Nov. 4, 1969 W. D. STEADMAN 3,475,873

MODULAR, BONDED BUILDING WALL

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FIG. 2

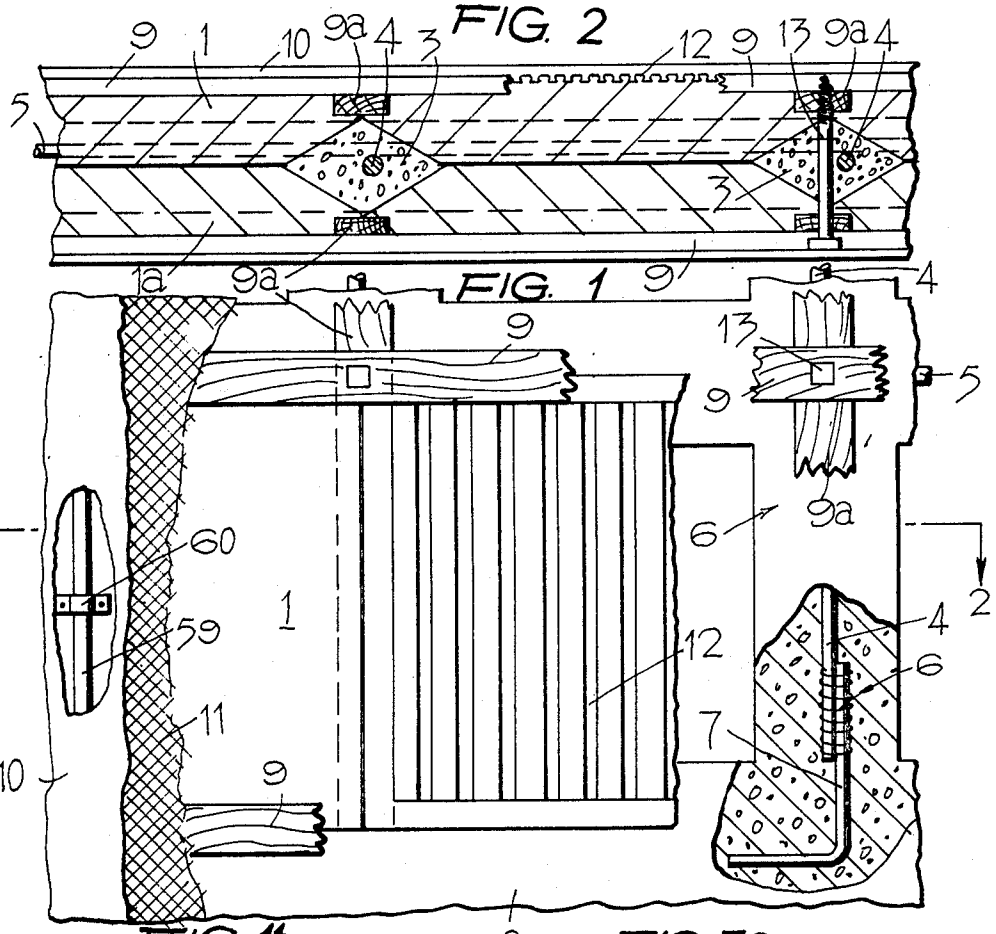


FIG. 1

FIG. 1b

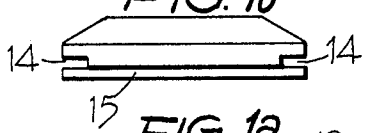


FIG. 3a

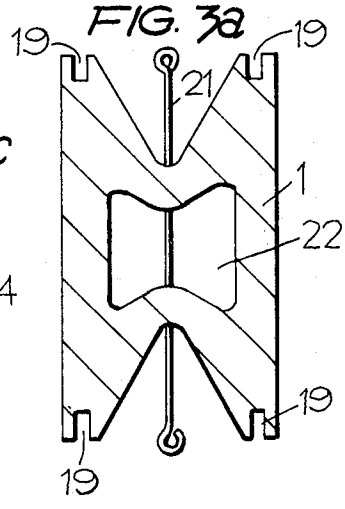


FIG. 1a

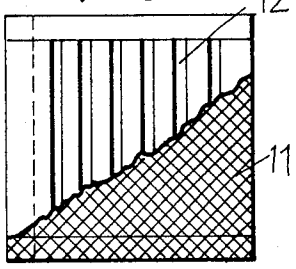
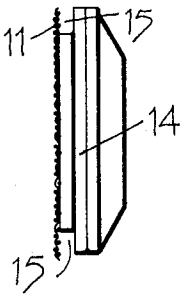


