United States Patent [19]

Miram

[11] **3,872,635**

[45] **Mar. 25, 1975**

[54] **MULTI-UNIT BUILDING CONSTRUCTION**

[76] Inventor: **Oleg V. Miram,** 759 Flood Bldg., San Rafael, Calif. 94102

[22] Filed: **Aug. 21, 1972**

[21] Appl. No.: **282,401**

Related U.S. Application Data

[62] Division of Ser. No. 134,623, April 16, 1971, Pat. No. 3,724,157.

[52] **U.S. Cl.** **52/227,** 52/224, 52/236, 52/237

[51] **Int. Cl.** **E04b 5/02,** E04b 5/43

[58] **Field of Search** 52/224, 259, 251, 250, 52/236, 227, 223, 79, 432, 230, 237

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Primary Examiner—John E. Murtagh
Attorney, Agent, or Firm—Phillips, Moore, Weissenberger Lempio & Strabala

[57] **ABSTRACT**

A method of constructing buildings of modules is disclosed in which the modules are formed of overhead and wall panels fabricated with means embedded therein having no portion extending beyond the boundaries thereof for distributing the weight thereof to a plurality of points spaced from each other along their edges, which edges are mechanically interconnected by removable hinge joinder means extending between the embedded means in adjacent panels when they are in selected juxtaposition. Means for raising the overhead panels to an elevated position including said removable hinge joinder means are described. Preferred means for forming the overhead and wall panels in the selected juxtaposition and preferred removable hinge joinder means are disclosed. Preferred methods and means for interconnecting vertically and horizontally adjacent modules into structural units of the final building structure before or after removal of said removable hinge joinder means are described.

4 Claims, 30 Drawing Figures

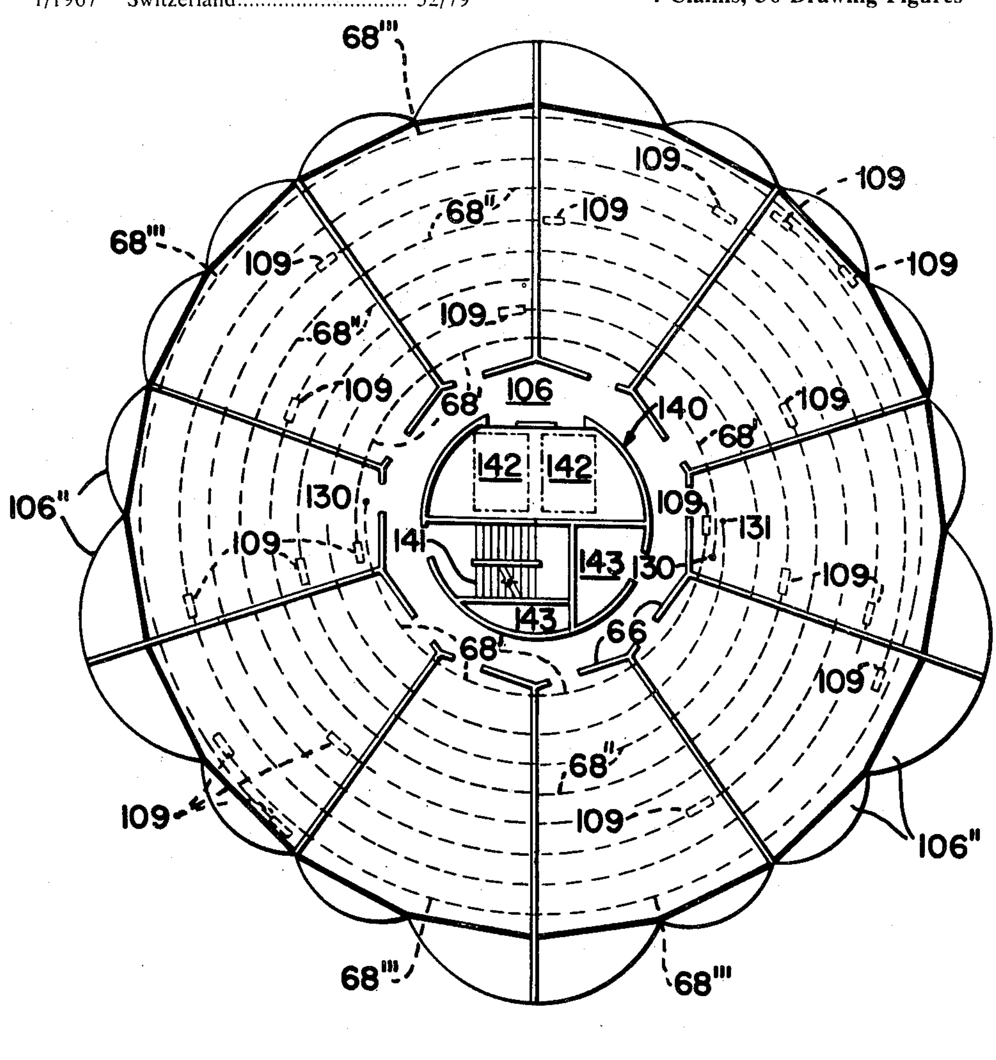
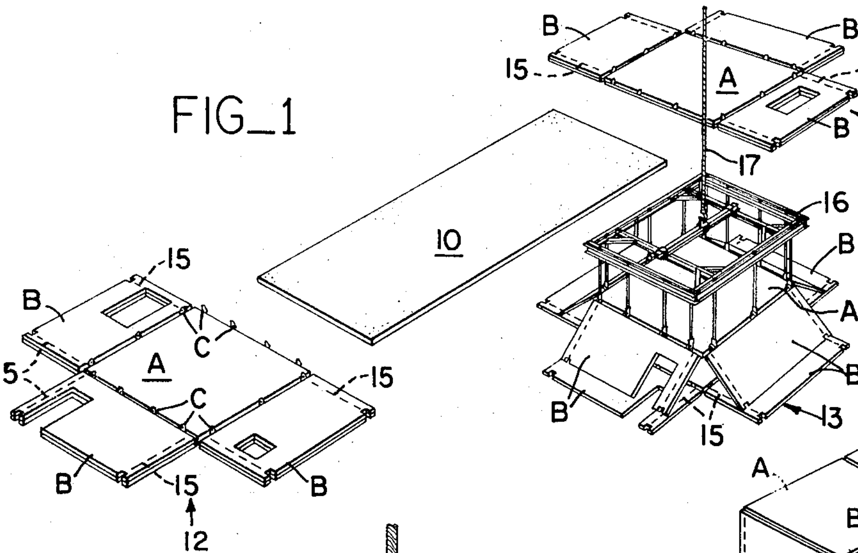


FIG_1



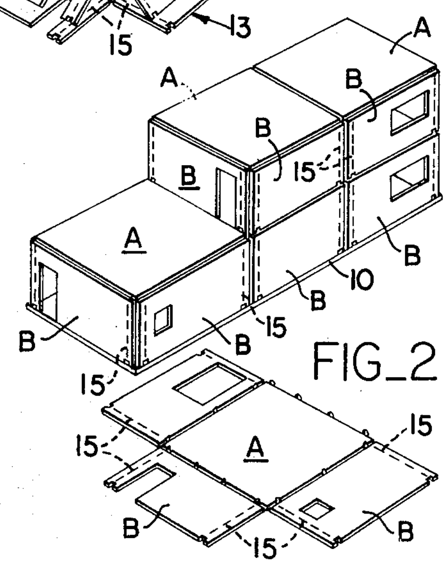


FIG_2

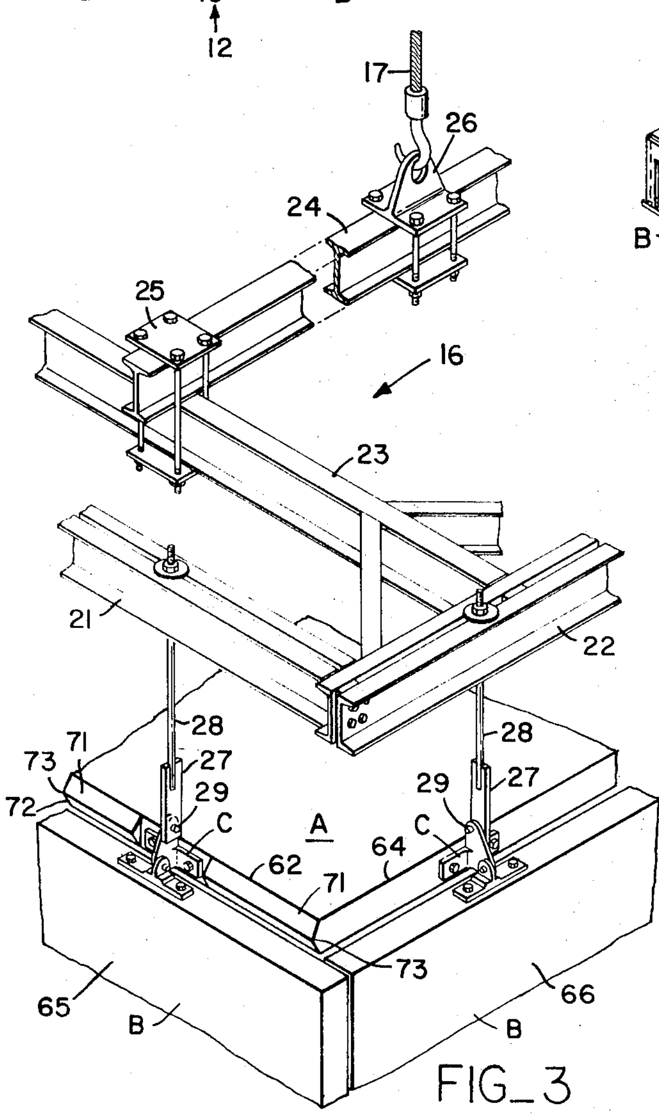


FIG_3

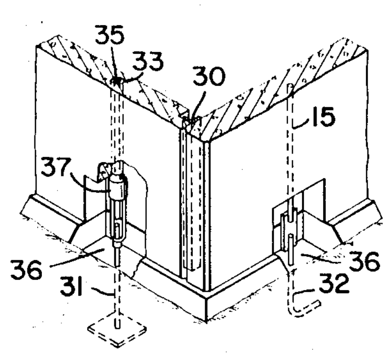
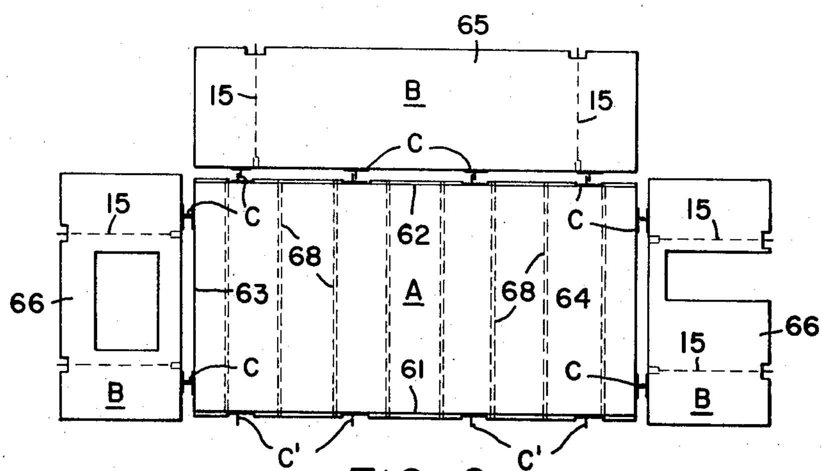


FIG_4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C'
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FIG_6

