United States Patent [19]

Appenzeller

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[45] **Apr. 17, 1973**

[54] PREFABRICATED STRUCTURES

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[52] **U.S. Cl.** **52/81,** 52/82

[51] **Int. Cl.** **E04b 1/32**

[58] **Field of Search** 52/80, 81, 82

[56] **References Cited**

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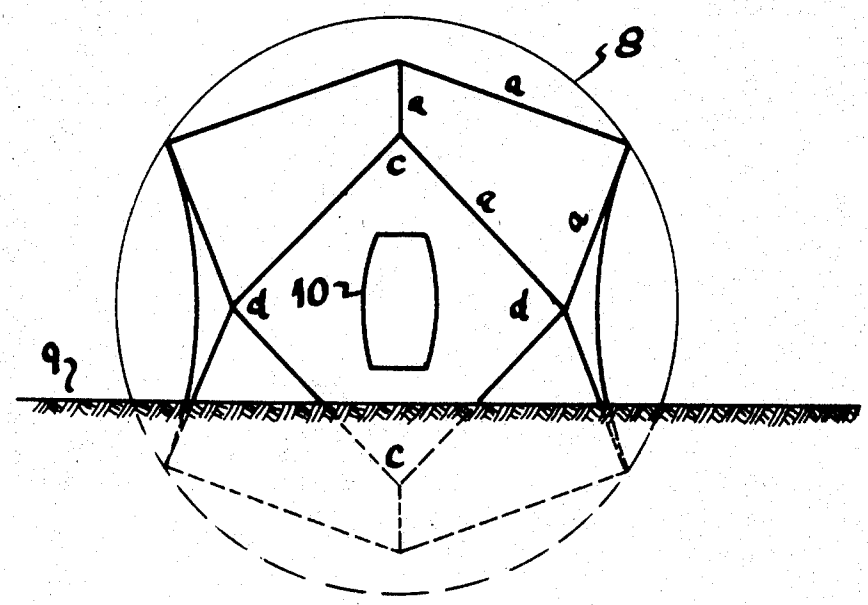
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[57] **ABSTRACT**

A prefabricated structure constituting at least the major portion of a body formed of 12 hyperbolic paraboloidal panels respectively secured together at their edges, each panel having four equal edges enclosing substantial right angles and having a diagonal whose length is substantially equal to four-thirds the length of the panel edge, the ratio of the elevation of the panel to the edge length thereof being substantially equal to 0.44.

