United States Patent [19]
Cox et al.

[11] **3,772,835**
[45] **Nov. 20, 1973**

[54] **HOUSING**

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[21] Appl. No.: **191,505**

[52] **U.S. Cl.** **52/79**, 52/91, 52/125, 52/274, 52/293
[51] **Int. Cl.** **E04b 7/02**, E02d 27/42
[58] **Field of Search** 52/91, 79, 274, 293, 52/125, 602

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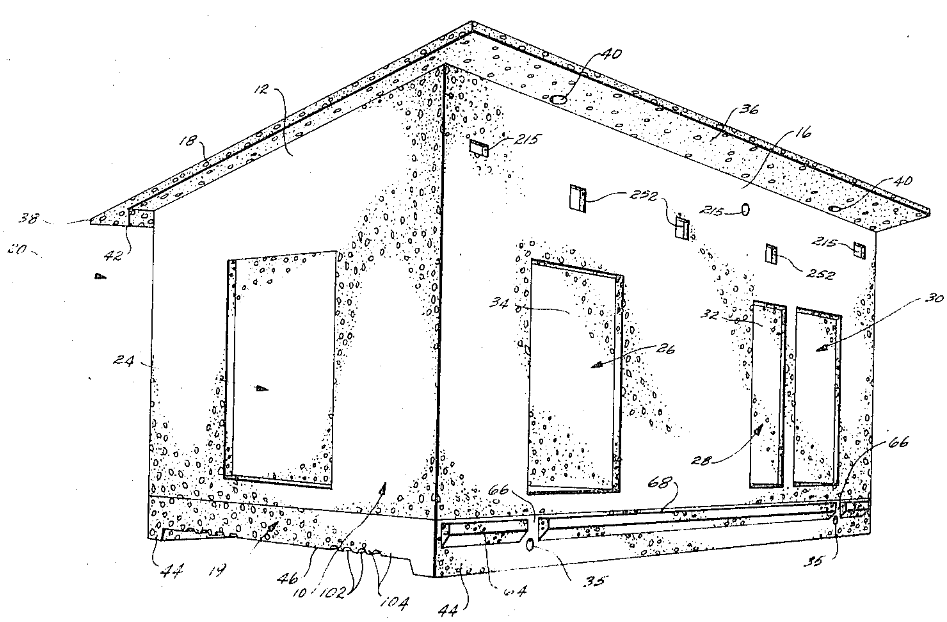
[57] **ABSTRACT**

A pair of precast concrete building units are joined together to form a modular concrete house. Each concrete building unit includes a floor slab, upright load-bearing exterior walls joined with the perimeter of the floor slab, and a sloping roof cast integrally with the tops of the exterior walls. The building units are arranged so that the roof of each unit slopes upwardly toward the other unit, with the elevated ends of the roofs meeting to form an inverted V-shaped pitch roof. In one embodiment of the building unit, the elevated end portion of each roof projects outwardly to form a cantilevered overhang, with the cantilevered portions of two side-by-side building units covering an elongated corridor formed between the two units. An upright concrete shear panel covers each end of the corridor and rigidly connects the two building units together. Alternatively, the cantilevered overhang may be eliminated and two side-by-side units connected together without a central corridor or shear panels being present between them. Interior walls are cast integrally with the exterior walls and the roof to divide the building units into separate rooms. The bottoms of the interior walls are spaced above the floor slab so that no loads are transmitted to the floor slab by the walls, and plumbing and wiring are run through the space between the bottom of the interior walls and the floor slab. A reinforcing cage formed from welded wire mesh is embedded in each exterior wall. Insulation boards preferably made of plastic foam are placed inside each wire mesh cage and spaced longitudinally apart along the length of each wall, thereby forming spaced apart transverse concrete webs which join together opposite faces of the wall. A separate elongated longitudinal ridge extending along each longitudinal edge of the floor slab projects downwardly from the undersurface of the floor slab. Several parallel transverse ridges extend the width of the floor slab between the longitudinal ridges and project downwardly from the undersurface of the floor slab. A plurality of spaced apart downwardly opening notches are cast in the bottom edges of the transverse ridges to form shear keys which are embedded in the foundation to prevent movement of the floor slabs relative to each other or the foundation.

19 Claims, 22 Drawing Figures



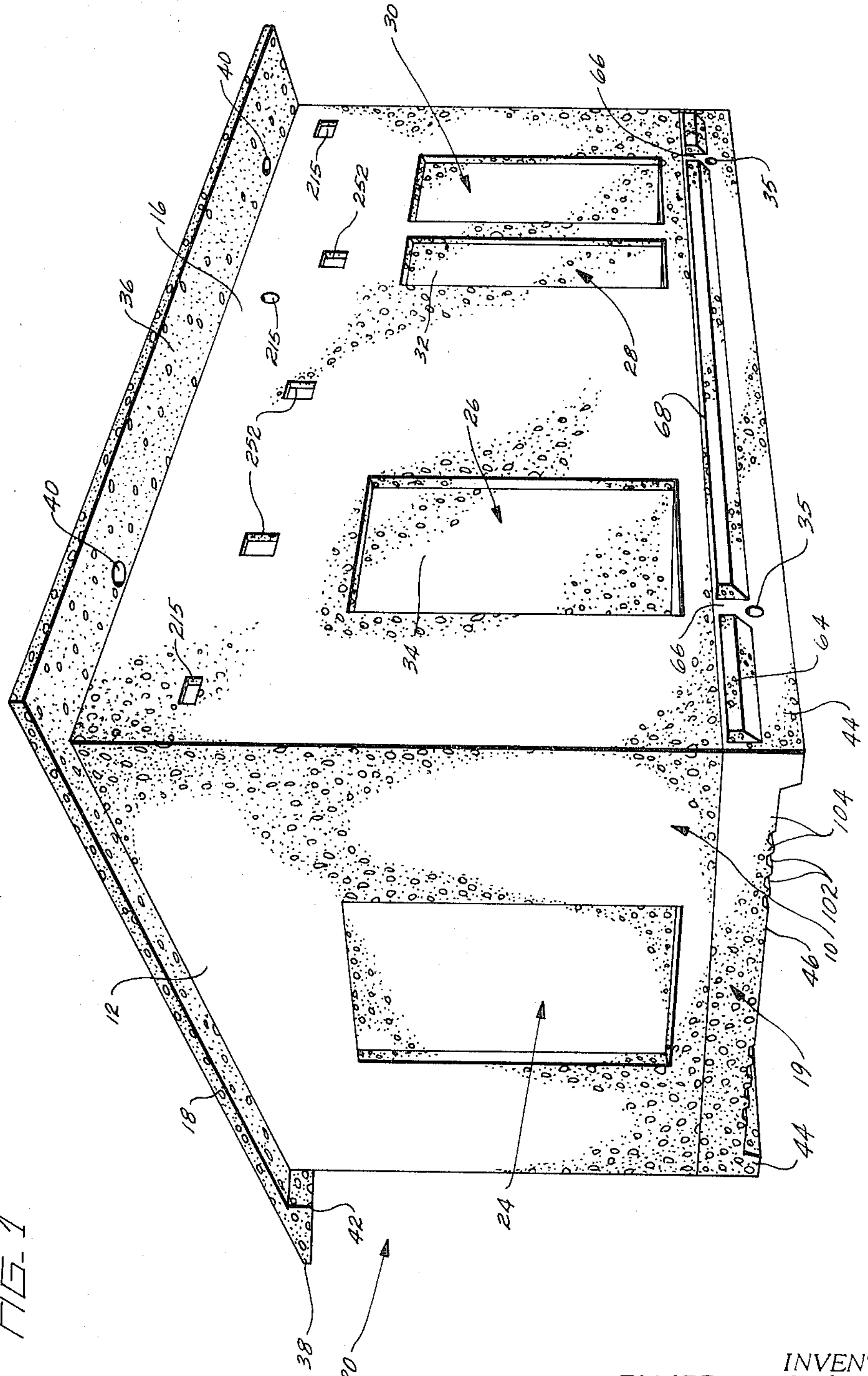


FIG. 1

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Christie, Parker & Hale
ATTORNEYS

