

July 15, 1969

E. K. RICE

3,455,074

BUILDING STRUCTURE AND MEANS AND METHOD OF ITS MANUFACTURE

Filed Aug. 23, 1967

4 Sheets-Sheet 1

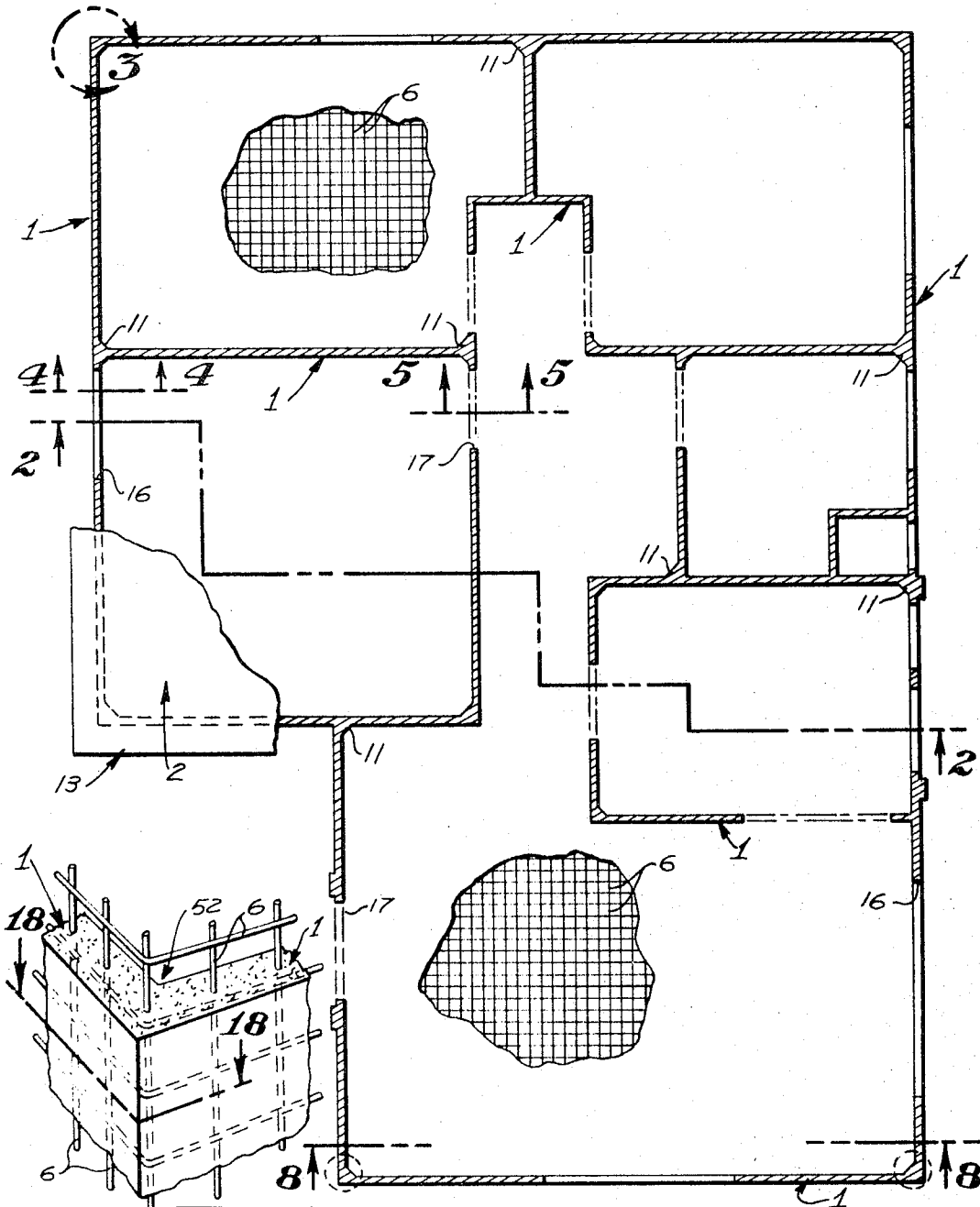


FIG. 17

FIG. 1

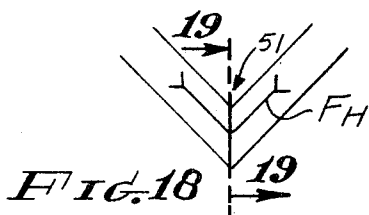


FIG. 18



FIG. 19

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4 Sheets-Sheet 2

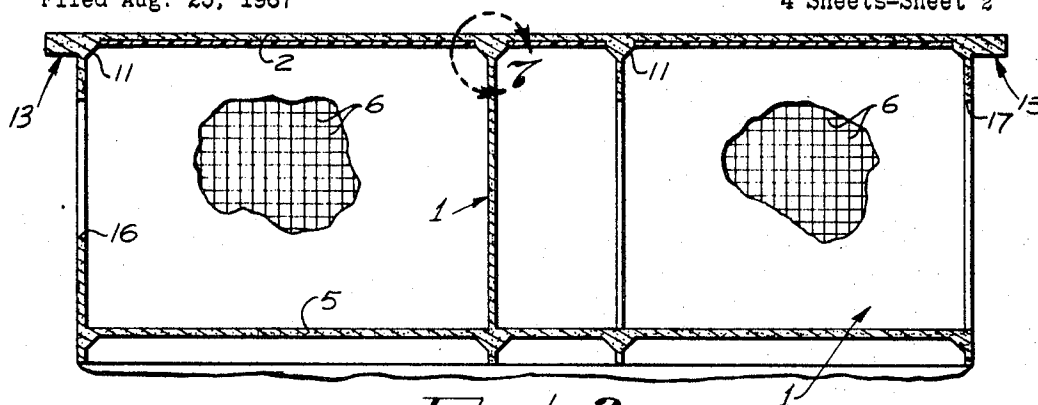


FIG. 2

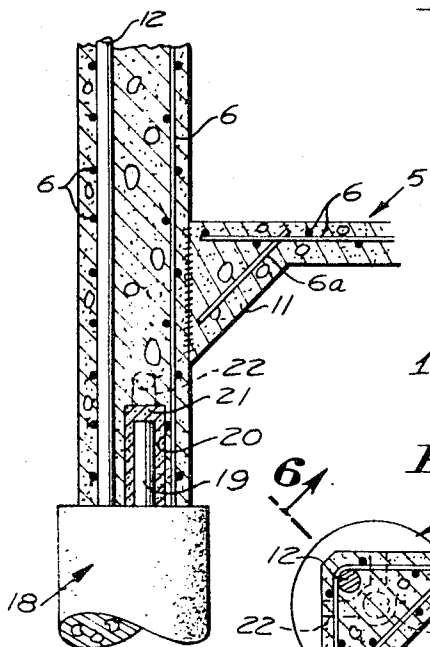


