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Geiger et al.

[11] **3,886,961**

[45] **June 3, 1975**

[54] **PRESTRESSED MEMBRANE STRUCTURE**

[76] Inventors: **David H. Geiger,** 788 Riverside Dr., New York, N.Y. 10032; **Horst Berger,** 18 Chestnut Dr., Hastings on Hudson, N.Y. 10706

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[21] Appl. No.: **409,779**

Related U.S. Application Data

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[52] **U.S. Cl.** ..... **135/1 R;** 52/23; 52/80; 52/82

[51] **Int. Cl.** **E04b 1/347;** A43f 1/00

[58] **Field of Search** ..... 135/1 R, 3 R, 5 R; 52/222, 52/86; 1/18, 80, 82

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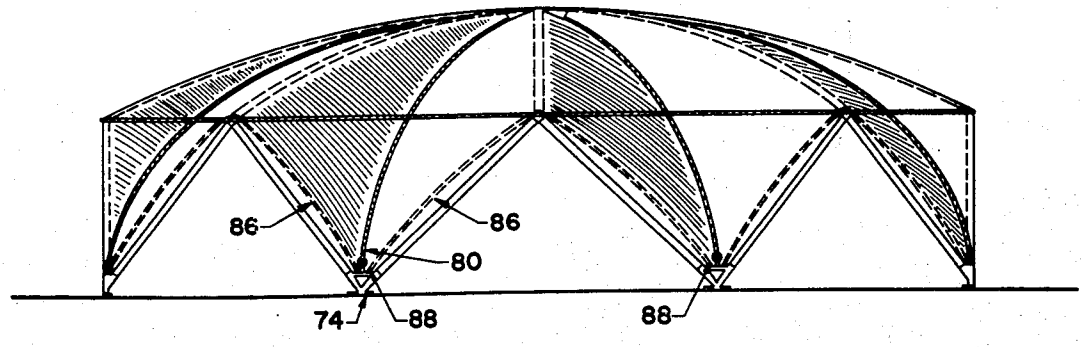
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Primary Examiner—John E. Murtagh
Attorney, Agent, or Firm—Arthur V. Smith, Esq.; Pasquale A. Razzano, Esq.

[57] **ABSTRACT**

A building structure has a plurality of elongated flexible compression arches or ribs to which a flexible membrane is operatively connected to span spaces between the arches in a folded pattern with the arches located at the apices of the folds and valleys formed between the apices. A plurality of cables are operatively associated with the membranes by prestressing and are located in the valleys formed between the arches in order to maintain the membrane in tension under substantially all load conditions so that the flexible arches are braced against buckling by the membrane. As a result, the flexible components of the structure cooperate to form a relatively rigid structural system capable of spanning relatively long distances for covering sports stadiums and the like.

