United States Patent [19]

Johnson

[11] **3,831,337**

[45] **Aug. 27, 1974**

[54] **METHOD OF ERECTING FOLDABLE BUILDING STRUCTURES**

[76] Inventor: **Delp W. Johnson,** 240 Oakview Dr., San Carlos, Calif. 94070

[22] Filed: **Aug. 2, 1972**

[21] Appl. No.: **277,445**

[52] **U.S. Cl.** **52/745,** 52/70, 52/71, 52/122, 52/583

[51] **Int. Cl.** **E04g 21/14**

[58] **Field of Search** ..... 52/64, 316, 69–71, 52/122, 583, 316, 745; 46/1 L, 12, 19, 21, 30; 229/39 B

[56] **References Cited**

UNITED STATES PATENTS

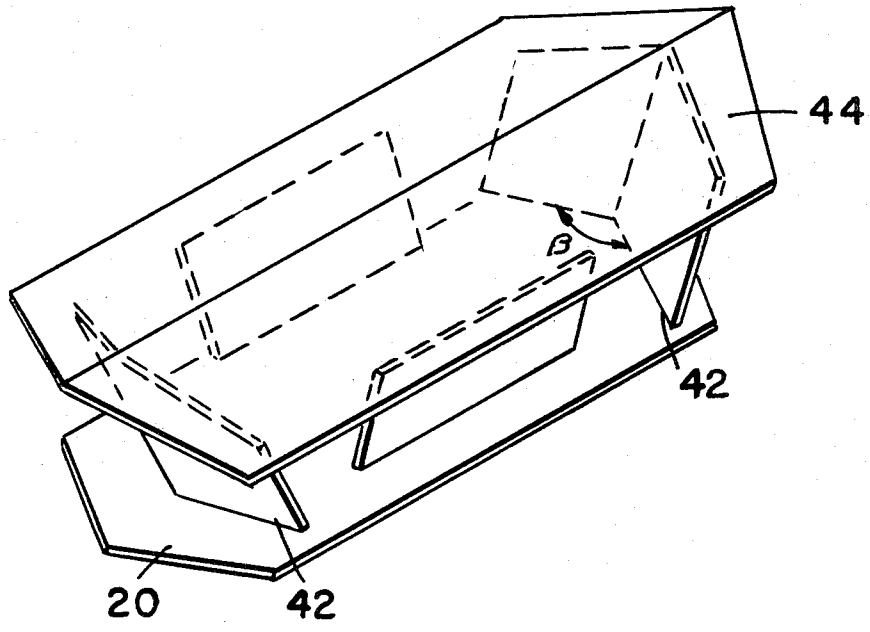
1,361,831	12/1920	Crew	52/69 X
3,012,291	12/1961	Rice	52/70 X
3,494,092	2/1970	Johnson et al.	52/69 X
3,527,008	9/1970	Greenhalgh	52/122 X
3,531,851	10/1970	Douglas	52/71 X
3,593,482	7/1971	Johnson	52/69 X
3,713,265	1/1973	Wysocki et al.	52/69 X
3,714,749	2/1973	Aitken	52/70 X
3,724,157	4/1973	Miram	52/745 X

Primary Examiner—John E. Murtagh
Assistant Examiner—Leslie A. Braun

[57] **ABSTRACT**

A building having a roof constructed of a plurality of initially flat, side by side, hinged together roof sections. Beneath the roof are two opposing end walls each constructed of a like plurality of wall panels that are hinged together. Each wall panel is further hinged to a corresponding roof section. The hinge lines are arranged so that every set of two roof sections and corresponding two wall panels has hinge lines that originate from a common point. The angle between the hinge axes connecting corresponding sets of roof sections and wall panels is other than 180° and such that the sum of the angles between the hinge axes of a given set of two wall panels equals the sum of the angles between the hinge axes of a corresponding set of two roof sections. When lifting the roof the panels pivot downwardly with respect to the roof sections into relative angular inclination with each other. Simultaneously there with the roof sections are pivoted out of their common plane into relative angular positions. The relative angularity is a function of the relative positioning of the hinge axes and can be varied as desired to construct buildings having a wide variety of shapes and sizes.

