United States Patent [19]

Salas

[11] **3,854,266**

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[54] **METHOD OF CONSTRUCTING BUILDING STRUCTURES OF ZIG-ZAG PROFILE**

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[52] **U.S. Cl.** **52/742,** 52/18, 52/71, 52/745

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

[58] **Field of Search** 52/745, 18, 742, 743, 64, 52/70, 71, 747, 285, 583, 432

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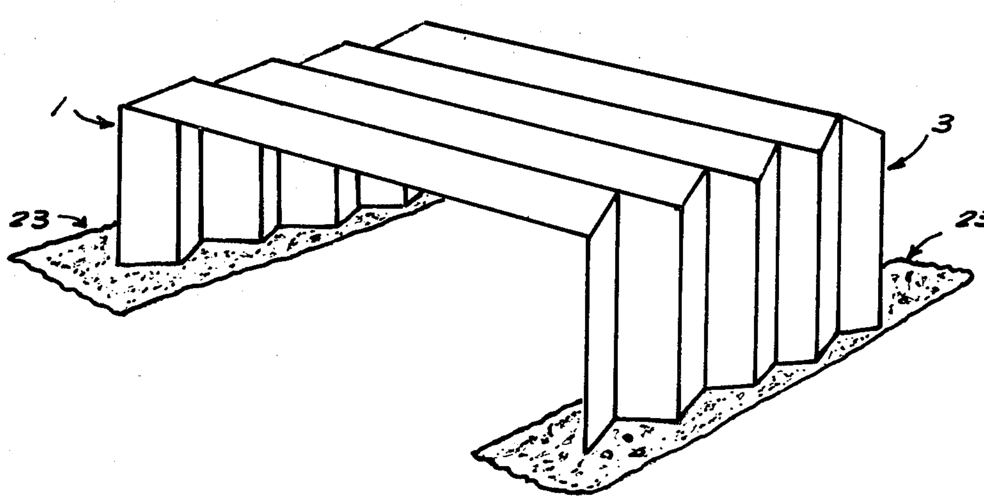
[57] **ABSTRACT**

A method of constructing building structures having walls of zig-zag profile, the steps of arranging panels in a juxtaposed, hinged-together, coplanar relationship, lifting the entire assembly at predetermined lifting points to erect the structure and to simultaneously form the zig-zag configuration by virtue of the gravity-caused angular movement of the panels with respect to one another and grouting all the hinges to "freeze" the erected structure.