12 Claims, 12 Drawing Figures



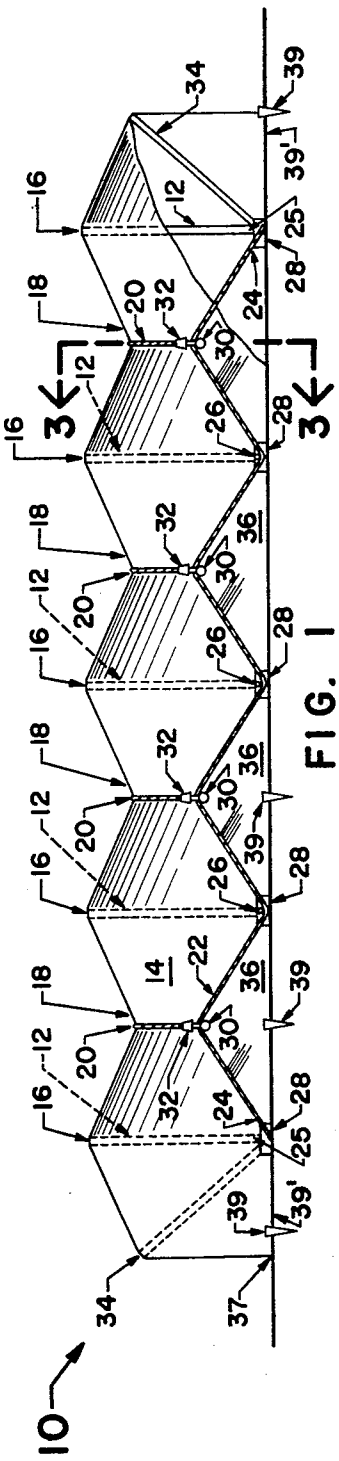

10
34
37
39
39'
25
28
24
12
16
18
20
32
30
26
36
14
22
3
3

FIG. 1

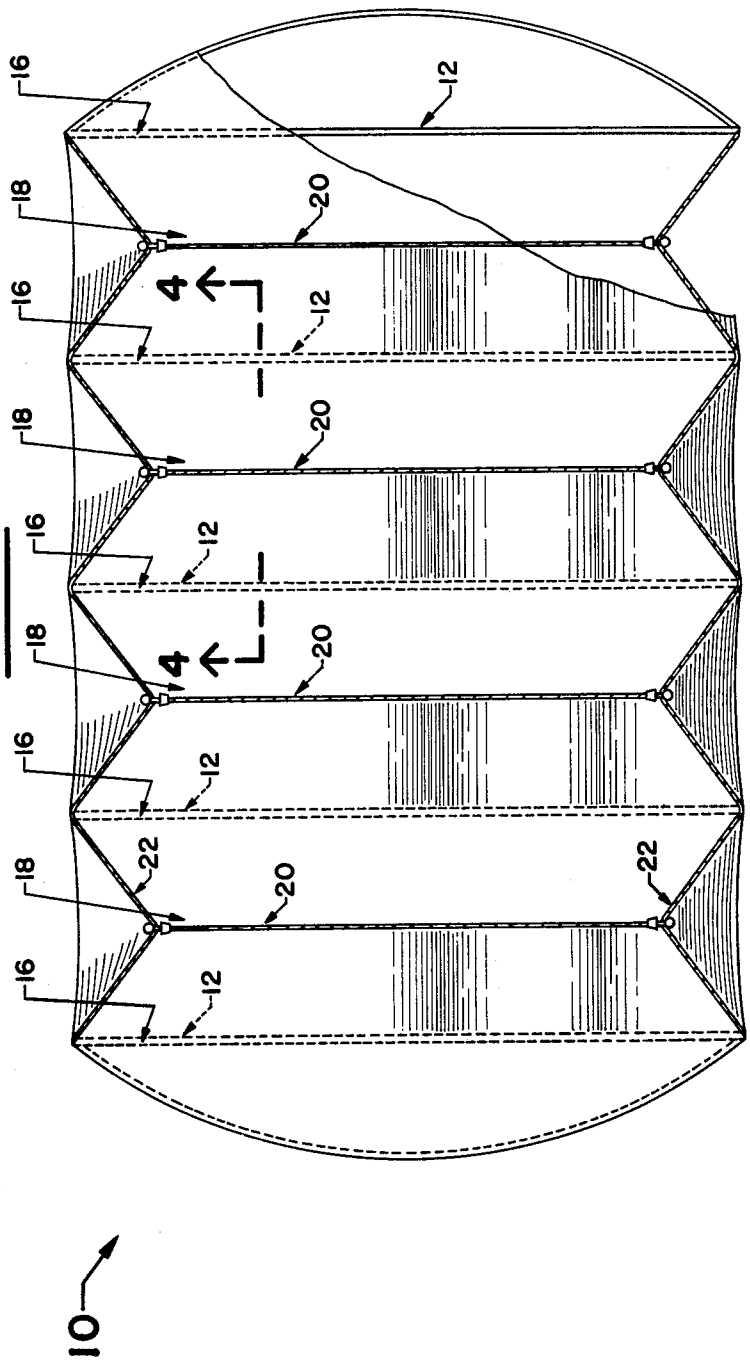

10
12
16
18
20
22
4
4

FIG. 2

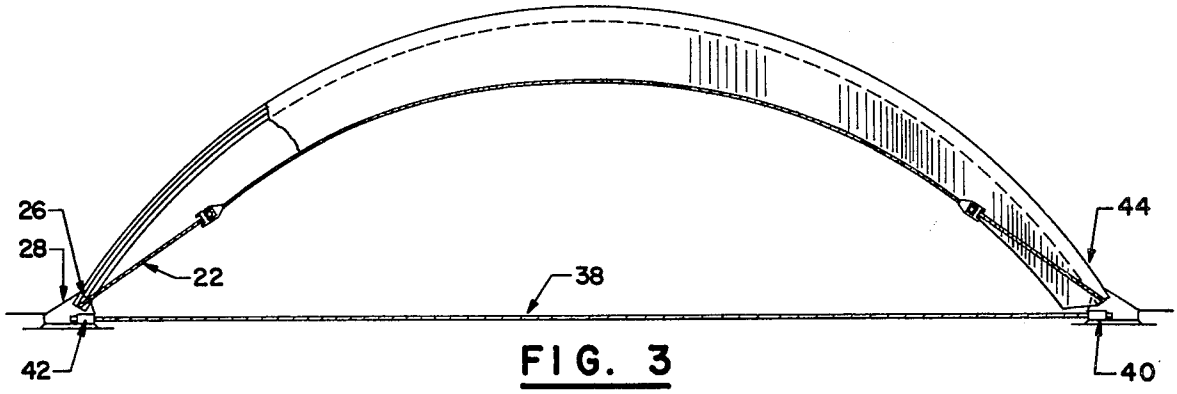


FIG. 3

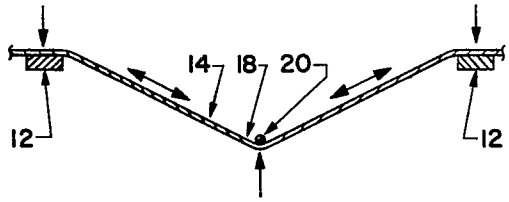


FIG. 4

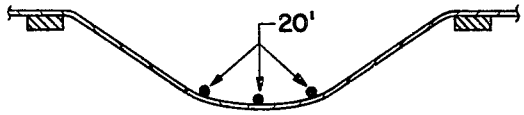


FIG. 5

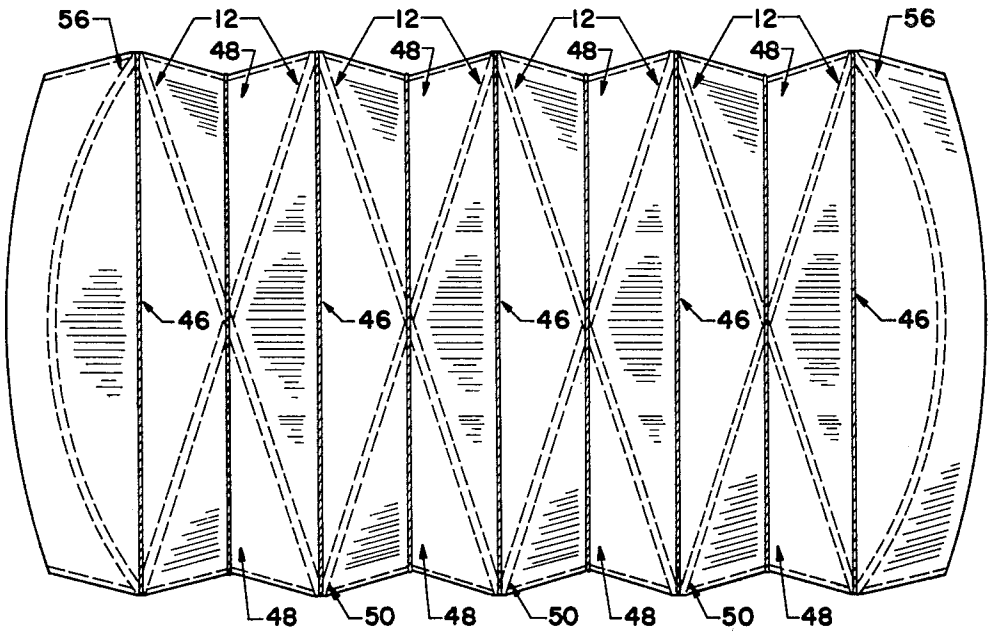


FIG. 6

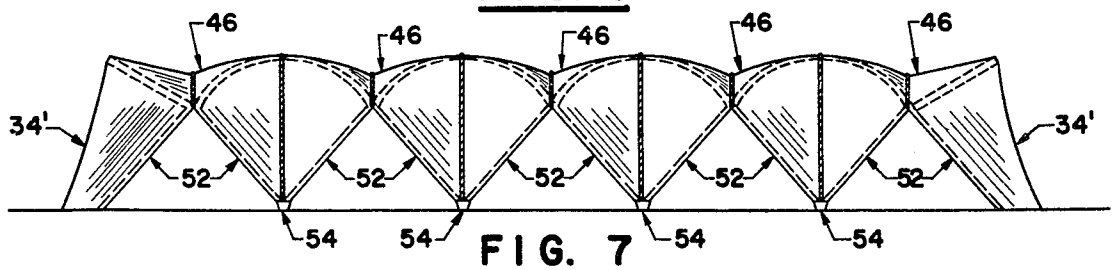


FIG. 7

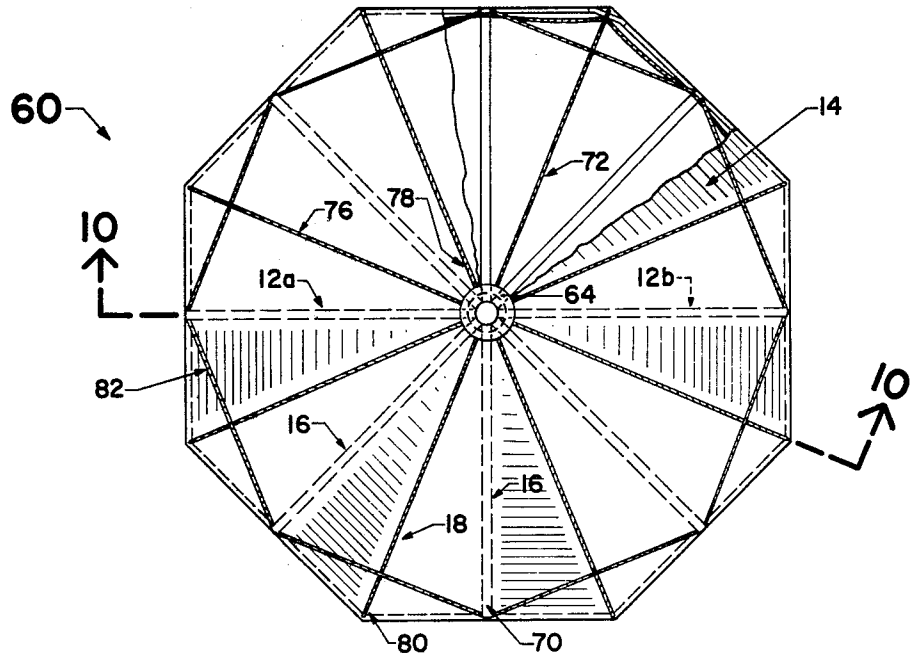


FIG. 8

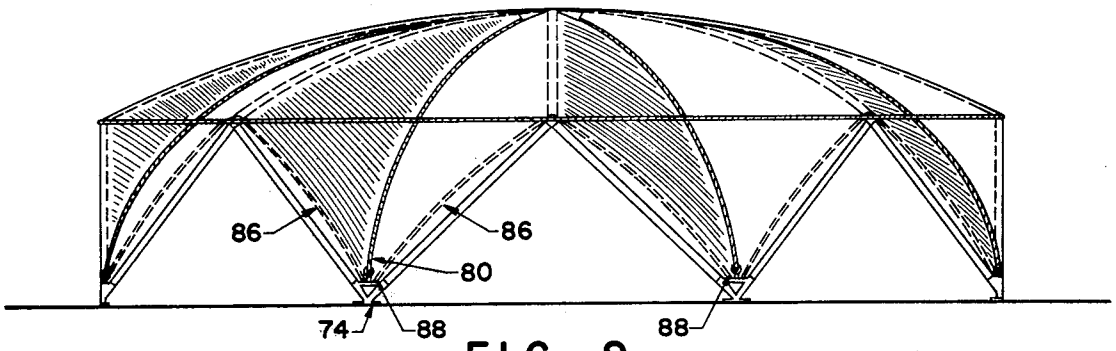


FIG. 9

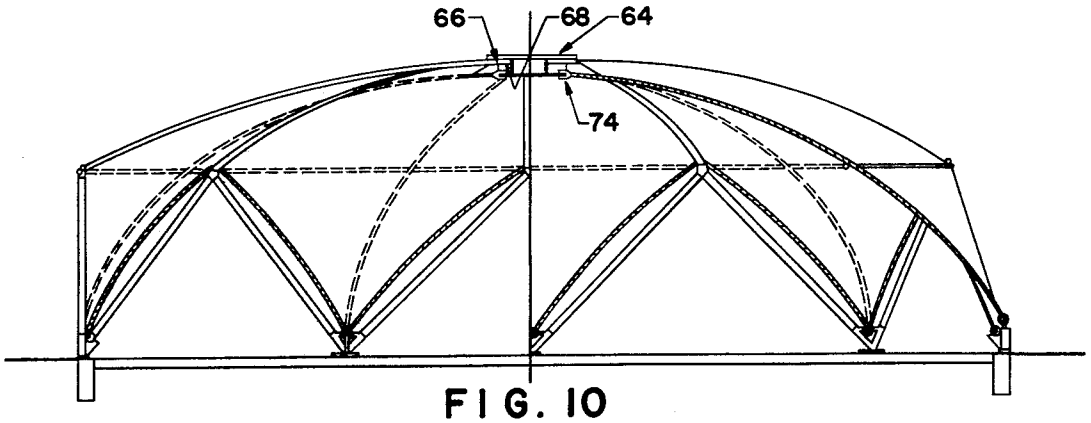


FIG. 10

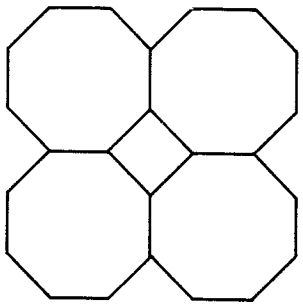


FIG. 11

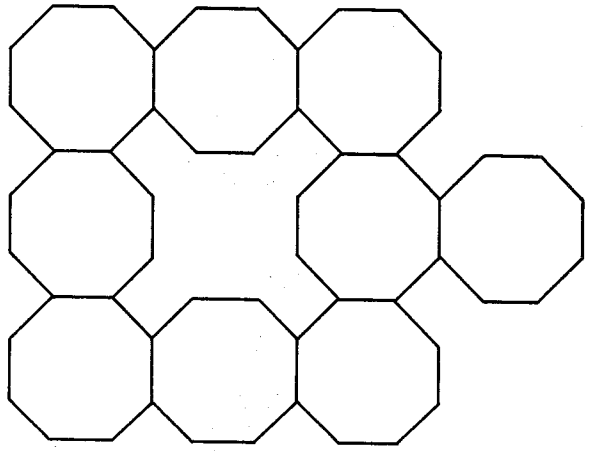


FIG. 12

PRESTRESSED MEMBRANE STRUCTURE

This is a division, of application Ser. No. 234,238, filed Mar. 13, 1972, now U.S. Pat. No. 3,807,421.

The present invention relates to building structures and more particularly to a structural system suitable for use as temporary or permanent enclosures of various sizes.

In recent years there has been an increased demand for inexpensive housing and shelter structures due to the increased costs of labor and material required for erecting previously proposed types of buildings. Moreover, this demand includes a need for