Oct. 6, 1970 K. M. DOUGLAS 3,531,851

METHOD OF ASSEMBLING TRAPEZOIDAL PLATE STRUCTURE

Filed Sept. 5, 1968 4 Sheets-Sheet 1

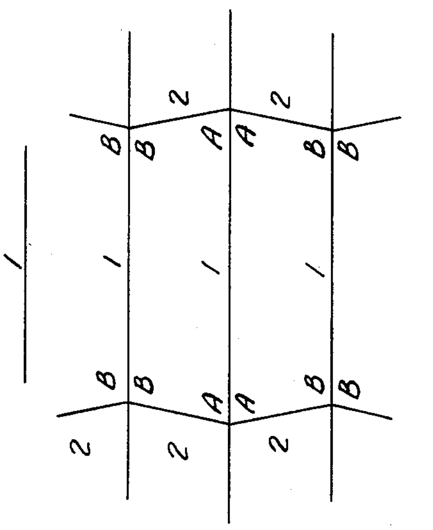

Fig. 1

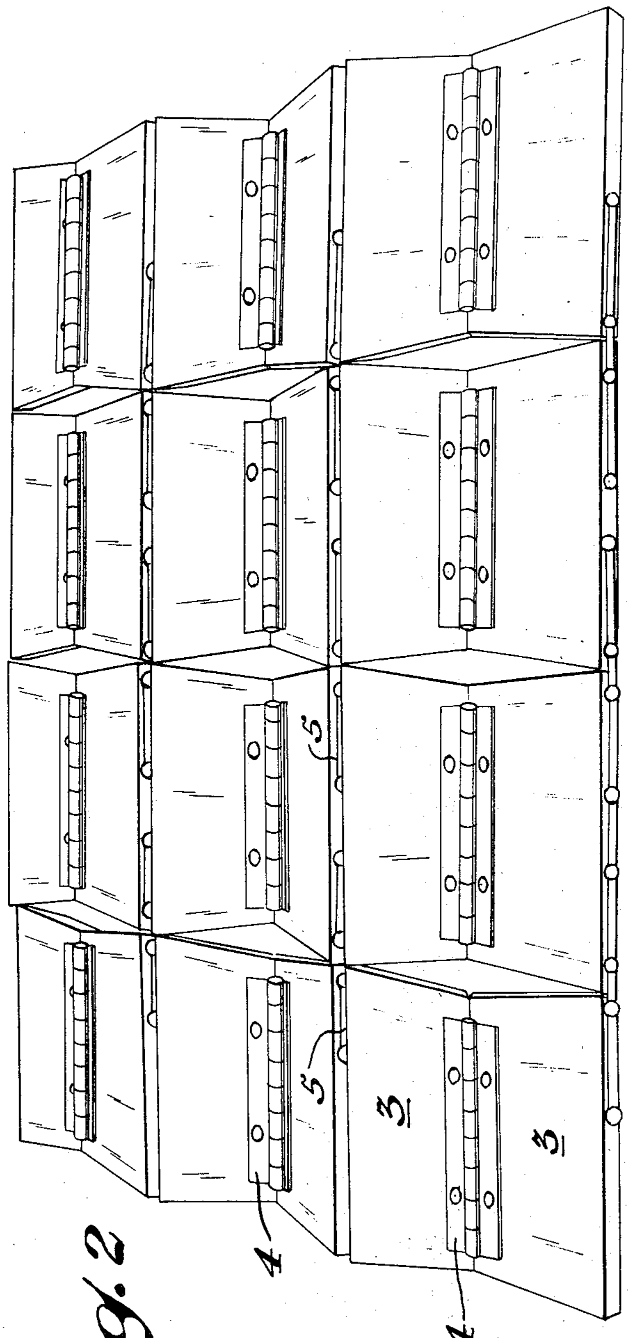

Fig. 2

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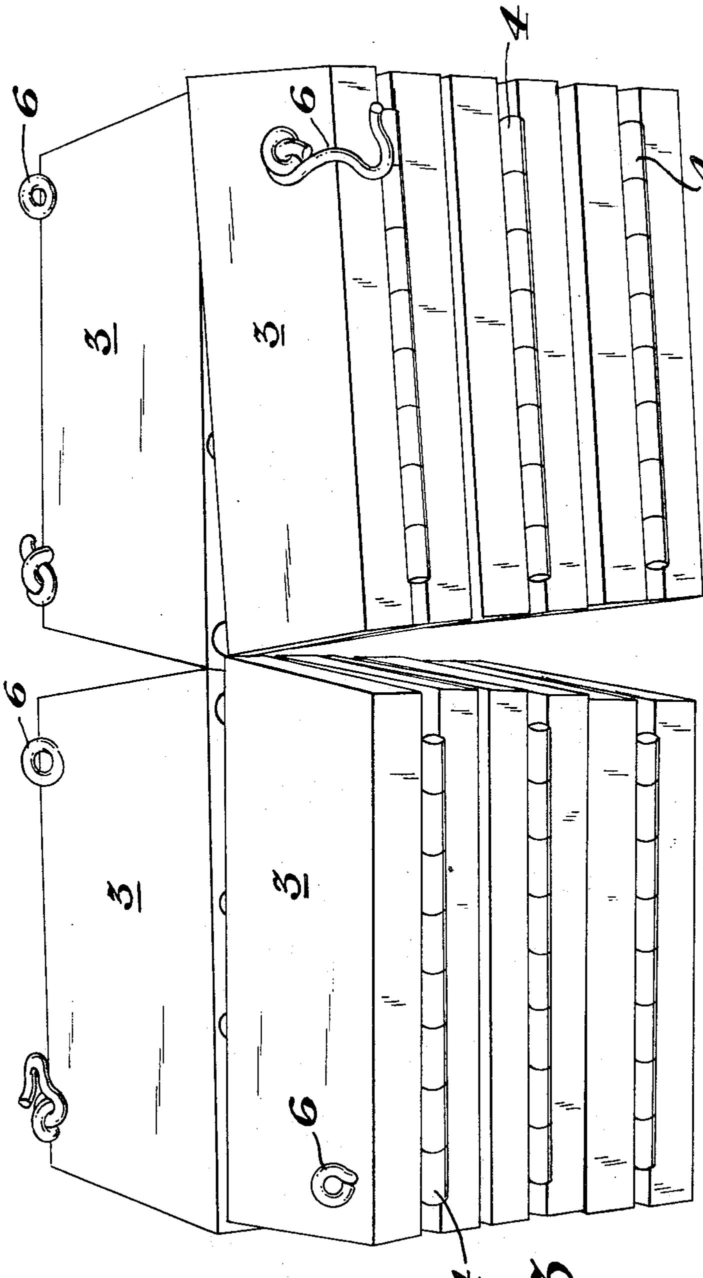

