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Johnson

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[54] **METHOD OF THREADING A CABLE THROUGH PANEL AND TUBE SECTIONS TO MAKE A FOLDING STRUCTURE**

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[52] **U.S. Cl.** ..... **29/433,** 46/29, 52/758 H

[51] **Int. Cl.** **B23p 19/04**

[58] **Field of Search** ..... 29/433; 46/29; 52/758 H

[56] **References Cited**

UNITED STATES PATENTS

1,347,808	7/1920	Franklin	46/29 X
1,851,159	3/1932	Dodge	46/29 UX
1,973,536	9/1934	Mack	46/29
2,343,827	3/1944	Beckwith et al.	29/433 UX
3,498,654	3/1970	Diaz et al.	52/758 H
3,546,773	12/1970	Gerstin	29/433

FOREIGN PATENTS OR APPLICATIONS

512,969	8/1952	Belgium	52/758 H

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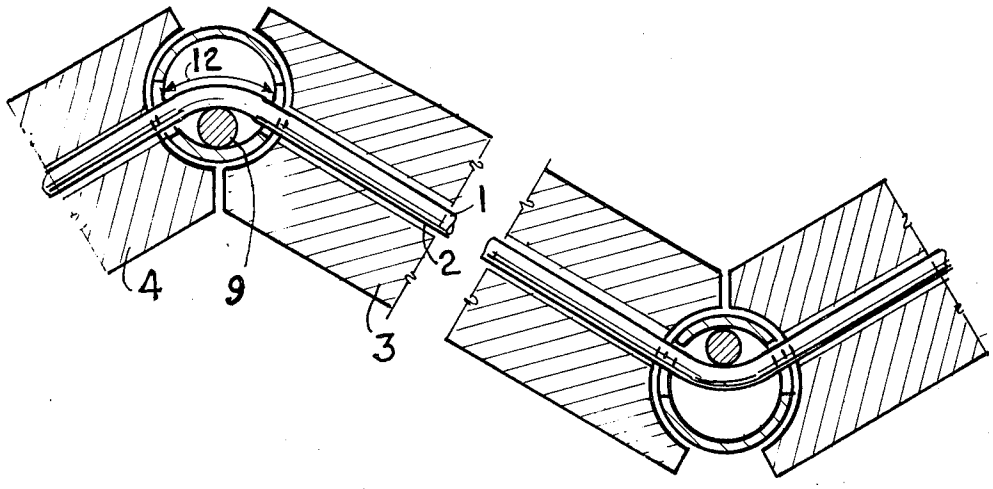
Assistant Examiner—D. C. Reiley, III

[57] **ABSTRACT**

A method of constructing a structure whose surface can be approximated by a series of folded intersecting planes; in which a series of panels and tubes are arranged in an alternating sequence in a coplaner relationship; and which series of panels and tubes is fastened together by cables threaded continuously through the panels and holes in the tubes, and securing the ends of the cables to make taut and hold the edges of the panels tight against the tubes. The holes in the tubes are of a size and configuration to permit the panels to rotate freely around the tube and in so doing to increase the tension in the cables. The object of the invention is to provide a method of construction for folding structures wherein the folding action of panels serves to increase the tension in cables holding the structure together.

