United States Patent

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[54] **COMPOUND-CURVED STRUCTURE**

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[52] **U.S. Cl.** **161/77,** 156/178, 161/78, 161/89, 161/93, 161/144

[51] **Int. Cl.** **D03d 17/00**

[58] **Field of Search**....................161/77, 89, 92, 93, 76, 78, 161/140, 141, 142, 143, 144; 9/6; 244/1; 156/176, 178, 179, 180, 181, 214, 215

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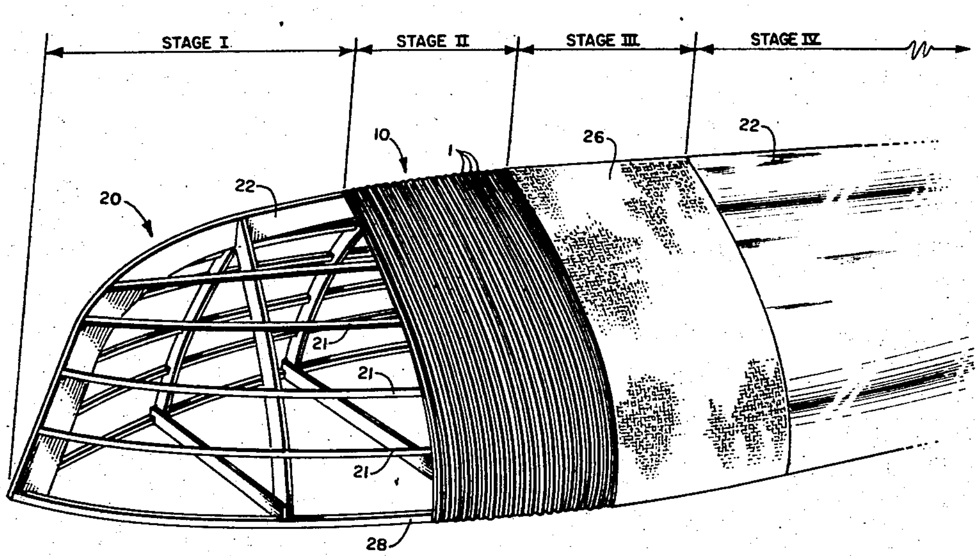
[57] **ABSTRACT**

A method of constructing boat hulls by fiberglass or ferrocement techniques utilizing a surface defining base material of a pliable sheeting material of, for example, a loosely woven fabric or elastic mesh reinforced with springy rods of, for example, fiberglass or steel; the base material is attached to a skeleton framework and readily and easily assumes and forms the compound-curved surface of the hull, and a resin or concrete is subsequently added and allowed to harden.