FIG. 3

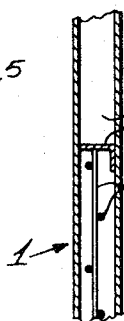


FIG. 4

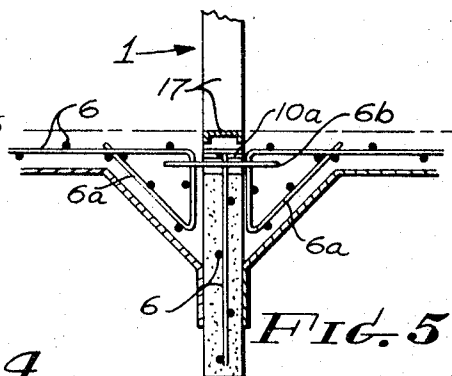


FIG. 5

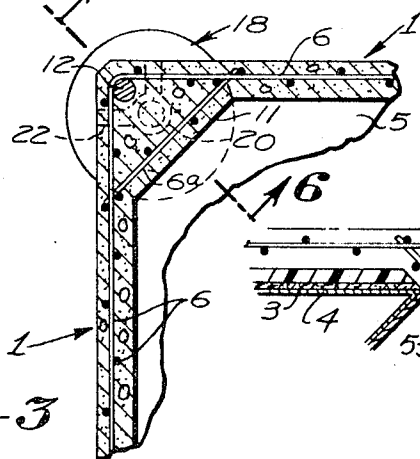


FIG. 6

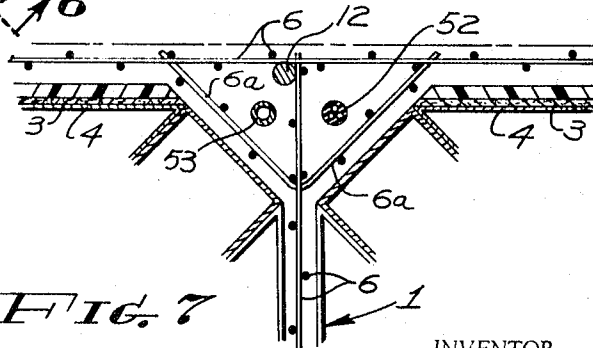


FIG. 7

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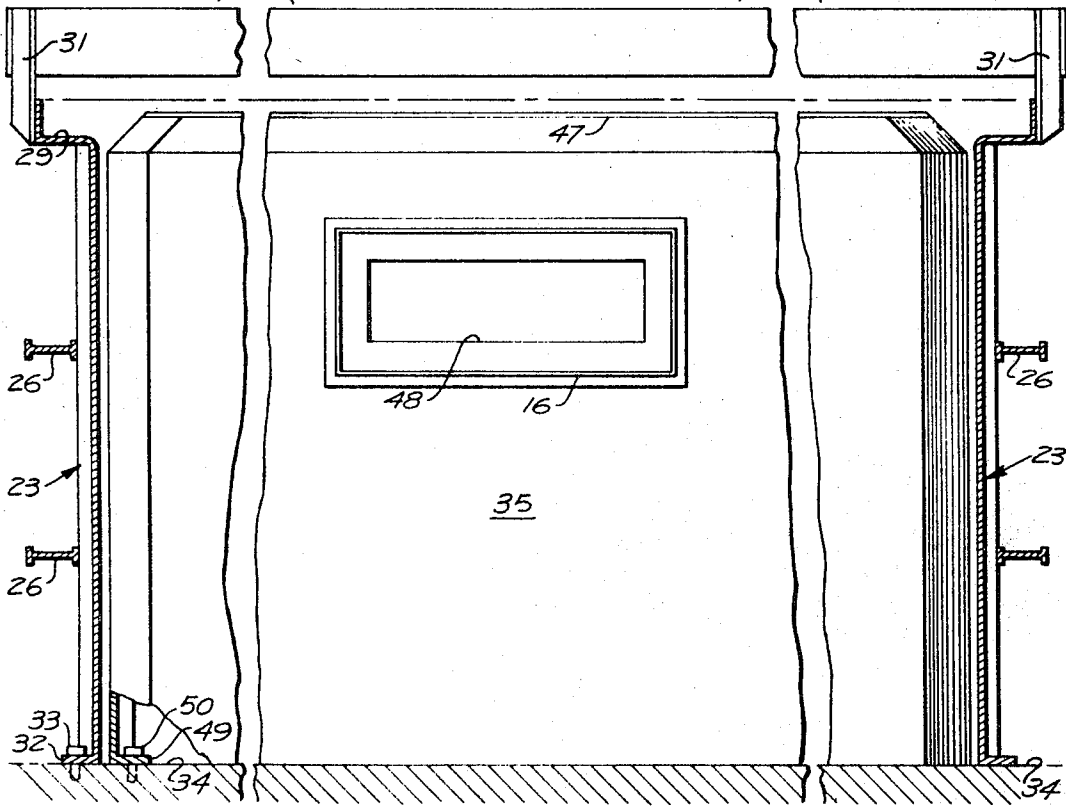
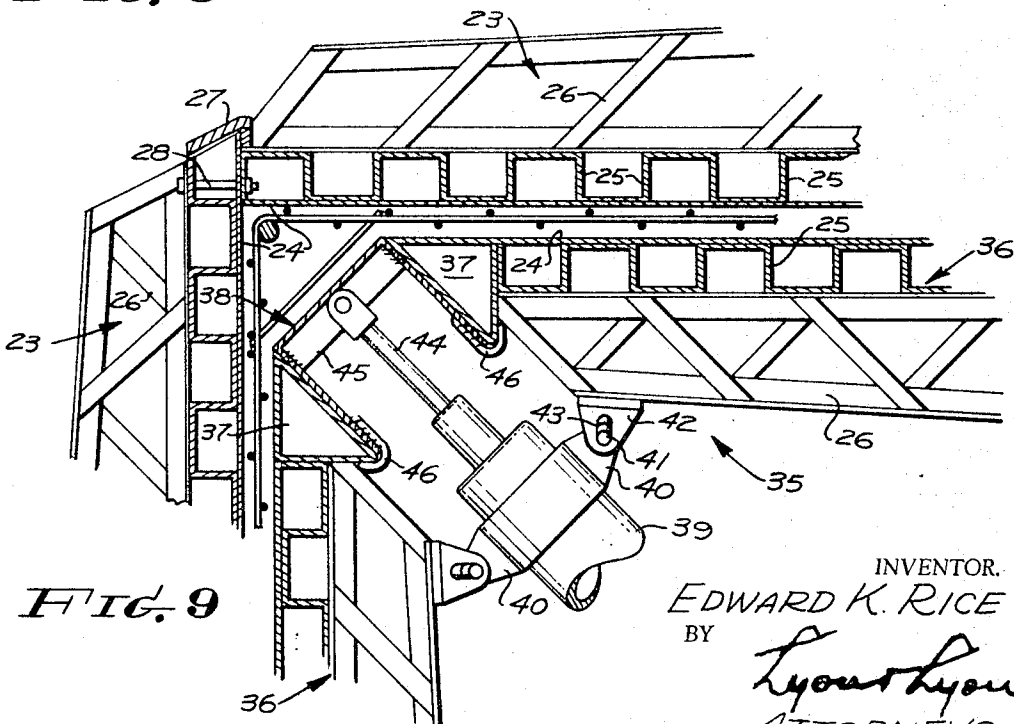
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4 Sheets-Sheet 3