FIG. 2

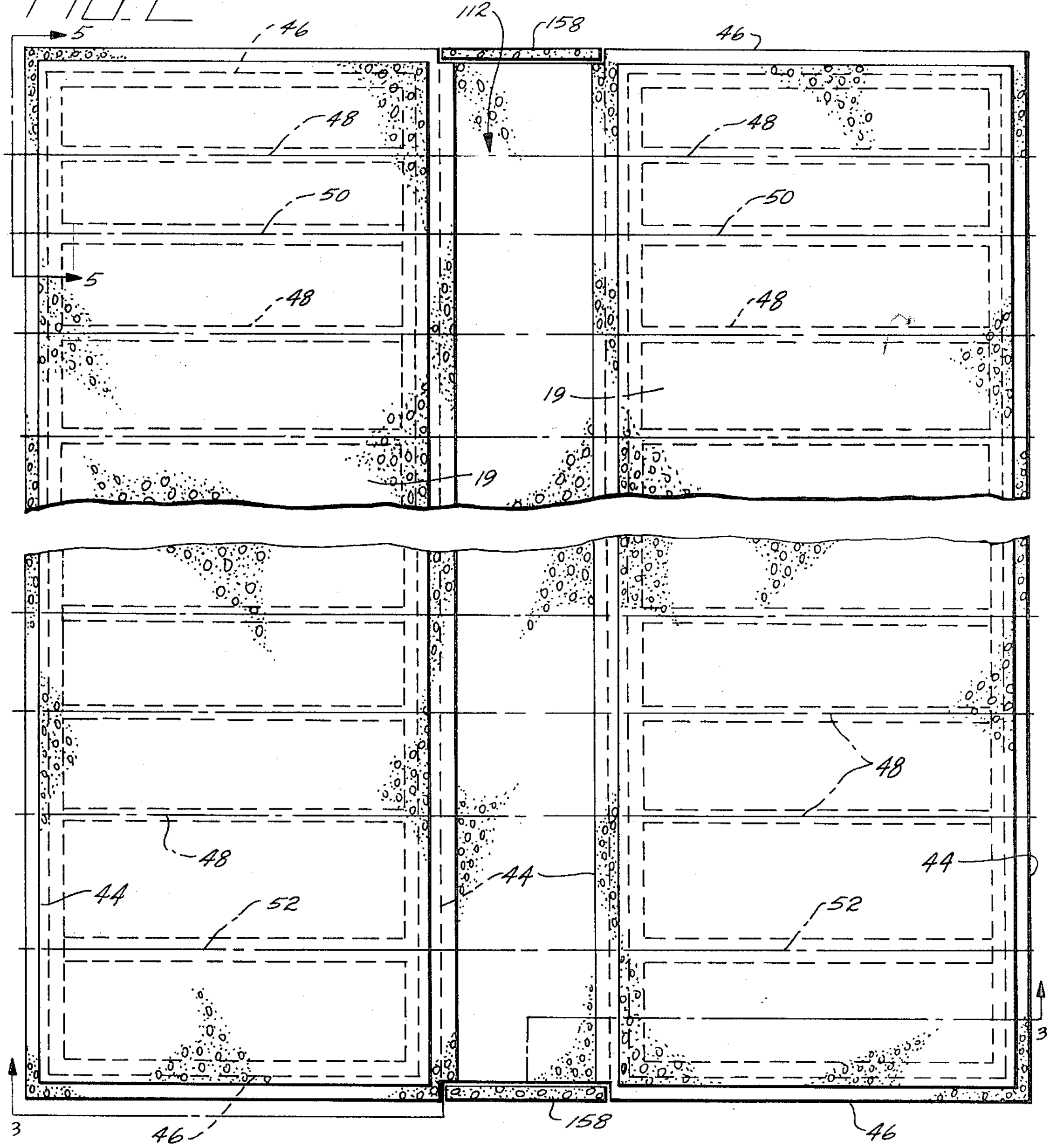
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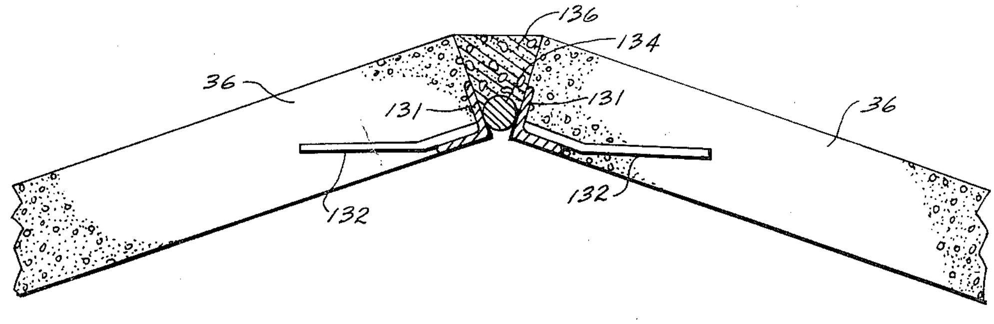
FIG. 12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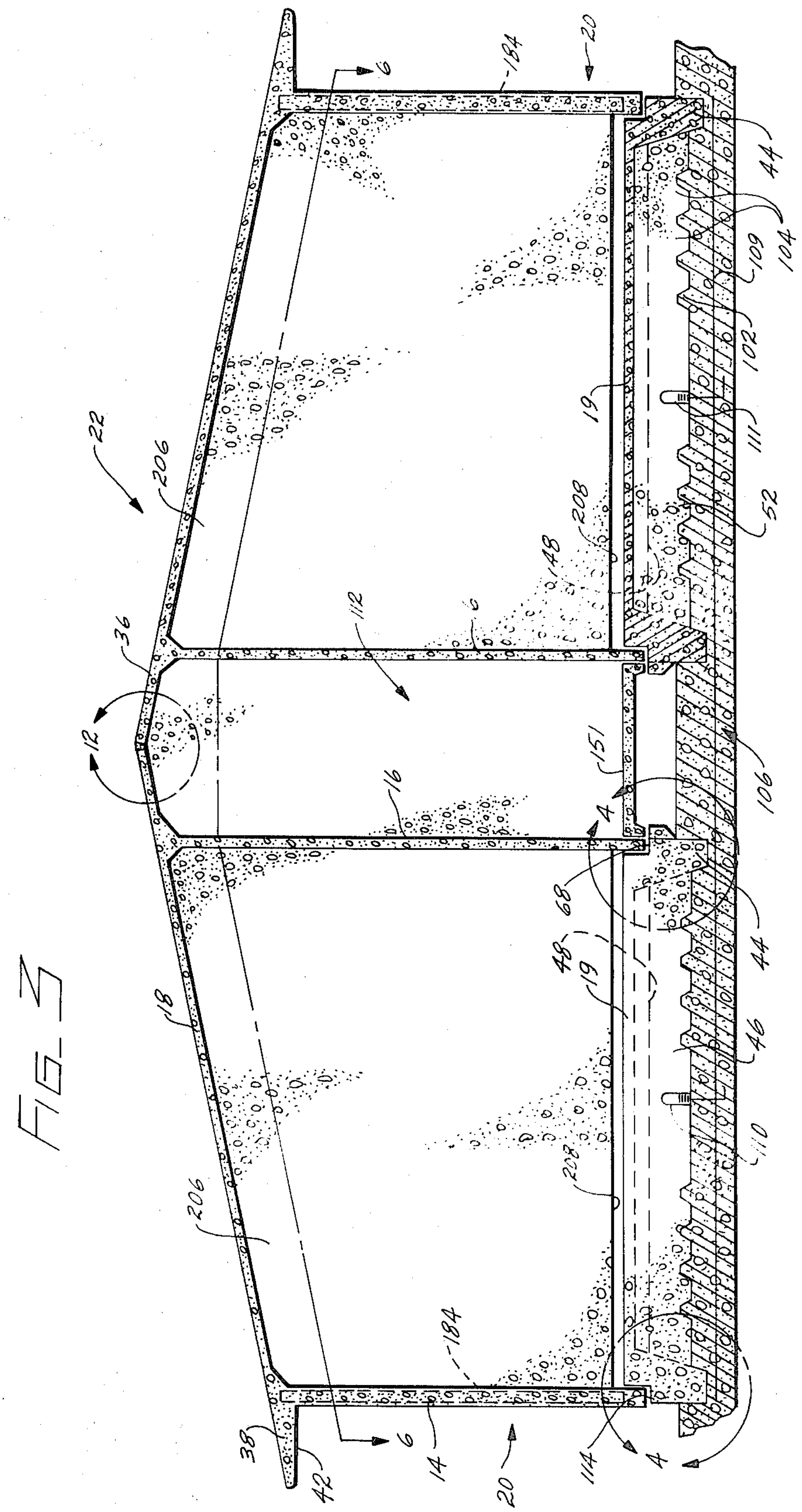

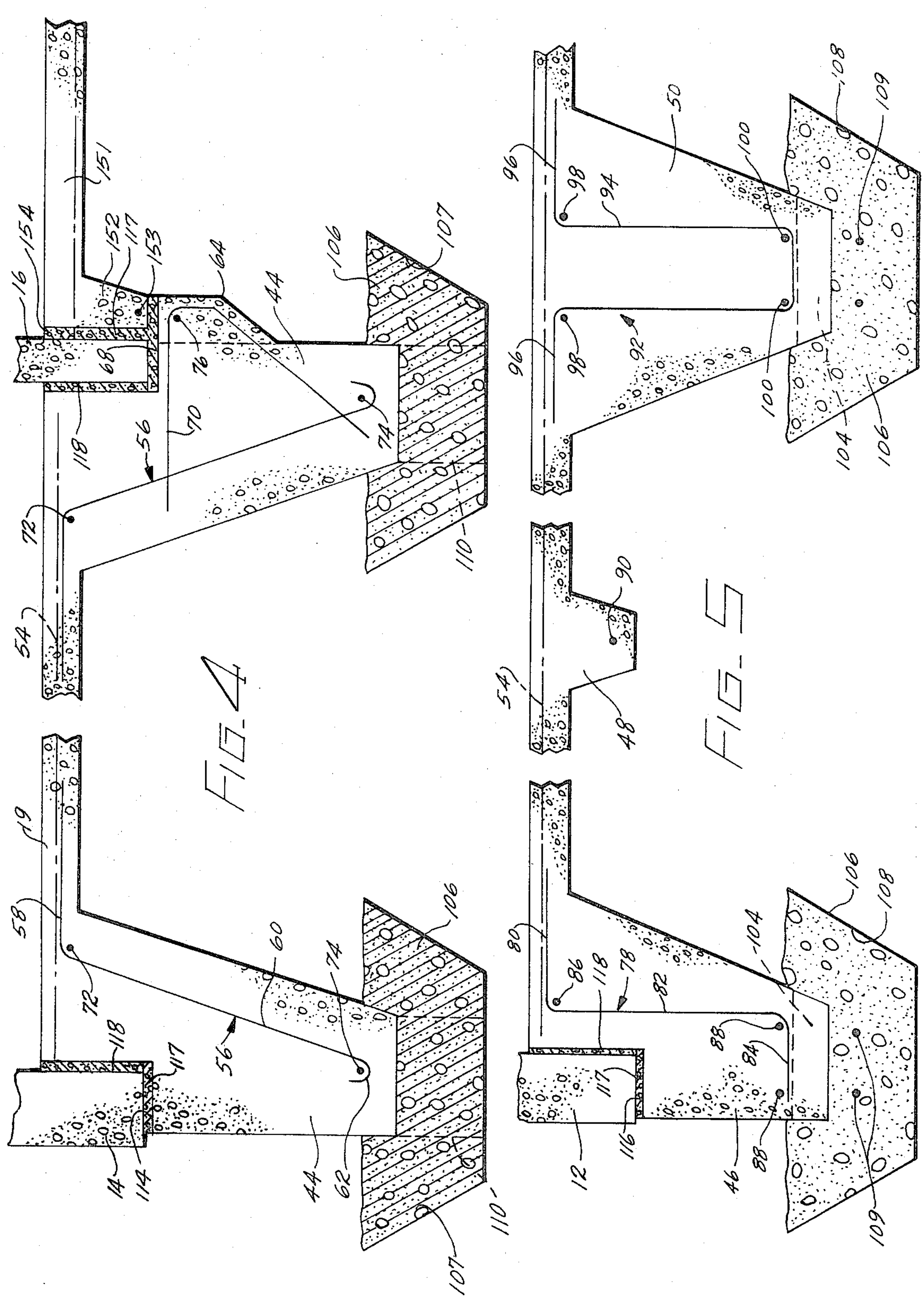

FIG. 4

FIG. 5

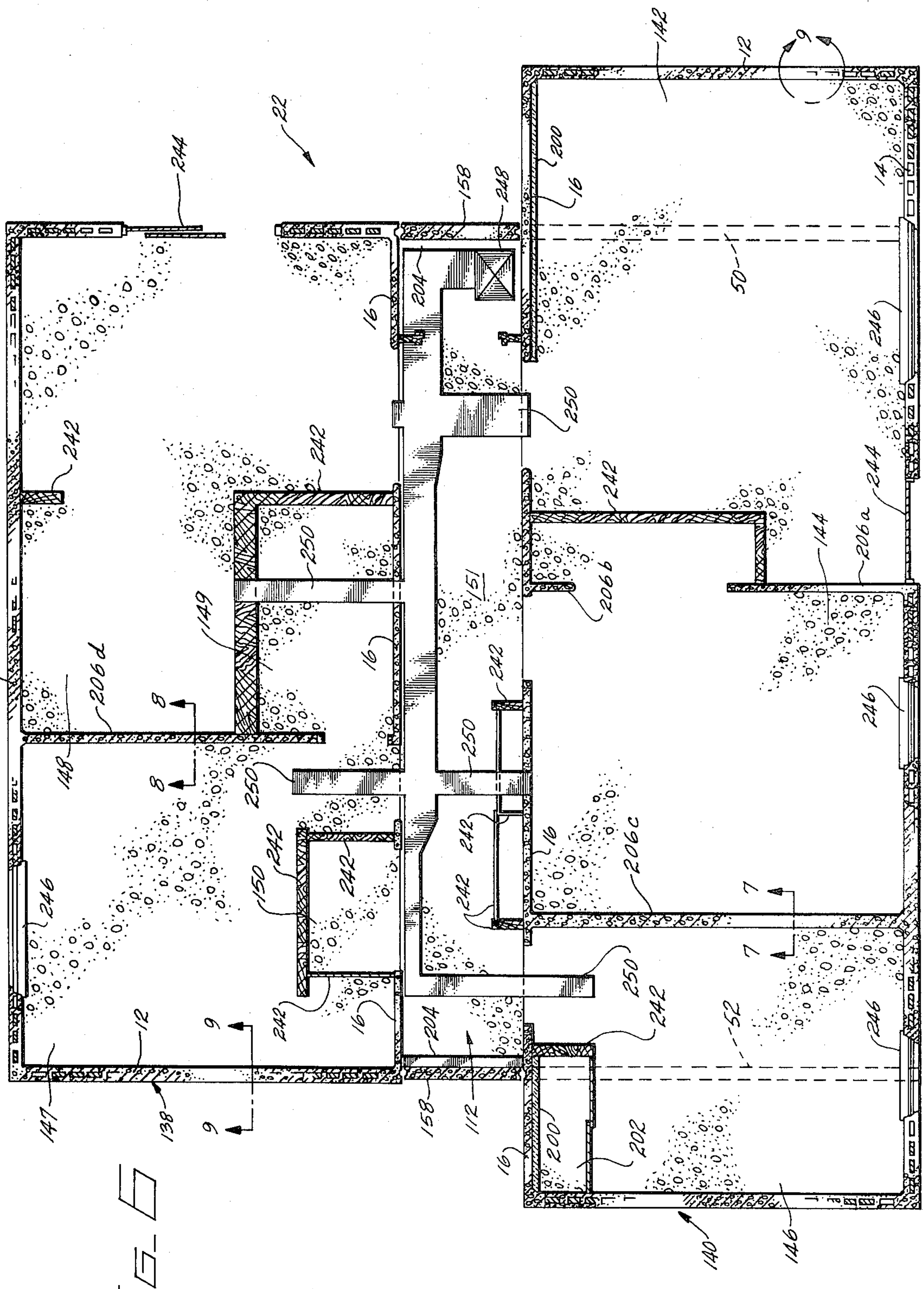
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FIG_6

