

2,995,797

Filed Dec. 24, 1959

3 Sheets-Sheet 1

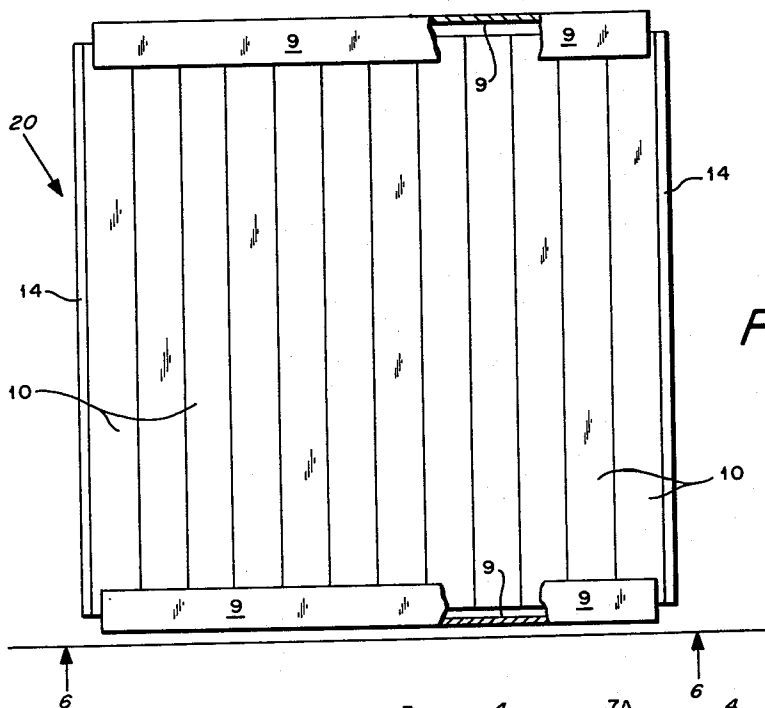


Fig. 1

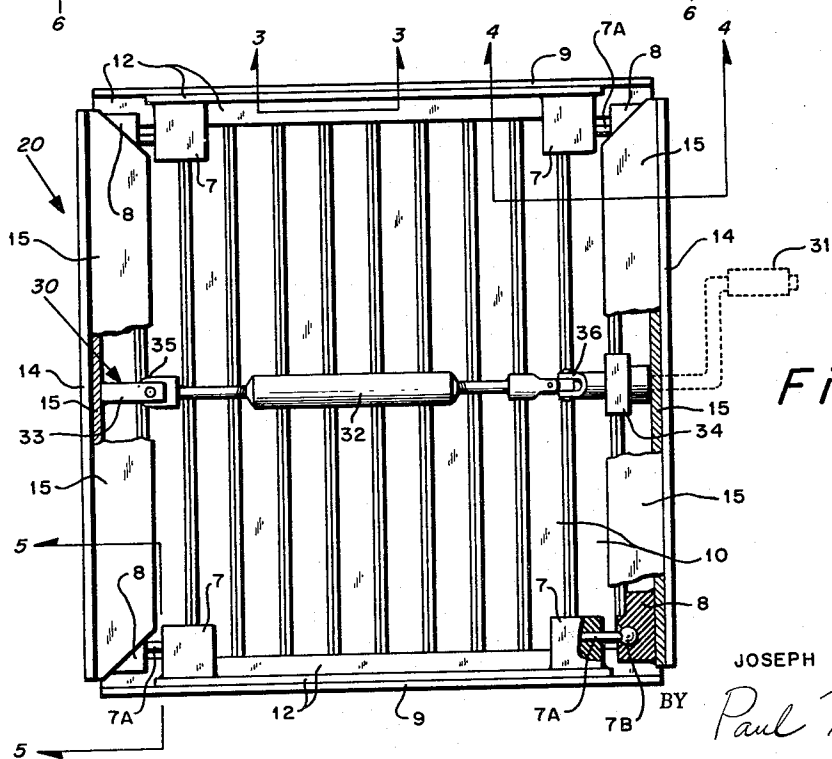


Fig. 2

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Aug. 15, 1961

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ADJUSTABLE FORM

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3 Sheets-Sheet 2

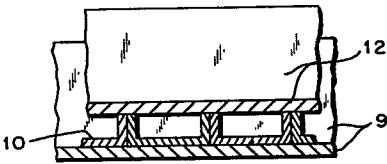


Fig. 3

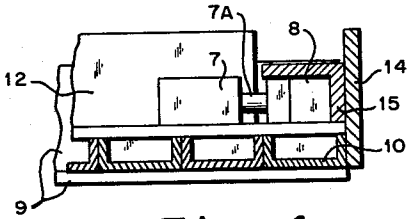


Fig. 4

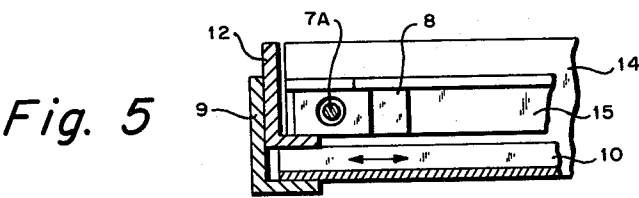


Fig. 5

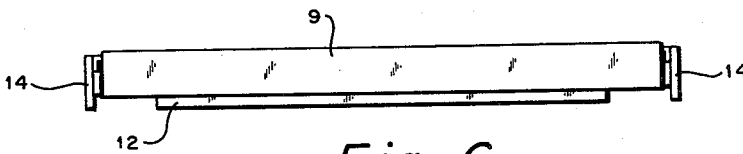


Fig. 6

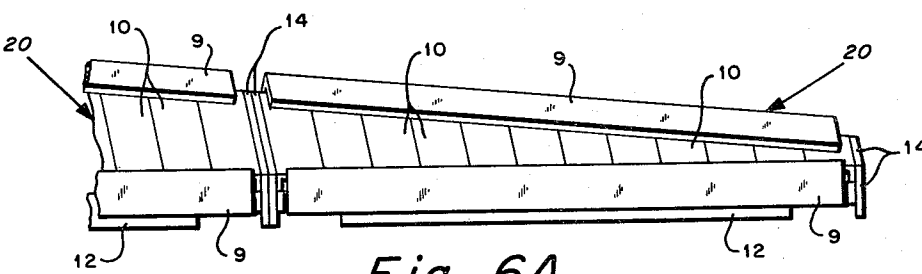


Fig. 6A

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3 Sheets-Sheet 3

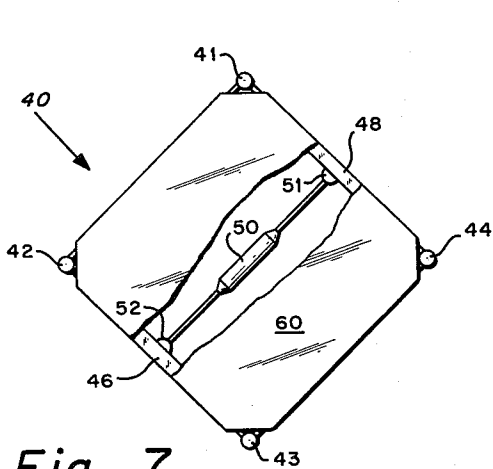


Fig. 7

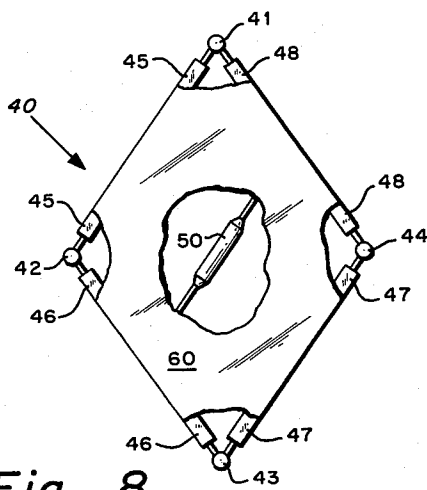


Fig. 8

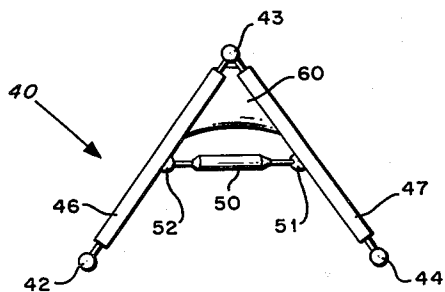


Fig. 9

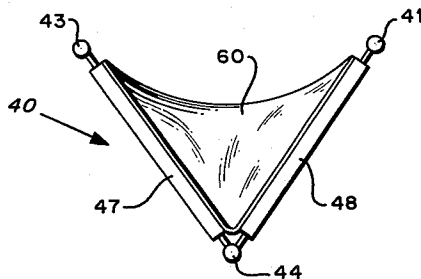


Fig. 10

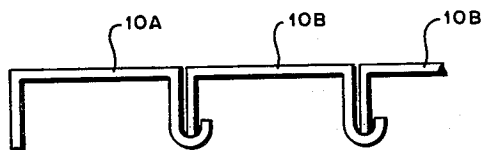


Fig. 11

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2,995,797

ADJUSTABLE FORM

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10 Claims. (Cl. 10-118)

This invention relates to an adjustable form. It relates to a single adjustable form and a series or assembly of a plurality of individual adjustable forms to produce a larger overall form. The invention relates particularly to adjustable forms adapted to and usable for the erection of concrete structures and elements of structures by pouring concrete into or on said forms.

