Sept. 8, 1970 W. C. MEAD 3,527,002

MODULAR BUILDING STRUCTURE

Filed Feb. 15, 1968 7 Sheets-Sheet 1

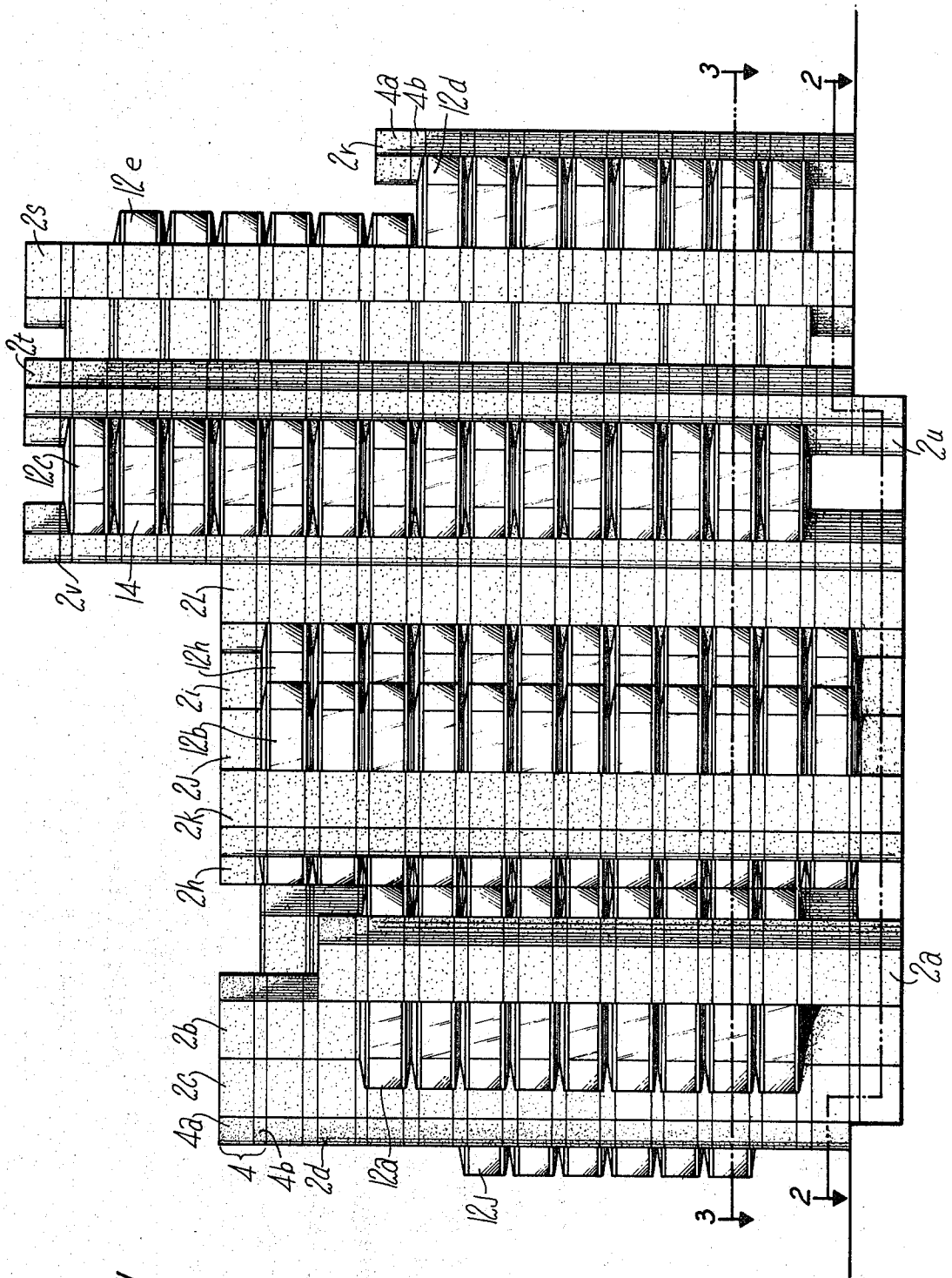


FIG. 1

INVENTOR.
WILLIAM C. MEAD

BY
Fishman and VanKirk
ATTORNEYS

