United States Patent [19]

Barraud

[11] 3,772,834

[45] Nov. 20, 1973

[54] **MODULAR MULTIPLE-UNIT BUILDING CONSTRUCTION**

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[22] Filed: **Jan. 15, 1971**

[21] Appl. No.: **106,652**

[52] **U.S. Cl.** **52/79,** 52/236

[51] **Int. Cl.** **E04b 1/348**

[58] **Field of Search** 52/79, 236, 726, 52/601, 568, 569

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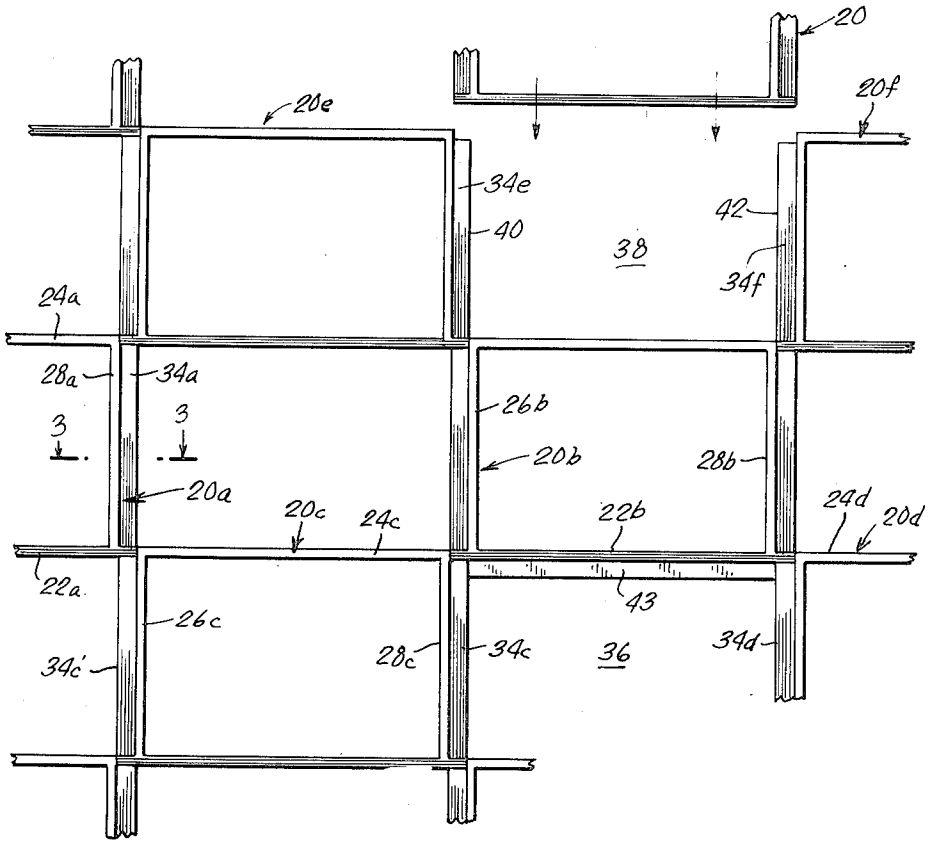
[57] ABSTRACT

Modular building construction utilizing box-like modules. Each module has side walls and a floor slab and a ceiling slab. One or more support columns are included on the outside surface of each side wall. Each support column comprises a metal shell substantially U-shaped in section and which extends vertically along the side wall. The shell is capped at its ends by metal plates which may be welded to corresponding plates of other support columns of modules thereabove and therebelow in a multi-level building to provide for a continuous metallic support column vertically throughout the building. In a multi-level building the modules in each level are spaced apart from each other, with the modules in one level being positioned over the spaces between modules of the next lower level. The side walls of a module in a level are positioned inside the planes defined by the outside edges of the columns of two-spaced apart modules in the next lower level and the next higher level to ensure that the side walls of the modules are non-load bearing. Thus, all vertical loads in the structure are supported by the columns. Post tensioning may be employed in abutting floor and ceiling slabs at any level in a multi-level structure or horizontal beams may be employed in the spaces between modules to account for horizontal loading. In the making of the modules a floor slab is first cast. A mold is positioned over the floor slab, and the spaced-apart side walls are cast along with a ceiling slab. The mold is then removed from the structure thus formed without any movement of that cast structure so as to position the mold for another casting operation.