FIG. 1c



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FIG. 3

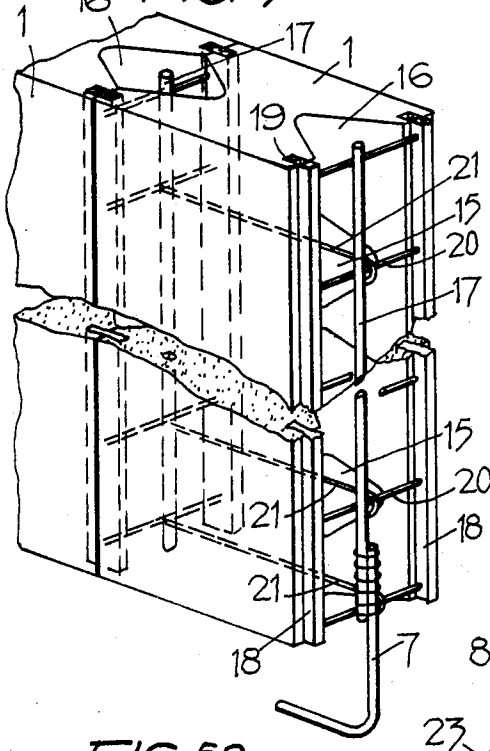


FIG. 4

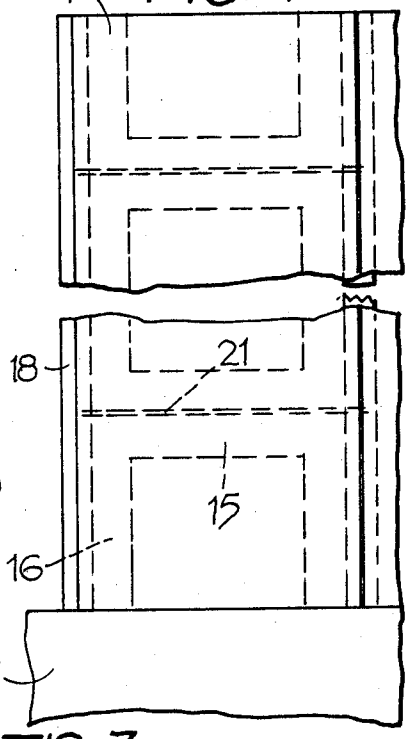


FIG. 5a

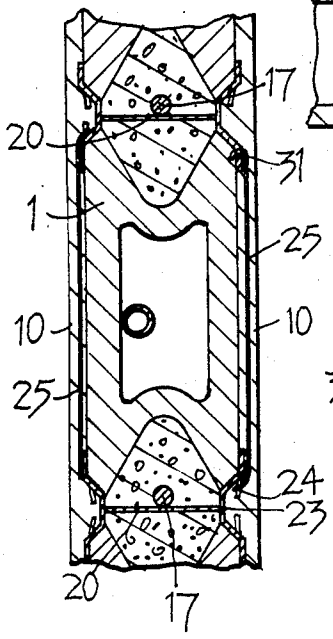


FIG. 7

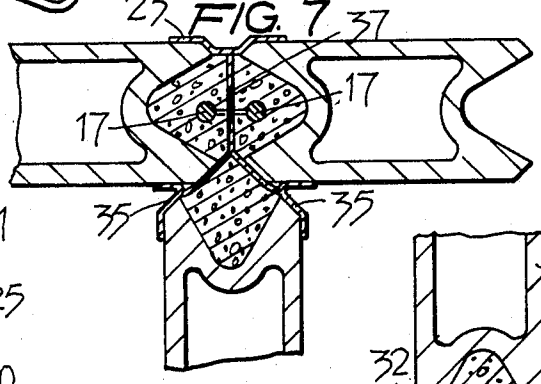
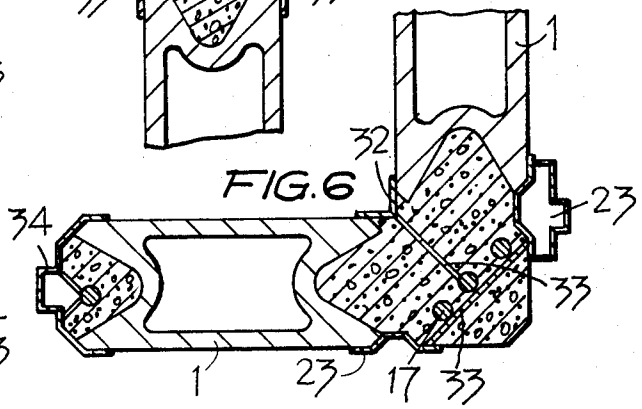


FIG. 6



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FIG. 5

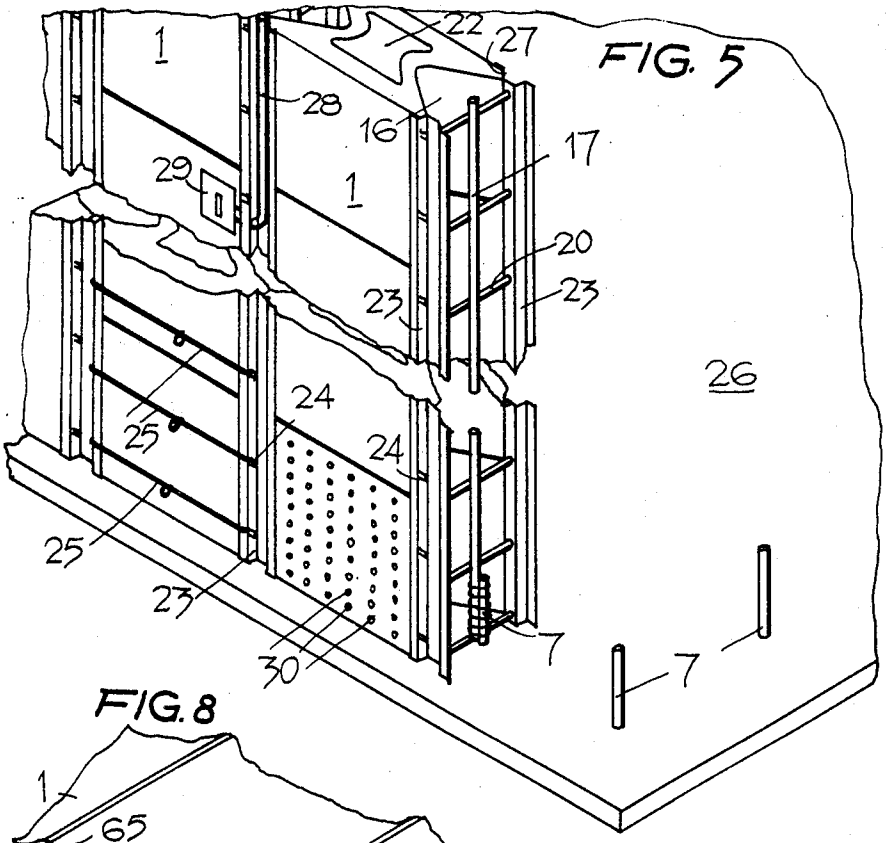


FIG. 8

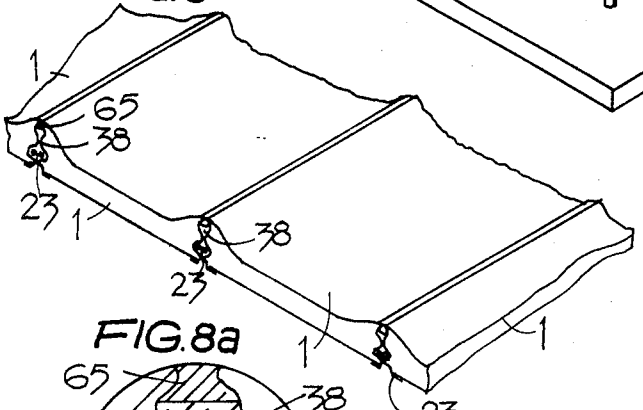


FIG. 8a

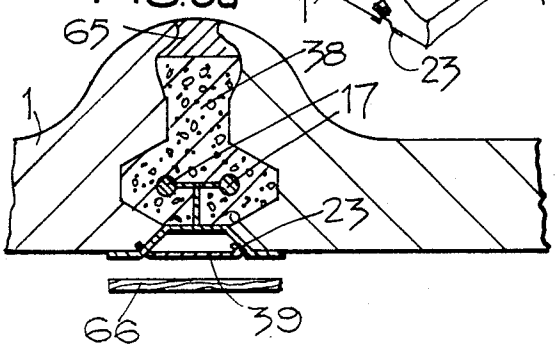
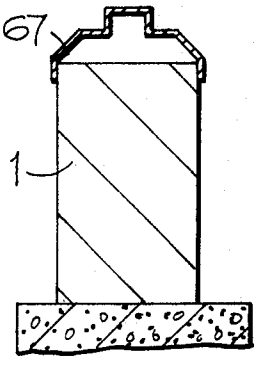