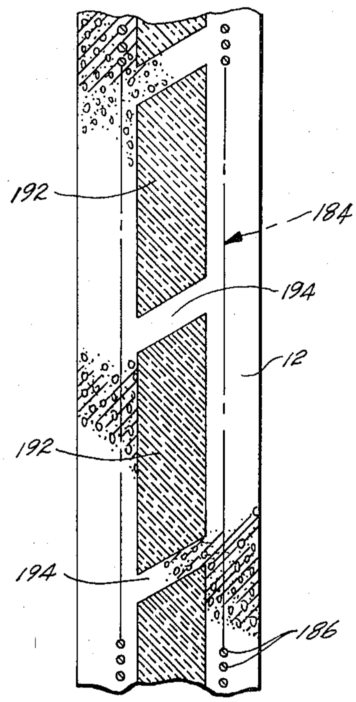

FIG.10

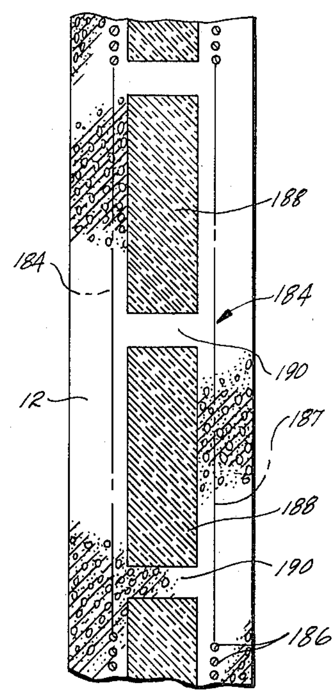

FIG.9

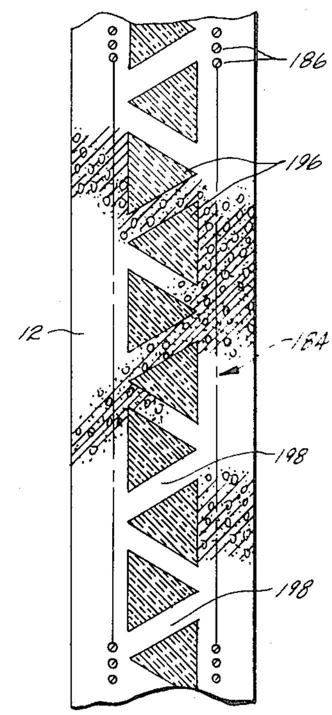

FIG.11

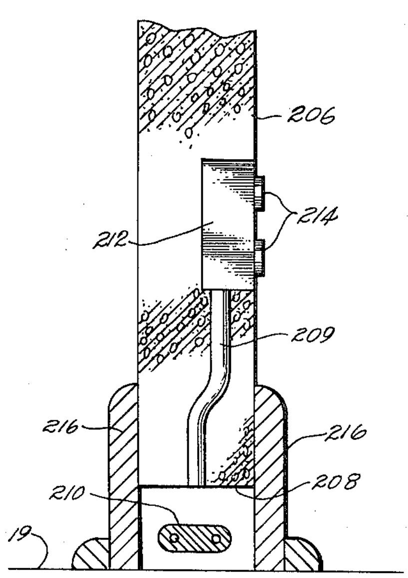

FIG.7

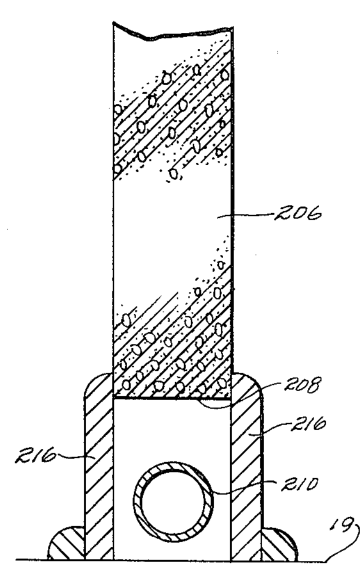

FIG.8

FIG_13

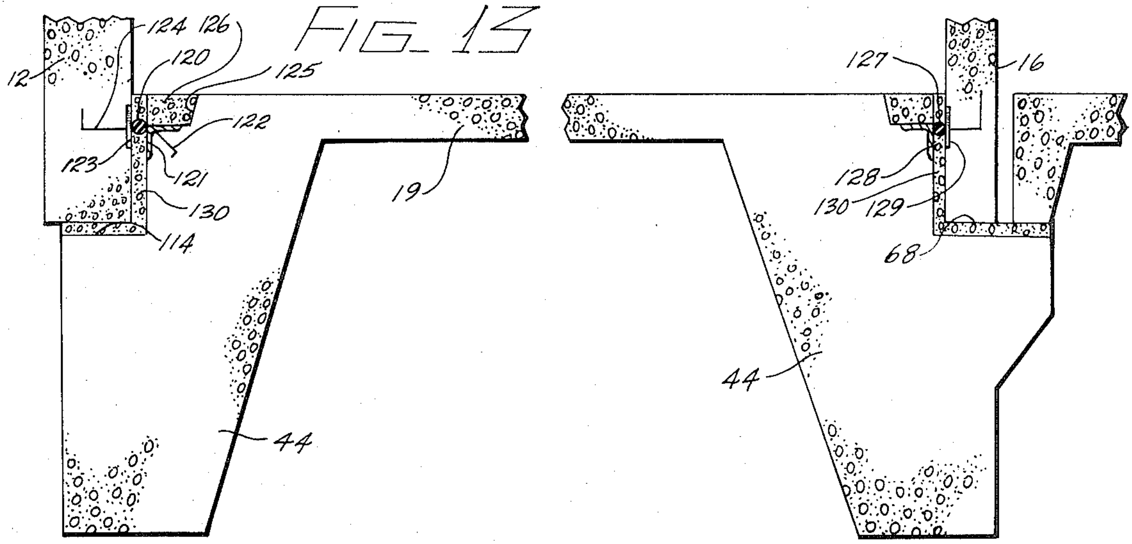

FIG_14

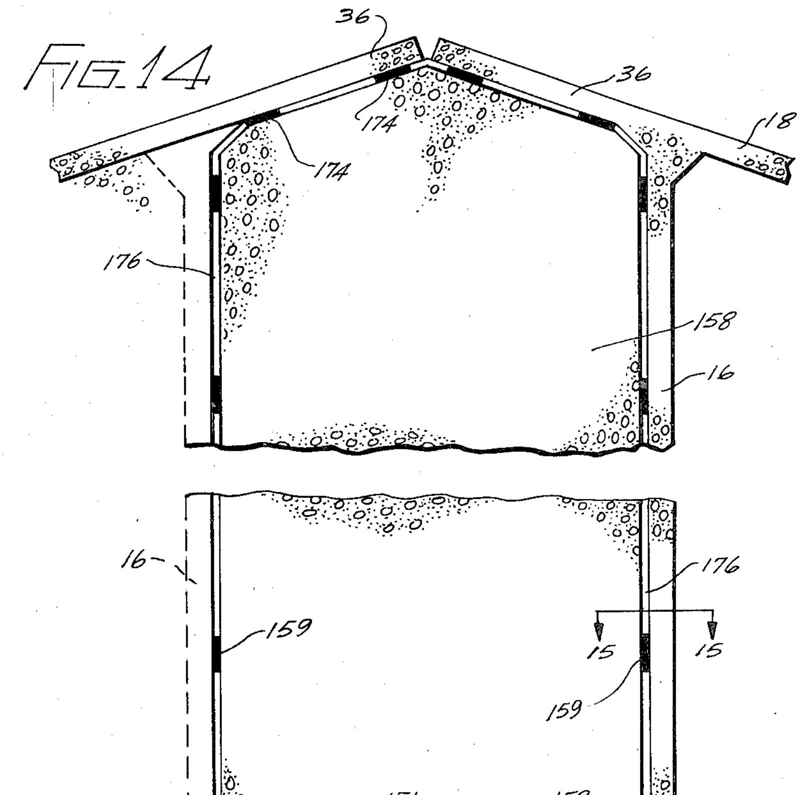
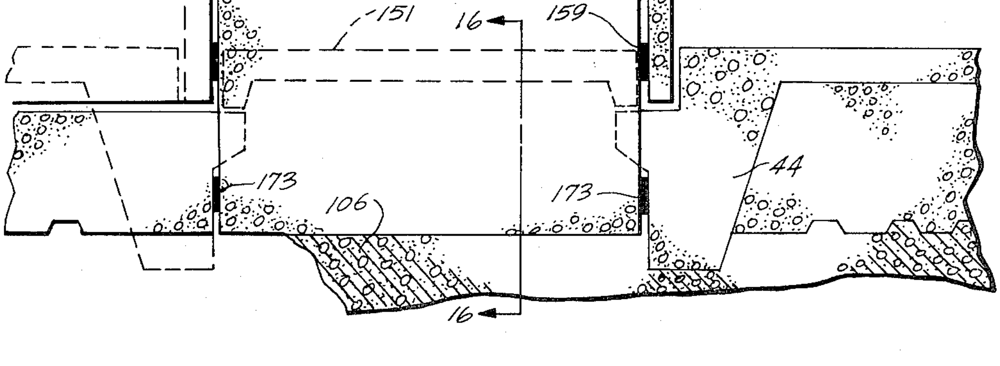