9 Claims, 12 Drawing Figures

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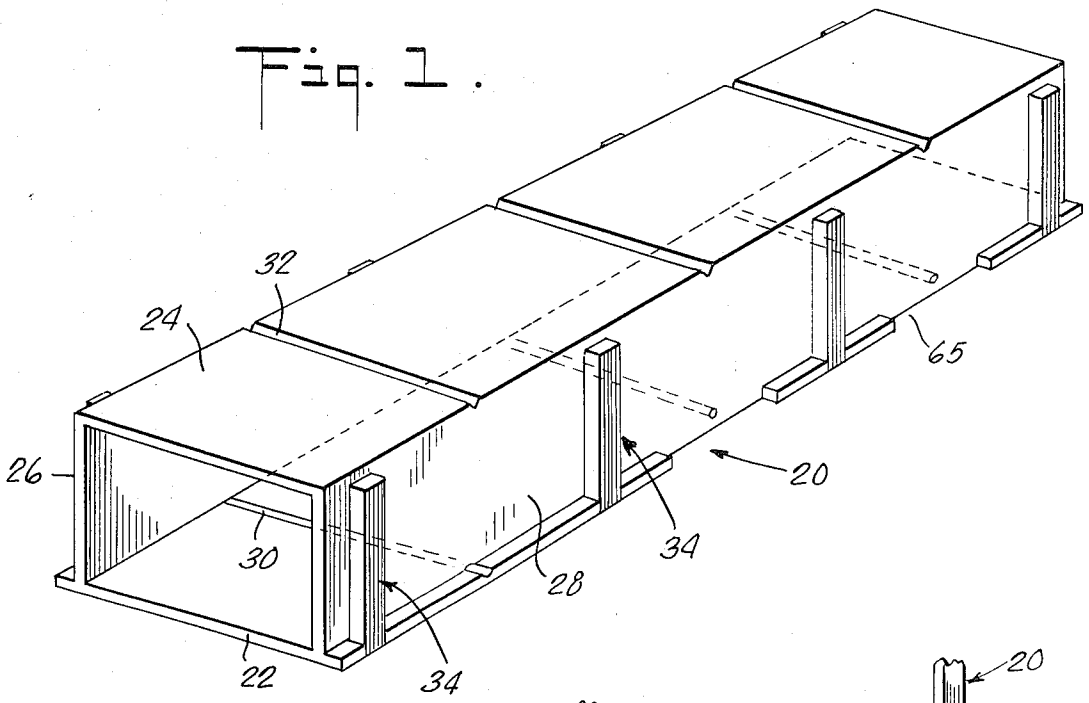


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Fig. 1.



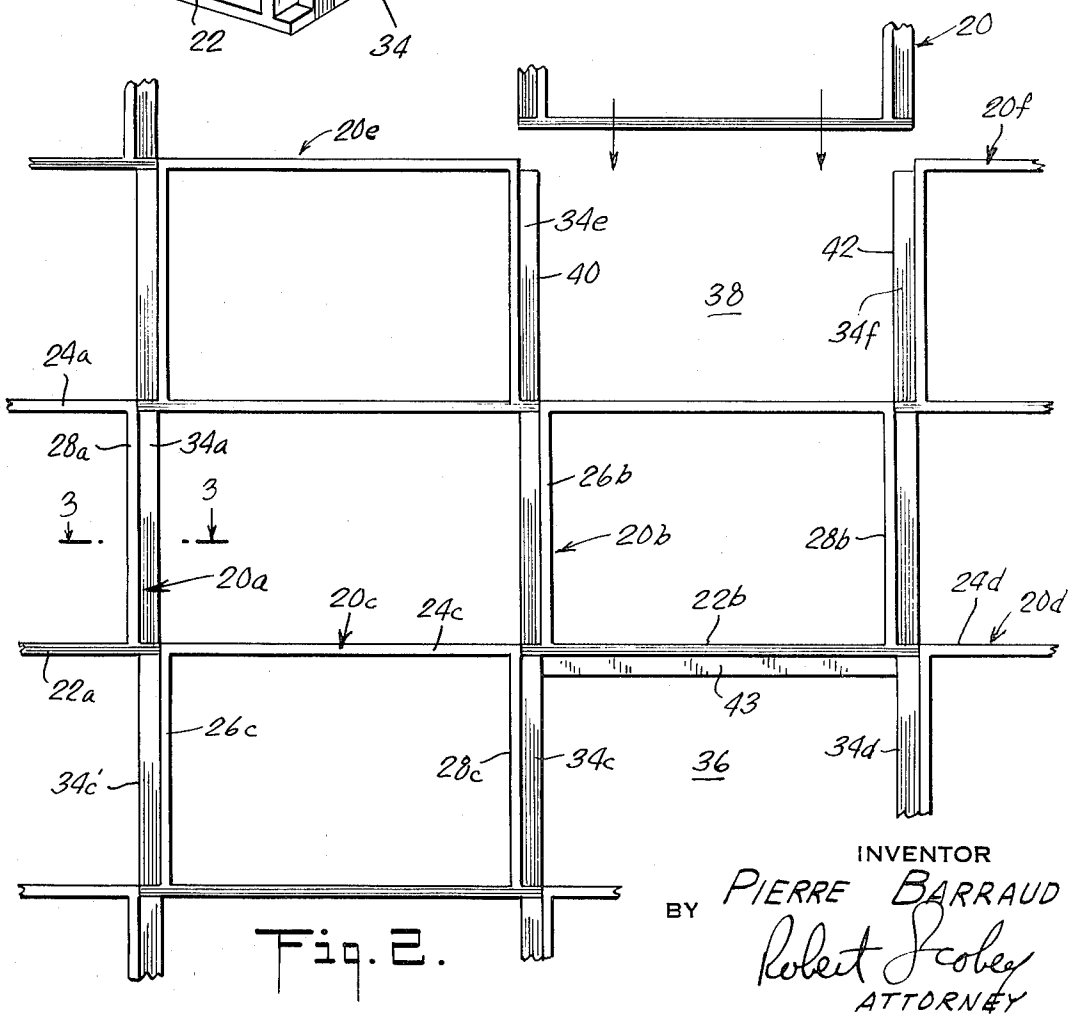


Fig. 2.

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Fig. 3.