FIG. 15



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FIG. 9

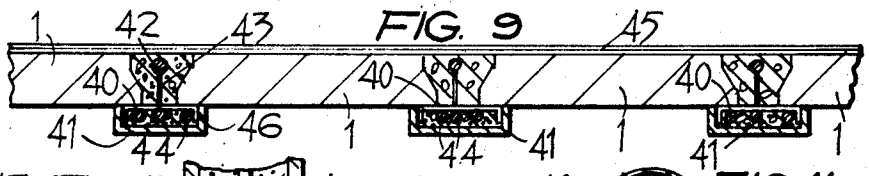


FIG. 10

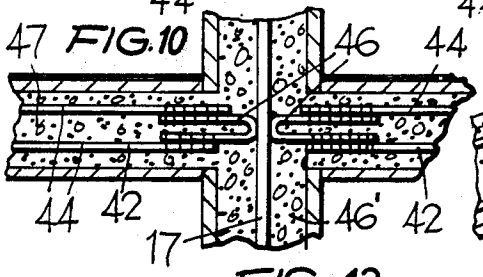


FIG. 11

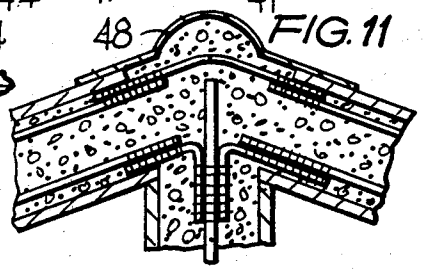


FIG. 12

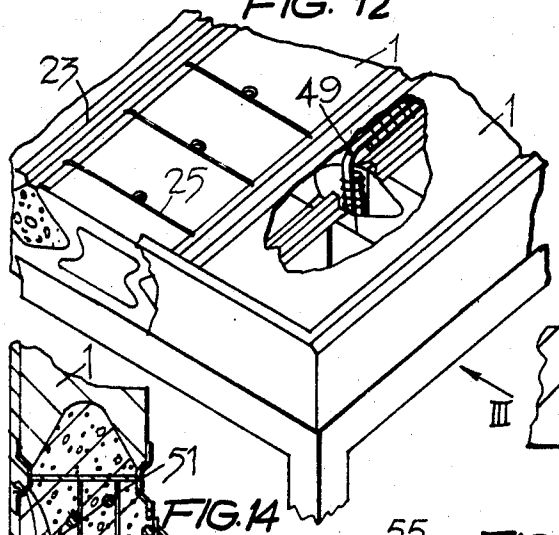


FIG. 13

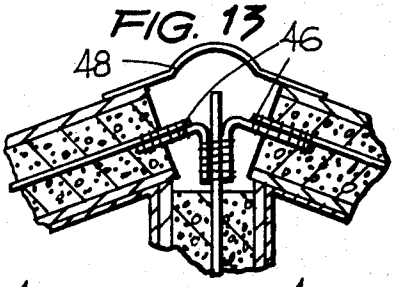
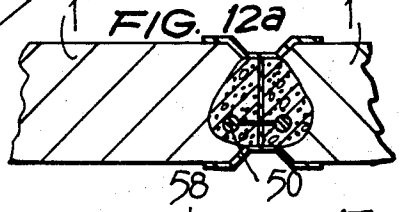


FIG. 12a



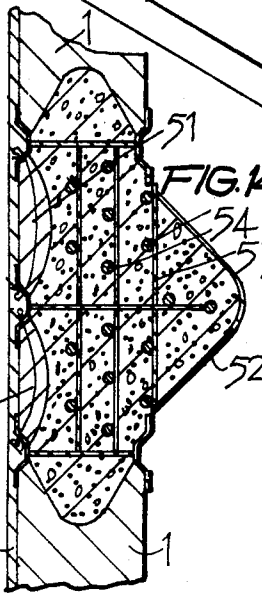


FIG. 14

FIG. 16

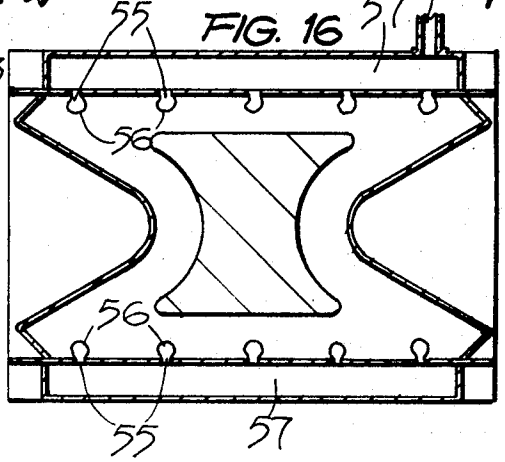
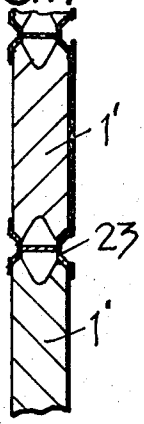


FIG. 17



United States Patent Office 3,475,873 Patented Nov. 4, 1969

3,475,873

MODULAR, BONDED BUILDING WALL

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Filed Sept. 12, 1967, Ser. No. 667,251
Claims priority, application Great Britain, Sept. 14, 1966, 41,093/66, 41,094/66
Int. Cl. E04b 5/19; E04c 5/01; E02d 27/32
U.S. Cl. 52—293 3 Claims

ABSTRACT OF THE DISCLOSURE

A building structure comprises a multiplicity of modules made of insulating material, each module being shaped around terminal faces to provide, between adjacent modules, channels containing a mortar set to form a structural skelton such as one comprising a lattice of intersecting orthoganal reinforced concrete filled passages. The terminal faces of adjacent modules are located in predetermined relative positions by elongated frame members which engage these adjacent faces. The frame members may be tied together by tie members, such as reinforcing rods or wires, and the elongated frame members may be provided in two orthoganal directions so that they cross at a multiplicity of intersections to form a lattice engaging and locating the terminal faces. Each module can comprise two initially separable layers positioned and retained in back-to-back relationship. A pair of such lattices may be provided, one to each side of the building structure, tied together by the bolts passing through the lattice members at the positions of intersection. A stronger concrete column is provided in an upright wall by omitting the modules and filling the space with a column of reinforced concrete monolithically cast with the skelton of the structure. The insulating material may be shaped around the terminal faces to generally concave surfaces with terminal faces provided with elongated frame engaging formations, the module being adapted for combining in terminal face-to-face relationship with adjacent modules, with the elongated frame members engaging between the adjacent faces.