10 Claims, 4 Drawing Figures



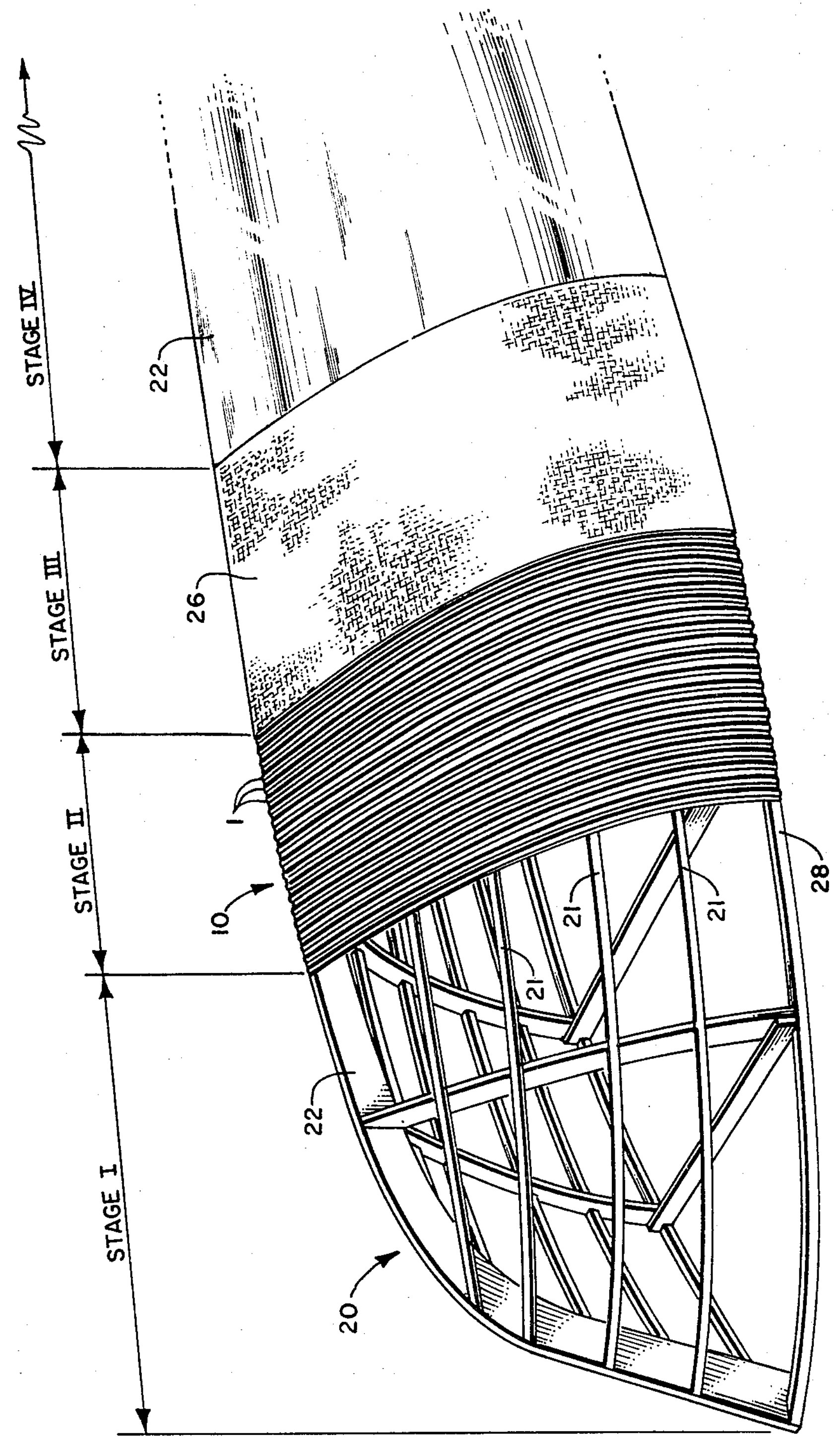


FIG. 1.

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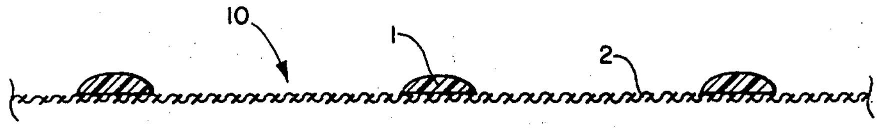

FIG. 2.

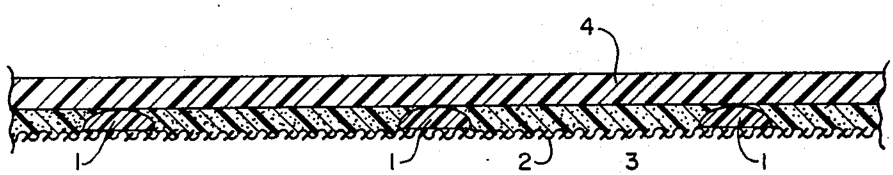

FIG. 3.