2 Claims, 9 Drawing Figures



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SHEET 1 OF 3

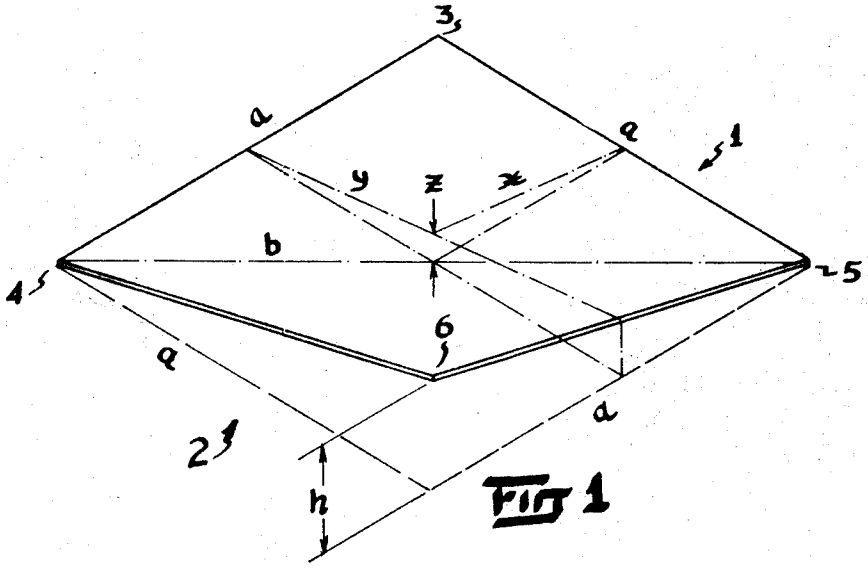


FIG 1

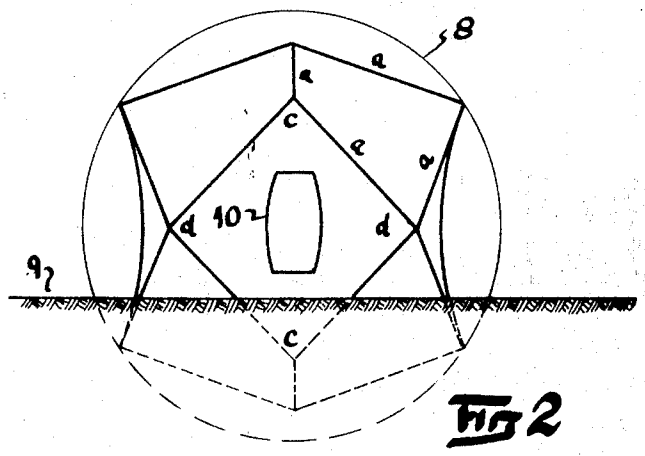


FIG 2

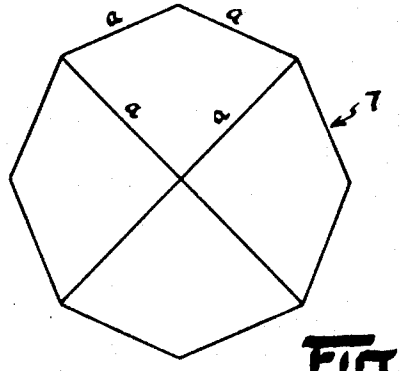


FIG 3

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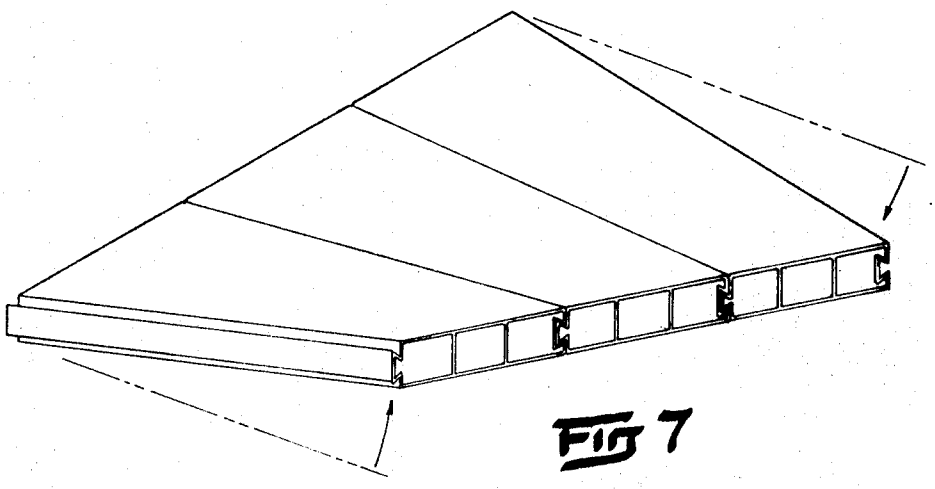