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4 Sheets-Sheet 4

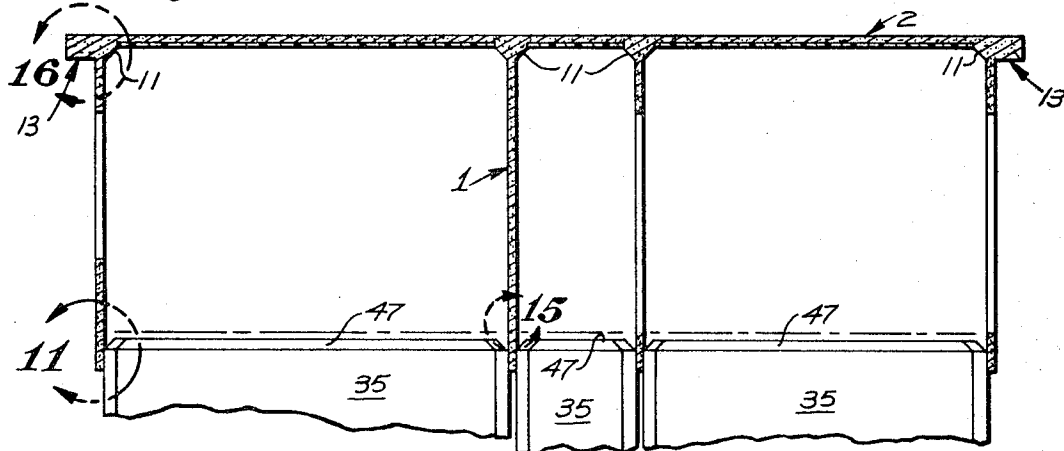


FIG. 10

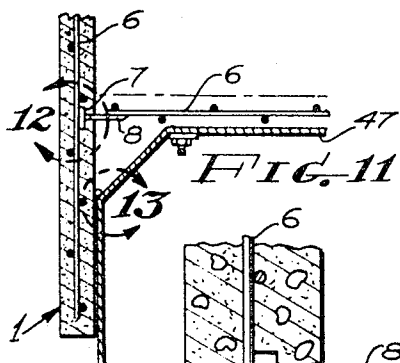


FIG. 11

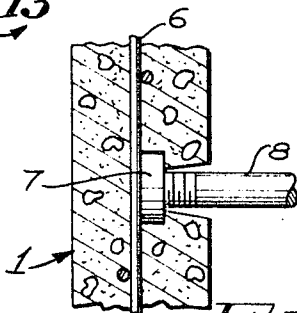


FIG. 12

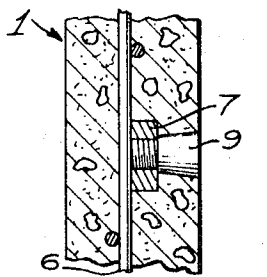


FIG. 14

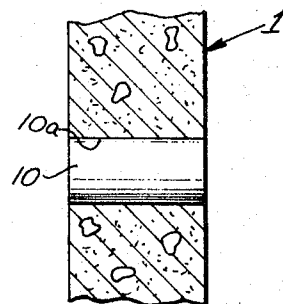


FIG. 15

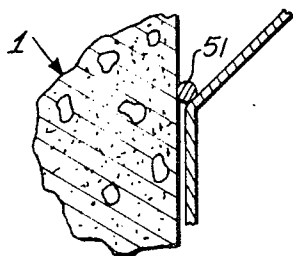


FIG. 13

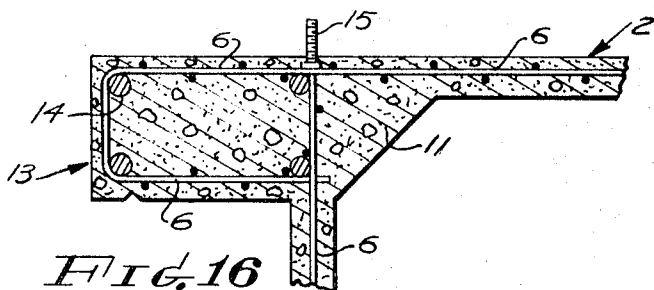


FIG. 16

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1

3,455,074

BUILDING STRUCTURE AND MEANS AND METHOD OF ITS MANUFACTURE

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Continuation-in-part of application Ser. No. 346,348, Feb. 20, 1964. This application Aug. 23, 1967, Ser. No. 662,602

Int. Cl. E04c 3/10, 5/08, 3/26

U.S. Cl. 52—223

13 Claims

ABSTRACT OF THE DISCLOSURE

A self-stressed reinforced concrete structure of a size suitable for human occupancy, and its means and method of manufacture. The structure utilizes expansive concrete and includes at least two adjoining walls forming an edge or corner junction, and containing a substantially continuous reinforcement network extending throughout the walls and stressed in tension by expansion of the concrete whereby the reinforcing holds the entire body of concrete including said junction in compression.

The method of manufacture involves the provision of forms to define the walls and junction of the structure, the placement of the reinforcement of a type which bonds to the concrete early in the expansive cycle of the concrete in the form of a network, the pouring of expansive concrete throughout the cavity provided by the forms before effective expansion occurs, then permitting the concrete to expand to place the reinforcement under tension and the concrete under compression.

The means of manufacture involves a cooperating set of forms arranged for manipulation on an underlying work surface to cast the structure, the forms including readily retractable interforms, and exterior forms, selected forms being releasable for movement relative to the underlying work surface to permit expansion of the concrete.

BACKGROUND OF THE INVENTION

This application is a continuation-in-part of my previous application, Ser. No. 346,348, filed Feb. 20, 1964, now abandoned, entitled, Building Structure and Means and Method of its Manufacture.

This invention utilizes an expansion concrete. Expansive concrete contains ingredients which cause the concrete to expand or grow during a critical period ranging from a few hours to several days. The expansion is used to stress internal reinforcing in tension while stressing the concrete in compression.

Examples of cement formulations which produce expansive concrete of the type suitable for use with the present method are found in Patents 3,155,526; 3,251,701; and 3,303,037 issued to Alexander Klein. It has been found, for example, by tests conducted by T. Y. Lin and A. Klein and reported in the A.S.I. Journal, Proceedings, vol. 60, No. 9, September 1963, pages 1187-1218, that concrete bodies of simple shape can be formed with highly expansive stressed concrete if the concrete is cast about reinforcing steel, and the concrete is properly bonded to the steel before appreciable expansion takes place. The resulting concrete body is held in compression by the reinforcing and the reinforcing is placed under tension.