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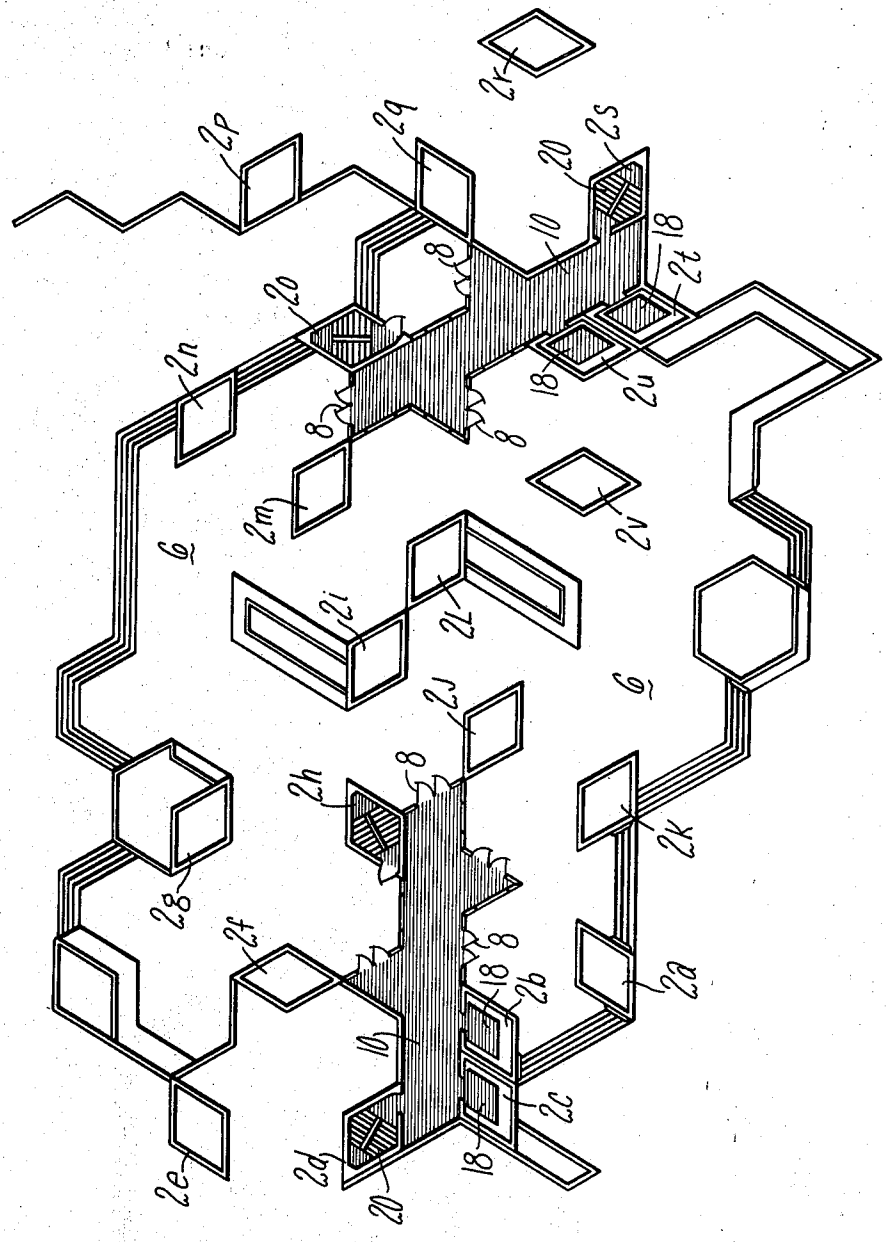


FIG. 2

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MODULAR BUILDING STRUCTURE

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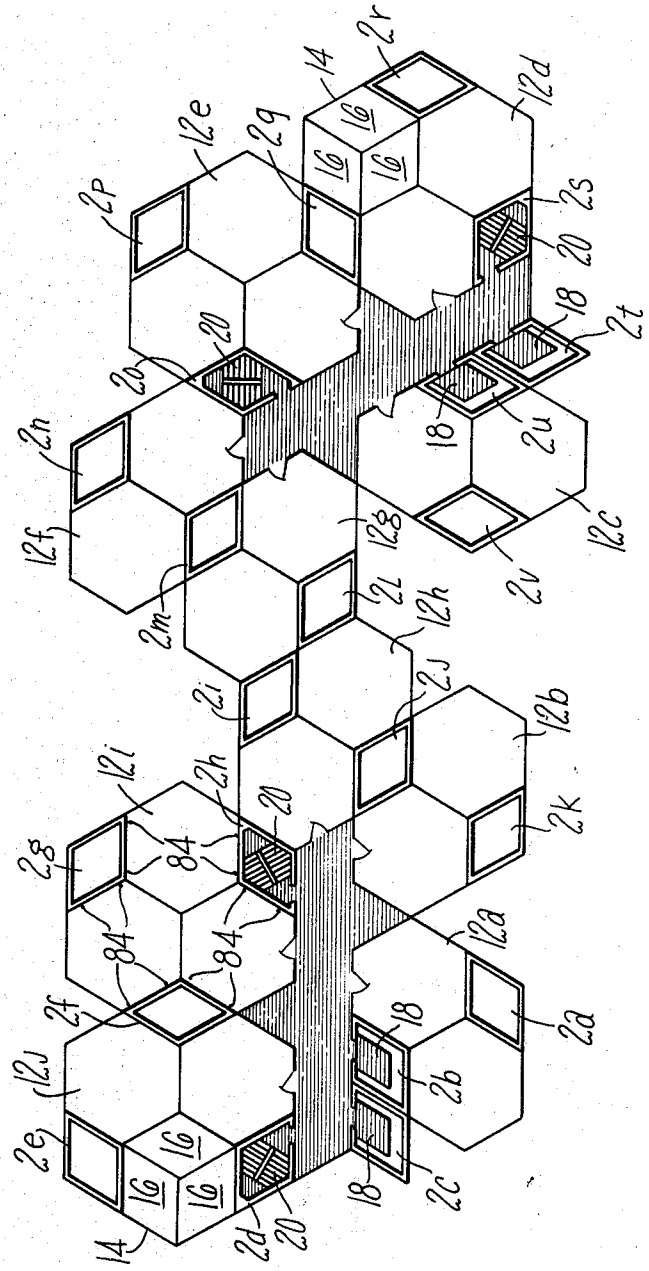