Background of the invention

This invention concerns improvements in or relating to wall, roof or like building structures and provides a means and method of making the same.

One object of this invention is to provide a building structure which is as close as possible to conventional building in the final product quality-wise i.e., in terms of appearance, durability and permanence which does not have the disadvantages inherent in prefabricated or industrialised building concepts, but with additional advantages attainable, in particular good insulation, quick and easy erection, largely by unskilled labour.

Some embodiments avoid plastering and like finishing work; other embodiments facilitate plastering by providing surfaces specially adapted to hold plaster in a manner superior to many conventional prefabricated building modules.

Some embodiments provide a module useable both, for example for building walls and for building roofs, and other structural features while other embodiments provide modules for a more attractive roof.

The economic advantages which are to be obtained by substantially reducing the building time of an average dwelling or other structure are well recognised. It would furthermore be a great advantage for a very inexperienced person who wants to build his own house to be able to erect the building structure himself and with the help of an experienced concrete pouring company, plumber, electrician or other specialists, complete his own dwelling. Yet another object of the invention or at least of preferred embodiments thereof is to cut down the cost of transportation of building materials and the man hours used in material handling.

Summary of the invention

A building structure forming a wall, floor, roof and/or ceiling or other feature in accordance with this invention comprises a multiplicity of modules being in the form of panels, slabs, blocks or the like made from a heat and/or sound insulating material (such, for example, as a foamed plastics polymer or bonded fibre), each module shaped around at least some of its terminal faces to provide between faces of at least some adjacent modules channels containing a bonding mortar or aggregate set to form a structural skeleton, in which at least some terminal faces of adjacent modules are located in predetermined relative positions by one or a pair of elongate frame members engaging these adjacent faces.

In the case of a pair of elongate frame members, these are preferably tied together by ties extending between the members, which advantageously provide additional containing means to contain the poured concrete.

In accordance with a preferred embodiment of the invention elongated frame members of a building structure, separated by modules, are connected by rods, wires or wire lacing, whether set in the mortar or not.

The bonding mortar or aggregate set to form a structural skeleton is preferably a reinforced concrete, but the invention is not limited to this: the mortar could be an unreinforced concrete, a lightweight concrete, a soilcrete or other mortar having suitable properties to set to a structural skeleton which is stronger than the modules or which bonds them into a coherent structure. In the claims below the term mortar shall be used as a generic term covering all the above mentioned alternatives.

One of the most important needs is for better insulated structures.

It is an object of this invention to provide a module for a building structure that inherently has comparatively high heat and/or sound insulating values. In this specification the term "insulating material" shall be taken to mean a material of good heat insulating properties which is usually also a good sound insulating material.

A module in the form of a panel, slab, block or the like for making a building structure in accordance with the invention comprises an insulating material shaped around at least some of its terminal faces to channel-like or generally concave surfaces and with at least two terminal faces provided with one or a pair of elongate frame engaging grooves, bevels or other formations, the module being adapted for combining in terminal face-to-face to relationship with adjacent modules in accordance with the invention, with elongate frame members engaging between at least some adjacent faces for the purpose of making up a building structure such as a wall, floor, roof and/or ceiling or other feature.

In accordance with a first preferred aspect of the invention the modules comprise two separable layers of heat and/or sound insulating material which may be positioned and retained in back to back relationship in the finished structure.

In accordance with a further preferred aspect of the invention the module comprises a unitary integral panel, slab, block or the like.

A method of building a structure in accordance with this invention comprises bringing together in terminal face to terminal face relationship a multiplicity of modules adjacent one another so that there exists, between some terminal faces of adjacent modules, channels, with some terminal faces of adjacent modules keyed in their rela-

tive positions by the addition of one or a pair of tied together elongate frames engaging these adjacent terminal faces introducing to the channels a bonding mortar or aggregate and allowing it to set so as to form a structural skeleton.

Preferably the bonding mortar or aggregate comprises concrete, and the method preferably also includes the step of adding reinforcing members before introducing the mortar.

Where the building structure comprises a wall it is preferred to initially lay a pad which is in the form of a floor and/or wall foundations, with preferably reinforcing tie anchors whereby the elongate reinforcing members may be anchored to the pad.

It is furthermore preferable for the modules to be cast on the site of the building or at a suitable casting site as a step included in the method in accordance with the invention.

There is thus in accordance with the invention provided a mold box adapted for the purpose of molding a module which comprises a box having the necessary draught and dismantleable after casting in it a module in accordance with the invention, which is provided with a number of apertures through which may be inserted a number of rubber bulbs or balloons on the face(s) which will eventually be the external face(s) of the molded module, with a manifold space enclosing said apertures to which may be applied a gaseous or hydraulic pressure.

Brief description of the drawings

The invention will be more fully described with reference to the accompanying drawings which illustrate preferred embodiments of the invention by way of non-limiting examples.

In the drawings;

FIG. 1 is a view looking onto the face of a wall, floor, roof and/or ceiling or other building structure shown in graduated part sections from the outer facing to the centre of the thickness of the wall in accordance with the preferred embodiment of the invention,

FIG. 1*a* is a view on the front face of a module half layer as used in the building structure illustrated in FIGS. 1 and 2,

FIG. 1*b* is a plan view of the half layer module shown in FIG. 1*a*,

FIG. 1*c* is an end view of the half layer module shown in FIG. 1*a*,

FIG. 2 is a view on section 2—2 of FIG. 1 of the structure illustrated in FIG. 1,

FIG. 3 is a perspective view of a building structure built in accordance with a further embodiment of the invention, in this case as a wall although it could with necessary obvious adaptions be suitable for a floor, roof, ceiling or other feature,

FIG. 3*a* is a sectional view of an alternative form of module suitable for a building structure as shown in FIG. 3,

FIG. 4 is an elevation on the front face of the building structure illustrated in FIG. 3,

FIG. 5 is a perspective view of a pad comprising a floor and wall foundation on which a wall building structure has been erected in accordance with a preferred embodiment of the invention, in which the stages and method of construction are illustrated,

FIG. 5*a* is a plan sectional view of a module in accordance with a preferred embodiment of the invention shown built in to a completed wall building structure similar to that illustrated in FIG. 5,