3 Claims, 14 Drawing Figures



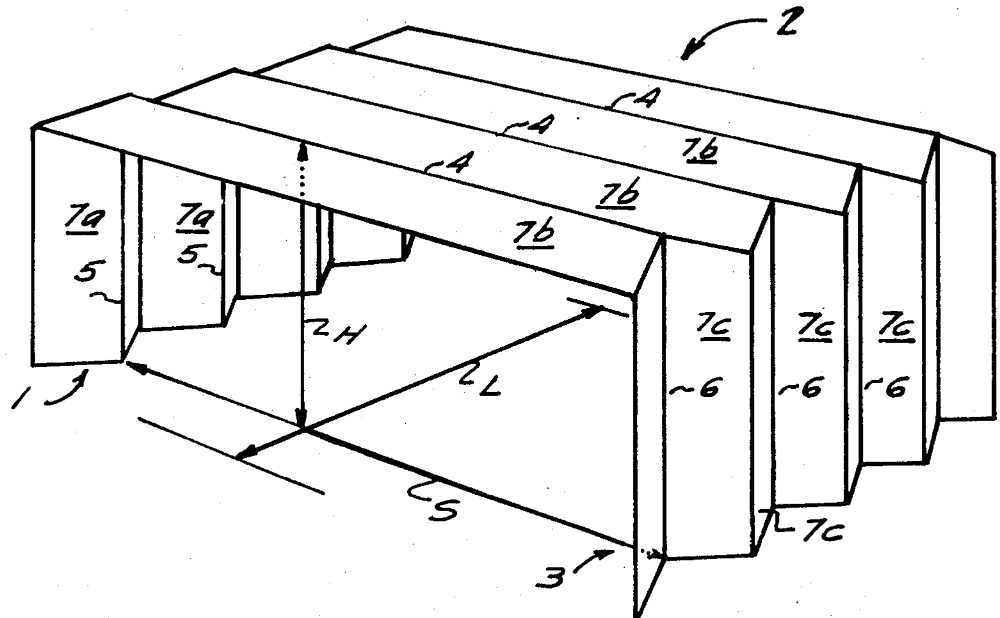


FIG. 1

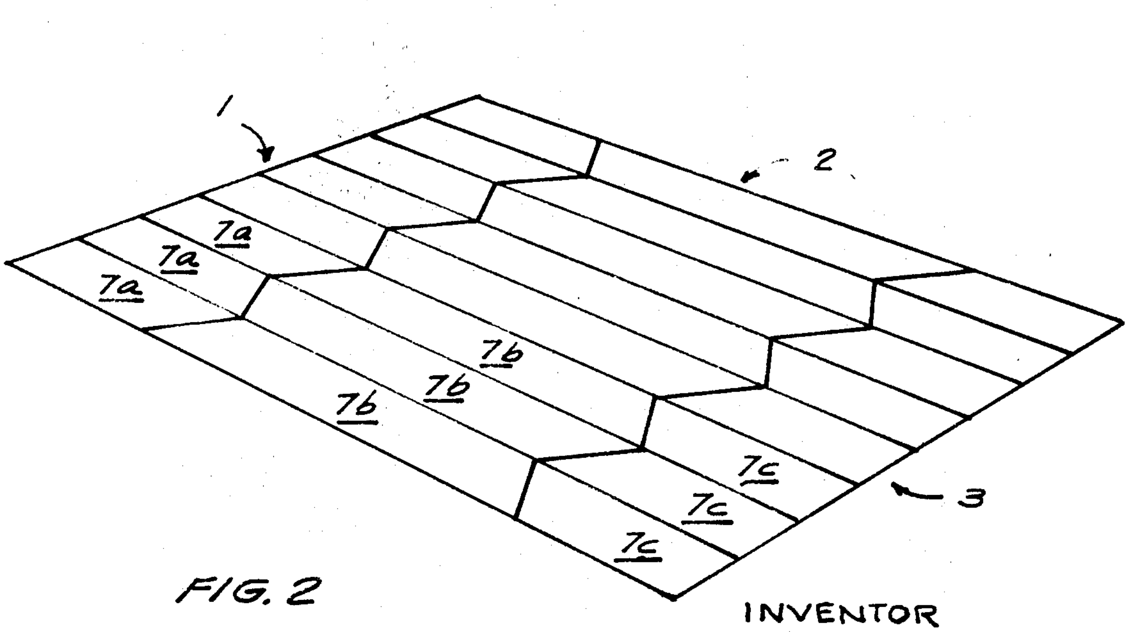


FIG. 2

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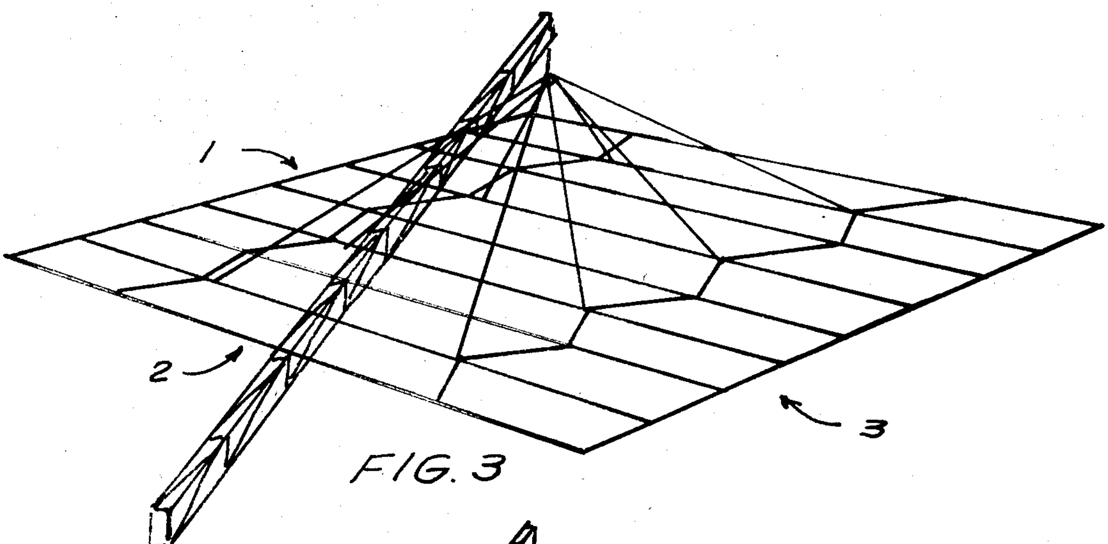