FIG_16

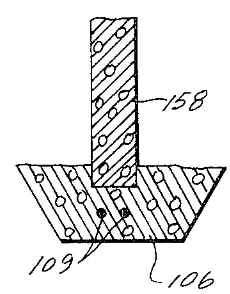

FIG. 15

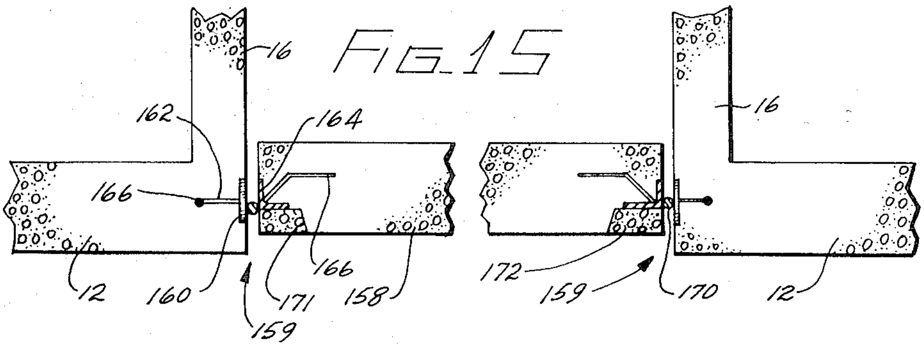

FIG. 17

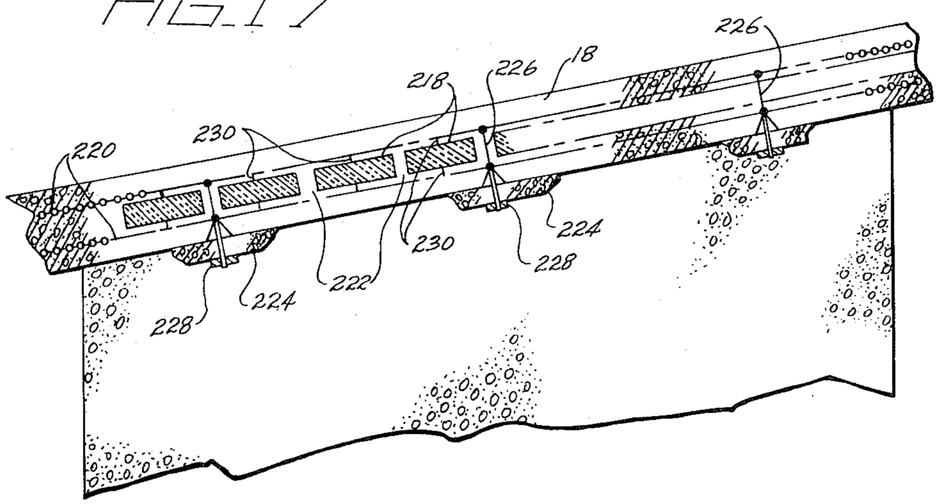

FIG. 19

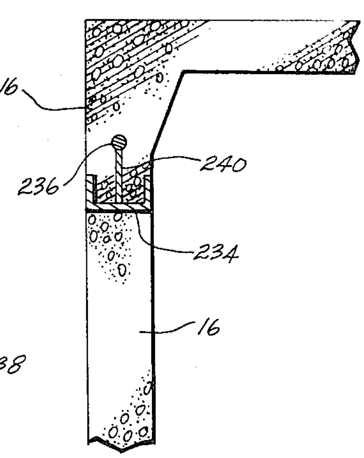

FIG. 18

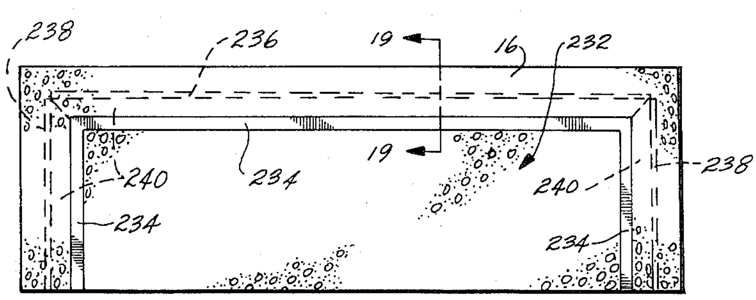

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FIG. 21

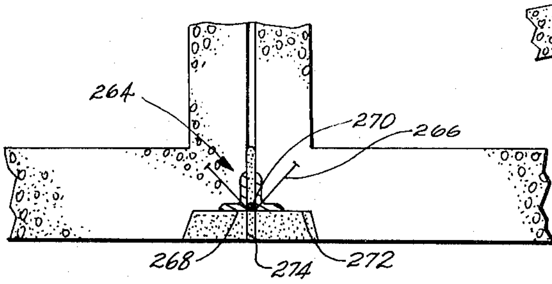


FIG. 22

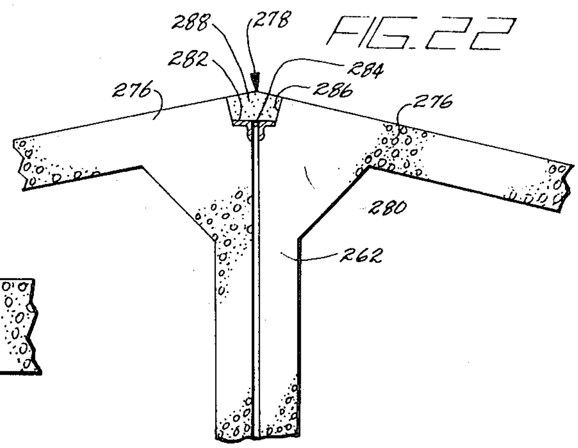
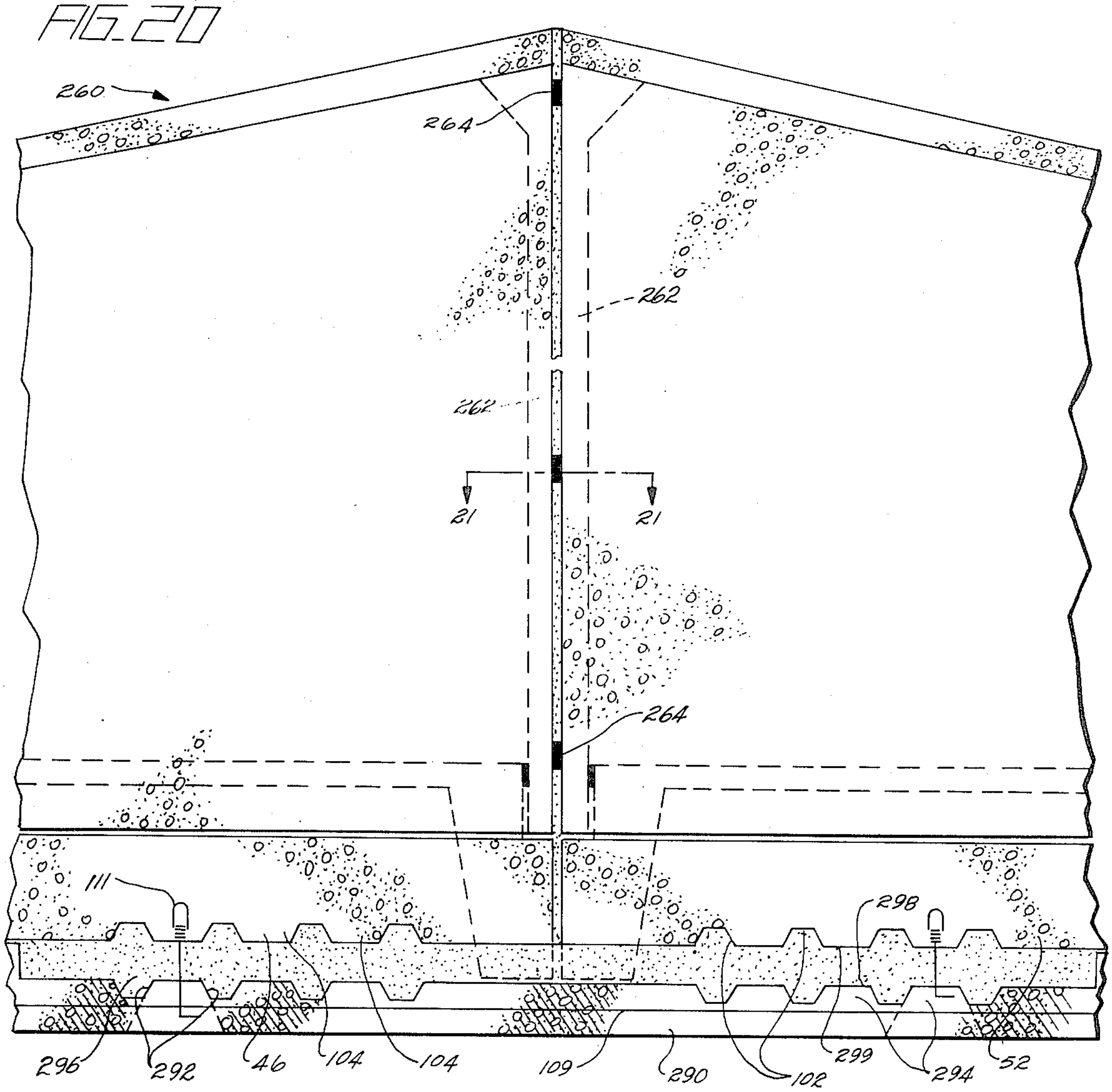


FIG. 20



HOUSING

BACKGROUND OF THE INVENTION

This invention relates to housing, and more particularly to precast concrete modular dwelling units.

The recent housing shortage and increase in construction costs has stimulated the development of prefabricated modular housing. There is a need especially among low-income families for a durable high quality house that can be mass produced at a lower cost than conventionally built houses.

Most modular housing is in the form of wood frame houses made from prefabricated building wall panels, frames, and trusses. A major disadvantage of this type of housing is that the wall panels, frames, and trusses must be constructed with extreme precision on relatively expensive framing machines. The prefabricated wall panels, frames, and trusses then are transported to the building site where substantial additional costs are incurred in erecting them into houses.

Concrete modular houses also have been produced to satisfy the need for prefabricated housing. Generally, modular concrete houses are assembled from concrete modular units, or segments, and separate interior and exterior wall panels. The modular units and wall panels are transported to the building site where a substantial amount of construction must be done to erect them into a completed house.

SUMMARY OF THE INVENTION

This invention provides a precast concrete building unit which may be joined with one or more similar precast concrete building units to form a concrete modular house. The building units may be precast in a casting yard and transported to the construction site where they are placed on a foundation and connected together to form a completed concrete swelling house.

In its preferred form, each building unit includes a floor slab, exterior walls joined with the floor slab, a roof cast with the exterior walls, and interior walls cast with the roof and the insides of the exterior walls. Finishing procedures such as installation of doors, windows, electrical lines, plumbing, and painting are performed at the casting site. Thus, a minimum amount of construction at the building site is required to connect the buildings together. This work consists primarily of setting the modules on the foundation, connecting them together, and making the necessary utility connections.

In one form of the invention, spaced apart longitudinal ridges, or skirts, project downwardly from the underside of each floor slab. Spaced apart transverse ridges, or beams, between the longitudinal ridges project downwardly from the undersurface of the floor slab a shorter distance than the longitudinal ridges. This permits lifting devices such as cables and the like to be placed under the floor slab to facilitate lifting of the modular building unit.

One or more of the beams include spaced apart downwardly opening notches which form spaced apart shear keys. The floor slab is placed over a foundation slab, with the shear keys being embedded in the grout between the beams and foundation slab. Preferably, the foundation slab has shear keys matching the shear keys in the beams. The shear keys provide an undulating interface between the grout and beams on one hand and

the grout and foundation slab on the other hand which prevents movement of the floor slab relative to an adjacent floor slab or to the foundation. One or more anchor bars embedded in the beam extends into the foundation grout to provide additional resistance to the floor slab and foundation from being pulled apart.

Spaced apart horizontal lifting holes are cast either in the longitudinal beams of the floor slab or the side of the floor slab to receive lifting pins which are hoisted by a lifting device such as a spreader bar strapped to the lifting pins.