Fig. 3

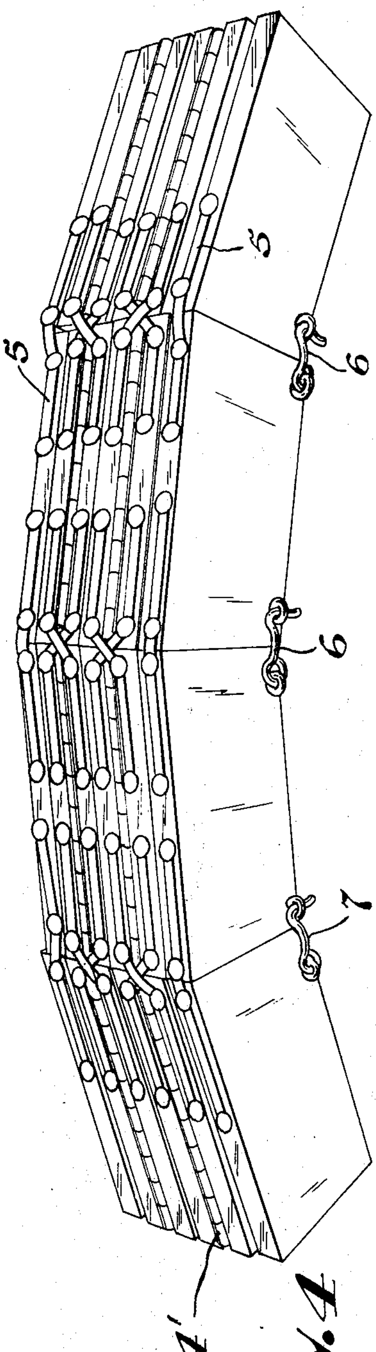

Fig. 4

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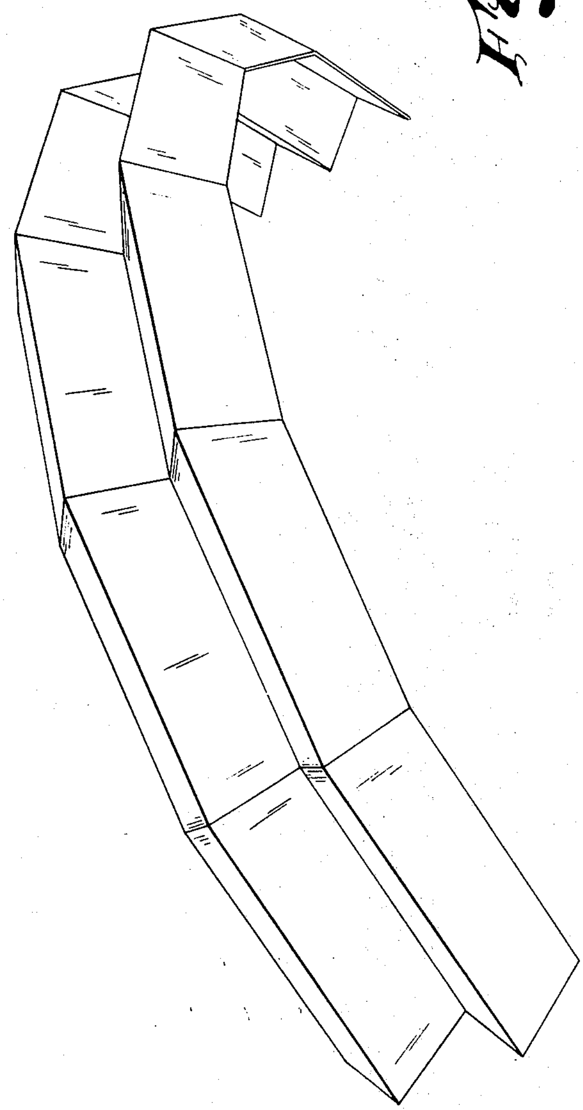
Fig. 6



