Jan. 20, 1970 J. S. HAMMOND 3,490,186

MODULAR BUILDING WITH CURVED PRECAST CONCRETE WALLS

Filed Feb. 29, 1968 5 Sheets-Sheet 1

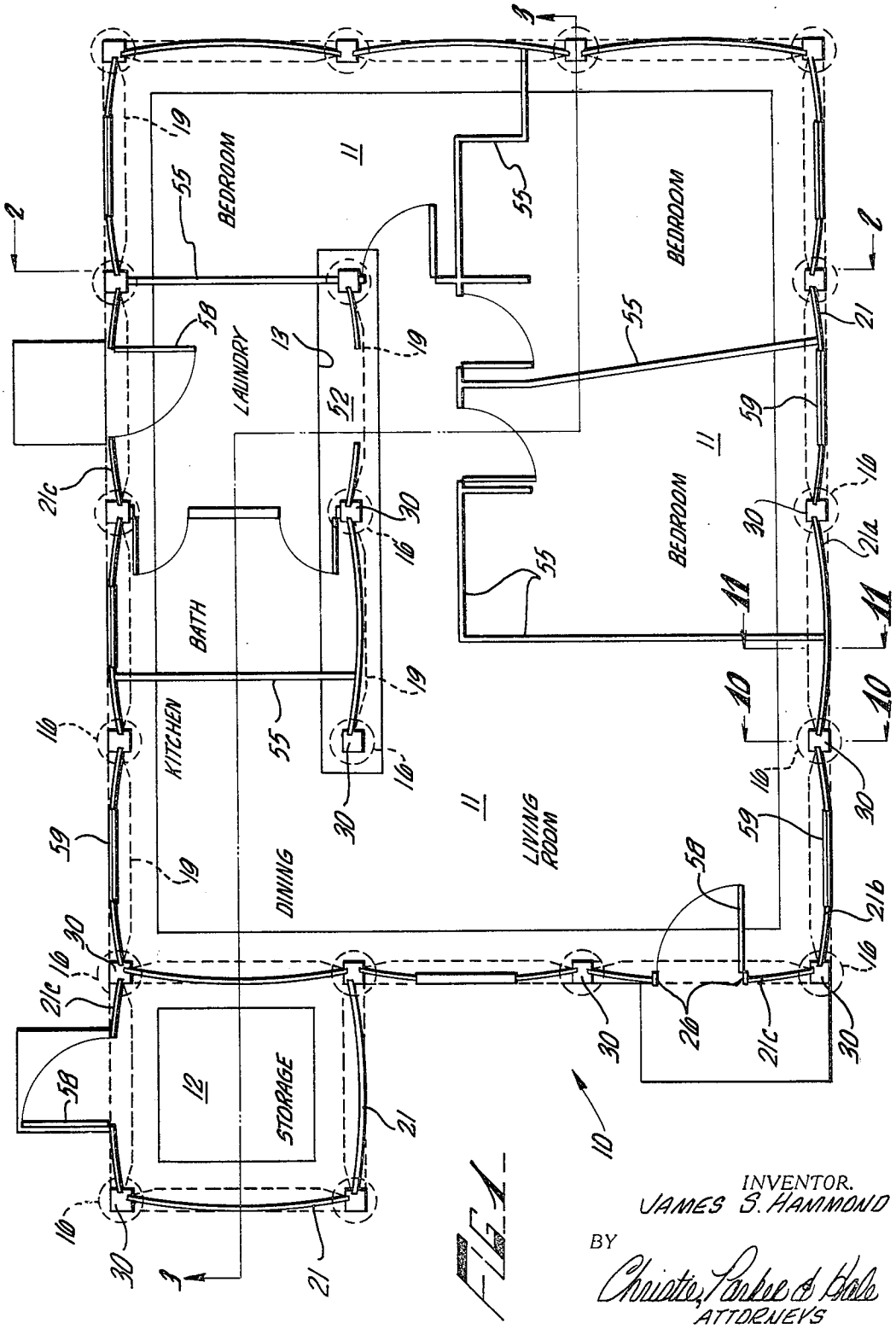


FIG. 1

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Filed Feb. 29, 1968 5 Sheets-Sheet 2

