June 18, 1968 J. L. WALING 3,389,202

METHOD OF FORMING SHELL ROOF STRUCTURE

Filed Feb. 7, 1966 3 Sheets-Sheet 1

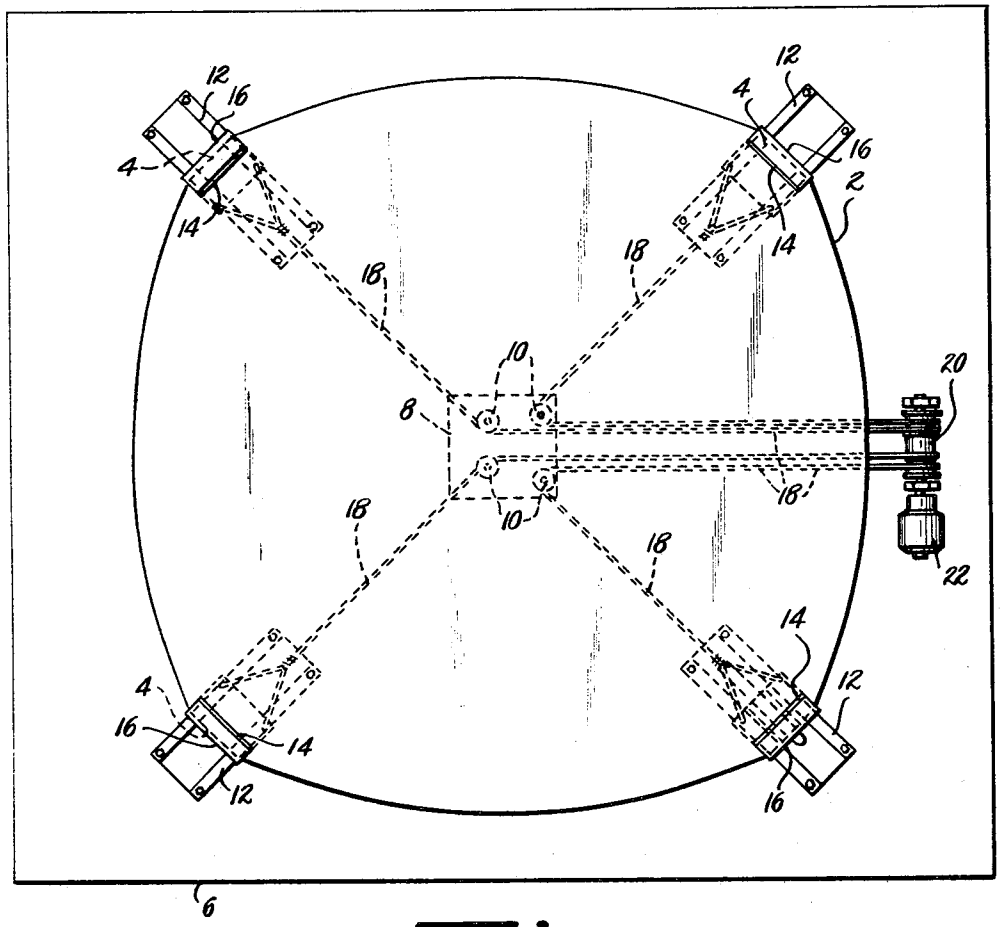


Fig. 1.

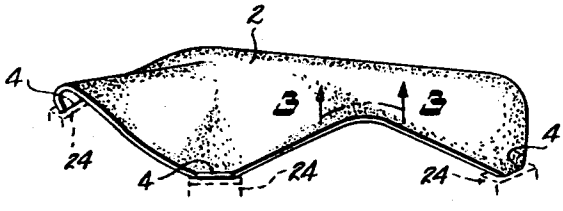


Fig. 2.

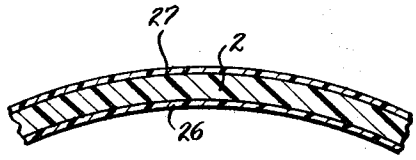


Fig. 3.