The use of the adjustable forms of this invention in the direction of poured concrete structures and elements thereof is a particular and general application of this invention. The forms of this invention may be utilized in other ways as well, as is pointed out in more particularity below. For example, the adjustable forms of this invention may be provided in comparatively small dimensions and adapted to be usable in a construction of models of form assemblies, structures, or elements of structures, for purposes of strength and appearance testing.

It is understood that the most important area of use of this invention lies in the provision of molds or mold elements, either in full scale or less than full scale, but for certain purposes as more fully set forth below, particularly in relation to small scale models, the devices described below may be utilized as actual structural elements or to represent such elements.

The invention is described below as an adjustable form used in the erection of poured concrete surfaces and structures, since that is the most typical application of the invention and its principle. The particular surface configuration of concrete for which the form is intended, is a hyperbolic paraboloid. More particularly, the invention relates to an individual form element which normally presents a flat surface, and which can be adjusted to present a hyperbolic paraboloid surface. The invention contemplates the successive abutment of a plurality of these individual forms to provide a larger substantially continuous hyperbolic paraboloid surface of desired curvature and extent.

It is an object of this invention to provide an adjustable structural element.

It is an object of this invention to provide an adjustable molding form.

It is another object of this invention to provide an element having an adjustable surface configuration and adapted to be assembled with other like elements so as to provide a structure or form having the configuration of a hyperbolic paraboloid.

It is yet another object of this invention to provide an adjustable form comprising a structure with a normally planar surface, means to adjust or warp this surface into a hyperbolic paraboloid configuration of desired curvature, and means to detachably assemble said structure to other like structures or to supporting structures, whereby a molding form or a structural surface, either of full scale or model scale is provided.

Other aims and objects of this invention are made apparent in the following specification and claims.

