 is secured to its associated beam 30 or 32 in much the same manner as previously described for a post 16. Briefly, the post is inset in a notch in a flange of its associated beam whereby one face of tube 18 may rest flush with, and be secured, as by welding, to a web of its associated beam. Further, a support plate 50, similar to support plate 48 previously described, is secured as by welding, to upper and lower flanges of its associated beam, and secured, as by welding, along one of its upright edges to a side of post 18 to provide further support for the post. This connection between post 18 and the lower frame assembly also provides a moment resistant connection therebetween.

Since posts 16, 18 at opposite ends of the structure are of different cross sections the chance that harmonic vibrations may occur in the structure as it is transported between job sites or in case of an earthquake is minimized.

Referring again to FIGS. 1, 2 and 3, secured atop posts 16 and extending transversely thereof is an elongate channel 54 which is disposed with its web substantially horizontal and its flanges projecting upwardly. The length of channel 54 is slightly less than the length of beams 40 at opposite ends of the lower frame assembly. As is seen in FIG. 2, opposite end portions of the upwardly projecting flanges of channel 54 are cut away.

Spaced a distance below channel 54 and secured to an inner set of edges of posts 16 is an elongate channel 56. Channel 56 has substantially the same length as channel 54, extends transversely of post 16 and is disposed substantially horizontal with its flanges projecting upwardly. A pair of diagonal angle braces 60 are secured, as by welding, adjacent their opposite ends to posts 16 and outer ends of channel 54 for providing side to side bracing for the upright posts and channels.

Referring to FIGS. 1 and 5, it will be seen that posts 18 have a similar channel 54 secured to their tops and a similar channel 56 secured to their inner sides a distance below channel 54. The lengths and positioning of channels 54, 56 secured to posts 18 is similar to that indicated for like channels secured to posts 16. Further, similar diagonally disposed angle braces 60 are secured to posts 18 and channel 54 to provide side to side bracing for the posts and channels at this end of the frame.

A pair of elongate, laterally spaced, trusses 64, 66 extend longitudinally of the space frame and are spaced to opposite sides of the longitudinal center line of the frame. The trusses are substantially similar in construction, and thus only one will be described in detail.

Referring specifically to truss 66, as illustrated in FIGS. 1, 2 and 3, the truss includes an elongate member of T-shaped cross section 70 which may be either a T-beam or a pair of elongate angle members welded in back to back relation. Another elongate T-shaped member 72 extends parallel to and is spaced below member 70. Member 72 also may be either a T-beam or a pair of angles welded in back to back relationship. Member 70 is disposed with its central leg pointing down and member 72 is disposed with its central leg pointing up.

A plurality of diagonally disposed angle braces 74 extend between and are secured, as by welding, adjacent their opposite sets of ends to members 70, 72, to complete the truss.

As is best seen in FIG. 3, secured to the underside of each of the end extremities of member 70 is a short T-
shaped member 76. Member 76 is disposed with its central leg facing upwardly and its flanges disposed horizontally on its lower side. Member 76 thus is adapted to rest on and be secured to an end extremity of channel 54, as seen in FIGS. 2 and 3. Lower T member 72 is secured adjacent its opposite ends to channels 56 at opposite ends of the frame.

As is best seen in FIG. 1, a plurality of cross trusses 80 extend between and are secured adjacent their opposite ends to T members 76 of trusses 64, 66. Each of cross trusses 80 includes an elongate angle member 82 extending horizontally across its top, and a pair of diagonally disposed angle members 84, 86 secured together adjacent the center of the truss, and disposed at angles whereby they join at their spaced upper ends to opposite ends of member 82. An upright center post 88 secured between members 82, 84, 86 completes the cross truss to form a substantially rigid truss to aid in rigidifying the upper frame assembly.

Four elongate channels 80, 82, 84, 86 are interconnected adjacent their ends to form a rectangular frame which extends peripherally about the upper frame assembly. As is best seen in FIGS. 2, 3 and 5, these channels are secured to the underside of T-shaped members 72 forming the lower member in the elongate truss structures, and to the underside of channels 56 at opposite ends of the frame. As is seen in FIGS. 2, 3 and 5, all of the channels are disposed with their webs upright and their flanges facing inwardly toward the central region of the frame.