FIG. 3

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FIG. 4

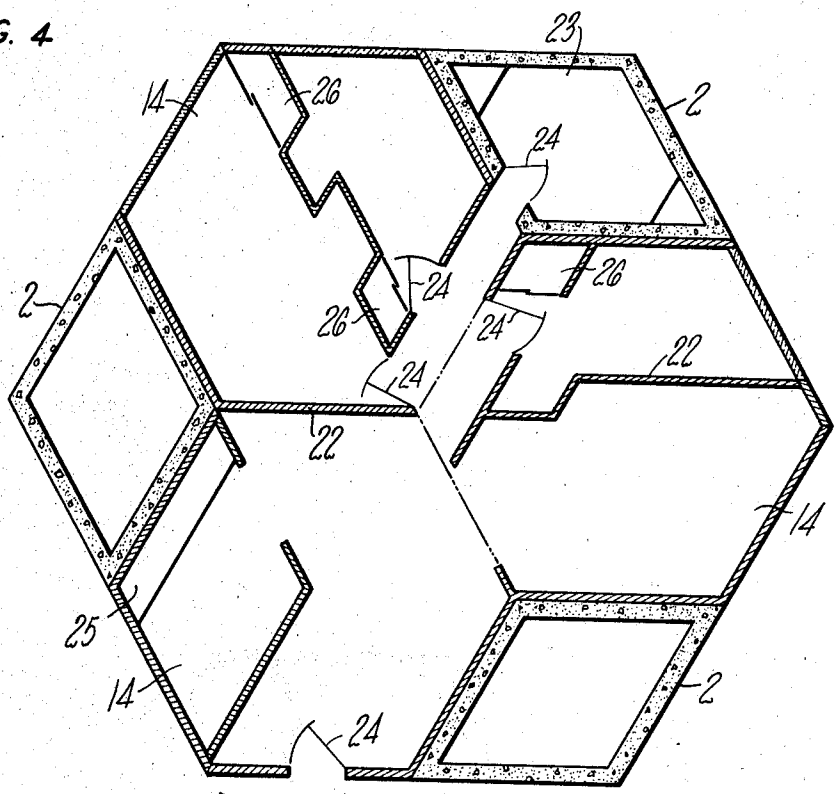
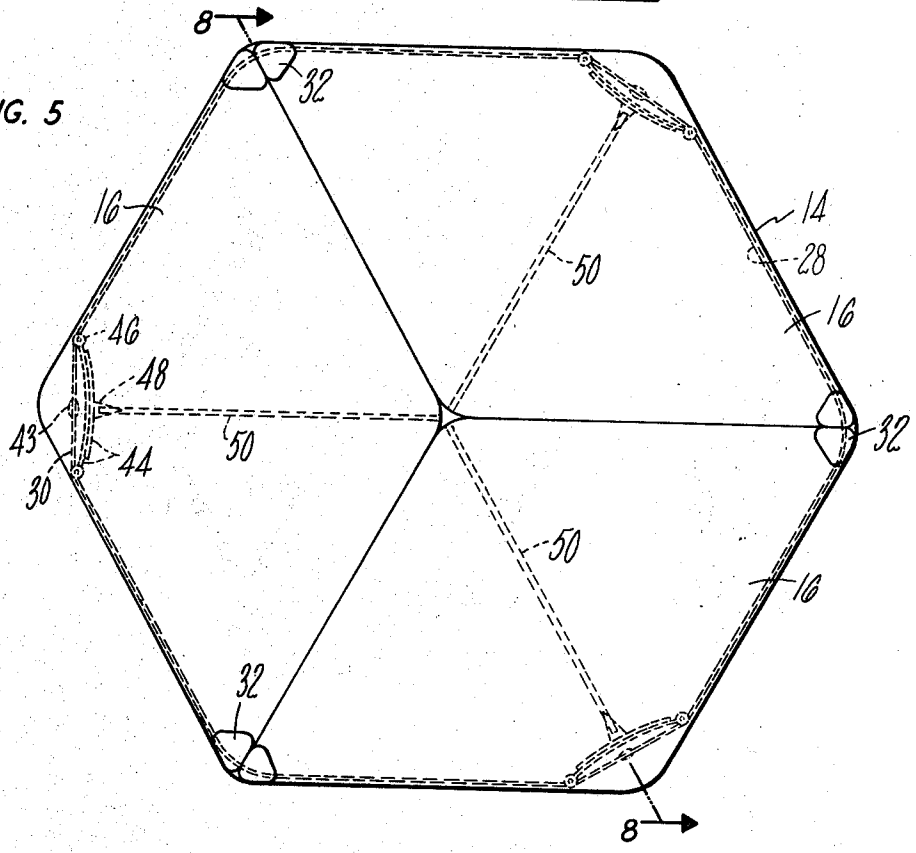


FIG. 5



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FIG. 6

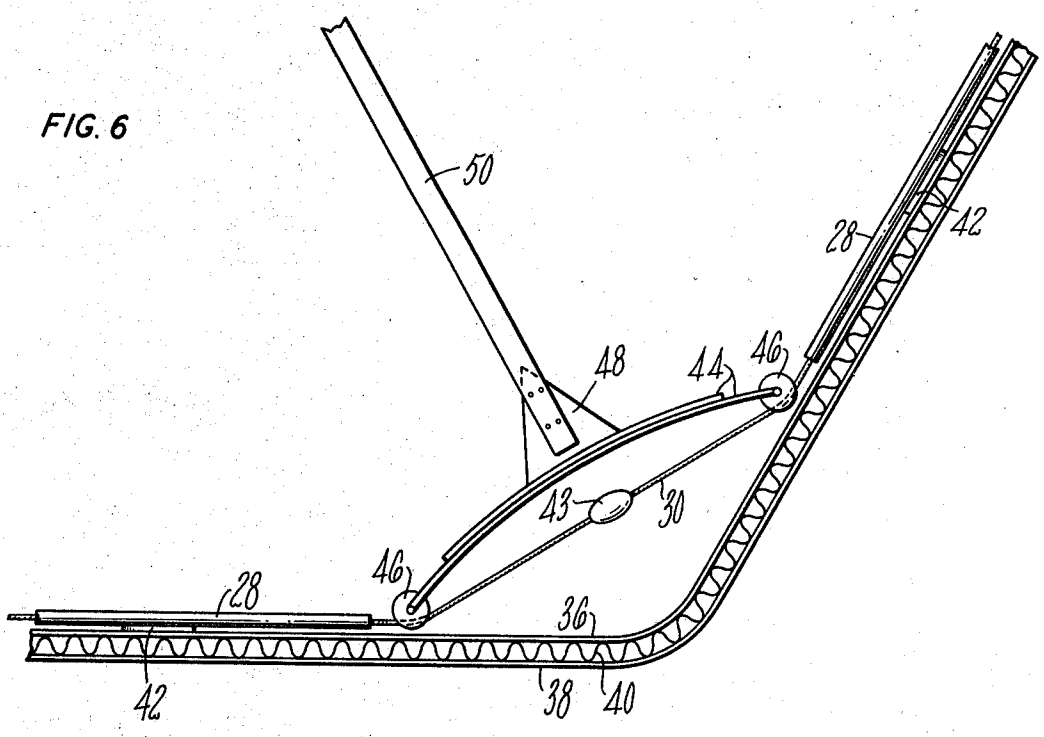
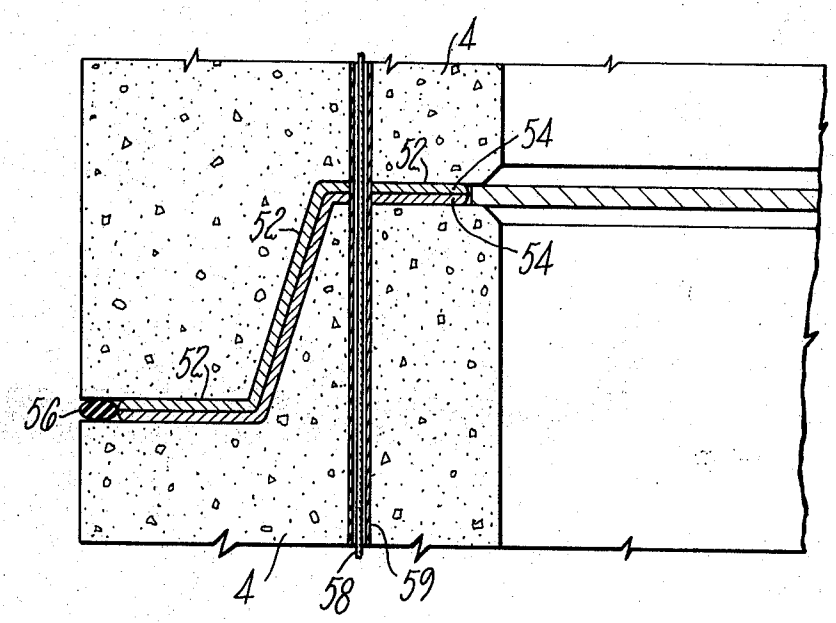