In a preferred form of the modular building unit, the roof, the exterior walls, and the interior walls are cast integrally with an appropriate pitch on the roof so that when two of the modular units are joined together, the completed house has a pitch roof. The interior walls preferably are cast to be spaced above the upper surface of the floor slab when the exterior walls are joined with the floor slab. Thus, no load is transmitted to the floor slab by the interior walls. An elongated strip of molding on each side of each interior wall covers the space between the floor slab and the bottom of the interior wall to form an enclosed area for electrical cables, plumbing lines, and the like.

In one embodiment of the invention, two modular building units are rigidly connected to each other by an upright concrete shear panel at each end of the house. In the preferred means of connection, the shear panel at each end of the house also is connected to the floor slabs so that the beams of the floor slab, the shear panels, the roof, and the exterior walls form the equivalent of at least an 8-foot beam which provides substantial rigidity and strength for the house. In another form of the invention, two side-by-side modular units may be welded together without the shear panels.

The preferred form of the exterior walls includes a pair of laterally spaced apart wire mesh netting panels embedded in the concrete wall and extending lengthwise with respect to the wall. Longitudinally spaced apart insulating blocks are embedded in the concrete wall between the wire mesh netting panels and arranged to extend lengthwise with respect to the wall. The insulating blocks are of a density less than that of the concrete, and are preferably made of plastic foam material such as polystyrene foam, or polyurethane foam. Thus, the exterior walls provide the house with good temperature insulation, and the spaces between insulating blocks provide concrete webs which strengthen the wall.

Electrical outlets and conduits preferably are cast in place in the exterior and interior walls. The conduits preferably are pre-wired prior to casting to facilitate installation of the electrical wiring.

During the casting of the exterior walls, tie down devices and spacers keep the wire mesh netting panels centered within the forms and prevent the insulation blocks from moving relative to the wire panels.

In a preferred form of the house in which two modular building units are placed side-by-side, a separate opening may be formed in each of two adjacent exterior walls to form a large room extending from one modular unit to the other. For houses of this type, a reinforcing arch is cast integrally in the concrete surrounding each opening. Preferably, the reinforcing arch includes a reinforcing bar embedded in an interior portion of the concrete wall, an elongated plate exterior of the wall and bordering at least a portion of the opening, and a rigid transverse support member embedded in the wall and rigidly secured to the reinforcing bar at one end and to the plate at the other end.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view showing a precast concrete modular building unit;

FIG. **2** is a fragmentary plan elevation view showing the floor slabs of a pair of side-by-side modular building units which are connected together to form a house;

FIG. **3** is an elevation view showing the end of a pair of modular building units connected together to form a house, and an elevation view of the floor slabs of the building units taken on line **3—3** of FIG. **2**;

FIG. **4** is an enlarged fragmentary elevation view of the reinforcing means shown within the circle **4** of FIG. **3**;

FIG. **5** is a fragmentary elevation view taken on line **5—5** of FIG. **2** showing the reinforcing means for the transverse beams of the floor slab;

FIG. **6** is a plan elevation view showing the floor plan of a completed house;

FIG. **7** is a sectional elevation view taken on line **7—7** of FIG. **6** showing an interior wall of the modular building unit with an electrical outlet and an electrical conduit cast in place in the wall;

FIG. **8** is a sectional elevation view taken on line **8—8** of FIG. **6** showing an interior wall of the modular building unit with a gas line between the bottom of the wall and the floor slab;

FIG. **9** is a sectional elevation view taken on line **9—9** of FIG. **6** showing the means for reinforcing an exterior wall of the modular building unit;

FIG. **10** is a sectional elevation view showing an alternate form of the reinforcing means shown in FIG. **9**;

FIG. **11** is a sectional elevation view showing a further alternate form of the reinforcing means shown in FIG. **9**;

FIG. **12** is an enlarged elevation view of the means for connecting the roofs shown within the circle **12** of FIG. **3**;

FIG. **13** is a fragmentary schematic elevation view showing means for securing an exterior wall to the floor slab;

FIG. **14** is a fragmentary schematic elevation view showing means for securing a shear panel between two modular building units;

FIG. **15** is an enlarged fragmentary elevation view taken on line **15—15** of FIG. **14**;

FIG. **16** is an elevation view taken on line **16—16** of FIG. **14**;

FIG. **17** is a sectional elevation view showing means for casting the insulation in the roof of the modular unit;

FIG. **18** is an elevation view showing a reinforcing arch cast in the concrete surrounding an opening in an exterior wall of the modular unit;

FIG. **19** is a sectional elevation view taken on line **19—19** of FIG. **18**;

FIG. **20** is a fragmentary elevation view showing two alternate modular building units secured together without a shear panel;

FIG. **21** is a plan elevation view taken on line **21—21** of FIG. **20**; and

FIG. **22** is an enlarged elevation view of the means for connecting the roofs shown within the circle **22** of FIG. **20**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, a precast concrete building unit **10** includes a pair of parallel upright exterior side walls **12**, a long exterior end wall **14** (shown in FIG. **3**) cast integrally at its ends with a respective end of each side wall, a long exterior center wall **16** cast integrally at its ends with the other ends of exterior side walls **12**, and a roof **18** which is cast integrally with the tops of exterior walls, **12**, **14**, and **16**. The roof slopes upwardly toward center wall **16**, thereby making the height of center wall **16** greater than that of end wall **14**.

The exterior walls of building unit **10** are joined with the perimeter of a rectangular precast concrete floor slab **19** to form a modular concrete half-dwelling unit **20** which forms half of a completed house **22** shown best in plan view in FIGS. **2** and **6**, and in end view in FIG. **3**. The means for joining building unit **10** with floor slab **19** will be described in detail below.

Window openings, such as an opening **24** in side wall **12**, may be cast in either of side walls **16** or in end wall **14**. One or more doorway openings, such as openings **26**, **28**, and **30** which are cast in center wall **16**, may be cast in end wall **14** and either of the side walls, as well as the center wall. Openings **28** and **30**, which are spaced relatively close to each other, are separated by an interior wall **32** which divides modular unit **20** into separate rooms. A second interior wall **34** adjacent door opening **26** also divides the unit into separate rooms. Thus, each room in dwelling unit **20** has direct access to the mating other half of house **22** either through door openings **26**, **28**, or **30**.

Building unit **10** and floor slab **19** are cast separately in a casting yard. Horizontal lifting holes **35** are cast in the long sides of floor slab **19** to receive lifting pins (not shown). A spreader bar (not shown) strapped to the lifting pins hoists the floor slab.

The elevated end portion of roof **18** above center wall **16** is cast in an outwardly and upwardly projecting overhang **36**. A downwardly and outwardly projecting overhang **38** is cast with the lower edge of roof **18** above end wall **14**. Longitudinally spaced apart vertical lifting holes **40** are cast in each overhang **36** and **38** to permit the passage of lifting devices, such as cables (not shown), from a gantry crane (not shown) positioned over building unit **10**. A lifting arm (not shown) secured to the end of each cable bears aginst the undersurface of each overhang portion of the roof to permit the building unit **10** to be lifted when the cables are drawn upwardly by the gantry crane.

Overhang **38** has a flat, horizontal undersurface **42** to permit the wall of the casting form (not shown) to be moved horizontally outwardly from end wall **14** without having its movement interrupted by the overhang portion of the roof.

Referring to FIGS. **1** through **5**, a separate elongated longitudinal ridge or beam **44** extends along each long edge of the floor slab and projects downwardly from the underside of the floor slab. A separate elongated outer transverse ridge or beam **46** extends along each short edge of the floor slab and projects downwardly from the underside of the floor slab. The ends of the outer transverse beams **46** are cast integrally with respective ends of longitudinal beams **44**. Longitudinal beams **44** project several inches below the transverse beams **46**. This configuration of the beams permits lifting devices, such as cables and the like, to be placed under the floor slab to facilitate its handling.

A plurality of spaced apart and parallel inner transverse ridges or beams 48 extend the width of the floor slab and project downwardly from the undersurface of the floor slab. Inner transverse beams 48 are parallel to outer transverse beams 46, with their ends being cast integrally with the inside of longitudinal beams 44. As shown best in FIG. 5, transverse beams 48 project downwardly from the undersurface of the floor slab approximately one-fourth the distance of outer transverse beams 46. The width of each inner transverse beam 48 is approximately one-third that of outer transverse beams 46.

As shown best in FIG. 2, the spacing between each side-by-side pair of inner transverse beams 48 is substantially the same, except that each floor slab has a downwardly projecting large transverse beam 50 which extends the width of the floor slab and replaces one of the inner transverse beams. Similarly, a downwardly projecting large transverse beam 52 at the other end of each floor slab extends the width of the floor slab and replaces one of the inner transverse beams at a point adjacent to an outer transverse beam 46. As shown best in FIG. 5, large transverse beam 50 preferably projects downwardly from the undersurface of the floor slab substantially the same distance as outer transverse beams 46. Large transverse beam 50 also is slightly wider than outer transverse beams 46. The configuration of large transverse beam 52 is identical to that shown for beam 50 in FIG. 5.

Floor slab 19 is cast as a unit by constructing a rigid reinforcing steel cage in a mold (not shown) and pouring concrete into the mold to form the floor slab and the beams which project downwardly from the undersurface of the floor slab. The configuration of the preferred reinforcing steel cage is shown best in FIGS. 4 and 5. The horizontal portion of floor slab 19 is reinforced by a horizontal wire mesh panel 54 (shown schematically in FIGS. 4 and 5) made of pieces of six-gauge wire which are welded together to form a reinforcing grid. The wire mesh panel covers substantially the entire horizontal area of the floor slab.

Each longitudinal beam 44 has a plurality of spaced-apart reinforcing bars or stirrups 56, each having a horizontal upper portion 58 which is embedded in the floor slab 19 below wire mesh panel 54, a downwardly and outwardly projecting intermediate portion 60 embedded substantially in the center of the longitudinal beam, and an upwardly opening curved lower portion 62. The stirrups 56 in each longitudinal beam 44 preferably are spaced 24 inches apart on center along the length of the floor slab.

As shown best in FIG. 4, an elongated outwardly projecting ridge 64 is cast integrally with the side of the longitudinal beam 44 which is below center wall 16. Ridge 44 extends along the long edge of floor slab 19, with two notches 66 (shown in FIG. 1) being formed in the ridge above lifting holes 35. Notches 66 provide room for lifting devices, such as cables or the like, which are strapped to lifting pins (not shown) in holes 35 when the floor slab is lifted. Ridge 64 provides a horizontal bearing surface 68 along the length of the floor slab for a purpose described in detail below. Ridge 64 is reinforced by a plurality of spaced apart inwardly opening, substantially U-shaped steel reinforcing bars 70, each of which is curved to fit the contour of the ridge. Reinforcing rods 70 preferably are spaced 24 inches apart on center along the length of the floor slab.

A separate elongated upper reinforcing bar 72 extends the length of the floor slab along a path transverse to each row of stirrups 56. Each upper reinforcing bar 72 is embedded in the top portion of the floor slab adjacent to the angled corner formed between horizontal portion 58 and intermediate portion 60 of each stirrup 56. Each reinforcing bar 72 is rigidly secured to the corner of each stirrup 56 which crosses it by a separate tie rod (not shown). Alternately, the bar may be secured to the stirrups by welding.

A separate elongated lower reinforcing bar 74 extends the length of the floor slab along a path transverse to the row of stirrups 56. Each lower reinforcing bar 74 is embedded in the lower portion of a respective longitudinal beam 44 inside curved portions 52 of stirrups 56. Each reinforcing bar 74 is rigidly secured, such as by tying or welding, to the adjacent curved portion 62 by each stirrup 56 which traverses it.