The invention is best understood in connection with the accompanying drawings in which like reference numerals refer to like parts and in which:

FIGURE 1 is a top view, partially fragmented and partially in section of an embodiment of the form,

FIGURE 2 is a bottom view of the form of FIGURE 1, partially fragmented, partially in section, and partially in phantom line,

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FIGURE 3 is a fragmented partial sectional view taken along line 3-3 of FIGURE 2,

FIGURE 4 is a fragmented partial sectional view taken along line 4-4 of FIGURE 2,

5 FIGURE 5 is a fragmented partial sectional view taken along line 5-5 of FIGURE 2,

FIGURE 6 is an end view taken along line 6-6 of FIGURE 1,

10 FIGURE 6A is an end view as shown in FIGURE 6 wherein the surface has been warped and the form has been attached to another form,

FIGURE 7 is a top view, partially fragmented, of another embodiment of the form,

15 FIGURE 8 is a top view, partially fragmented, of the form of FIGURE 7 wherein the surface has been warped,

FIGURE 9 is a side view of the form of FIGURE 8, taken toward reference numeral 43,

FIGURE 10 is an end view of the form of FIGURE 8, taken toward reference numeral 44,

20 FIGURE 11 is a partially fragmented end view of an embodiment of slats or channels comprising part of the embodiment illustrated in FIGURES 1-6A.

The principle of the invention may best be initially described in connection with the embodiment illustrated in FIGURES 7-10, since this is a simpler embodiment. Broadly, the invention consists of providing a form having a flat surface, preferably square, and means incorporated therewith by which the planar surface can be warped, adjusted, or deformed into a "saddle" shape, more accurately described by the geometric shape, hyperbolic paraboloid. Referring to FIGURE 7, and the reference numerals identifying the corners of the square therein shown, the invention may be broadly described as a flat plane defined by points 41, 42, 43, and 44, which is adapted to be modified to a surface curved in two directions, about the 42-44 axis, and the 41-43 axis, with the radius of each curve originating from a different point, said different points lying on opposite sides of the plane 41, 42, 43, 44. FIGURES 8, 9, and 10 are different views of the planar square of FIGURE 7, after adjustment or warp into the hyperbolic paraboloid.

FIGURE 7 shows a plan view of a form in its undistorted state. Four joints 41, 42, 43, and 44 are provided. Each of these joints has at least two degrees of freedom, as exemplified by a ball and socket joint or equivalent universal joint, or by a double hinge having pivotal movement in two planes at right angles to each other. The term "universal joint" is understood to have its customary dictionary definition and to include all the above-mentioned joints. The joints are shown schematically in FIGURE 7, although a preferred embodiment of a specific joint is shown in more detail in the embodiment of FIGURE 2.

55 The joints 41, 42, 43, and 44 connect four rigid sides to form a square. Two of these sides, 46 and 48 are shown in FIGURE 7. The other two sides, 45 and 47, hidden in FIGURE 7, are shown in FIGURE 8.

60 An elastic sheet 60 is stretched across the frame defined by these sides and is attached in any suitable manner to said sides. Artificial or natural rubber is suitable for the sheet 60.

One pair of opposite sides 46 and 48, are connected by a spacing member. In the embodiment of FIGURE 7, the spacing member comprises a turnbuckle 50, connected to sides 46 and 48 by joints or swivels 52 and 51 respectively. When turnbuckle 50 is shortened, the form, generally designated by reference numeral 40, is distorted into the shape shown in FIGURES 8, 9, and 10. The surface or elastic sheet 60 changes from the flat plane illustrated in FIGURE 7 to the saddle or hyperbolic paraboloid best shown in FIGURE 10 when the spacing

member or turnbuckle 50 is adjusted so that its length is less than the length of the frame sides to which it is parallel.

For the purposes of clearer presentation, several dimensions in FIGURES 8, 9, and 10 are exaggerated. The shortening of the turnbuckle 50 is best shown by reference to FIGURE 9. This shortening is shown far greater than would normally be the case, and the swiveling and angling of the sides around their joints is shown as much greater than would ordinarily be provided. The distortion from a square shape in the 41, 42, 43, 44 plane is exaggerated in FIGURE 8 to better indicate the resulting shape, and the dimensions shown in FIGURE 8 do not necessarily correspond with the dimensions shown in FIGURE 10.