FIG. 7

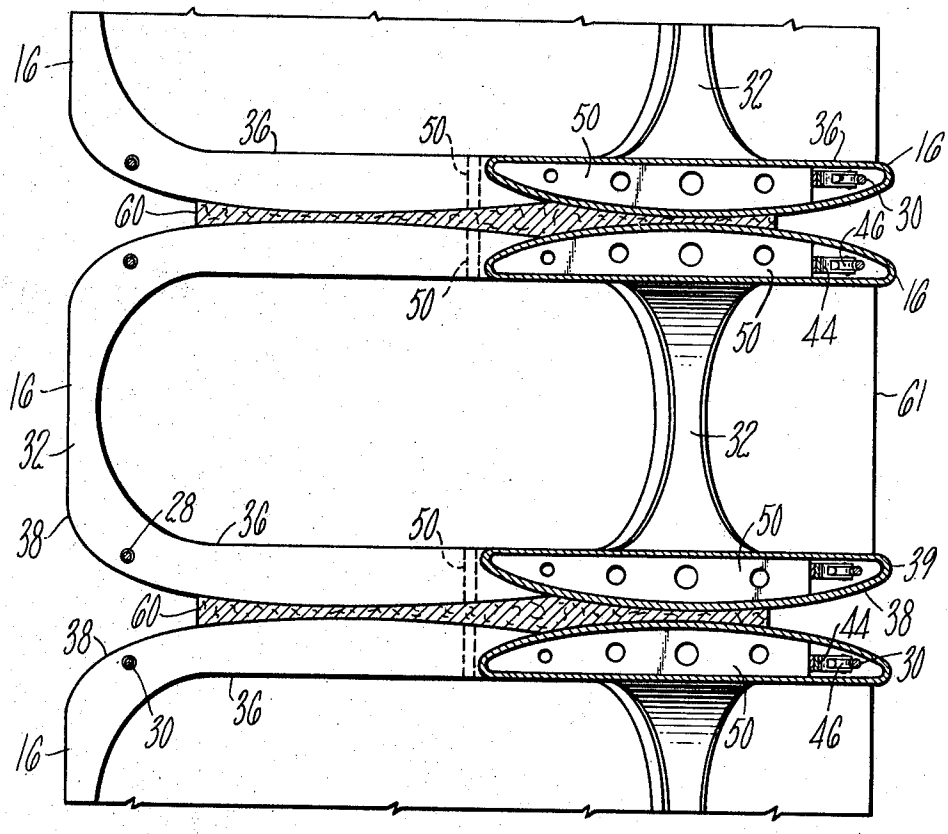


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MODULAR BUILDING STRUCTURE

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FIG. 8

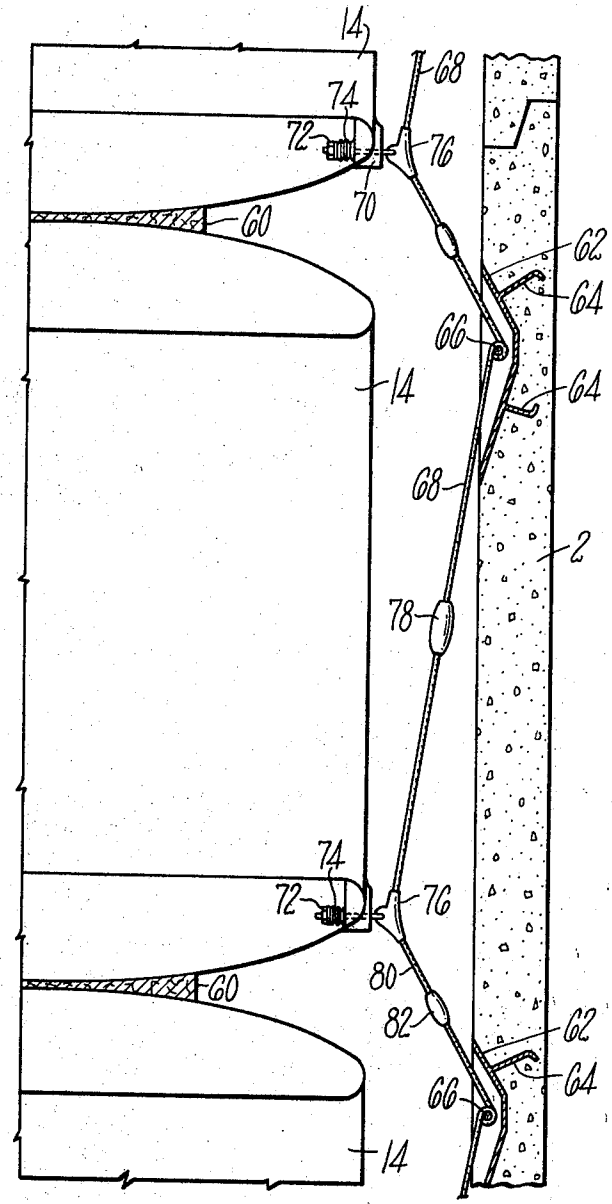


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FIG. 9



United States Patent Office 3,527,002
Patented Sept. 8, 1970

3,527,002

MODULAR BUILDING STRUCTURE

William C. Mead, Granby, Conn., assignor to Austin and Mead, Hartford, Conn., a partnership organized under the laws of Connecticut

Filed Feb. 15, 1968, Ser. No. 705,774
Int. Cl. E04b 1/34, 1/348, 1/04
U.S. Cl. 52—79 16 Claims

ABSTRACT OF THE DISCLOSURE

A modular building structure in which all components of the structure other than foundation are derived from a single basic elemental shape, the modular structure allowing for substantial variations and changes in size to accommodate changes in population density. The single basic elemental shape is a 60°–120° equilateral parallelogram in plan cross section. Service columns for both utilities and support are composed of this elemental shape, and functional modular units are composed of three such elemental shapes joined together to form a hexagon, each hexagon preferably being supported by two service units. One, two or three functional hexagonal units can constitute a living unit, depending on space desired, and installations constructed of the modular building unit are expandable both vertically and horizontally, demountable and reusable.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to building structures. More particularly, this invention relates to a multi-purpose building structure of modular design which is vertically and horizontally expandable, demountable, and reusable, and which employs one elemental shape, either singly or in multiples, to provide substantially the entire structure other than foundation.

Description of the prior art

Conventional building construction, especially for dwelling purposes, has entailed the digging of a foundation, the erection of a frame structure, and then the erection of floors, ceilings, and interior and exterior walls, most of which are permanent or at least semi-permanent. Essentially that same construction method is followed whether the building is wood, metal, brick, stone or any other conventional building material, and essentially that same construction process is followed regardless of whether the building is a single family dwelling unit, a multi-family dwelling unit, a low density town-house type dwelling unit, a low density apartment type dwelling unit, or a high rise, high density multi-family dwelling unit. Indeed, the same construction process is followed for any type of dwelling unit, including but not limited to dormitories, hotels and motels.

Such conventional building procedures are, of course, extremely expensive and time consuming. More importantly, this prior art construction process leads to the erection of substantially inflexible dwelling unit structures. That is, each dwelling unit so constructed, whether it be single family, multiple family, town house, apartment house, or high rise, high density structure, retains its characteristic purpose indefinitely and can be expanded only through a substantial reduplication of the construction process. Such units are also even more inflexible from a reduction standpoint in that any reduction in size can be accomplished only by essentially destroying the part to be removed. Such units are also basically immobile in that they cannot be easily dismantled and re-erected on another site. Thus, the prior art conventional building processes have not been able in any practicable way to cope with the modern problem of changes in population density, with time, economics, sociological needs, and other pertinent factors.