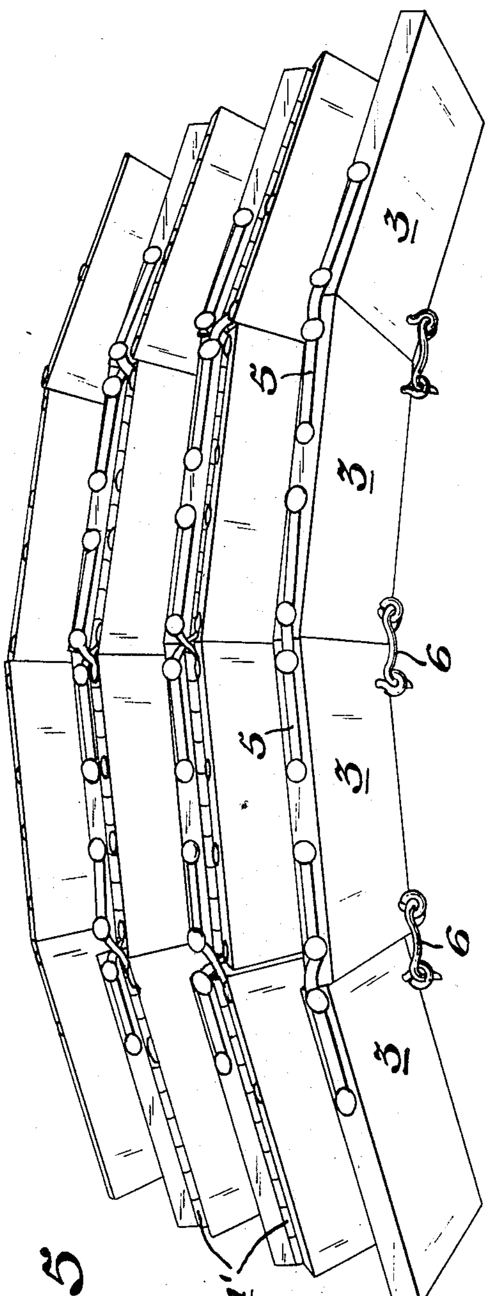


Fig. 5

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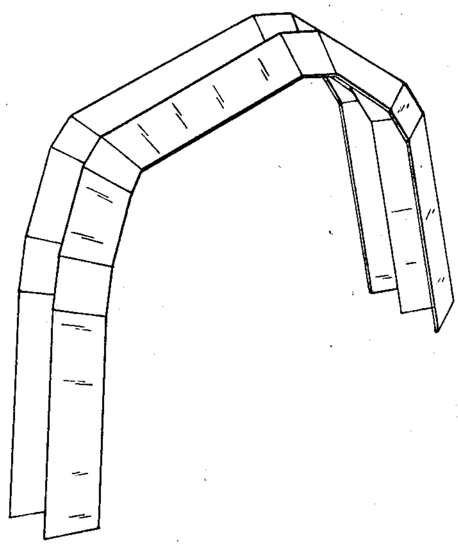
Fig. 7