11 Claims, 9 Drawing Figures



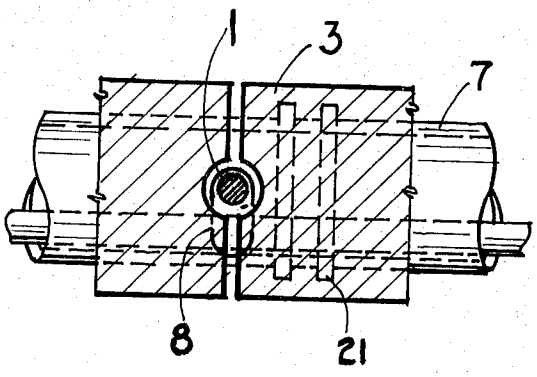


FIG. 5

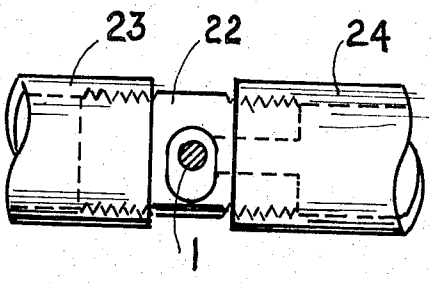


FIG. 6

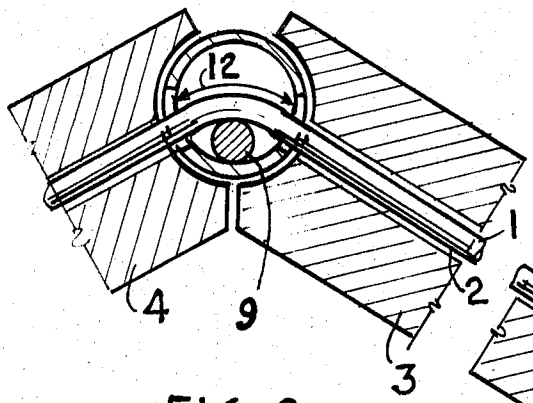


FIG. 2

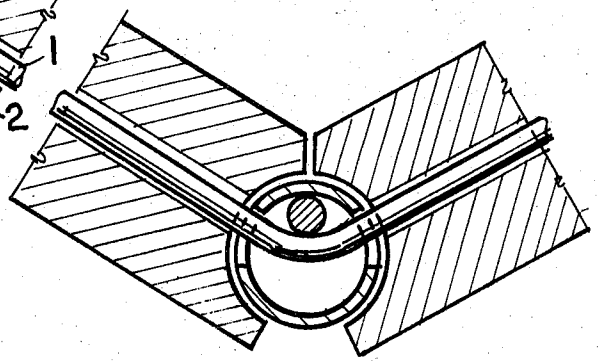


FIG. 4

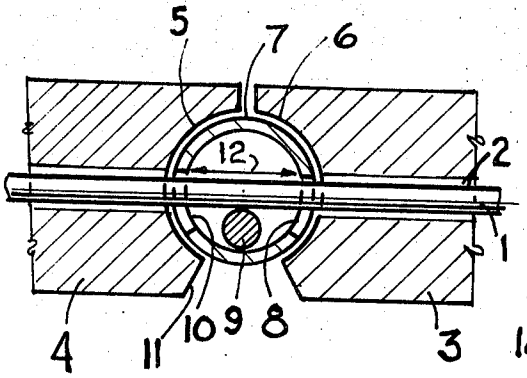


FIG. 1

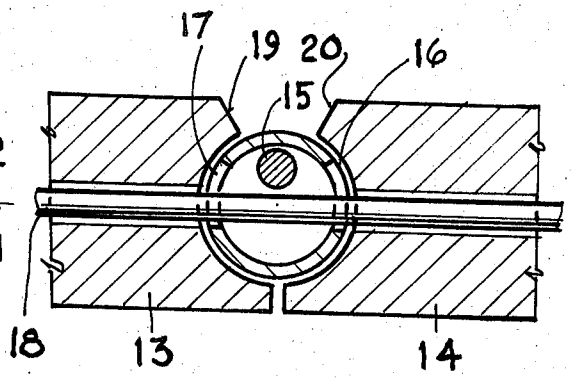


FIG. 3

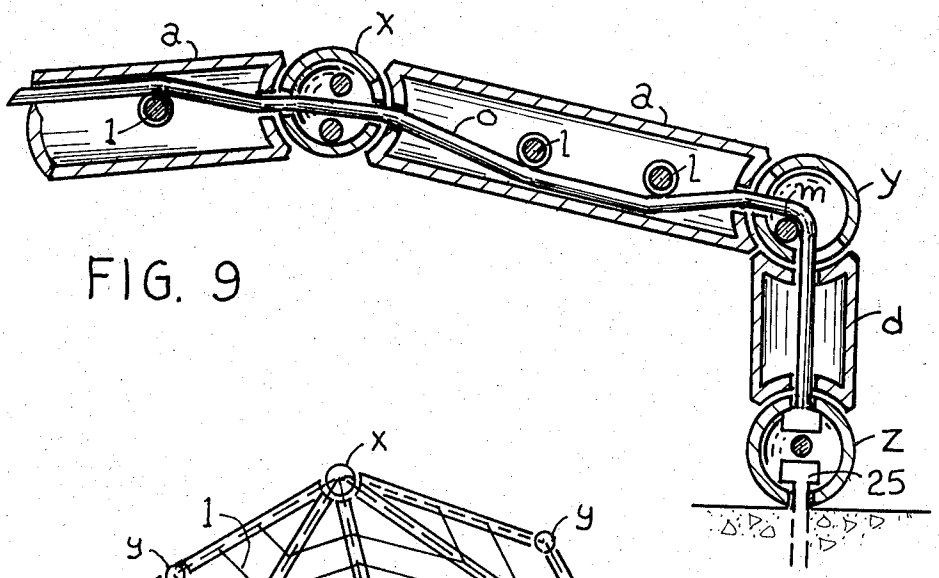


FIG. 9

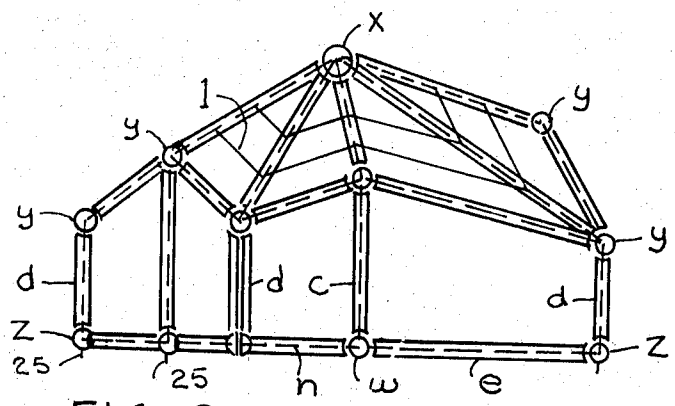


FIG. 8

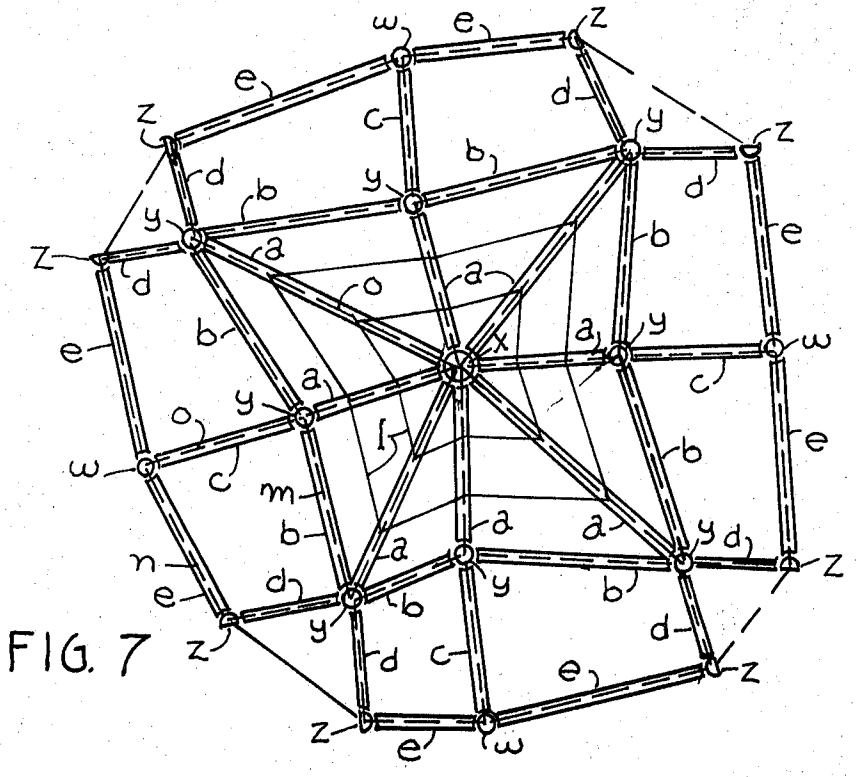


FIG. 7

METHOD OF THREADING A CABLE THROUGH PANEL AND TUBE SECTIONS TO MAKE A FOLDING STRUCTURE

DETAILED DESCRIPTION

A method of connecting panels for folding structures by use of a plurality of cables, in which each cable is threaded through adjacent panels parallel to the flat surface of the panels, the edges of which panels are shaped to a concave profile to fit neatly against a round tube placed parallel to and between the edges, and in which arrangement a cable passes through one panel, through the tube, and through the next panel, and continues tieing all panels together.

The hole in the tube through which the cable passes is slotted at right angles to the axis of the tube, so that as the panels rotate around the axis of the tube, the cable has room to move in the slot, along with the edge of the panel. The movement of the cable within the tube and in the slot is controlled by a bearing fulcrum surface inside the tube, which fulcrum supports the cable, and which fulcrum is of such shape and dimension so that the cable is placed in tension as the panel rotates.

Any number of cables spaced along the tube may be used, as required by a specific design, and the panel may be of any desired shape to suit a particular structural design. The panels may be of any desired material or combination of materials so long as the edges are shaped to conform to the tube, and provision is made for the cables.