Referring to FIG. 3, an elongate channel member 88 extending substantially parallel to channel member 80 is secured as by welding, to the outer set of edges of posts 16. A similar channel is secured to the outer edges of posts 18.

In use, a pair of adjacent space frames 10 may be connected together in side by side relation in the manner illustrated in FIGS. 4 and 5. Referring first to FIG. 5, with a pair of such space frames in side by side relation, opposite end portions of elongate threaded rods, such as that indicated generally at 90, extend through accommodating bores in longitudinal I-beams 30, 32 in adjacent space frames. Appropriate washers and nuts 92 screwed onto opposite ends of rod 90 serve to draw the two space frames into abutting relationship as is seen in FIGS. 5 and 9, with portions of angle frames 44 extending longitudinally along the sides of the space frames being drawn into abutting contact. Screws, such as that indicated generally at 94 extending through sections of angle frame 44, in FIG. 9, also may be used for further securing the frames together.

At the upper portions of a pair of side-by-side space frames 10, lugs 96 are secured to outer end portions of cross trusses 80 and a turnbuckle 98 is connected adjacent its opposite ends to the lugs on adjacent frames. Tightening of turnbuckle 98 further serves to draw the adjacent space frames toward each other and hold them in position adjacent each other.

With such means for connecting adjacent space frames, a space frame may be set in an approximate position adjacent another space frame, and then by screwing action of the nuts on threaded rods 90 and the screwing action of turnbuckles 98 the two side by side space frames may be drawn into abutting contact. This, then, simplifies the connecting procedure over that required in the past.

A space frame 10 is adapted to mount enclosing roof, side and end wall panels thereon as illustrated in FIGS. 8, 9 and 10. Referring first to FIG. 8, at 100, 102, 104 are indicated generally modular building units, each of which comprises a space frame as described above, which building units are connected together in side by side relation to form a building.

As is seen in FIG. 8, unit 100 has been left substantially open to form a porch for the building constructed of the interconnected building units. A single wall panel 108 is shown attached to a corner portion of unit 100, which panel might be used for hanging a sign or other decorative items, and an end panel 114 is illustrated secured to the far end of the unit. Each of the units is provided with a floor, as indicated generally at 110 for unit 100, secured to the lower frame assembly, and a roof 112 secured to the top of the upper frame assembly.

Still referring to FIG. 8, opposite ends of a unit, such as unit 102 may be enclosed by end wall panels 114 which are secured at their upper ends to the upper frame assembly and at their lower ends to the lower frame assembly, as will be described in greater detail below. An end wall 114 may be designed to carry lateral or shear loads to further support the unit against side to side movement, and may be secured in the unit to transmit such loads to the lower frame assembly and foundation.

An elongate side wall, such as the side wall of unit 102 facing the viewer and facing toward the porch unit, may be either left open, or have solid or glass wall panels, door, or window units secured thereto. In the illustration, it may be assumed that certain ones of panels 116 are a solid wood or composite material and others may be door, window, or glass areas. Due to the inherent rigidity and strength of the space frames in the units, there is no need for interior supporting walls within the building. The space frames, with their end support posts and the lower and upper frame assemblies, are of sufficient strength to permit fully open interior spaces without additional support being provided.

Referring to FIG. 9, the attachment of floor panels, side wall panels, and roof panels are shown in greater detail. Referring first to floor 110 for a unit, it includes a prefabricated sandwich panel having a length substantially equal to the width of the lower frame assembly. The panel is comprised of a pair of outer sheets such as plywood, 120, 122 and a foamed, polyurethane core 124. Such a panel has substantial strength and excellent insulation characteristics, and may be secured easily to the underlying lower frame assembly by means of screws or other conventional fasteners.

Surface flooring materials, such as tile or carpeting, indicated generally at 126 may be laid over floor panels 110. An elongate cover strip, such as indicated generally at 128, may be secured over the edges of the floor panels where such join over a connection line between adjacent building units.