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METHOD OF FORMING SHELL ROOF STRUCTURE

Filed Feb. 7, 1966 3 Sheets-Sheet 2

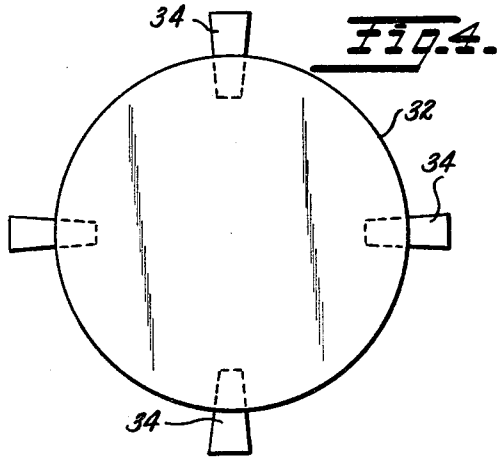


Fig. 4.

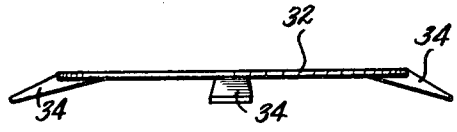


Fig. 5.

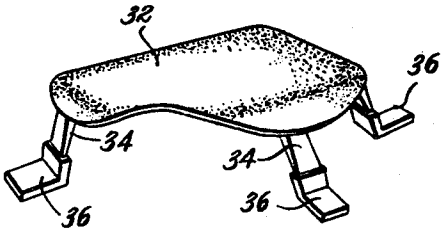


Fig. 6.

Fig. 7.

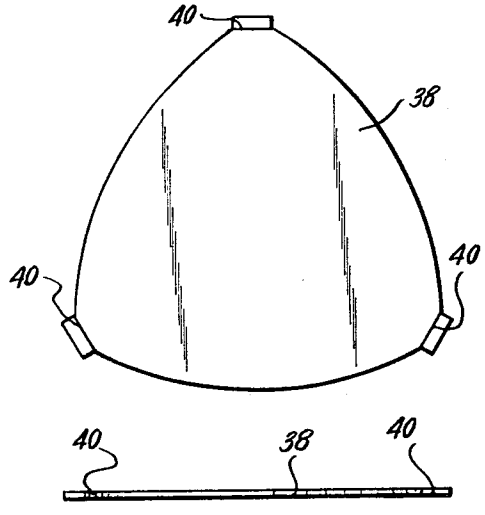


Fig. 8.

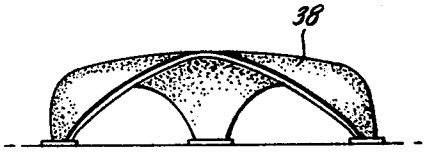


Fig. 9.

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METHOD OF FORMING SHELL ROOF STRUCTURE

Filed Feb. 7, 1966 3 Sheets-Sheet 3

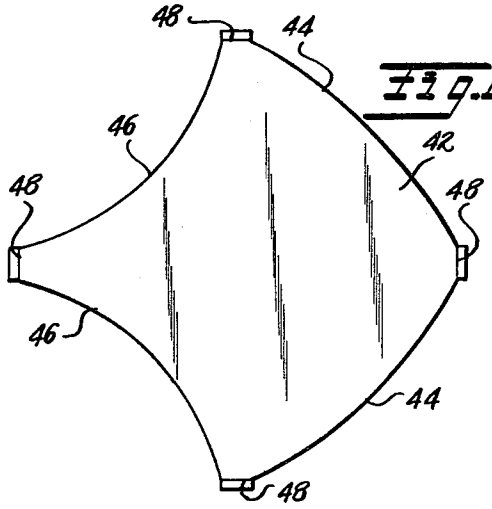


Fig. 10.

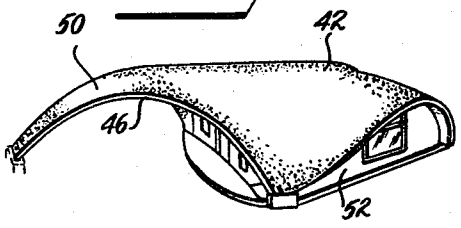


Fig. 11.