FIG. 3

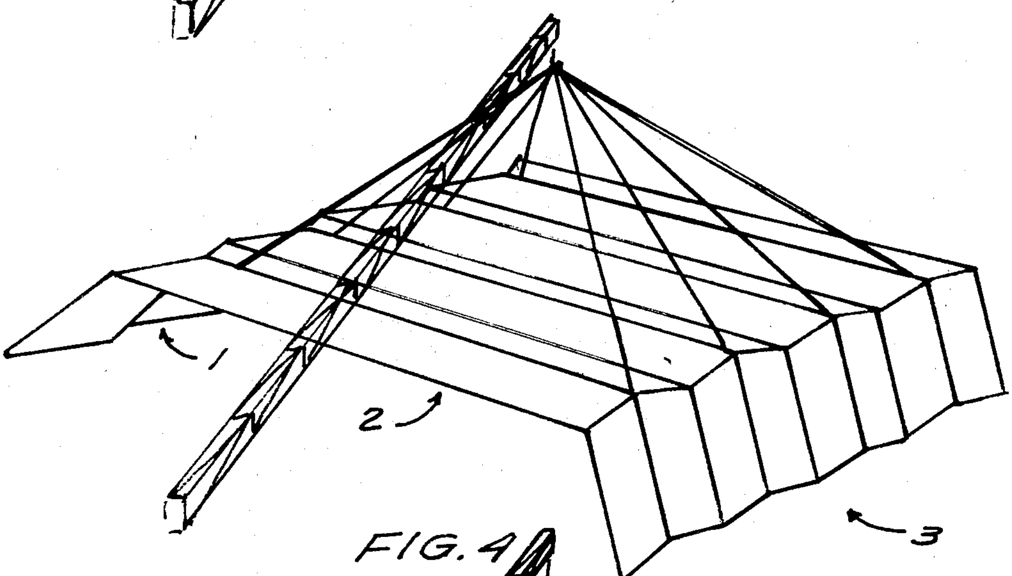

FIG. 4

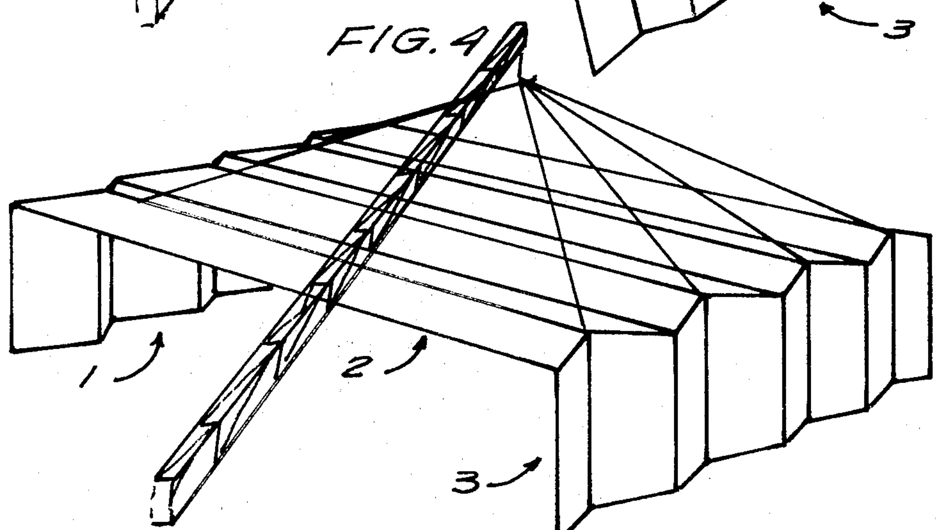

FIG. 5

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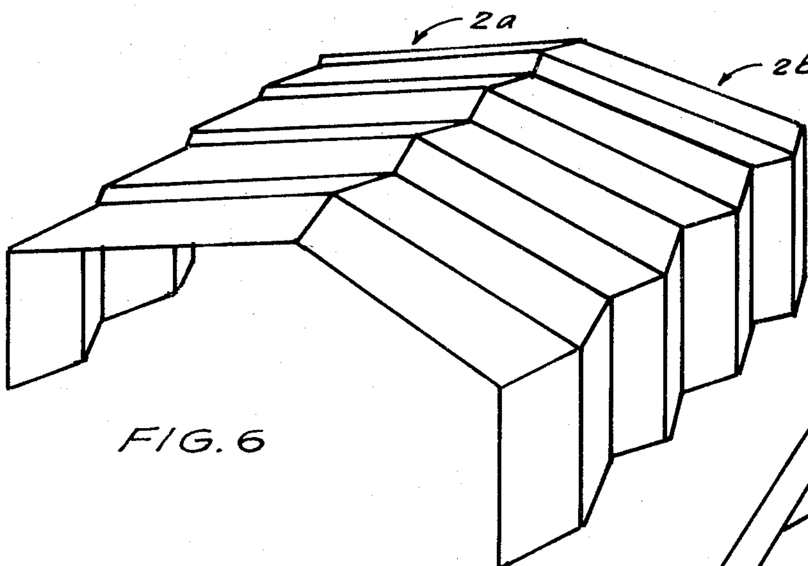