flexible building structures which can be readily converted from temporary to permanent usage and which are readily assembled and maintained. Similarly, lightweight and easily erected structures are required for spanning relatively large distances or spaces to form domes for stadiums and like structures.

In previously proposed building structures of both a temporary and permanent type, some or all of the structural components utilized are rigid members in order to provide the structure with stability. Such members normally account for a substantial portion of the cost of the building structure and are relatively difficult to transport from the fabrication plant to the building site. As a result, temporary shelters, particularly emergency shelters for use in hurricane or earthquake disasters or the like are both relatively expensive and difficult to transport to the required location. Moreover, once at the site, such structures are relatively difficult to erect, normally requiring specialized equipment or tools and large numbers of laborers.

Accordingly, it is an object of the present invention to provide a relatively simply constructed and erected structure which is economical in manufacture and use.

Yet another object of the present invention is to provide a building structure which is readily erected and converted from emergency or temporary shelter to a permanent use.

Yet another object of the present invention is to provide a building structure or system which is suitable to a number of uses including that of forming entire building structures or portions of structures, such as domes for stadiums and the like.

In accordance with an aspect of the present invention, a building structure is provided in which a plurality of compression arches, which are formed from normally flat flexible structural members, are held in an arched configuration to support a flexible membrane. The latter is operatively connected to the arches in a folded configuration having a plurality of ridges and valleys, with the flexible arches located at the ridges in the folded membrane and the valleys therein taking shape between the ridges. A flexible cable is located between the arches in the membrane valley therebetween, and is prestressed to hold the membrane in tension against the arches. As a result, the flexible arches are braced against buckling by the tensioned membrane, under substantially all load conditions, so that a relatively rigid structure is created from the combination of the flexible arches, flexible membrane and flexible cables.