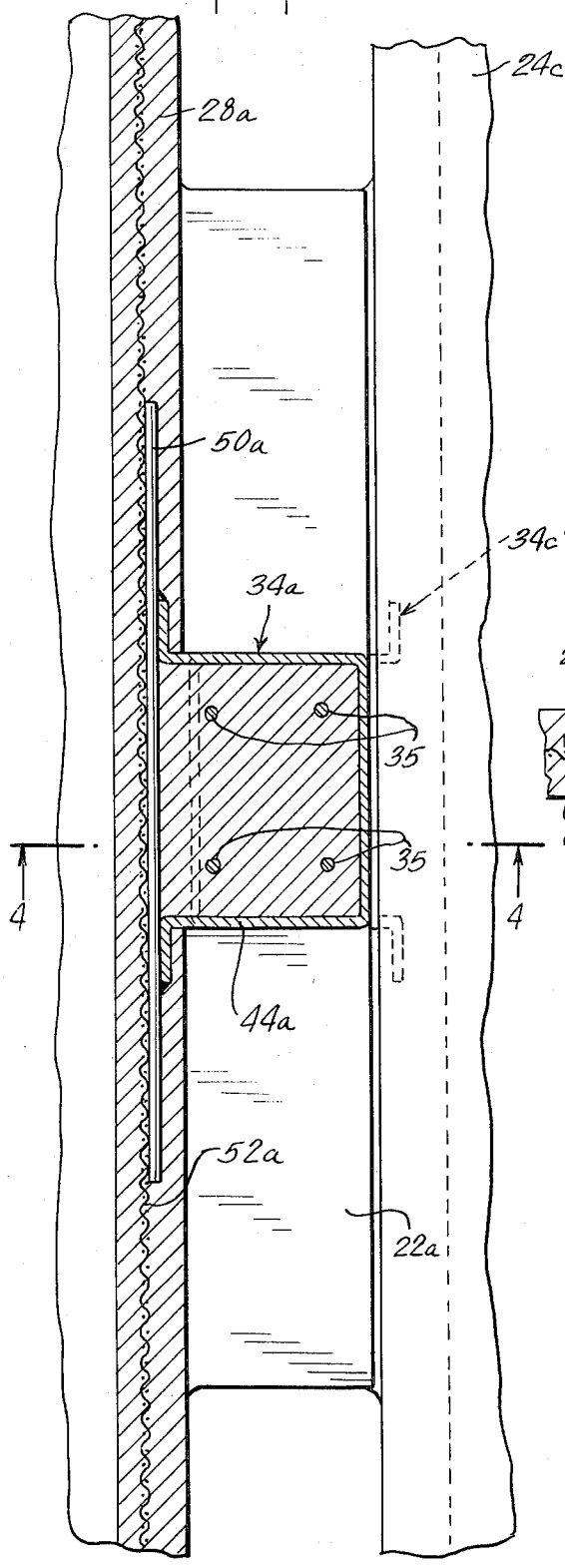

24c
28a
50a
34c'
34a
35
35
4
4
44a
52a
22a

Fig. 4.

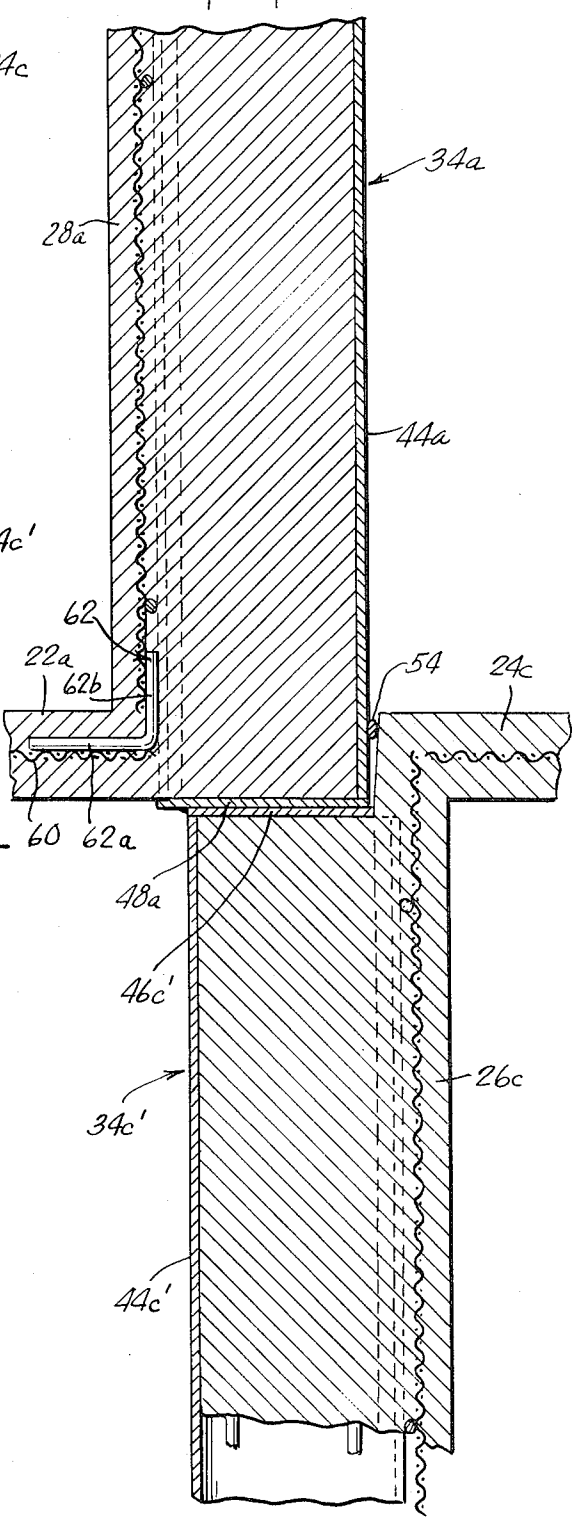

34a
28a
44a
62
22a
62b
54
24c
60
62a
48a
46c'
26c
34c'
44c'

Fig. 7.