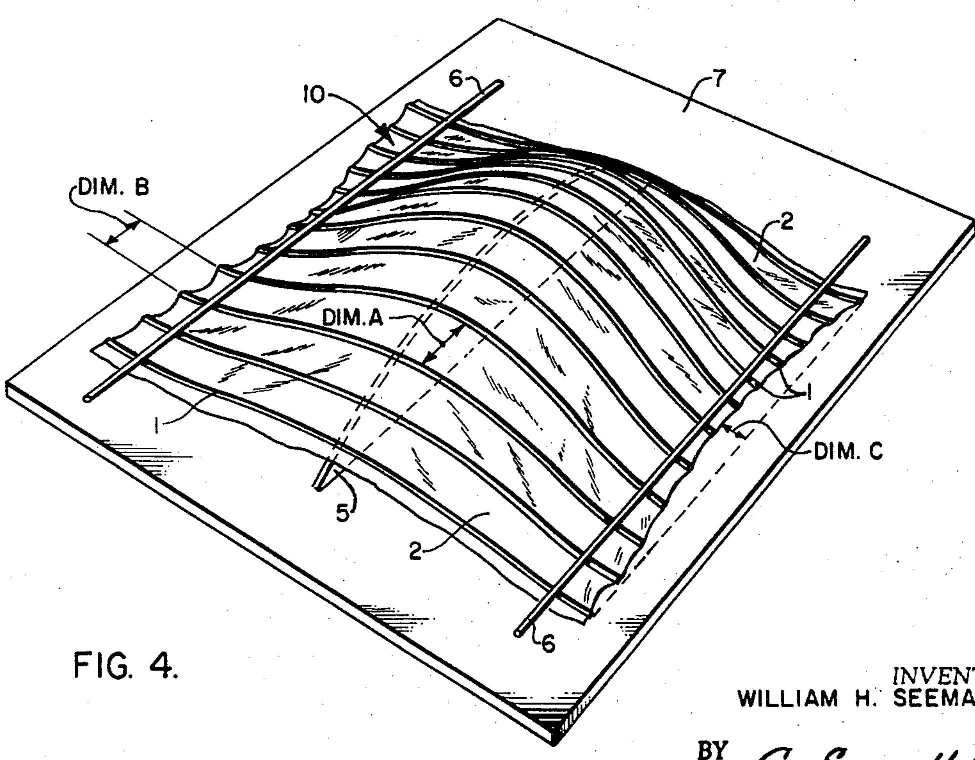

FIG. 4.

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COMPOUND-CURVED STRUCTURE

FIELD OF INVENTION

This invention relates to a method and means for forming compound-curved surfaces, a particularly successful application being in the construction of fiberglass and ferrocement boats.

DESCRIPTION OF THE PRIOR ART

Heretofore in the prior art various complex, costly and time consuming devices and methods were resorted to in order to form compound-curved surfaces. Most of the prior art methods involve making some sort of form or plug out of many, various strips and blocks which would be individually shaped, stretched or bent into shape to form the compound surface.

For example, in the fiberglass molding of boat hulls, it has been the practice to first produce a plug or shell by complex, costly and detailed hand methods, the plug then being used to form a mold. A fiberglass hull is then produced utilizing the mold.

It is true that many types of sheet material have been proposed in the prior art that would take a fair shape over a suitable frame. However, because of their constant flexibility, when the framework contained a compound curve or changed its degree of curvature in any radical manner, the sheets have usually been unsatisfactory.

As compared to the limitations of the prior art, the present invention enables a fabricator to build up a shell more quickly and more cheaply and to use less material and labor. The prior art generally involved making more form work which did not become part of the finished product while in the present invention the material which is used to initially define the shape of the shell can be incorporated structurally into the finished product. In the case of boat construction the present invention enables the hull shell to be built directly over the internal stiffeners such as the bulkheads, the longitudinal stiffeners, the engine bearers, etc. In many cases these necessary internal stiffeners are enough by themselves to sufficiently define the shape of the hull so that the surface defining base material of the invention may be laid directly over them to form the full hull shape. In this case, little or no incidental form work, that is, material which is not necessary for the structural strength of the boat but only necessary to develop the shape of the hull shell, will be needed.