As will be described more fully hereinafter, the structure of the invention is relatively simple to erect because of the lightweight and flexible nature of the various components utilized therefor. Accordingly, the structure is readily erected at an emergency site, for use as temporary emergency shelter. Moreover, the components utilized to form the structure are lightweight, economic and readily transportable so that the structure is extremely economical for use in emergency situations. Since the structure can be readily transported and assembled, it is quite suitable for home use, as for example, a home temmis court shelter or the like.

The basic principal of the invention is the cooperation of the flexible arches, which serve as compression members in the structure, and the tensioned membrane and stressed cables which tension the membrane to brace the arches and form the rigid structure. The rigidity of the final structure is produced by means of stressing of the tensile cables in the valleys formed in the membrane. By putting these members under tension, a tensile stress is produced in the membrane, which in turn produces a load on the compression member or flexible arch, thus putting all of the components of the structure under a prestressed condition. All of the components are interconnected with each other in any convenient fashion, so that they form a three-dimensional space frame structure of which no part can move without movement of all of the other parts. With the basic arrangement and relation of the components, as described and claimed herein, the structure can be designed to a shape and stress so that under any design load case, the components will not lose this contact with each other so that the tensile members, i.e. the cable and membrane will always remain in tension, while the compression members will always remain in compression. As a result, the shape of the structure can be controlled to a degree such that the compression members cannot buckle and no member in the system can become overstressed.

This principal of cooperating elements provides an extremely flexible building system which can be used to form building structures or domes having a variety of shapes and patterns and which can be arranged with respect to one another in various arrays to achieve complete flexibility in the design layout and construction. Moreover, the patterns and arrangement of the arches and cables in the structure are repetitive so that standardized materials and sizes can be utilized throughout the building, which materials are readily presently available. This, of course, greatly reduces the cost of the structure and renders it substantially more economical than previously proposed structures.

The above, and other objects, features and advantages of this invention, will be apparent in the following detailed description of an illustrative embodiment thereof which is to be read in connection with the accompanying drawings, wherein:

FIG. 1 is an elevational view with parts broken away of a building structure constructed in accordance with one embodiment of the present invention;

FIG. 2 is a plan view, with parts broken away, of the building structure illustrated in FIG. 1;

FIG. 3 is a sectional view taken along line 3—3 of FIG. 1;

FIGS. 4 and 5 are diagrammatic illustrations of the operation of the present invention;

FIG. 6 is a plan view, similar to FIG. 3, of another embodiment of the present invention;

FIG. 7 is an elevational view of the building structure illustrated in FIG. 6;

FIG. 8 is a plan view of a building structure constructed in accordance with another embodiment of the invention;

FIG. 9 is an elevational view of the building structure illustrated in FIG. 8;

FIG. 10 is a sectional view taken along line 10—10 of FIG. 8; and

FIGS. 11 and 12 are diagrammatic illustrations of relative arrangements of a plurality of building structures constructed in accordance with the embodiment of FIG. 8.

Referring now to the drawing in detail, and initially to FIGS. 1 and 2 thereof, it is seen that a building structure 10, embodying the present invention, is formed from a plurality of flexible arches or ribs 12 which extend generally parallel to each other to form a generally rectangular building structure when viewed in plan. Arches 12 are covered by and operatively connected to a flexible membrane 14 which is positioned on the arches in a "folded" configuration so that the membrane has a plurality of ridges 16 and valleys 18 therebetween. The ridges 16 formed in the folded membrane are located along arches 12 while the valleys 18 therein are located between the arches.

Arches 12 are normally flat members formed of a flexible material, such as thin elongated bars of aluminum, wood or the like, which are relatively light in weight and readily transportable. These arches are initially placed in parallel relation to each other and are then bowed into their arched configuration to support membrane 14 in the completed structure, as more fully described hereinafter.

Before arches 12 are bowed, the flexible membrane 14 is placed thereon. Membrane 14 is preferably formed of a woven synthetic fabric material, although it is contemplated that other materials such as canvas or thin metallic foil membrane may also be utilized. In any case, the membrane is mechanically connected to the arches, as for example, by sewing, or the like, although it is also contemplated that the system of the present invention will operate efficiently if the membrane is merely placed on top of the arches, with no direct mechanical connection therebetween except at the edges of the membrane. In the latter situation, the frictional engagement between the arches and the membrane and the end attachment of the membrane to the arches will be sufficient to achieve the desired structural stability and rigidity in the building.

Arches 12 are braced against lateral movement and buckling by membrane 14 which is held constantly under tension in all load conditions by cables 20 located in membrane valleys 18. Cables 20 in turn are prestressed by edge cables 22 located at opposite sides of the arches. These are secured at their ends 24 to the ends 25 of the outermost arches 12 in the building and pass over guide pulleys or rollers 26 rotatably mounted at the ends of intermediate arches 12. The ends of arches 12 are pivotally mounted in base support or connectors 28 which can be simply seated on the ground or secured to footings to make the structure permanent. Between arches 12, cables 22 are guided over pulleys 30 mounted on the ends 32 of cables 20 and thus cables 22 are operatively connected to cables 20 to prestress them. Cables 22 are thus triangulated, that is, as seen in FIG. 1, they form triangularly shaped arrays between arches 12, with their points of connection to cables 20 being located at the apex of the triangles. In this manner, cables 20 and 22 are prestressed, with cables 22 serving to equilibrate the thrust of the arches 12 at the supporting structures 28, to draw cables 20 tightly against membrane 14 so that the membrane is held in tension. It is noted that the terms prestress or prestressing as used herein have their conventional meaning in the construction arts, that is, that a predetermined stress or pattern of stress is applied to the structure prior to adding superimposed loads thereon.