In use, the hyperbolic paraboloid curve followed by sheet 60 is less extreme than that illustrated. The extent of the curvature is determined by the amount of shortening of turnbuckle 50. It is apparent that for any given desired extent of curvature, there exists a fixed length of shortening of the spacing member or turnbuckle 50. Therefore, the turnbuckle may be marked in any desired way to indicate various lengths, so that a pre-set or desired degree of curvature of sheet 60 is obtained by shortening turnbuckle 50 to the mark.

In its most useful application, the form illustrated in FIGURE 10 is one of a plurality of such forms. Each of these forms may be set to the same degree of curvature or successive forms may be set to varying degrees of curvature. The other forms may be placed in a side to side relationship with the form 40 so as to provide a substantially continuous saddle curved surface 60. Means for attaching the form 40 to other similar forms are not illustrated in FIGURES 7-10, but such means are set forth in more detail in connection with the embodiment illustrated in FIGURES 1-6A.

The form 40 is particularly suitable for use in model work. A plurality of such forms, having side dimensions of perhaps several inches, may be provided for setting an assembly. The resulting model gives a three-dimensional graphic representation of a full scale structure or molding form. After such a model is constructed, plaster, plastic, or other material may be poured onto the resulting surface, to produce a hyperbolic paraboloid of desired curvature. The resulting cast shape may then be subjected to tests for strength, stress points, appearance, and other characteristics. The form 40 and the other like forms assembled with it as described above, may in themselves be used to represent for demonstration or testing purposes, a full scale structure.

The embodiment of FIGURES 7-10 is particularly adapted to use in model work because the structure as illustrated does not possess a very high degree of structural strength. Forms 40, if made of a size suitable for actual heavy construction use tend to be difficult to provide of sufficient strength to handle heavy loads, for example, the pouring of concrete. Elastic sheets of the sizes desirable for actual construction work are difficult and expensive to obtain of sufficient strength to avoid sagging.

Probably the major application of the principle of this invention lies in actual construction work, particularly in the construction of poured concrete surfaces. Where the invention is used for model work as a design tool or otherwise, the size and their connecting joints, which together comprise a frame can be of light and delicate materials. Little or no load bearing function has to be met in such an application. For some purposes in model work, the surface sheet 60 may be completely eliminated. In such a case, the frames of the plurality of connected form units represent a complete structure or part of a structure, for appearance and stress testing.

For use in full-scale construction work, a different order of structural strength must be considered in utilizing the principle of the invention.

The erection of poured concrete shells, walls, and other structural elements is becoming increasingly important. It is customary to build wooden forms for concrete pouring. These forms generally comprise a series of adjacent wooden slats or strips which are warped by steaming to fit over predetermined wooden or other scaffolding or framework. Without describing this known method a length, suffice to say that the labor costs are high and that the forms are not reusable.

Other expedients have been proposed, such as the provision of permanently shaped reusable metal or wood form sections which can be assembled. One obvious difficulty with this expedient is that only certain curvatures may be provided.

Forms provided according to the teaching of this present invention may be shipped to the job in a flat condition, which makes for easier handling and shipping, since for example, a number of the forms may be stacked for transport. Forms constructed according to this invention may be rapidly and accurately adjusted to meet any specified hyperbolic paraboloid curvature for any construction application, since the individual form units may each be adjusted to provide the proper amount of curvature for the specified area to be covered by that form unit. In addition, after use the form units may be knocked down to the flat condition and shipped or stored for later reuse.

FIGURE 1 shows a top view of such a construction form generally designated 20. The form is preferably made of metal, usually steel, although other materials such as aluminum may also be used. The light unit weight of aluminum is a factor in its favor as a material.

The form 20 may be of any rectangular shape, although the square shape shown in FIGURE 1 is most convenient for ordinary applications. The side dimensions may vary widely without departing from the spirit of this invention, although for most construction applications, dimensions of four feet square have been found satisfactory.