The roof for such a modular building unit also may comprise prefabricated sandwich panels, which also include opposite outer face sheets, such as plywood 130, 132, between which is secured a foamed polyurethane core 134. Extending longitudinally of the building component, and secured adjacent opposite edge margins of the roof panel, are elongate boards 136.
An exterior side wall 116 may comprise upper and lower sections 116a, 116b as illustrated in FIG. 9. Both of panels 116a, 116b may comprise sandwich panels having plywood outer faces and a foamed polyurethane core, as previously described for floor 110 and roof 112. Lower panel 116b has sufficient height to extend from the lower frame assembly to a position adjacent the channel frame extending about the underside of the upper frame assembly. This is best illustrated by the outer face plywood sheet of panel 116b resting in abutting relationship with and being secured, as by screws, to angle frame member 44 at its lower end, and the inner face sheet of panel 116b being in abutting relationship with channel 82 adjacent its upper end.

Upper panel 116a is of sufficient height to overlap the upper end of panel 116b and extend above the upper surface of roof panel 112. With such construction, fasteners, such as screws, may extend through panels 116a, 116b where they overlap adjacent channel 82 and be fastened to channel 82. At its upper end panel 116a it may fastened, as by nailing or screwing, to boards 136.

Referring to FIG. 10, an end panel 114 also may comprise upper and lower sandwich panel sections 114a, 114b, each of which has outer plywood faces with a foamed polyurethane inner core. The lower end of panel section 114b abuts an angle frame member 44 and may be secured thereto by screws of other fasteners. The upper edge of panel 114b abuts channel 88 near the upper end of an upright end post. The lower edge of panel 114a overlaps the upper edge of panel 114b and its upper edge abuts and may be fastened to an outer flange of channel 54. A single fastener may extend through the overlapping edges of panels 114a, 114b to secure the same to channel 88.

At interior regions of a building made up of a plurality of such interconnected building units, the interconnection between adjacent units at the roof line may be through a pair of elongate, upright panels indicated generally at 140 secured to the edges of the roof panels, which extend the full length of the units and project above the tops of roof panels 112. Conventional roofing material, such as a mopped roof 142, may be applied over roof panels 112. Elongate channel-formed flashings 144 cover the upwardly projecting panels at the longitudinal connection between the adjacent building units to produce a rainproof covering for the connection between the units.

Interiorly of the building, the channel frame suspended from the undersides of the trusses provides inwardly facing shoulders for supporting ceiling and light covering panels. Conventional acoustical ceiling panels, such as those indicated generally at 148, may be supported in the structure with their opposing edge margins resting in the channels, such as those indicated at 82, 86. The space between frame members 82, 86 in adjoining units may be covered by a conventional cover strip such as a board 150 secured to the undersides of the channels.

The modular building construction described, incorporating the subject moment resistant space frame, is easily transported to a construction site, and joined to adjacent building units to form an enclosed or open building structure. At the building site enclosing wall, floor and roof panels, and doors and windows may be attached by the simple connection methods described above.

Because of the structural strength provided in the frame the end, or corner, support posts 16, 18 are the sole support required between the upper and lower frame assemblies. This permits great flexibility in the manner in which the units may be used by allowing the space frame to be used as an open or an enclosed structure.

Since end posts 16, 18 at opposite ends of the structure are different in cross section and size, the tendency for harmonic vibrations to occur in the structure during hauling or during an earthquake is minimized. The manner in which the upright support posts are connected to the upper and lower frame assemblies also serves to rigidify the structure.

The design of such units also greatly facilitates the assembly of several of such units to form a building. In assembling a plurality of such units, a first unit is set in position on a suitable foundation and secured in place. The next unit then may be placed in an approximate position adjacent the first unit, and then by operation of the lower connecting rods 90 and the upper connecting turnbuckles 98, the second unit may be drawn into abutting relationship with the first unit. This substantially increases the speed with which a building may be assembled from such modular building units.

Since the space frame has sufficient strength to support itself, the side and end wall panels need not bear vertical loads within the structure. For this reason, the structure is extremely versatile allowing clear, open interior areas, the use of glass panels to form full wall sections or a substantially open structures as has been illustrated for unit 100 in FIG. 8.