Expansive concrete which is useful in the practice of the present invention may also be prepared from portland type cements described in Klein and Troxell's paper, entitled Studies of Calcium Sulfoaluminate Admixtures for Expansive Cements published in ASTM Proceedings, vol. 58, pages 986-1008 (1958), or it may be of the type developed by the French technologist Lossier and the affil-

2

ated French company, Poliet & Chausson. The Lossier-Poliet & Chausson cement are described in considerable detail by LaFuma in a paper entitled, "Expansive Cements," appearing in the proceedings of the Third International Symposium on the Chemistry of Cement, London, 1952, pages 581-597. LaFuma was of the opinion that Lossier-Poliet & Chausson cements did not contain calcium aluminosulfate but, rather, that they contained a mixture of salts (see page 584). The cements of the Klein patents contain a unique anhydrous compound, calcium aluminosulfate, whose formula can be expressed as $(\text{CaO})_4(\text{Al}_2\text{O}_3)_3\text{SO}_3$ or $(\text{CaO})_3(\text{Al}_2\text{O}_3)\text{CaSO}_4$. See also Halstead & Moore, J. Applied Chemistry, vol. 12, pages 413-417 (1962), and Fukuda, Journal of Ceramic Association of Japan, 69 (6) 1961.

These latter cements (hereinafter referred to as the "Klein cements") are preferred. They contain, in addition to calcium aluminosulfate, also lime (CaO) and calcium sulfate and it is this complex which is the effective expansive agent when cement containing it is mixed with mineral aggregate and water and the mixture is allowed to set and cure. This complex may be prepared separately and mixed with portland cement. For example, a clinker of this complex may be inter-ground with portland cement clinker, or the ground complex and ground cement clinker may be mixed together. Alternatively the feed to a cement kiln may be proportioned so that the end product is a complete portland cement containing the calcium silicates essential for portland cement and containing also the calcium aluminosulfate-CaO-CaSO₄ complex of the Klein patents. Other points to note are that the concrete may be shrinkage compensated (i.e., the concrete does not expand but neither does it shrink) or it may be expansive, that is to say, it undergoes a net expansion. Whether a cement is non-shrinking or expansive depends upon the proportion of expansive complex. For purposes of the present invention, expansive cements are employed.

The term "expansive" as used herein means a net expansion. Both the shrinkage compensated (non-shrinking) and the expansive cements of the Klein patents do, in fact, produce concrete which undergoes drying shrinkage, but this drying shrinkage is compensated, in the case of the shrinkage-compensated cement, or it is overcompensated in the case of the expansive cements. In the first case, expansion brought about by the calcium aluminosulfate-CaO-CaSO₄ complex compensates for the drying shrinkage and in the latter case it overcompensates and causes a net expansion. It is the latter variety of cement which is contemplated by this present invention and to which the word "expansive" is applied.

Although the Klein cements are preferred, as stated above, other expensive cements may be employed. The only requirement for cements to be used in the present invention is that they undergo a net expansion during curing and drying and that the expansion be of a character and magnitude such that it exerts a sufficient force on conventional steel reinforcement members that the latter are stretched and placed in tension thereby placing the concrete in compression.

This type of product has been referred to as chemically prestressed selfstressed concrete, as distinguished from mechanically prestressed or poststressed concrete. It is well known that concrete has extremely high strength in compression, but no appreciable strength in tension. This has brought about the use of pretensioned and post-tensioned structures which are so designed that under the intended loads, the concrete is held under compression by highly stressed steel tendons.

When under adequate compression, concrete is virtually impervious to water as well as other fluids unless, of course, they react chemically with concrete; whereas, conventional concrete has some degree of porosity and if un-

der tension is apt to contain cracks, increasing its porosity. Previous use of post-tensioned and pretensioned building structures has established the many advantages of such structures.

However, insofar as known, no attempts have been made to utilize expansive or selfstressed concrete in the construction of complex hollow three-dimensional structures such as buildings or units thereof.

SUMMARY OF INVENTION

This invention relates to building structures and means and method of constructing buildings and included in the objects of this invention are:

First, to provide a building structure or structural component thereof, a method of its manufacture, and a means of its manufacture, which utilizes expansive concrete to stress elastically an internal reinforcing network in tension not only throughout each wall, but particularly at the junctures or corners between the walls, so that the concrete throughout the completed structure is held in compression, and constitutes a single monolithic unit.

Second, to provide a building structure and a means and method of its manufacture as indicated in the preceding object, which may involve in its simplest embodiment two angularly related walls, or more complex embodiments involving walls and a ceiling or floor, or both, or even several rooms having doors, windows and other openings, as desired.

Third, to provide a building structure and a means and method of its manufacture as indicated in the preceding objects wherein the walls may be extremely thin not merely without loss in strength but actually with increased strength along the axes in which the major loads are imposed; for example, in the order of one-and-one-half to two-inches thick, as compared with comparable standard concrete walls which have a thickness in the order of six, eight and ten inches, thereby effecting a substantial saving in weight and in the cost of materials while producing a stronger structure.

Fourth, to provide a building structure and means and method of its manufacture wherein the resulting structure, though constituting a large building unit having several rooms, is sufficiently lightweight and amply strong to permit manufacture at a plant site and shipped to a point of use.

Fifth, to provide a means and method of manufacturing a building structure in which the forms required to define the structure are set in place with the reinforcing installed therebetween and, in particular, extended around the junctures between angularly related walls, and with window or door frames, if any, secured in place; thereafter the expansive concrete is poured and subjected to vibration to fill all the voids preferably before the concrete has undergone its initial set of established an effective bond with the reinforcing; then, after occurrence of initial set and initial bond to the extent that the concrete is self-supporting, but before significant expansion has occurred, at least some of the forms are moved clear of the concrete, or are released; whereupon the concrete is permitted to expand with minimal restraint by the forms, but under control of the reinforcing until the expansion cycle is completed or nearly so and the resulting structure is strong enough for removal from the forms and transported.

Sixth, to provide a building structure and means and method of its manufacture, in which the resulting structure may include a ceiling and floor as well as walls with appropriate window and door openings, all forming a monolithic unit, the walls functioning as beams of substantial depth, with the result that the building structure may be readily lifted and transported as a unit, and placed on appropriately placed piers, no other foundation being required.

Seventh, to provide a building structure and means and method of its manufacture, which is particularly applicable, although not limited to, the solution of lowcost housing without sacrifices in quality, the resulting structure be-

ing exceptionally strong, fire and earthquake resistant, easily maintained in a clean and sanitary condition, and capable of withstanding hard use, even abuse, all without sacrifice in appearance.

Eighth, to provide a means of manufacturing building structures or components thereof of the type indicated in the preceding objects which include wall casting forms supported vertically with respect to an underlying work surface in such a manner as to permit casting of the walls, then after initial set has occurred, selected forms being readily retractable to permit translatory movement of the walls relative to the work surface thereby to permit free expansion of the concrete except as restricted by its internal reinforcing.