FIG. 6

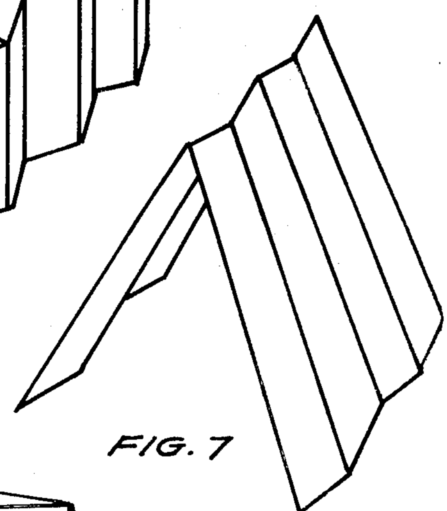

FIG. 7

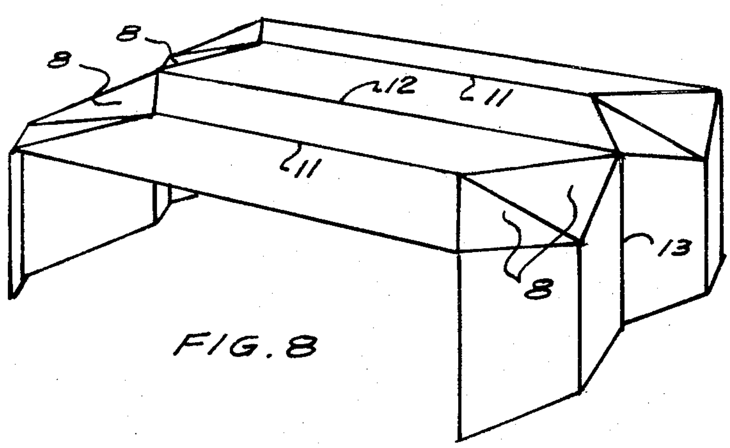

FIG. 8

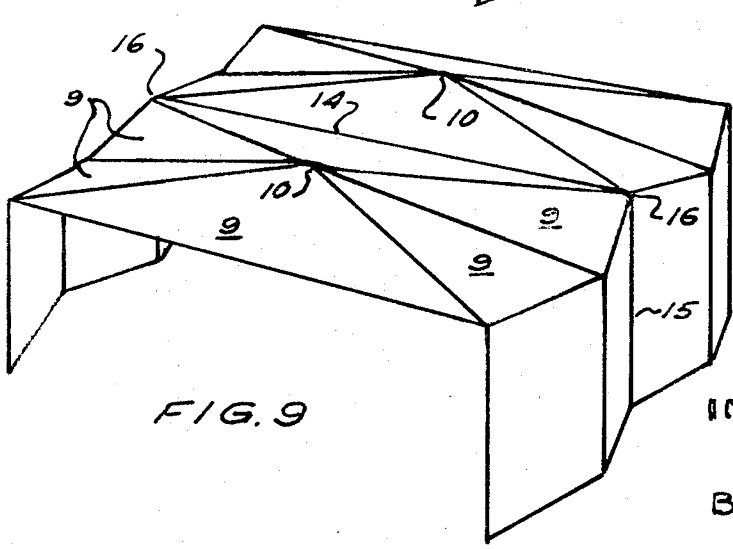

FIG. 9

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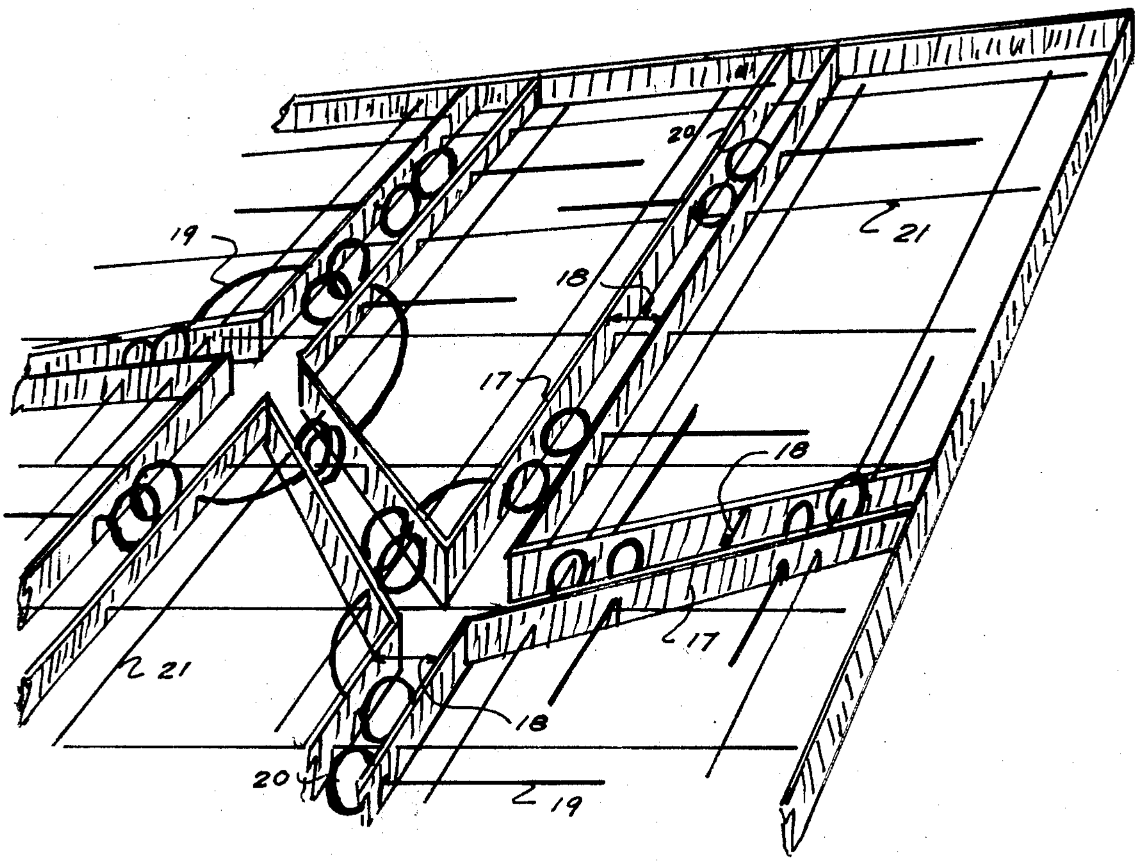

FIG. 10

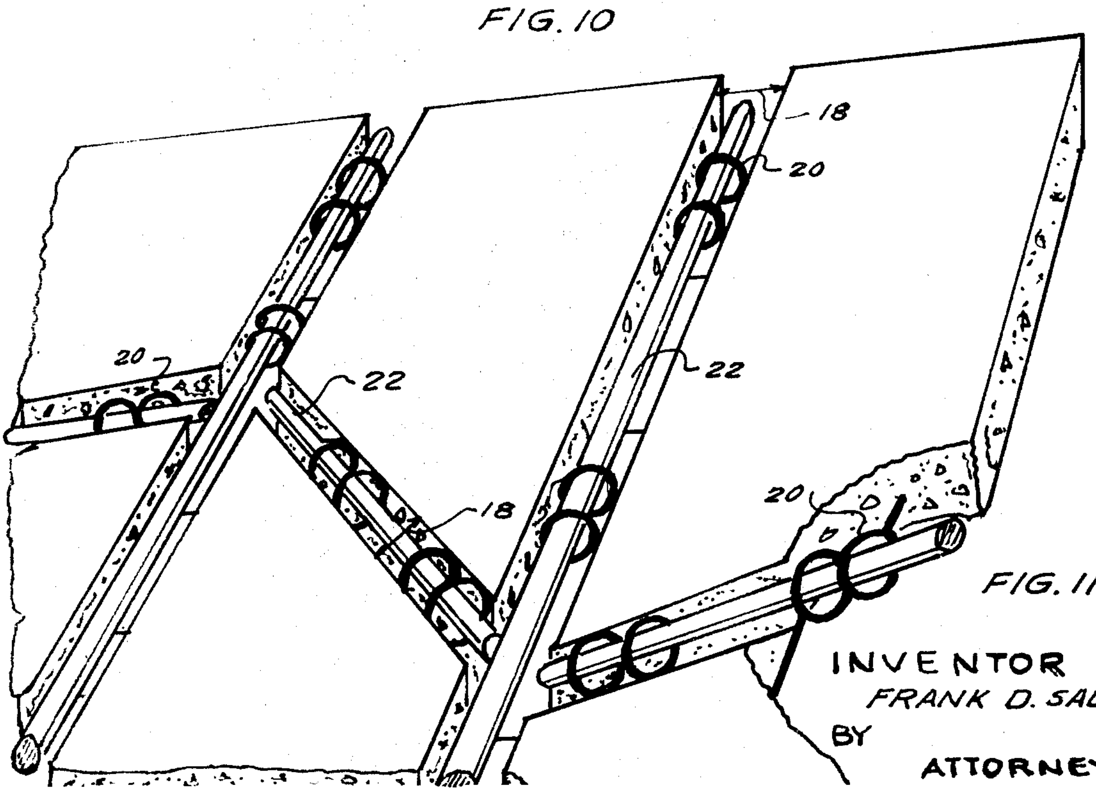

FIG. 11

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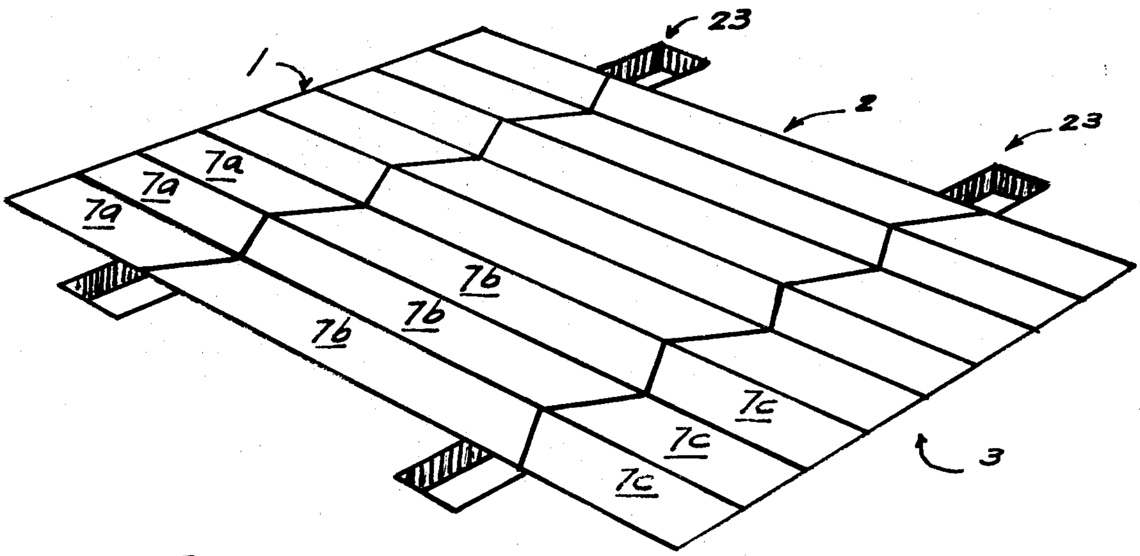

FIG. 12

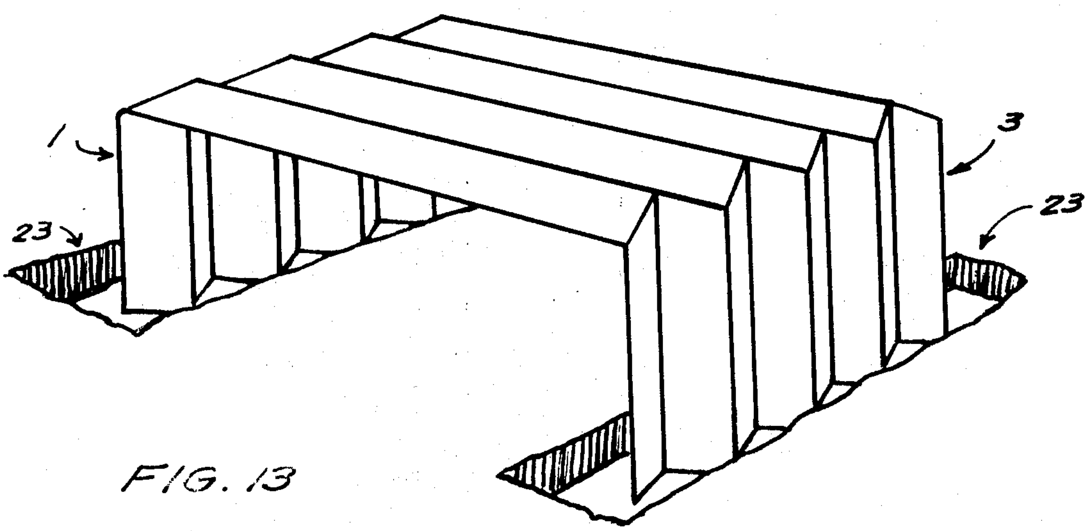

FIG. 13

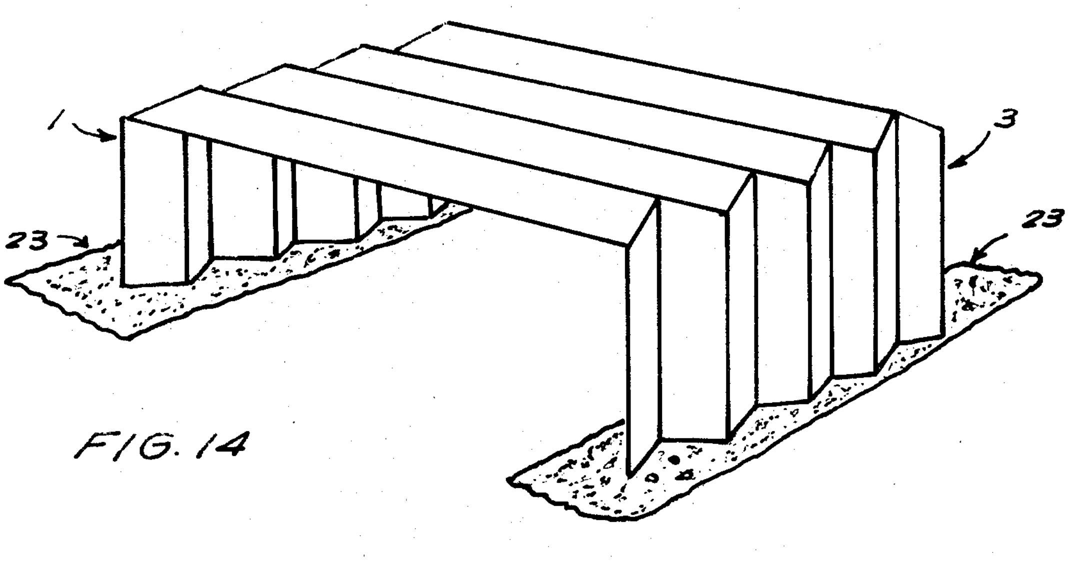

FIG. 14

METHOD OF CONSTRUCTING BUILDING STRUCTURES OF ZIG-ZAG PROFILE

BACKGROUND OF THE INVENTION

This invention relates to a method of constructing building structures of the type that have a plurality of walls each, formed of generally elongated panels attached to one another at adjoining edges and forming an angle so as to produce a zigzag profile. Structures of this zig-zag type have a particularly high rigidity and therefore a high load-carrying capacity.