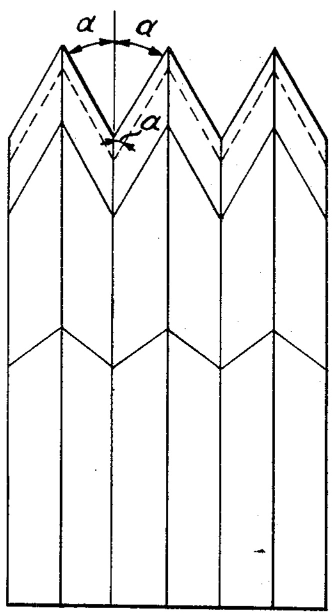


Fig. 10

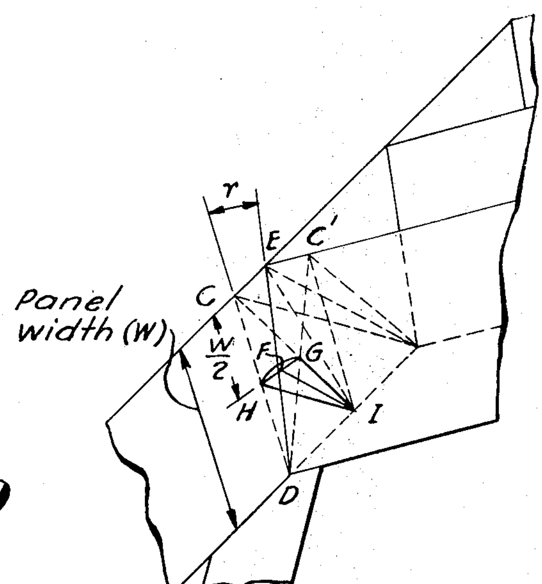


Fig. 9

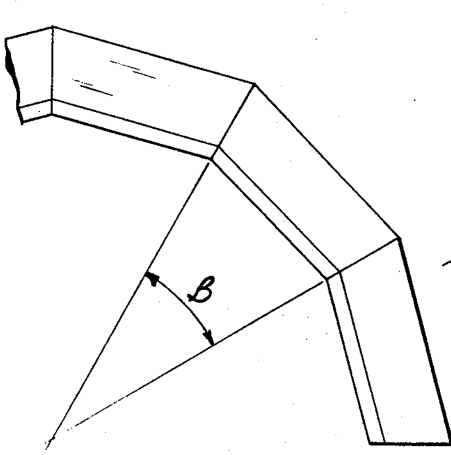


Fig. 8

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METHOD OF ASSEMBLING TRAPEZOIDAL PLATE STRUCTURE

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U.S. Cl. 29—434 6 Claims

ABSTRACT OF THE DISCLOSURE

A new and useful system of structures is described. A method for the economic production of identical trapezoidal plates from a variety of materials is taught. The use of similar and/or identical symmetrical trapezoidal plates in construction results in a novel modular structure of unimodular construction but with greatly increased strength.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to modular structures which are composed of similar and/or identical symmetrical trapezoidal plates.

Description of the prior art

In the past, various thin shell structures have been generated utilizing triangular plates. My invention differs from the known art by achieving a non-triangular, unimodular, folded plate structure. With my invention I am able to achieve a unimodular construction without the use of triangular folded plate shell structures.

SUMMARY OF THE INVENTION

This invention improves on existing prismatic folded plate shells in that it constitutes a unimodular system of constructing folded plate building shells utilizing symmetrical trapezoids. By the use of such trapezoids there are no helical fold lines as in conventional triangular folded plate structures described above. All fold axes lie in planes parallel or perpendicular to the axis of generation. If identical trapezoidal modules are utilized, a regular polygon building cross-section is formed. If similar symmetrical trapezoid modules are utilized, flat plate-like prismatic shell structures and also spans of varying radii of curvature may be produced. If hinged and fastened properly, the resultant structure is collapsible.

It is an object of this invention to create a unimodular structure wherein all fold axes lie in planes parallel or perpendicular to the axis of generation.

It is a further object of this invention to produce a shell structure which can be made of building material having the configuration of identical trapezoids.

It is a further object of this invention to produce trapezoidal plates for construction of unimodular structures which may be produced from flat sheets or plates or sandwich panels in such a manner that waste can be minimized.

A further object of this invention is to provide a system of structures whereby infinite sets of modules can be produced by simply changing the base to altitude proportions of the flat layout basic symmetrical trapezoid.

Still another object of my invention is to create flat spans and spans of various radii by changing the lengths of the basic symmetrical trapezoid, but not the angles or sides, to produce similar, but not identical trapezoidal configurations for use in one shell structure.

A further object of this invention is to simplify warehousing problems by providing only symmetrical trapezoidal configurations.

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Other objects of this invention will appear in the following description and claims, with reference being made to the accompanying drawings forming a part of this specification.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are shown in the drawings wherein:

FIG. 1 is an arrangement for preparing trapezoidal panels for use in the present invention;

FIG. 2 is an isometric view of a plurality of identical symmetrical trapezoids connected and hinged so as to form a grid;

FIG. 3 is an isometric view of the grid shown in FIG. 2 but folded in such a manner as to create a compact package;

FIG. 4 is an isometric view of the compact package of trapezoids of FIG. 3 but partially unfolded to form an arch;

FIG. 5 is an isometric view of the arch of FIG. 4 but where the arch folding has been expanded along the axis of the shell until the sides of all the trapezoidal pairs are meeting edge to edge;

FIG. 6 is an isometric view of a permanent, noncollapsible structure assembled utilizing identical symmetrical trapezoidal panels in accordance with the present invention;

FIG. 7 is an isometric view of a permanent noncollapsible structure assembled, utilizing similar symmetrical trapezoidal panels;

FIG. 8 is an isometric view of a structure assembled utilizing identical symmetrical trapezoidal panels in accordance with the present invention to show angle data;

FIG. 9 is an isometric view of a structure assembled utilizing identical symmetrical trapezoidal panels in accordance with the invention, to particularly show the dihedral angle analysis;