5 Claims, 29 Drawing Figures



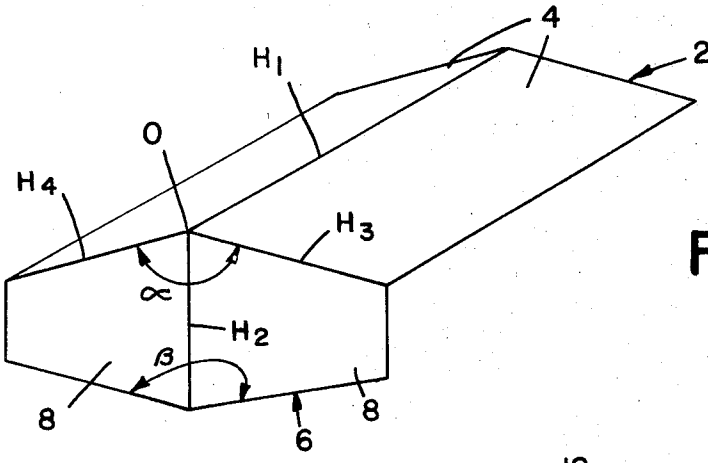


FIG_1

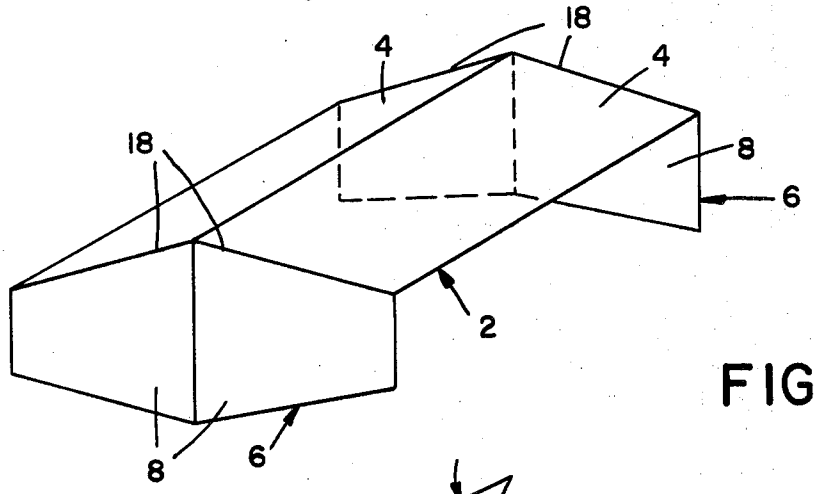


FIG_2

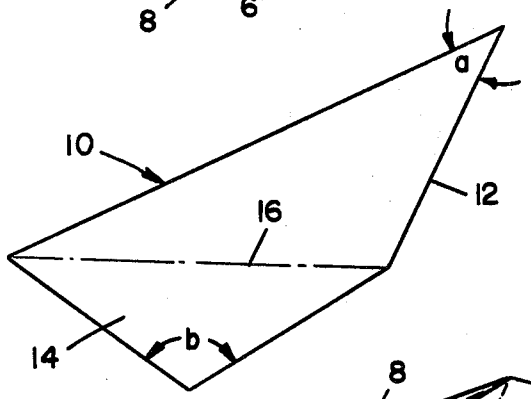


FIG_3

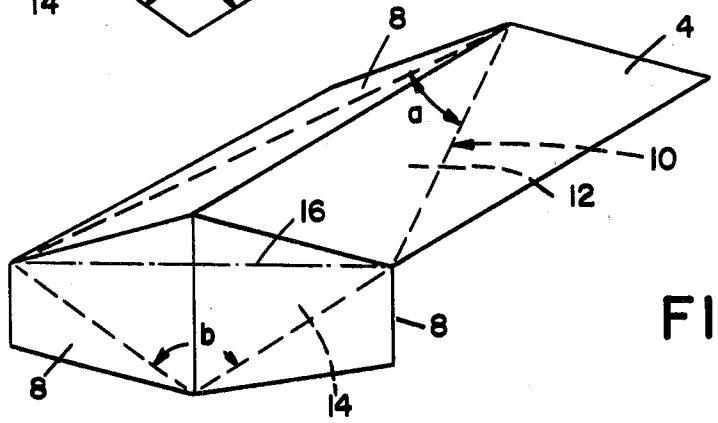
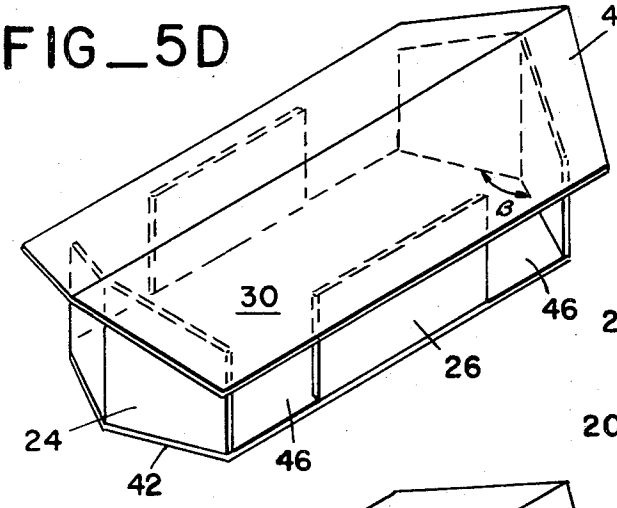


FIG_4

FIG_5D



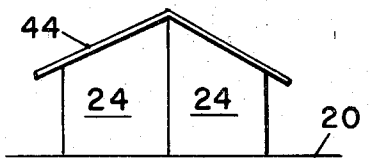


FIG_5H

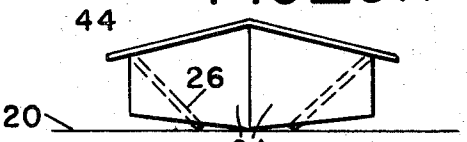


FIG_5G

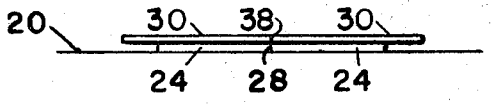
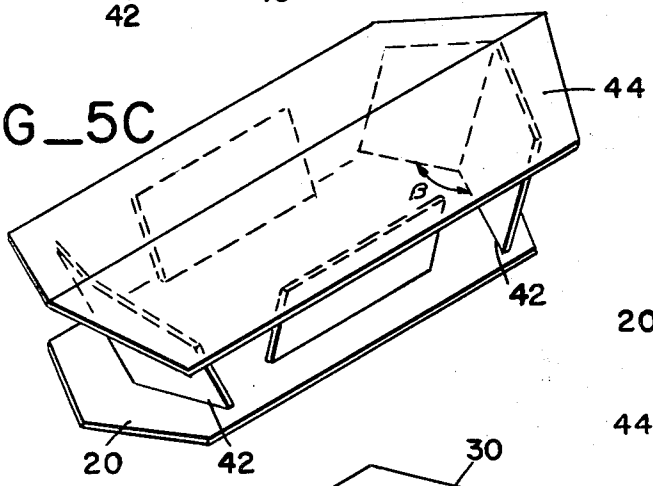


FIG_5F

FIG_5C



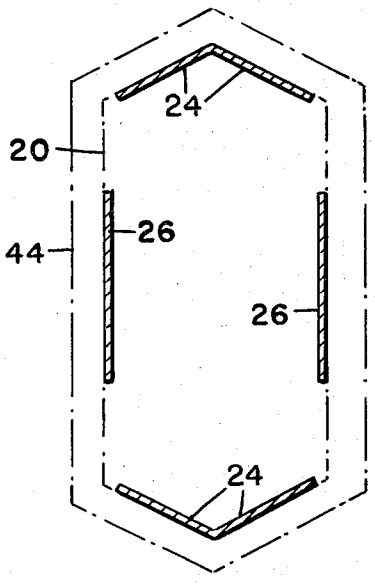
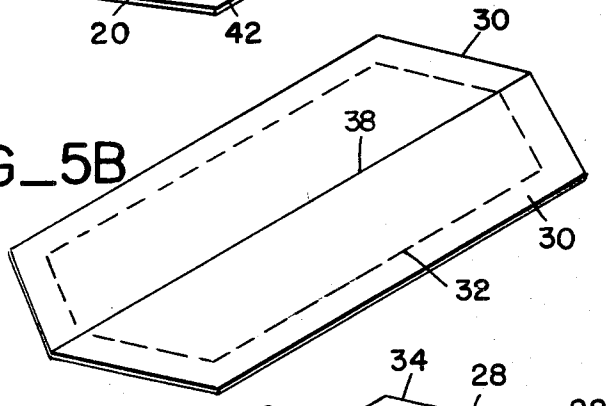


FIG_5E

FIG_5B



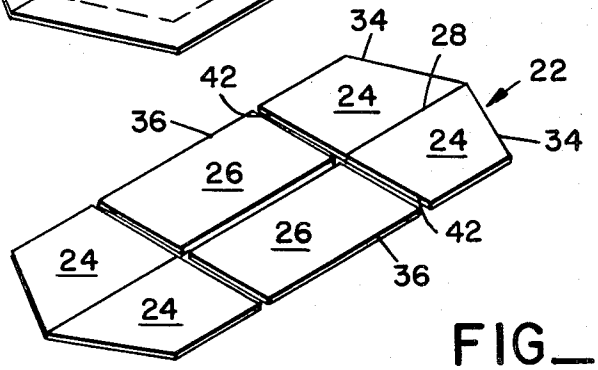


FIG_5A

FIG_6D

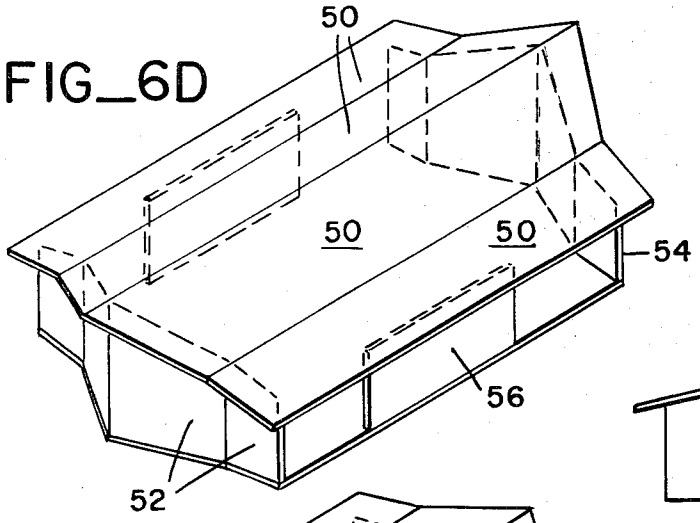


FIG_6C

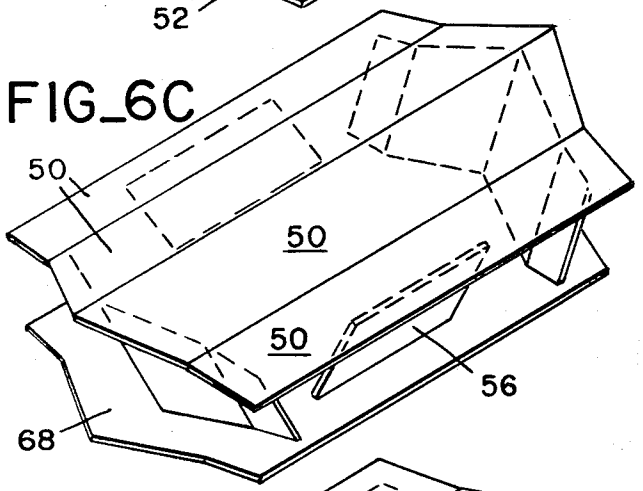
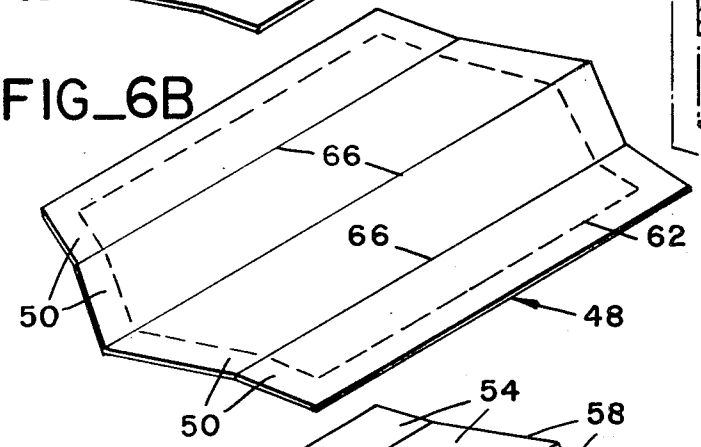


FIG_6B



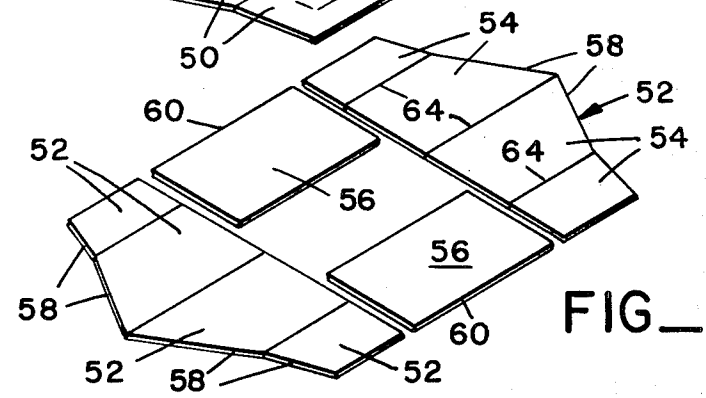


FIG_6A

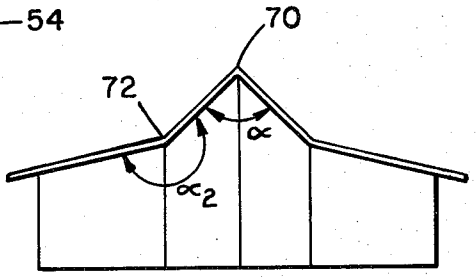


FIG_6F

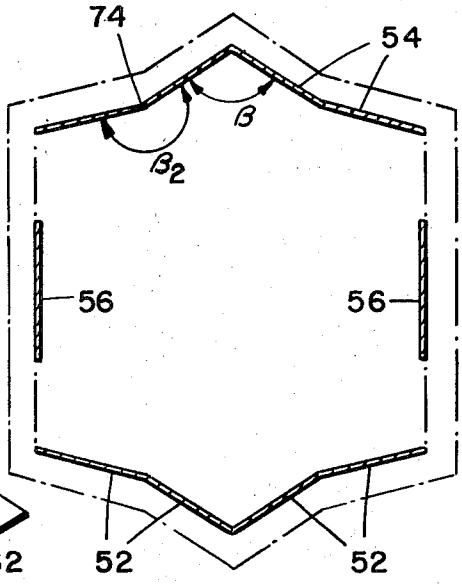


FIG_6E

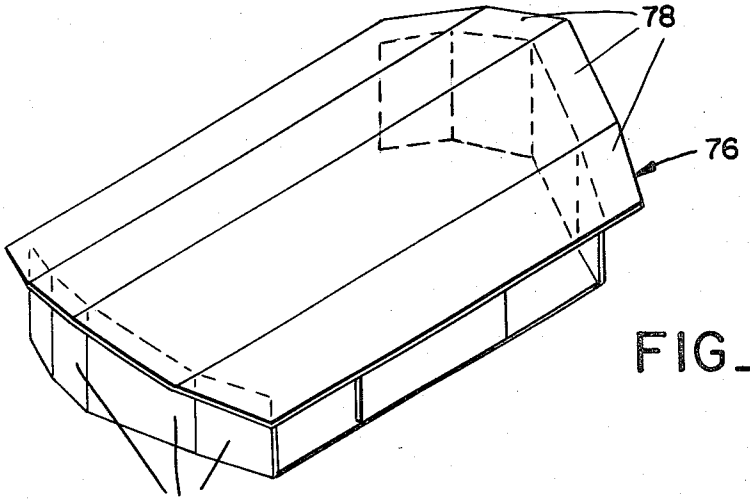


FIG_7

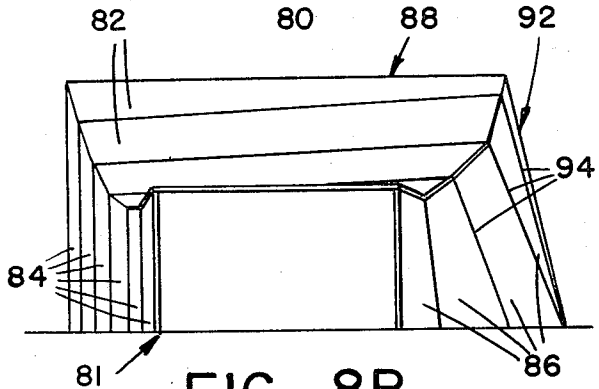


FIG_8B

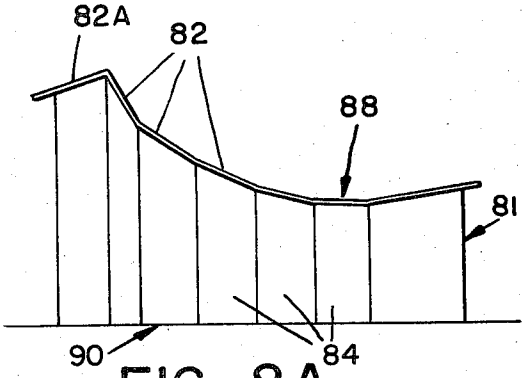


FIG_8A

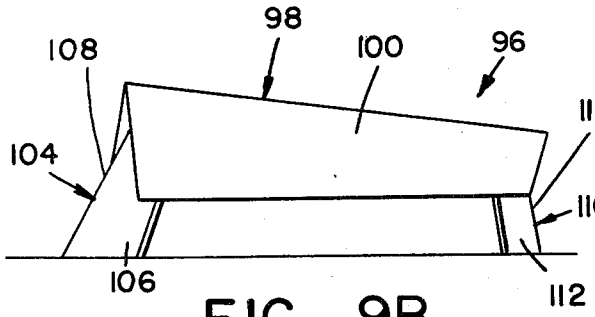


FIG_9B

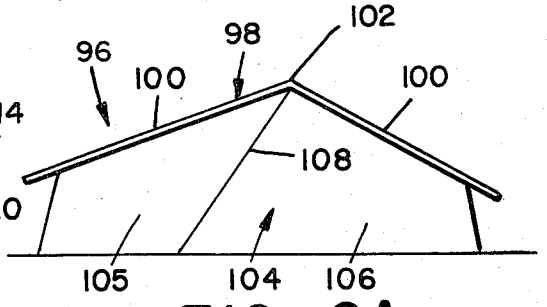


FIG_9A

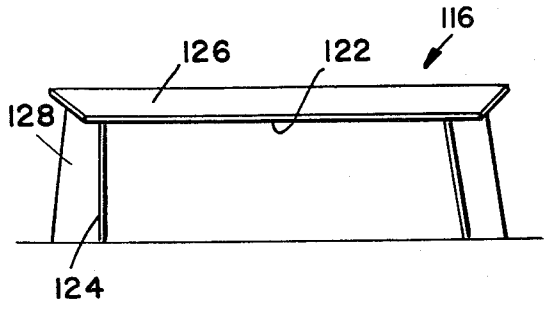


FIG_10B

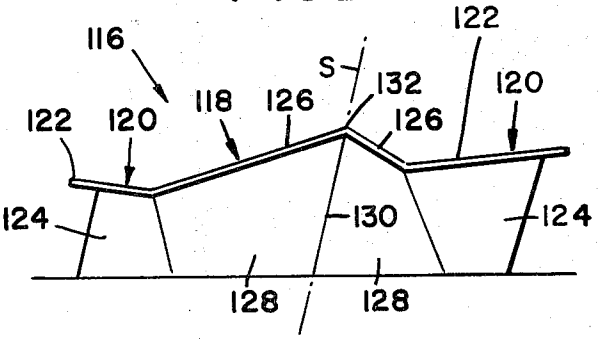


FIG_10A

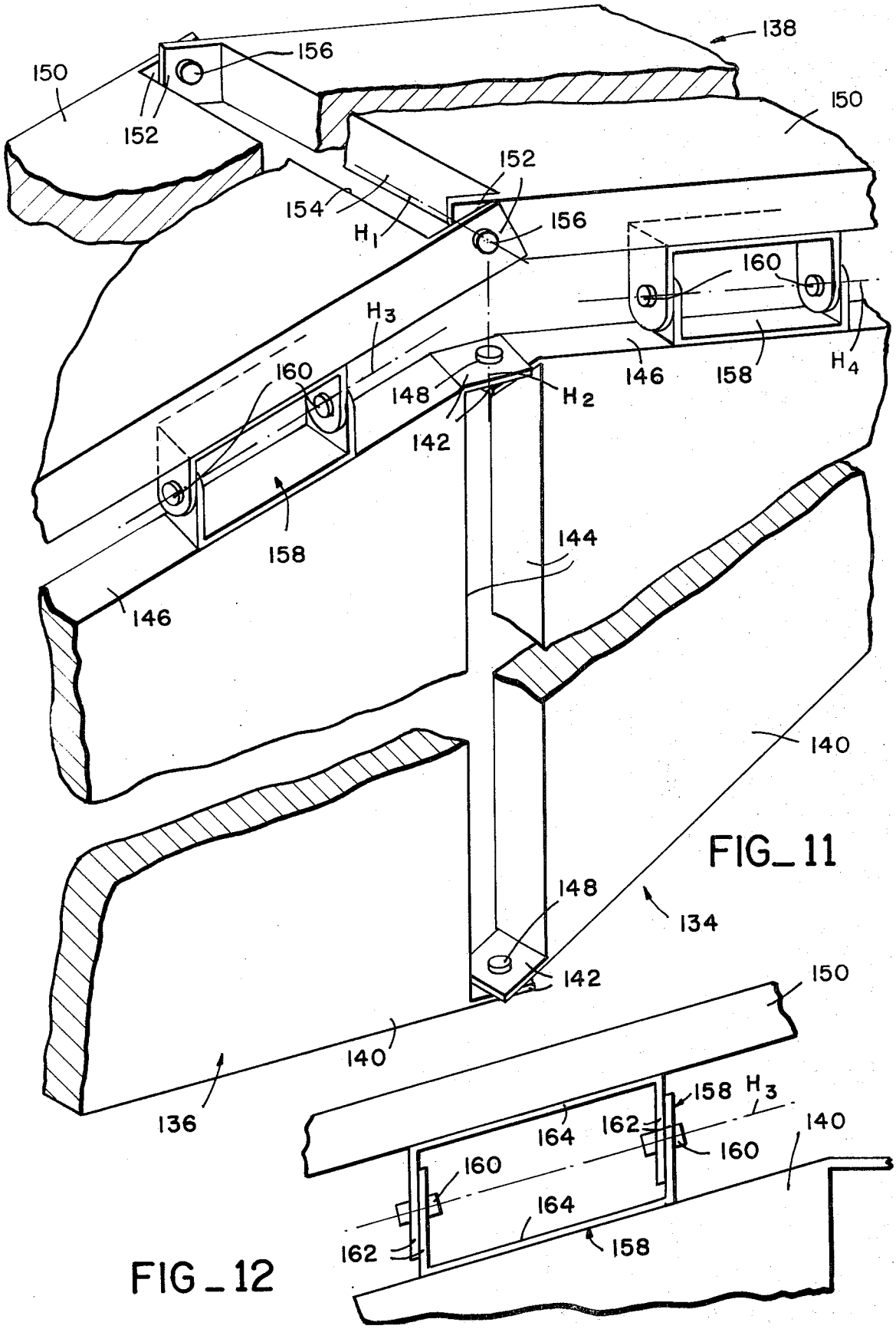

138
156
150
152
150
152
154
H1
156
160
H3
160
148
H2
146
158
H4
142
158
144
146
140
148
134
142
150
140
136
158
H3
164
162
160
140
160
164
162
158

FIG_11

FIG_12

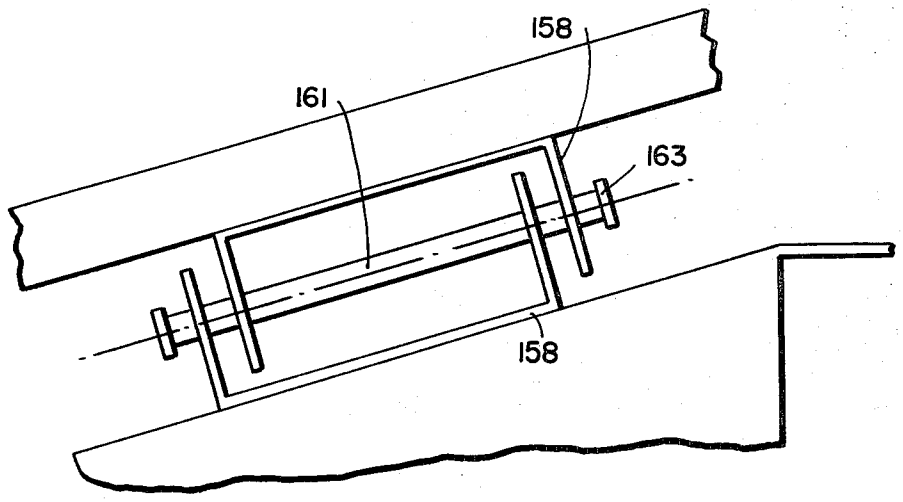


FIG_13

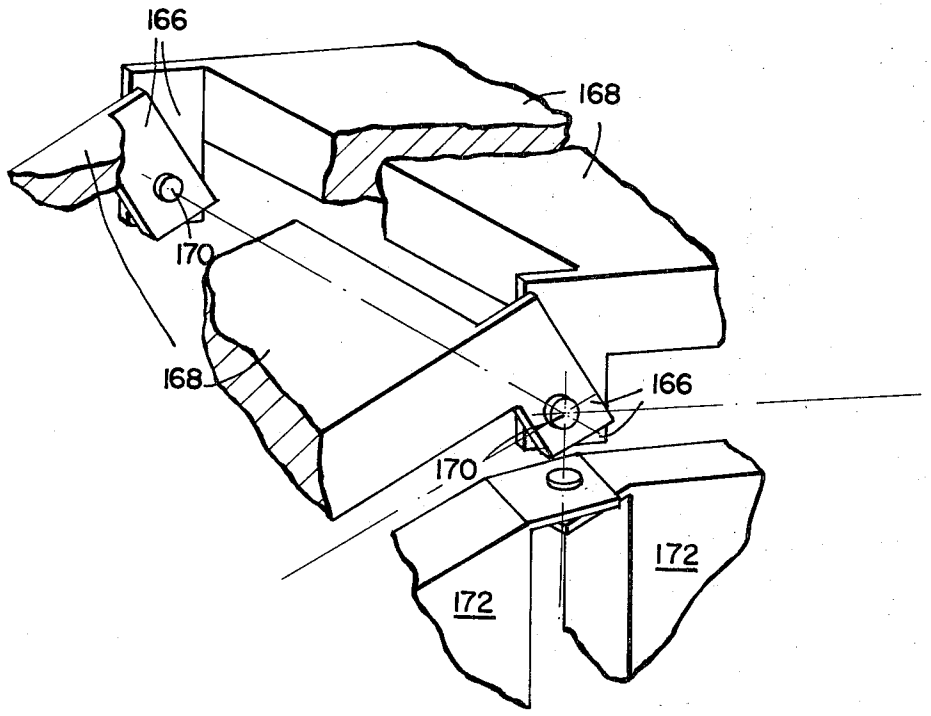


FIG_14

METHOD OF ERECTING FOLDABLE BUILDING STRUCTURES

BACKGROUND OF THE INVENTION

One of the largest cost factors in building structures such as houses is the cost of labor. Tedious work is required for building the walls and the roof of a house which requires great amounts of labor and is, therefore, very costly.

Attempts have been made to reduce labor costs through employing economies of scale, that is through using mass manufacturing techniques. Usually this has resulted in prefabricated housing modules. Such modules are difficult to transport, are difficult to erect at certain building sites and have a limited aesthetic appeal.

Attempts have also been made to reduce labor costs by eliminating the amount of labor required. U.S. Pat. No. 3,494,092 discloses the construction of conventional, rectilinear building modules by forming the ceiling and four sides of the module in a common plane, hingeably connecting the sides to the ceiling, and thereafter lifting the ceiling so that the sidewalls pivot downwardly. This construction permits the construction of the module from relatively low cost concrete slabs and the like and has substantially reduce building costs. A drawback with this construction is the limited architectural effect that can be obtained from a simple rectilinear structure, the large flat surface area that is required for casting and hinging the ceiling and sidewalls, and the initial instability of the structure once erected and before its corners are bolted together.

U.S. Pat. No. 3,593,482 is a further development of the approach taken by the '092 patent. In the '482 patent multishaped structures can be initially cast on the ground and are thereafter lifted into position. Especially the construction illustrated in FIGS. 8A and 8B of the '482 patent improves the construction of foldable buildings by combining interesting shapes with self-supporting characteristics since the erected slab is self supporting. Thus, the structure can be finished in place, grouted, etc., without tying up a crane or requiring costly braces.

However, even the advanced concept disclosed in FIGS. 8A and 8B of the '482 patent is not fully satisfactory. In particular, for casting the slabs they require relatively large flat supporting surfaces which greatly exceed the ground floor or foundation of the building. In some instances, as when building on a slope, or in cases where buildings stand side by side, there might not be sufficient space to cast the slabs. Furthermore, the relative positioning of the hinge lines which extend over a complete circle, that is exactly 360°, architecturally limits the building that can be constructed to buildings having a gabled roof and inwardly protruding building sidewalls. From an aesthetic point of view this might not always be desirable. Moreover, the available covered roof space of the structure is inefficiently utilized because the inwardly extending walls subtract from the available covered living space. If the walls extended outwardly they would add to the living space. However, the structure disclosed in the '482 patent does not permit outward extension of the walls on a building having a gabled roof.

SUMMARY OF THE INVENTION

The present invention provides a building which can be erected from flat panels such as concrete slabs, composite sandwich panels and the like. Initially the panels are folded over each other. Thus, casting concrete slabs, for example, requires a flat support surface only slightly greater than the foundation generally provided for the building. The building is erected by lifting the roof whereby the walls pivot downwardly into positions in which the walls are also inclined with respect to each other. They thereby form a stable support for the roof. Costly bracing, the tie-up of costly cranes or the like while the wall intersections are fixed, as encountered with prior art structures, are thus eliminated. Furthermore, the invention allows the design of structures of virtually any desired shape. Thus, conventional houses are as easily constructed as auditoriums, convention halls, or church structures, for example. In each instance the available floor space is efficiently utilized.

In its broadest form, the present invention provides a building structure that has a roof defining a gable and/or a valley and that is constructed of at least one set of four planar panels that are hingeably interconnected for relative pivotal movement along four angularly inclined hinge lines. The hinge lines between the four panels intersect at a common point and the sum of the angles between the hinge lines is other than 360° or 180°.

Such a building is constructed from a prefabricated, folded unit which has a roof formed of a plurality of flat coplanar roof sections that overlie a pair of oppositely positioned end walls. Each end wall is constructed of a number of flat coplanar end panels which equals the number of roof sections. First hinges connect the roof sections, second hinges connect the wall panels, and third and fourth hinges connect each set of two panels to a corresponding set of two roof sections. The hinge axes have a common origin and, in addition, the sum of the angles between the first and the third and fourth hinge axes equals the sum of the angles between the second and the third and fourth hinge axes, the sum being further other than 180°.

In this manner, upon lifting the roof, the wall panels swing downwardly to thereby automatically pivot with respect to each other into a relative angular configuration. The relative angular inclination formed between the wall panels is repeated between corresponding roof sections. Once the wall panels are vertically oriented they can be lowered onto the foundation. The hinged connection of the panels and the sections between themselves and between each other results in interdependent angles and relative positions of the sections and the panels; that is, any angle formed between any pair of adjacent panels, adjacent sections or an adjacent panel and an adjacent section determines the angle between all other panels and sections. Since the weight of the panels and the sections firmly biases the sections against the support surface or foundation the panels can be considered fixed and immobilized. This immobilizes all other angles and thus renders the building stable as soon as lowered on the foundation. Thereafter, the crane can be disconnected and the building is stable and ready to finish.

It will be noted that all wall panels and roof sections of the building are hingeably connected at all times. Their relative positions are always interdependent and

the relative angular position between any two wall panels or roof sections automatically determines the relative angular position between all other wall panels, roof sections and between the end walls and the roof.

It is thus apparent that the present invention permits the full realization of cost savings afforded by foldable modular building construction techniques. Its self-supporting stability further eliminates a potential hazard since the initially erected building cannot collapse. Since all slabs for the wall panels and roof sections are cast or assembled on top of the building base or in a sandwich-like manner which is frequently the only flat and/or level surface available at the construction site, the invention is not limited for use only under certain, ideal and frequently non-existing conditions. In addition, the builder is free to select a building design that is aesthetically appealing to him.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic, side elevational view of two roof sections and two wall panels hingeably assembled and erected in accordance with the present invention;

FIG. 2 is a view similar to FIG. 1 but shows further details of the schematic structure illustrated in FIG. 1;

FIG. 3 is a "quadrangle" illustrated for a better understanding of the geometric relationships underlying the structure of the present invention;

FIG. 4 is a view similar to FIG. 1 having superimposed thereover a "quadrangle" shown in phantom lines;

FIG. 5A is a perspective elevational view of wall panels and sides of a house, the panels and sides being placed over a foundation in a folded relationship with hinges being schematically illustrated as hinge lines only;

FIG. 5B is a view similar to FIG. 5A of the roof sections that are placed on top of the wall panels and sides shown in FIG. 5A;

FIGS. 5C and 5D illustrate the folded house first partially and thereafter completely erected;

FIG. 5E is a plan view of the vertical end wall panels and sidewalls only of the fully erected house and shown in phantom lines the foundation and roof outlines;

FIGS. 5F–5H are side elevations of the completely folded, partially and fully erected house, respectively;

FIGS. 6A-6F are figures similar to FIGS. 5A–5E and 5H but illustrate another house configuration having a somewhat more elaborate roof and end wall design;

FIG. 7 is a perspective side elevational view of a house or building having a generally convex roof and end walls;

FIGS. 8A and 8B are front and side elevations, respectively, of an auditorium constructed in accordance with the invention;

FIGS. 9A and 9B are front and side elevations, respectively, of a house or building constructed in accordance with the present invention in which the end wall panels are inclined from the vertical;

FIGS. 10A and 10B are similar to FIGS. 9A and 9B but illustrate a more elaborate roof and end wall design;

FIG. 11 is an enlarged fragmentary perspective view of a portion of a building constructed in accordance with the invention in which a set of two wall panels and two roof sections meet and illustrates the positioning of the pivot or hinge axes when taking slab thicknesses into consideration;

FIG. 12 is an enlarged, fragmentary view illustrating a hinge construction in which the hinge line between adjacent roof sections is slightly elevated from the intersection of the remaining hinge axes;

FIG. 13 is a view similar to FIG. 12 and illustrates the relative linear motion between the wall panels and the roof sections and another approach to accommodating such motion; and

FIG. 14 is a fragmentary perspective elevational view of a hingeable connection between two wall panels and corresponding to roof sections similar to FIG. 11 and shows an offset hinge axis between the roof sections so that all hinge axes coincide exactly at a common point.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG.1, in its simplest form a building constructed in accordance with the present invention comprises a roof **2** defined by at least two flat roof sections **4** and a supporting end wall **6** defined by at least two end wall panels **8.** The roof sections are pivotable with respect to each other along a hinge axis H_1, the wall panels are pivotable with respect to each other about a hinge axis H_2 and corresponding panels and sections are pivotable with respect to each other about hinge axes H_3 and H_4. All four hinge axes extend from a common origin **0,** that is all hinge axes intersect point **0.** The illustrated basic structure has a gabled roof with roof sections **4** being angularly inclined with respect to each other by an angle α. Similarly, the wall panels are inclined with respect to each other by an angle β.

The hinged interconnection of the panels and the sections has the effect that once any angle between any pair of panels, sections or between a panel and a corresponding section is fixed all other angles between the panels and sections are determined and fixed. Thus, so long as any one of the angles can be maintained, as by frictionally or mechanically engaging a pair of such panels or sections, the structure is stable and does not need further support.

Referring now to FIGS. **1–4,** the geometric relationship between the panels and the sections can be considered on hand of a quadrangle which is a four-sided figure having sides of a given length. In a quadrangle, the determination of any one of the angles between its sides determines and fixes all other angles. This is so because in the quadrangle of FIG. **3,** defined by two triangles **12, 14** separated by diagonal **16,** the angle *a* in the righthand triangle determines the length of diagonal **16** which in turn determines angle *b* of the lefthand triangle.

The quadrangle of FIG. **3** can be superimposed on the building illustrated in FIG. **1** as is shown in FIG. **4,** where the quadrangle is illustrated in phantom lines. The triangles **12, 14** of the quadrangle lie in two planes that intersect along diagonal **16.** The four sides of the quadrangle are the illustrated diagonals across the roof sections **4** and wall panels **8,** respectively, and are therefore fixed in length. The relative position of the roof sections and the wall panels, that is, their relative angular inclinaton, determines the angles *a* and *b* of the quadrangle. Consequently, once any angle between any

pair of panels or sections is fixed, the angle of the other panels and sections is also determined and fixed.

In practice the building will normally have two oppositely positioned end walls **6** hingeably connected to ends **18** of roof **2** as is shown in FIG. **2.** Each two wall panels **8** and corresponding roof sections **4** form a set of cooperating four flat members that function in a quadrangular fashion as above outlined, that is, in which the angular positioning of one pair of the members, e.g., of the roof sections, determines the angular position of the other pair of the members, e.g., the wall panels, of the set. Thus, the building illustrated in FIG. **2** has two sets of quadrangularly arranged members, namely the lefthand and the righthand end walls combined with the end portions of the roof sections.

Referring now to FIG. **4,** to enable the folding of the side panels beneath the roof sections, for the earlier discussed advantages of requiring a flat supporting surface substantially equal to the foundation for the building, it is necessary that the roof sections **4** and the wall panels **8** are of like angularity. By "like angularity" it is meant that the angles α and β (FIG. **1**) are either open or closed angles, that is both angles are either less or more than 180°. When that condition is met, the roof sections and wall panels both form either a ridge (as in FIGS. **1** and **4**) or a valley (further described below on hand of specific examples). The roof sections may not define a ridge while the wall panels define a valley. Under such conditions the wall panels cannot be folded beneath the roof sections but can only be folded outwardly as, for example, in the above-referenced '482 patent.

The desired foldability of the wall panels beneath the roof sections further requires that the sum of the angles between hinge axes H_1 and H_3, H_4 equals the sum of the angles between hinge axes H_2 and H_3, H_4. When that condition is met, and only when that condition is met, can the wall panels be fully pivoted beneath the roof sections.

Furthermore, for stability of the erected building it is necessary that wall panels **8** are anglularly inclined with respect to each other, that is, that angle β is either less or more than 180°. Were it 180°, in which event the above described sum of the angles between the hinge axes about origin **0** would equal 360°, the building would be unstable because the building walls would be parallel with respect to each other and, therefore, not self-supporting. In effect, the building would be a conventional rectilinear slab building as, for example, disclosed in the above referenced '092 U.S. Pat.

FIGS. **5A–5H** illustrate a practical embodiment of the invention. A flat slab foundation **20** is at the building site and two end walls **22** each defined by two wall panels **24** are conventionally cast on the foundation. Also cast are two rectangular building sides **26** disposed between the end walls. Suitable hinges (not shown in FIG. **5**) connect the panels along hinge axes **28.** After the panels and sides have been cast elongate roof sections **30** are cast on top of the sides. Suitable hinges positioned along hinge line **32** hingeably connect the roof sections with upper edges **34** of the wall panels and upper edges **36** of the building sides. The roof sections are hingeably connected along a longitudinal line **38.** The stacked or sandwiched appearance of the wall panels and the roof sections is shown in FIG. **5F.**

The building is erected by lifting roof sections **30** with a crane or the like. As the roof section elevates above foundation **20** the weight of wall panels **24** and sides **26** gravitationally biases them downwardly relative to the roof sections. As the wall panels pivot downwardly and outwardly the angle β between them decreases. Due to the above-discussed interrelationship of the angles between the panels and the roof sections the roof sections pivot about line **38** to form a gabled roof **40.** Once the end panels are in a vertical position, as shown in FIG. **5D,** the structure is lowered until underside **42** of the end panels rest on foundation **20.** The weight of the panels and the roof sections carried by the end walls generates substantial friction between the panel underside and the foundation so that angle β can be considered fixed. This in turn fixes and immobilizes all other angles, in particular the angles between the roof sections and renders the building stable as soon as erected without auxiliary braces.

FIG. **5E** shows the relative position of the upright building members, namely end wall panels **24** and sides **26** with respect to the outline of foundation **20** (in phantom lines) and the outline of roof **44** (in phantom lines). During the casting of the various slabs the sides and wall panels are fully disposed over foundation **20.** The portions of roof **44** overhanging the foundation can be cantilevered during casting or small and simple supports can be provided. In essence, however, except for the roof overhang, and the extra roof width due to the shortening effect when the roof is folded all walls and roof sections of the building can be cast on the slab foundation.

The building sides **26** extend only over the center portion of roof sections **30.** Maximum stresses in the roof sections are encountered in the center portion so that the sides and end wall **22** can then be closed with attractive doors, windows, or walls (not shown).

Referring now to FIGS. **6A–6F,** the construction of a more intricate house is illustrated. Roof **48** is constructed of four roof sections **50** which are cast on site over previously cast end walls **52** each defined by four end wall panels **54** and building sides **56.** The panels, sides and roof sections are hinged together as above described. Thus, upper edges **58** of the panels and upper edges **60** of the sides are hinged to the underside of roof sections **50** along hinge line **62.** The wall panels are hinged together along three hinge lines **64** while the roof sections are hinged together along three hinge lines **66.**

The house is again erected by lifting roof **48** above slab foundation **68** until the wall panels **54** and sides **60** are vertically oriented.

The house illustrated in Fig. **6** has a roof that is gabled along its centerline and there defines a ridge **70.** Laterally spaced therefrom, however, the roof defines a valley **72** with an angle α_2 between adjacent roof sections **50** that is greater than 180°.

Consequently, as described above, while the angle β_1 between the innermost end panels is less than 180°, as is angle α_1 between the center roof panels, angle β_2 between the outer end wall panels is greater then 180°. The outer end panels, therefore, form between each other a valley **74** just as do the corresponding roof sections. In cross section (FIG. **6E**) the end wall panels no longer define a purely convex or concave pattern but a weaving or generally zig-zag pattern in which the panels define both open and closed angles such as angles

β_1 and β_2. The wide variety of architectural effects that can be achieved with buildings constructed in accordance with the present invention should now be obvious. The shape of both roofs and the end walls can be changed to suit a virtually unlimited range of tastes.

Referring now briefly to FIG. **7**, another building **76** constructed in accordance with the invention is structurally similar to the building illustrated in FIG. **6**; however, it has a substantially different architectural appearance. The angle between adjacent roof sections **78**, and therefore between adjacent wall panels **80** is closed, that is less than 180° so that the end wall has a generally convex configuration. Instead of the gabled appearance of the house of FIG. **6** the building illustrated in FIG. **7** has a barn-like appearance.

Referring now briefly to FIGS. **8**A and **8**B, in another embodiment of the invention an auditorium **81** is constructed of a multiplicity of roof sections **82** which are hingeably joined to first, vertical wall panels **84** and, at their other end, to second, inclined wall panels **86.** The roof sections are hinged to the wall panels so that they define a concave roof **88** (except for the outermost roof section **82***a*). As a consequence of the concave roof, the wall panels **84** define concave end walls **90** and **92.** However, hinge axes **94** between the inclined wall panels are non-vertical and lie in a plane that includes the corresponding hinge line between two roof sections and which is inclined from the vertical as is more fully described below in conjunction with the description of the structures shown in FIGS. **9** and **10.**

The outer appearance of auditorium **81** differs greatly from the outer appearance of the previously discussed structures and houses, that is, the auditorium has no aesthetic resemblance to the more conventional, house-like structures of FIGS. **1–7.** Nevertheless, the principles of the invention discussed above apply equally and are employed in the construction of the auditorium.

Referring to FIGS. **9**A and **9**B, a conventionally appearing structure such as a house **96** has a gabled roof **98** constructed of two roof sections **100** pivotally connected along hinge axis **102.** It will be observed that the roof sections have an irregular shape, that is a non-rectangular shape, and that the hinge axis is inclined with respect to the horizontal.

Both end walls of the house illustrated in FIGS. **9**A and **9**B are inclined with respect to the vertical. Thus, the lefthand end wall **104** (as seen in FIG. **9**B) is constructed of two inclined end wall panels **105** and **106** hinged together along a slanted hinge line **108** that is also inclined with respect to the vertical. Similarly, the righthand end wall **110** (seen in FIG. **9**A) is constructed of two panels, only panel **112** being shown in the drawings, which are substantially smaller than the panels of the lefthand end wall due to the slanted roof and which are joined along another slanted hinge line **114** that is inclined from the vertical. As before, the respective end walls are all hinged to roof sections **100** so that the various hinge axes of each set of two wall panels and two corresponding roof sections intersect a common point.

Referring now to FIGS. **1** and **9**A–**9**B, the angular relationship between the roof sections and wall panels, however, differs somewhat from the relationship of structures having vertical end panels. In particular, the relative angular inclination between each set of two roof sections is not the same as the relative angular inclination between the two corresponding wall panels. It will be remembered that in the structure illustrated in FIG. **1,** which has vertical wall panels, these angles, identified as α and β, respectively, are identical.

However, the sum of the angles between the end wall hinge axis **108** (or **114**) and the hinge axes connecting the panels to the corresponding roof sections still must be the same as the sum of the angles between the hinge axis **102** between roof sections **100** and the end wall panel-to-roof section hinge axes, just as the sum of the angles between H_1 and H_3, H_4 in FIG. **1** must equal the sum of the angles between H_2 and H_3, H_4. In that case, and in that case only, is it possible to fold the end panels beneath and parallel to the roof sections when the roof sections are coplanar and flat so that the panels and the sections can be cast and hingeably joined before their erection.

The house **96** illustrated in FIGS. **9**A and **9**B has some very distinct architectural characteristics, particularly the slanted roof and end walls. Nevertheless, in spite of the unusual and apparently nonsymmetric construction of the house it can be folded in accordance with the invention to provide the above-described cost advantages in constructing the house.

Referring briefly to FIGS. **10**A and **10**B, another house **116** is illustrated which expands on the basic construction of house **96** illustrated in FIG. **9.** In particular, the house comprises a center portion **118,** which is structurally the same as the house illustrated in FIG. **9,** and two outer sections **120** joined to the center section. Each outer section has a roof section **122** and corresponding end panels **124.** The roof section and end panels are hingeably joined to remaining roof sections and end panels **126, 128,** respectively, and the hinge axes between the roof sections and the end panels are arranged so that the angularity of the roof, in cross section, changes into a general zig-zag or up-and-down pattern. The end wall, therefore, also has a zig-zag shaped cross section. It will be noted that the hinge axes between the end wall panels are also slanted and inclined with respect to the vertical.

The slanted orientation of the end wall panel hinge axes places them in a plane, e.g., plane S illustrated in FIG. **10**A, that includes the hinge axis between the corresponding roof sections and which is inclined from the vertical. When the building is folded in its planar position prior to its erection corresponding hinge lines, e.g. hinge line **130** between adjacent panels and hinge line **132** between the corresponding adjacent roof sections are non-parallel and extend angularly away from their imaginary origin (the origin **0** shown in FIG. **1**).

In the preceding theoretical discussion of the invention no provision was made for wall thicknesses, space taken up by hinges, and the like. In practice, it may be desirable to space the wall panels and roof sections (as shown in FIG. **12,** for example), to provide space for the installation of the hinges. For purposes of this specification and the following claims the terms "intersecting," "having a common origin," "meeting at a common point" and the like, all terms denoting that the hinge line of each set of two panels and corresponding two roof sections hinge about axes that originate from a common point, is intended to mean, means and includes deviations in the relative positioning of the axes, either while folded and/or when fully erected, from their geometrically ideal positions to enable the efficient construction of such structures.

All four hinge axes for a given set of two wall panels and corresponding two roof sections can be arranged to precisely meet at a common point even though the wall panels and roof sections have thickness. This can be achieved by constructing the hinges of foldable high strength cables, such as aircraft quality stainless steel cables, in which lower edges of the roof sections, for example, abut the inside of the wall panels. The opposing sides of the wall panels and roof sections are undercut to allow for their respective folding. During actual folding, since the hinge axes coincide at a common point, no relative linear motions between the panels and the sections occur.

Referring now to FIG. **11,** another practical embodiment of the invention is shown in the form of a fragmentary sideelevational perspective of the portion of a building constructed in accordance with the invention where two wall panels and the respective roof sections meet. The thickness of the panels and the corresponding roof sections is clearly apparent from the illustration shown in FIG. **11.**

A fragmentarily illustrated house **134** comprises a vertical end wall **136** and a gabled roof **138.** The end wall is constructed of two end wall panels **140,** preferably two concrete slabs which include cast-in flat steel bars **142** that extend past inner ends **144** of the panels.

Upper edge **146** of the panels is sloped and the free ends of the steel bars at the upper panel edge are bent into a horizontal position. Aligned pivot pins **148** pivotally secure the wall panels to each other and permit relative pivotal movements between the panels about hinge axis H_2.

Roof **138** is constructed of two roof sections **150,** preferably also concrete slabs which have integrally cast-in flat steel bars **152** which extend past inner slab ends **154.** Pivot pins **156** secure the roof sections to each other and permit relative pivotal movement about hinge axis H_1. In the illustrated embodiment of the invention the hingeable connection between corresponding wall panels **140** and roof sections **150** are defined by hinge brackets **158** between the panels and the sections. The brackets have a generally U-shaped configuration and are respectively secured to, e.g. cast-in, the respective concrete slabs and interconnected by pivot pins **160** to permit relative pivotal movements between the roof sections and the wall panels about hinge axes H_3 and H_4.

To provide space for brackets **158** hinge axis H_3 is elevated above the intersection of the remaining hinge axes H_2–H_4. Thus, all hinge axes do not intersect a common point. The failure to intersect all hinge axes results in relative linear movements between the roof sections and the wall panels when the building is erected.

Referring briefly to FIG. **13,** brackets **158** are illustrated in their relative positions when the house is fully erected. The roof has moved inwardly, that is towards the center of the house with respect to the wall panel. This movement must be compensated for to prevent stressing and possible damage to the connecting hinges and/or the wall panels and roof sections. In one approach this is accomplished by permitting brackets **158** to slide relative to each other along an elongated pin **161** provided with suitably enlarged ends **163** that retain the pin to the brackets. The extent to which the brackets move relative to each other is determined by the misalignment of the hinge axes.

FIG. **12** illustrates another approach to accommodating relative linear movements between the roof sections and the wall panels. The U-shaped brackets **158** are constructed so that upon the erection of the building they yield, that is they permit deformation of their flanges **162** relative to their webs **164** into a generally trapezoidal shape.

Such relative linear movements can also be accommodated by slotting the flat steel bars **142** (the slots are not illustrated in FIG. **11**) so that the panels can move with respect to the roof sections or by correspondingly slotting steel bars **152** of roof slabs **150.** Alternatively, the hinges defining hinge axes H_3 and H_4 can be recessed into the roof section, the wall panel, or both (not illustrated) with the provision of suitable protrusions on the opposing panel or roof section so that the intersection of axes H_3 and H_4 is raised to coincide with the intersection of axes H_1 and H_2. Such a recessed, hinged connection can be slotted to snugly abut the roof sections and wall panels. Such a hinge construction for use in foldable building constructions is disclosed in the inventor's copending patent application bearing Ser. No. 219,237, filed Jan. 20, 1972 and entitled STRUCTURAL HINGE FOR FOLDING SLAB CONSTRUCTED BUILDINGS, now abandoned. The disclosure of that copending patent application is incorporated herein by reference.

Referring to FIG. **14,** a still further alternative to accommodate relative linear movements between the wall panels and the roof sections is to lower hinge line H_1 to coincide with the intersection of the remaining hinge lines. For this purpose an L-shaped member **166** is affixed, e.g. cast into roof slabs **168.** The L-shaped members are pivotally secured together with a hinge pin **170,** the center of which is at the intersection of all hinge axes defined by the hinges between wall panels **172** and corresponding wall panels and roof sections. The latter hinge axes can be defined by rigid, U-shaped, hingeably connected brackets (as illustrated in FIG. **13** but without provisions for axial movement) between the bracket.

I claim:

1. A method for constructing side and roof portions of a building comprising the steps: providing a pair of coplanar first and second panels; providing a pair of coplanar third and fourth panels above said first and second panels; pivotally connecting all four panels on four axes, each axis intersecting the other three axes at a common point of intersection, one axis connecting the first and second panels, a second axis connecting said third and fourth panels, a third axis connecting said first and third panels, and fourth axis connecting said second and fourth panels, the sun of the angles between the axes of pivotal intersection being substantially less than 360°; and lifting said third and fourth panels, causing said first and second panels to pivot upwardly relative to said one axis and said third and fourth panels to pivot downwardly relative to the second axis; whereby said panels become rigidly inclined with respect to connecting panels.

2. The method of claim **1,** the angles of intersection between said second axis and said third and fourth axes being substantially equal and acute.

3. The method of claim **1,** said first and second panels having parallel side edges that extend perpendicular to intersecting base edges, said first and second panels

forming a stable support for said third and fourth panels.

4. The method of claim **1** and further comprising the steps: providing a fifth panel coplanar with said first and second panels; providing a sixth panel coplanar with said third and fourth panels; and, pivotally connecting said fifth and sixth panels on a fifth axis that intersects said third axis, pivotally connecting said fifth panel with said first panel on a sixth axis, pivotally connecting said sixth panel with said third panel on a seventh axis, said sixth and seventh axes intersecting said fifth and third axes at a common point of intersection.

5. A method for constructing a roofed building comprising the steps of hingeably connecting a number of flat end panels to construct two opposing end walls for the building, each end wall having a pair of panels; placing a pair of flat roof sections over the panels; hingeably connecting the roof sections to construct a roof for the building, hingeably connecting an end wall to each end of the roof with the hinge axes between any pair of corresponding panels and sections intersecting at a common point, the sum of the angles between hinge axes which meet at a common point being substantially less than 360°; and thereafter erecting the building by lifting the roof sections, allowing the wall panels to pivot gravitationally downwardly with respect to the sections and causing the sections and panels to become rigidly inclined with respect to its pair; then supporting the panels on the ground to form a stable support for the roof sections.

* * * * *