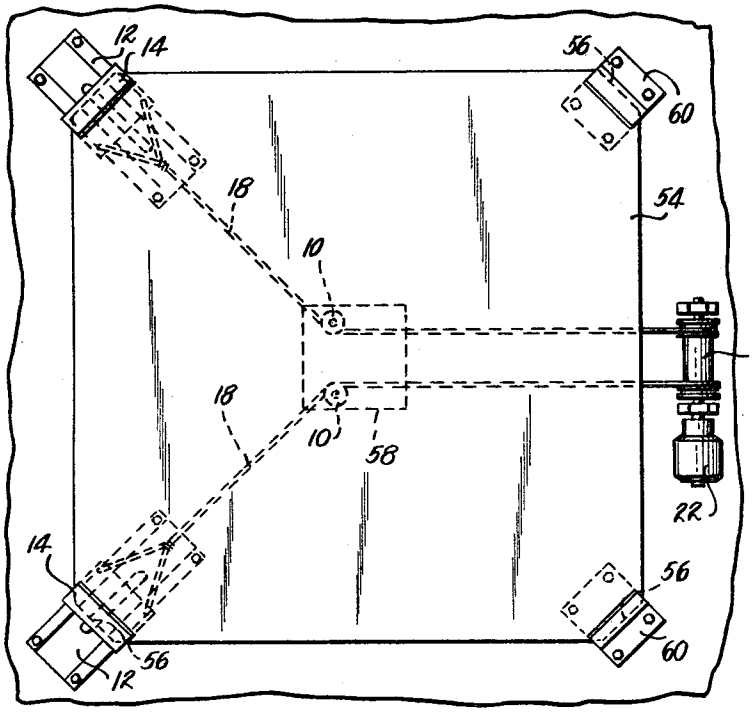


Fig. 12.

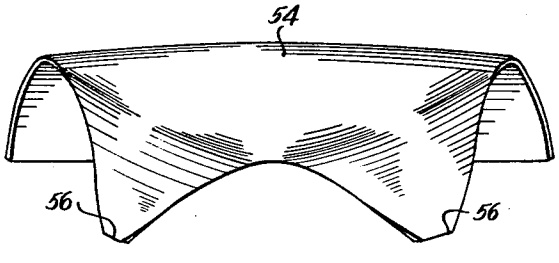


Fig. 13.

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United States Patent Office 3,389,202 Patented June 18, 1968

3,389,202

METHOD OF FORMING SHELL ROOF STRUCTURE

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Filed Feb. 7, 1966, Ser. No. 525,474
6 Claims. (Cl. 264—134)

This invention relates to the method of forming a shell roof structure, that is a roof shell comprising a sheet of material buckled or formed to the desired shape and contour and being completely self-supporting.

In carrying out the broad aspects of the invention, a large sheet of suitable bendable material, for example, foamed polystyrene, is laid out at the site. The sheet is cut to the desired outline and then by means of suitable power operated equipment radially inward pressure is applied to at least three circumferentially spaced points around the periphery of the sheet and those points are pushed inwardly to thus buckle the remaining portions of the sheet upwardly to form a compoundly curved somewhat domed shell. As will be described, various means are employed for rigidifying the shell in its final shape whereby the power machinery may be withdrawn and the shell remains as a self-supporting roof structure. The regions in which the pressure was applied become the lowermost or bearing portions of the shell and may be anchored to suitable footings, pillars, or the like, depending upon the type of finished structure desired. Various means are disclosed for coating and/or stiffening the sheet of material and for controlling the location and extent of the buckling thereof.

It is, therefore, a principal object of this invention to provide a method of forming a self-supporting roof shell from bendable sheet material, requiring no forms, molds, or the like.

Other and additional objects and advantages will become apparent to those skilled in the art as the description proceeds with reference to the accompanying drawings wherein:

FIG. 1 is a plan view of one representative adaptation of the invention, showing the power machinery in a schematic manner;

FIG. 2 is a perspective view of the shell resulting from the sheet of FIG. 1;

FIG. 3 is a fragmentary enlarged sectional view taken on the line 3—3 of FIG. 2;

FIG. 4 is a plan view of a different embodiment;

FIG. 5 is an edge elevational view of the form shown in FIG. 4;

FIG. 6 is a perspective view of the completed shell resulting from the material shown in FIGS. 4 and 5;

FIG. 7 is a plan view of a further modification employing a sheet of different shape;

FIG. 8 is an edge view of the sheet of FIG. 7;

FIG. 9 is a side view of the finished shell resulting from the shape of FIG. 7;

FIG. 10 is a plan view of a still further embodiment showing an alternative sheet outline;

FIG. 11 is a perspective view of a building constructed with the roof sheet of FIG. 10;

FIG. 12 is a plan view of a further alternative form wherein a differently shaped sheet is employed and showing an alternative power arrangement for buckling the sheet; and

FIG. 13 is a perspective view of the roof shell formed from the sheet of FIG. 12.