FIG. 10 is a side view of the structure shown in FIG. 9 to more clearly show the angle of inclination of the side cut of the plate element.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Looking now with more particularity at the drawings, FIG. 1 shows the basic flat layout that is employed in accordance with the present invention to produce a trapezoidal collapsible folded plate structure. Essentially a series of parallel lines 1 are drawn a predetermined equal distance from one another. The ends of the symmetrical trapezoid are constructed by connecting lines 1 with spaced lines 2. To make the trapezoids symmetrical, the obtuse angles B of the trapezoid are, by definition, the supplement of the acute angles A of the trapezoids. All angles B are equal to each other and all angles A are equal to each other. The trapezoids shown in FIG. 1 are identical, symmetrical trapezoids. Similar though nonidentical symmetrical trapezoids may also be constructed in accordance with the invention. In all cases it can be seen these trapezoid modules are laid out in such a manner that they nest, thereby minimizing waste. In the construction of the trapezoids shown in FIG. 1 and subsequent figures, a proportion of 3 to 1 was used. This proportion is the ratio of the length of the longest side to the altitude of the trapezoid. The acute angle of the module is chosen to be the same as the base angle of an isosceles triangle whose base to altitude ratio is 1:3.

FIG. 2 shows a grid of these trapezoids which are assembled in the following manner: Pairs of these trapezoids 3 are first hinged at the edges, base to base with hinges 4' (not shown, but see FIG. 4). These pairs are then arrayed in such a manner that the acute corners of the trapezoid pairs are touching only similar corners and all hinges are laying in the same plane. The sides between the obtuse angles of the trapezoids are now hinged with hinges 4, edge to edge, in pairs, with these hinges 4 occurring on the opposite surface of the trapezoid from the first set of hinges. The ends of the bases of the trapezoids are now joined with hinges 5 in such a manner that a continuous flexible hinge occurs on these axes from edge to edge of the grid.

FIG. 3 shows the grid of FIG. 2 folded in such a manner as to create a compact package. Hooks and eyes 6 shown in FIG. 3 are for the purpose of locking the sides of the perimeter trapezoids together as will be seen below.

FIG. 4 shows the compact folding of FIG. 3 partially unfolded and the sides of the perimeter trapezoids of the grid locked together using hooks and eyes 6. FIG. 4 gives one a base view of the trapezoidal arch thereby showing with greater clarity hinges 5 and hinges 4'.

FIG. 5 shows the arch of FIG. 4 expanded along the axis of the shell until the sides of all the trapezoidal pairs are meeting edge to edge. By connecting these edges in a non-extensible manner in a variety of ways well known in the art a stable symmetrical trapezoid folded plate structure is formed.

It is not necessary that the structure be collapsible. FIGS. 6 and 7 show permanent type arch configurations in accordance with the present invention. Such permanent structures may be assembled in a normal manner. These panels may be joined edge to edge by any of the techniques known in the art as previously indicated. For example, edge-joining is accomplished by any suitable adhesive material which is relatively rigid and has insulation properties or sealing strips of plastic materials or the like may be achieved over the seams between panels. Overlapping connecting members running the length of the edges using bolts, nails or other fastening means can also be employed or flanges (not shown) protruding from the edges at the desired angle can be bolted or glued to each other to effect joiner of the panels. Depending upon the thickness of the panels used, beveling of modular edges may or may not be necessary to effect a good joinder.

Utilizing the trapezoidal plate elements of the present invention, a great variety of structures may be constructed within certain limits. These limits may be shown in the dihedral angle analysis. Referring now to FIGS. 8, 9 and 10 we see that angle γ as shown in FIG. 9, determines the specific geometric articulation of the planar trapezoid. Angle γ in turn controls angle β shown in FIG. 8. From these the degree of curvature of the longitudinal cylinder is established. Angle α in FIG. 10, the angle of inclination of the side cut of the plate element, determines to a large extent the transverse rigidity of the articulate cylinder. Angle α has practical limits of 0° and 90°; at 0°, the cylinder will have a constant wall thickness, the magnitude of which will exactly match the width of the plate element; at 90°, the cylinder will have a constant wall thickness, the magnitude of which exactly matches the thickness of the plate element.