Ninth, to provide a means of manufacturing building structures involving walls defining several rooms, which include wall casting forms, at least some of which are adapted for translatory movement with respect to an underlying work surface, and which in particular, include forms defining the interior surfaces of each room, these forms being especially arranged for rapid constriction away from the wall surfaces.

DESCRIPTION OF FIGURES

FIGURE 1 is a substantially diagrammatical, plan view of a building structure produced by the method herein disclosed with its walls shown in cross section.

FIGURE 2 is a substantially diagrammatical, transverse, sectional view taken through 2—2 of FIGURE 1.

FIGURE 3 is an enlarged, fragmentary, sectional view taken within circle 3 of FIGURE 1.

FIGURE 4 is an enlarged, fragmentary, sectional view taken through 4—4 of FIGURE 1, prior to pouring the concrete in order to indicate the forms and the reinforcing.

FIGURE 5 is an enlarged, fragmentary, sectional view taken through 5—5 of FIGURE 1, prior to pouring the concrete in order to indicate the forms and the reinforcing.

FIGURE 6 is an enlarged, fragmentary, sectional view taken through 6—6 of FIGURE 3.

FIGURE 7 is an enlarged, fragmentary, sectional view taken within circle 7 of FIGURE 2, prior to pouring the concrete in order to indicate the forms and the reinforcing.

FIGURE 8 is a fragmentary, partial sectional, partial end view showing the exterior and interior forms employed in the manufacture of the building structure, the view being taken substantially along the line 8—8 of FIGURE 1.

FIGURE 9 is an enlarged, fragmentary, sectional view showing confronting corners of the interior and exterior forms corresponding to the region of circle 3 in FIGURE 1, and showing the reinforcing in place.

FIGURE 10 is a substantially diagrammatical, transverse, sectional view similar to FIGURE 2, showing the upper portions of the interior forms and illustrating one method by which the floor slabs may be cast.

FIGURE 11 is an enlarged, fragmentary, sectional view taken within circle 11 of FIGURE 10.

FIGURE 12 is a further enlarged, fragmentary, sectional view taken within circle 12 of FIGURE 11.

FIGURE 13 is a still further enlarged, fragmentary, sectional view taken within circle 13 of FIGURE 11.

FIGURE 14 is a fragmentary, sectional view similar to FIGURE 12 showing the temporary plug employed to cast a stud-receiving hole.

FIGURE 15 is a fragmentary, sectional view taken within circle 15 of FIGURE 10, showing a typical plug cast in a wall slab to form an aperture for the reception of floor-slab reinforcing.

FIGURE 16 is an enlarged, fragmentary, sectional view taken within circle 16 of FIGURE 10 showing the construction of the eave girder.

FIGURE 17 is a fragmentary, perspective view illus-

trating a typical corner juncture or between two walls, a wall and the ceiling, or wall and an integral floor.

FIGURE 18 is a diagrammatical view taken in the plane 18—18 of FIGURE 17.

FIGURE 19 is a diagrammatical view taken in the plane 19—19 of FIGURE 18.

SPECIFICATION

A typical building structure forming a part of this invention includes wall slabs 1 formed of reinforced concrete and constituting both the exterior and interior walls of the building structure. The wall slabs 1 are united by a roof-ceiling slab 2 also formed of reinforced concrete. As will be brought out in more detail hereinafter, the wall slabs 1 and roof-ceiling slab 2 are cast simultaneously so as to form a monolithic unit, and expansive concrete together with specially arranged reinforcing is employed so that all of the concrete in the resulting structure is under compression and the reinforcing is under tension.

Within the rooms of the building structure the roof-ceiling slab 2 is provided with a layer of insulation 3, preferably a rigid, foamed, plastic material protected on its underside by a coating 4, such as a plaster coating. Each room of the building structure is provided with a floor slab 5 of reinforced concrete joined to the wall slabs 1 near their lower extremities.

The slabs though formed of reinforced concrete are relatively thin; they need be no greater than one and three-quarters inch in thickness. The reinforcing is preferably formed of high strength steel wire mesh 6 arranged in a gridwork pattern, as indicated within the sectional areas in FIGURES 1 and 2. The gridwork pattern is also employed in the roof-ceiling slab 2 as well as the floor slabs 5.

In order to connect the reinforcing within the floor slabs 5, reinforcing tie nuts 7 are welded to the reinforcing gridwork 6 of the wall slabs 1 at appropriate locations, and are arranged to reinforce tie studs 8 which overlap or are joined to the reinforcing within the floor slabs 5.

Initially, plugs 9 cover the tie nuts 7, as shown in FIGURE 14, so that the reinforcing tie studs 8 may be inserted after the roof-ceiling slabs and wall slabs 1 have been cast. Similarly, through plugs 10 are inset in appropriate locations so that the floor reinforcing gridwork in the different rooms may be connected through the wall slabs 1.

Most of the internal corners between the roof-ceiling slabs 2 and wall slabs 1, between angularly related wall slabs 1, and between the floor slabs 5 and wall slabs 1 are provided with relatively large corner fillets 11, as shown in FIGURES 1, 2 and 3, which form an integral part of the slabs. The corner fillets 11, especially those forming the outside corners of the building structure and those joining the roof-ceiling slab 2 and wall slabs 1, are provided with reinforcing bars 12. The reinforcing gridwork 6 is bonded to the bars 12, or, is extended around the bars or adjacent sections of the gridwork are overlapped.

The roof-ceiling slab 2 projects horizontally beyond the external wall slabs 1 to form eave girders 13 extending around the entire periphery of the house. Each eave girder 13, shown best in FIGURE 16, is provided with reinforcing bars 14. As it is intended that the building structure be capable of being lifted and transported, the roof-ceiling slab is provided with lifting studs at appropriate locations anchored firmly to the reinforcing therein.

The various openings in the building structure, such as the window and door openings, are refined by rigid metal frames 16 and 17, respectively, as indicated more particularly in FIGURES 4 and 5. These frames may be formed of angle iron or channel iron and the reinforcing gridwork is welded or otherwise attached thereto. As a consequence, the wall slabs 1 function as beams having great rigidity in vertical planes. The building structure is there-

fore extremely rigid and is capable of being supported at a minimum of points; for example, the building structure may be supported solely at its corners, such as the five corners shown in FIGURE 1.

In place of a foundation in the usual sense, vertical reinforced concrete piers 18 are utilized. Prior to positioning the building structure, shafts of appropriate depth are bored in the ground and the piers 18 cast therein. The piers 18 include upwardly extending corner posts 19 and the corners of the building structure are provided with mating sockets 20. Grouting 21 applied through filler ports 22 anchor the building structure to the piers 18, as shown in FIGURE 6.

One form of the means for manufacturing the building structure includes exterior forms 23, which include plates 24 preferably formed of sheet metal. The plates 24 are backed by vertically extending, stiffening ribs 25 which may be formed by folding the sheet metal, and the ribs in turn are backed by horizontal girders 26, as shown in FIGURE 9.