Modular building proposals have been made in the prior art, usually involving the stacking of modules in a mutually supporting arrangement, or inserting modules in previously erected frame structure, or suspending modules from a tower by means of vertical suspension cables. Such modular proposals have, however, for a variety of reasons not been practicable heretofore.

SUMMARY OF THE INVENTION

In the present invention a single elemental shape, singly and in combination, is employed in the construction of a multiplicity of dwelling units ranging from single family units for low population density areas to high rise, high density apartment buildings for high population density areas. The elemental unit of the present invention makes feasible for the first time an expandable, demountable and reusable building concept which is architecturally and engineeringly sound while at the same time is completely compatible with and provides a solution for the problems raised by major changes in population density in any given area and also allows long range city planning, development and redevelopment.

The elemental unit of the present invention is a 60°–120° equilateral parallelogram in plan cross section. The elemental shape is used to provide both service units and functional units, the service units being composed of one element and the functional units being composed of three such elements joined together to form a hexagon. A single hexagon could serve as a living unit, or two or more hexagons could be connected together to form a larger living unit. Each hexagonal unit is supported from two service units. In the simplest arrangement of a single family dwelling, the service units would be one story high and would support one or more functional units each also one story high. In the most elaborate form of the high rise, high density apartment arrangement, the service units would be stacked one upon another to form support columns and functional units would be attached to the columns at various heights. The service units would be of precast, prestressed concrete, and vertical assemblies would be connected by rebated doweled joints. These service units would function both as structural support columns to which the living units are attached, and also as service columns carrying all plumbing piping, heat and air conditioning ducting, sprinkler systems, electrical wiring, elevators, stairways and any other needed services. They could, if desired, also carry some household fixtures such as kitchen fixtures and bathroom fixtures, and also could provide storage and other utility spaces.

The elemental parallelogram units combined to form the hexagonal living units have a basic structural arrangement of top and bottom surfaces (serving to form ceiling and floor structure) connected together by two connecting webs extending between the top and bottom surfaces at the ends of the major axis of the parallelogram shape. The entire structural unit would preferably be manufactured of sheet metal material such as aluminum or stainless steel using a monocoque structural system. Wood, plastic, shell concrete and other similar materials could also be used and sandwich structure with intermediate honeycomb could also be employed. These parallelogram units would, therefore, be rigid structural units and would readily lend themselves to assembly line factory manufacturing techniques. The basic structural arrangement of top and bottom surfaces joined together by vertical webs provides large amounts of open spaces at the sides of the structural elements thereby allowing for free flow of space

internally of the elements when they are joined together. The hexagonal living units made up of three of the elemental parallelogram units could constitute industralized housing packages, even complete with furnishings and interiors, and could provide a substantial new business activity for industries such as the aircraft industry.

The premanufactured elements, both the service elements and the functional elements could be shipped by any standard transportation method to an erection site. Foundations of custom design and conventional construction would be provided, and the service units would be installed on the foundation. Multiple story service units would be erected with a standard jacking boom crane. The hexagonal living units would then be lifted into place with the same crane after each is assembled on the job site by combining three elemental functional units if they were shipped in their parallelogram shape rather than being combined at the factory.

As previously indicated, the final structure to be erected could vary anywhere from a single family unit to a high rise apartment unit, or modification could be made at any time to approach either extreme after the original building is erected. By way of example, the original structure could be a one or two family dwelling, and could be expanded later on in a horizontal direction by the addition of more foundation or in a vertical direction by the stacking of more service units and more living units. Any size structure could also be partially or totally dismantled by the removal of desired numbers of housing units and service units which could then be transferred to and reused at another desired site. In the extreme, an entire building could be dismantled, moved to another site, and re-erected, leaving only the original foundation at the original site.

Accordingly, one object of the present invention is to provide a novel and improved modular building unit.

Another object of the present invention is to provide a novel and improved modular building unit of a single elemental shape for both service purposes and functional purposes.

Still another object of the present invention is to provide a novel and improved modular building unit having the single elemental shape of a 60°–120° equilateral parallelogram.

Still another object of the present invention is to provide a novel and improved modular building unit whereby buildings can be constructed ranging from single family dwellings to high rise apartments using the modular building unit depending on population density requirements.

Still another object of the present invention is to provide a novel and improved modular building unit using a single element modular shape and wherein any building can be either expanded or dismantled by adding or subtracting one or more of the modular units.

Still another object of the present invention is to provide a novel and improved modular building unit which can be transported from site to site and reused as often as desired.

Still another object of the present invention is to provide a novel and improved modular building unit which can be manufactured at one location, transported to a building site and erected on a foundation to provide a desired building, which building can then, if desired, be expanded or partially or totally dismantled by the addition or subtraction of modular units.

Other objects and advantages will be apparent and understood from the following detailed description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, wherein like elements are numbered alike in the several figures,

FIG. 1 is an elevation view of a high rise apartment structure in accordance with the present invention.

FIG. 2 is a ground floor level view of the structure of FIG. 1 taken along line **2**—**2** of FIG. 1.

FIG. 3 is a sectional view along line **3**—**3** of FIG. 1 showing the plan view of one floor of the structure of FIG. 1.

FIG. 4 is a sectional plan view of a residential unit composed of three hexagonal living units in accordance with the present invention.

FIG. 5 is a plan view of the three structural elements forming the shell of a single hexagonal living unit made of three elemental parallelogram shapes in accordance with the present invention.

FIG. 6 is an enlarged view of a detail of FIG. 5.

FIG. 7 is a sectional elevation view showing the joint between service elements in accordance with the present invention.

FIG. 8 is a view along line **8**—**8** of FIG. 5 showing the structural shell.

FIG. 9 is a partial sectional elevation view showing the attachment of living units to the service columns.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1, 2 and 3, an elevation and two plan sectional views, respectively, are shown of a high rise apartment type dwelling incorporating the present invention. The service columns **2***a*–**2***v* are all of the identical elemental shape in plan cross-section of an equilateral 60°–120° parallelogram. As best seen in FIG. 1, these service columns are made up of individual stacked segments **4**, the stacked segments **4** each being approximately one story high and being placed one upon the other to form service columns **2***a*–**2***v* of varying heights as desired. The segments **4** may be divided into a large section **4***a* and a small **4***b* to allow for flexibility in the upper and lower parts of a service column.

Referring to FIG. 2, the ground floor or other similar lower floors may be left with relatively large open interior areas **6** serviced by doors **8** and corridors **10**. These large open areas **6** may be employed for storage, or stores, specialty shops and offices of any desired type. It will be observed that corridors **10** can be formed from segments of nonstructural material having the same elemental parallelogram shape of the modules of the present invention.

Referring to FIG. 3, a plan view is shown of a typical upper floor of the high rise, high density apartment building of FIG. 1. The floor plan shows ten apartment units **12***a*–**12***j*, each of which is composed of two or three hexagonally shaped dwelling units **14**, apartments **12***a*, **12***b*, **12***c*, **12***f*, **12***g* and **12***h* each having two hexagonal units, and apartments **12***d*, **12***e*, **12***i* and **12***j* each having three hexagonal units. The hexagonal units **14** are joined together in any desired way. Each of the hexagonal units **14** is in turn composed of three segments **16**, each of the segments **16** in plan cross-section being of the elemental 60°–120° equilateral parallelogram shape. One of the hexagonal units in apartments **12***a* and **12***j* are shown with the parallelogram shaped divisions. Each of the hexagonal shaped dwelling units **14** is a separate unit one story high and each is connected to and supported by at least two service columns. Because the structural shell of the parallelogram units **16** has open sides, open space flow can be achieved between the units **16** in any hexagonal unit **14** and also between the units **14**; also, if desired, there may be any other form of interconnecting access such as doors, archways, etc.

From the foregoing description it can be seen that the service columns and dwelling units are all formed from segments having the same basic elemental shape of a 60°–120° equilateral parallelogram. In erecting a building from these service columns and dwelling units, a standard foundation would first be formed. The segments **4** of precast, prestressed concrete would then be stacked one upon the other to form the service columns **2**. Each service segment **4** carries a segment of vertical utility plumbing, piping, wiring, conduits, etc. and these utility

segments are connected together by standard plug or snap connections. Next, the preformed and preassembled dwelling units, which could constitute complete, fully equipped and fully furnished industrialized housing packages, would be lifted into place and connected to the service columns.

As can be seen from a combined viewing of FIGS. 1, 2 and 3, a building erected from the elemental shapes of the present invention can easily be provided with an irregular height profile and an irregular (i.e. non-slab or non-flat exterior), a result which would be prohibitively expensive with ordinary building practices. Thus, significant architectural and design modifications can be achieved without incurring exorbitant cost consequences.

Some of the service columns, e.g. 2*b*, 2*c*, 2*t* and 2*u* house elevators **18**; other service columns, e.g. 2*d*, 2*h*, 2*o* and 2*s* house stairways, and the remaining service columns carry plumbing, electrical wiring, heating and air conditioning conduits, sprinklers, etc. At least one hexagonal unit in each apartment is connected to one of the service columns carrying these utility lines, and appropriate gasketed connections are provided to "plug in" the dwelling units to the utility conduits.

Referring now to FIG. 4, a sample apartment unit is shown made up of three hexagonal shaped dwelling units **14**. As can be seen, each of the units **14** is connected to and supported by two of the service columns **2**. The sample unit shown in FIG. 4 includes, merely for purposes of illustration, a possible arrangement of wall partitions **22**, doors **24**, closets **26**, etc. to show how a typical apartment unit might be layed out and divided. As shown, a bathroom **23** would be located in one service column, and kitchen fixtures **25** could be arranged to abut and connect to plumbing on another column.

Referring now to FIG. 5, structural details of a single hexagonal dwelling unit are shown. As previously described, the hexagonal unit **14** is made up by joining together three of the elemental shaped 60°–120° equilateral parallelograms **16**, the parallelogram segments **16** being arranged so that one of the 120° angles of each is at the center of the hexagon. The segments **16** are formed of a shell having sheet metal material on the top and bottom interconnected by end webs. A pair of conduits **28** are provided around the exterior periphery of each of the elements **16** immediately within the inner surface thereof, one each of the conduits being provided adjacent the top of the segment and the other conduit being provided adjacent the bottom of the segment. A continuous taut cable **30** is located in conduit **28** in each of the segments **16** so that cable **30** completely encircles and joins together the three segments **16** at the top and bottom thereof. End webs **32** in the 60° corners of the parallelograms segments join the tops and bottoms of the segments to complete the structural shell so that the outer periphery of the top and bottom of unit **14** are joined by web elements at alternate junctions of the sides of the hexagon.

Referring now to FIG. 6, a partial enlarged view of a 120° corner of the edge of the top or bottom of one of the segments **16** is shown along with structural details. The outer skin structure of the shell for the top and bottom surfaces may have inner and outer metal sheets **36** and **38**, respectively, of monocoque construction; alternatively, the inner and outer sheets **36** and **38** could be formed from one sheet doubled upon itself to form two layers. The edge shown in FIG. 6 corresponds to the edge **39** shown in FIG. 8. If only a single sheet were used, the edge shown in FIG. 6 would be a single sheet only, but could be thickened as desired. A honeycomb type reinforcement **40** may be sandwiched between sheets **36** and **38** regardless of whether the structure is formed from two separate sheets or one sheet folded upon itself.

The conduit **28** is attached to the inner sheet **36** at intervals by attaching ribs **42** and a tension loading is maintained on cable **30** to provide the necessary adjustment for thermal expansion and contraction to insure continued proper connection between the parallelogram elements by means of cable **30**. The tension loading is accomplished by a turn buckle **43** and a pair of leaf springs **44**, each of which has a roller **46** attached thereto. The rollers engage cable **30** in the outermost 120° angle corner of each parallelogram and maintain the necessary constant tension load on the cable. Conduit **28** may be filled with a rust inhibitive lubricant. The leaf springs **44** are mounted on a support flange **48** which is in turn connected to a compression rib **50** which runs along most of the length of the minor diagonal of the parallelogram structure. It will, of course, be understood that the structure shown in FIG. 6 is repeated at both the top and bottom surfaces of the segments **16** with the compression ribs **50** being positioned between the inner sheet **36** and the outer sheet **38** at both the upper and lower surfaces.

Referring now to FIG. 7, a sectional elevation view is shown of the doweled and rebated joint between two successively stacked service segments **4**. The joint would extend along the entire mating surfaces of the segments. The abutting service segments each have mating stepped or labyrinth surfaces **52** on which are located conformingly shaped bearing plates **54**. Stacking an assembly of service segments is accomplished by placing one upon the other and allowing them to mate along the bearing plates **54**. As viewed in FIG. 7, the outer surface of the service segments is at the left, and thus the arrangement of the joint tends to prevent any leakage of fluids, dirt or any other material into the interior area of the service segments. In addition, a seal such as an O-ring seal **56** can be provided in the joint adjacent the outer surface of the segments for additional sealing. A tension cable **58** is also provided which is anchored in the foundation and extends through tubing **59** in each of the segments **4** and is connected to a bearing plate on the top of the service column.

Referring now to FIG. 8, a view is shown taken along line **8—8** of FIG. 5, showing the structural shell of the units **16**. Actually, the view along line **8—8** of FIG. 5 would show only the complete segments **16** shown in the center of FIG. 8. The partial segments **16** shown above and below the central segments **16** are added for purposes of illustration to show the arrangement between successively stacked segments. As shown, the space between stacked segments is filled with a resilient insulating material **60** to provide acoustical and thermal insulation between units. The compression ribs **50** shaped to conform to the space between sheets **36** and **38** are also shown in each of the elements **16** in each level, and it will be understood that additional items such as wiring, sprinkler system pipes, etc. could also be included in the shell space along with the ribs **50**.

As previously stated, the inner and outer sheets **36** and **38** could be a single sheet doubled over or two separate sheets. The upper sheet **36** in any unit defines ceiling structure, and the lower sheet **36** in any unit defines floor structure. The webs **32** are the only connecting structure between the upper and lower parts of a parallelogram unit **16**, and thus the four sides are essentially open to allow any desired degree of open space access between adjoining units. The sides of the units **16** which border on the exterior form window lines **61** which may contain any form of window or other closure element.