Further, the side and end wall panels, the roof panels, and the floor panels all may be constructed in such a manner that they are easily connected to or detached from the space frame. This facilitates use of such a building unit as a temporary structure which may be moved as required. The panels may be standardized in size so that they are interchangeable from unit to unit. Further, since the wall panels are not required to bear structural loads in the unit they may be made light enough to be easily handled by workmen and shipped more cheaply than can panels which must bear structural loads.

While a preferred embodiment of the invention has been described herein, it should be apparent to those skilled in the art that variations and modifications are possible without departing from the spirit of the invention.

It is claimed and desired to secure by Letters Patent:

1. A moment resistant space frame for a modular building unit comprising an elongate, horizontally disposed lower frame assembly,
an elongate, horizontally disposed upper frame assembly overlying and spaced above said lower frame assembly, with one end of the upper frame assembly positioned over one end of the lower frame assembly and the opposite end of the upper frame assembly positioned over the opposite end of the lower frame assembly,
said upper frame assembly being supported above said lower frame assembly solely by a pair of upright support posts adjacent one set of ends of said frame assemblies and another pair of upright support posts adjacent the opposite set of ends of said frame assemblies, said posts in each of said pairs
being secured adjacent their lower set of ends to said lower frame assembly and secured adjacent their upper set of ends to said upper frame assembly in a manner to provide moment resistant connections between said upper and lower ends of the posts and said frame assemblies, and wherein said posts in said pair adjacent one set of ends of the frames assemblies have cross sections as viewed from above which differ from the cross sections as viewed from above of the posts in the pair adjacent the opposite set of ends of the frames, with a post in said pair adjacent one set of ends of the frame assemblies comprising a beam having a web and flanges projecting outwardly therefrom and said beam is disposed in said frame with the web thereof occupying a plane substantially paralleling a vertical plane occupied by the longitudinal axis of the frame and with the flanges thereof disposed substantially normal to said plane.

2. A moment resistant space frame for a modular building unit comprising
an elongate, horizontally disposed, lower frame assembly,
an elongate, horizontally disposed, upper frame assembly overlying and spaced above said lower frame assembly with one end of the upper frame assembly positioned over one end of the lower frame assembly and the opposite end of the upper frame assembly positioned over the opposite end of the lower frame assembly, said upper frame assembly including a pair of elongate, laterally spaced trusses extending along opposite sides of said upper frame assembly and a substantially rectangular, horizontally disposed channel frame secured to the undersides of said trusses and extending peripherally about said upper frame assembly, said channel frame having flanges thereon facing inwardly of the upper frame assembly to present supportive shoulders within the upper frame assembly, and a plurality of upright support posts disposed adjacent opposite ends of said frame assemblies secured adjacent their lower set of ends to said lower frame assembly and secured adjacent their upper set of ends to said upper frame assemblies through moment resistant connections to support said upper frame assembly over said lower frame assembly.

3. A moment resistant space frame for a modular building unit comprising
an elongate, horizontally disposed lower frame assembly,
an elongate, horizontally disposed upper frame assembly overlying and spaced above said lower frame assembly, with one end of the upper frame assembly positioned over one end of the lower frame assembly and the opposite end of the upper frame assembly positioned over the opposite end of the lower frame assembly,
said upper frame assembly being supported above said lower frame assembly by a pair of upright support posts adjacent one set of ends of said frame assemblies and another pair of upright support posts adjacent the opposite set of ends of said frame assemblies, said posts in each of said pairs being secured adjacent their lower set of ends to said lower frame assembly and secured adjacent their upper set of ends to said upper frame assembly in a manner to provide moment resistant connections between said upper and lower ends of the posts and said frame assemblies, said posts in said pair adjacent said one set of ends of said frame assemblies each having a first cross-sectional configuration and the posts in the pair adjacent the opposite set of ends of said frame assemblies each having a second cross-sectional configuration which is dissimilar from said first cross-sectional configuration, with a post in said pair adjacent said one set of ends of said frame assemblies comprising a beam having a web and flanges projecting outwardly therefrom and a post in the pair adjacent the opposite set of ends of the frame assemblies having a tubular cross section.

4. The space frame of claim 3, wherein said beam is disposed in said frame with the web thereof occupying a plane substantially paralleling a vertical plane occupied by the longitudinal axis of the frame and with the flanges thereof disposed substantially normal to said plane.