Referring first to FIG. 1, numeral 2 represents a large sheet of material from which the roof shell is to be formed and may comprise a built-up slab of formed polystyrene or the like. The slab is a relatively large area and is preferably formed by cementing or adhering conventional planks or slabs of the material in edge-to-edge relationship to define a large unitary sheet which is cut to the desired outline. Such material is obtainable in plank form of varying thickness up to several inches.

In the form shown in FIG. 1, the outline of sheet 2 is generally square but wherein the sides are curved or arced outwardly and the corners are truncated as at 4 to define abutment surfaces. The sheet 2 is laid out in a generally horizontal plane and supported in a flat condition in any suitable manner, either directly on a supporting slab 6 or on a suitable framework to hold it elevated above the ground. A power mechanism comprises an anchor arrangement 8 on which a plurality of sheaves 10 are journalled. Below each of the truncated corners 4 a suitable guiding trackway 12 is mounted and upon which a carriage 14 is slidably guided. Each carriage 14 includes a shoulder structure 16 abutting the truncated corner surface 4 of the sheet 2. A similar arrangement is provided at each of the corners of the sheet 2 and from each carriage 14 a cable 18 extends radially inwardly to and around one of the sheaves or pulleys 10, then outwardly to a winch drum 20 driven by a suitable motor or engine 22. In the form shown, there is a slidable carriage 14 at each corner of the slab 2 and each carriage is connected by a cable 18 to the winch 20. As will be obvious, operation of the motor or engine 22 to cause winch 20 to rotate will draw each of the cables 18 an equal amount and thus pull their respective carriages 14 inwardly toward the center of the structure. This results in an upward buckling of the sheet 2 to a compoundly curved shape, such as that shown in FIG. 2 of the drawings. Any bendable sheet material suitable for the practice of this invention becomes much stiffer and stronger when anchored in the buckled shape shown and serves admirably as a roof shell. After the sheet has been buckled upwardly, it is held in that position by securing the corner portions 4 in any suitable manner to or on footings or pillars 24 (FIG. 2). The power machinery comprising the trackways 12, carriages 14, anchor arrangement 8, and engine 22 and winch 20 may then be withdrawn. Suitable stiffening steps are performed to rigidify the sheet and render it completely self-supporting and capable of withstanding the forces of nature.

The material employed for the shell may suitably be the foamed polystyrene referred to but it may also comprise foamed polyurethene, foamed glass, Masonite, or other bendable materials or combinations and laminations thereof.

Also, as will be obvious, the plate may be of flat configuration and of constant thickness or on the other hand, the thickness of the plate or slab 2 may be varied from place to place to thus control its flexibility and predetermine the shape of the finally buckled shell. In addition, different portions of the sheet 2 may be of different density or may be provided with hollow portions and/or flat plate or spine-like attachments to stiffen certain portions thereof while leaving the remaining portions more flexible.

Obviously, the buckled shell must be rigidified to be usefully self-sustaining and this may be accomplished in many ways. After buckling, a coating of epoxy resins, fiberglass reinforced plastics or the like may be applied to the inner or under surface of the shell and caused to rigidify to thus render the shell sufficiently stiff and strong to support workmen for the application of an outer or weatherproofing coating. On the other hand, a layer 27 (FIG. 3) of settable resinous material, compatible with the sheet material 2 and containing fiberglass, asbestos, or other suitable reinforcing fiber, fabric, or mat, may be first applied to the upper surface of the sheet 2 and the buckling of the sheet so timed that it is performed

while the materials **27** are still in a plastic state and so that those materials **27** will solidify or set after buckling takes place. This upper stiffening layer coupled with a similar stiffening of the under surface, either during or after buckling of the sheet **2**, rigidifies the shell sufficiently to permit application of any desired additional materials to the exterior and/or the interior of the shell. The outer or weather side of the shell may be finished as desired with additional layers of reinforcements such as fiberglass strands or fabric, asbestos fibers or mat impregnated with epoxy, polyesters, or other plastics. Or it may be finished with reinforced concrete and an outer coating of waterproofing material, if needed for the particular building. Or it may be finished with a thin skin of metal such as sheet aluminum or sheet steel glued to the stiffened shell. The interior surface may be finished with additional layers **26** of reinforced plastics, plaster, or other architectural treatment.