The edges of the panels, in addition to being shaped to permit rotation around the axis of the tube, may be shaped with grooves or ridges, at right angles to the tube, or fitted with abrasive or other material so as to restrain a panel from moving along the length of the tube. This permits transfer of shearing stresses between the tube and the panel. The size of the bearing fulcrum will determine the amount of tension in the cables.

Before folding the panels, the cables are secured at the extreme ends to hold the entire assembly together. These cables may also be anchored to the foundation after folding to hold the entire folded structure in the folded position.

The tubes may be continuous the full length of panels or may be short length located at the points the cable connects panels.

It is the object of this invention to provide a means of connecting panels by means of thru cables holding the assembly together while tension is generated in the cables by the folding action of the panels, pulling the cables over the bearing fulcrum, and in which condition the tension in the cables holds the panels so tight against the tube so that no other connections are required between the panels to transfer structural loads between them to fulfill their structural requirements for the erected structure. This same tension can draw the joints together to permit a weathertight joint.

In complex folded structures, the joint between ends of tubes at intersecting fold lines may be formed by a hollow sphere in which the ends of the tubes are shaped to fit against the surface of the sphere, slotted holes are provided in the sphere in line with the center of each tube meeting at the intersection, so that a cable threaded lengthwise through a tube passes through the sphere and into the next in line tube. Inside the sphere, a bearing fulcrum is placed to support this cable, and the dimensions and shape of this bearing fulcrum is such as to cause a tension to develop in this cable during the folding action.

A series of cables threaded lengthwise within the tubes may be utilized to tie the entire structure together, utilizing the sphere as crossover points for the cables, where more than two tubes intersect a sphere.

It is a further object of this invention to utilize the force of gravity to both fold and tension the structure. This is done by means of lifting certain parts of the structure and letting gravity cause other parts to fold down and rotate the panels around the tubes on fold lines and so cause the cables to become tensioned. These cables are then anchored to a support and the entire structure has become tensioned tightly together.

It is a further object of this invention to make possible the prefabrication of buildings utilizing standardized panel sizes with a common edge profile standard for all panels and in which structure the panels are held tightly in compression between tubes by the post tensioning effect of the cables.

It is a further object of this invention to permit construction of folded structures by a means of assembling the individual panels flat on the ground in such a manner that the lifting action will cause them to fold to the intended configuration, and thereby into stable three dimensional structures with the desired amount of tension induced by the folding action.

GENERAL DESCRIPTION OF DRAWINGS

FIG. 1 shows a section of connection in the flat position with cable taut.

FIG. 2 shows the same connection with the adjacent panels folded down.

FIG. 3 shows a section of the connection in the flat position with cable taut.

FIG. 4 shows the same connection with the adjacent panels folded up.