According to one known method, the entire interconnected structure is shipped to the construction site in an accordionlike collapsed state, in which the hingedly interconnected panels are stacked face-to-face so that the angle between adjoining panels is close to zero. An end view of such collapsed or folded structure shows substantially the same configuration as in its final position. At the site of erection, the accordion-like folded structure is positioned upright and pulled open by a force normal to its span. This method of erection is practiced mostly with light-weight, thin, flexible materials wherein the panels have been preformed by suitable folding. These lightweight structures usually form the building itself which is generally of temporary nature (tents, temporary light shelters, and the like). This method is not adaptable to panels of heavyweight and rigid material such as concrete, since the weight and bulkiness of the interconnected components render it impractical for shipment and unfolding to a final position at the site of erection.

In another conventional method, the building structure of zig-zag profile, particularly if it is of the heavy-weight type, is assembled, panel by panel, with the aid of construction scaffolds. According to this method, each panel is mounted in its final position and thus no relative angular movement of the panels takes place.

Known methods of assembling structures of zig-zag wall profile, particularly of the type that consist of heavyweight panels, such as concrete slabs, is a relatively lengthy, slow and circumstantial process, normally requiring extensive scaffolding and costly form work.

OBJECT AND SUMMARY OF THE INVENTION

It is an object of the invention to provide an improved method for the construction of buildings or structures having multiple walls of zig-zag profile. This method permits a greatly simplified erection of the components and assemblies involved and a wide choice of building configurations and construction materials.

Briefly stated, according to the invention, trapezoidal and/or triangular panel elements are first juxtaposed and hingedly interconnected at the construction site to form a planar, coherent assembly, wherein the panels form as many series as there are walls in the eventual structure.

As a subsequent step, hoisting means are attached to the panel assembly at predetermined lifting points.

Subsequently, the assembly is lifted whereupon, by virtue of the cooperation between the gravitational force and the lifting force attacking at particularly selected lifting points, the walls of the structure and the zig-zag profile of each wall are gradually formed. During the lifting operation the roof walls are raised to a predetermined height while the terminal walls swing inwardly towards one another until the desired, predetermined angle with respect to the ground is obtained.

Thereafter, by means of grouting or the like, all the hinges between all the panels forming the structure are "frozen" and the terminal walls are anchored to the ground, or a supporting structure, whereupon a rigid, permanent, high load resistant building structure is obtained.

The invention will be better understood, as well as further objects of the invention will become more apparent, from the ensuing detailed specification taken in conjunction with the drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a schematic perspective view of an exemplary building structure in an erected position;

FIG. **2** is a schematic perspective view of the same building structure laid out coplanar prior to erection;

FIGS. **3–5** illustrate schematically and in perspective views successive steps of erecting a building structure according to the invention;

FIGS. **6–9** are schematic perspective views of four further exemplary building structures in an erected position;

FIG. **10** is a fragmentary perspective view of a form for casting a building structure which can be constructed with the method according to the invention;

FIG. **11** is a fragmentary perspective view of an assembly of hinged slabs obtained from casting in a form shown in FIG. **10** and

FIGS. **12, 13** and **14** are schematic perspective views of a building structure in successive operational phases of the method according to the invention.

GENERAL DESCRIPTION OF THE METHOD

Turning first to FIG. **1**, there is shown a particular configuration of a typical structure in its final, permanent position subsequent to the completion of the construction method practiced according to the invention. As seen, this structure comprises three walls **1**, **2** and **3**. Walls **1** and **3** are terminal walls, the free ends of which are supported on or in the ground. The wall **2** will be hereinafter designated as the roof wall. The distance between the two terminal walls **1** and **3** measured at the ground is the span S, while the horizontal dimension normal to the span is the length L of the structure. The vertical distance between the roof wall and the ground is the height H.

Each wall has a zig-zag profile with alternating ridges and valleys. It is noted that in this particular configuration any imaginary vertical plane normal to the length dimension L and containing a ridge (as viewed from the outside) of the roof wall **2**, also contains a valley in each of the terminal walls **1** and **3**. Stated in different terms, each ridge **4** in the roof wall **2** changes into a valley **5** in terminal wall **1** and into a valley **6** in terminal wall **3**.

Each wall of the building structure consists of a series of trapezoidal panels. The latter are designated at **7**_a_, **7**_b_ and **7**_c_, forming walls **1, 2** and **3**, respectively.

Turning now to FIG. **2**, as an initial step of the method according to the invention, all the panels are juxtaposed and hinged together at the construction site.

The panels which are all trapezoids in this example, are arranged in a plurality of adjacent series. Each panel series will eventually constitute one wall of the structure. The panels belonging to the same series are juxtaposed in such a manner that identical long sides of adjoining panels are immediately adjacent and are in exact alignment with one another.

The panels of one series (e.g., panels 7*a*) are so arranged and hinged to the panels of an adjacent series (panels 7*b*) that the immediately adjacent short sides of two adjoining panels 7*a* and 7*b* are in exact alignment with one another.

It will be apparent from a comparison of FIGS. 1 and 2 that the width and number of panels in one series, as well as the angle between adjoining panels, will determine the eventual length L of the structure.

Each panel is hingedly joined to the immediately adjacent panel at least at two points on each side.

As a subsequent step, the location of lifting points on the presently planar panel assembly is determined. The primary consideration in determining the lifting points is to ensure that the initial, overall planar assembly will be transformed into a structure where all the walls are of a zig-zag profile. In the given example the central panel series consisting of panels 7*b* will form the roof wall 2 and consequently, this entire wall will be spaced from the ground. As a comparison of FIGS. 1 and 2 indicates, the shorter one of the two long, parallel sides of each trapezoid will form a ridge 4. The straight line continuation of each such designated ridge is the longer one of the two long, parallel sides of adjoining panels 7*a* and 7*c* of the terminal walls 1 and 3. They will form valleys 5 and 6, respectively. It will now be apparent that in order to obtain a zig-zag profile of the roof structure, lifting points have to be located on each ridge of the roof. The number of lifting points on any ridge of the roof wall is not critical for practicing the invention; for the purpose of reducing erection stresses, however, the optimal solution would be to have as many lifting points along one particular ridge as practical. As a practical solution, it has been found satisfactory to have two lifting points per ridge; each lifting point being close to the ends adjoining the panels that form the terminal wall.