An elongated reinforcing bar 76 extends the length of the floor slab along a path transverse to the row of reinforcing rods 70. Reinforcing bars 76 are embedded in ridge 64 inside the U formed by reinforcing rod 70 and is rigidly secured, such as by tying or welding to each reinforcing rod 70 which crosses it.

Preferably, upper and lower reinforcing bars 72 and 74 are number six steel rods, and reinforcing rod 76 is a number three steel rod. However, the size of these reinforcing rods may be changed to fit the design and load-bearing conditions of the floor slab.

Each outer transverse beam 46 has a plurality of spaced-apart substantially S-shaped reinforcing bars or stirrups 78. Each stirrup 78 has a horizontal upper portion 80 embedded in floor slab 19 below wire mesh panel 54, a vertical downwardly extending intermediate portion 82 embedded substantially in the center of outer transverse beam 46, and a horizontal outwardly extending lower portion 84 embedded in the lower portion of transverse beam 46. Stirrups 78 preferably are spaced 24 inches apart along the length of the floor slab. An elongated reinforcing bar 86, which extends the width of the floor slab along a path transverse to the row of stirrups 78, is embedded in the floor slab adjacent to the angled corners formed by each upper portion 80 and intermediate portion 82 of stirrups 78. Reinforcing bar 86 is rigidly secured, such as by tying or welding, to the corner of each stirrup which intersects it.

A pair of parallel, horizontally spaced apart elongated reinforcing bars 88 extend the width of the floor slab along a path transverse to the row of stirrups 78. Reinforcing bars 88 are embedded in the lower portion of outer transverse beam 46 slightly above horizontal portions 84 of stirrups 78. Each reinforcing bar 88 is rigidly secured by suitable means to the horizontal portions 84 of the stirrups which intersect them.

A separate rigid elongated reinforcing bar 90, which extends the width of the floor slab, is embedded substantially in the center of each inner transverse beam 48.

Each large transverse beam 50 has a plurality of spaced-apart substantially U-shaped reinforcing bars or stirrups 92 embedded in it. Each stirrup 92 has an upwardly opening channel-shaped portion 94 embedded substantially in the center of beam 50, and outwardly projecting substantially horizontal marginal ends 96 at the upper ends of channel 94. Marginal ends 96 are embedded in floor slab 19 below wire mesh panel 54. Stirrups 92 preferably are spaced 24 inches apart along the length of transverse beam 50. A separate rigid elongated reinforcing bar 98 which extends the length of the floor slab along a path transverse to the row of stirrups 92, is embedded in the floor slab adjacent to each angled corner formed between a respective marginal edge 96 and channel portion 94 of each stirrup 92. Each reinforcing bar 98 is rigidly secured by suitable means to the nearby corner of each stirrup 92 which intersects it. A pair of parallel, horizontally spaced apart rigid elongated reinforcing bars 100 extend the length of transverse beam 50 along a path transverse to the row of stirrups 92. Reinforcing bars 100 are embedded in the lower portion of transverse beam 50 slightly above the bottom of channel portion 94 of each stirrup 92. Each reinforcing bar 100 is rigidly secured to a respective corner of the channel portion 94 of each stirrup 92 which intersects it.

Preferably, stirrups 78 and 92 are made of number three steel rods, reinforcing bar 98 is made of a number four steel rod, and reinforcing bars 86, 88, 90, and 100 are made of number six steel rods. However, the sizes of these reinforcing rods may change with the design and load conditions of the floor slab.

Spaced apart downwardly opening notches 102 are cast in the bottom surfaces of the outer transverse beams 46 and large transverse beams 50 and 52, thereby forming spaced apart downwardly projecting teeth or shear keys 104 in each beam. When floor slab 19 is placed on a foundation 106 (shown best in FIG. 5), the shear keys are embedded in the foundation grout to form an undulating interface between the floor slab beams and the foundation, which aids in preventing movement of the housing floor slab 19 relative to the foundation. The shear keys also prevent movement of the floor slab relative to a floor slab of an adjacent modular half-dwelling unit 20 which makes up the other half of the completed house 22. Foundation 106 preferably comprises a separate elongated trench 107 (see FIG. 4) of pumped-in grout which forms a concrete pad below each longitudinal beam 44, and separate transverse trenches 108 of pumped-in grout forming concrete foundation pads below each outer transverse beam 46 and below each of the large transverse beams 50 and 52. Before the floor slab is placed on the foundation, levelling pads 110 (shown in dotted lines in FIG. 4) are placed at spaced apart locations in trenches 107. Longitudinal beams 44 rest on the pads when the floor slab is placed on the foundation, with a sufficient number of the pads being used at each location to level the floor slab.

As shown best in FIG. 5, a separate pair of parallel elongated reinforcing bars 109, which extend the width of the floor slab, are embedded in foundation grout 106 below each outer transverse beam 46 and below each of the large transverse beams 50 and 52. Reinforcing bars 109 preferably are number six steel rods. A separate vertically extending anchor 111 (shown in FIG. 3) embedded in each outer transverse beam 46 extends into the foundation grout between the respective pair of reinforcing bars 109 below it. Each anchor 111 is rigidly secured, such as by tying or welding, to each of the reinforcing bars 109 to provide additional resistance to the floor slab 19 and foundation 106 from being pulled apart. A separate identical anchor 111 embedded in each of the large transverse beams 50 and 52 extends into the foundation grout between the pair of reinforcing bars 109 below it. Each of these anchors is rigidly secured by suitable means to a corresponding one of the reinforcing bars 50, 52.

As shown best in FIG. 3, the completed modular house 22 is formed by placing two modular half-dwelling units 20 parallel to each other on foundation 106, with the cantilevered overhang 36 of one half closely spaced from that of the other half so the two roofs 18 cooperate to form a conventional pitch roof. When house 22 is in its assembled form, an elongated open-ended corridor 112 is formed between the parallel center walls 16. Each half-dwelling unit 20 is placed on its respective floor slab so that the bottom of center wall 16 rests on the horizontal ridge 68 of the floor slab. The bottom of each end wall 14 rests on an elongated outwardly projecting horizontal outer ridge 114 cast integrally with the edge on the long side of the floor slab 19 opposite ridge 68. The bottom of each side wall 12 rests on an elongated outwardly projecting horizontal ridge 116 (see FIG. 5) cast integrally with the edge on each short side of the floor slab.

FIG. 4 shows an example of one means for securing the bottom portions of exterior walls 14 and 16 to the floor slab. The bottom portion of end wall 14 is set in a layer of bonding material 117, such as grout, on outer ridge 114 of the floor slab. The bottom of center wall 116 is set in an identical layer of bonding material 117 on bearing surface 68 of ridge 64. The space between the inner edge of each wall and the floor slab is filled with a layer of epoxy grout 118 to complete bonding of the walls to the floor slab. FIG. 5 shows an identical means for securing the bottom portion of each side wall 12 to the floor slab.

FIG. 13 shows means which are presently preferred for securing the bottom portions of the exterior walls of the floor slab. In the example shown in FIG. 13, elongated, spaced apart, horizontal anchor bars 120, preferably number six steel rods, are placed between the inside of exterior side wall 12 and the vertical outer edge of floor slab 19. The anchor bars preferably are spaced 32 inches apart along the floor slab. An angular L-shaped weld plate 122, which runs the length of the floor slab, is exposed at the vertical edge of the floor slab adjacent to anchor bars 120. The angular weld plate 121 is held in place by spaced apart anchor rods 122 which are embedded in the floor slab. Spaced apart flat weld plates 123 are exposed along the inside of exterior side wall 12 adjacent to each anchor bar 120. Weld plates 123 are held in place by respective inwardly extending anchor rods 124 which are embedded in exterior side wall 12. It is preferred to place an anchor bar 120 and a cooperating weld plate 123 at least 8 inches from the corners of the floor slab and the corners of any interior walls. One side of each anchor bar 120 is welded to weld plate 121, and the other side of each anchor bar is welded to a respective weld plate 123 to rigidly fasten exterior end wall 12 to the floor slab. Access for welding is obtained by blocking out spaced part notches 125 in the edge of the floor slab adjacent to each anchor bar 120. After welding is completed the blocked out notches are filled with grout 126.

On the other side of the floor slab identical means are used to secure center wall 16 to the floor slab. Spaced apart anchor bars 127 are placed between the inside of center wall 16 and the floor slab, with a continuous angled weld plate 128 embedded in the floor slab on one side of the anchor bars, and respective spaced apart flat weld plates 129 embedded in center wall 16 on the other side of each anchor bar.

Grout 130 is poured in the respective spaces between exterior walls 12 and 16 and the floor slab after welding is finished to complete the bonding of the walls to the floor slab.

Means similar to that shown in FIG. 13 preferably are used to secure exterior side walls 14 to the floor slab.

FIG. 12 shows the preferred means for securing together the adjacent ends of overhang portions 36 of roofs 18. A SEPARATE elongated right-angle weld plate 131 is exposed at the lower corner of each overhang 36, so the two weld plates face each other. Each weld plate 131 extends the length of the roof and is held in place by spaced apart elongated anchor rods 132 which are rigidly secured to the inside of their respective weld plates and embedded in concrete overhang 36. Anchor rods 132 preferably are spaced 18 inches apart along the length of the roof.

An elongated anchor bar 134, which runs the length of the roof, rests between weld plates 131. Each weld plate 131 is welded to a respective side of anchor bar 134 to rigidly secure the overhang portions of the roofs together. Grout 136 is poured in the space between the ends of overhang portions 36 above anchor bar 134 to complete bonding of the roofs.

FIG. 6 shows a plan view of a completed concrete modular house 22 assembled from a short modular half-dwelling unit 138 which is interconnected with a long half-dwelling unit 140. The arrangement of half-dwelling units shown in FIG. 6 is used for example only, and other arrangements of dwelling units of various sizes and shapes may be used without departing from the scope of the invention. For example, a modular house may be constructed from a pair of interconnected halves the same size as short modular units 138, or a larger modular house may be assembled from halves the size of long modular units 140.

In the floor plan shown in FIG. 6, long half-dwelling unit 140 provides the "dry" side of the house, with rooms such as a living room 142, a master bedroom 144, and a second bedroom 146. The short half-dwelling unit 138 provides the "wet" side of the house, with rooms such as a third bedroom 147, a kitchen and dining room 148, a bathroom 149, and a laundry room 150. The short half of the house is termed the "wet" side because only the rooms in that side of the house require plumbing such as water lines and gas lines.

Referring to FIG. 4, an elongated concrete corridor floor slab 151 extends substantially the entire length of the house to provide the floor for the corridor or hallway 112 between the two half-dwelling units. The horizontal upper surface of corridor floor slab 151 is in the same plane as the upper surface of each floor slab 19. A pair of parallel, laterally spaced apart, elongated marginal ridges 152 project downwardly from the underside of the corridor floor slab along the outer edges of the slab. Each marginal ridge runs the length of the corridor floor slab, with a separate elongated reinforcing bar 153 being embedded substantially in the center of each ridge. Each reinforcing bar 153 runs the length of the corridor floor slab and preferably is a number four steel rod. The corridor floor slab is mounted between the modular half-dwelling units so each marginal ridge 152 rests on the outwardly projecting horizontal upper surface 68 of a respective one of the ridges 64 which extend the length of the corridor.

Preferably, each marginal ridge 152 is set in grout bed 117 which also secures center wall 16 to the floor slab. Spaced apart leveling pads (not shown) may be set below marginal ridges 152 to shim the corridor floor slab. Grout 117 also fills a portion of the space between the outer edge of the corridor floor slab and the adjacent outer edge of the center wall 16. A portion of the space above grout 117 is filled with an epoxy grout 154 to complete bonding of the corridor floor slab to the center wall. Alternatively the corridor floor slab may be welded to each center wall in a manner akin to that shown for the exterior walls in FIG. 13.

As shown best in FIGS. 14 through 16 the half-dwelling units are rigidly interconnected by a separate upright shear panel 158 at each end of corridor 112. Each shear panel 158 preferably is a precast concrete slab which is shaped to fit into the opening at each end of the corridor in front of corridor floor slab 151. Each edge of the shear panel is joined with the edge of an adjacent center wall 16 by welding it at a plurality of vertically spaced apart points shown schematically at 159 in FIG. 14.

The preferred means for joining the shear panel to the center wall is shown in FIG. 15 in which vertically spaced apart flat weld plates 160 are mounted at the edge of each exterior center wall 16. Each weld plate 160 preferably is held in place by a pair of vertically spaced apart anchor rods 162 embedded in center wall 16. The vertical spacing between adjacent weld plates 160 preferably is 32 inches. A separate continuous vertical weld plate 164 is mounted at each vertical edge of shear panel 158. Each angular weld plate is held in plate by spaced apart anchor rods 166 embedded in the shear panel. Spaced apart, vertical elongated anchor bars 170 are placed between each weld plate 160 and angular weld plate 162. The weld plates are welded to opposite sides of anchor bars 170 to rigidly secure each edge of shear panel 158 to a respective center wall 16. Access for welding is obtained by blocked out notches 171 formed in each edge of the shear panel adjacent to anchor bars 170. After welding is completed the notches are filled with grout 172.

The lower edges of each shear panel 158 are secured to the outer edges of beams 44 of the floor slab at points shown schematically at 173 in FIG. 14. Connecting means identical to that shown at 159 in FIG. 15 preferably are used to connect the lower portions of the shear panels to the floor slab beams. The lower edge of each shear panel 158 is embedded in foundation grout 106 as shown best in FIG. 16. Connecting means identical to that shown in FIG. 15 also are preferably used to secure the upper edge of each shear panel to overhang portions 36 of roofs 18. (These connecting means are shown schematically at 174 in FIG. 14). Thus, each shear panel is rigidly secured around its perimeter to center walls 16, the longitudinal beams 44 of the floor slab, the foundation 106, and the roof overhang 36 to provide the equivalent of at least an 8 foot beam which provides substantial rigidity and strength for each end of the completed house. After the shear panels are mounted in place, the space 176 between the edge of each shear panel and the adjacent center walls 16 and roof overhang 36 is filled with grout to complete the bonding of the shear panel to the modular half-dwelling units.

As shown best in FIG. 6, when a short modular half-dwelling unit is interconnected with a long modular half-dwelling unit, the edge of one shear panel **158** is secured to the floor slab of the long modular unit in the same plane as large transverse beam **50** of floor slab **19**, and the edge of the other shear panel is secured to the floor slab in the same plane as large transverse beam **52**. This arrangement provides the equivalent of a continuous reinforcing beam running the entire width of the completed house at each end of the house.

As shown best in FIG. 6, the exterior side walls **12** and exterior end walls **14** of each half-dwelling unit have a central core of insulation which makes these walls thicker than exterior center walls **16**. Preferably, insulated side walls **12** and end walls **14** are about 5 inches thick, and the center walls are about 3 inches thick. Center walls **16** are reinforced by a vertically disposed welded wire mesh panel (not shown) similar to that used to reinforce floor slab **19**. FIG. 9 shows a detailed view of the insulation and reinforcing for side wall **12**, which includes a reinforcing cage formed from laterally spaced apart welded wire mesh panels **184** which are inserted in the form (not shown) used to cast the side wall. Each welded wire mesh panel **184** is formed from longitudinally spaced apart vertically extending wire reinforcing rods **186** welded to intersecting vertically spaced apart horizontal wire reinforcing rods **187** (shown schematically in FIG. 9) to form a reinforcing grid.

Longitudinally spaced apart rectangular thermal insulation blocks **188**, which are preferably polystyrene foam boards or other suitable insulating material such as polyurethane foam, sulphur, or the like, are placed between the two wire mesh panels **184** and embedded in the wall along its longitudinal center line. The spacing between insulating blocks **188** provides transverse concrete webs **190** which join together the opposite faces of the concrete wall. In the preferred form of the wall, the insulating blocks are about 2 inches wide and about 6 inches long when viewed in plan view as in FIG. 9. The spacing between insulating blocks, and therefore the thickness of the webs **190**, is about one inch.

Exterior side walls **14** preferably are reinforced and insulated by insulating blocks and a cage of welded wire mesh panels identical to that shown in FIG. 9.

Insulating blocks **188** insulate the interior of the house against temperature extremes outside. Transverse concrete webs **190** provide strength for the insulated walls when compared with a concrete wall having a continuous longitudinal core of insulation, such as polystyrene foam.

FIG. 10 shows alternate means of insulating walls **12** and **14**, in which longitudinally spaced apart insulating blocks **192** shaped as parallelograms are embedded in the concrete wall between two welded wire mesh panels **184**. In this form of the wall, angular transverse concrete webs **194** join together opposite faces of the concrete wall. The angular webs **194** provide good strength for the wall as explained above. In addition the parallelogram-shaped thermal insulation blocks **192** provide good temperature insulation for the interior of the house because the angular transverse edges of each block overlap the angular edges of the blocks on both sides to slow down heat transfer through angular concrete webs **194**, so that the entire string of blocks provides a temperature insulating barrier continuously for the length of the wall.

FIG. 11 shows further alternative means for insulating the exterior walls **12** and **14** in which longitudinally spaced apart triangular insulating blocks **196** are embedded in the concrete wall between the two welded wire mesh panels **184**. In this form of the invention, alternating diagonal transverse concrete webs **198** are formed between adjacent insulating blocks **196**. The triangular insulating blocks perform the same function as parallelogram-shaped blocks **192** in slowing down the heat transfer through the concrete webs **198** to provide a continuous temperature insulating barrier along the length of the wall.

In the house shown in FIG. 6, the end portions of the center walls **16** of the long modular half-dwelling unit **140** are exposed to the outside and thus require means for insulating the interior of the dwelling unit against temperature extremes. Thus, a separate sheet **200** of insulating material is bonded to the interior of center wall **16** at each of its ends. Preferably, insulation sheet **200** is a one-fourth inch thick prefinished plywood sheet backed with 1-inch thick polystyrene insulation. The finished plywood sheet is preferred when center wall **16** makes up a portion of the finished wall of a room such as living room **142**. Alternately, insulation **200** may be one-inch thick polyurethane insulation which is not backed by a finished panel. The polyurethane insulation is preferred when the insulated portion of the center wall is inside a closet **202**, such as shown in bedroom **146**.

Shear panels **158** also contain no insulation embedded in them, and thus are backed with sheets **204** of insulating material such as a one inch thick polyurethane insulating panel or a fiberglass panel backed with ½-inch gypsum wallboard.

Several concrete interior walls **206** are cast integrally with the interior of each modular half-dwelling unit. Preferably, the top of each interior wall is cast integrally with the underside of roof **18**, with at least one side of the interior wall being cast integrally with the inside of one of the exterior walls. For example, in long modular half-dwelling unit **140** shown in FIG. 6, an interior wall **206*a*** extends approximately half the width of the modular unit. The end of wall **206*a*** is cast integrally with end wall **14** and at its top is cast integrally with roof **18**. A short interior wall **206*b*** in the same plane as interior wall **206*a*** is integral with center wall **16** at its end and with roof **18** at its top. A third interior wall **206*c*** extends the entire width of the modular unit. The ends of wall **206*c*** are cast integrally with end wall **14** and center wall **16**, and the top of wall **206*c*** is cast integrally with roof **18**. In short modular half-dwelling unit **138**, an interior wall **206*d*** extends about three-fourths of the width of the unit. One end of wall **206*d*** is integral with end wall **14**, and the top of wall **206*d*** is integral with roof **18**.

As shown best in FIG. 3, each interior wall **206** is cast so each wall has a lower surface **208** which is spaced a short distance above the upper surface of floor slab **19** when the modular half-dwelling units are joined with the floor slab. Thus, the interior walls and roof transmit no load to the thin portion of the floor slab under the interior walls. Instead, the interior walls are held in tension by the roof and at least one exterior wall, with all the load of the roof and the interior walls being transmitted down through the exterior walls and shear panels.

Preferably, the interior walls 206 are cast so that their bottom edges 208 are at least one inch above the upper surface of floor slab 19. As shown best in FIG. 7, this spacing permits electrical wiring such as a conventional Romex electrical cable 210 to be run under interior wall 206 and connected with a conduit 211 from a conduit box 212 providing electrical outlets 214. Electrical conduits and conduit boxes are cast in place in the interior walls and extension walls. The conduits are prewired prior to casting to facilitate installation of the electrical wiring. Electrical cables (not shown) strung from a main power source (not shown) are connected to the pre-wired conduits through openings 215 (see FIG. 1) which are cast in center wall 16. Preferably, a spacing of one inch is provided between the bottom 208 of interior wall 206 and floor slab 19 in the arrangement shown in FIG. 7.

FIG. 8 shows another use for the spacing between the bottom of an interior wall and the floor slab. A larger spacing, preferably 2 or 3 inches, is provided for plumbing, such as a water line or gas line 210 to be run under the interior wall.

The space below each interior wall is enclosed by a separate elongated strip of molding 216 extending vertically from each side of the interior wall to the floor slab. The molding is releasably secured to the wall and floor slab to permit access to the electrical lines or plumbing.

The plumbing and wiring are run to the exterior of the house through openings (not shown) formed in either the floors or walls by blocks (not shown) when the modular dwelling units are cast. The blocks are removable from the modular units and the openings are covered by suitable means after the plumbing or wiring are run through them.

Roof 18 may be cast with no insulation embedded in it, with insulation being provided from the interior with sheets of insulation (not shown) in manner similar to that used for insulating shear panels 58 and the ends of center walls 16. However, it is preferred to insulate and reinforce the roof as shown in FIG. 17. Insulation blocks 218 of polystyrene foam, polyurethane foam, or the like, are spaced longitudinally apart between a pair of welded wire mesh panels 220, thereby forming transverse concrete webs 222 which join together opposite faces of the roof. The insulation blocks are substantially less dense than the concrete and therefore are buoyant in the concrete before the concrete sets in its forms 224. Thus, suitable tie-down devices are used to prevent the buoyant insulation blocks from carrying the upper wire mesh panel to the top of the roof form. The preferred tie-down devices are spaced apart elongated, rigid, transverse anchor rods 226 which extend through several of the concrete webs 222 and are rigidly secured to each welded wire mesh panel. Each anchor rod 226 extends downwardly from the roof through form 224 to the interior of the dwelling unit where it is tightly secured to the form with a fastener, such as a nut 228, threaded on the end of the anchor rod. The tie-down devices keep the welded wire mesh panels centered within the roof form. Suitable spacers 230 rigidly maintain each insulation block 218 centered between the two adjacent welded wire mesh panels 220. After the concrete sets the anchor rods may be removed from the roof, with the spaces left by them being filled with grout.