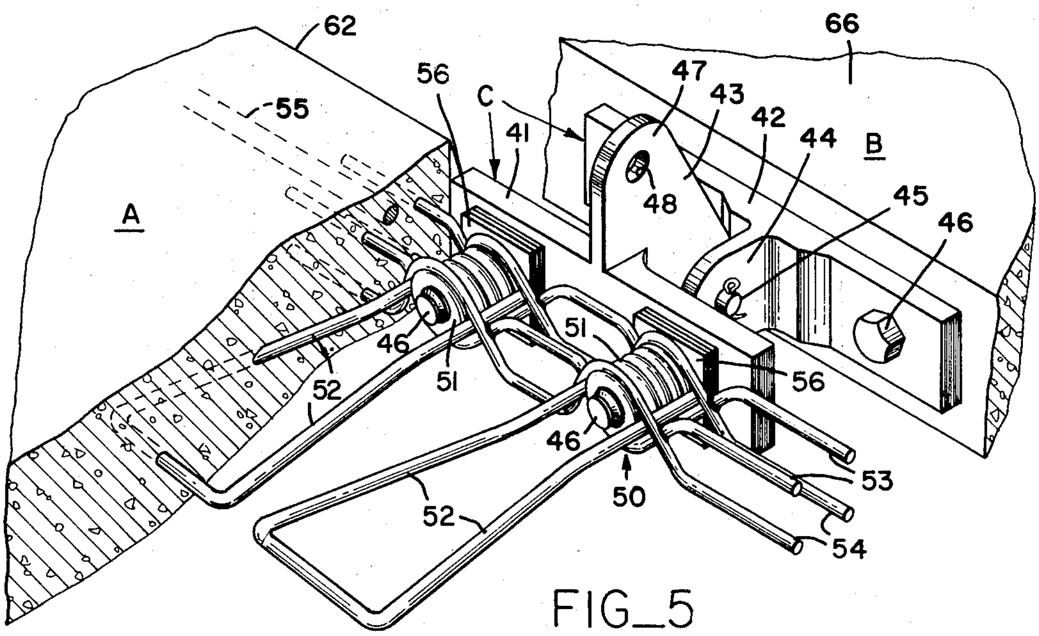
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FIG_5