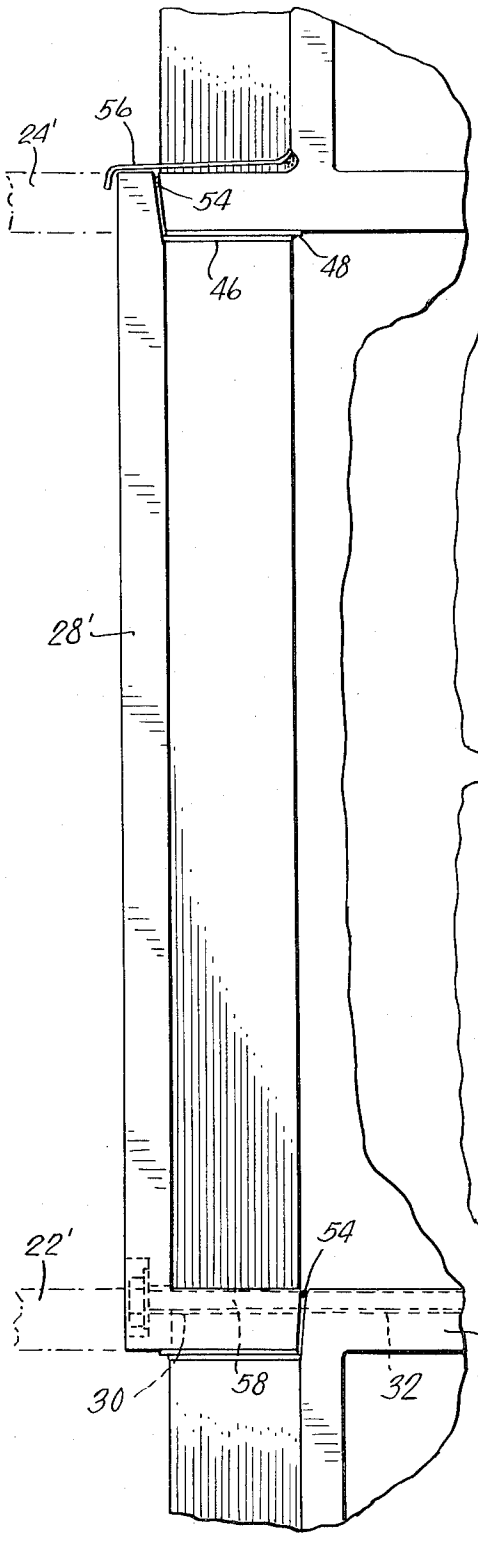


Fig. 5.

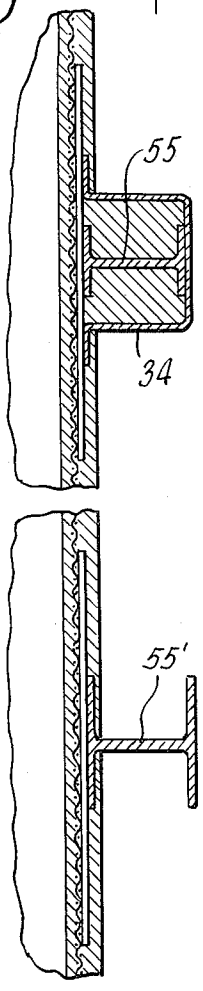


Fig. 6.

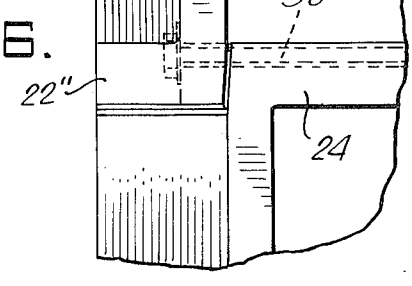


Fig. 8.

Fig. 9.

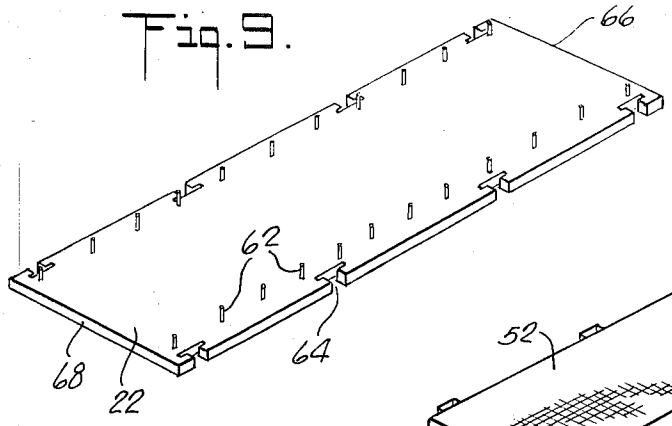
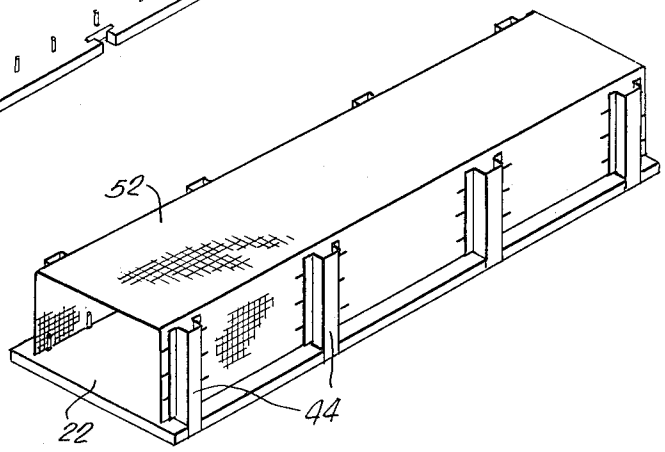


Fig. 10.