The surface of the form 20 generally consists of the slats 10. Each form has a number of these elongated slats arranged in parallel relationship. While in theory flat slats would be operable, it has been found that providing the slats 10 as channel or U-shaped members is preferable. A relatively short extension depends from each long side of each slat 10. FIGURE 2 better shows these extensions. The extensions or flanges take shear transmitted from one slat to another and also enable the presentation of a generally continuous surface even though adjacent slats move relative to one another in a vertical plane. Such movement often occurs during the warping step. The use of the flanges or extensions also contributes greater stability to the entire apparatus.

In FIGURE 11, an end view is shown of one preferred embodiment of the slats. A series of adjacent slats 10B and an end slat 10A are shown. As is seen, one leg of each slat is straight and the other is provided with a hook or groove which receives the end of the straight leg of the adjacent slat. It has been found that this is a satisfactory arrangement, although it will be appreciated that the slats may take other shapes in their dependent extensions and still meet the requirements of providing means to handle transmitted stress, vertical displacement, and to provide stability.

The slats 10, which provide a surface analogous to the surface 60 in the embodiment of FIGURE 7, are mounted in a frame which is analogous to the sides and joints of the embodiment of FIGURE 7.

The sides of the form 20 abutting the ends of slats 10 each comprise a grip 9, shown in FIGURE 1, attached to a backing member 12, shown in FIGURE 2. These two members define a recess or slot in which the ends of the slats 10 are inserted. The recess defined by members 9 and 12 is deep enough to retain the slats, as can be seen by reference to the fragmented portion of FIGURE 1. FIGURES 3 and 4 show in greater detail how grip 9 and backing member 12 are assembled. FIGURES 3 and 4

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also show transverse sectional views of the slats 10. Note that in this simplified embodiment of the slats, the dependent extensions or flanges on each slat are straight.

As illustrated, members 9 and 12 are angle irons. It is understood that these members need not be angle irons. Any member which defines a retaining groove 4 for the slats 10 and also which resists bending is workable. The backing member 12 receives a bending load due to the load applied to flat surface of slats 10. As the surface is warped, the slats move within the recess defined by members 9 and 12. For that reason, as will be noted by reference to FIGURE 1, the slats have clearance at their ends from grip 9, and also are free to move within the recess.

The remaining two sides of the form 20 each comprise a retainer. In the embodiment shown, each retainer includes a plate 14 attached to an angle iron 15. Details of the retaining means 14, 15 are shown in FIGURES 2, 4, and 5. The angle iron 15 also serves as a turnbuckle base. When the turnbuckle is shortened to warp the form surface, as is described below, the angle irons 15 tend to bend due to this tightening force. It is understood that the turnbuckle base 15 need not be an angle iron in shape. Any shape which can take the applied bending force is suitable. The plate or stop plate 14 is not absolutely essential to the operation of form 20. In the embodiment shown, stop plates 14 serve as convenient members to abut adjacent similar forms or what ever support is applied to a side of the form. When a plurality of these forms are assembled to produce a larger surface, a thrust is transmitted from one form to the other until the extreme edge of the larger surface is reached, at which point the cumulative thrust is taken by the framework, scaffolding, or other supporting means.

When a shell is constructed of a plurality of these forms, the edges of the shell will be skewed. Because of the resultant shear forces at the edge of the shell, as described above, additional structure is required at the edges of the shell to absorb these forces. Because this structure is required to take the forces, it is apparent that the additional structure can also be used to fill in additional required molding or shell surface left uncovered because of the skewing.

The slats 10 are subjected to twisting and bending stresses. They are preferably relatively thin to take the twist, and the U shape is preferably relatively deep to take the bending. The slats get stiffer with the twisting, which accompanies the warp. The flanges on slats 10 take the shear between the slats, and the stop plate 14 absorbs this shear. When the form is warped, the slats in the middle of the form slide further into the recesses or slots, as described. In the preferred embodiment, the slats can be removed and replaced if damaged.