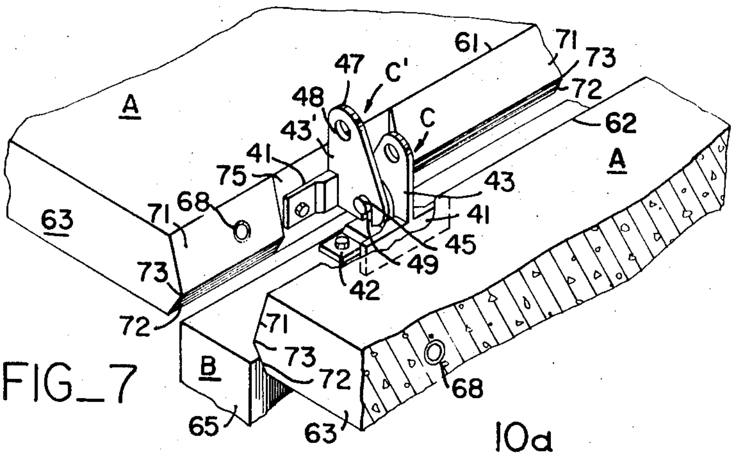


FIG_7

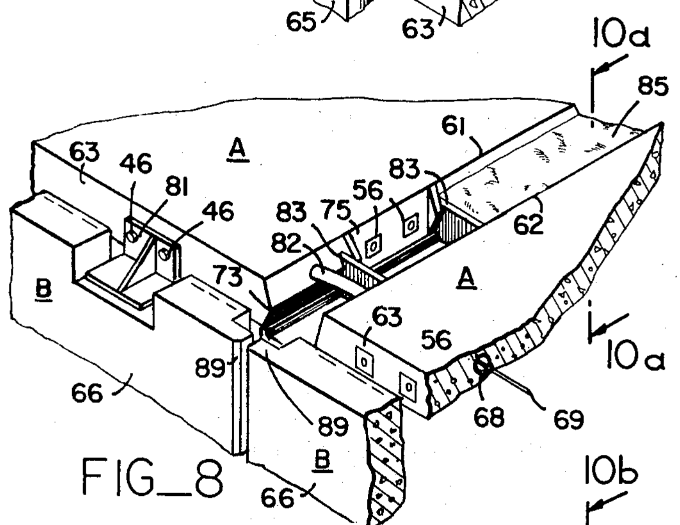


FIG_8

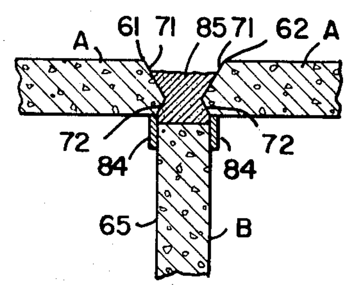


FIG_10a

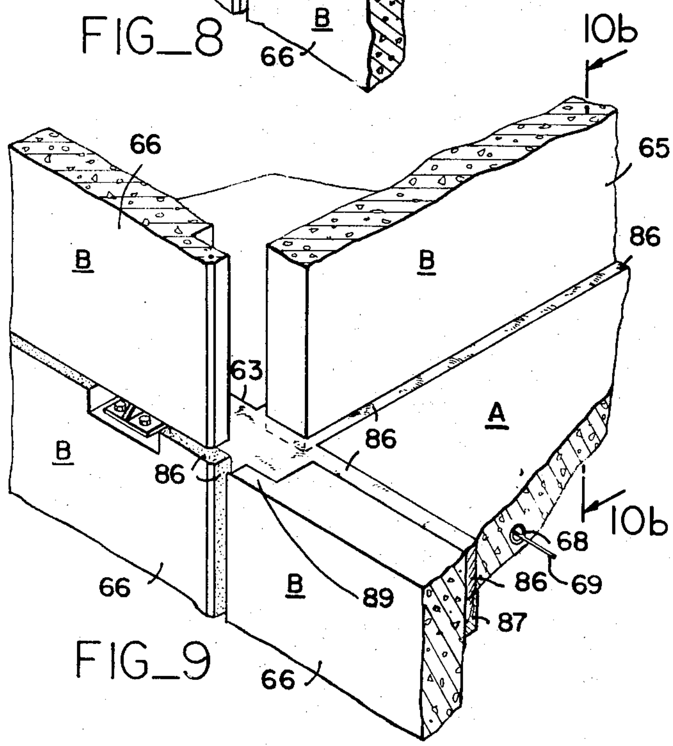


FIG_9

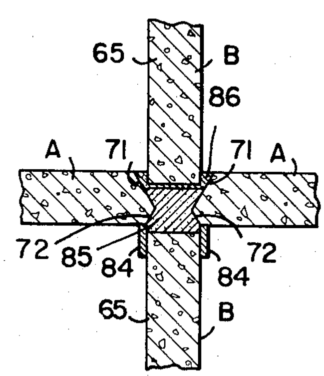


FIG_10b

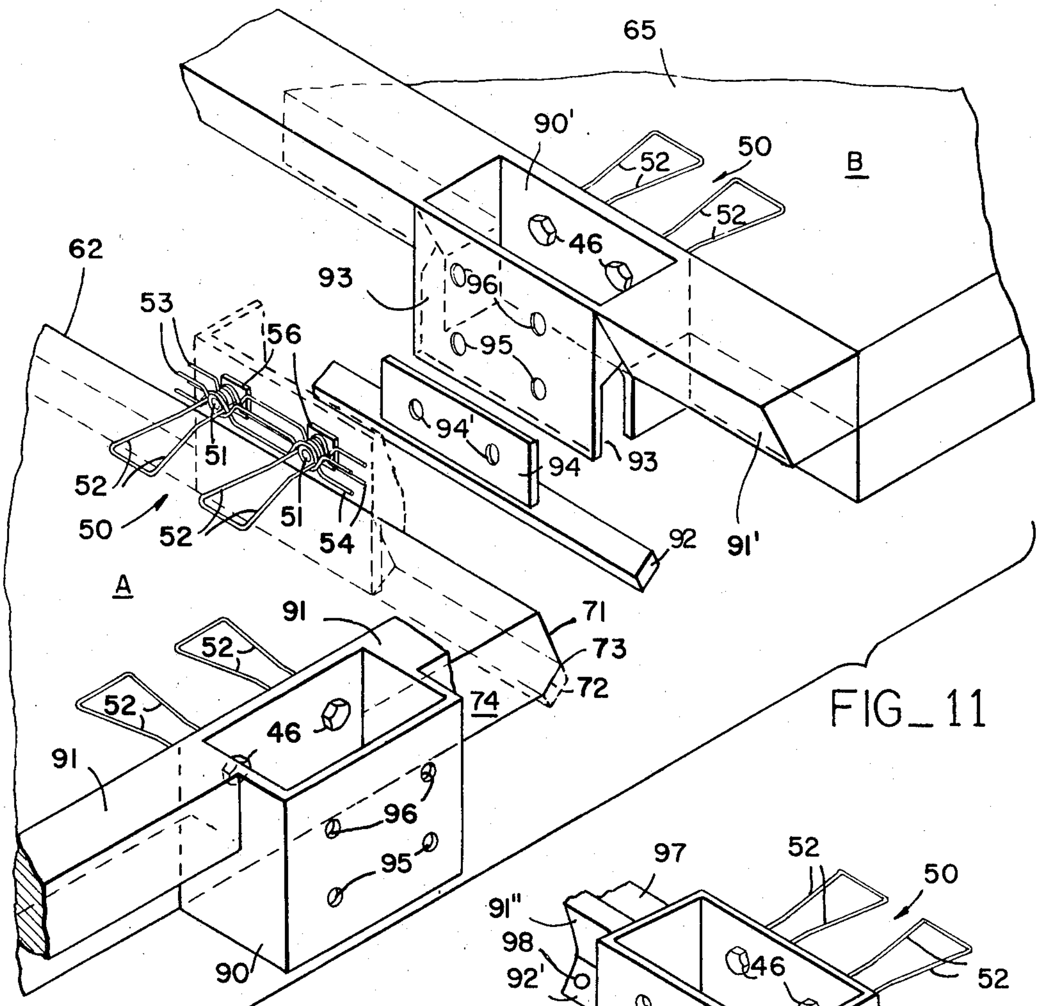


FIG_11

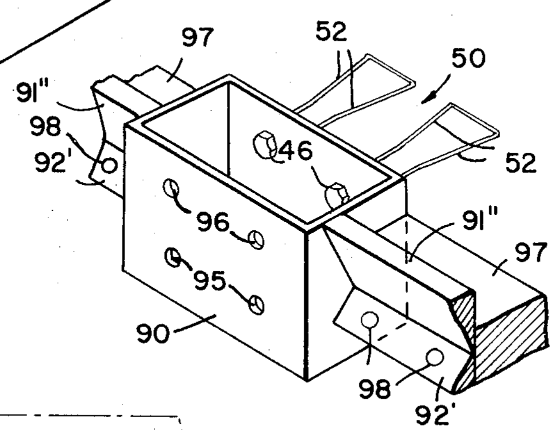


FIG_11a

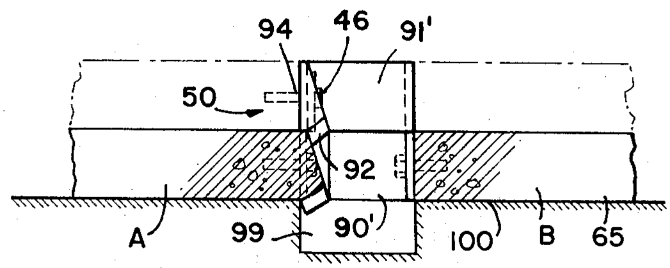


FIG_12

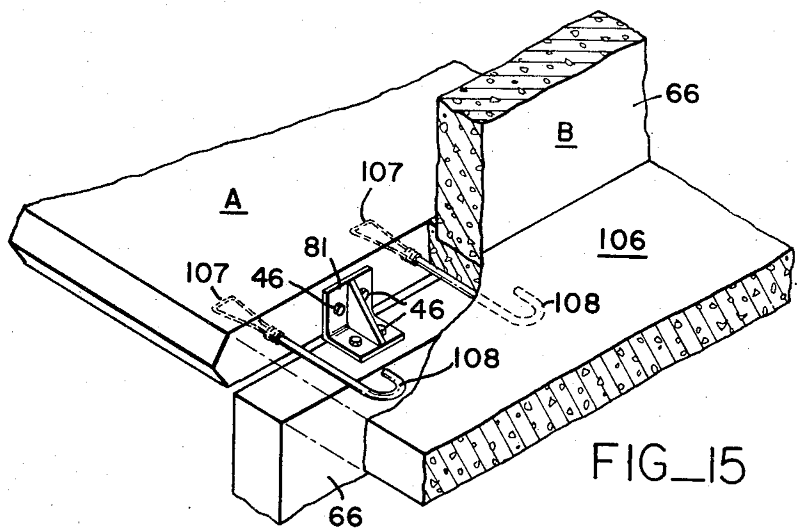


FIG_15

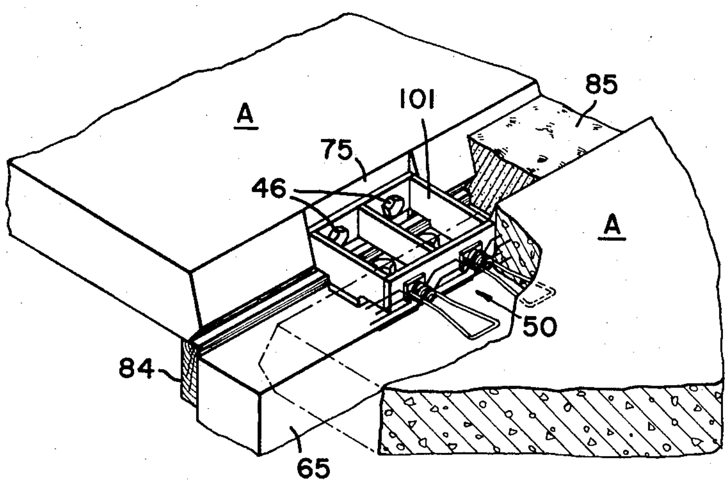


FIG_13

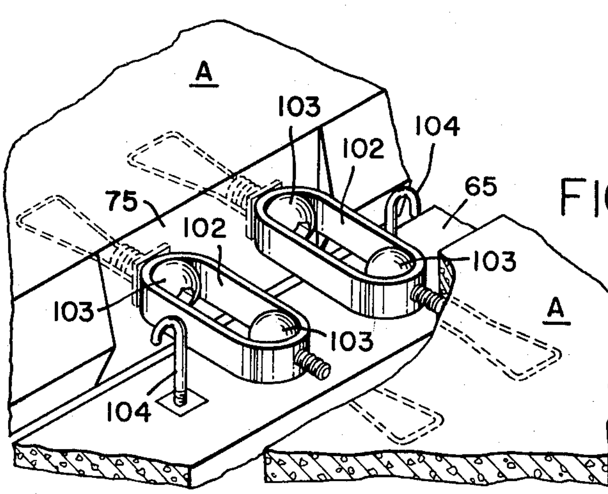


FIG_14

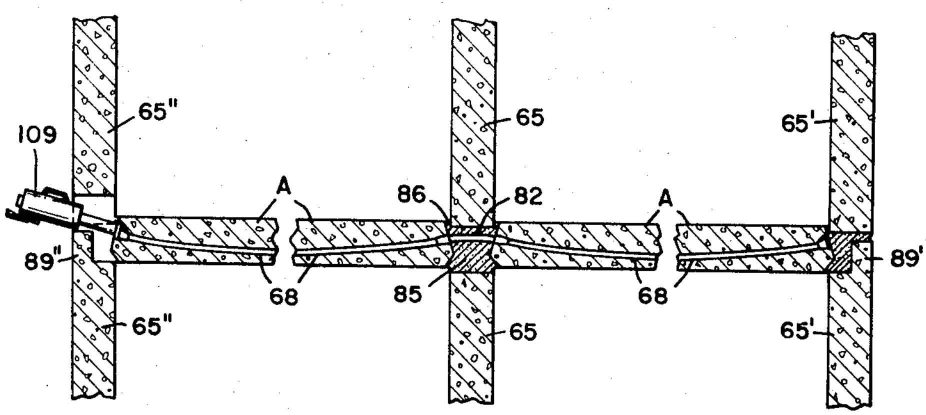


FIG_17

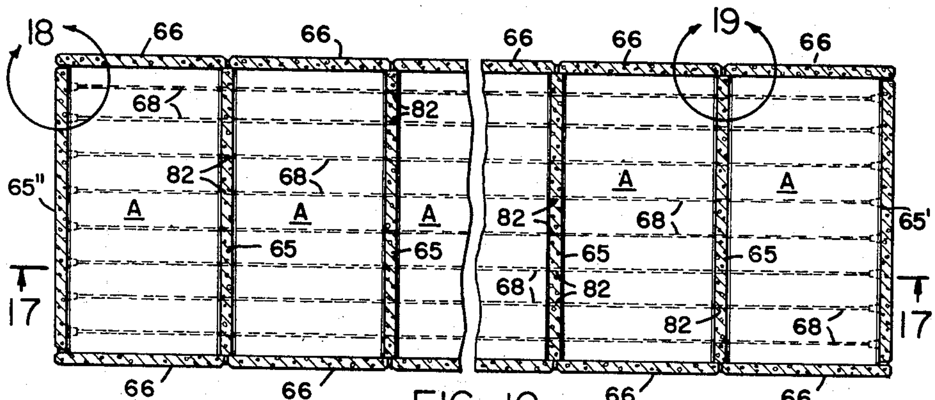


FIG_16

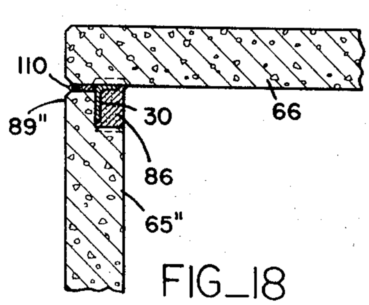


FIG_18

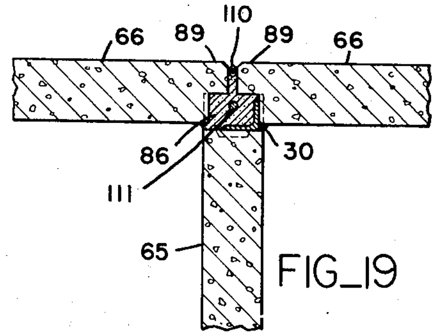


FIG_19

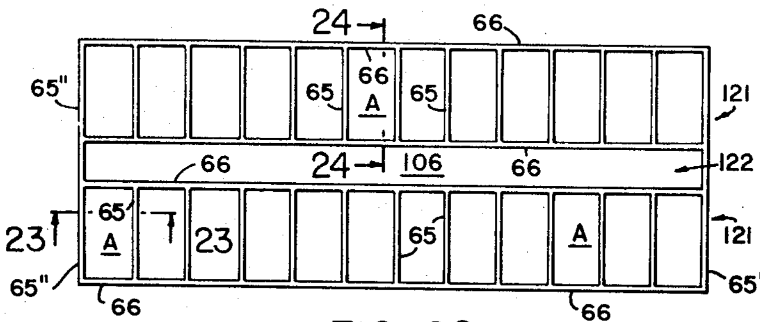


FIG_20

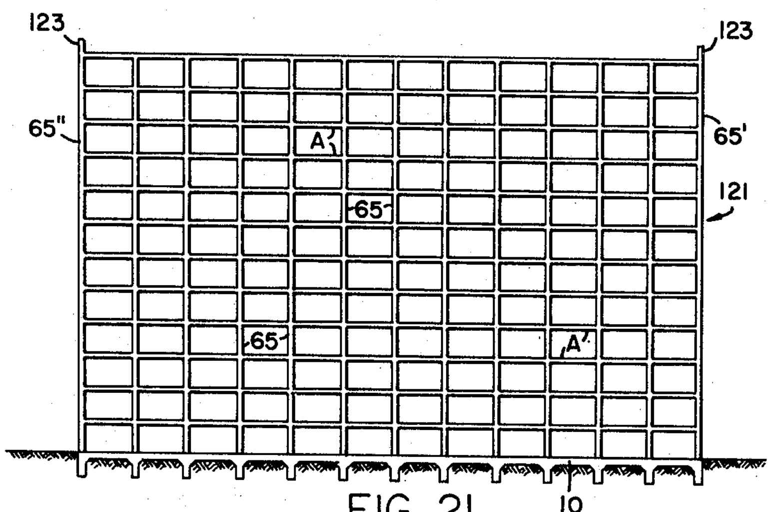


FIG_21

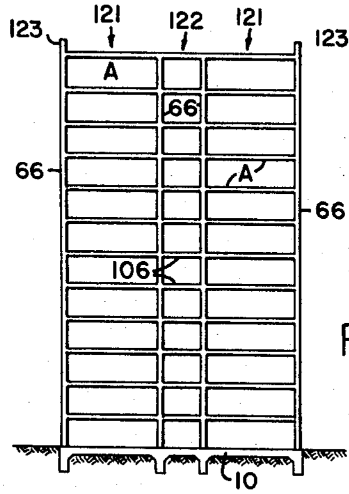
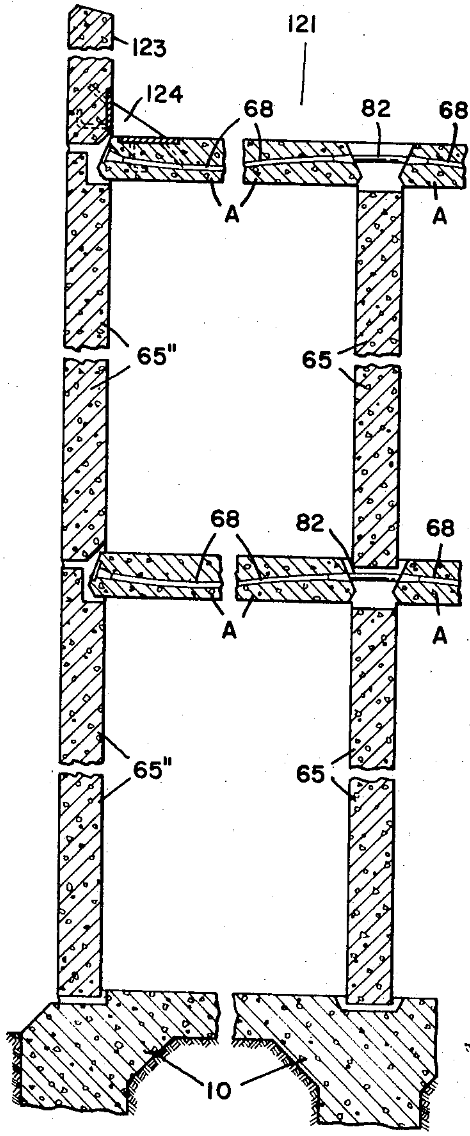


FIG_22


123
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10

FIG_23

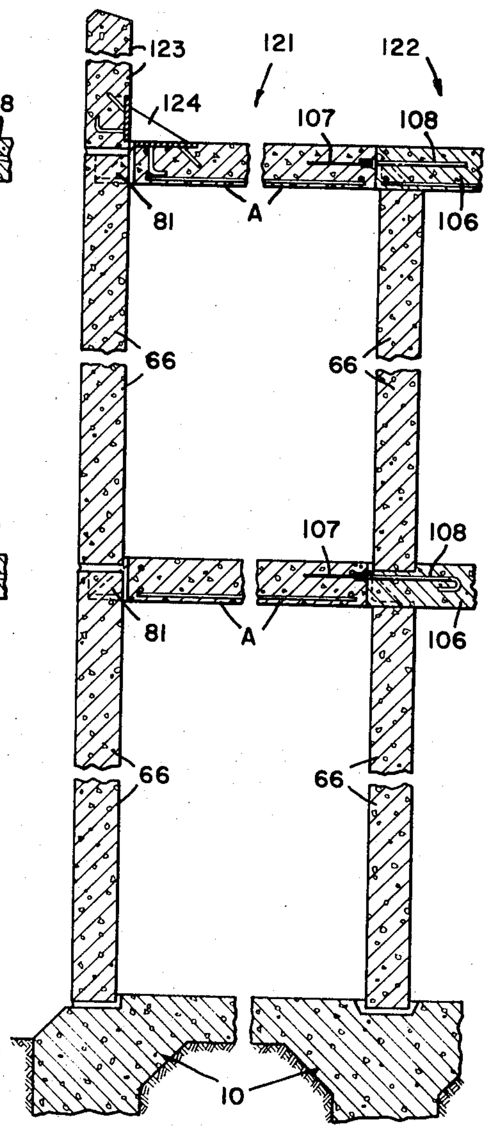
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FIG_24