SUMMARY OF THE INVENTION

The surface defining base material, which forms part of the invention, includes the combination of a series of springy elements fastened or generally attached to a pliable sheeting such as a screen or stretchy fabric or film base, resulting in a material having a series of alternating springy regions and pliable or flexible but generally non-elastic regions, that is, non-elastic in a direction perpendicular to the plane of the sheeting. The pliable regions serve to connect the series of springy elements together, that is, to bridge or fill the voids between the springy elements and generally take whatever form the springy elements define. The springy elements generally force and hold the material in shape over a skeleton framework, while the pliable or flexible, non-elastic areas allow maximum flexibility and relative displacement between the springy elements so that the material can assume a compound-curved shape. Thus, in combining the springy elements with the stretchy, screen or loosely woven sheeting material, the advantages of both maximum flexibility and shape retention or forming are achieved.

The springy elements will normally be in the form of elongated members or rods while the pliable sheeting will usually be a loosely woven fabric or screen or mesh material. For best results the pliable sheeting allows relative displacement of the springy elements in both the longitudinal and lateral directions.

In use the base material is laid over an appropriate skeleton framework, with the springy elements forcing the material to take and generally hold the proper shape and the flexible or pliable areas, in filling the spaces between the springy elements, allowing the material to generally define the surface. A hardening agent, for example, a laminating resin is added and saturated into the materials and allowed to harden, permanently producing the compound form. Subsequent layers of reinforcing materials and hardening agents can be added until the desired thickness and strength is achieved.

The elongated, springy members are designed to be stiff enough to hold the pliable sheeting to shape, that is, to pull the sheeting into shape, in the spaces between the framing members over which the base material is laid; but not so stiff as to make it difficult to bend the springy elements into place. Thus the elongated elements or rods have the characteristics of a spring, that is, are very resilient and elastic. Furthermore, it is usually desirable not to exceed the elastic limit of the springy elements in placing the base material in the shape to be constructed; although in some instances, for example, when using steel rods, it may be desirable or at least permissable to bow the rods past their elastic limit. Moreover, the rods should be spaced close enough together so that it is easy to fill the spaces between them and to present a very close approximation of the compound-curved surface desired.

The pliable sheeting to which the springy elements are attached and the form of attachment itself are designed to allow as much movement of the individual rods as possible with the following design desirata:

a. the pliable sheeting should be compatible with the plastic material which is to be applied to it to complete the structure, for example, woven fiberglass fabric for a reinforced polyester resin structure, or woven nylon fabric or unwelded steel mesh for a reinforced concrete structure; and

b. the pliable sheeting should assist in building up as much strength as possible when it is impregnated with a suitable plastic material so that the resulting substructure is strong enough to withstand the weight of an additional layer or layers of reinforced material.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a boat hull in its various stages of construction, using the base material of the invention;

FIG. 2 is a cross-sectional, side view of the base material;

FIG. 3 is a cross-sectional, side view of a fiberglass reinforced plastic structure including the base material; and

FIG. 4 is a perspective, elevational view illustrating how the base material takes on a compound-curved shape.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings in detail, a particularly successful application of the techniques of the present invention is in the building of round-bottomed fiberglass boat hulls like that illustrated in its various stages in FIG. 1.

Broadly speaking, the method of construction is as follows. In Stage 1 a basic support form or skeleton framework **20** is built of, for example, wood, having a series of longitudinal stringers **21**, generally defining the desired shape of the hull. The balance of the form can be any desired internal stiffeners or strengthening members, such as bulkheads, engine bearers, etc. In Stage II, the base material **10** is placed over the stiffener system or skeleton framework **20**, smoothed out and fastened to the framework. An appropriate resin is then added to and saturated in the base material **10** and allowed to harden. Additional layers of resin **26** and reinforcing material can be added (note Stage III) until the desired degree of hull thickness and strength is reached. The surface of the hull **28** is then made smooth by sanding and finished by the addition of a gel coat (Stage IV).