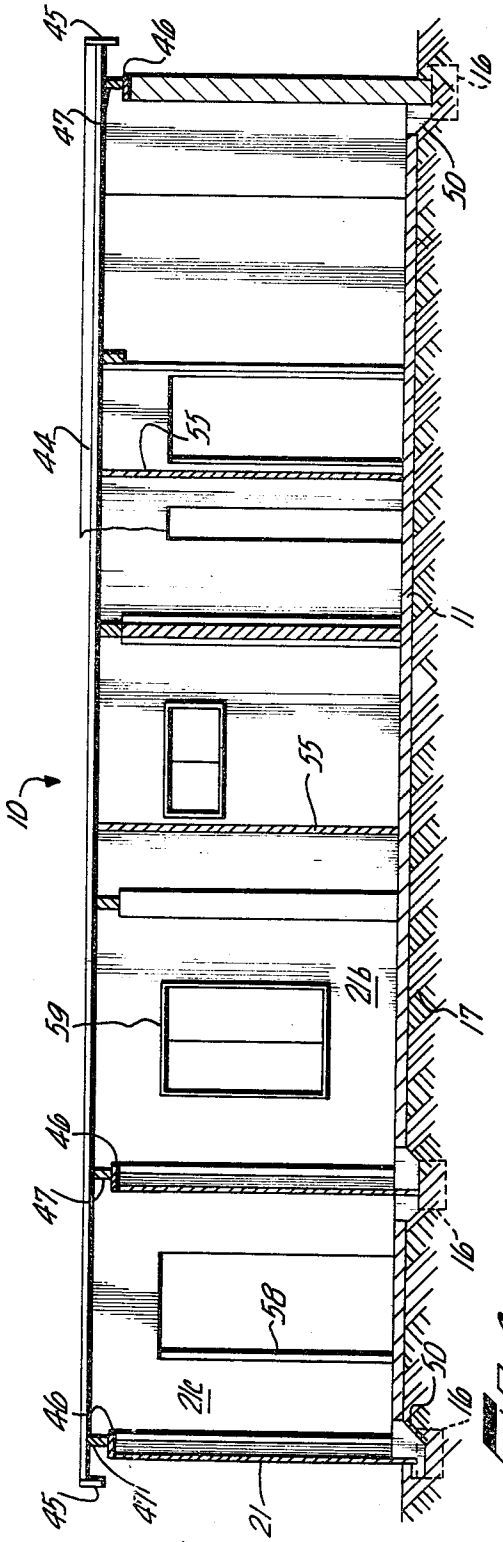


FIG. 5

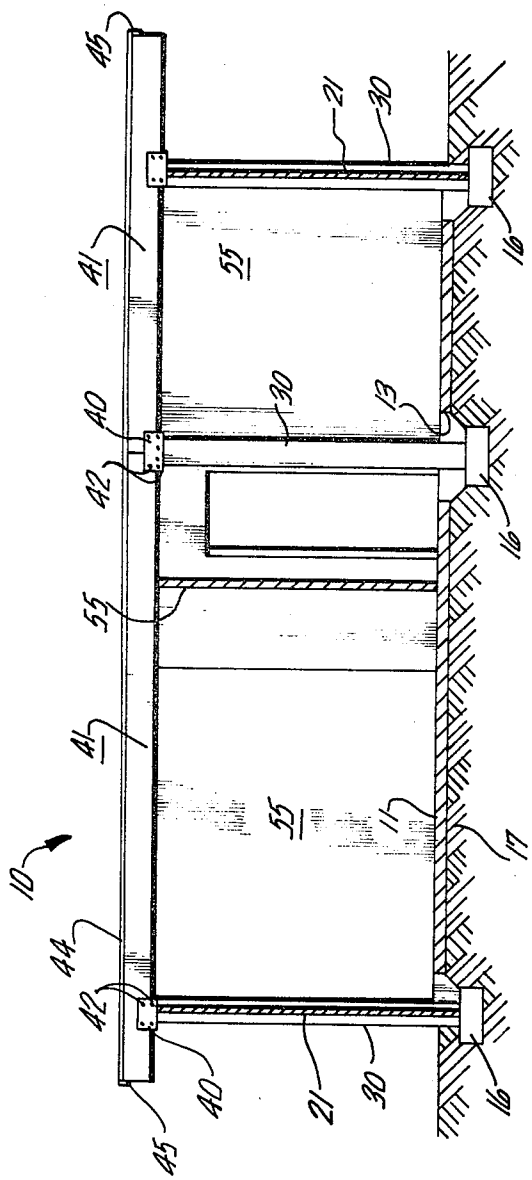


FIG. 6

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MODULAR BUILDING WITH CURVED PRECAST CONCRETE WALLS

Filed Feb. 29, 1968 5 Sheets-Sheet 3

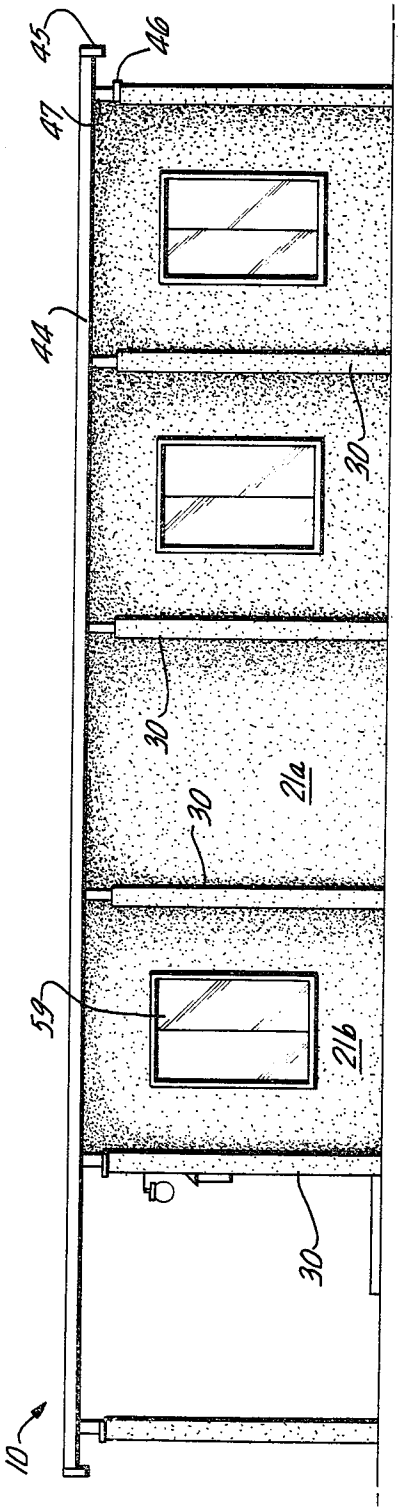