The warping means, generally designated 30, comprises a turnbuckle 32, a universal joint 35 at one end thereof and another universal joint 36 at the other end thereof. Joint 35 is mounted on pivot block 33 which in turn is fastened to the turnbuckle base or angle iron 15. Universal joint 36 is mounted in bearing 34, which in turn is mounted on the other member 15. As is best shown in FIGURE 2, the warping means extends across the form 20 perpendicular to the long axes of the slats 10.

Turning means are provided to adjust the turnbuckle 32 and hence the length of the warping means 30. In the illustrated embodiment, this turning means comprises a removable crank 31. Crank 31 is shown in phantom lines because it is removed from the form after adjustment and before assembly. It is understood that a crank is merely a representative turning means; the turnbuckle could be adjusted by hand or with a standard or ratchet wrench. It is apparent that with some available turning means, such as a wrench, pivot blocks 33 could be used at each end of turnbuckle 32.

The positioning of the warping means or tie-rod 30 as

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shown permits a large warp to be obtained with a relatively short change in length in the rod. Because of increased strength, purity of obtained geometrical form, and shorter required change in length, mounting the tie rod between opposite sides is preferable to mounting it between opposite corners.

The form sides parallel to the tie bar are in compression and some bending when the warp is applied, and the other two sides are in horizontal bending. Appropriate support or framework is applied to a shell or other structure assembled from the forms in accord with known requirements.

While the warping means is shown attached at the mid-points of opposite sides, the bending in these sides can be reduced by spreading the force application along a substantial length of the sides, as by the provision of a yoke or gusset instead of merely attaching the pivot block 33 and bearing 34 at one point.

At each corner is a joint analogous to the joints 41, 42, 43, and 44 in the embodiment of FIGURES 7-10. The structure of these joints is best shown in FIGURES 2, 4, and 5. The joints are here shown in a preferred embodiment as ball and socket joints. Each joint comprises a block 7 having therein a pin 7A, on the end of which is a ball 7B. This section of the joint cooperates with another block 8 having a cavity adapted to receive the ball 7B. The entire joint can be cast or otherwise fabricated of one piece. It is understood that these corner joints may take many varying embodiments and shapes, and that the warping means may also vary widely. For example, instead of the joint and pivot block 33, 35, in certain applications where less stress is encountered, a simple hook and eye will suffice.

FIGURES 6 and 6A respectively show end views of the form 20 before and after applying a warp. In FIGURE 6A, a form 20 is shown attached to an adjacent form, and is representative of a series of attached forms as has been described above. The view of the form in the warped state is somewhat difficult to represent meaningfully. The representation in FIGURE 6A is slightly schematic. Actually, the upper member 9 might be shown with its right hand end somewhat displaced to the left, so that the length of the upper member 9 would exactly agree with the length of the lower member 9, which is of course the case.

The hyperbolic paraboloid shape is an increasingly important one in construction work, and it can be combined with other curved or other shapes in the production of complete structures. It is understood that the structure described herein represents only one side of a molding form, and additional assemblies may be made to cooperate with those as described to produce the other walls of the complete form. In FIGURE 6A, wherein the joint action of a plurality of forms is shown, no specific fastening means is illustrated. It is understood that any convenient removable means, such as threaded bolts and nuts for example, may be used. The invention is not to be limited to any particular fastening means.

As has been described above, an assembly of forms when warped has a projected planar surface outline which does not have right angles at the corners. If it is desired to obtain a rectangular horizontal projection, several expedients may be followed. Adjustable triangular shaped fillers may be provided between adjacent assembled forms. The amount of filler spacing required is a function of stress, and it is therefore possible to calibrate such fillers so as to indicate stress. The ability to obtain stress values directly from reading calibrated members indicates one of the advantages of this invention as a design tool to architects and engineers.

To compensate for the loss of rectangular horizontal projection, it is also possible to make the sides of the forms of unequal length or to make them of adjustable length.