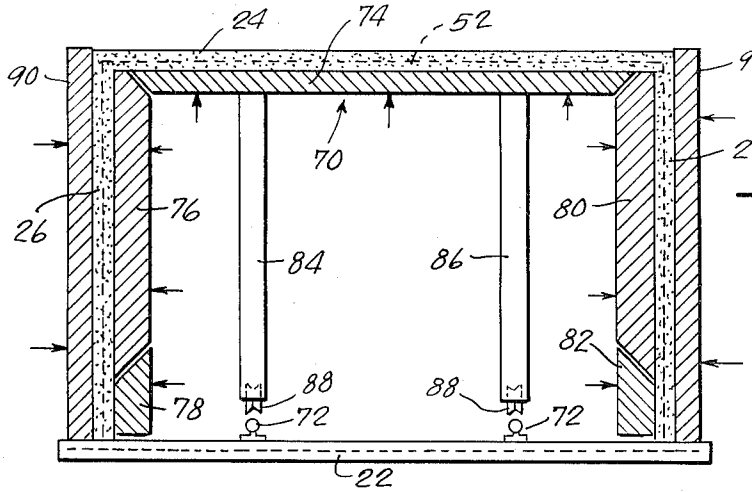
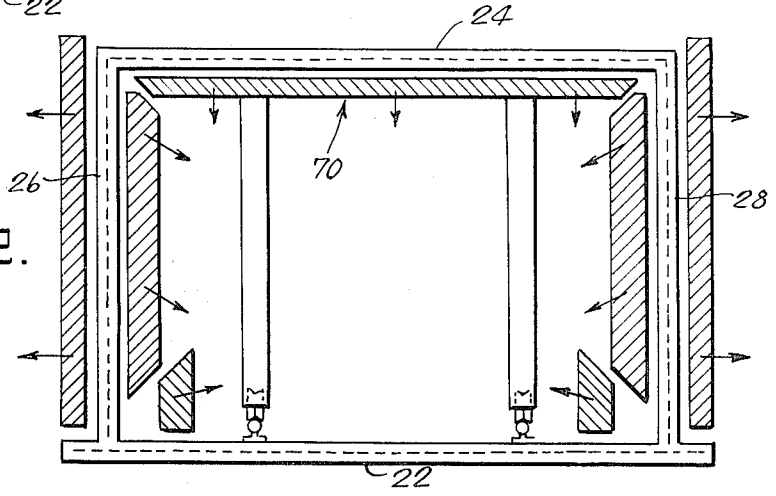


Fig. 11.

Fig. 12.



MODULAR MULTIPLE-UNIT BUILDING CONSTRUCTION

BACKGROUND AND BRIEF DESCRIPTION OF THE INVENTION

This invention relates to modular building construction. More particularly, it relates to modular building construction utilizing box-like modules.

Box-like modules have been used in the past for building purposes. Green and Shelley U.S. Pats. Nos. 3,430,398 and 3,503,170 disclose modular box-like building components which are positioned in a checkerboard relationship in the fabrication of a multi-level structure. A checkerboard pattern is intended to mean one in which in any level of a multi-level structure modules are spaced apart from each other; the modules in any level are positioned above the spaces between adjacent modules in the next lower level and below the spaces between adjacent modules in the next upper level. A major disadvantage of the structures shown in the Green and Shelley patents is that the side walls of the modules are load bearing. As will be described in more detail below, the side walls of modules constructed in accordance with the present invention are non-load bearing.

To avoid having the side walls of the module bear vertical loads, a column structure is employed in the present invention on the outside of the side walls of the modules. The column structure, when combined with a checkerboard positioning of modules in a multi-level structure, provides a structurally sound building while at the same time enjoying significant cost reductions through the use of non-load bearing side walls. Stucky et al. U.S. Pat. No. 3,416,273 discloses the use of a column structure. Because Stucky et al. utilize box-like modules that are stacked one over another, the side walls of each module are necessarily load bearing. The columns are provided simply for additional stiffness and support. Netherlands Pat. No. 6401392 also discloses use of a column structure. The column structure is located inside the module and not outside, thereby preventing the checkerboard positioning of modules as in the present invention.

Comm U.S. Pat. No. 3,514,910 discloses the use of ribs on the outside of module side walls. The ribs are used for spacing purposes, and modules are stacked one over another, thereby requiring that the side walls be load bearing. Van Hezik U.S. Pat. No. 3,507,080 discloses a modular building construction in which modules are supported by a skeleton building structure. The side walls of the modules are not attached to the skeleton support structure. Although the side walls of the modules are non-load bearing, the support advantages of a column structure as in the present invention are completely lacking in this system, as well as the advantages of the checkerboard positioning of modules.

Accordingly, the present invention is directed toward improving modular building construction practices.

An important object is the providing of an improved building component module.

Another object of the invention is to provide for an improved module casting technique.

These and other objects of the invention are achieved by the utilization of box-like modules in which the side walls include support columns on the outside surfaces thereof. In a multi-level structure the modules in each level are spaced apart from each other. The modules in any level are positioned over the spaces between modules of the next lower level and under the spaces between modules of the next higher level. The side walls of a module in a level are positioned inside the planes defined by the outside edges of the columns of two spaced-apart modules in both the next lower level and the next higher level. This ensures that the side walls of the modules are non-load bearing.

In a multi-level building the floor slab of one module in a level abuts the ceiling slabs of two spaced-apart modules in the next lower level. Post tensioning carried out by one or more tension members passing through abutting floor and ceiling slabs may be employed for support in a multi-level structure with respect to horizontal loads. This horizontal post tensioning is easier to accomplish by virtue of the accessibility of the channels for the tension members in the horizontal floor and ceiling slabs, as compared with vertical post tensioning in vertical column structures as utilized in the system of the Shelley Pat. No. 3,503,170, referred to above, for example. Horizontal beams may be utilized in the spaces between modules, as needed, for resisting horizontal loads such as wind and earthquake loads.

In the construction of the present invention each support column may comprise a metal shell which is substantially U-shaped in section and which extends vertically along the wall structure. The metal shell may be capped at its lower and upper ends by metal plates which may be welded to corresponding plates of other support columns of modules thereabove and therebelow in a multi-level building to provide for a continuous metallic support column vertically throughout the building. I-beams and reinforcing rods, for example, may be employed in the column structures. The structurally strong support column provided thereby obviates the necessity of vertical post tensioning as required in the Shelley system referred to above.

In the casting of individual modules, a floor slab is first cast. A mold is then positioned over the cast floor slab, and two spaced-apart parallel side walls are cast simultaneously with a ceiling or roof slab. Thereafter the mold structure is removed from the cast structure without any movement of the cast structure; and the mold is moved to another position over another floor slab for another casting operation. Each module may be finished in place, according to a sequence. In any event, all movement of a cast structure is avoided until that cast structure is to be transported for placement in a building.

The invention will be more completely understood by reference to the following detailed description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a module in accordance with the invention;

FIG. 2 is a front view of a part of a building formed from a plurality of modules positioned in checkerboard fashion in accordance with the invention;

FIG. 3 is a sectional view, to an enlarged scale, of part of the structure of FIG. 2, taken along the section 3—3 in FIG. 2;

FIG. 4 is a sectional view of the structure shown in FIG. 3, taken along the section 4—4 in FIG. 3;

FIGS. 5 and 6 are sectional views of alternative column structures;

FIGS. 7 and 8 are views of alternative structures employed on the edges of a building;

FIG. 9 is a perspective view of a cast floor slab;

FIG. 10 is a perspective view of reinforcing mesh and columns positioned over the floor slab of FIG. 9 in connection with a casting operation;

FIGS. 11 and 12 are schematic views showing the operations involved in a casting procedure in accordance with the invention.

DETAILED DESCRIPTION

Referring to FIG. 1 a box-like module **20** is shown. The module includes a floor slab **22**, a ceiling or roof slab **24**, and wall slabs **26** and **28**. Channels **30** and **32** are included respectively in the floor and ceiling slabs **22** and **24** to contain tension members for horizontal post tensioning purposes, to be described in detail below. One or more column structures **34** are included on the side walls of the module for the purpose of support, to be described in more detail below.

The module shown in FIG. 1 is typically of cast concrete. As an example, it might be 30 to 70 feet long, and varying in width from 8½ to 15 feet. The weight of the module might be 20 to 60 tons. The size of the module varies according to the requirements of the module and its intended use in a building structure.

The module **20** shown in FIG. 1 is a box-like structure having open ends. It is adapted to be used with other modules of similar shape to form a multi-level structure, as shown in FIG. 2. However, it should be noted that the module of FIG. 1 may be used by itself or with other modules to form a single-level structure. In a multi-level structure the columns **34** are for support purposes, and the walls **26** and **28** are intended to be non-load bearing.

Referring to FIG. 2, a multi-level structure is shown. In this structure the modules **20** are placed in a "checkerboard" pattern. To elaborate, the modules in each level are spaced apart from each other. For example, modules **20***a* and **20***b* are spaced apart from each other by a distance roughly corresponding to the distance between side walls **26** and **28** of a single module. Specifically, the modules in each level are positioned over the spaces between modules of the next lower level and under the spaces between modules of the next higher level. For example, the module **20***b* is positioned over the space **36** between modules **20***c* and **20***d* in the first level shown; the module **20***b* in the second level is also positioned beneath space **38** between modules **20***e* and **20***f* in the third level shown. Note that there is no overlapping of walls, and the space between modules is slightly wider than the width of a module.

It will be noted that, in the checkerboard positioning of modules **20** in the multi-level building structure of FIG. 2, the columns **34** of the modules provide for support and absorb all vertical loads. The walls **26** and **28** are non-load bearing. Specifically, and with reference to module **20***b* for example, the side walls **26***b* and **28***b* of this module are positioned inside the planes (vertical) designated **40** and **42** in FIG. 2 and which are defined by the outside edges of the columns **34***e* and **34***f* of the two spaced-apart modules **20***e* and **20***f* in the next upper level. The side walls **26***b* and **28***b* are also positioned inside these same planes **40** and **42** which also include the outside edges of the columns **34***c* and **34***d* of the modules **20***c* and **20***d* that are spaced apart from each other in the next lower level of the structure shown in FIG. 2. Essentially then each wall structure **26** and **28** of each module has nothing above or below it (except for a small portion of the floor slab **22** and ceiling slab **24**) by which or through which vertical forces can be transmitted. Thus, the wall slabs **26** and **28** of each module are truly non-load bearing, and simply constitute curtain walls in the modular construction. All support is provided with respect to vertical loads by the column structures **34**.

For the purpose of resisting horizontal loads, the floor and roof slabs of adjacent modules may be employed, as will be explained in detail below. Horizontal beams positioned in the spaces between adjacent modules may also be employed; for example, beam **43** in space **36** is attached to opposed columns **34***c* and **34***d* of spaced-apart modules **20***c* and **20***d*. The beam is positioned below and against the floor slab **22***b* of the module **20***b* thereabove and provides support against wind and earthquake loads, for example.

The details of the column structures are shown in FIGS. 3 and 4. From FIG. 3 it will be noted that the column **34***a* forming a part of the module **20***a* is defined by a U-shaped metal (preferably steel) shell **44***a* which extends vertically along the wall structure **28***a* of that module. The shell may be concrete filled and include reinforcing rods **35**. The metal shell on each module terminates below the top surface of the roof slab **24** (see FIG. 1). See also the metal shell **44***c'* that constitutes the column **34***c'* in FIG. 4 that forms a part of the module **20***c*. Note that the top of the metal shell **44***c'* is capped by a metal plate **46***c'*, which is welded to a plate **48***a* that caps the lower portion of the metal shell **44***a* that defines the column **34***a* of the module **20***a* in FIG. 4. The two plates **46***c'* and **48***a* are welded together as noted. Thus, a continuous metal column structure is provided throughout the vertical extent of the building as shown in FIG. 2. By virtue of the welding employed to join together vertically adjacent column parts, (e.g., the welding of the plates **46***c'* and **48***a*) the need for vertical post tensioning is obviated inasmuch as the column metal structure provides sufficient support for and resistance to vertical loads.

From FIG. 3 it will be noted that the metal shell **44***a* is welded to a reinforcing rod **50***a*. The rod **50***a* is loosely tied to mesh **52***a*, as will be explained in more detail below. The concrete which forms the wall **28***a* and the column **34***a* is continuous; however, the module **20***a* essentially "floats" inside the column **34***a* inasmuch as the side walls **26***a* and **28***a* of this module are not load bearing. The connection between concrete in the column **34***a* and concrete constituting the wall **28***a* is a sheer connection only and does not render the walls of the modules load bearing.

It will be noted from FIGS. 1 and 4 that the floor slab **22** of each module extends beyond the outer surfaces of the side walls **26** and **28**. The amount of outward extension is equal to the depth of the column **34**. It is possible to include no such outward extension of floor slab; however, the outward extension is preferable in the casting of the module, to be described below in more detail. Because of the outward extension of the floor slab, it will be noted that the columns **34** (see FIG. 1) terminate beneath the upper edges of the roof slab **24**. In FIG. 4 this distance is equal to the thickness of roof slab **22***a* plus the thickness of metal plates **48***a* and **46***c'*. If there were no such outward extension of the floor slab **22***a* for example, it would be possible to ex-

tend the metal shell 34c' so that it is essentially flush with the top surface of the roof slab 24c. Any number of constructions is possible; what is essential is that the side walls 26 and 28 of the modules be non-load bearing and positioned inside the outer edges of the column structures to ensure this. Thus, the column structures assume all vertical loads.

To overcome leakage between joints, as shown in FIG. 4, a gasket material 54 may be employed between joints between adjacent roof and floor slabs 22 and 24, (for example, between the joint between floor slab 22a and roof slab 24c).

FIGS. 5 and 6 show alternative column structures. In FIG. 5 an I-beam 55 may be utilized inside the metal shell of the column. Concrete inside the shell may be omitted. In FIG. 6, simply an I-beam structure 55' with no metal shell is utilized. Any number of arrangements, including reinforcing rods and the like, may be utilized for the vertical support column structures in a module.

FIGS. 7 and 8 show two alternative constructions used in the sides of a building to terminate the modular construction. In FIG. 7, wall slab 28' normally would be secured to a roof slab shown in dotted line and designated 24' as well as to a floor slab also shown dotted and designated 22'. In this case, however, the floor and roof slabs are omitted, and thus the wall slab 28' constitutes the outer surface of the building. Flashing is provided by metal plate 56. In the construction shown in FIG. 8, a part of a box-like module is employed to terminate the modular construction. All of side wall 26' is utilized along with a part of floor slab 22''. In this case, the module is essentially severed to provide a small portion of the floor slab. In practice, a module may be severed longitudinally close to the side wall 26 or 28, or a separately cast structure may be employed, to produce the structures shown in FIGS. 7 and 8.

FIGS. 7 and 8 also show the details of horizontal post tensioning that may be employed to provide greater stability against horizontal loads in the modular construction. As noted above in connection with FIG. 1, the floor and roof slabs 22 and 24 are formed with channels 30 and 32. A tension element, such as rod 58, may be employed as shown in FIGS. 7 and 8. Specifically, the rod 58 extends through channels 30 and 32 which are aligned in all modules in a given level and is suitably tightened to provide post tensioning of the floor and roof slabs 22 and 24 in a given level. Specifically, it will be noted that the floor and ceiling slabs in any level substantially define a horizontal plane. For example, in FIG. 2 floor slab 22a, roof or ceiling slab 24c, floor slab 22b and roof or ceiling slab 24d all together define a horizontal plane. The channels 30 and 32 in the floor and ceiling slabs in this plane are all aligned and the tension member 58 passes through these aligned channels. Following the tightening of the tension member, concrete or similar grout material may be used to fill the channels and to cover the tension member.

The use of horizontal post tensioning as just described advantageously utilizes the floor and roof or ceiling slabs as structural support members in the modular construction of this invention. This is much more suitable to vertical post tensioning, for example, which is difficult to carry out in practice because of the long vertical channels which must be filled with grout material.

Referring now to FIGS. 9 to 12, these Figures illustrate the casting technique employed in producing modules in accordance with the present invention. FIG. 9 shows an illustrative floor slab 22, which is preliminarily cast in any suitable fashion. The floor slab typically includes a reinforcing mesh structure inside it, such as the mesh designated 60 in FIG. 4. Also included are L-shaped reinforcing rods 62 shown in FIG. 4 and in FIG. 9. These L-shaped reinforcing rods are positioned so that one leg (62a in FIG. 4) is inside the floor slab, while the other leg (62b in FIG. 4) is inside a wall slab (wall slab 28a in FIG. 4). This L-shaped reinforcing rod structure facilitates in the joining together of wall and floor slabs which are cast separately.

The floor slab may be cast with cutouts 64 to permit the metal column shells 44 to extend therethrough. If desired, channels 65 as shown in FIG. 1 and as provided by additional cutouts may be employed for the positioning of electrical equipment, plumbing lines and like structure. Cutouts need not be employed, and the floor slabs may simply have straight side edges the same as at ends 66 and 68 of the floor slab. It should be noted that the interior of the columns 34 may be used to house electrical and plumbing equipment.

Following the casting of the floor slab 22, a mold structure 70, such as shown in FIG. 11, is moved into place on the floor slab. For this purpose rails 72 may be employed upon which the mold structure is mounted. The mold structure is shown diagrammatically and includes a ceiling or roof support 74 and side wall supports 76, 78 and 80, 82. Before any casting takes place, these supports are in the positions shown in FIG. 12, for example, permitting the mold 70 to be rolled into position. The side wall and roof supports are all articulated together (by mechanisms not shown) and are actuated to be moved to the positions shown in FIG. 11. In these positions the support structures designated 84 and 86 which carry rollers 88 that ride upon tracks 72 are moved to an upper position in which the rollers 88 are out of engagement with the tracks 72. Additional side wall structures 90 and 92 are then moved into place in anticipation of the concrete-pouring operation. Before any concrete is poured the mold walls are cleaned and sprayed with any suitable glazing material to prevent adherance of the concrete to the mold walls.

Prior to the positioning of the outer mold walls 90 and 92 in place, a reinforced steel cage is fitted outside the mold 70. This cage includes the column metal structure 44, as shown in FIG. 10. Following the positioning of the mesh with the column structure, the outer mold parts 90 and 92 are closed by any suitable hydraulic system (not shown), concrete is next placed between the outer and inner molds to form the side walls 26 and 28 and the roof or ceiling slab 24 of the module. Any suitable mix can be employed such as regular mix with a crushed-stone aggregate or a lightweight concrete mix or steam-injected concrete, to name some examples. The concrete is then cured, following which the molds are removed simultaneously. As shown in FIG. 12, the mold parts move away from the concrete in the module, the mold part 70 is in engagement with the rails 72 and may be advantageously moved to another location on another floor slab 22 for a subsequent molding operation.

It will be noted that there is no movement of the concrete in the casting procedure just described. Specifi-

cally, mold parts and not concrete are made to move. In this fashion the final finishing operations which typically include the following steps in the following sequence may be completed without any mold movement:

a. Repair of concrete walls;
b. Coating with a prime finishing material;
c. Installation of sheet rock walls;
d. Rough plumbing;
e. Rough electrical work;
f. Closure panels placed at the open ends of the module;
g. Carpentry and mill work;
h. Aluminum and glass installation;
i. Ceramic tile installation;
j. Flooring and acoustical ceiling installation;
k. Installation of plumbing fixtures;
l. Fire protection of metal columns through the use of asbestos cement or similar material; and
m. Painting and touch-up of any defects.

The finished box-like modules are loaded onto any suitable vehicle that will transport them from the fabrication location to the job site. Typically, a frame involving a three-point bearing to support the module will be used to transport it. The bearing points normally will be the bases of the columns, although any suitable rigging can be employed to lift and set the modules in place while avoiding undue torsion moments which can harm the structure.

It will be noted that the present invention provides a unique box-like module for building construction and a unique casting technique. The invention is susceptible of modification. Some specific changes possible have been designated above. Others will occur to those skilled in the art. Accordingly, the invention should be taken to be defined by the following claims.

I claim:

1. A multi-level building formed from precast concrete parallelepiped modules each having spaced-apart side walls, respectively having upper and lower edges,

a top slab extending between said upper edges of said side walls and a bottom slab extending between said lower edges of side walls,

the modules in each level being spaced apart from each other with the modules in a level being positioned over the spaces between modules of the next lower level, each module including,

one or more support columns formed in a substantially U-shaped metal shell on the outside surface of each side wall, and said bottom slab extends beyond said side walls a distance so that the outer extension is coplanar with the base of said U-shaped metal shell,

said support columns extending upwardly from said lower edges and terminating below said upper edges a distance substantially equal to the thickness of said top slab,

said columns of a module in a level being positioned over the columns of two spaced-apart modules in the next lower level to provide support of the modules in a multi-level structure, the side walls of a module in a level being positioned inside the planes defined by the outside edges of the columns of two spaced-apart modules in the next lower level to ensure that the side walls of the modules do not overlap and that said columns receive the loads of said building,

said top slab of one module abuts and is longitudinally co-planar with the bottom slab of a module in the next upper level and a plurality of tension members passing through the abutting top and lower slabs to provide for support in the multi-level structure with respect to horizontal loads.

2. Structure according to claim 1, in which each metal shell is capped at its lower and upper ends by metal plates which may be welded to corresponding plates of other support columns of modules thereabove and therebelow in a multi-level building to provide for a continuous metallic support column vertically throughout the building.

3. Structure according to claim 1, in which the metal shell is capped at its upper end by a metal plate.

4. Structure according to claim 1, including a gasket material positioned between the abutting surfaces of abutting bottom and ceiling slabs to prevent leakage.

5. Structure according to claim 1, in which each column comprises a metal beam.

6. Structure according to claim 1, in which each column includes reinforcing bars encased in concrete.

7. Structure according to claim 1, including a structural beam positioned in the space between two modules in a level.

8. Structure according to claim 7, in which said beam is connected to opposed support columns of spaced-apart modules.

9. Structure according to claim 7, in which said beam is positioned below and against the bottom slab of the module thereabove.

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