With the relative configuration of the components thus described, the amount of prestressing can be adjusted so that membrane 14 will be constantly under tension in all load conditions. As a result, arches 12, which act to take the compression loads on the structure, are braced against buckling and the entire structure is thus substantially rigid.

The ends of building 10, as illustrated in FIGS. 1 and 2, are formed from a pair of additional flexible arches 34 which are also pivotally connected to the end base support members 28. The areas 36 between the triangulated cables 22 can be left open to permit access to the building structure or, alternatively, the membrane 14 may extend down into the areas 36 to close the sides of the building. The membrane structure in this area would also be tensioned by cables 20 and 22 so that the membrane at those points is substantially rigid. In addition, it is noted that the free edges 37 of membrane 14 are secured tightly to the ground adjacent the building by conventional earch anchors or stakes 39 in order to maintain the prestressing or tension in the membrane at the vertical ends 39' thereof and in the areas 36 between cables 22 and the ground.

In erecting the structure illustrated in FIG. 1, the normally flat flexible arches 12 are drawn into their bowed or arched configuration, by means of a cable 38 extending between the base support members 28 to which the arches are pivotally connected in any convenient manner. Referring to FIG. 3, each cable 38 is rigidly connected at one end to one of the base support members 28 associated with their respective arch by a conventional cable anchor system 40. The other end of cable 38 is passed through a similar anchor 42 at the opposite base support member 28 (at the left in FIG. 3) and is drawn therethrough. As a result, the right end 44 of each arch 12 (and the base member 28 to which it is connected) is moved in to the left, as seen in FIG. 3, and the arch is bowed, thereby lifting membrane 14 into its folded configuration. When the desired bow or arch is obtained, cable 38 is locked in position in anchor 42 so that the arch configuration is maintained. It is noted that during use of the structure, cables 38 serve to equilibrate superimposed loads, such as snow loads, imposed on the arch during use of the structure. Alternatively, cables 38 may be eliminated and cables 20 and 22 may then be used alone to maintain bow in the arches and equilibrate superimposed loads.

Thus, it is seen that the structure is designed so that the cables 20, 22 serve to equilibrate the natural thrust of the flexible arches 12 and to tension membrane 14, while cables 38 serve to equilibrate the thrust loads created by superimposed dead loads on the structure. As a result, a rigid structure is formed from only flexible components and this structure will maintain its rigidity under substantially all load conditions.

Referring to FIGS. 4 and 5 of the drawing, the basic operation of the building structure during use is schematically illustrated. As seen in FIG. 4, compression

arches 12 have membrane 14 superimposed thereon, with a prestressed cable 20 located in the valley 18 between the arches and maintaining the membrane in tension. In the event a superimposed load is applied to the building structure, such as for example, a snow load, as represented by the arrows S in the drawing, arches 12 would tend to move downwardly under the load. Such downward movement would cause the valley of the membrane to move upwardly in the direction of the arrow T to relieve the stress on the membrane. However, prestressed cable 20 prevents this upward movement of the membrane at point T, thereby maintaining the tension in membrane 14, and as a result, the membrane continues to brace arches 12 against buckling. Thus, the superimposed load S is transmitted through the arches in compression to the base support members 28 where it is equilibrated by cables 22 and the horizontal cables 38.

It is noted that cables 38, in the embodiment illustrated in the drawings, are located on the ground, and such cables would be covered by a false flooring arrangement in the building to prevent interference with the use thereof. Alternatively, the entire structure illustrated in FIGS. 1–3 could be utilized as a dome for a building such as a stadium or the like, with base support members 28 seated on a peripheral wall or individual columns, so that the structure shown would be raised above the ground. In that event, cables 38 would be above the ceiling of the structure and out of the way of interference with the use thereof.

Referring to FIG. 5 of the drawing, a somewhat modified embodiment of the invention is illustrated, where in lieu of the single cable 20, three cables 20′ are utilized. Each of these cables serves the same function as cable 20 in that they are prestressed and serve to maintain the tension in membrane 14 between arches 12. In addition, more than one arch may be used at the ridges of the membrane, depending upon the design of the structure, size of the load to be carried, and the size of the building.

Another embodiment of the present invention is illustrated in FIGS. 6 and 7 of the drawings. This embodiment is similar to the embodiments of FIGS. 1–3 in that it is generally rectangular in plan. However, in this case, arches 12 are arranged in pairs forming a plurality of X's across the longitudinal axis of the building. As a result, the ridges 16 formed in membrane 14 are skewed with respect to the longitudinal axis of the building and a greater number of valleys are formed therebetween. That is, valleys 46 are formed between the ends of arches 12 and additional valleys 48 are formed between the legs of each of the X's. In each of these valleys cables 20 are placed in order to pretension the fabric in a manner similar to that described in the previous embodiment.