FIGS. 6 and 7 are plan sectional views of parts of walls being respectively a corner and a T-joint in wall structures,

FIG. 8 is a perspective view of the building structure in accordance with the further preferred embodiment of the invention which is particularly adapted to be suitable for molding a roof having an attractive external appearance,

FIG. 8*a* is an end sectional view of the building structure illustrated in FIG. 8 illustrating module and the preferred arrangement of joining adjacent modules,

FIG. 9 is an end sectional view of an upper floor building structure in accordance with a preferred embodiment of the invention,

FIG. 10 is an end sectional elevation viewed at right angles to the view of FIG. 9 showing the joining of an upper floor building structure to a wall building structure in accordance with the preferred embodiment of the invention,

FIG. 11 is an end sectional elevation similar to that of FIG. 10 showing the joint of a roof building structure to a wall building structure in accordance with the preferred embodiment of the invention,

FIG. 12 is a perspective view of a roof building structure in accordance with the preferred embodiment of the invention,

FIG. 12*a* is a part sectional end elevation showing a preferred terminal face shaping of the modules,

FIG. 13 is an end sectional elevation in the direction of arrow III of FIG. 12 showing the joint of the roof building structure of that figure to a wall building structure in accordance with the preferred embodiment of the invention,

FIG. 14 is a plan sectional view of part of the wall building structure which is suitable for multi-storey construction in accordance with the preferred embodiment of the invention, providing a strong weight-supporting pillar,

FIG. 15 is an end sectional elevation of a detail of a wall building structure in accordance with the preferred embodiment of the invention illustrating an adaptation to a window sill,

FIG. 16 is a plan view in section of a mold box in accordance with the preferred embodiment of the invention for molding a module, and

FIG. 17 is a plan sectional view of a building construction in accordance with the preferred embodiment of the invention for an interior wall of a dwelling.

Referring first to FIGS. 1 and 2 the building construction illustrated comprises in this particular example an upright wall for a dwelling house or for any other building but which could in principle be adapted for any other type of building structure. The building structure comprises a multiplicity of modules in two separable layers **1**, **1***a* manufactured of heat and/or sound insulating material such as a foam synthetic plastics material, for example expanded polystyrene foam or urethane foam, a bonded cork, a light weight concrete or soilcrete or any form of bonded fibre such as a bonded vegetable fibre or other material having these properties. These layers **1**, **1***a* of modules are positioned and retained in back to back relation and are shaped around the terminal faces in such a manner as to form channels **3** so that when the blocks are arranged in terminal face to terminal face relation, the channels **3** of adjacent blocks **1**, **1***a* combine to form intersecting passages for the reception of reinforcing rods **4** and **5** and also a concrete mix so that the wall comprises at the centre of its thickness a lattice work of reinforced concrete **6** (see FIG. 2). The reinforcing rods **4** which extend outwards through the vertical passages are wire bound at their lower ends to comparatively short rods **7** imbedded in a concrete footing **8**.

The layers of insulating material **1**, **1***a* of an assembled multiplicity of blocks are held together initially by a pair of lattices of light weight timber framing **9** and **9***a*, one to each side of the building structure, and the terminal faces of both layers of blocks **1** and **1***a* are grooved all round near the edges to accept the thickness of these frames **9** and **9***a*, the vertical grooves **2***a* and horizontal grooves **2** offset relative to each other by the thickness of timber frames **9** and **9***a* to permit these frame members to cross one another at their points of intersection. The frame members **9** and **9***a* at each side of the wall are all secured together by tie bolts **13** which are positioned so as to avoid said reinforcing rods **4** and **5**. The grooves

2*a* and 2 need not be offset if the timber frames 9 and 9*a* are rebated flush into each other or are located by metal X-shape channel joiners.

The outer faces of the blocks 1*a* and 1 are adapted to receive a plaster or concrete facing 10. For example the outer faces of the insulating layers may have a wire mesh bonded thereto as indicated at 11. As shown at the upper side of FIG. 1 and on one of the blocks in FIG. 2 the insulating material 1 and 1*a* may be formed with ribs 12 for the purpose of keying the plaster facing 10.

The method of erecting the building structure in this example comprises laying a multiplicity of blocks 1*a* in rows using the timber frames 9 and 9*a* to locate the blocks. As the first layer of blocks is laid on the footing 8 the upright frame members 9*a* are progressively added and then as further rows of blocks are laid on the first layer the horizontal timber frames are added progressively. After one side of blocks 1*a* has been fully laid reinforcing rods are then located in positions where channels 3 will be formed, and the other side of blocks 1 may be laid in the same maner, and the blocks are tied together by means of bolts 13 which pass through the timber frames 9 and 9*a* on both sides at some positions of intersection thereof.

Concrete is preferably pumped into the intersecting passages formed by an assembly of blocks 1 and 1*a* from the base so as to eliminate air being trapped in the resulting reinforced lattice of concrete, reinforcing rods 4 and 5 having been inserted in the apertures at previous stages of the erection.

When it is desired to incorporate services such as electric wiring conduits or water pipes 59 in the thickness of the blocks then the insulating material is channelled or grooved out and wire mesh 11 cut away to accommodate an electric line conduit or a plumbing pipe and to cross the frame members 9, with metal straps 60 to hold the pipes in place. When the plaster or facing 10 is applied the said services are concealed.

An important advantage of the present invention is that the wood framing 9 and 9*a* is light in weight and easy to handle and therefore facilitates easy and quick erection of a wall. However, the framing 9 and 9*a* could be metal strip, if desired.

An advantage of constructing the blocks of two layers of insulating material 1 and 1*a* is that half a sandwich of the wall can be assembled in a vertical plane and the vertical reinforcing wires 4 and the horizontal reinforcing wires 5 can then be positioned in the half formed passages and then be enclosed during the formation of the other half sandwich.

The blocks are made of standard sizes, and doorways and windows as multiples of this dimension may quite easily be incorporated in a wall without having to cut away any of the blocks.

The blocks in accordance with a preferred embodiment of the invention as employed in the building construction illustrated in FIGS. 1 and 2 are illustrated in FIGS. 1*a*, 1*b* and 1*c*. Grooves 14 and 15 are provided offset from each other and dimensioned to later receive the timbers 9 and 9*a*.

As already mentioned, the grooves 9 and 9*a* need not necessarily be offset, and if not offset, the advantage is achieved that the cross section of passages 3 (see FIG. 2) can be increased.