FIG 7

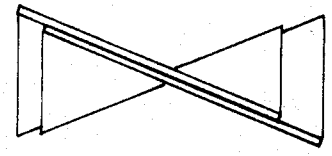


FIG 5

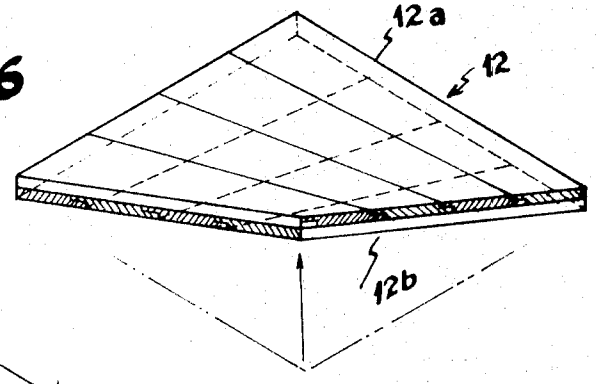


FIG 6

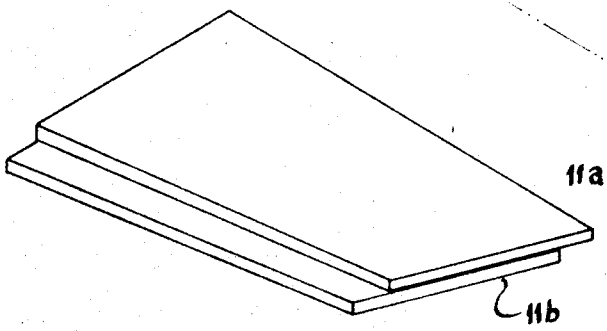


FIG 4

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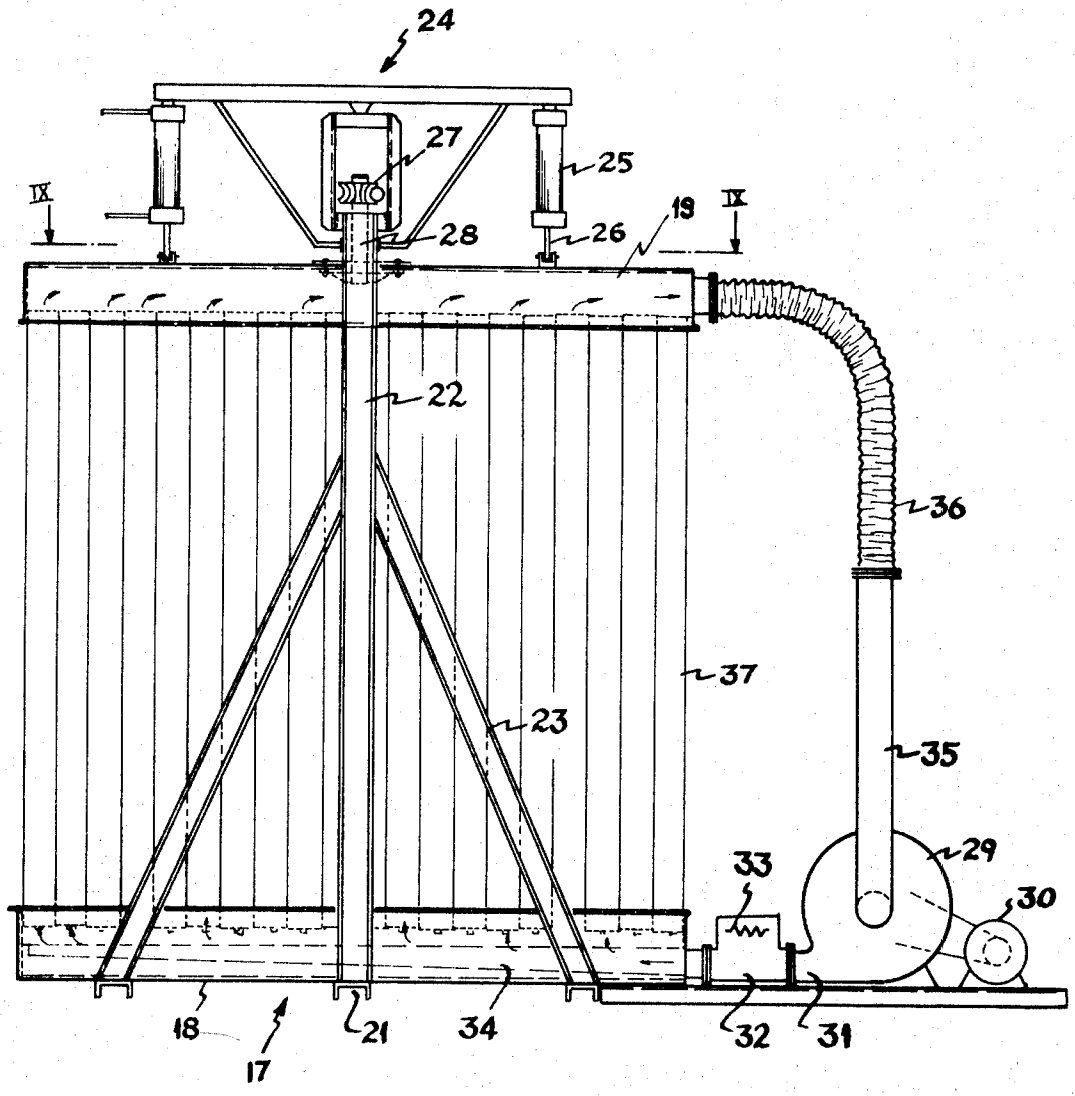


FIG 8

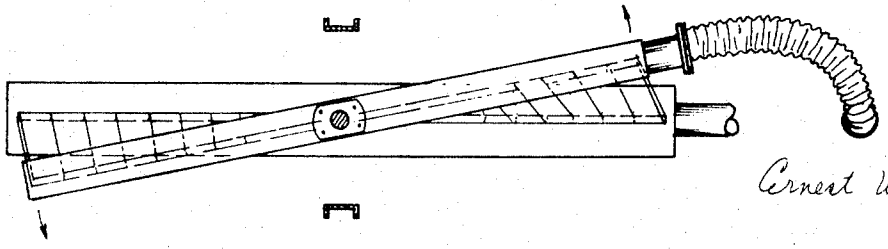


FIG 9

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PREFABRICATED STRUCTURES

This invention relates to prefabricated structures and to structural panels for use in their construction.

It is the object of the present invention to provide a prefabricated structure which can be readily and easily assembled from a relatively limited number of constructional panels.

It is a further object of the present invention to provide a method of and apparatus for constructing constructional panels for use in constructing the structure.

The invention is based on the discovery that it is possible to construct a body which corresponds substantially to a dodecahedron from 12 similar corresponding panels each of which is constituted as a hyperbolic paraboloidal surface having specific characteristics to be defined below, said body contacting at eight of its 14 corners the inner surface of an imaginary sphere.

For a better understanding of the invention and the manner in which it is to be carried out reference will now be made to the drawings, wherein:

FIG. 1 is a view of one constructional panel in accordance with the invention;

FIG. 2 is a front elevation of a structure formed using the structural panel shown in FIG. 1;

FIG. 3 is a view from above of the structure shown in FIG. 2;

FIG. 4 shows in perspective view a shaped elongated element;

FIG. 5 shows in an exaggerated form a side elevation of the element shown in FIG. 4;

FIG. 6 is a perspective view of a composite panel formed of elements as shown in FIGS. 4 and 5.

FIG. 7 is a perspective view of a portion of a shaped panel in accordance with the invention formed of a further form of elongated element;

FIG. 8 is a schematic front elevation of an installation for shaping panels in accordance with the invention, and

FIG. 9 is a cross-sectional view of the installation shown in FIG. 8 taken along the line IX — IX after a shaping operation.

Reference will now be made to FIG. 1 of the drawings for a description and a definition of the basic structural panel in accordance with the invention. As seen in the Figure the panel 1 has a hyperbolic paraboloidal shape having four equal sides of length a. The panel 1 is shown as if it were resting on an imaginary flat horizontal surface 2 (shown in broken lines), three corners 3, 4 and 5 of the panel 1 are disposed in contact with the flat surface 2 whilst the fourth corner 6 is raised by an amount h, hereinafter referred to as the elevation of the element.

The parameter b which is the length of the diagonal joining the corners 4 and 5 on the imaginary flat surface is given by the relationship:

$$b = \sqrt{2a^2}$$

12 panels 1, each as shown in FIG. 1 of the drawings can be connected together (by any suitable means, such as, for example, suitably shaped profile bars), each panel being connected at its four sides to four adjacent panels so as to form an enclosed structure 7 which can be entirely enclosed within an imaginary sphere 8 (FIG. 2) of radius $r = 2\sqrt{b^2/b}$ eight corners

of the 14 corners of the structure contacting the inner surface of the sphere 8.

Thus, the prefabricated structure 7 of FIGS. 2 and 3 constitutes at least a major portion of a body formed of 12 hyperbolic paraboloidal panels which are secured together at their edges, each panel having four equal edges enclosing substantial right angles and having a diagonal whose length is substantially equal to four-thirds the length of the panel edge. This structure is derived from a 24-sided regular polyhedron, each side of which is a right-angled isosceles triangle, but wherein each pair of adjacent triangles having a common base has been replaced by a hyperbolic paraboloidal surface having four equal sides.

Each of a first pair of opposite corners c of each panel is congruent with two adjacent corners c of two adjacent panels whilst each of a second pair of opposite corners d of each panel is congruent with three adjacent corners d of three adjacent panels. It is found in practice that whilst each corner c encloses an angle substantially equal to 90°, each corner d encloses an angle which is slightly less than 90°, about 88.5°.

As can be clearly seen in FIG. 2 of the drawings the structure can be terminated at any suitable plane by correspondingly cutting the appropriate elements through which this plane passes. In point of fact the panels themselves are preliminarily cut so that the structure so formed can then rest on the ground the ground constituting the plane referred to. Such a structure is shown schematically in FIG. 2 where the ground level 9 forms the lower limit of the structure the missing portion of the whole structure being shown in dotted lines.

It will be appreciated that the structure can be terminated at any suitable plane or series of planes so as to form a structure of any required height and shape.

The size of the structure obtained is determined by the size of the sides of the panels.

As seen in FIG. 2 of the drawings one of the panels is provided with a door hole 10 which can be previously formed in any appropriate panel.

The panels themselves can be formed of any suitable material such as, for example, a thermoplastic material, wood or metal which lends itself to shaping. Thus, the elements can be pressed out of metal sheets into the required hyperbolic paraboloidal shape or, alternatively, they can be press-molded in plastic form.

Reference will now be made to FIGS. 4 and 5 of the drawings which illustrate an elongated element for use in constructing a structural panel in accordance with the invention. As seen in these Figures, the element which, in the case of the present embodiment, is formed of plywood, comprises two similar overlapping portions 11a and 11b bonded together by a suitable adhesive. These superimposed portions are introduced into a press with the adhesive located between successive pairs and when the bonding adhesive has still not set the elements as a whole are given the required hyperbolic paraboloidal shape after which the adhesive is allowed to set, the elements thereupon retaining this shape. The elements can then be coupled together at their overlapping edges by any suitable means such as bonding, riveting or the like.

The elements shown in FIGS. 4 and 5 of the drawings acquire the required hyperbolic paraboloidal shape by

being given a twist in a particular sense. If now a panel **12** is constructed from profiles which have been twisted in an opposite sense and the two elements **12***a* and **12***b* thus formed are superimposed and bonded together as shown in FIG. **6** of the drawings, a composite panel **12** of very considerable strength is obtained.

Whilst the invention has so far been described with reference to panels formed of two-piece elements which are shaped and bonded together, the bonding succeeding in retaining the desired shape, a panel formed of single piece elements is shown partially in FIG. **7** of the drawings. The panel is formed of hollow elements **13** formed by extrusion of a suitable plastic material. One longitudinal end of the element **13** is provided with an elongated dovetail groove **15**. Such an element **13** can be given the required shape during extrusion itself. The interengagement of successive elements **13** so shaped leads to the production of a suitably shaped panel. On the other hand, substantially planar elements **13** of the kind shown in FIG. **5** can be coupled together so as to form an initially planar panel which is then subjected to required shaping under heat and pressure.

It will be realised that the element shown in FIG. **5** can equally be made of any material such as aluminum which lends itself to extrusion.