With the arches arranged in this manner, the loads imposed upon the structure are triangulated and distributed to improve the equilibrium and stability of the building structure. In this regard, as illustrated in FIG. 7, the ends of each arch 12 are connected at a common point 50 with the end of an arch from an adjacent pair of arches. At these common points the arches are rigidly secured to rigid structures 52 which serve to support the arch members above the ground and are interconnected by tying cables corresponding to cables 38 of the prior embodiment, which maintain the arches in a bowed configuration and equilibrate the thrust thereof. Support structures 52 are rigid inverted V-shaped arrangements which serve to triangulate the forces applied to the dome and transmit them to the ground at footings 54. Moreover, cables 20 are anchored in any convenient manner to the support structures 52 on the opposite sides of the structure to hold membrane 14 under tension in cooperation with the action of arches 12.

The ends of the structure illustrated in FIG. 7 are formed by flexible arches 56 which are secured to the membrane 14 and the support structures 52 at the ends of the building. Additional membrane sections may be used to close the ends of the arches or these ends may be left open for a temporary shelter. As with the prior embodiment, earth anchors or stokes 39 are used to secure the free edge of the membrane to the ground to maintain the vertically extending ends 34′ of the membrane in tension. Alternatively, prefabricated end wall segments having doors and windows therein can be utilized to make this structure a semi-permanent dwelling or emergency housing structure.

Referring now to FIGS. 8 through 10, yet another embodiment of the invention, which utilizes the basic principles of operation and construction of the previously described embodiments, is disclosed wherein a dome shaped structure 60 is provided, having a regular polygonal configuration in plan. In this embodiment flexible arches are also utilized, however, the arches are formed in two sections 12*a* and 12*b*. These sections are normally flat members and are interconnected in radial alignment with each other by a rigid annular central ring 64. As illustrated in FIGS. 8 and 10, this interconnection may be a simple male female arrangement, in which the ends 66 of the arches are received in radial apertures 68 in the ring. Such an arrangement is suitable for use in temporary structures. For more permanent structures, the connection C can be made rigid by bolting, welding or the like. All of the arches 12 are connected in this manner to central ring 64 and the flexible membrane 14 is placed over the arches. As in the prior embodiments, the membrane may be mechanically secured to the arches by sewing or the like or it may simply be laid across the arches for frictional engagement therewith.

After membrane 14 is placed over arches 12, central ring 64 is raised so that the arches bow of their onw flexibilith from the central ring to the ends, thereby forming the ridges 16 and valleys 18 in the membrane. The free ends 70 of each of the arches are rigidly secured to a pair of angularly related rigid columns 72 forming an inverted V-shaped supporting structure which hold the arches in their bowed configuration and thus maintains the arches in compression. Columns 72 are in turn connected, as illustrated in FIG. 9, to a support ring or foundation anchor 74 which defines the outer peripheral shape of the structure.

With the components positioned membrane this arrangement, radially extending cables 76, which are secured at their inner ends 78 to ring 64, are positioned over membrane 14 in the valley 18 formed between ridges 16 of the membrane. These cables are secured at their outer ends 80 to foundation anchors 74 and are prestressed, in order to tension memberane 14. A peripheral cable 82 is engaged with the free ends 70 of arches 12 in a groove formed in the end of the arch, or over a pulley rotatably mounted in the arch, and prestressed in a conventional manner, for example, by a

turn buckle secured to its ends in order to equilibrate superimposed loads on the dome structure.

In this embodiment of the invention the free edge **34** of the membrane is secured to edge cables **86** which are tensioned about the inverted V-shaped supports provided by columns **72.** Each cable **86** is a separate member secured at its ends **88** to footing anchors **74** and contacting the apex **90** of each inverted V at its center. In this manner the stress in membrane **14** is transferred to supports **74** only at their ends and thus these supports are subjected only to compressive stresses. As a result, these columns can have a smaller diameter than would be necessary if the membrane were connected directly to them. This arrangement is also suitable for use with the previously described embodiments.

Accordingly, it is seen that the roof skin or membrane **14** of each of the above described embodiments is utilized as a structural component of the building, which, by the prestressing of cables **20,** becomes an integral part of the whole building structure. The membrane thus functions as an element spanning between the arch ribs, to provide shelter for the enclosure, while it also acts as a tensile and shear structural web interconnecting the cables and arches.

The peripheral cables of the dome structure illustrated in FIGS. **8** to **10** serve to carry the thrust of the dome ribs and to produce sufficient stress in the membrane so that it remains taught under any load condition, thereby guaranteeing an integral composite structure made of compression ribs, tensile cables and the membrane surface. Each of these components is normally flexible, but with the arrangement of the components as described in accordance with the present invention, render the structure relatively rigid.

The buckling stability normally required of an arch ridge for dome structures is usually supplied by constructing the rib as a rigid member, making the ribs or arches relatively expensive and difficult to transport. By the present invention the stability is replaced by the integral structural system described wherein the membrane restrains the arch from buckling. The degree of restraint required can be achieved by varying the spans between the arches, the slope of the membrane against the arch, the stiffness of the cable selected, and the amount of stress the cable and membrane produce.

The dome made in accordance with this invention permits a simple erection procedure as described, in order to create an extremely lightweight roof structure which is translucent, depending upon the material selected for the membrane **14,** and waterproof. The structure can be put up by very simple systems in a very short period of time and can readily span large spaces. In fact, it is contemplated that structures such as illustrated in FIGS. **8** through **10** can easily span a space from 50 to 1,000 feet in diameter and can be built at a substantially lower cost than conventional structures.