The internal edges of the blocks are bevelled so that when two half sandwiches of blocks are put together in face to face relationship a channel is formed around the terminal faces thereof. A wire mesh 11 is bonded to the outer face of the blocks, which provides a bonding for the plaster to be added to the constructed wall or the like structure, or the outer surface has ribs 12 for bonding.

As a further alternative, a wire mesh could be added to cover the entire face of a wall or like building structure, after all the modules were assembled, to bond plaster; this could also provide a certain amount of structural bracing.

It is to be appreciated that an assembly of blocks could quite easily be used in the construction of a roof structure.

With reference to FIGS. 3 and 4 each building panel 1 is made of floor-to-ceiling height (or the full width of the wall), and is constructed in one piece of a heat or sound insulating material such as a foam plastics material.

These panels are formed with internal horizontal passages 15 and the vertical terminal faces of the panels 1 are formed with grooves or channels 16 communicating with passages 15, and which combine when the panels are assembled to form vertical passages which intersect the horizontal passages. Metal reinforcing rods 17 are arranged in said passages so that when a mix of concrete is poured into the said passages a lattice work of reinforced concrete is contained within the thickness of the assembled wall. Instead of making each panel from a single piece of insulating material the panels may each be made in two layers which are abutted back to back together, the edges of the panels being suited to the same shape so that when the halves of the panels are placed together their terminal faces present channels which combine with channels in the edges of adjacent panels to form said vertical passages 16 and the horizontal passages 15 being constituted by mating channels in the opposite back faces of the layers.

The outer faces of each panel 1 are prefinished so as to avoid having to apply a finishing material such as plaster thereto when the wall or like structure has been assembled. This can be achieved by spraying the inner molding surface of the mold with blown chopped strands of fibre glass prior to filling the mold with the insulation material of which the panel is made so that when the panel is subsequently removed from the mold its outer faces are already faced with the said fibre glass material or by embossing or marble chips or any other prefinish.

As clearly illustrated in FIG. 3 a wooden or metal frame 18 is interposed in each of the abutting vertical terminal faces of the panels 1 and the side members of this frame again engaged in preformed grooves 19 near the edges of the insulating panels 1 and locate or key these edges. Frames 18 are joined together by metal tie rods 20 which equips them to resist the hydraulic pressure of the concrete when this is cast into the wall, obviating belts as shown in FIGS. 1 and 2.

The vertical hollow passages 16 between the panels 1 each accommodate a reinforcing rod 17 which is tied at its lower end by wires to the rod 7 projecting from the concrete footing 8 (not shown in FIG. 3). These rods 17 are welded or otherwise suitably connected at spaced apart intervals to transfer tie rods 20

Horizontally disposed reinforcing rods 21 are provided which extend through the horizontal passages 15 and are looped or otherwise suitably connected to tie rods 20 at the intersections of the latter with the rod 17 The method of building a structure as illustrated in FIGS. 3 and 4 comprises first securing the wooden timbers 18 joined complete by tie rods 20 in position and then bringing the first panel 1 into the engagement therewith so that the grooves 19 lock onto the timbers 18. An upright reinforcing rod 17 is then spot welded or otherwise secured into position and the horizontal reinforcing rods 21 are added. This procedure is repeated until the length of wall has been erected.

Panels are made of a predetermined width, for example 12, 16, 24 or 36 inches and any doors or windows to be built into the panel are made as multiples of this dimension. The thickness of the panels may be the desired thickness of the wall, for instance a 12 inch wall for external walls or a smaller dimension for internal walls.

Any suitable facing material can be sprayed into the mold prior to casting the insulation panel, for example a synthetic plastics material, fibre glass, asbestos, plaster, marble chips or the like.

A further possibility is to apply a laminate to the outside faces of the modules, such, for example, as wood veneer, synthetic wood panels, plastics and other laminates and the like: this could be done either by gluing the panel to the cast module or by placing the panel in the mold and molding it into or onto the module, e.g. when polyurethane is used.

The facings of the insulating panels may also be embossed so as to provide for a great variety of finished surfaces.

By means of this method it will be appreciated that the normal interior finishing work such as plaster work, painting etc. which are normally costly and time consuming are eliminated.

Services such as electric wiring, water pipes or the like may be built into the thickness of the panel so that they are not visible when the wall is complete. This could advantageously be done by molding such items as plumbing pipes, and electrical conduits into the modules **1** when they are molded.

Electrical or hot water radiator type heaters could also be molded into the modules **1** so that you could have a completely flush surface on the interior of the building walls being internally heated. These could be bonded asbestos panels in the module or bonded asbestos modules themselves: the material chosen must of course be sufficiently heat resistant. Refrigerating or cooling panels could also be provided. This arrangement could be provided in any of the embodiments illustrated in the drawings.

Referring to FIG. 3*a* it illustrated that blocks **1** could be provided with a hollow, a vertical space **22** which does not communicate with the channels **16** or **15** and which could carry such items as electrical wires conduits or plumbing pipes. The tie rods **21** would then be passed through small apertures which would not allow much leakage of concrete when this was poured, or could be molded in the module when cast.

Referring to FIG. 5 a pad is illustrated which comprises a floor and wall foundations of cast concrete on the surface of which the building is to be erected. Around the perimeter of the pad a number of tie rods **7** are cast in, projecting at the spacing which corresponds to the width of the building panels **1**. In this example the building panels **1** are keyed in relative positions by means of channel shaped metal elongate members **23** which are joined again by tie rods **20** into a ladder-like structure. Each of the channel-shaped elongate members **23** is provided with punched out tabs **24** onto which tie wires **25** are attached, so as to brace the whole structure. Instead of tie wires **25** a continuous diagonal lacing could be applied using wire. Upright reinforcing rods **17** are again applied to the vertical channels **16** of the modules **1**, though in this case the modules **1** are provided in relatively short heights which are placed one on top of another to make out the full wall height, or they could again equal the full wall height. The upright reinforcing rods **17** are again tied to the reinforcing rod **7** cast into the pad **26**.

The method of building the building structure illustrated in FIG. 5 comprises initially erecting a first ladder-like structure formed by two metal channel elongate members **23** joined by tie rods **20** and then laying one on top of another a series of modules **1** until the wall height is achieved or adding a single full wall height module. A second ladder-like structure is then applied to the edges of the modules **1**, engaging suitably formed edge regions thereof **27** and is laced to the first ladder-like structure by means of a wire or else by several tie lengths of wire or by means of wire mesh.

The channel forms of the elongate members **23** provide recesses in which electrical conduits **28** can be located and brought down from ceiling height to a height suitable for a light switch fitting **29** which is recessed into the module **1** and fastened to the members **23**. Holes are provided in the sides or channel walls of the elongate members **23** to allow the conduit **28** to pass through.