The exterior forms 23 are joined at the corners by interlocking means 27, as shown in FIGURE 9, and are secured together by separable fasteners 28, such as bolts and nuts. The exterior forms 23 are provided at their upper margins with horizontal and upward extensions to provide eave forms 29. To restrain the upper margins of the exterior forms 23 against spreading, opposed exterior forms are connected by bridging beams 30 having depend-hangers 31. The lower margins of the exterior forms 23 are provided with flanges 32 which are joined by separable fasteners 33, such as bolts and nuts, to an underlying supporting slab 34.

An interior form 35 is provided for each room of the building structure, as shown in FIGURES 8 and 9. Each interior form comprises four side forms 36, each including plates 24, stiffening ribs 25, and girders 26, similar to the exterior forms 23. In addition, the ends of each side form 36 are provided with beveled or triangular corner posts 37. The corner posts of adjacent forms define therebetween a slot which tapers slightly in an outward direction with respect to the forms. Fitted within each such space is a corner form 38 which may be channel-shaped with slightly diverging side walls. The corner form 38 is shaped so as to cast a corner fillet 11.

The side forms 36 and corner forms 38 may be attached by separable fasteners, such as bolts and nuts, so that side forms 36 may be collapsed inward a limited distance by inward movement of the corner forms 38.

For more rapid displacement of the corner forms 38 a cylinder 39 having side yokes 40 may be connected by pins 41 to brackets 42 having slots 43 therein. A piston rod 44 extends from each cylinder 39 and is joined to a cross bar 45 provided in the corresponding corner form 38. Hook elements 46 are attached to the corner forms 38 so as to limit outward movement thereof and to interlock with the side forms 36. The piston means may be employed in each of the four corners of the interior forms 35 or may be disposed in diagonal corners, and in some cases need be provided in only one corner, depending upon the shape of the room to be cast by the form. Mounted on the top of the side forms 36 are ceiling casting forms 47. The upper margins of the interior forms 35 are beveled to form fillets 11.

As it is desirable to enter the interior forms 35, access openings 48 are provided in the regions of appropriate window and door openings of the building structure.

Prior to casting the roof-ceiling slab 2 and wall slabs 1 of the building structure, the window and door frames 16 and 17 are secured in place between the forms and frame the access openings 48. The sides of the interior forms 35 are provided at their lower extremities with internal flanges 49 attached by separable fasteners 50, such as bolts and nuts, to the underlying or supporting slab 34.

As set forth more fully in the previously listed Klein Patents 3,155,526; 3,251,701 and 3,303,037, expansive

concrete may be formulated to obtain the desired degree of expansion, from an expansion just sufficient to compensate for the usual shrinkage which occurs in conventional concrete, to a substantial expansion sufficient to place steel embedded therein under the desired degree of tension. Expansion begins immediately on mixing the concrete with water; however, effective or constrained expansion begins as the initial set occurs and an initial bond develops between the concrete and the reinforcing.

To prepare for pouring the concrete, the interior forms 35 are secured in place progressively and reinforcing as well as the window and door frames 16 and 17 are set in place, the external forms 23 are secured in position. Blankets of insulation 3 are placed over the interior forms 35, then reinforcing for the roof-ceiling slab 2 is positioned.

The expansive concrete is then poured. Vibrators are used to ensure flow of concrete between the forms and under the window frames 16. All of the wall slabs 1 and the roof-ceiling slab 2 are thus formed as one monolithic casting.

During the initial period of effective expansion and when the concrete has, with the aid of the reinforcing, developed sufficient strength to be self supporting, the interior and exterior forms 35 and 23 are loosened with respect to their supporting surface 34, so that as the concrete continues to expand, the forms are free to move in compliance therewith. To aid such movement, lubricant may be provided under the forms. In this respect a coating of free sand may serve as a lubricant or friction-reducing means. The reinforcing plays an important role in controlling the expansion of the concrete with the result that, when cured, the concrete is subjected to predetermined optimum compression loads and the reinforcing is under tension without its expansion exceeding the elastic limit of the steel.

By reason of the controlled expansion of the concrete, the interior forms 35 tend to strip automatically from the concrete so that the building structure may be lifted from the forms. Thus it is not necessary in all instances to utilize the corner-form retracting means shown in FIGURE 9, or to separate the corner forms 38 from the side forms 36 if these members are bolted together. However, by collapsing the forms slightly, freedom of movement of the cast building structure is facilitated.

The building unit thus formed may be stacked on similar building units to produce a multiple-story structure. If a single story structure is desired, the ceiling form may be used as a floor form by raising the building unit utilizing the lifting studs 15 until the lower margins of the wall slabs 1 are near the upper extremities of the interior forms 35, as shown in FIGURE 10. The building structure is preferably raised by jacks, not shown, so that it may be held steady in this elevated position to permit the casting of the floor slabs 5.

Inasmuch as the concrete has expanded free of the interior forms 35, space exists between the forms and the concrete as shown in FIGURE 13. This space is closed by sealing strips 51 formed of rubber or the like. As shown in FIGURE 5, the floor slab reinforcing gridwork 6 is placed in each room over the interior forms 35 and reinforcing ties 6b are thrust through the openings 10a cast in the lower portions of the wall slabs 1, and attached to or placed in overlapping relation with the reinforcing 6. The floor slabs 5 are then poured and their upper surfaces troweled smooth.

The expansive concrete mixture used to pour the floor slab 5 is formulated so as to have reduced expansion or extra reinforcing 6 is employed to provide extra constraint so that the slight expansion which does occur does not place damaging lateral stress on the surrounding walls of the previously cast structure. Interior walls such as indicated in FIGURE 7, are subjected to opposed or self-cancelling expansion forces generated by the floor slabs in adjacent rooms and thus prevent damaging expansion of the floor slabs. The external walls may be backed ex-

ternally by suitable abutments, not shown, so as to contain the floor slabs.

As an alternative to the use of the upper portions of the interior forms 35 to cast the floor slabs 5, the building structure may be lifted completely from the interior forms 35 and set over other interior forms identical to the telescoping portions of the forms shown in FIGURE 10. In this case the original forms are freed at an earlier stage for reuse, and leakage between the wall slabs 1 and the forms is immaterial. In any case, the substitute forms may be made slightly larger to compensate for the previous expansion of the concrete.

Once the building structure is completed by the casting of the floor slabs 5, it is a particularly rigid structure which may be readily transported while suspended from the lifting studs 15, or while resting on an underlying surface. Due to the fact that the concrete is under compression, expansion cracks do not develop; so that the exterior walls and roof are impervious to water and need no further covering.

Because the building structure is formed entirely of concrete, there is no need to provide an open space under the floor slab 5. Thus the region under the floor slab may be sealed by covering the lower margins of the exterior side walls. In doing so, the region under the floor slab 5 forms a large plenum which may be utilized as a part of a hot air or cool air distributing system from an appropriate heater or air conditioner. In this case, of course, the underlying ground is given a dust-inhibiting coating.