The base material **10** comprises a series of rods **1** or springy elements fastened to a stretchy fabric or film base **2**. The rods, **1**, when sprung over the framework of the stiffener system **20**, will assume the shape which is to be obtained and pull the fabric or film **2** into this shape. As is explained more fully below, the fabric or film **2**, will allow the rods **1** to move relative to one another so that they can assume the various different curves which may be required in the surface which is being fabricated.

An exemplary embodiment of a base material **10** useful in fiberglass boat building is made as follows. Wet saturated strands of fiberglass continuous roving are laid in parallel strips at 1-inch intervals on a section of standard fiberglass woven roving (e.g. 18 or 24 ounces to the square yard weight) and bonded thereto by allowing the strands to dry and harden. The strands serve as the springy elements **1** and the woven roving as the pliable sheeting **2**. The fiberglass woven roving is an example of the loosely woven fabric type of pliable sheeting **2**.

The strands of fiberglass continuous roving are made of four strands of standard continuous filament strand roving (e.g., Owens-Corning ECG 135 strand, 60 end count with a No. 880 hard Silane sizing and an 041 treatment) saturated with a standard polyester laminating resin. The strands **1** are continuously bonded to the fabric base **2** but the areas between the strands **1** still retain their pliability or complete flexibility. This particular base material has been found suitable for longitudinal framing members **21** spaced up to 24 inches apart.

In fabricating the boat of FIG. **1**, "planks" or sections of the base material **10** are laid upon the longitudinal framing members **21** at right angles to the keel of the boat. The "planks" are extended from keel **22** to gunwale **28**, starting in the center of the boat and working to each end. The base material **10** is fastened to the longitudinals at the keel and sheer with waxed battens (not illustrated), temporarily screwed into the longitudinals, and the base material **10** is pulled into any concave areas by the same technique. The battens are waxed so as to permit easy removal. Once the base material **10** is completely in place, a light coat of standard wax-free polyester laminating resin is brushed on or sprayed over the whole area and allowed to harden. When it is hardened, the base material **10** will have been permanently set into shape and bonded to the longitudinals enough so the waxed battens can be removed.

Next a mixture of approximately three parts standard polyester laminating resin, one part talc and one part quarter inch chopped fiberglass fibers, measured by volume, is brushed onto the surface of the set base material **10** at right angles to the direction of the rods **2**. A sufficient amount is applied to produce layers **3** and substantially fill the "valleys" between the rods completely. The surface is then rolled with conventional grooved metal rollers which produces a smooth, relatively strong shell substructure. The entire shell substructure surface is then sanded to remove the high spots.

For further fabrication the shell substructure can be used in several manners, depending upon the final type of hull structure desired.

As is shown in Stages III and IV of FIG. **1**, the hull shell substructure from Stages I and II may be built up to make a homogeneous fiberglass reinforced plastic (FRP) hull shell by using one or more layers **4** of fiberglass reinforcing saturated with polyester or epoxy resin. Note FIG. **3**. The procedure for this build up can be standard procedure followed in the industry when molding a fiberglass reinforced plastic boat over a male mold.

A second alternative would be to provide a "sandwich" structure hull by building up first an inner layer of FRP on the hull substructure, bonding to the FRP a core of foam or balsa wood, and completing the hull with an outer layer of FRP. The standard procedure in the industry for constructing a sandwich structure FRP hull over a male mold can be used.

Although in the final stages of the FRP hull constructions described above, standard procedures are used, the unique techniques of the initial hull shell substructure stages (Stages I and II) provide substantial, overall advantages. For example, there is a minimum of extra work involved because most, if not all, of the forming members are used as structural stiffeners; the actual hull shape is developed very quickly without the necessity of detailed cutting and shaping materials to the compound curves involved; and the shape that is obtained in the hull shell substructure is very fair and smooth because the longitudinal framing system **20** generally fairs the shape in the longitudinal direction and the base material **10** fairs it in an athwartship direction.