Subsequently, cables of a hoisting device, such as a crane, are attached to the lifting points, as illustrated in FIG. 3. The choice of the particular hoisting device is not critical and may be guided solely by practical considerations. Thus, for example, instead of a crane, it is feasible to use a trolley-type hoist or helicopters.

FIGS. 4 and 5 illustrate the building structure in an intermediate and in a final position, respectively, during and upon completion of the lifting operation.

As the structure is being lifted by cables at the previously determined lifting points, the formation of the accordion-type configuration of not only the roof wall 2, but also of the terminal walls 1, 3 will simultaneously and progressively take place. During this operation, two types of angular changes will take place simultaneously by virtue of the hinged attachment between panels and the interaction between the lifting and the gravitational forces: in the first place, the originally 180° angle between adjacent panels in each series will decrease leading to the zig-zag profile of each wall and, in the second place, the originally 180° angle between adjacent panel series will decrease whereby the angular disposition of one wall with respect to an immediately adjacent wall will appear. The decrease in the first angle shortens the length of the assembly to approach the predetermined length L and the decrease of the second angle reduces the span of the structure to approach the predetermined span S. During these angular changes, the distance of the roof wall 2 from the ground gradually increases until the structure approaches its predetermined height H. It is thus seen that the building structure of predetermined design is formed from the entirely planar panel assembly by imparting thereto a "dual folding," during the course of which there are simultaneously (a) formed the structurally rigid zig-zag profile of each wall and (b) effected the angular disposition of one wall with respect to an adjoining other wall. As mentioned before, all the angles are initially 180° and decrease gradually as the dual folding progresses. During this dual folding operation none of the panels need to undergo a deformation and therefore the panels may be, and preferably are, of practically entirely rigid material, such as concrete. Thus, at any given moment during the dual folding operation and after the completion thereof, between any two adjoining panels in any wall, the angle will have a constant value along the joining line of two such panels.

When the predetermined dimensions (span, length and height) of the structure are obtained, the lifting operation is terminated and thereafter steps are taken to prevent any further angular change in the relative position of the panels with respect to one another. This is achieved by rigidizing the hinges between panels, for example, by means of grouting, and anchoring the lower ends of the terminal walls to the ground or to a supporting structure.

The aforedescribed method is adapted to be used with a great variety of structural configurations consisting of walls having a zig-zag profile. Thus, in addition to the two terminal walls which engage the ground or a supporting structure, the building structure may have two or more roof walls instead of the single roof wall 2 of the structure shown in FIG. 1. Thus, the structure shown in FIG. 6 is similar to that of FIG. 1, except that the roof is formed of two roof walls 2*a* and 2*b*.

In general, if the building structure includes more than one roof wall, the lifting speed for different points of the roof wall panels is different. It is the highest at those points of a ridge that will be eventually positioned highest in the erected structure and decreases for those ridge points that are closer to the terminal walls.

The invention may also be practiced in case of a structure having only terminal walls (A-frame) as shown in FIG. 7.

The method according to the invention and described hereinbefore in connection with structures formed solely of trapezoidal panels may be equally practiced in case of structures which include triangular panels. Two such examples are illustrated in FIGS. 8 and 9.

In FIG. 8, the roof wall formed of trapezoidal panels is connected to the terminal walls, also formed of trapezoidal panels, not directly as shown, for example, in FIG. 1, but with the interposition of triangular subpanels 8.

The structure depicted in FIG. 9 is developed from the configuration according to FIG. 8 by reducing the length of the adjoining panel sides of the roof to zero. In this manner the roof wall is formed only of triangular panels 9 meeting in points 10 situated along the length dimension of the structure.

Turning now to the determination of lifting points in case of the structures according to FIGS. 8 and 9, it is apparent that at least one (but preferably more) lifting point should be selected on each ridge 11 in FIG. 8. Further, on the same structure, there should be one lifting point at the intersection between each valley 12 of the roof wall and each valley 13 of the terminal walls.

In the structure according to FIG. 9, there should be a lifting point at each peak 10 and also, at the intersection between each valley 14 of the roof wall and each valley 15 of the terminal walls.

Generalizing the selection of lifting points with regard to the structures illustrated in FIGS. 1, 6, 8 and 9, it may be said that there should be at least one lifting point between any two valleys lying in a vertical plane that is substantially normal to the length dimension of the structure. If such two valleys are interconnected by a ridge (such as ridge 4 in FIG. 1 or ridge 11 in FIG. 8), then preferably several lifting points are used, distributed along such ridge. If, on the other hand, two valleys intersect (such as shown in FIG. 9 at points 10 and 16), then the point of intersection will be designated as a lifting point.

DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

In the description that follows, there will be set forth an on-the-site casting and erection of a reinforced concrete building structure integrally incorporating the aforedescribed method.

As a first step, in the ground where the structure is to be erected, two parallel linear trenches are excavated. They are spaced from one another at a distance that corresponds to the predetermined span of the building structure, while their lengths correspond to the predetermined length of the building. The depth and the width of each trench are so designed as to receive, for anchoring and support purposes, the lowermost portion of a terminal wall of the building structure.

As a next step, over and symmetrically with respect to the two trenches a planar mold or form is built having a plurality of partitions forming spaces of trapezoidal and/or triangular configuration. These spaces are disposed with respect to one another in the same relationship as the intended building structure when laid out prior to the lifting operation. Further, between each trapezoidal and/or triangular space, the partitions define clearances, the purpose of which will become clear hereinafter.

As shown in fragmentary FIG. 10, the partitions 17 are spaced from one another to define continuous clearances 18 therebetween. In each partition there are inserted eye bars 19 each having an eye 20 arranged in the aforenoted clearances 18 and the opening of which lies in a vertical plane. In each individual clearance 18 the eyes 20 of all the eye bars 19 are arranged in axial alignment. For reinforcing purposes a continuous mesh 21 — made for example of wire — extends horizontally over the entire form and thus also passas through the partitions and through the clearances 18.