It should be noted that prior to casting the building structure, appropriate conduits 52 and 53 for electricity, water, or gas are placed in the regions which later become the corner fillets 11, as suggested in FIGURE 7.

It should be observed that by providing a relatively large and rigid peripheral eave girder, the degree of restraint of the roof-ceiling slab 2 is increased, which allows some latitude in the expansive characteristics of the concrete mixture without causing expansion beyond the design limits.

It should be further observed that, if desired, the proportion of the expansive ingredient in the concrete may be such that the internal reinforcing, including the reinforcing within the roof-ceiling slab girders, as well as the external constraint afforded by the forms, may prevent any significant expansion of the concrete, yet assuring the proper compression forces within the concrete. In such case, means, such as shown in FIGURE 9, for collapsing the internal forms is desirable.

The utilization of chemically prestressed concrete eliminates cracks and reduces materially the amount of concrete and steel reinforcement required, it being noted that a nominal wall thickness in the range of one and one-half to two inches is feasible; whereas comparable conventional reinforced concrete walls range from 6 to 10 inches. Also, the prestressed condition ensures that the roof and walls are watertight without use of roofing or special coatings.

It is essential in order to reinforce the concrete properly, to place all parts of the concrete under proper constraint and that the reinforcing 6 be properly distributed. A simple essentially two dimensional structure such as a slab having no significant thickness poses little problem. A simple gridwork of reinforcing extending to the boundaries of the slab, can establish the proper constraint.

The problem becomes much more complex when the structure assumes the form of a hollow three-dimensional shape such as that of a building or unit thereof with several rooms. The juncture between two angularly related walls, or between a wall and ceiling or floor and the more complex junctures at the corners between two walls and the ceiling must be so constrained as to maintain the integrity and strength of the concrete at such juncture.

Proper constraint is attained very effectively at a wall-

to-wall or a wall-to-ceiling juncture by extending the reinforcing gridwork 6 around the juncture or corner as shown in FIGURES 3, 7, 9 and 16. The reinforcing rod 12 improves the strength of the corner; however, proper constraint can be attained by the gridwork alone. Furthermore, the presence of the fillet 11 is not required to effect proper constraint, but greatly increases the column strength. In order to ensure that the concrete within the fillet be properly constrained, it is desirable to place a diagonal gridwork 6a, as indicated in FIGURES 3, 5, 6 and 7, or at least to provide horizontal reinforcing wires.

As stated above, it is an important object of the present invention to provide a monolithic concrete structure of a size suitable for human habitation and which consists of at least two slabs which abut one another along an edge to form a junction, and to ensure that this junction is strong and is resistant to cracking during usage after the structure has been put in place and while it is being lifted from the place of fabrication and transported to the intended site. The invention of course, relates to more complex monolithic structures which include two or more adjoining wall sections and a ceiling and/or a roof slab adjoining the walls. However, the invention in its basic essentials may be illustrated by a simple two-slab structure such as shown in FIGURES 17, 18 and 19.

FIGURE 17 is a fragmentary perspective view of a junction 54 between two slabs 1. For example, FIGURE 17 depicts a corner formed by two walls. This corner is shown without a fillet but it may have one as shown in FIGURE 3 of the drawing. The two walls 1 and the corner 54 are cast as a single monolithic unit as described above and this unit contains a reinforcing mesh 6 which is continuous throughout the length and height of each wall. Moreover, this continuity extends without interruption around corner 54. As stated, this reinforcement mesh is placed in the form before the concrete is poured and it is of steel or other material which stretches in response to expansion of the concrete during curing and drying. The expansion of the concrete is isotropic, that is, it occurs equally in all directions unless restrained. Consequently, the mesh 6 is placed under tension vertically and horizontally and in all places the concrete is placed in compression, both horizontally along each wall and vertically as shown by the force diagrams of FIGURES 18 and 19. In these diagrams F_h signifies a horizontal compressive force and F_v signifies a vertical compressive force. By reason of the continuity of the mesh 6 at the corner 54 as well as along the length and height of the walls 1, the concrete structure is placed uniformly in compression at all points with no sharp break or discontinuity in compression at any point such as at the corner 54. The compression is tri-axial; it is directed along the length of each wall 1 and it is also directed along the height of the walls and the corner 54. Of course, the compressive force exerted by a reinforcing rod or wire under tension will diminish with the distance of the concrete from the rod or wire. For example, it would be less at the surfaces of the slabs 1 than at interior locations adjacent the reinforcement mesh 6. However, even this effect may be diminished by making the walls thin or by using more or larger reinforcement members.

It is not essential, although it is preferred, to have each horizontal reinforcement member (or most of them) extend continuously from one wall to the next as in the case of the horizontal rods 6 shown in FIGURE 3. Such continuity may be achieved by bending rods or wires around the corners or edges or by welding the ends together. Practical continuity may also be achieved by providing an overlap of rods or wires or by placing them closely adjacent one another, e.g., in abutting relation. In such cases (overlap or abutting relationship) each small segment of steel is under tension and it holds the neighboring concrete in compression. Accordingly, the desired result of isotropy of compression (not ideal iso-

tropy, but practical uniformity of compression without sharp discontinuities) is assured.

As stated above, a corner such as that shown at 52 may also have vertical reinforcing bars such as shown at 12 in FIGURES 3 and 6.

It is preferred that the concrete forming a juncture between two walls, or wall and ceiling and the adjacent regions be poured at one time or at least before initial set has occurred in the first poured expansive concrete. That is, should any appreciable expansion of the first poured concrete at one side of a junction occur ahead of the expansion of the last poured concrete at the other side of the junction, a discontinuity may occur, the conditions indicated in FIGURES 17, 18 and 19 may not be obtained and the juncture may be severely weakened.

It is preferred that the entire length of a juncture be poured at one time or at least before initial set of the first poured concrete has occurred; however, a hiatus in the pouring of the expansive concrete transverse to a juncture is not as serious as a hiatus in the pouring of the expansive concrete along opposite sides of a juncture. For example, more delay may be tolerated between pouring the lower half of the walls and pouring the upper half of the walls, than can be tolerated between pouring the walls and pouring the ceiling.

The best and most uniform stressing of the concrete in compression and reinforcing steel network or gridwork in tension is obtained if all of the concrete is poured before initial set has occurred in the first poured concrete. The interval between mix and initial set and initial bond between the concrete and the reinforcing may be lengthened or shortened by changing the formulations of the cement and its expansion producing ingredients. An optimum period is about 5 hours; however, this period may be increased to 12 hours or longer.

As indicated previously, the monolithic, isotropically compressed structures thus described can be made with thin walls, therefore they can be light in weight. This lightness of weight and uniform strength allow the structures to be lifted and transported from a construction site and placed upon foundations or piers or upon other similar previously deposited structures without cracking or breakage. The concrete buildings so provided are strong and much less pervious to moisture than ordinary reinforced concrete.