A third alternative is to lay and attach reinforcing mesh over the hull shell substructure and proceed to build a ferro-cement boat, using generally the techniques of the standard "wood mold" method of building ferro-cement boats. Again the advantages in using the hull substructure of the present invention are substantial. The hull shape is much more quickly obtained than is possible using wood and having to fit planks, butt blocks, etc.; there is no danger of wood rot as can occur when the wood mold is left in the ferro-cement boat on completion; and the FRP inner hull will eliminate any possibility of water seepage as is sometimes a problem with ferro-cement boats. To thermally insulate the boat, a 1-inch layer of 4-pound density polyuerthane foam could be sprayed onto the hull shell substructure before attaching the mesh.

While one particular embodiment of the surface defining base material **10** has been described, many combinations of springy and pliable materials are possible. However, a major feature of any such combinations is that the springy elements, for example, the springy rods **1**, should be capable of relative movement. The ideal situation is one in which the rods **1**, although attached to the sheeting material **2**, can move both longitudinally and laterally with respect to each other, that is, relatively slide, and move closer together or further apart, without causing the pliable sheeting to bunch up or wrinkle.

An example of this two-way movement is illustrated in FIG. **4**, wherein the base material **10** (like that described in detail above) is mounted over a single curved frame member **5** extending perpendicularly from a flat surface **7**. The base material **10** is secured near its ends to the flat surface **7** by means of battens **6**. It is clear that in assuming the compound-curved surface generally defined by the frame member **5** and the flat surface **7**, the rods **1** in the middle of the base material **10** have moved inwardly along the compound-curved surface relative to the rods at the ends of the base material **10** by a distance C while the rods **1** are spaced further apart at the curved raised area A than at the flat, base area B (note Dim. A and B).

This relative movement is allowed by one or more of the following typical actions in the pliable sheeting material **2** and the type of or form of attachment between springy elements **1** and the sheeting **2**. In a mesh or fabric formed or woven of an elastic filament, the inherent or resulting elasticity of the mesh or fabric itself will allow the relative movement. In a loosely woven fabric or mesh the gauge of the fabric weave or mesh spacings can vary by relative dislocation or movement of the fabric or mesh filament themselves, that is, the intersticies defined by the fabric or mesh can expand or contract as needed. In contracting, the fabric or mesh, in a sense, folds into itself. A further action permitting the relative movement is articulation within the fabric or weave or the twisting or biasing thereof. In general these actions provide the pliability of the base material **10** between the springy elements, yet, when the whole material is saturated with resin and allowed to harden, it becomes rigid and strong.

However, it is noted that it is still possible to form moderate compound-curved surfaces, such as those in a boat hull, if the rods are capable of relative longitudinal movement but are less capable of relative lateral movement. Thus, for example, in some applications a large or heavy mesh material may be suitable wherein the springy rods are merely inserted within or into the mesh itself and restrained from sliding out of the mesh.

An additional example of a pliable sheeting material 2 to which springy rods 1 of strands of continuous fiberglass woving, as described above, can be attached is a nylon fabric. A suitable nylon fabric for boat hull building would be a forty denier, 28-gauge nylon two bar tricot material. As above, the fiberglass rods are bonded or sewn to the nylon fabric at one inch intervals. This base material has been found suitable for longitudinal framing members 21 spaced up to 24 inches apart.

Other exemplary combinations would be fiberglass roving attached to a polypropylene or a polyester mesh fabric like Dynel, or flexible steel rods over nylon or some other type fabric.

A base material using steel rods is particularly suitable for constructing a ferro-cement boat. One embodiment useful in ferro-cementing is a base material of ¼-inch, high tensile, steel rods sewn to nylon mesh screening (e.g, Sears Roebuck Catalogue No. 6W76005 nylon screening) sewn on one inch centers with No. 8 dacron thread using a half inch long zig-zag stitch and a grooved sewing machine pressure foot.