For houses which require extra-large rooms, a large opening 232 substantially the width of one room is cast in the center wall 16 of each modular half-dwelling unit. The dwelling units are positioned on the foundation so that openings 232 face each other to form a large room (not shown) which extends from one unit to the other. In this form of the house, an upwardly opening channel-shaped reinforcing arch 234 is cast integrally with the concrete surrounding each opening 232. An elongated horizontal anchor bar 236, preferably ¾ inch rebar, is embedded in the concrete above, and parallel to, opening 232. Separate identical vertical anchor bars 238 are embedded in the concrete at each side of opening 232. Each horizontal and vertical anchor bar is rigidly secured to reinforcing arch 234 by a separate steel plate 240 which is rigidly secured to the anchor bar at one end and rigidly secured to the inside of the reinforcing arch at the other end to hold the reinforcing arch in place around opening 232.

The modular half-dwelling units 20 are particularly suitable for being produced and outfitted in completed form in an assembly-line fashion in a casting yard. Floor slab 19 and the walls of building unit 10 are cast separately, with building unit 10 being lifted onto the floor slab at the casting yard after the concrete has set and the mold forms are removed. The exterior walls of the building unit are joined with the perimeter of the floor slab to form the outer shell of the modular half-dwelling unit 20. Shear panels 58 and corridor floor slab 51 are cast as separate units in the casting yard.

The interior of the modular half-dwelling unit also is finished at the casting site. Plumbing and electrical wiring is run under interior walls 206 of each modular unit, and molding strips 216 are fastened to the bottom of each interior wall to finish the interior walls. Insulation panels 200 are mounted against center walls 16 if the completed house is to include a long unit and short unit. A ceiling (not shown) made of nonload-bearing wallboards such as gypsum wallboard is placed on mounting tracks (not shown) in the upper portion of each modular half-dwelling unit. A similar ceiling is mounted in the upper portion of corridor 112 to form an attic space. Several removable nonload-bearing vertical wall panels 242 (see FIG. 6) are placed on mounting tracks (not shown) on the floor slab and ceiling to separate the interior of the modular unit into rooms and to provide partitioning for closets and the like. Door jambs (not shown) are constructed, exterior doors 244 and interior doors (not shown) are mounted, windows 246 are installed, and the exterior and interior of the modular unit are painted. Interior fixtures such as a bathtub and kitchen facilities also are preferably added at the casting site.

The completed modular half-dwelling units are then transported to the building site where they are assembled to form a completed house. Two units are set side-by-side on foundation 106. The overhang portions 36 of the roofs 18 are connected together, and the corridor floor slab 151 is mounted between half-dwelling units. Shear panels 158 are then mounted at the ends of the house to connect the half-dwelling units together. An air conditioning and heating unit 248 (see FIG. 6) is mounted in the upper portion of the corridor at one end of the house. Ducts 250 in the attic space above the ceiling in the corridor deliver air from the heating and air conditioning unit to each room in the house. The ducts open into each room through openings **252** (see FIG. 1) which are cast in center walls **16.** Exterior trimming (not shown) is then added to the house and the house is in its completed form ready for use as a single family dwelling unit.

FIGS. **20** through **22** show a pair of side-by-side alternate modular half-dwelling units **260** which are secured together without shear panels. The completed building unit formed by this arrangement has substantially the same rigidity as the building unit with the shear panels. Each modular half-dwelling unit **260** is substantially identical to half-dwelling unit **20,** with the major exception being that the cantilevered overhang **36** of the roof is eliminated. Thus, no central corriodor is formed between half-dwelling units **260.**

The two modular units **260** are connected together by placing them close to each other on the foundation so that about a 1-inch gap exists between their adjacent exterior center walls **262.** Obviously, the center walls have door openings (not shown) which are aligned with each other when the two units are placed side-by-side on the foundation. Half-dwelling units **260** are rigidly secured together by vertically spaced apart welded joints **264** at the ends of center walls **262.** Preferably, weld joints **264** are spaced apart so that there are a minimum of five weld joints at each end of the building.

FIG. **21** shows a typical weld joint **264** in which anchor studs **266** embedded in the center wall **262** hold vertically spaced apart angle plates **268** in place at each corner of the half-dwelling unit. Each pair of spaced apart angle plates are welded to a respective anchor beam **270** between them. The corner at each weld joint is blocked out during casting of the modular unit to form a notch **272** for access during welding. After welding, the space between the center walls at the weld joints is filled with grout **274.** The exterior seam formed at each end of the house between the connected half-dwelling units is covered by a beam (not shown) or other suitable finishing.

The side-by-side ends of roofs **276** of half-dwelling units **260** are secured together by welding at longitudinally spaced apart weld joints **278,** one of which is shown in FIG. **22.** Anchor studs **280** embedded in the concrete roof hold longitudinally spaced angle plates **282** in place at the corner formed between the top of center wall **262** and roof **276.** The side-by-side anchor plates are welded to longitudinally spaced apart anchor bars **284** placed between them. Each corner of the roof is blocked out during casting of the modular unit to form a notch **286** for access to angle plates **282** and anchor bars **284** during welding. After welding, the space between the ends of the roofs is filled with grout **288.**

FIG. **20** also shows an alternate foundation in which the transverse beams **46, 50** and **52** of the floor slab **19** are disposed over respective precast concrete foundation slabs **290.** Each foundation slab **290** has upwardly opening notches **292** formed in its upper surface to provide longitudinally spaced apart shear keys **294** matching shear keys **104** in floor slab **19.**

The undersurfaces of the transverse ridges are vertically spaced from their respective foundation slabs, and grout **296** is pumped into the void between them. Thus, vertically spaced apart undulating interfaces **298** and **299** are formed in the grout between the foundation slab and the floor slab, respectively, which provides means for resisting lateral movement of the floor slab relative to the foundation.

I claim:

1. A precast concrete building unit to be joined with a concrete foundation, the building unit including a floor slab having a pair of laterally spaced apart longitudinal edges intersected by a pair of longitudinally spaced apart lateral edges, one or more upright, load-bearing walls joined with the floor slab, a pair of laterally spaced apart elongated longitudinal beams cast integrally with and projecting downwardly from the undersurface of the floor slab, the longitudinal beams extending the length of the slab along the opposite longitudinal edges of the slab, a series of longitudinally spaced apart elongated transverse beams cast integrally with the floor slab to project downwardly from the undersurface of the floor slab and extend the width of the slab, a pair of said transverse beams extending along the opposite lateral edges of the floor slab, with one or more of said transverse beams being located intermediate the lateral edges of the slab, each transverse beam projecting downwardly a major portion of the height of the longitudinal beam so the longitudinal and transverse beams can be concurrently embedded in the foundation, a series of longitudinally spaced apart elongated transverse reinforcing ribs cast integrally with the floor slab to project downwardly from the undersurface of the floor slab by a distance less than the height of the transverse beams, the transverse ribs extending the width of the floor slab and being spaced between adjacent lateral beams of the floor slab to provide reinforcement for the slab, a separate elongated rigid reinforcing rod embedded in and extending the length of each transverse beam to provide reinforcement therefor and to be rigidly anchored to cooperating reinforcing means in the foundation.

2. Apparatus according to claim **1** including means forming an undulating undersurface of the transverse beams to prevent movement of the floor slab relative to the foundation when the transverse beams are embedded in the foundation.

3. Apparatus according to claim **2** including a concrete foundation slab below the floor slab, the foundation slab having undulating upper surface areas disposed below the undulating undersurfaces of the transverse beams, and grout between the transverse beams and the foundation slab, the transverse beams and foundation slabs providing vertically spaced apart undulating interfaces with the grout between them to prevent movement of the floor slab relative to the foundation.

4. Apparatus according to claim **1** in which the longitudinal beams project below the undersurface of the transverse beams to permit lifting devices or the like to be placed under the floor slab.

5. Apparatus according to claim **1** including an array of elongated rigid reinforcing rods embedded in the floor slab to provide reinforcement therefor.

6. Apparatus according to claim **5** including elongated rigid reinforcing rods embedded in the foundation slab to provide reinforcing therefor, a series of upright reinforcing rods embedded in each transverse beam and spaced apart along the length thereof, the upright reinforcing rods being rigidly secured to the reinforcing rods of the floor slab for providing an integral reinforcing structure for the floor slab and beams.

7. Apparatus according to claim 6 including a series of upright reinforcing rods embedded in each longitudinal beam and spaced apart along the length thereof, the upright reinforcing rods of the longitudinal beams being rigidly secured to the reinforcing rods of the floor slab to provide an integral reinforcing cage for the floor slab and beams.

8. Apparatus according to claim 7 including a separate upright load-bearing concrete wall joined with the top surface of the floor slab along each lateral edge thereof so the reinforced transverse beams can transmit the loads imposed by the walls to the foundation.

9. Apparatus according to claim 1 including elongated rigid reinforcing rods in the transverse ribs of the floor slab.

10. Apparatus according to claim 1 including a concrete foundation slab below the floor slab, elongated rigid reinforcing rods embedded in the foundation and disposed below the transverse beams of the floor slab, and rigid anchor means rigidly connected between the reinforcing rod of each transverse beam and a corresponding reinforcing rod in the foundation.

11. Apparatus according to claim 10 including means forming an undulating undersurface of the transverse beams to prevent movement of the floor slab relative to the foundation when the transverse beams are embedded in the foundation.

12. A building structure to be joined with a foundation, the building structure including a first precast concrete building unit including a floor slab, and one or more load-bearing walls joined with the floor slab; a second precast concrete building unit including a floor slab, and one or more load-bearing walls joined with the floor slab; means joining the first and second building units along a mutual interface to form a modular building structure; a separate elongated transverse beam projecting downwardly from the undersurface of each floor slab along an axis transverse to the interface; and an undulating surface formed on the bottom of each transverse beam and extending along the length of the beam to prevent movement of the floor slabs relative to each other when they are embedded in the foundation.

13. Apparatus according to claim 12 including a pair of said transverse beams projecting downwardly along opposite outer edges of the floor slab, and additionally including one or more of said transverse beams located intermediate the outer edges of the floor slab.

14. Apparatus according to claim 12 including a concrete foundation below the floor slab, the transverse beams being embedded in the foundation to form an undulating interface between the floor slab beams and the foundation to prevent movement of the floor slab relative to the foundation.

15. Apparatus according to claim 12 including a concrete foundation slab below the floor slab, means forming an undulating upper surface in the foundation slab below each transverse beam, and grout between each transverse beam and the foundation slab, each beam and the foundation slab forming vertically spaced apart undulating interfaces with the grout between them to prevent movement of the floor slabs relative to the foundation.

16. Apparatus according to claim 15 including a rigid anchor bar extending between each transverse beam and the foundation.

17. Apparatus according to claim 12 in which the floor slab has a pair of laterally spaced apart longitudinal edges intersected by a pair of longitudinally spaced apart lateral edges, in which the building units are connected along adjoining longitudinal edges, and further including a pair of laterally spaced apart longitudinal beams projecting downwardly from the undersurface of the floor slab along the longitudinal edges thereof, and in which a pair of said transverse beams extend downwardly along opposite lateral edges of the floor slab, and additionally including one or more of said transverse beams located intermediate the outer edges of the floor slab.

18. Apparatus according to claim 17 in which the transverse beams project downwardly a major portion of the height of the longitudinal beams so the longitudinal and transverse beams can be concurrently embedded in the foundation.

19. Apparatus according to claim 18 including a foundation slab below the floor slab, separate elongated rigid reinforcing bars in each transverse beam and extending the length of each beam, separate elongated rigid reinforcing bars embedded in the foundation and disposed below each reinforcing bar in the transverse beams, and separate rigid anchor means rigidly interconnecting the reinforcing bars of the transverse beams with the reinforcing bars of the foundation.

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