Equipment for imparting the required shaping to initially planar panels of the kind shown in FIG. **7** is illustrated schematically in FIGS. **8** and **9** of the drawings.

The equipment consists of an installation **17** comprising a lower support beam **18** which is essentially of channel-shaped cross section and an upper turning beam **19** also of channel-shaped cross section. The open longitudinal ends of the beams **18** and **19** face each other whilst their side ends are closed. The lower support beam **18** is mounted on a support frame **20** consisting of horizontally extending beams **21** upon which the lower support beam **18** rests and a pair of vertical beams **22** secured to the horizontal beams **21** and strengthened by means of angular struts **23**. The upper ends of the vertical beams **22** carry an upper beam, displacing and turning structure **24**. This structure **24** is coupled to the upper turning beam **19**. The structure **24** consists of a pair of hydraulic or pneumatic cylinder mechanisms **25**, having piston rods **26** coupled to the upper turning beam **19**. Thus, depending on the direction of inflow of hydraulic fluid into the mechanisms **25**, the upper turning beam **19** can be raised or lowered as required into and out of a predetermined position. The structure **24** furthermore includes a beam turning mechanism which consists of a worm drive **27** arranged to be driven by means (not shown) and having a driven axle **28** which is coupled to the upper turning beam **19**.

An air compression pump **29**, driven by a motor **30** has its outlet **31** coupled via an air heating conduit **32**, having an electrical heating element **33**, to the input of an air distributing pipe **34** which extends through the lower support beam **18** and is provided with air outlet apertures distributed along the length thereof. As can be seen in the drawing the air distributing pipe **34** is of conical shape, tapering gradually from the end adjacent the pump **29**. The pipe is given this tapering shape so as to ensure a substantially uniform air flow through the apertures along the entire length thereof. The outlet **35** of the pump **29** is coupled, via a flexible conduit **36**, with an outlet of the otherwise sealed upper turning beam **19**.

In operation a plurality of substantially planar panels **37** constituted of hollow elements of the kind shown in FIG. **7** of the drawings, is introduced into the installation. The lower ends of the panels are located within the support beam **18** above air distributing pipe **34** whilst the hydraulic cylinders are so arranged that the upper turning beam **19** is in a raised position. When the panels are all suitably located with respect to the lower support beam **18**, the hydraulic cylinders are actuated so as to lower the upper turning beam **19** into a position where the upper ends of the panel **37** project into the beam **19**. In this way the panels are firmly and air tightly clamped to the installation. The motor **30** and heating element **33** are actuated and hot air is passed continuously via the air distributing pipe **34** through the hollow panel elements and out of the beam **19** and the flexible conduit **36**. When the passage of the hot air has proceeded for a length of time sufficient to render the panels slightly flexible, a drive is imparted to the worm drive **27**, as a result of which the upper beam is rotated by a predetermined amount (as shown in FIG. **9**). In consequence the panels are twisted by the same amount thereby imparting to them the required shape. The panels are held in position and cold air is passed therethrough by means of the pump **29** for a time sufficient to allow the panels to rigidify in their new shape. When the panels have cooled down sufficiently the hydraulic cylinder mechanism is actuated so as to raise the upper turning beam **19** and thereby facilitating the removal of the shaped panels.

With an installation as just described it is possible to impart simultaneously the required shaping to the entire number of panels required to form the subsequent prefabricated structure.

We claim:

1. A prefabricated structure constituting at least the major portion of a body formed of **12** hyperbolic paraboloidal panels, each said panel having four edges and each said panel being secured to four adjacent panels at its four edges, each of the edges of each said panel being of equal length, each of the four angles of each panel defined by two adjacent edges being substantially a right angle, each panel having a diagonal whose length is substantially equal to four-thirds the length of the panel edge, whereby all adjoining corners of said panels lie along or within the surface of an imaginary sphere.

2. The structure of claim **1** having 14 corners, whereby eight of the corners of said body lie along the surface of an imaginary sphere.

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