In a further step, concrete, or any other suitable casting material (for example, gypsum) is poured in the form between clearances so as to form trapezoidal and/or triangular panels connected by the mesh. Subsequent to the hardening of the casting material, the partitions are removed. Each planar trapezoidal or triangular slab now has embedded in each of its sides eye bars 19 with axially aligned eyes 20.

Turning now to FIG. 11, through each series of eyes 20 in one linear clearance 18, there are inserted rigid metal rods or cables 22, the length of each equals approximately the length of the two immediately adjacent panel sides. Thus, the eye bars 19 embedded in the cast slab and the rods 22 threaded therethrough form a hinge connection between any two adjacent trapezoid or triangular slabs. It is to be noted tha the adjacent slabs are also connected by the mesh 21.

Thereafter, the lifting operation may be performed as described earlier in the specification. It is also noted that the lifting cables may be fastened to the appropriate rods 22 or to the eye bars 19 which coincide with the predetermined lifting points on each panel. The mesh 21 will bend in the clearances 18 by virtue of the weight of the cast slabs, thus permitting the latter to assume the aforedescribed angular relationship with respect to one another.

As soon as the free ends of the terminal walls drop into the preformed trenches, the lifting operation is terminated.

In order to render the structure entirely rigid, the clearances between the panels are grouted and further, concrete is poured into the trenches to provide an anchor for the terminal walls.

FIG. 12 illustrates the relationship between two parallel linear trenches 23 and a panel assembly having walls 1, 2 and 3 prior to the lifting operation.

FIG. 13 depicts the building structure after the side walls 1 and 3 have dropped into the respective trenches 23 and the lifting mechanism has been removed.

FIG. 14 shows the trenches 23 filled with an anchoring material, such as concrete, to permanently fix the building structure in its erected position.

The aforedescribed construction method greatly simplifies the casting and erection of concrete building structures. It is seen that no transporting of the concrete slabs is necessary since the entire structure is erected directly from the position in which it was cast.

What is claimed is:

1. A method of constructing a building structure of predetermined design formed of walls each having a zig-zag profile bounded by alternating ridges and valleys, each wall consisting of a plurality of edge-wise adjoining and interconnected planar, straight-edged polygonal panels disposed at an angle to one another, comprising the following steps:

A. excavating two parallel trenches spaced from one another at a distance corresponding to the intended width of the building structure, each trench having a length corresponding to the intended length of the building structure, each trench having a width and a depth adapted to receive lowermost zones of two walls of the building structure;

B. juxtapositioning and hingedly interconnecting all panels to form a coplanar, coherent assembly, panels constituting one and the same wall follow each other along the length dimension of said structure and are disposed at an angle of 180° with respect to one another, panels constituting different walls follow each other along the span dimension of said structure, wherein adjoining walls are disposed at an angle of 180° with respect to one another, said coplanar, coherent assembly being laid over said trenches;

C. imparting a dual folding to said coplanar assembly in a single operation for gradually forming said zig-zag profile of all of said walls and, simultaneously, gradually decreasing the angle between adjoining walls, wherein all the angles of inclination between any two adjoining panels in any wall decrease in unison and have all identical magnitudes at any moment of the folding operation, whereby each panel maintains unchanged its planar configuration at all times;

D. dropping, in the course of said dual folding operation, said lowermost zones of two walls into said trenches, whereby said predetermined design is reached;

E. discontinuing, subsequent to step (D), said dual folding operation;

F. fixing, subsequent to step (E), all the hinges between all the panels to obtain a permanently rigid building structure of said predetermined design; and

G. filling, subsequent to step (E), said trenches with a material to permanently immobilize said lowermost zones.

2. A method of constructing a building structure of predetermined design formed of walls made of casting material, each wall having a zig-zag profile and consisting of a plurality of edgewise adjoining and interconnected planar, straight-edged polygonal cast slabs disposed at angle to one another, comprising the following steps:

A. excavating two parallel trenches spaced from one another at a distance corresponding to the intended span of the completed building structure, each trench having a width and depth adapted to receive for anchoring and support, the lowermost wall portion of the building structure;

B. building, over said trenches, a planar form having partitions enclosing upwardly open spaces of the shape of the slabs to be formed, said spaces adjoining one another with a clearance on each side;

C. placing eyebars in each partition for each side of each space, the eyes of said eye bars being arranged in a vertical plane and in a horizontal alignment in each clearance;

D. pouring a casting material in each partition, subsequent to steps (B) and (C), to obtain a coplanar cast slab assembly wherein slabs constituting one and the same wall follow each other along the length dimension of said structure and are disposed at an angle of 180° with respect to one another, slabs constituting different walls follow each other along the span dimension of said structure wherein adjoining walls are disposed at an angle of 180° with respect to one another;

E. placing rod means in each clearance to pass through each eye disposed therein; said eye bars and rod means forming hinges;

F. removing said form after hardening of the casting material subsequent to step (D);

G. attaching hoisting means to a plurality of predetermined lifting points on said coplanar slab assembly;

H. imparting a dual folding to said coplanar slab assembly in a single operation for gradually forming said zig-zag profile of all of said walls and, simultaneously, gradually decreasing the angle between adjoining walls by lifting, subsequent to step (G), said cast assembly by said hoisting means to a predetermined height, whereby all the angles of inclination between any two adjoining slabs in any wall decrease in unison and have all indentical magnitudes at any moment of the folding operation, whereby each panel maintains unchanged its planar configuration at all times;

I. dropping, in the course of said lifting operation, said lowermost wall portions into said trenches, whereby said predetermined height is reached; and

J. fixing, subsequent to step (H), all the hinges between all the cast slabs to obtain a permanently rigid building structure.

3. A method as defined in claim **2,** including the step of pouring concrete into said trenches subsequent to the termination of step (I).

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