In building a ferro-cement boat with this base material, a different technique than that described with respect to the hull shell substructure above can be used. As before, a suitable longitudinal framing system is erected over a transverse system and the base material is laid over the longitudinals and stapled thereto at the keel and shear and any other place necessary to pull the base material to the correct shape. The base material of this embodiment has been found to be satisfactory for longitudinals spaced up to 24 inches apart.

Once the base material is in place, the wire mesh reinforcing is laid over the base material and fastened in place by running wires through the mesh and under the steel rods 1. When all the reinforcing mesh is in place, the standard plastering operation can proceed. When the hull is cured, the wooden longitudinal stringers can either be left in place or they can be cut out and the protruding staples ground flush with the surface.

One advantage of using the base material in this manner is that again the basic hull shape is quickly obtained with a material which becomes part of the actual hull structure. Moreover, the plastering operation is expedited because the cement mortar is prevented by the nylon mesh from pushing through the reinforcing mesh on into the inside of the hull yet the pores in the mesh will allow air to escape as the plaster is worked into the reinforcing mesh from the outside. This substantially reduces the possibility of air voids being created and allows the use of a thicker mortar mix.

Several preferred modes and embodiments of the present invention have been illustrated and described in connection with a particular field of application, namely, boat hull building. It should be understood, however, that many other changes and modification may be made without departing from the spirit and scope of the present invention. The details and variations indicated above are merely representative of the many details and variations possible in structure, method and field of application of the present invention.

Having thus described the invention, what is claimed as (invention) is:

1. A continuous, sheet-like construction base material for forming a continuous compound-curved surface when attached to a series of substantially spaced-apart skeleton form elements or framework which generally define the compound curve of said compound-curved surface comprising:

a continuous flexible sheeting material which by itself is inherently pliable throughout,

a series of springy, elongated elements of reinforced plastic material, each at least generally attached to and located parallel to the plane of said sheeting material at spaced apart locations with respect to said sheeting material, each of said elongated elements being hard and flexurally strong and elastic in a direction perpendicular to the plane of said sheeting material and providing structural support to said sheeting material along the direction of elongation of said elements and in a direction perpendicular to the plane of said sheeting material, said sheeting material providing a continuous, pliable bridging surface between said elongated elements, thereby providing alternating springy, flexurally strong regions and pliable regions, the attachments between said elongated elements and said sheeting material allowing relative movement of the elongated elements with respect to each other, at least longitudinally, the combined elongated elements and sheeting material having as a prime physical characteristic that it forms and holds a compound-curved surface when attached to a skeleton framework generally defining a compound-curve, said elongated elements generally forcing and holding said sheeting material into and in the shape of said compound-curve and at least some of said elongated elements moving relative to each other at least longitudinally when the combined elongated elements and sheeting material are attached to the skeleton framework.

2. The construction base material of claim 1 wherein said elongated elements are in the form of rods and are parallelly aligned with respect to each other when attached to said sheeting material.

3. The construction base material of claim 1 wherein said sheeting material is comprised of fibrous material interconnected together to form a pliable sheet.

4. The construction base material of claim 1 wherein said sheeting material is comprised of a continuous sheet of elastomeric material.

5. The construction base material of claim 1 wherein said sheeting material has a woven, mesh structure and said elongated elements are positioned within the mesh structure.

6. The construction base material of claim 1 wherein said elongated elements may also move laterally with respect to one another.

7. The construction base material of claim 1 wherein said elongated elements comprise a resinous material reinforced with a high strength fibrous material and said sheeting material comprises a woven fibrous material.

8. The construction base material of claim 7 wherein said resinous material is thermosetting, said fibrous material is made up of glass fibers and said woven fibers are also of glass.

9. The construction base material of claim 1 wherein there is to be added thereto within the interstices thereof a hardening agent, the material composition of said elongated elements and said flexible sheeting material being chemically and structurally compatible and forming a strong bond with the hardening agent, each structurally enhancing and reinforcing the other when the hardening agent is added to the construction base material.

10. The construction base material of claim 9 wherein the hardening agent is a thermosetting resinous material and wherein the material composition of said elongated elements includes a thermosetting resinous plastic material.

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