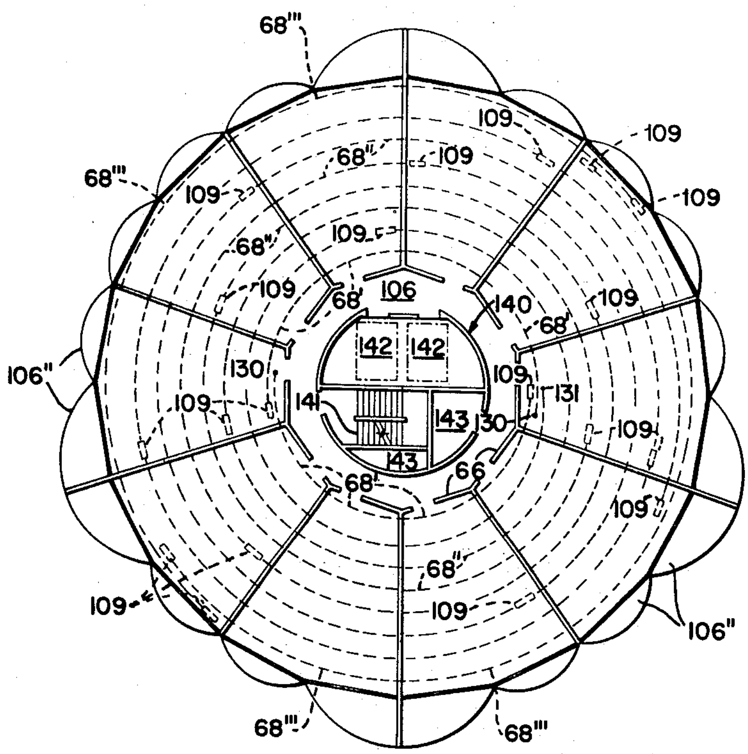

FIG_25

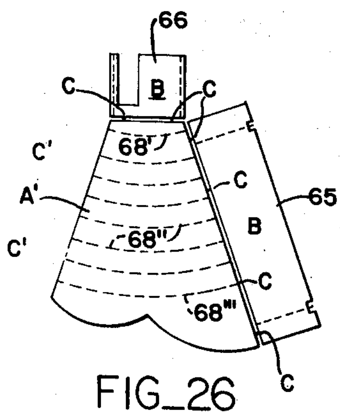

FIG_26

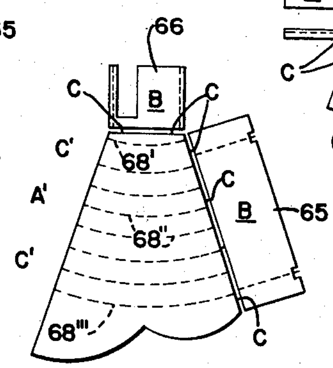

FIG_27

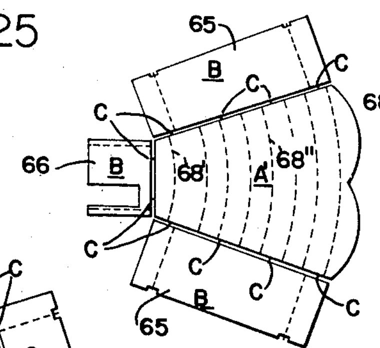

FIG_28

MULTI-UNIT BUILDING CONSTRUCTION

CROSS-REFERENCE TO RELATED APPLICATION

This application is a division of patent application Ser. No. 134,623, filed Apr. 16, 1971 now U.S. Pat. No. 3,724,157.

BACKGROUND OF THE INVENTION

This invention relates to a method of and means for constructing permanent building structures of a module or modules comprising an overhead panel and depending wall panels, and more particularly to such a method in which the overhead panels and wall panels are prefabricated with means embedded therein having no portion extending beyond the boundaries thereof for distributing the weight thereof to a plurality of points spaced from each other along their edges and a module is subsequently formed by attaching a set of wall panels to an overhead panel by removable hinge joinder means extending between the embedded means in accordance with the teaching of this invention, which hinge joinder means may be subsequently removed and the panels interconnected by other means in the final structure.

It is known in the prior art to prefabricate overhead panel structures and wall panel structures with means for interconnecting such panels into modules projecting from and forming a permanent part of each panel as shown by U.S. Pat. No. 1,886,962 to La Roche. Such panels may be prefabricated at the construction site or elsewhere but in any event must be individually placed in juxtaposition and interconnected with the other panels of the module either before or after the panels are in their final position in the structure. In order to accomplish the desired interconnection the individual interconnection means on the panels must be brought into registry and alignment thus requiring each panel to be individually moved and carefully adjusted in position with respect to the other panels. This is a tedious and time consuming operation requiring much labor and equipment to handle the various panels individually.

It is also known in the prior art to prefabricate overhead and floor panels in selected juxtaposition to each other, simultaneously joining a set of wall panels to each overhead panel by means extending between and embedded in or otherwise forming an integral part of the joined panels which means are capable of bending or swinging as taught by U.S. Pat. No. 1,361,831 to Crew and U.S. Pat. No. 3,494,092 to Johnson et al. This method avoids the disadvantages attendant to the individual movement of the panels into registry and alignment for interconnection into modules but a number of non-obvious disadvantages remain.

In the first place, whether the means interconnecting the panels into modules are embedded bendable members or integral hinge structures, they become a permanent part of the finished structure which fact imposes limitations, not only on the physical dimensions of the interconnecting means, but also on the structure itself. For example, the joint between the panels of vertically or horizontally adjacent modules must be designed with the means interconnecting the panels in mind. In addition, the panels themselves must be designed and fabricated in such a way as to provide for the transportation of the modules which they form into final positions with the location and physical characteristics of the means interconnecting the panels in mind. Furthermore, the fact that the panels must be fabricated with embedded or integral means interconnecting them, imposes limitations on the fabrication techniques that may be used both in fabricating the panels and in assembling the modules formed thereby into the final structure. Finally, the means interconnecting the panels into modules while a module is being transported to its final position must remain a permanent part of the structure in spite of the fact that other means may be preferred for use in interconnecting the panels of a module or vertically and horizontally adjacent modules into desired structural units of the final structure. Thus, the use of either embedded or integral interconnecting means between the overhead panels and wall panels of modules introduces structural limitations in the design of both the panels and the interconnecting means, imposes limitations on the fabrication techniques that may be used in making the panels and adds unnecessary expense in the cost of the finished structure.

Among the primary objects of this invention is the prefabrication of modules for building constructions comprising overhead and wall panels joined to each other by removable interconnecting hinge joinder means which do not form a permanent part of the panels, modules or finished structure and thus do not impose structural of fabrication limitations on the panels, modules or finished structures nor add to the expense of the finished structure.

SUMMARY OF THE INVENTION

Briefly, the multi-unit building of this invention comprises a foundation with a plurality of overhead panels and a plurality of wall panels mounted thereon. Each of the overhead panels and each of the wall panels having parallel major surfaces bounded by two rectilinear opposite edges and two other opposite edges. The overhead panels are arranged with their major surfaces in common planes and with one rectilinear edge of each in selected juxtaposition to a rectilinear edge of a further one of the plurality of overhead panels. One of the rectilinear edges of each of the wall panels is arranged in selected juxtaposition to a different pair of juxtaposed rectilinear edges of the overhead panels. The juxtaposed rectilinear edges of the overhead panels have a pair of planar surfaces each extending at an angle of less than 90° from a different one of the major surfaces of such panel toward the other major surface thereof which planar surfaces meet each other to form a ridge along the rectilinear edge of such panel. The overhead panels are arranged with respect to the wall panels so that such ridge projects over a wall panel with no portion of the major surfaces of the overhead panel projecting over the wall panels and a quantity of grout interconnects the juxtaposed edges of the overhead and wall panels.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects and features of this invention will be more fully understood from a reading of the following detailed description of preferred embodiments of this invention in conjunction with the appended drawing thereof wherein:

FIG. 1 is a perspective view of the foundation for building construction together with a plurality of stacks of overhead and wall panels joined to each other in sets for forming modules and includes a showing of a lifting means supporting a module in a partially raised position prior to transporting it to its final position on the foundation;

FIG. **2** is a perspective view of a plurality of modules according to this invention in their final position on a foundation slab and includes a showing of one of such modules formed of interconnected overhead and wall panels prior to being lifted into its final position;

FIG. **3** is a fragmentary perspective view showing a corner of a module in its fully elevated position together with a corner of the lifting means for raising the module to its elevated position;

FIG. **4** is a fragmentary perspective view, paritally in cross-section, of a corner formed by the lower ends of two wall panels of a module and includes a showing of connecting means suitable for connecting the wall panels to each other in their final position as well as connecting means for permanently affixing the module to the foundation slab;

FIG. **5** is a fragmentary perspective view, partially in cross-section, showing a removable hinge joinder means interconnecting an overhead and a wall panel in accordance with this invention and includes a showing of the embedded weight distribution means in accordance with the teaching of this invention;

FIG. **6** is an enlarged plan view of an overhead panel and wall panels as interconnected to form a module prior to the overhead panel being raised to its elevated position with certain structural features of the panels indicated in dotted lines;

FIG. **7** is a fragmentary perspective view, partially in cross-section, showing a pair of horizontally adjacent overhead members in their final position with respect to each other including a common wall depending from a hinge structure on one of said overhead members and a further hinge structure on the other of said overhead members mechanically engaging the first hinge structure;

FIG. **8** is a perspective view, partially in cross-section, showing the joint between the overhead panels of horizontally adjacent modules including the common wall and side walls of the modules at the end of an intermediate step in the permanent interconnection of the panels and modules with the hinge structures removed and other interconnection means substituted therefor;

FIG. **9** is a fragmentary perspective view, partially in cross-section, showing the completed joint between the overhead panels and side wall panels of a pair of horizontally adjacent modules together with the common wall panel and side panel of a vertically above adjacent module;

FIG. **10*a*** is a cross-sectional view taken along line **10*a*—10*a*** of FIG. **8**;

FIG. **10*b*** is a cross-sectional view taken along line **10*b*—10*b*** of FIG. **9**;

FIG. **11** is a fragmentary exploded perspective view of a corner of the forms suitable for use in fabricating overhead and wall panels in accordance with the teachings of this invention;

FIG. **11*a*** is a perspective view of a form member according to a further embodiment of this invention suitable for use in forming a specialized exterior load bearing wall panel;

FIG. **12** is a fragmentary side view in cross-section of the form members of FIG. **11** in their assembled relationship to each other;

FIG. **13** is a fragmentary perspective view, partially in cross-section, showing a permanent bracket means as substituted for a removable hinge joinder means between the overhead panels and common wall panel of horizontally adjacent modules in accordance with one embodiment of this invention;

FIG. **14** is a fragmentary perspective view, partially in cross-section, showing another bracket means which may be substituted for a removable hinge joinder means between the overhead panels and common wall of horizontally adjacent modules in accordance with a further embodiment of this invention;

FIG. **15** is a fragmentary perpsective view, partially in cross-section, showing a poured-in-place structural member attached to the overhead and a wall panels of one module in accordance with this invention as well as the lower portion of the wall member of a vertically adjacent module;

FIG. **16** is a plan view in cross-section of a plurality of horizontally adjacent modules interconnected with each other to form a structural unit of a building;

FIG. **17** is an enlarged fragmentary side view in cross-section taken from FIG. **16** and showing the interrelationship between the horizontally adjacent modules and vertically adjacent modules in a building construction in accordance with the teaching of this invention;

FIG. **18** is an enlargement of the joint indicated by circular line **18** in FIG. **16**;

FIG. **19** is an enlargement of the joint indicated by circular line **19** in FIG. **16**;

FIG. **20** is a schematic plan view of a twin tower building constructed in accordance with the teaching of this invention;

FIG. **21** is a schematic side view in elevation of a multi-story building constructed in accordance with the teaching of this invention as shown in FIG. **20**;

FIG. **22** is a schematic end-view in elevation of the building shown in FIGS. **20** and **21**;

FIG. **23** is an enlarged fragmentary cross-sectional view taken along line **23—23** of FIG. **20**;

FIG. **24** is an enlarged fragmentary cross-sectional view taken along line **24—24** of FIG. **20**;

FIG. **25** is a plan view of a circular building constructed in accordance with the teaching of this invention; and

FIGS. **26–28** are schematic plan views of the module used in constructing the building of FIG. **25** comprising overhead panels and wall panels interconnected and ready to be raised for assembly into the building structure.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIGS. **1** and **2** the construction of a building according to the teaching of this invention is illustrated. As shown in these figures the building is constructed on a foundation slab **10** and comprises two floors or stories of three modules each. Each module consists of an overhead panel **A** to the edges of which a plurality of wall panels **B** are connected by hinge joinder means **C**. As shown in FIG. **1** the overhead panels **A** and wall panels **B** are prefabricated and arranged in co-planar relationship with an edge of each wall panel **B** in selected juxtaposition to a different edge of an overhead panel **A**. In this position the adjacent edges of the overhead panel and wall panels are hingeably interconnected by the hinge joinder means **C**. Thus, when the overhead panels **A** are subsequently raised to an elevated position the hinge joinder means C will allow the wall panels B to rotate with respect to the overhead panel A. When the overhead panels A have been fully elevated the wall panels B depend vertically from the edges of the overhead panel A and are supported by the hinge joinder means C. In this position the modules each form a box-like enclosure or room so that when such module is placed on a suitable foundation and the panels permanently fixed with respect to each other and the foundation a building or unit of a building is formed. As shown in FIGS. 1 and 2 the overhead panels A form both the ceiling of one module and the floor of the vertically above adjacent module. As also shown in FIGS. 1 and 2 horizontally adjacent modules may share a common wall panel.

It will be understood that the building construction shown in FIGS. 1 and 2 is merely illustrative of the type of building construction to which the present invention pertains. It is not necessary that the modules be rectangular nor that they all be of the same general dimensions as shown in FIGS. 1 and 2. Similarly, it is not necessary that the building constructed from the modules be rectangular or that the modules be regularly arranged as shown in FIGS. 1 and 2 in order for the teaching of this invention to be applicable. However, the building structure illustrated in FIGS. 1 and 2 does represent a particularly desirable type of building construction for the application of the teaching of this invention. Thus, the following detailed description of this particular application of the teaching of this invention is given to insure full understanding of a particular application of the invention and not by way of limitation of the application of the invention.

In the particular application represented by FIGS. 1 and 2 the foundation slab **10**, the overhead panels A and the wall panels B are all concrete slabs poured flat at the construction site. Furthermore, as represented in FIG. 1, the vertically adjacent modules of each story are identical to each other and thus the panels of such modules may be poured on top of each other with appropriate bond breaking layers therebetween as represented by stacks **12, 13** and **14.** It will be seen that the modules of stack **13,** which are the center modules in each story or floor of 3 modules each, have four wall panels whereas the end modules of stacks **12** and **14** have only three wall panels each. Thus, each of the end modules share a common wall panel with the central module.

As shown in FIG. 1 a building is constructed from the modules by first raising the overhead panel A of a central module from stack **13** to a elevated horizontal position thereby allowing the wall panels B of such module to roate downwardly to vertical position. With the panels A and B in this position the module is transported to the proper location on the foundation slab **10** and the lower edges of the wall panel B lowered into contact therewith. Wall panels B are then permanently affixed with respect to each other and with respect to the foundation slab **10** producing a free standing self-supporting structural unit. A module is then raised and transported into position from each of the end stacks **12** and **14** and the panels thereof affixed to each other and to the central module and foundation slab to complete the first row or story of the building construction. The same process is repeated for the second story or floor of the building construction using the first story as the foundation. Thus, as shown in FIG. 2 all of the modules of the first story, as well as the central module and one end module of the second story, are in place with the final end module awaiting raising and transportation into place. As indicated by the dotted lines **15** in FIGS. 1 and 2 tension means are provided extending through the walls B from top to bottom to enable the walls of upper stories or rows of modules to be tied directly to the foundation slab **10** as will be more fully described hereinafter.

As indicated in FIGS. 1 and 3 the raising and transportation of the modules is accomplished through the use of a lifting frame **16** attached by means of a cable **17** to an appropriate crane or similar machine (not shown). As shown in greater detail in FIG. 3 an important aspect of this invention is that the lifting frame **16** is mechanically connected directly to the hinge joinder means C in order to raise the modules and transport them into position. Thus, according to the teaching of this invention it is not necessary for the overhead panel A to support any portion of the weight of the wall panels B during the elevation and transportation of the module into position. This is made possible through the use of removable hinge joinder means C as will be more fully described hereinafter.

According to the embodiment of this invention shown in FIGS. 1 and 3, the lifting frame **16** has a shape and dimensions corresponding to that of the overhead panel A. Thus the frame **16** comprises end girders **21** and side girders **22** permanently affixed to each other at their ends as by welding or bolts to form a rectangle corresponding to the rectangular edges of the overhead panel A. A pair of brace girders **23** are affixed to and extend between the side girders **22** parallel to the end girders **21** and spaced from each other by a distance equal to a substantial portion of the length of the side girders **22.** A lifting girder **24** spans the distance between the bracing girders **23** and is slideably attached thereto at each of its ends as by means of a bolt and plate arrangement **25.** Similarly, a lifting eye plate **26** is slideably attached to the lifting girder **24** as by means of a bolt and plate assembly as shown in FIG. 3.

The lifting eye plate **26** may be located at any point along the length coincide the lifting girder **24** by loosening the bolts associated therewith and sliding the plate along the girder. When the desired location is reached, the bolts may be retightened in order to fixedly secure the lifting eye plate at the desired location. Similarly, the lifting girder **24** may be located at any point along the length of the bracing girders **23** by loosening the bolts of the plate and bolt assembly **25,** sliding the lifting girder **24** to the desired location and retightening the bolts. Thus, the interconnection between the frame **16** and the cable **17** may be adjusted to conicide with the center of gravity of a particular module to be lifted thereby.

Where the module consists of an overhead panel A and four wall panels B, the lifting eye plate **26** will be located at approximately the center of the frame **16** as shown in FIG. 1. However, when the frame **16** is attached to one of the end modules having only three wall panels it will be necessary to slide the lifting eye plate **26** along the lifting girder **24** toward the end of the frame **16** which is opposite the edge of the overhead panel A to which no wall panel is attached. This will enable the module to be balanced in an elevated position with the overhead panel A thereof in a horizontal plane. It will be understood that a module in accordance with this invention may have only two wall panels attached to adjacent edges of the overhead panel or even but a single wall panel attached to the overhead panel. In either of the above instances, it will be necessary to shift the location of the lifting girder 24 along the bracing girders 23, or the lifting eye 26 along the lifting girder 24, toward the edge of the overhead panel to which a wall panel is attached. Thus, it will be seen that the lifting frame 16 may be adjusted to enable a module to be lifted by means of a single cable 17 with the overhead panel thereof in a horizontal plane regardless of the number of wall panels included in the module on their position.

As most clearly shown in FIG. 3 a module is suspended from the frame 16 by means of a plurality of elongated hangers 28. One end of each of such hangers 28 is adjustably attached to an end 21 or side 22 girder of the frame 16 and terminates at its other end in an appropriate means for attachment to a hinge joinder means C. Thus, as shown in FIG. 3 the end and side girders 21, 22 may be vertically slotted and the hangers 28 may comprise rods which pass through the slots and are suspended from the girders 21 and 22 by means of a washer and a nut secured to threads on the end of the rod projecting above the girder. An appropriate plate like member 27 having a transverse pin 29 fixed therethrough may be welded to the other end of the rod like member of the hanger 28. Thus, it will be seen that the members of each hanger 28 may be located at desired points along the end and side girders 21 and 22 by simply sliding the hanger members 28 along the slots provided therein. The nut at the upper end of the hanger members 28 provides a convenient means for adjusting the length of the hanger members 28 so that they all extend an equal distance below the frame 16. The hanger members 28 may be easily attached to the hinge joinder members C by simply inserting the pin 29 into an appropriate eye provided in such hinge joinder members C as will be described hereinafter.

After the frame 16 has been attached to a particular module and the overhead panel A thereof elevated to a horizontal plane at a sufficient height above the ground to allow the wall panels B to depend vertically therefrom, the lower ends of adjacent wall panels B may be temporarily attached to each other as by means of an angle iron 30 secured to such panels by screw or other convenient means at the corner formed thereby as shown in FIG. 4. This will prevent the wall panels B from moving relative to each other during transportation of the module to its desired location on the foundation slab 10. As also shown in FIG. 4 the foundation slab 10 may be provided with appropriate anchor means 31, 32 embedded in the foundation slab 10 and projecting within recesses 36 in such slab. Such anchor means may comprise, for example, a steel rod welded to a transverse plate 31 or a steel rod bent in the form of a hook 32, as shown in FIG. 4, with an appropriate portion of the steel rod exposed within the recesses 36 but not projecting the upper surface of the foundation slab 10. Thus, the foundation slab 10 may be used as a casting bed for the overhead and wall panels A, B, if desired, since there is nothing projecting from its upper surface and the recesses 36 may be filled with sand or otherwise closed.

As shown in FIGS. 1, 2 and 4 the wall panels B may be formed with a plurality of notches in their lower edges, each corresponding to the location of an anchor means 31, 32 embedded in the foundation slab 10. The wall panels B may also be provided with an embedded steel rod 15 passing through the panels from each of the notches in their lower edges to their upper edges when in their erected position as mentioned hereinabove in connection with FIGS. 1 and 2. Each rod 15 may be permanently affixed to an anchor member 32 embedded in the foundation slab 10 as by means of welding a steel plate or other metal member between the adjacent ends of the rod 15 and anchor member 32 within the notches. Similarly, the end of the rods 15 at the upper edge of the wall panels B may be adapted to be welded or similarly attached to the lower ends of the rods 15 passing through the wall panels of vertically adjacent modules in order to provide a continuous anchoring means from top to bottom of a multi-floor building. Such continuous anchoring means provided by the interconnection of steel rods 15 will enhance the ability of the building to withstand lateral forces due to the effects of wind or earthquake on the building structure.

Alternatively, as shown in FIG. 4, a hollow tube 33 with a post-tensioning cable 35 received therethrough may be substituted for the rods 15. The cable 35 may be attached to an anchor member 31 (embedded in the foundation slab) by means of an appropriate coupling member 37 within the associated notch. The cable 35 may pass through all vertically adjacent wall panels from top to bottom of the building structure in order to enable the entire wall thereof to be placed in compression and thereby further enhance the ability of such wall to withstand lateral forces.

Referring to FIG. 5 a hinge joinder means C together with means 50 for distributing the weight of the panel to the hinge joinder means in accordance with the teaching of this invention are shown in detail. The hinge joinder means C comprises a first plate 41 and a second plate 42 each of which have a flat major surface for engagement with the edge of a panel. The other major surface of each of the plates 41, 42 is provided with a protruding hinge leaf 43, 44 and both of such hinge leaves are apertured to receive a hinge pin 45 whereby the plates 41, 42 are hingeably interconnected. Each of the plates 41, 42 is provided with a pair of apertures extending through the major surfaces thereof whereby the plates may be removably attached to a wall and overhead panel respectively by means of bolts 46, for example. In accordance with the teaching of this invention, the hinge leaf 43 of the plate 41 attached to the overhead panel A is provided with an upwardly extending projection 47 having an aperture or lifting eye 48 therethrough.

The lifting eye 48 is adapted to be engaged by the hook means or pin 29 of the hanger members 28 depending from the lifting frame 16 in order to enable the overhead panel A of the module to be elevated to a horizontal position so that the wall panels B may rotate to a vertical position about the pin 45 of the hinge joinder means C. Thus, it will be seen that the weight of the wall panel B is supported directly by the lifting frame 16 through the hanger means 28, hinge leaf 43, hinge pin 45, hinge leaf 44 and plate 42 attached to the wall panel B. Since no portion of the weight of the wall panel B is borne by the overhead panel A while the module is being lifted and transported into position, it is not necessary to design and fabricate the overhead panel A to bear such weight as was necessary in accordance with the teaching of the prior art.

However, it is necessary to design and fabricate the overhead panel in such a way as to distribute the weight of the overhead panel to the points of attachment of the plates 41 of the hinge joinder means C. Similarly, it is necessary to design and fabricate the wall panels B in such a way as to distribute the weight of the wall panels to the points of attachment of the plates 42 of the hinge joinder means C. This is accomplished by means of reinforcing rods 52, 53, 54 and 55 embedded in the overhead panel A and wall panel B adjacent the point of attachment of the hinge joinder members C thereto. As shown in detail in FIG. 5 a first plurality of reinforcing rods 53, 54 are embedded in the panels parallel to the edge thereof at such point of attachment and a second plurality of rods 52 are embedded in the panels extending normally to the edge at such point. Such reinforcing rods together with the usual reinforcing rods 55 embedded in the panels parallel to the edges thereof tend to evenly distribute the weight of the panels A, B to the points of attachment of the hinge joinder members C thereby avoiding the production of undue bending moments and stresses in the panels during the elevation and transportation of a module to its final location.

As shown in detail in FIG. 5 the preferred embodiment of such embedded means comprises a pair of tightly wound coils 51 having their axes extending normally to the edge of the panel in which they are embedded and having turns adapted to mate with the threads of the bolts 46. A pair of reinforcing rods 52 are welded or otherwise attached to the turns of each coil and extend generally parallel to the axis of each coil. As shown in FIG. 5 such reinforcing rods 52 may comprise the legs of a U-shape formed by bending a single reinforcing rod into a loop. Two pairs of reinfording rods 53, 54 extending transversely to the axis of the coils 51 and parallel to the adjacent edge of the panel are welded to both coils 51. The reinforcing bars of each pair 53, 54 are spaced from each other along the length of the coil 51 and are preferably bent into a serpentine shape so that the coils 51 are received in generally U-shape convolutions thereof to partially surround the coils 51 and provide greater area for bonding the rods 53, 54 to the coils 51. It is also preferable that the reinforcing rods of the pair 54 extending adjacent the lower major surface of the panel, as fabricated, be bent to pass over the top of the coils 51; whereas the reinforcing rods 53 of the pair adjacent the upper major surface of the panel, as fabricated, be bent to extend under the coils 51. It is also preferable that the reinforcing rods 55 which are normally embedded in the panel parallel to the edges thereof, be received between the reinforcing rods 53, 54 of each pair or at least be located in sufficiently close proximity thereto to enhance the distribution of the weight of the panel to the hinge joinder means C. It will be understood that the length and spacing of the reinforcing rods 52, 53 and 54 will vary with the dimensions of the panel. It will also be understood that it is desirable to provide appropriate resilient pressure blocks 56 between the exterior ends of the coils 51 and the plates 41, 42 of the hinge joinder means C. Such pressure blocks 56 will avoid the chipping of the outer surface of the concrete and will provide for the uniform bearing of the plates 41, 42 against the concrete surface of which the slabs are formed during the attachment and removal of the hinge joinder means C.

In accordance with the teaching of this invention no portion of the means for distributing weight to the points at which hinge joinder means C are connected projects beyond the boundaries of the panels. Thus, the coils 51, reinforcing rods 52, 53, 54 and pressure plates 56 are all embedded within the panels. As will be more fully described hereinafter, this enables greater freedom in the selection of fabrication techniques for forming the panels and in addition enables the joint between adjacent panels to be completely free of any obstruction once the hinge members C have been removed after erection of the building.

Referring to FIG. 6, it will be understood that hinge joinder means are attached to all edges of the overhead panels A including those edges to which no wall member is attached. This is necessary in order to enable the modules to be raised and subsequently supported without placing undue stresses on the overhead panel A. However, the hinge joinder means C′ attached to the edge of an overhead panel A to which no wall panel is attached are different from the hinge joinder means attached to other edges of the panel A in accordance with the teaching of this invention. As shown in FIG. 7 such hinge joinder means C′ comprises a plate 41 having a hinge leaf 43′ that includes a projection 47 and lifting eye 48. However, instead of being apertured to receive the hinge pin 45, the hinge leaf 43′ is provided with an open ended slot 49 adapted to hook over the hinge pin 45 of an aligned hinge joinder means C of a horizontally adjacent module. Thus, as shown in FIG. 7 one wall panel B may be common to two horizontally adjacent modules when the modules are placed in their final positions in the building structure.

According to the preferred embodiment of this invention each module includes only two load bearing walls at least one of which is shared in common with a horizontally adjacent module. Thus, as shown in FIG. 6 two of the opposite edges 61 and 62 of the overhead panel A are load bearing edges and are each adapted to cooperate with wall panels B which are load bearing as indicated by the numeral 65. The other two opposite edges 63, 64 are nonload bearing edges and the wall panels B attached thereto are non-load bearing wall panels 66. In addition as shown in FIG. 6 and in accordance with a further embodiment of this invention a plurality of tubular openings 68, indicated by dotted lines, extend through the overhead panel A from one load bearing edge 61 to the other load bearing edge 62, through which post-tensioning cables may be passed so that all of the overhead panels of a particular floor or story may be affixed to each other and post-tensioned as a unit, as will be more fully described hereinafter.

Referring to FIG. 7 each of the load bearing edges 61, 62 of the overhead panels A which are associated with a load bearing wall 65 are formed with planar surface 71, 72 each extending at an angle less than 90° with respect to the extended plane of the major surface of the panel A adjacent thereto in order to thereby form a projecting ridge 73 extending the length of the edge 61, 62. It will be seen that the planar surfaces 71, 72 and ridge 73 formed thereby are interrupted periodically along the length of the load bearing edges 61, 62 to provide recessed portions or pockets 75 in which the hinge joinder means C and C′ are mounted. The purpose of such pockets 75 is to facilitate the attachment of the hinge joinder means C and C′ to the load bearing edges 61, 62 of the overhead panels A by providing a flat surface perpendicular to the major surfaces of the overhead panels A at the point of attachment of the hinge joinder means. The non load bearing edges **63,** 64 of the overhead panels are provided with a single flat planar surface extending between the major surfaces thereof and perpendicular to such major surfaces.

As most clearly shown in FIGS. **3** and **7** the hinge joinder means C and C′ according to the teaching of this invention are constructed and dimensioned so that the plane of the lower major surfaces of overhead panels A is maintained above the upper extremity of the wall panels **65, 66** when a module has been raised and transported into its final position. It will also be seen that the hinge joinder means C and C′ are constructed and dimensioned so that the only portion of the overhead panels A which overlaps wall panels **65** and **66** when a module has been raised and transported into position is a portion of the ridge **73** formed by planar surfaces **71** and **72** on the load bearing edges of the panels A which slightly overlaps the upper extremity of the load bearing wall panels **65.**

Referring now to FIGS. **8, 9, 10***a*, and **10***b* the permanent interconnection of the overhead panels A and wall panels B to each other and the overhead panels and wall panels of horizontally and vertically adjacent modules according to this embodiment of the invention will be described in detail. Referring to FIG. **8** the joint between a pair of horizontally adjacent modules is shown in perspective at the end of an intermediate step in the permanent interconnection of the overhead and wall panels thereof. As shown in FIG. **8** the hinge joinder means C and C′ have been removed from the panels. However, it will be understood that the hinge joinder means C and C′ cannot be removed before a permanent interconnection is made between the overhead and wall panels. In the case of the non load bearing wall panels **66,** each hinge joinder means C may be removed one at a time and an appropriate bracket **81** substituted for each in turn to provide a mechanical interconnection between the overhead panels A and wall panels **66.** Such bracket **81** may be a simple angle iron provided with apertures by which it may be fixed to the panels using the same bolts **46** that were used to attach the hinge joinder means C. The primary function of the brackets **81** is to hold the non load bearing wall panels **66** in place during subsequent steps in the permanent interconnection of the wall panels **66** to the overhead panels A and to resist lateral forces throughout the life of the building structure.

According to the embodiment of this invention shown in FIGS. **6–10,** one step in the interconnection of the overhead panels A to each other and to the load bearing wall panels **65** is to pass the post-tensioning cables **69** through the tubular openings **68** in the overhead panels A. In doing so, a plurality of hollow tubes **82** are placed in the space between adjacent load bearing edges of overhead panels A and each tube **82** extends between a pair of aligned openings **68** in the overhead panels A. Thus, the post-tensioning cable **69** is conducted through the tubular member **82** in passing from the tubular opening **68** in one overhead panel A to the tubular opening **68** in an adjacent overhead panel A. A pair of baffle or dam members **83** are then placed on opposite sides of each pocket **75** containing hinge joinder means C, C′. The dam members **83** extend between the opposed load bearing edges **61, 62** of adjacent overhead panels A and have a width sufficient to extend from near the upper major surfaces of panels A to the top of wall **65.** At the same time a pair of forming strips **84** (see FIG. **10***a*) are affixed to opposite sides of the load bearing wall **65** each in abutment with the lower major surface of one of the overhead panels A. The baffles **83** and forming strips **84** may be of inexpensive material, such as wood for example, and may be attached by an convenient means since their only function is to serve as forming members in connection with a layer **85** of grout which is then poured into the space between the adjacent overhead panels A and wall panels B. Such grout may be poured either before or after applying post-tensioning forces to the overhead panels A through the use of cables **69** passing through the tubular openings **68** and tubular member **82** and either before or after the removal of the hinge joinder means C and C′. However, the preferred sequence of steps, as will be more fully described hereinafter, is to first partially post-tension the overhead panels A, either by applying full or partial post-tensioning forces to the cables **69** passing through a selected number of the tubular openings **68,** or by applying partial post-tensioning forces to all of the cables **69** passing through the tubular openings **68** in the overhead panels. The layer **85** of grout is then poured and the hinge joinder means C and C′ are removed after the grout has set. It will be noted that the layer **85** of grout is sufficient to half fill the space between the adjacent overhead panels A and wall panel B.

It will be seen that the planar surface **72** adjacent the lower major surface of the overhead panels A serves to interface with the hardened layer of grout **85** in such a way as to provide for the efficient transfer of the weight of the overhead panels A to load bearing wall panel B. It will also be seen that the post-tensioning forces applied by means of the cables passing through the tubular openings **68** in overhead panels A and the tubes **82** between adjacent overhead panels A will not only strengthen the overhead panels A and tie them together as a structural unit, but will also cooperate with the layer of grout **85** and the planar surface **72** to provide for the incremental support of the overhead panels A on the load bearing wall panels B throughout substantially the entire length of the load bearing edges **61, 62.**

Referring to FIGS. **9** and **10***b* the planar surfaces **71** on the load bearing edges of the overhead panels A enable the load bearing wall **65** of an upper vertically adjacent module to be supported directly on the load bearing wall **65** of a lower vertically adjacent module. It is an important feature of the method of building construction according to the teaching of this invention that the stress imposed on the joint between an overhead panel A and the load bearing wall B of a particular module by modules located vertically above it is reduced toward minimum. Thus, as shown in FIGS. **9** and **10***b*, the planar surfaces **71** of the overhead panels A enables the weight of the upper load bearing wall panel B to be conducted through grout layers **85** and **86** directly to the lower load bearing wall panel B with minimum contribution of stress to the joint between the overhead panel A and such lower load bearing wall panel. When the building structure is completed, it will be seen that the vertically adjacent load bearing wall panels **65** together with grout layers **85** and **86** will form a vertical column with the load of the overhead panels A of each floor of the structure being tributarily conducted thereto in such a way as to reduce toward minimum the additive contribution of stress to the joint between the lower overhead panels and such vertical column by the upper modules.

When the wall panels **65** and **66** of the vertically adjacent module have been transported into place and interconnected with the wall panels of lower module by means of rods **15** or post-tensioning cable **35** (if such are used) a final layer of grout **86** is poured on top of the layer **85** to complete the joint. Such final layer **86** of grout may fill the space created by the dam members **83** from which the hinge joinder members C and C′ have been removed. In addition, the horizontal space between the non load bearing edges **63, 64** of the overhead panels A and the non load bearing wall panels **66** as well as the vertical space between the wall panels **65, 66** themselves may be filled with the final pour of grout **86.** It is, of course, necessary to attach further forming members **87,** to the non load bearing walls to close all of the seams between the panels. The brackets **81** need not be dammed off but may be embedded in the grout **86.** It will be seen in FIGS. **8** and **9** that the non load bearing panels **66** may be fabricated with flanges **89** along their vertical edges in order to reduce the dimensions of the gaps in the exterior surface of the completed wall which must be filled by the grout **86.**

Referring to FIGS. **7–10,** it will be seen that one important advantage of the use of removable hinge joinder means C and C′ in accordance with this invention is that it would be impossible to design integral or embedded hinge joinder means which would enable the modules to be elevated and transported by the hinge joinder without interfering with the desired characteristics of the final joint between the overhead panels A and wall panels B. This is due, in part, to the incompatible dimensional considerations introduced by the need for the size of the hinge joinder means to be large and for the size of the space between the panels to be small. The hinge joinder means must be large in order to have sufficient strength to support the weight of the module in transit. The space between the panels must be small in order to insure intimate interconnection therebetween with as little grout as possible in order to approach the characteristics of a monolithic structure. Finally, the use of integral or embedded hinges will not only add to the expense of the structure where some additional interconnecting means is required such as post-tensioning, for example, but may actually interfere with the efficiency of such additional interconnecting means. In other words, the use of embedded or integral hinge joinder means may prevent the overhead panels of a particular floor of a building structure from being post-tensioned to form a single structural unit without introducing undesired stresses into the load bearing wall panels through such hinge joinder means. The fact that the removable hinge joinder means can be repeatedly used in constructing a particular building or in constructing other buildings will provide important economic advantages over the use of integral or embedded hinges.

Referring to FIGS. **11** and **12** a still more important feature of this invention resulting from the use of removable hinge joinder means is that it enables fabrication techniques of great precision but which are simple and economically feasible to be used in fabricating the panels of the modules. Thus, as shown in FIGS. **11** and **12,** the forms for fabricating panels in accordance with this invention though precisely dimensioned are not only simple but also reusable since there is no need for the forms to be designed and fabricated to allow for integral or embedded hinge structures projecting from the panels. According to the prior art, it was necessary for the forms to be provided with apertures through which the integral or embedded hinge joinder means could project. This required that the forms for each panel be dismantled in order to remove it from the completed panel. According to this invention, forming techniques closely approximating slip forming techniques may be used to fabricate a plurality of identical panels one on top of the other with bond breaking layers therebetween. Thus, the stacks **12, 13** and **14** of overhead and wall panels as shown in FIG. **1** may be quickly and precisely fabricated in situ without using expensive forming techniques involving the construction and removal of a separate form for each of the panels. This is made possible by the fact that no portion of the weight distribution means **50** embedded in the panels according to this invention projects beyond the boundaries of the panels and the fact that the removable hinge joinder means C and C′ are not attached to the panels until after the forms have been removed.

As shown in FIG. **11** the basic elements of the forms used in fabricating concrete overhead and wall panels A and B in accordance with the teaching of this invention are precisely dimensioned open ended hollow box structures **90, 90′** and precisely dimensioned elongated members **91, 91′** which may be attached to or integrally formed therewith. The dimensions of the box structures **90, 90′** are carefully matched with the dimensions of the hinge joinder means C, C′ and the dimensions of the elongated members **91, 91′** are adopted to provide precise spacing between, as well as dimensions of, the overhead and wall panels A and B. The box structures **90, 90′** have a height between open ends thereof equal to twice the thickness of the overhead and wall panels A, B and appropriate opposite walls of the hollow box structures are provided with two vertically spaced sets of apertures **95** and **96** with the apertures of each set corresponding to the apertures in the plates **41, 42** of the hinge joinder means C, C′, and adopted to receive bolts **46.** Thus, it will be seen that stacks of successive overhead and wall panels A and B may be fabricated, one on top of the other, with precise dimensions and spacing by moving the form elements **90, 90′, 91, 91′** upwardly and remounting them on the previously completed set of overhead and wall panels A, B, as described below with reference to FIGS. **11** and **12.**

A first set of bolts **46** are passed through the lower set of apertures **95** in the walls of each box structure **90, 91′** and engaged with the corresponding load distribution means **50** of the previously completed set of overhead and wall panels A and B. According to the preferred embodiment of this invention, the elongated members **91, 91′** are permanetly attached to such box structures **90, 90′** and are thus automatically positioned to form a second set of overhead and wall panels A and B with dimensions and spacing identical to that of the previously completed set of panels. A second set of bolts **46** are passed through the upper set of apertures **96** in the walls of each box structure and each set is engaged with a corresponding load distribution means **50** to rigidly support it in the final position it will have after the panels are completed. The elongated members **91, 91′** may have a vertical thickness sufficient to overlap a desired portion of the corresponding edge of a previously completed panel A, B. Any additional structural members, such as reenforcing rods **15** and **55** or tubes **33** (see FIGS. **5** and **6**) or tubular members to provide tubular openings **68** (see FIGS. **6–9**) may then be placed within the forms thus provided and appropriately attached to the elongated members **91**, **91'**. Finally, concrete may be poured into the forms thus provided to complete the panels A, B and embed the various structural elements. When the concrete has set or hardened, the bolts **46** are removed to release the form members **90, 90', 91, 91'** and the process may be repeated to fabricate a further set of panels A, B on top of those previously completed. It will be understood that an appropriate layer of bond breaking compound is applied to the upper surfaces of each set of overhead and wall panels A, B before the concrete for the next set is poured in order to facilitate their subsequent separation for erection as modules of a building structure.

As shown in FIGS. **11** and **12**, the box struture **90'** and elongated member **91'** may be adapted to cooperate with a further form member **92** to provide the planar surfaces **71, 72** which form the projecting ridge on a load bearing edge **62** of the overhead panel in accordance with one embodiment of this invention. Thus, the further member **92** comprises an elongated member having a surface **92'** dimensioned to mate with a surface **91''** on the elonagted member **91'** to provide the desired surfaces **71, 72** on the load bearing edge **62** of the overhead panel A. The end walls of the box structure **90'** are provided with slots **93** extending upwardly from their lower ends to receive the elongated member **92** and the elongated member **92** is provided with vertically extending apertured plates **94** each adapted to be received within a box structure **90'** with the aperture **94'** thereof in alignment with the lower set of aperture **95** in the side wall of the box structure **90'**. Thus, the elongated member **92** may be mounted in its appropriate position with respect to elongated member **91'** by the same bolts **46** which mount the box **90'** and elongated member **91'** to previously completed overhead and wall panels A, B. Thus, the box **90'** provides the pocket **75** and the members **91'** and **92** provide the projecting edge **73** in the load bearing edge of the overhead panels A.

Referring to FIG. **11***a*, it will be understood that special edge formations and projections may be provided on the edges of the overhead and wall panels A, B in accordance with this invention, as desired, by means of precisely dimensioned form elements which are not moved with the other form elements **90, 90', 91, 91'** but instead are left in place and duplicates used in forming subsequent panels. Thus, in order to form a flange **89'** or **89''** on the upper edge of an exterior load bearing wall (see FIG. **17**) an elongated form member **91''** of reduced transverse dimension may be used in conjunction with separable elongated member segments **97** of rectangular cross-section. The segments of separable elongated member **97** may be simply placed adjacent the elongated member **91''** of reduced transverse dimensions within the form in end abutment with box structure **90'** so that when concrete is poured in the form the member segments **97** will be embedded to provide the desired flange **89', 89''**. After a particular set of overhead and wall panels A, B have been elevated slightly, the member segments **97** may be recovered for re-use.

As shown in FIG. **11***a*, elongated member segments **92'** may be substituted for the elongated member **92** by attaching segments **92'** of proper shape and dimensions to the segments **97** as by means of nails **98**, for example. The segments **92'** could also be made integral with the segments **97** and in either case a plurality of identical segments **97, 92'** would be used in forming a plurality of sets of overhead and wall panels A, B since the segments **97, 92'** would be left in place until the modules formed by the overhead and wall panels A, B were erected.

Referring to FIG. **12**, it will be understood that the first set of overhead and wall panels A, B of each stack would be formed on an appropriate substrate **100**. It will also be understood that in accordance with this embodiment of the invention such substrate would be provided with appropriately spaced and dimensioned depressions **99** including appropriate mounting means to accommodate the form members **90, 90', 91, 91'** for the fabrication of such first set of overhead and wall panels A, B.

It will be understood that post-tensioning of the overhead panels A may not be required in all of the building structures to which the teaching of this invention is applicable. However, in most building structures, it will be desirable to mechanically interconnect horizontally adjacent overhead panels A and the load bearing wall panels **65** common thereto. Referring to FIG. **13** a bracket **101** which may be substituted for the hinge joinder means C and C' according to the teaching of this invention is shown. Such bracket **101** may comprise an open metallic box dimensioned to fit in the pockets **75** when the hinge joinder means C and C' have been removed. The side walls of the bracket **101** may be apertured to receive the bolts **46** so that the bracket **101** may be attached to the overhead panels A in place of the hinge joinder means C and C'. Similarly, the bottom wall of the metallic bracket or box **101** may be apertured to receive the bolts **46** to enable the bracket **101** to be mechanically attached to the load bearing wall panel **65**. As shown in FIG. **13** the bracket **101** is provided with a strengthening webb parallel to the end walls and extending between the side wall of the bracket **101** centrally thereof. The brackets **101** may be substituted for the hinge joinder means C and C' after the first layer **85** of grout is poured as described hereinabove. Alternatively a bracket **101** may be substituted for the hinge joinder means C and C' in each pocket **75** one at a time until all of the hinge joinder means have been replaced by brackets **101** and then the first layer **85** of grout may be poured.

Referring to FIG. **14** a means for mechanically interconnecting horizontally adjacent overhead panels A and the load bearing wall panels **65** associated therewith according to another embodiment of this invention is shown. According to this embodiment of the invention a pair of generally oval shape metallic members **102** are fastened between the overhead panels A in place of the hinge joinder means C and C'. As shown in FIG. **14** spherical headed bolts **103** may be used in place of the bolts **46** in attaching the brackets **102** between the overhead wall panels A. The use of spherical headed bolts **103** and bracket members **102**, adapted to be deformed from a more circular shape to the oval shape shown when the bolts **103** are tightened, will enable a certain amount of post-tensioning of the overhead panels A. The use of brackets **102** will also enable the accommodation of a certain amount of misalignment between horizontally adjacent overhead panels A. As shown in FIG. 14 a pair of hook shape reinforcing rods 104 of appropriate diameter and having their shank portion threaded may be substituted for the bolts 46 after the hinge joinder means C have been removed from the load bearing wall panel 65. Such hook shape reinforcing rods are adapted to be embedded in the grout subsequently poured in the joint to provide improved mechanical interconnection between the overhead panels A and load bearing wall 65 to enhance resistance to seismic forces. As discussed hereinabove the brackets 102 and reinforcing rods 104 may be substituted for the hinge joinder means C and C′ before the first layer 85 of grout is poured or afterwards if appropriate dam members 83 are used.

Referring to FIG. 15 it may be desirable to provide a building structure constructed in accordance with the teaching of this invention with poured-in-place structural members 106 such as balconies or hallways. In order to provide for such poured-in-place members 106, additional load distributing means 107 are embedded in the overhead panels A along the appropriate edge thereof. Such load distributing means 107 may be similar to load distribution means 50 and may be conveniently embedded in the overhead panels through the use of bolts 46 extending through the forms and to which the load distributing means 107 are attached as described in connection with load distributing means 50. Upon erection of a module, appropriately shaped (i.e. hook shaped) reinforcing members 108 having the proper diameter and a threaded shank may be engaged with the load bearing means 107 so that they project from the non load bearing edge of the overhead panel A and across the joint between such overhead panel A and the associated wall panel 66 as shown. It will be understood that no grout is poured in such joint. Instead the poured-in-place structural member 106 extends into such joint and is mechanically interconnected with the overhead panel A through the reinforcing means 108. As shown in FIG. 15 the poured-in-place structural member 106 is not formed until the vertically adjacent module, if any, is in place. Thus the poured-in-place structural member 106 may also serve to embed the lower end of the non load bearing walls 66 of the next vertically adjacent module as described hereinabove in connection with the second layer 86 of grout.

Referring to FIG. 16 a plan view showing a number of horizontally adjacent modules in cross-section as interconnected to form a building structure in accordance with the teaching of this invention is presented. As shown in FIG. 16 the overhead panels A are adapted to be post-tensioned by means of cables as described hereinabove. Thus the overhead panels A are provided with tubular openings 68 extending through the panels between the load bearing edges thereof. As shown in FIG. 16 the tubular openings of the various overhead panels are aligned with each other and interconnected at the joints therebetween by means of tubes 82.

As indicated in FIG. 17 the tubular opening 68 may be conveniently provided by embedding tubular metallic members in the overhead panels A. As also indicated in FIG. 17 a cable threaded through a set of aligned tubular openings 68 and securely fastened at one end thereof may be conveniently tensioned as by means of a portable hydraulic unit 109 attached to the other end of the cable. When a desired amount of tension is achieved through the use of the hydraulic unit 109 the end of the cable adjacent to hydraulic unit 109 is also secured to the overhead panel A. Since the tubular opening 68 formed by embedding metallic tubes in the overhead panels A are caused to sag as indicated by exaggeration in FIG. 17, the tensioning of the cable will produce a slight arch in the overhead panels A thereby enabling them to withstand greatly increased vertical loading or, alternatively, enabling thinner overhead panels A to stand the same amount of vertical loading as overhead panels A of greater cross-sectional thickness. As discussed hereinabove the post-tensioning of the overhead panels A may be partially performed prior to pouring the grout layers 85 and 86. This may be accomplished by tensioning the cables received in alternate ones of the tubular openings 68 or by partially tensioning all of the cables received in tubular openings 68. Full post-tensioning of the overhead panels A is not applied according to the preferred embodiment of this invention until after the grout layers 85 and 86 have been poured and are set or hardened.

As shown in FIG. 17 the exterior load bearing walls 65′ and 65″ of the building structure may be provided with flanges 89′ and 89″ in order to facilitate the exterior finishing of the building by reducing the area of grout layers 85, 86 which are exposed on the exterior walls of the building. It will be seen that exterior load bearing walls 65″ are provided with notches to enable ready access to the post-tensioning cables received in tubular openings 68 and the attachment thereof to portable hydraulic post-tensioning means 109.

Referring to FIGS. 18 and 19 the vertically extending joints between adjacent load bearing wall panels 65, 65″ and non load bearing wall panels 66 according to the preferred embodiment of this invention are shown in detail. It will be seen that the flanges 89 on the non load bearing wall panels 66 and the flange 89″ on the exterior load bearing wall panels 65″ provide a minimum area of exposure to the exterior of the building of the grout 86 poured in the joints as shown. Furthermore, an appropriate gasket member 110 may be wedged in such joint from the exterior of the building, thereby eliminating the need for forming members as discussed hereinabove and providing a permanent long-life weather seal to protect the grout 86. The gaskets 110 may be made of any suitable long-life material such as metal, plastic or rubber, and an appropriate bevel on the adjacent edges of the wall panels may be provided to facilitate the insertion of the gasket 110. The angle irons 30 used to attach the wall panels 65, 65″ and 66 to each other during transportation of the modules into their final position are shown in FIGS. 18 and 19. In addition a reinforcing rod 111, which may be positioned in the joint between the panels 65 and 66 prior to pouring the grout 86 in order to strengthen such joint, is shown in FIG. 19.

Referring to FIGS. 20, 21, and 22 a multi-story building structure comprising a pair of adjacent towers 121 each constructed of a plurality of horizontally and vertically adjacent modules in accordance with the teaching of this invention and joined together by a hallway section 122 comprising a plurality of poured-in-place members 106 forming a plurality of vertically adjacent hallways, is shown schematically. As shown in FIGS. 21 and 22 the towers 121 are erected on a common foundation slab 10. As also shown in FIGS. 21 and 22 the building structure may be provided with a parapet structure **123** if desired.

Referring to FIGS. **23** and **24** fragmentary cross-sectional views of the building structure shown in FIGS. **20–23** are presented. The cross-sectional showing of the grout in the joints between the overhead panels A and wall panels **65, 65''** and **66** has been omitted for purposes of clarity. FIG. **23** shows the joints between the overhead panels A and the load bearing wall panels **65, 65''** of the building structure and FIG. **24** shows the joints between the overhead panels A and the non load bearing wall panels **66** thereof. As shown in FIGS. **23** and **24** a parapet wall structure may be mounted at the top of the building structure, if desired, through the use of appropriate brackets **124.** As most clearly shown in FIG. **24** the poured-in-place hallway structure **122** consisting of a poured-in-place structural member **106** formed in the plane of each set of overhead panels A and extending between the interior non load bearing wall panels **66** of the adjacent towers **121** is used to join the two towers together. It will be understood that the building structure shown in FIGS. **20–24** is only one of the building structures to which the teaching of this application is applicable. It will also be understood that one of the non load bearing walls **66** could be omitted from each of the modules in practicing the teaching of this invention to construct the building structure shown schematically in FIGS. **20–22.** For example, exterior non load bearing walls **66** could be omitted in constructing the building structure to provide for the insertion of a glass wall panel or to provide for the insertion of exterior wall panels having a special texture or exterior appearance. Such glass wall panels or special texture panels could be transported into position and permanently attached affter the building structure is complete.

It will also be understood that according to the preferred embodiment of this invention only one module on each floor or story of the building structure includes two load bearing walls when transported into position. The remaining modules of a particular floor or story would each have but one load bearing wall and would share a load bearing wall in common with a horizontally adjacent module. It would of course be possible for all of the modules of a particular floor or story to be formed with a single load bearing wall panel **65** as transported into position in which case the first module transported into position would not be self-supporting and some sort of shoring would have to be substituted for a load bearing wall panel until the appropriate load bearing wall panel was placed in position and incorporated into the building structure.

Referring to FIGS. **25–28** a further multi-unit building structure to which the teaching of this invention is particularly applicable is shown. According to this embodiment of the invention the building structure is generally circular and comprises a plurality of pie-shape modules formed of pie-shape overhead panels A' and rectilinear wall panels B. As indicated by the reference numeral **65** the wall panels B extending radially of the building structure are the load bearing wall panels. As shown in FIGS. **26, 27,** and **28** each module comprises a single non load bearing panel B indicated by the reference numeral **66** at the inner edge of each pie-shape overhead panel A'. The wall panels **65, 66** are hingeably connected to the overhead panels A' by hinge joinder means C as described hereinabove. Similarly,

hinge members C' may be attached to the radially extending edge of a pie-shape overhead panel A' to which no wall panel **65** is attached in order to facilitate the elevation and transportation of the module into place. It will be seen that the pie-shape overhead panels A' are provided with tubular passage ways **68', 68''** and **68'''** extending from one load bearing edge thereof to the other load bearing edge. It will also be seen that the tubular passage ways **68'** adjacent the inner end of the pie-shape overhead panels A' and the tubular passage ways **68'''** adjacent the outer end of the pie-shape overhead panels A' have a circular curvature whereby such tubular openings or passage ways **68'** and **68'''** form arcs of circles which are concentric with each other and with the building structure. the remaining tubular openings or passage ways **68''** in each panel have a curvature such that when the modules are in place in the building structure the tubular openings or passage ways **68''** will be aligned to form a continuous planar spiral of increasing diameter from adjacent the inner ends of the overhead panels A' to the outer ends of the overhad panels A'. In post-tensioning a building structure as shown in FIGS. **25–28** in accordance with the teaching of this invention a post-tensioning cable received in the innermost circular tubular openings **68'** and a cable received in the outermost circular tubular openings **68'''** are at least partially tensioned. Grout is then poured in the joints between the overhead panels A' and the wall panels **65.** When the grout has set the removable hinge joinder means C and C' are removed and a cable received in the spiral tubular openings **68''** is tensioned to complete the post-tensioning of the building structure.

As shown in FIG. **25** it is preferred that the tubular openings **68'** adjacent the inner ends of the overhead panels A' form two overlapping semi-circular arcs of substantially the same diameter. A separate post-tensioning cable is received in each of such semi-circular arcs. Each of such cables is anchored at one end **130** thereof and a portable hydraulic unit **109** is attached to the other end thereof. Thus, the cable of each semi-circular arc may be tensioned independently of or simultaneously with the cable of the other semi-circular arc. Similarly, the tubular openings **68'''** adjacent the outer ends of the overhead panels may form overlapping semi-circular arcs of substantially the same diameter and each containing a separate cable. As shown in FIG. **25** portable hydraulic units **109** may be attached to opposite ends of each cable at the outer ends of the overhead panels A' in order to insure adequate tensioning of each cable. It will be understood that the cable received in the inner tubular openings **68'** and outer tubular openings **68'''** may be only partially tensioned prior to pouring the grout and removing the removable hinge joinder means C an C'. It will also be understood that after the cables are fully tensioned the cables will be anchored at both ends and the portable hydraulic means **109** removed.

It will be seen from FIG. **25** that the post-tensioning cable received in the intermediate tubular openings **68''**, which are aligned to form a spiral, is tensioned in sections after the grout has hardened and the removable hinge joinder means C and C' have been removed. Thus, the inner end of the cable received in tubular openings **68''** is anchored at **131.** Such cable is then tensioned in sections from the inner end of the cable to the outer end of the cable as by means of a plurality of hydraulic units **109** distributed along the spiral. Alternatively a single portable hydraulic means **109** may be moved from a point to point along the spiral, as indicated, to tension each section of the spiral in turn. It will be understood that when each section has been tensioned it will be anchored before the portable hydraulic unit **109** is moved to the next point for tensioning the next section of the spiral. Thus, when the final section of the cable has been tensioned by the hydraulic unit located at the outer end thereof and such outer end has been anchored the cables of the inner and outer semicircular arcs may be retensioned and anchored to complete the post-tensioning of the building structure.

As shown in FIG. **25** a central core **140** housing a stairwell **141**, elevators **142**, and appropriate utility space **143** may be constructed within the interior of the building structure by any suitable technique. If the building structure is a multi-story structure, appropriate hallways may be provided by poured-in-place structural members **106'** as described hereinabove. Similarly, balconies or other overhanging structural elements may be provided about the outer periphery of the building structure by suitable poured-in-place structural members **106''** as described hereinabove.

From the above it will be seen that the teaching of this invention is applicable to a wide variety of building structures regardless of their shape and whether or not they consist of multi-stories or floors. Ir will be understood that the overhead panels A, A' and wall panels B need not be made of poured concrete in order for certain teachings of this invention to be utilized. Instead, it is believed that those skilled in the art will adapt teachings of this invention to a wide variety of structural materials as well as to a wide variety of building structures.

What is claimed is:

1. A building structure on a foundation comprising a plurality of overhead panels and a plurality of wall panels, each of said overhead panels and each of said wall panels having parallel major surfaces bonded by two rectilinear opposite edges and two other opposite edges;

a. said overhead panels being arranged with their major surfaces in common planes and with one rectilinear edge of each in selected juxtaposition to a rectilinear edge of a further one of said plurality of overhead panels, one of said rectilinear edges of each of said wall panels being arranged in selected juxtaposition to a different pair of juxtaposed rectilinear edges of said overhead panels, said rectilinear edges of said overhead panels having planar surfaces forming a ridge thereon projecting over the rectilinear edge of said one of said wall panels juxtaposed thereto, and a quantity of grout interconnecting each of the juxtaposed edges of said overhead and wall panels;

b. said major surfaces of said overhead panels forming pie-shaped sections of upper and lower common circular annular surfaces with said two rectilinear opposite edges of said overhead panels extending radially of said annular surfaces and said two other opposite edges of said overhead panels forming inner and outer boundaries of said annular surfaces, and said wall panels extending radially of said annular surfaces;

c. each of said overhead panels being provided with a tubular opening passing therethrough from one rectilinear edge to the other in an arcuate path, the tubular openings through adjacent overhead panels being in alignment with each other to form a portion of a spiral passageway; and

d. a continuous flexible tension member slidably received in and passing through said passageway portion, said tension member being permanently fixed at each of its ends under tension.

2. A building structure on a foundation as claimed in claim **1** wherein each of said overhead panels is provided with a plurality of tubular openings each forming an arc of a different turn of a planar spiral extending from adjacent the inner boundary to adjacent the outer boundary of said annular surfaces.

3. A building structure as claimed in claim **2** wherein said major surfaces of said plurality of overhead panels form complete upper and lower annular surfaces, with said tubular opening aligned to form a planar spiral having a plurality of turns and with said flexible tension member extending continuously through all of said turns of said spiral.

4. A building structure on a foundation as claimed in claim **3** wherein each of said overhead panels is provided with a pair of arcuate tubular openings, one adjacent the inner edge thereof and the other adjacent the outer edge thereof, said one of said pair of arcuate tubular openings in each of said plurality of overhead panels forming an arc of a common circle of smaller diameter than the smallest turn of said planar spiral and the other of said pair of arcuate tubular openings in each of said plurality of overhead panels forming an arc of a circle of larger diameter than the largest turn of said planar spiral, said pairs of arcuate tubular openings in said plurality of overhead panels being aligned with each other to form circular passageways and flexible tension members extending through each of said circular passageways, each of said flexible tension members being permanently fixed to said overhead panels under tension at opposite ends of said circular passageways, and wherein said flexible tension member received in said planar spiral passageway is permanently fixed to said overhead panels under tension at a plurality of points along said planar spiral passageway.

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