FIG. 5 shows a side elevation of the connection in FIG. 1 with the cable and the slotted hole.

FIG. 6 shows a connection formed by a slotted plug inserted into the tube end.

FIG. 7 shows an assembly in the flat of tubes and spheres to form a framework for a structure.

FIG. 8 shows the same assembly folded into a stable structure.

FIG. 9 shows a section of series of tubes with spherical joints located between the tubes and connected by cables threaded within the tubes.

DETAILED DESCRIPTION OF DRAWINGS

FIG. 1 shows cable **1** threaded through hole **2** in panel **3** and panel **4**. The edges **5** and **6** are shaped to fit against tube **7**. The cable **1** passes from panel **3** through the slotted hole **8** in one side of the tube over the bearing fulcrum surface **9** and through the other slotted hole **10** and then through the other panel **4**. The edges of the panels **3** and **4** are shaped with a bevel **11** to permit the panels to rotate.

FIG. 2 shows the same panels **3** and **4** rotated around the tube. Cable **1** is pulled tightly over the bearing fulcrum **9**. The actual shape of the bearing fulcrum **9** may vary but must be of such dimension that the length **12** of cable **1** inside the tube remains the same or is made

slightly longer by the folding action, pulling the cable **1** into tension in each of the panels.

FIG. **3** is shown with the bearing fulcrum located above the cable **18,** with the slotted holes **16** and **17** shown in position to permit the cable **18** to move along with the edges of the panels as shown in FIG. **4.** The bevels **19** and **20** are shown to permit rotation of the panels.

FIG. **5** shows the side elevation of the connection shown in FIG. **1.** The bearing fulcrum **9** is shown as a cable, but it should be noted that this bearing fulcrum can be of any design as long as the dimensions and shape fulfill the requirements of permitting the cable to rotate while maintaining or increasing the tension of the cable. In the preferred embodiment, the bearing fulcrum **9** would be a cable linking the tubes together lengthwise. Element **21** illustrates a ring formation on the surface of tube **7** to restrict the longitudinal movement of panel **3** along the length of tube **7,** a requirement for transfer of shear stresses. The rings **21** are illustrative only of one form of contour for the corrugations of the tube, and may be incorporated in whatever number and profile to accomplish the objective of permitting rotation while restraining longitudinal movement of the panels.

FIG. **6** shows an alternate method of forming the slotted connection, by use of a plug **22.** Here, plug **22** is also used as a splicing connection between tube **23** and tube **24.**

FIG. **7** shows a series of tubes *a* arranged radially around a sphere *x*. These tubes at their outer extremities fit against spheres *y* which are separated by tubes *x*. Additional tubes *c* and *d* are arranged outside spheres *y* and terminated against spheres *w* and *z*. A series of cables **1** are arranged concentrically around sphere *x*, passing through slotted holes in tubes *a*, in a manner similar to cable **1** in FIG. **1** and cable **18** in FIG. **3.**

Additional cables *m* are threaded through tubes *b*, and another cable *n* is threaded around the entire outside perimeter, through tube *e* and spheres *w* and *z*.

Additional cables *o* are threaded through tubes *a* and *d*, and *a* and *c*, with each cable continuous across the structure, and these cables crossing over in sphere *x*.

It is now evident that the entire structure is strung together similar in arrangement to a spider web.

Now, when the structure is caused to fold to the shape shown in FIG. **8,** all the cables except *n* are drawn into tension by the folding action, and when the cables *o* are anchored to the foundation, the structure is rigid and stable and the entire structure is under tension.

During the folding action, the cable *n* must be shortened enough to cause tubes *d* to rotate around spheres *y* so as to close the corners of the structure.

The object of the invention is to connect together the entire framework with cables so arranged that the folding action tensions the entire structure with the tube and spheres being in compression, and further, by selection of various lengths of the tubes, to predetermine the desired configuration of the folded structure.

The number, dimension and arrangement of the tubes is not limited, and in general, any structure whose surface may be approximated by a series of folded intersecting planes, may be constructed by this method. It may be assembled in the flat, and then lifted and folded into a totally integrated structure with tubes in compression and the cables in tension.