The central aperture **22** which interconnects a complete hole vertically through the height of the wall can also be used for electrical conduits or plumbing pipes or the like. It may be observed that modules **1** when constructed from the foamed plastics material are very light and as a result the job of erecting a wall can be done very quickly. When concrete grouting is poured into the vertical apertures **16** between adjoining modules **1** a very rigidly braced structure is provided having excellent insulating properties.

The external faces of the wall are then plastered, the tie wires **25** providing a bonding for the plaster which is applied for the surface.

In order to provide an additional keying bond holes **30** may be applied to the external surfaces of the modules **1** as an alternative to the grooves illustrated in preceding figures.

In FIG. 5*a* a module as used in the embodiment illustrated in FIG. 5 is illustrated on a larger scale in plan view, all the corresponding integers being given the same reference numbers as those described in relation to FIG. 5, with the addition of the plaster surfaces **10**. The shape of the end regions **27** adapted to engage the elongate members **23** may be more clearly seen in this embodiment and it may be observed here that the ties **20** may be strips or bars instead of round section rods. It is also illustrated at reference **31** that the tie wires **25** may be hooked into holes in the edges of the elongate elements **23** instead of being hooked onto the tabs **24**.

With reference to FIGS. 6 and 7 it may quickly be seen how the building construction in accordance with the embodiment illustrated in FIG. 5 may be adapted for the purpose of building corners and T-joints in walls. The same modules **1** are used here, but instead of the normal ladder-shaped pair of elongate members **23** joined by cross ties **20** there is provided a unit of two channel shaped elongate members **23** and one corner member **32**, these three elements joined by ties **33** so that they may be erected in a corner position and then upright reinforcing rods **17** located in position. A mold must be provided around the apex of the corner and then the concrete can be cast into the corner pillar.

As shown also in FIG. 6 a molded section adapted to provide a sill or edge of a window **34** may be provided, which could be in a material other than steel if desired, and preferably suits standard windows.

As shown in FIG. 7 the normal ladder shaped pair of elongate members **23** is again here replaced by the one channel shaped elongate member **23** and two corner members **35** which again are tied together by tie rods **36** and **37** allowing vertical reinforcing rods **17** to be located in position again.

As shown in FIG. 8 the modules **1** may be adapted to somewhat different shape for constructing a roof of attractive appearance. The modules **1** have again channel shaped elongate members **23** at their intersection, with elongate reinforcing rods **17** again located in the gaps between the modules **1**. Reinforcing concrete is then poured into the gaps **38** from the top. A bung of insulating material **65** could be added to reduce heat transfer through the joint, if necessary.

As shown in FIG. 8*a* the reinforcming rods **17** are preferably located in the lower part of the concrete so as to reinforce the tension side of what is in effect a beam. A heat insulating bung **65** is illustrated. As also illustrated in this view the channel shaped elongate members **23** may be provided with filler strip plates **39** so as to close-in the channel, alternatively a wooden or other strip **66** could be attached. The reinforcing rod **17** may be located by means of ties **40** which are connected to the elongate panel members **23**.

As shown in FIG. 9 a preferred construction for an upper floor comprises modules **1** with elongate members engaging their edge regions which are in the form of a box-like frame **41** which to external appearances provides

a beamed ceiling or roof. The box-like channel **41** is located in position by means of brackets **40** to which are attached tie members **43** which locate a reinforcing rod **42**, reinforcing rods **44** being attached to the brackets **40**. A conventional floor **45** may be laid on top of the modules **1**.

As shown in FIG. 10 the floor structure illustrated in FIG. 9 may be attached to upright walls by means of breaking through the sides of modules **1** of the wall (and floor, if necessary) so that the passages which are to be filled with concrete communicate with the concrete filled passages of the floor the former being indicated here by **46'** and the latter by **47**, being cast monolithically. One could, however, if necessary, shear off the whole wall of one module. An alternative construction could provide steel cushion channels to support normal floor beams, e.g. for a wood floor. The reinforcing rods **42** and **44** of the floor are tied by means of a tie member **46** to the upright reinforcing rod **17** of the walls.

As shown in FIG. 11 the joint of a roof to the upright walls may be done in substantially the same manner with a capping piece or ridging for weather proofing **48** being provided.

As shown in FIG. 12 the building construction illustrated with reference to FIG. 5 may be used for building a roof, being in all practical details the same. A tie rod **49** may be used for tying reinforcing rods of the roof construction to reinforcing rods of the wall construction. An upper surface cladding of a suitable roof material should be provided and could compirse any conventional roofing material but preferably a plastered surface or a tarred surface on which are scattered chips for a pleasing appearance or any other suitable finish, such as tiles laid on the roof or shingles and the like.

As shown in FIG. 12*a* an improved section for the space between adjacent panels would provide a greater area lower down in order to take the tension forces applied on what in effect is a beam. In the reinforced concrete filling the reinforcing rods **50** would also preferably be located near the lower edge of the concrete filling. The improved space is achieved by a different shape for the terminal faces of the modules.

In FIG. 13 a method of joining the roof to the upright walls is again illustrated being substantially similar to that illustrated in FIG. 11.

In FIG. 14 an adaptation of the building method is shown, for example for purposes of multi-storey buildings, in which suitably spaced stronger concrete columns are required in order to take the weight of the multi-storey building. For this purpose modified moldings **51** and the forming pan **52** are provided with tie rods **53** being used to locate a multiplicity of vertical heavy reinforcing rods **54**. These features take the place in this particular example of a single building module **1**, occupying the same width of such a module. The enclosed region is filled with concrete which when set forms a reinforced pillar monolithically cast with the structure skeleton when we have horizontal passages. Obviously the dimensions and proportions of the pillar as well as the frequency of these in any given wall may be varied to suit the desired requirements of the particular structure. As shown on the one side of the wall the pillar may be finished flush with the remainder of the wall by plastering over panels **51** with plaster **10**, while as an alternative arrangement on the other side the forming pan may provide a projecting pillar. Panels **51** could be initially tied in place by projecting ends of reinforcing wires cast into them.

In FIG. 15 a steel capping **67** is illustrated which is located on the tops of the modules **1** and which is used for a window sill. This could again be in any suitable section and material.