Referring now to FIG. 9, the dihedral angle between the plate elements in the radial direction will be described. The angle is described for any corresponding two dimensional planes in the plate thickness. Since this angle is the angle between any two corresponding planes in each of the plates of finite thickness, it is also the angle between the plates. Line CD lies in the plane of the trapezoid and is perpendicular to the two parallel sides. The trapezoid side is DG. Lines HI and GI are perpendicular to CD and C'D, respectively. Since lines HI and GI are perpendicular to lines in the plane, they are perpendicular to the plane; hence, they are normals to the planes. Now, by geometry, the angle between two normals is the angle between two planes. Hence, the angle between two corresponding planes is calculated by trigonometry. The angle of cut on a plate with a finite thickness is HIF.

A structure made of identical symmetrical trapezoid modules will have a building cross-section configuration of regular polygon which is tangent to an inscribed circle as in FIG. 6. Flat spans and spans of varying radii may be accomplished with this system by changing the module configuration as in FIG. 7. The width (or altitude) of the trapezoids must remain constant throughout the structure, but the base to altitude proportions of some of the trapezoids in the brid may be changed. One way that this may be done is to alternate with a trapezoid a rhombic module of the same obtuse angle and acute angle as the trapezoid and the same distance between these two angles. This in effect creates a new symmetrical trapezoid module. When these trapezoidal variations are assembled in an orderly pattern, variations in span configuration occur in accordance with the invention. It is to be noted, however, that as the structure gains desired depth through addition of trapezoidal panels, such panels must be connected at their common lengths to identical, symmetrical trapezoidal panels. In all cases, angled footings are added, as needed, to provide a firm base.

Prismatic structures built in accordance with the invention can fill any needs. Its possible collapsible characteristic lends itself to portable shelters for people, equipment and animals. It would also lend itself to military applications. As a permanent structure, its folded characteristics give rise to its use as a structure where an area must be covered without interior support, such as a stadium cover.

This invention can beneficially use a variety of materials. For example, plywood panels may be used as well as steel plates, fiberglass panels, plastic panels or sandwich type panels.

The above detscription of the invention along with the accompanying drawings are for the purpose of illustrating the preferred embodiments, and it is to be understood that changes may be made in the structural details and application of same without departing from the scope of this invention.

What is claimed is:

1. A method of preparing a collapsible structure which conforms generally to at least a portion of a cylindrical surface having a serrated cross-section, the steps of the method comprising (1) fabricating a plurality of panels, each of the panels having the configuration of a symmetrical trapezoid of equal altitude, equal obtuse angles, and equal acute angles, connecting a plurality of pairs of said panels along a common equal length with a hinge, arbitrarily designated as a right-handed hinge, connecting said pairs of panels to adjacent pairs of panels at their remaining common equal length with a hinge, arbitrarily designated as a left-handed hinge to form a row of said panels, arranging a plurality of said rows adjacent to each other to form a regular grid, flexibly connecting said plurality of adjacent rows at the juncture formed thereby of the acute angle of said panels, folding said collapsible structure until the sides of said panels meet edge to edge with the sides of panels in said adjacent rows, and connecting said sides with nonextensible locking means.

2. A method as claimed in claim 1 wherein said panels have the configuration of generally congruent, symmetrical trapezoids.

3. A method as claimed in claim 1 wherein said plurality of pairs of panels are first connected with said right-hand hinges along their bases.

4. A method as claimed in claim 3 wherein said panels have the configuration of generally congruent symmetrical trapezoids.

5. A method as claimed in claim 1 wherein said plurality of pairs of panels are first connected with said

right-handed hinges along their common length opposite their bases.

6. A method as claimed in claim 5 wherein said panels have the configuration of generally congruent, symmetrical trapezoids.

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HENRY C. SUTHERLAND, Primary Examiner

U.S. Cl. X.R.

29—155; 52—71, 81, 86, 747