Referring now to FIG. 9, hexagonal shaped dwelling units **14** are shown attached to a service column **2**. As in the FIG. 8 showing, the central portion of FIG. 9 shows part of a full story unit **14** and segments of other units in a stack are shown immediately above and immediately below. A plurality of evenly spaced casings **62** are imbedded in column **2** at positions along the height thereof corresponding to the position of dwelling units to be supported. Each casing **62** is secured to service column **2** via imbedding anchors **64**. Each casing **62** carries a rod **66** as an integral part thereof, and a cable **68** is hooked

to rod **66** and extends from rod **66** to a suspension plate **70** at the base of dwelling unit **14**. Suspension plate **70** is fastened to unit **14** by bolt **72** and Belleville washers **74** which allow for thermal expansion and contraction. A cast integral connecting unit **76** attached to cable **68** engages an eye opening at the outer end of bolt **72** to connect the suspension plate to the cable, and a turnbuckle **78** is provided for adjustment on the cable to take up slack and level the housing unit. A second cable **80** with turnbuckle **82** also extends from cast hook **76** and is hooked to the next lower rod unit **66**, and thus the base of unit **14** is secured to column **2** at two successive locations along the height of the column.

The connecting structure described immediately above is repeated a second time at a horizontally displaced station along the service column so that each unit **14** is secured at at least two connection stations to each service column from which it gains its support. Bearing in mind that each living unit **14** is supported by at least two service columns, there are thus provided at least 4 connecting stations with a total of 8 connections for securing a living unit to a service column. For purposes of illustration, reference is now made to apartment unit **12***i* of FIG. 3 where the location of connecting stations are indicated as points **84**.

In accordance with one of the basic concepts of ease of demountability achieved by the present invention, it can readily be seen by reference to FIG. 9 that any dwelling unit **14** can easily be removed by disconnecting it from its support structure, and any segment **4** of a service column can be removed merely by disconnecting it from the tension cable and lifting off of the next lower unit. Thus, an easily demountable and reerectable building concept has been obtained.

While a preferred embodiment of the present invention has been described, it is to be understood that various modifications may be made thereto without departing from the spirit and scope of the present invention. Accordingly, it is to be understood that the present invention has been described by way of illustration and not limitation.

What is claimed is:

1. A modular building structure including:

a pair of spaced service columns each of said service columns being composed of a plurality of prefabricated load bearing modular elements stacked one upon the other to form a load bearing column, said service columns each approximating a 60°–120° parallelogram in shape in plan cross section, each of said service columns having a side positioned in spaced relation to a side of the other service column to receive a functional modular unit therebetween;

a plurality of prefabricated cellular functional modular units suspended in a vertical array between said sides of said service columns, said functional units being vertically structurally spaced from each other, the plan size and shape of each of said functional modular units approximating a hexagon of the approximate size and shape of three of said parallelograms; and

connecting means detachably connecting each of said functional units to said sides of said service columns at at least two horizontally spaced apart stations on each of said service columns, said functional units being selectively individually detachable from said service columns.

2. A modular building structure as in claim **1** wherein:

said functional unit forms a shell having top and bottom surfaces of approximate hexagonal shape, said top and bottom surfaces having connecting webs extending therebetween adjacent the outer periphery at three alternate junctures of sides of the hexagonal shape.

3. A modular building structure as in claim **2** wherein:

the sides of said shell are open between said connecting webs.

4. A modular building structure as in claim **1** wherein:

said functional unit is composed of three elements of 60°–120° equilateral parallelogram shape, said three elements cooperating to define said functional unit of approximate hexagonal shape.

5. A modular building structure as in claim **4** wherein:

each of said elements of said functional unit has a shell having top and bottom surfaces of approximately 60°–120° parallelogram shape joined by connecting webs.

6. A modular building structure as in claim **5** wherein:

said shell has skin of monocoque construction.

7. A modular building structure as in claim **5** wherein:

said connecting webs extend between corresponding 60° corners of said top and bottom surfaces.

8. A modular building structure as in claim **5** wherein:

each of said top and bottom surfaces has a compression rib therein; and including

cable means in said top and bottom surfaces for joining together said three elements; and

means connected to each of said compression ribs for maintaining said cable means taut.

9. A modular building structure as in claim **5** wherein:

the sides of said shells are open between said connecting webs.

10. A modular building structure including:

a plurality of service columns at least some of said service columns being spaced from each other, each of said service columns having a plurality of prefabricated load bearing modular service units of a predetermined elemental size and approximating a 60°–120° parallelogram in shape in plan cross section, said service units being stacked one upon the other to form said service columns;

a plurality of prefabricated cellular functional modular units, each of said functional units being supported by two of said spaced service columns, the plan size and shape of each of said functional modular units approximating a hexagon of the size and shape of three of said service units, at least some of said functional units being in a vertical array and being vertically structurally spaced apart; and

connecting means detachably connecting each of said functional units to two of said service columns at at least two horizontally spaced apart stations on each of said two service columns, said functional units being selectively individually detachable from said service columns.

11. A modular building structure as in claim **10** wherein:

said functional units are composed of three elements of 60°–120° equilateral parallelogram shape, said three elements cooperating to define said hexagonally shaped functional unit.

12. A modular building structure as in claim **10** wherein:

each of said functional units is detachably connected to two of said service columns at two spaced sides of the functional unit hexagon;

said functional units being detachable from said service columns, and said service units in said service columns being detachable from each other.

13. A modular building structure as in claim **11** wherein:

each of said elements of said functional unit has a shell having top and bottom surfaces of approximately 60°–120° parallelogram shape joined by connecting webs, and

each of said service units is of approximately 60°–120° parallelogram shape in plan cross section and has doweled, rebated ends for joining adjacent service units in a column.

14. A modular building structure as in claim 13 wherein:

said shell has skin of monocoque construction; and

said service units are of precast, prestressed concrete.

15. A modular building structure as in claim 14 wherein:

the sides of said shell between said webs are open.

16. A modular building structure as in claim 10 wherein:

said service columns contain utility supply lines; and

said functional units are supported by said service columns and are connected to utility supply lines in said columns.

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HENRY C. SUTHERLAND, Primary Examiner

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