FIG. **7** shows the arrangement of the tube, with panels not shown, but it is intended that some or all of the areas between tubes *a* and *b*, between tubes *b*, *c*, *d* and *e*, would be filled in with panels. Those not filled in could be windows or other desired openings.

FIG. **8** shows one method by anchor **25** of holding the structure to its foundations. This may be accomplished by many different methods. It should be noted that the relative length of tubes *c* and *d* cause the edge of the roof section to assume the different profiles, so that by proper selection of their lengths, the desired profile can be achieved.

It should be noted that tube *d* and spheres *z* are shown as full tubes and spheres and appear in the drawing to overlap. In actual construction, the tube *d* and sphere *z* would be modified to half tubes and hemispheres to permit a proper closing during the folding action.

FIG. **9** illustrates a typical longitudinal section through sphere *x*, tubes *a*, sphere *y*, tube *d* and sphere *z*. A similar section would occur through sphere *x*, tube *a*, sphere *y*, tube *c* and sphere *w*. Cables *o* are threaded within the tube *a* forming the bearing fulcrum for cables **1.** The cable *o* is shown terminating in sphere *z*. The cable *m* serves as a bearing fulcrum for cable *o*. It should be understood that the actual size of the various cables at the bearing fulcrum point may be increased with sleeves or collars or bushings as required to provide the desired tension, and the cable size selected is determined by the stress design in the total engineering of the structure.

FIG. **9** shows a location **25** for one type of anchor.

Referring to FIG. **1** again, it should be understood that the space between the edge of panel **6** and the tube **7** may be sealed with a gasket compressed by the folding action, or may be made otherwise irregular in section to provide the desired closure.

I claim:

1. A method of constructing a structure whose surface can be approximated by a series of folded intersecting planes, said method comprising: positioning in a coplaner manner an alternating series of panels and tube sections, each of said panels having at least one longitudinally extending opening therein, each of said tube sections having a pair of aligned holes in the tubular wall thereof, threading at least one cable through the openings and the holes, and fastening the ends of said cable whereby the cable is made taut and the panels are free to rotate around the tubes, said holes being of such size and configuration that rotating the panels around the tubes during folding of the assembled structure serves to increase the tension in the cable.

2. A method according to claim **1** where the configuration of the holes through the tube is determined by a cable threaded lengthwise within the tube.

3. A method according to claim **1** where the configuration of the hole through the tubes maintains a constant degree of tension in the cable during all positions of rotation so that the form of the structure can be changed by changing the plan of the structure, without affecting the tension in the cable.

4. A method according to claim **1** where the configuration of the hole can be modified to increase the degree of tension developed in the cable, in proportion to the degree of rotation of the panels.

5. A method according to claim 1 where the path of the cable within the panel follows the tensile line of stress within the panel so that the cable serves to act as reinforcing for the panel, in addition to holding the assembly together.

6. A method according to claim 1 wherein compressive action between adjoining tubes and panels caused by the tension in the cable serves to make weather-tight the joints between adjoining tubes and panels.

7. A method according to claim 2 wherein each end of the cable is anchored to a foundation in order to fix the shape of the assembled structure.

8. A method according to claim 2 where the tubes are coated with a bond breaker, and the space between the tubes is filled with concrete or other plastic material while the tubes are in the flat, to form concrete panels.

9. A method according to claim 2 where the configuration of the holes increases the tension in the cable in proportion to the rotation of the tubes.

10. A method according to claim 2 wherein surfaces of the tubes are corrugated to permit each of the panels to rotate around adjoining tubes while restricting movement of each panel along the length of the adjoining tubes.

11. A method of constructing a folding structure, said method comprising: positioning in a coplaner manner an alternating series of tube sections and hollow spheres, each of said spheres being positioned between ends of adjacent tubes, and having a pair of aligned holes therein, threading at least one cable through the tubes and the holes in the spheres, and fastening each end of the cable whereby the cable is made taut and the tubes are free to rotate around the spheres, said holes being of such size and configuration that rotating the tubes around the spheres during the folding of the assembled structure serves to increase the tension in the cable.

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