It should be noted, that this is accomplished without exposure of any reinforcing. By contrast, if pre-tensioning or post-tensioning techniques were used with conventional concrete, the reinforcing or tendons would need to protrude from the edges of each wall; that is, in two directions at each corner. This would be prohibitively costly and impractical, particularly with walls in the order of only two inches thick.

While particular embodiments of this invention have been shown and described, it is not intended to limit the same to the exact details of the constructions set forth.

I claim:

1. A method of producing a monolithic, concrete dwelling-type structure of a size suitable for human occupancy and having at least two adjoining slabs in intersecting planes forming an edge or corner junction, said structure being integral and monolithic and being formed of chemically expansive portland cement concrete reinforced by a substantially continuous reinforcement network extending throughout said slabs including said junction, said reinforcement network being in tension and acting to hold the entire body of concrete including said junction in compression, said method comprising the following steps:

(a) erecting and relatively securing an interior form and an exterior form spaced apart to provide slab cavities forming a junction, and installing a substantially continuous reinforcement network within said cavities, said reinforcement network extending around said junction, the material of such reinforcement network being such that chemical expansion of con-

11

- crete poured into said cavities and embedding the network will place the network in tension;
- (b) filling said cavities with a portland cement type concrete which undergoes chemical expansion during curing of the concrete and which is effective to place the reinforcement network in tension thereby causing said concrete to be placed in compression;
 - (c) allowing the concrete to set sufficiently to develop an initial bond to said reinforcement network;
 - (d) relieving at least said exterior form of securement whereby it can move laterally in response to expansion of said concrete;
 - (e) and causing said concrete to further expand and completely set.
2. A method, as defined in claim 1, wherein vertical walls and a ceiling wall are formed, characterized by:
- (a) placing a horizontal floor form within said vertical walls and below said ceiling wall;
 - (b) placing a reinforcing gridwork over said horizontal form;
 - (c) pouring chemically expansive concrete over said form to embed said gridwork and fill the area defined between said vertical walls;
 - (d) and controlling expansion of said concrete floor within the limits permitted by said wall members.
3. A method of manufacturing a multiple room building unit, each room having walls and ceiling, said method characterized by:
- (a) preparing an underlying work surface;
 - (b) erecting upright forms on said surface for lateral movement thereon and initially positioning and fixing said upright forms in relative position to define the interior and exterior walls of said multiple room building unit;
 - (c) placing ceiling forms on those wall forms defining the interior surfaces of the walls of each room of said building unit and placing a constraining gridwork, capable of elastic elongation when tensionally stressed, between confronting wall forms and over said ceiling forms;
 - (d) filling the spaces between confronting wall forms and covering said ceiling forms with chemically expansive concrete and thereby completely embedding said reinforcing constraining gridwork in said concrete in intimate contact therewith;
 - (e) permitting the expansive concrete to undergo an initial set sufficient to effect an initial bond with said constraining gridwork while said concrete is constrained by said forms;
 - (f) and releasing selected forms for movement relative to said work surface thereby to permit further but restricted expansion of said concrete and corresponding displacement of the rooms formed thereby, under control of said constraining gridwork.
4. A method, as defined in claim 3, in which certain of said forms have beveled corners to form filleted corners between angularly related walls and which is further characterized by:
- (a) extending constraining means across said filleted corners;
 - (b) filling said filleted corners with expansive concrete;
 - (c) and permitting restricted expansion of the concrete in said filleted corners under control of said constraining gridwork and constraining means in concrete with the concrete elsewhere between said walls and on said forms until said concrete is cured; thereby to place said corner forming concrete under compression and said constraining means as well as said constraining gridwork under tension.
5. A method as defined in claim 3, which is characterized by the further steps of:
- (a) placing a floor form within the area defined by the walls of each room;
 - (b) placing an expansion restraining gridwork over said form;

12

- (c) pouring a floor of chemically expansive concrete to cover said gridwork;
 - (d) and controlling the expansion of said floor concrete within the limits imposed by said wall members.
6. A method, as defined in claim 3, which is further characterized by:
- (a) placing column bars along the corner junctures defined by said wall forms;
 - (b) and wrapping said constraining gridwork right angularly about said column bars.
7. A method, as defined in claim 6, further characterized by:
- (a) lifting said multiple room building as a unit relative to said forms;
 - (b) positioning floor forms within each room;
 - (c) placing a constraining gridwork within each room over each floor form;
 - (d) pouring expansive concrete over each of said floor forms to form a floor slab;
 - (e) utilizing said constraining gridwork, at least in part, to control expansion of the concrete in said floor slab, and confine said expansion to dimensions determined by the surrounding walls of said building unit.
8. A building structure, comprising:
- (a) at least two wall members joined together to form a juncture;
 - (b) a concrete expansion constraining and reinforcing gridwork of metal filaments under tension within their elastic limit, said gridwork being embedded within and extending throughout said members and around the corner constituting said juncture between said members;
 - (c) and a monolithic body of cured chemically expanded self-expanding concrete forming said members and the juncture therebetween, said concrete body being intimately bonded to said metal gridwork throughout the same and held thereby under compression and thereby prevented from expanding fully.
9. A building structure, as defined in claim 8, which further comprises:
- (a) a fillet located within the corner formed by said juncture, said fillet including metal constraining means under tension within its elastic limits extending diagonally between adjacent wall members inwardly of said juncture, and cured chemically self-expanding concrete, integral with the concrete within said wall members, and held in compression by said metal constraining means.
10. A building structure, as defined in claim 8, wherein:
- (a) at least four of said wall members are disposed vertically to define the sides of a room and form junctures joining the sides thereof;
 - (b) a fifth wall member is disposed horizontally and is joined to said vertical wall members to form additional junctures;
 - (c) said gridwork extends throughout said vertical and horizontal walls and the junctures therebetween;
 - (d) said monolithic body of cured chemically self-expanding concrete forming said wall members and said junctures is intimately bonded to said gridwork throughout the same, the entire body of concrete being held thereby under compression.
11. A building structure, as defined in claim 10, which further comprises:
- (a) a second horizontal wall of cured chemically self-expanding concrete disposed between said vertical walls;
 - (b) and an expansion constraining gridwork under tension within its elastic limits distributed throughout said second horizontal wall and intimately bonded throughout to said concrete, said gridwork and the surrounding wall holding said concrete under compression.

13

12. A building structure, as defined in claim 10, wherein:

(a) said vertical wall members form beams of substantial depth and are capable of bridging between selected points of suspension or support while maintaining said gridwork under tension and said concrete under compression.

13. A building structure, as defined in claim 12, wherein:

(a) said vertical walls having a thickness approximately two inches.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,455,074

July 15, 1969

Edward K. Rice

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 11, lines 64 and 65, "concrete" should read -- concert --.

Signed and sealed this 17th day of March 1970.

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.

Commissioner of Patents