As shown in FIG. 16 a mold box may be provided for the purpose of molding building modules **1**. The mold box is constructed in accordance with mold box principles, having the necessary draught and being adapted for dismantling after the module has been cast in it. A mold box in accordance with the invention however is provide with a number of apertures **55** through which are inserted a number of rubber bulbs or balloons **56** projecting into the mold on the face which will eventually be the external face of the molded module. The rubber bulbs or balloons **56** communicate with a manifold region **57** which is enclosed and to which may be sealingly connected a pipe **58** for the application of air pressure, water or other hydraulic or pneumatic pressure. Thus when the air pressure or water pressure is applied the rubber bulbs or balloons **56** are blown up into an approximately spherical or swollen tapered form depending on the characteristics given to the bulb itself, and the module may be molded in the mold in this condition. Pressure may then be removed so that the bulbs collapse and are able to be withdrawn from the molded article, thereby providing a plurality of gripping, retaining cavities or key holes in the surface of the molded module, for retaining plaster.

As shown in FIG. 17 the modules **1'** for an interior wall for example of a dwelling or office building may be comparatively narrow, although in other respects similar to those illustrated before.

The fact that concrete is preferably pumped into the apertures of the walls from below may generally eliminate bad bubbles in the cast structure, and a small portable vibrating machine would be applied to difficult areas of the wall surface to ensure that the concrete would flow completely throughout the full aperture system in the wall.

Where doorways and window openings occur these would be installed at the time of the erection of the modules **1** of the basic system and on pouring the concrete this would bond these frames for these openings as a monolithic structure.

When the perimeter walls and dividing walls are erected and properly cast with a concrete internal system, this would now be ready for the installation of a roof. For the installation of a flat roof the modules would be fixed together with binding wires or lacing (FIG. 5) or internal rods (FIG. 3) in sections of a size that could be handled conveniently. These sections would then be lifted into place if desired by hand without the use of lifting tackle and would be firmly supported by wood or steel upright framing until the complete roof area would be covered with the grid system structure. Reinforcing rods could then be located and external roof edgings would be arranged so that weather proofing and drainage systems could be built in. Concrete would then be poured into the flat roof and vibrated until all of the internal apertures are again filled, but a number of apertures in this case cut into the modules **1** could allow the concrete to fill the entire system. After the concrete is fully set a plaster float finishing or plastic can be used for roof surfaces. It would be desirable for a steel mesh to be used on the inner or ceiling surface of the roof to assist bonding of the plaster interior finishing. Additional services such as electrical conduits and plumbing pipes would of course be incorporated in the roof before casting the concrete.

Known machines for pumping concrete could be used for filling the apertures throughout the wall grid system.

Where larger dimensions of internal vertical apertures are required special modules could be made so that at certain positions along upright walls it would be possible to have these large sections all concrete as illustrated in FIG. 14.

As shown in the preceding figures the elongate frame members are preferably manufactured from steel sheet pressed and formed and stretched to the necessary shape. They could also be a steel fabrication that was made by automatic welding or steel ¼" rod butt welded.

Curved roofs could be formed by the use of modules either molded as a curved section as in a continuous type, or affixed into the wood frame system with a smaller dimensional inset block for the under layer, and larger dimensional blocks in the upper half of the sandwich section. This could give a completely domed roof.

When the plastering of the outer surfaces of the assembled structure is finished and the outside facial concrete or other finishing, you are left with an improved insulated structure. The lightness of the modules means that the work is so much lighter and easier to erect than at present that the benefits for quick erection are rewarding without the aided benefit of the fully insulated structure. Also in bad weather conditions this structure can still be built.

It may be observed that while the embodiments of the building construction illustrated in FIGS. 1, 2, 3 and 4 show a concrete lattice work of intersecting vertical and horizontal reinforced concrete passages the embodiments of FIG. 5 and subsequent illustrations comprise a skeleton of vertical or unidirectional adjacent columns of reinforced concrete, the skeleton columns in these embodiments are joined transversely by the tie rods inserted between the adjacent columns of reinforced concrete, or by external wire lacing or tie wires provided on the outer face of the modules. Whichever construction is adopted a very highly braced and rigid structure is attained, practically speaking monolithic when completed and possessing excellent insulating properties of the material from which the module is cast. Certain features of embodiments illustrated in some figures could be transferred to embodiments illustrated in other figures and vice versa.

Apertures in the modules could be provided for the purposes of air conditioning channels or passages.

In the construction illustrated in FIG. 5 for a dwelling home it is necessary for a seal against moisture to be provided at the base of the walls between the walls and the pad. It would be preferable for the walls to be laid in this case in a rebate in the pads.

The method in accordance with the invention brings many advantages including speedy erection and cheapness and practicability for unskilled labour. Furthermore the modules may be cast or molded on site so that the material for molding the modules in the case of the foamed module could be brought in drums in relatively small volumes which would further ease the transport position. Despite these advantages the resulting building is very like a conventional building and if the outside of the walls are plastered is indistinguishable therefrom, but nevertheless having far better insulating properties.

A roof structure in accordance with the invention does not often need additional supporting girders or rafters, so that the saving in useable under-roof space is considerable compared with rafter-supported roofing.

Modules in accordance with the invention could be provided with such items as sinks, basins, toilet bowls and other facilities cast on or in the module.

A further advantage of the invention is that elongate frame members could be used as supporting form-work for laying modules in a roof construction, obviating scaffolding. After several separate spans were individually cast, the intervening spaces could be filled in.

What I claim is:

1. A permanent building structure, comprising:

a flat foundation pad on which said structure is laid and having a plurality of tie rods cast therein at predetermined locations, said tie rods having an upper portion projecting above said pad surface,

a plurality of aligned vertically-disposed horizontally-spaced elongated frame strips disposed in pairs back-to-back and carrying engaging means for the hereinafter-mentioned module panels and tying wires,

a side-by-side series of vertically-disposed structurally weak module panels made of expanded material and having enwardly-hollowed sides, the edges of one side of each of which engage in mortar-sealing relation said engaging means on one side of said paired frame strips,

a series of laterally-disposed spacing and reinforcing members attached to and between the inner faces of said frame strips,

vertically-disposed reinforcing members having their bottom ends attached to said pad projecting tie rods and also attached to said laterally-disposed members within said frame strip pairs,

at least one laterally-disposed tying wire spanning each module panel and connected to said frame strip engaging means at each side of said panel thereby binding different pairs of frame strips,

mortar filling the spaces between said panels and filling said frame pairs and serving as a supporting skelton, and

plastering covering at least one of the vertical surfaces of the aforesaid structure.

2. A permanent building structure, according to claim 1, comprising at least one laterally-disposed channel within each module panel and in connecting relation with said hollowed sides.

3. A permanent building structure, according to claim 1 wherein the expanded material is an expanded polymer.

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