As a design tool, used in scale models, the forms of

this invention have another useful function. Reference to FIGURES 8-10 is helpful in understanding this function. As the form is warped by adjusting the tie-bar or other means, which may be a cable as well as the illustrated turnbuckle for example, angles and linear dimensions change. For example, the angle between sides 46 and 47, in one plane as shown in FIGURE 8 and in another plane as shown in FIGURE 9, change. Distances, such as the vertical distance from joint 43 to a line between joints 42 and 44, as shown in FIGURE 9, also change with warping. For a given form, it is possible to calibrate the form or to measure the changes. The stresses in the form are a function of these changes, and therefore stresses can be read directly by measuring changes in angle or linear distance. It is apparent that the relationship between the change and the stress it represents can be determined by a skilled design engineer, depending on the exact conditions to be dealt with.

The description and drawings are intended to be illustrative only and not limiting, and it is understood that the scope of this patent is to be determined by the appended claims and is not to be limited to the particular embodiment or embodiments shown and described.

I claim:

1. An adjustable form comprising four sides arranged end-to-end to define a closed area, a universal joint permitting pivotal movement in two planes at right angles to each other between each of said sides at the ends thereof and attached thereto and connecting said sides in said end-to-end relationship, a deformable surface supported on said sides and substantially covering the area defined by said sides, means attached to said form to adjustably position said sides with respect to each other and to hold said sides in said adjusted position, whereby said surface is deformed when said adjusting means adjusts the respective position of said sides.

2. A form comprising four rigid side members arranged end-to-end to define a closed area, four universal joints, each joint permitting pivotal movement in two planes at right angles to each other and connecting each of said side members at an end thereof to the end of an adjacent side member, a flexible, deformable surface supported on said side members and extending substantially over the area defined by said side members, adjustable and settable warping means attached to said form between two opposite sides to adjustably change the relative positions of said sides by shortening the distance between said opposite sides, whereby when said warping means is operated to shorten said distance, said surface follows the curvature of a hyperbolic paraboloid.

3. A form as set forth in claim 2 wherein said warping means comprises an adjustable tie-bar.

4. A form as set forth in claim 3 wherein said adjustable tie-bar includes an adjustable turnbuckle whereby the length of said tie-bar may be changed.

5. A form as set forth in claim 2 wherein said surface

comprises a sheet of flexible deformable, resilient material.

6. A form as set forth in claim 2 wherein said surface comprises at least one slat.

7. An adjustable structural element, adapted to represent in reduced scale a larger structural element, comprising four rigid sides normally defining a rectangle, a universal joint permitting movement in two perpendicular planes at each corner of said rectangle and attached to said adjacent sides, a flexible, deformable, resilient, relatively thin sheet attached to each of said sides and disposed over a major portion of said defined rectangle, warping means on said form disposed on one side of said sheet, and comprising a tie-bar attached at each end thereof to said form, said tie-bar being of adjustable length, whereby when said length is shortened, said sides do not define a rectangle.

8. An adjustable form as set forth in claim 7 wherein said tie-bar is disposed between two opposite said sides at about the mid-points thereof.

9. An adjustable structural element having two opposed sides, each of said opposed sides having a recess therealong, a plurality of elongated slats disposed between said opposed sides, each of said slats having a dependent flange extending from each long side thereof, and each of said slats having its ends inserted into said recesses, two other sides connecting said two opposed sides at the ends thereof, joints connecting the ends of each of said sides, and adjustable warping means connected between said other sides.

10. An adjustable form comprising two opposed sides, each of said sides having a recess therealong, said recesses facing each other, a plurality of deformable metal slats disposed in side by side relationship and extending between said opposed sides, each of said slats having its ends movably inserted into said recesses, a second pair of sides connecting said opposed sides at the ends thereof, a universal joint permitting motion in two planes having at least two directions inserted between each of said sides at the ends thereof, and warping means connected to said sides, said warping means comprising a tie-bar having a settable and adjustable length.

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