FIG. 4

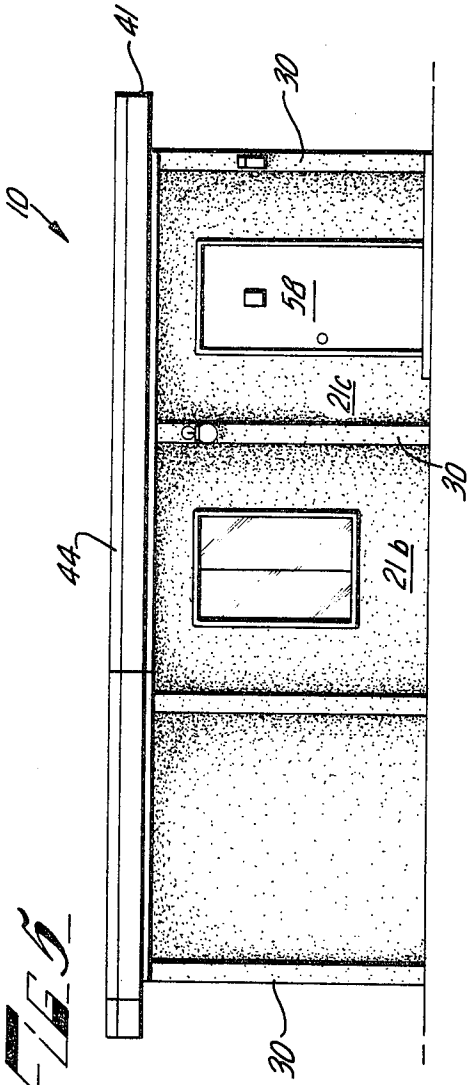


FIG. 5

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MODULAR BUILDING WITH CURVED PRECAST CONCRETE WALLS

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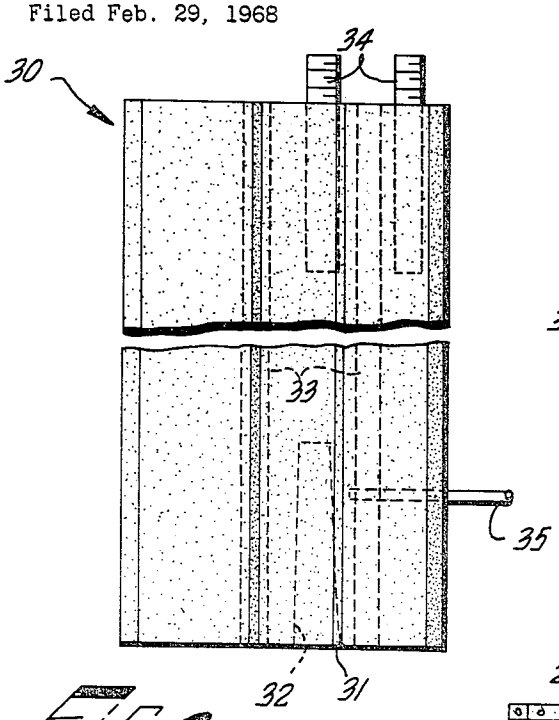


FIG 6

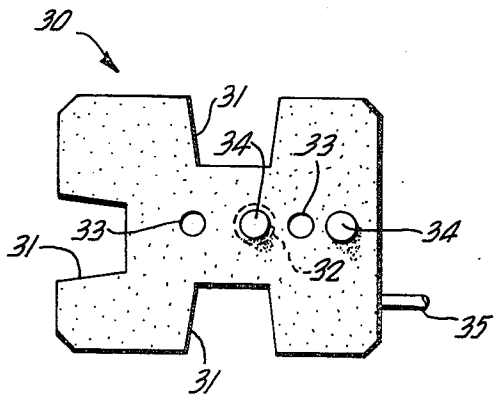


FIG 7

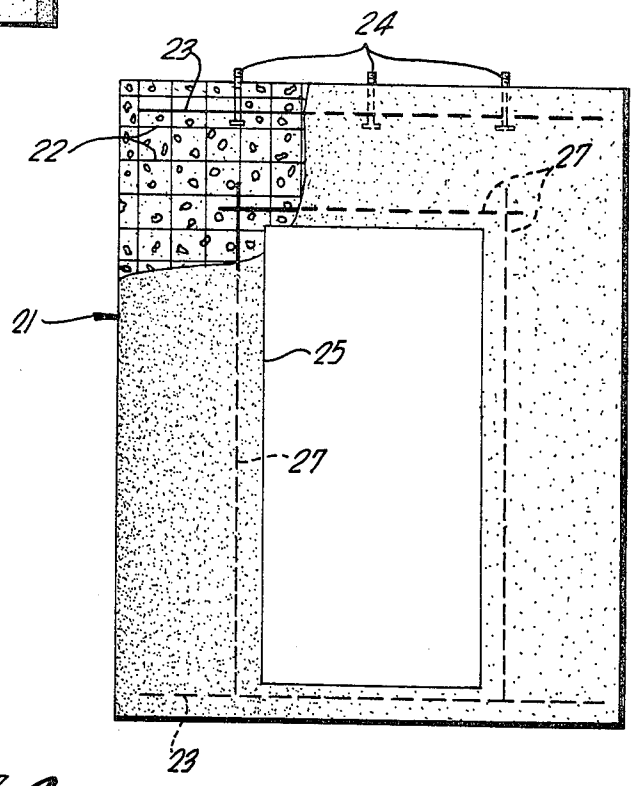


FIG 8

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MODULAR BUILDING WITH CURVED PRECAST CONCRETE WALLS

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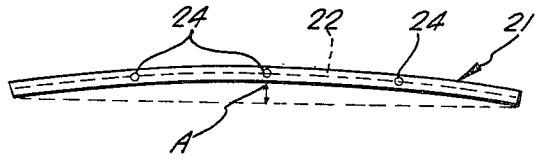


FIG 9

FIG 10

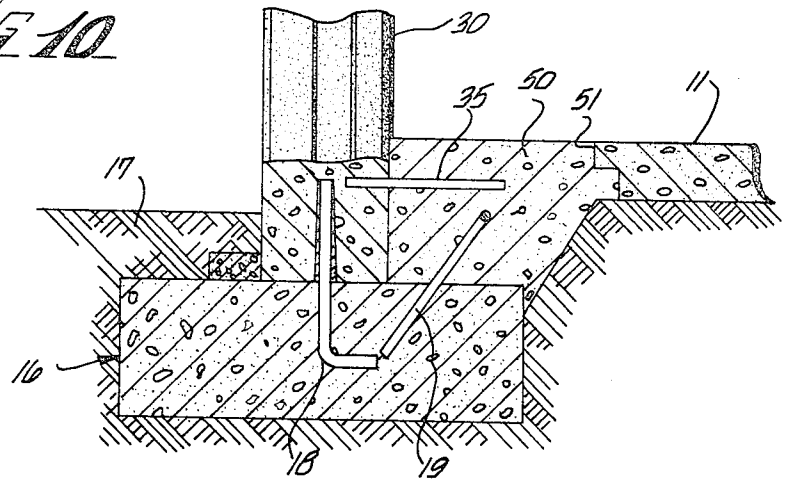
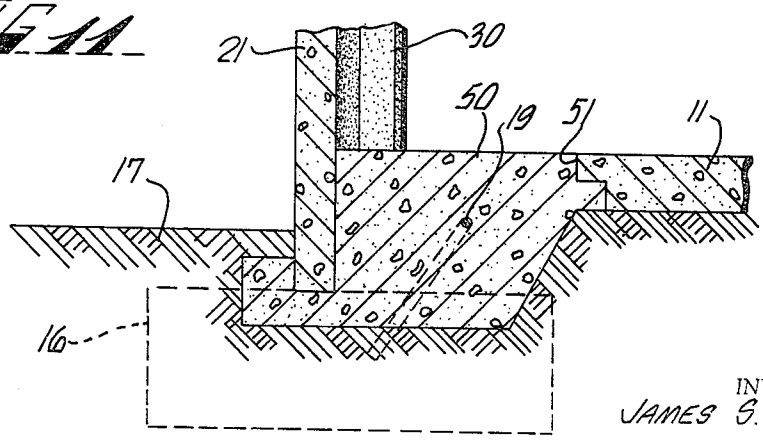


FIG 11



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United States Patent Office

3,490,186

Patented Jan. 20, 1970

3,490,186

MODULAR BUILDING WITH CURVED PRECAST CONCRETE WALLS

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Filed Feb. 29, 1968, Ser. No. 709,442

Int. Cl. E02d 27/34; E04h 9/02

U.S. Cl. 52—169 1 Claim

ABSTRACT OF THE DISCLOSURE

A building having precast concrete wall panels held in place by pre-cast upright concrete columns. The walls are outwardly curved in horizontal cross section so wind loads place the walls and columns in compression rather than in tension. The walls do not carry roof loads, and are formed as thin, relatively lightweight panels which fit into elongated grooves in the columns. Each column is supported on a concrete footing or pad having a pin fitting into a tapered socket in the bottom of the column. A concrete grade beam is poured under the wall panels between the columns and around the periphery of a floor slab. High resistance to seismic forces is provided by providing a largely above-ground foundation and by permitting a slight relative motion between the wall panels and supporting columns.

BACKGROUND OF THE INVENTION

Many designs for low-cost housing have been developed in recent years, but these designs have failed to meet the combined requirements of economical and fast construction, resistance to the elements and to earthquake forces, comfortable and reasonably spacious accommodations for family living, and aesthetic acceptability. The building of this invention meets all these requirements, and can provide adequate housing for many low-income families presently residing in grossly sub-standard dwellings. While my design finds primary application in the housing field, it can also be used in other types of structures such as manufacturing or office buildings, structures for storage of commodities, and various barriers such as sea walls.

A particular advantage of my design is that structural integrity has been maintained in a building which uses thin, precast concrete walls. Individual wall panels are cast (preferably at or near the building site) from a lightweight aggregate having low thermal conductivity so heat transfer through the building walls is minimized. The panels are generally rectangular in shape, but are slightly bowed or curved around a vertical axis so wind loads or other forces tend to place the panel in compression where it has great strength. The recognized weakness of concrete in tension is thus avoided, and the use of an economical and easily handled thin (about two and one-fourth inches) panel is made possible.

The precast wall panels are supported by precast concrete columns which have vertical grooves to accept the ends of the panels. The columns are in turn supported by concrete pads spaced around the periphery of a floor slab, and the column tops are connected by roof beams installed after the walls are in place. After erection of the columns and wall panels, a concrete grade beam is

poured under the walls to tie together the pads, and to seal the undersurface of the walls. Interior walls in the building are of conventional construction, and either a flat or pitched roof is used.

A feature of my design is the modular character of the columns and wall panels. Columns are fabricated in several different styles to provide an appropriate number of grooves to accept two or three intersecting walls. Walls are cast as solid panels, and also as panels which include openings for window and door frames. These basic components can then be assembled in a variety of different arrangements to provide buildings with varying numbers of rooms and floors, and to permit architectural flexibility in constructing a group of adjacent buildings. No special training of personnel is required to assemble the components, and a building can be erected and finished more economically and in a substantially shorter time than with conventional construction methods and materials.

SUMMARY OF THE INVENTION

Briefly stated, the invention contemplates an improved wall construction for use in a structure adapted to withstand substantial side loads applied in a generally predictable direction from winds, internally stored products, and the like. The wall construction includes a plurality of spaced-apart upright columns having elongated grooves therein. Anchoring means are provided for securing the columns to the ground, and a plurality of precast concrete panels are arranged to form a wall for the structure. Each panel is disposed between a pair of the columns and is engaged in the column grooves to be held in place. Each panel includes at least one surface which is convexly curved toward the direction from which the side load is expected. Preferably, the panel has inner and outer surfaces which are generally parallel and which curve convexly toward the direction from which the side load is expected.

In one form, the anchoring means is a set of concrete pads supporting the respective columns, each pad having a vertical dowel extending therefrom into a socket in the undersurface of the associated column. When used in a habitable structure, a floor slab and ceiling are added to form a complete enclosure. The floor-slab periphery stops short of the walls, and a concrete grade beam is poured to extend from the slab edges under the walls to abut the outer faces of the walls. The columns and pads are tied to the grade beam by lengths of reinforcing bar embedded therein.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in detail with reference to the attached drawings, in which:

FIG. 1 is a plan view of the floor and walls of a house constructed according to the invention and prior to installation of a roof;

FIG. 2 is a sectional elevation taken on line 2—2 of FIG. 1 after installation of the roof;

FIG. 3 is a sectional elevation taken on line 3—3 of FIG. 1 after installation of the roof;

FIG. 4 is a front elevation of the completed house;

FIG. 5 is a side elevation of the completed house;

FIG. 6 is an elevation of the upper and lower ends of a wall-supporting column;

FIG. 7 is a top view of the column shown in FIG. 6;

FIG. 8 is an elevation, partly broken away, of a precast concrete wall panel;

FIG. 9 is a top view of the panel shown in FIG. 8;

FIG. 10 is a partial sectional elevation taken on lines **10—10** of FIG. 1 showing a portion of a foundation for the house; and

FIG. 11 is a partial sectional elevation taken along lines **11—11** of FIG. 1 showing another portion of the house foundation.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIGS. 1–5 show a three-bedroom house **10** incorporating the design features of this invention. Construction of the house is begun by pouring a main concrete-floor slab **11** and a smaller slab **12** which is laterally spaced from the main slab and forms a floor in a storage area of the house. Main slab **11** has a rectangular opening **13** therethrough (see the upper central part of FIG. 1), and both slabs terminate slightly inwardly of the outer walls of the house. Filling of opening **13** and of the space from the periphery of the slabs to the undersurface of the outer walls is accomplished at a later stage of the construction process by pouring a concrete grade beam to be described below. The floor slabs are of conventional construction, and are typically about 3½ inches thick. Electrical and plumbing conduits (not shown) are embedded in the slab in accordance with conventional construction techniques.

The next step is to pour a set of concrete column-supporting footings or pads **16** which are spaced from and arranged around the periphery of slabs **11** and **12**. Three such pads are also formed within rectangular opening **13**. Pads **16** appear in phantom in FIG. 1, and are shown in detail in FIG. 10. Although the shape and dimensions of the pads can vary somewhat with the condition of underlying soil **17** (see FIG. 10), a typical shape is an upright cylinder having a diameter of about 24 inches and a height of about 8 inches. The top surface of the pad is preferably located about 4 inches below the surface of the surrounding ground, and about 8 inches below the upper surface of the floor slabs.

A dowel **18**, formed from an L-shaped steel reinforcing bar of about ⅝ inch diameter, is embedded in and extends upwardly from the center of each pad. A tie bar **19** of ½ inch diameter reinforcing bar, is also embedded in each pad and slopes upwardly away from the pad toward the floor slab. Tie bar **19** is bent horizontally above the pad and is rigidly secured to the respective tie bars of the adjacent pads to connect these pads together.

When the concrete slabs and pads have cured, the building walls can be erected. The walls are formed from a plurality of thin curved concrete panels **21** shown in detail in FIGS. 8 and 9. The panels are precast in conventional molds from a mixture which yields a lightweight concrete having low thermal conductivity. The following mixture has been found satisfactory for this purpose:

Components:	Measures (for one cubic yard dry basis)
Cement (HI early)	pounds 517
Crestlite sand	do 895
Crestlite ⅝" x #4 aggregate	do 728
Total water	gallons 52.5
Admixture—Pozzolite 3 LAA	pounds 1.10

The Crestlite materials are agitated in a mixer with about 25 gallons of water (per cubic yard) for about 10 minutes, and the balance of the materials are then added and mixed. Air content should be maintained at 6%–8%. Dry weight of this mixture is approximately 98 pounds per cubic foot. Concrete formed from the mixture will develop about 3,000 p.s.i. minimum compressive strength in about 28 days, and has a thermal conductivity K-factor of about 0.5.

Wall panel **21** has a rectangular cross section with a thickness of at least two inches and preferably has a thickness of about 2¼ inches. When fabricated in the preferred thickness, the wall preferably has a length of about eight feet. As shown in the plan view of FIG. 9, the wall is not flat, but has a distinct curvature or bow. That is, the panel is formed as an annulus of a hollow right-circular cylinder. The radius of curvature of the panel is preferably approximately 27 feet. Stated another way, the panel has a rise or bow (dimension A in FIG. 9) of about 3 inches.

Each wall panel is reinforced with a wire mesh **22** (see FIG. 8) which is embedded therein at the time the panel is molded. The mesh is conveniently formed of a grid of number-10 wires which are spaced apart and positioned at right angles to each other to form a 6-inch by 6-inch mesh. Additional horizontal reinforcement is provided by the inclusion of ⅜-inch steel reinforcing bars **23** embedded at the top and bottom of the panel. Also embedded in the panel are three laterally spaced anchor bolts **24** which extend upwardly from the top of the panel.

The wall panels are cast in several different forms, and can be solid (panels **21A** in FIG.1) or may include an aperture for a window (panels **21B** in FIG. 1) or a door (panels **21C** in FIG. 1). The wall panel shown in FIG. 8 includes a rectangular aperture **25** in which a conventional door frame **26** (see FIG. 1) is subsequently mounted. The apertured panels include an additional set of half inch steel reinforcing bars **27** embedded therein around the aperture (see FIG. 8).

The wall panels are supported by a plurality of elongated precast concrete columns **30** (FIGS. 6 and 7). Each column includes at least one tapered notch or groove **31** along its length to receive the end of a wall panel. The column may be provided with additional grooves to accept second or third wall panels which may terminate at the column position. The column shown in plan view in FIG. 7 includes three such grooves, and is thus suitable for use at the intersection of three wall panels. The columns are typically 8½ to 9 feet in height, and about 7½ inches by 9½ inches in horizontal cross section. The single-notch or two-notch forms of the columns preferably have a square horizontal cross section measuring about 7½ inches by 7½ inches.

Each column has a tapered hole **32** extending vertically upward from its undersurface. Each column also includes a pair of ½-inch steel reinforcing bars **33** embedded therein, and is further provided with a pair of laterally spaced cast-in bolts **34** which extend slightly from the top of the column. Another steel reinforcing bar **35** of about ⅝-inch diameter is also cast into each column, and extends about six inches horizontally therefrom at a height which will be below the upper surface of the floor slab when the column is in place.

To erect the walls of the house, one of the columns is first positioned upright on a pad **16** with dowel **18** fitting into tapered hole **32** in the column. The tapered hole is grouted prior to column placement so a positive bond will be formed between the column and dowel.

A wall panel is then elevated and placed in position as shown in FIG. 1. The wall is essentially free-standing due to its curved shape, and only a minimum of temporary bracing or support is needed. One side edge of the wall panel is fitted snugly into one of grooves **31** in the column. The tapered contour of the grooves simplifies assembly and compensates for the curvature of the panels. Another column is then erected at the free end of the wall panel, and this column is also grouted in place over the dowel on its associated pad.

This operation is continued until all the columns and walls have been erected. The last wall panel to be in-

stalled (called the key panel) must be lowered into place with its edges sliding down the grooves of the adjacent supporting columns which are already in place. The grooves are caulked after the walls are in place to insure a weathertight seal.

The next step in erecting the house is to tie the tops of the columns together, and to assemble a roof. A U-shaped steel saddle **40** (FIG. 2) is secured to the top of each column **30**, and is held in place by nuts (not shown) fitted on the ends of bolts **34** which extend upwardly from the column. Roof beams **41**, typically of **4**-inch by **10**-inch lumber, are then seated in the saddles and secured thereto by lag bolts **42**.

A roof **44** is then assembled and secured to the tops of the roof beams. The roof is constructed of the usual sheathing material and includes a facia **45** around its periphery. The roof is completed by placing 7/16-inch fiber glass insulation over the sheathing, and several layers of asphalt-saturated felt are then laid on the insulation. This surface can then be covered with gravel or given any other conventional treatment.

As best seen in FIG. 3, the wall panels have secured to their upper ends a plate **46** (which may be of 2-inch by 8-inch lumber) fitted over bolts **34** and locked in place by nuts (not shown). A beam **47** of 4-inch by 8-inch lumber is nailed to plate **46**, and extends upwardly to support the roof sheathing. The sheathing is nailed to the beam, and the joints between the wall panel, plate, beam and sheathing are caulked to form a watertight seal.

After the building has been thus assembled, earth is removed from beneath the wall panels between the pads to provide a gap having a height of about two inches between the ground and the underside of each panel. A concrete grade beam **50** (FIGS. 10 and 11) is then poured from the inner surface of each wall panel to the periphery of the floor slab. The slab is formed with an outwardly extending key **51**, and concrete forming the grade beam flows under the key to lock the beam to the floor slab.

The grade-beam concrete also flows under the wall panels through the excavated gap and rises above the undersurface of the wall against the lower part of the outer face of the wall panel to form a barrier to vermin and moisture. Reinforcing bar **35** of each column is embedded in the grade beam. Each column is thereby locked against rotation by bar **35** and against lateral movement by dowel **18** in the underlying pad. Tie bar **19** is also embedded in the grade beam, and ties all the column pads to the grade beam. A similar grade beam **52** is poured in rectangular opening **13** around the columns in the interior of the house.

Interior walls **55** are next erected in the house to define the various rooms as indicated in FIG. 1. The walls of the kitchen, bath and laundry room are preferably two-by-four wood stud walls to provide a solid support for subsequently installed plumbing and electrical equipment and storage cabinets. The remaining interior walls are preferably constructed according to the conventional studless wall system. In this system, a panel of rib lath is secured to the floor slab and ceiling, and the lath is then coated with cement plaster to form a cement-plaster wall of about two-inch thickness.

The building is completed by installation of doors **58** and windows **59** in the apertures provided in wall panels **21***b* and **21***c*. The usual interior doors are also provided, as well as conventional kitchen and bathroom fixtures, closet partitions and the like.

The house is now ready for occupancy, and provides a fireproof building of great structural integrity. The wall panels are able to withstand very high wind loads, as winds place the concrete panels in compression between the supporting columns. Furthermore, the columns themselves are placed in compression, rather than having the windloads transferred directly to the column flanges on either side of the column groove.

The house described above is a distinct departure from traditional thick-wall concrete construction, and is made possible by the use of the gently curved concrete wall panels which are held in place between the grooved columns. The great resistance of these curved panels to side loads as compared to a conventional flat wall makes possible the use of a thin, lightweight panel which is economical to fabricate and easy to handle during construction. Buildings constructed according to the invention have an attractive appearance, and the curved walls produce an aesthetically pleasing shadow line. It is believed that this type of construction is particularly suitable for shelters which might be used in a national emergency. Such shelters would have great strength against shock waves from explosions, and are also relatively nonpenetrable by radiation.

A feature of this design is the ability to withstand earthquake forces and other transient loads without damage. The columns and non-load-bearing walls are separate components which can move with respect to each other in response to seismic forces. Curvature of the wall panels increases the strength of the walls as the moments of inertia are distributed over a greater cross section and absorbed within the panels. Furthermore, most of the foundation structure is effectively above grade, permitting seismic waves to roll under the grade beam instead of through the foundation.

Although the invention has been described in terms of its application to a dwelling, the curved wall and curved wall panels and supporting columns are not restricted to this use. For example, this construction can be used in a building intended to contain large quantities of a commodity such as grain. In such an application, the curved walls would be reversed such that the inner faces of the walls are convex and the outer faces are concave. This is because the maximum expected load in such use is from the stored commodity rather than from exterior wind loads and the like.

The invention is also thought to have use in structures such as sea walls. In this use, the convex face of the wall panel would of course be positioned toward the body of water along which the sea wall is erected. As in all applications of the invention, construction expense and time are minimized by the use of the precast walls and columns which are quickly assembled using the techniques described above. Other applications of the invention will suggest themselves to those skilled in the art, and all such uses are intended to be encompassed.

What is claimed is:

1. A precast concrete building comprising:

a plurality of laterally spaced upright columns having elongated vertical grooves therein, the grooves tapering inwardly toward the column centers and extending along substantially the entire length of the columns;

anchoring means for securing the columns to the ground, including concrete pads disposed on the ground beneath the columns to support the bottoms of the columns, and a dowel extending upwardly from each pad into the associated column to prevent lateral movement of the column;

a plurality of precast concrete panels arranged to form a wall for the building, each panel being disposed between a pair of columns and engaged in the column grooves to be held in place, each panel being convexly curved toward the outside of the building whereby wind loads and the like place the panel in compression between the columns, each panel being formed as an annular section of a hollow right circular cylinder to have inner and outer surfaces which are generally parallel and convexly curved toward the outside of the building;

a concrete floor slab having a periphery which terminates short of the walls;

a concrete grade beam abutting the periphery of the floor slab and extending under the wall panels and

upwardly against the outer surfaces of the wall panels, the grade beam including a plurality of bars embedded therein and extending laterally into the columns to prevent rotation of the columns, the grade beam further including tie bars embedded therein and extending therefrom to be embedded in the pads, and

a roof supported on the columns.

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ALFRED C. PERHAM, Primary Examiner

U.S. Cl. X.R.

52—250, 263, 274, 293, 491