The ribs or arches used in each of the above described embodiments can be formed of many different types of materials, for example, laminated wood or aluminum strips, or integral or solid thin aluminum or other metal or wood materials. Preferably they are of lightweight construction and readily transported. The compression members or arches should have sufficient flexibility so that initially they are straight members but can be curved to the appropriate arc without exceeding their elastic limit, i.e. without forming a permanent deformation therein.

The cables utilized in all embodiments are preferably formed of high strength steel, particularly for relatively large buildings, although for temporary structures and structures of smaller size, other materials may be utilized. The membrane, on the other hand, is made of a material which can be folded for the purpose of shipment and can be shaped to fit the form of the structure as required.

As a result, it is seen that the structure requires no rigid or precurved components, as has been heretofore required with building structures. Rather, the structure is made entirely of straight flexible elements of extremely light weight. The fabric can be folded into a small package and the cables rolled into rings for transportation, while the flexible compression members come in flat easily manageable pieces so that the whole structure can be transported easily by any means of transportation and erected with the help of very light equipment and very few workmen.

In summary, the rigidity of the final structure is produced by means of prestressing of the tensile cables **20** located in the valleys between the membrane ridges. By putting these cables under tension, a tensile stress is produced in the membrane **14,** which, in turn, produces a load on the compression members or arches **12,** thus putting all components under stress and interconnecting them with each other into a three-dimensional space structure of which no part can move without movement of all other parts. The structure can be shaped and stressed so that under any load condition the components will not lose this contact with each other and the tensile members will remain in tension, the compression members will remain in compression and the shape will be controlled to such a degree that the compression members cannot buckle and that no member will become overstressed.

Such domes can be erected rapidly and inexpensively at an emergency site to provide temporary shelter. However, because the structure is relatively rigid, the structure can be conveniently converted into a semi-permanent or permanent housing unit. This can be done by the provision of modular interior components providing sanitary facilities and individual rooms, floors, and ceilings. In addition, because of the regular peripheral configuration of the dome structure, the domes can be placed in a variety of arrays or patterns to provide a pleasing and functional appearance. Two of such systems are illustrated by way of example in FIGS. **11** and **12** wherein it is seen that the domes can be clustered to provide interior or exterior court yards and passageways while providing a plurality of closely related building or housing units.

It is also to be noted that each structure constructed in accordance with the invention has a plurality of similar parts so that each component therein may appear a fairly large number of times. As a result, even a fairly small number of units could be made economically since production of similar components for use in the building represents a substantial economic savings over previously proposed arrangements wherein different sized components are used at all parts of the building depending upon the loads applied.

Although illustrative embodiments of the present invention have been described herein with reference to the accompanying drawings, it is to be understood that the invention is not limited to those precise embodiments and that various changes and modifications may

be effected therein by one skilled in the art without departing from the scope or spirit of this invention.

What is claimed is:

1. A building structure including a plurality of flexible arches, a flexible membrane operatively connected to said arches in a folded configuration having ridges and valleys therebetween with said flexible arches being located at said ridges, and a plurality of prestressed flexible cables respectively located in the valleys formed in the membrane between two adjacent arches to hold said membrane in tension against said arches, whereby said arches are braced against buckling by said membrane to form a relatively rigid structure; said arches being formed of normally flat flexible members arranged to extend radially with respect to each other, to define a generally circular dome structure; and said structure including means for maintaining said flexible members in an arched configuration; said prestressed cables holding said membrane against said flexible arches upon downward flexing of said arches and said flexible arches holding said membrane against said prestressed cables during upward movement of said arches whereby said membrane is held in tension against said arches under substantially all load conditions to brace said arches against buckling.

2. The building structure as defined in claim 1 wherein the innermost portions of said arches are located at a common point thereby to define said generally circular dome structure.

3. The building structure as defined in claim 2 wherein said means for maintaining said flexible arch members in an arched configuration includes a peripheral cable operatively interconnecting the free ends of the arches.

4. The building structure as defined in claim 3 wherein each of said arches is formed from two normally flat flexible elongated structural members and said structure includes a central connecting ring for said structural members, said ring being operatively connected to one end of each at said structural members, with the structural members of each pair extending in radial alignment from the ring.

5. The building structure as defined in claim 4 in which there are at least four pairs of said structural members whereby said dome has an octagonal shape in plan.

6. The building structure as defined in claim 4 including a plurality of inverted V-shaped dome support members associated respectively with the free ends of said arches, said support members being operatively connected to said arches at the apices thereof.

7. The building structure as defined in claim 6 wherein said membrane extends beyond the free ends of said arches to span between said support members.

8. The building structure as defined in claim 7 wherein said radially extending cables are secured at one end to said central connecting ring and at their opposite ends to said support members.

9. The building structure as defined in claim 8 wherein said support members form a side wall of said building and provide access thereto through the inverted V-shaped opening formed thereby.

10. The building structure as defined in claim 8 wherein said opposite ends of said cables are operatively secured to the free ends of the adjacent legs of two of adjacent inverted V-shaped support members.

11. The building structure as defined in claim 7 including cable means operatively connected between the edge of said membrane and the legs of each of said inverted V-shaped support members for transferring stress in the membrane to the support members.

12. The building structure as defined in claim 11 wherein said cable means are secured to said support members only at the apex and ends of the legs thereof whereby the stress transferred to said support members stress said support members in compression only.

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