FIGS. 4–6 illustrate another possible form wherein the starting sheet **32** is of circular configuration. Before buckling the same, the legs or pillars **34** are secured thereto substantially in the manner illustrated in the drawings, to extend downwardly and outwardly from the edges of the sheet **12**. The pressure-applying means would then be arranged to apply radially inward pressure to the outer ends of the legs **34** and since the latter are rigidly connected to portions of the sheet **32**, the latter is caused to buckle while the legs **34** swing downwardly to a generally vertical position. This is illustrated in FIG. 6 wherein the legs **34** are shown secured to suitable footings or foundation members **36**. FIG. 6 also shows the general shape assumed by the buckled shell resulting from the sheet of FIG. 4. FIGS. 7 through 9 show a generally triangular sheet **38** having truncated corners **40** to which pressure is applied to buckle the same to generally the shape shown in FIG. 9.

FIG. 10 illustrates a further possible configuration for a sheet **42** wherein two adjacent edges **44** are curved outwardly and two other adjacent edges **46** are curved inwardly, there being four truncated corner portions **48**, as shown. Obviously, buckling of the sheet **42** in the manner previously described will result in a shape similar to that indicated in the perspective view of FIG. 11 wherein the inwardly curved edges **46** define the edges of a carport or entry canopy **50**. FIG. 11 also illustrates schematically how the walls of the building or the like **52** may be erected beneath the dome thus produced.

FIGS. 12 and 13 illustrate generally a square sheet of starting material **54** having the previously described truncated corners **56**. This figure, however, illustrates a modified form of power equipment wherein the guiding tracks **12** are provided at only two adjacent corners of the sheet and there are only two sliding carriages **14**, one engaging each of the adjacent truncated corners. The anchor device **58** is provided with only two pulleys **10** thereon to guide the cables **18** attached to the two carriages **14**. The other two truncated corners of the sheet **54** abut against fixed anchor blocks or abutments **60** which are fixed in position and do not move. Obviously, upon operation of the motor or engine **22**, the winch **20** will draw only the two corners at the opposite side of the sheet inwardly and thus buckle the sheet in a different manner than it would if carriages were provided at all four corners. FIG. 13 illustrates generally the final buckled shell shape resulting from the sheet shown in FIG. 12.

The described buckling may be produced by power means other than the engine and winch schematically shown herein, for example, hydraulic jacks, screw jacks, or other equipment may be temporarily attached to and activated against the foundations to exert the necessary pressure to the edges of the sheet to produce the described buckling action.

As will be obvious, an infinite number of different shapes beyond those already described are possible and may be employed in combination with various distributions of buckling forces and to form a wide variety of thin shell roof shapes.

The stiffened or rigidified shell is capable of supporting workmen and all expected loads without requiring shoring or other support.

While a limited number of specific shapes have been described and shown herein, and even though the method has been broadly described, it is to be understood that the invention is not limited thereto but may encompass other features and/or steps falling within the scope of the appended claims.

I claim:

1. The method of forming a shell structure from a bendable sheet material, comprising the steps of: supporting a sheet of said material in a generally horizontal plane; simultaneously applying pressure inwardly to at least three circumferentially spaced portions of the outer periphery of said sheet to thereby cause said portions to move inwardly toward each other and said sheet to buckle to a compoundly curved shape; and securing said portions, in their inner positions ot hold said sheet in said buckled shape.

2. The method set forth in claim **1** including the further step of providing stiffening material on said sheet to hold it in said buckled shape substantially independently of said securement of said portions.

3. The method of claim **2** wherein said further step is performed by applying a layer of unhardened but hardenable material to at least one face of said sheet before buckling the same and then holding said sheet in said buckled shape while causing said material to harden to a substantially rigid state.

4. The method of claim **1** including the step of rigidly securing spaced support means to said spaced portions of said sheet to extend generally outwardly and downwardly therefrom, said radially inward pressure being applied to the outer ends of said support means whereby buckling of said sheet causes said support means to extend generally vertically and thereby elevate said sheet and said spaced portions thereof above said generally horizontal plane.

5. The method of claim **1** wherein said sheet is of substantially uniform composition and bendability throughout.

6. The method of claim **1** wherein preselected portions of said sheet are rendered stiffer than the remaining portions whereby to control the nature and extent of said bucklings.

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JAMES A. SEIDLECK, *Primary Examiner.*

P. E. ANDERSON, *Assistant Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,389,202 June 18, 1968

Joseph L. Waling

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

Column 1, line 70, "formed", second occurence, should read -- foamed --. Column 3, line 24, "12" should read -- 32 --. Column 4, line 24, "ot" should read -- to --.

Signed and sealed this 20th day of January 1970.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents