ABSTRACT
A large air supported structure of generally spherical or spherical-sectioned configuration for use as a stadium cover or the like comprising a cabling system in the form of lattice work of cables attached at their points of intersection by joining devices, so as to form interstices of triangular shaped configuration, and an air inflatable envelope having elements thereof closing the cable interstices and formed with a double curvature configuration having radii of curvature substantially smaller than the radius of curvature of said structure.

In the preferred embodiment, the cabling system includes three groups of continuous cables arranged such that the centermost cables of the groups intersect adjacent the crown of the spherical structure at approximately 60° angles and the groups of cables cooperate to define interstices approximating equalateral triangles. Also, the envelope elements are preferably in the form of individual panels removably joined about their marginal edges to the cables defining the interstices. Sealing devices are arranged so as to provide an air seal between adjacent envelope panels outwardly of the cabling system, such that panels are removable outwardly of the structure, while the cabling system is fully enclosed but accessible internally of the structure.

An inflatable work access shelter is removably attachable to the outer surface of the structure by anchoring devices carried by the cabling joining devices, so as to permit replacement or repair of individual panels from a point exteriorly of the structure without loss of inflation air therefrom.

20 Claims, 23 Drawing Figures
LARGE AIR SUPPORTED STRUCTURES
CROSS REFERENCE TO RELATED APPLICATION
This application is a continuation of application Ser. No. 862,245, filed Sept. 30, 1969.

BACKGROUND OF THE INVENTION
The stresses developed in an air-supported structure, as a result of the pressure differential that must be maintained within the structure in order to pretension and stabilize it sufficiently to resist wind and snow loads, are directly proportional to the diameter or size of the structure. In the case of a spherically shaped envelope structure, the stresses are distributed in an essentially uniform manner throughout the envelope. However, superimposed wind or snow loads result in a widely varying pressure differential across the envelope.

When a spherical envelope is fabricated with a conventional gore-shaped pattern, which results in tension fibers running in essentially radial and circumferential directions, the varying pressure differential and resulting distortion and redistribution of stress can cause severe stress concentrations. Distortion and stress concentrations can be controlled by using a bias plied material, which introduces load carrying fibers at an angle to the normal direction of the material-normally 45° for convenience in manufacture, to obtain isotropic characteristics in the envelope. This method of fabrication results in a much more dimensionally stable construction, making it practical to build large air-supported structures, such as the 210 ft. diameter Telstar radome developed by this inventor to cover the first satellite communications stations. However, as the fabric stresses are proportional to the radius of curvature of the envelope, exceedingly high stresses are developed in the larger domes, necessitating the use of very costly materials and construction methods and, accordingly, limiting the economic feasibility of this type of construction for large dome stadiums or similar structures.

In order to limit the stresses in the envelope and permit the use of lower cost materials, various types of strap, rope or cable reinforcing has been used. Reinforcement duplicating the 45° bias patterning development for radomes would be structurally acceptable but is not economically feasible. Because of the difficulty of developing a cabling system which would conform to a spherical contour, attempts at reinforcing spherical envelopes or the spherical end sections of generally symmetrical air structures have been largely limited to the use of radial cables joined at the crown. However, because of the varying width of envelope surface area acting on the cables, as the cables progress toward the crown, this arrangement results in a varying normal load on the cables and consequently severe distortion in the plane of the cables, i.e., the structure tends to flatten out at the top and bulge at the sides in an effort to equalize the loads along the cables. Unless the envelope is specially patterned, which is difficult to do, there is little reduction of stress in major sections of the envelope and the cabling thus fails to accomplish the desired reduction in stress levels. The flat top is also undesirable as it tends to trap snow causing additional distortion.

Of even greater concern, particularly for large structures for which the air structure offers the potential of greatest economic advantage is that the radial patterning, even with additional intermediary cables fails to provide the resistance to distortion and movement needed to achieve the stable configuration required if air structures are to be used to enclose large areas, such as stadiums. Conventional radial cabling systems also fail to provide controlled distribution of stress levels and thus do not appreciably reduce vulnerability to damage, or the propagation of any cuts or tears which can result in complete collapse of an air structure.

These deficiencies in the design of air structures have severely limited their application for use on large dome structures for which they potentially offer the greatest economic advantage.

SUMMARY
The present invention has been conceived and developed to overcome the deficiencies inherent to air-supported structures currently in use and is directed to large, air supported structures for use in forming a permanent covering for a large area, such as a stadium or athletic field having a diameter or width measured in hundreds of feet.

In the preferred embodiment of the present invention, there is provided a novel cabling system for a dome structure formed of a plurality of cables arranged in an intersecting relationship so as to define a pattern consisting of three groups of essentially parallel cables, wherein centermost cables of each group intersect at approximately 60° angles at or near the crown of the structure. Joining devices are provided for fixedly interconnecting the cables at their points of intersection, such that the cables of the three groups cooperate to define on the surface of the structure intersectics approximating equalateral triangles.

In the simplest form of the dome structure, an envelope, which when inflated supports the full weight of the structure together with the aerodynamic and snow loads imposed thereon, would be of unitary construction and disposed inwardly of the cabling system such that elements thereof protrude outwardly through the cable intersectics. Preferably, the elements are formed with a double curvature configuration having a radii of curvature substantially smaller than the radius of curvature of the overall structure so as to result in low fabric stresses. Also, by forming the panel elements in this manner there is obtained improved acoustical characteristics over that inherent in domes having smooth or relatively uniform surfaces.

The utilization of a lattice work or matrix formed from triangular cable intersectics allows for maximum structural stability of the dome structure under non-uniform wind or snow loading and also permits the utilization of continuous cables which may be end anchored directly to the domed structure base or support. A continuous cable arrangement simplifies fabrication and erection procedures and requires that heavy machine fittings be employed only at the ends of the cables where they are attached to the support. Simple, clamp-type joining devices may be employed to join the cables at their points of intersection since maximum load transfer occurs between cables of the respective groups due to the fact that the cables are arranged on approximately uniform continuous arcs with a minimum variation or deviation at the cable intersections.

The above described cabling system may also be employed in reinforcing an air supported ellipsoidal
shaped structure or one including a central generally cylindrical section and a pair of spherically shaped end sections attached thereto. In this instance, one group of cables would be oriented such that its central cables would lie within a plane which vertically bisects each of the sections and the cables of the other groups would extend along arcs arranged diagonally of the axis of the cylindrical section. The triangular interstice pattern is continued on the cylindrical section of the structure by connecting the cables of the other groups to the central cable of the one group at common points spaced substantially equally apart in a direction lengthwise of the cylindrical section in the same fashion as such cables are connected on the spherical end sections of the structure.

In a specific embodiment of the present invention, the air inflated envelope is formed from individual panels, which conform substantially to the interstices of the lattice work defined by the cables, and are removably joined about their marginal edges to the cables system. In this arrangement, the spacing between marginal edges of adjacent panels is fluid sealed by sealing devices which are preferably accessible exteriorly of the structure. The envelope panels, when employed within a lattice work or matrix of the type described above, are approximately equal in size such as to permit the development of essentially uniform cable loadings under normal envelope inflation pressures. Since these individual triangular envelope panels under normal inflation pressure provide for the transfer of essentially uniform loadings to or tensioning of their bounding cables, the cables of the cabling system of the present invention are subjected to relatively uniform loadings or tensioning conditions throughout their lengths, thereby minimizing distortion of the cables within their respective planes. This is to be contrasted with above mentioned conventional structures having radially extending cables joined at the crown of the structure wherein envelope inflation pressure produces non-uniform loading or tensioning conditions along the lengths of the cables, and thereby results in distortions of the cables within their respective planes and accompanying undesired flattening and bulging of the surface of the structure. Also, the cabling arrangement results in a series of duplications of identically sized interstices with the result that manufacture and installation of the panels is facilitated.

By providing removable envelope panels, the overall vulnerability of the structure to damages substantially decreased since damage to any given panel will not be propagated into adjacent panels. Furthermore, even though panels having edge dimensions of 50 or more feet may be used in structures having diameters on the order of 600 feet which are required to cover large stadiums or athletic fields, such panels would be sufficiently small with respect to the overall surface area of the structure. With the low, controlled stress levels maintained, the air losses through any openings likely to develop would be small and the structure would remain erect even with one or more panels severely damaged, thus making the air structure suitable for use as a permanent roof on large structures.

Further, in accordance with the present invention, suspension devices may be affixed to the cable joining devices so as to permit suspension of an acoustical and/or thermal liner or equipment, such as lighting fixtures from the roof of the domed structure with a minimum of distortion.

A particularly important feature of the present invention is the provision of an inflatable work access shelter, which is adapted to be mounted on the exterior surface of the structure and be removably attachable thereto by anchoring devices carried by the cabling system; the work access shelter when inflated affords a weather proof shelter for workmen and permits repair or removal of individual panels forming the envelope without escape of envelope supporting air. Furthermore, use of the shelter permits equalization of pressure across the panel over which it is positioned in order to relieve the tension on the panel and facilitate its repair or replacement.

In accordance with an alternative embodiment of the present invention, the cabling system is defined by main or central load carrying cables arranged so as to divide a domed structure when viewed in plan into 45° segments. A secondary cabling system is formed such that in each segment a first and second set of cables run essentially parallel to the two main cables bounding the segment and a third set of essentially parallel cables extend between the two main cables from the points of intersection thereof with the cables of the first and second sets. By connecting the cables of the secondary system to each other and to the main cables at their points of intersection, there is provided essentially uniform triangular interstices. However, with this cabling system, except on smaller structures, angular variation or deflection of the cables of the secondary system at their points of intersection with the main cables, prevents effective use of cables which are continuous through adjacent segments. As a result, relatively costly machine fittings must be employed to join the ends of cables of the secondary system to the main cables in place of relatively inexpensive clamps, which serve to connect the cables of the secondary system to each other.

DRAWINGS

The air supported structure according to the present invention will now be described in detail, making particular reference to the accompanying drawings wherein:

FIG. 1 is an enlarged perspective view of a large air supported structure formed in accordance with the present invention;

FIG. 2 is a perspective view similar to FIG. 1, but viewed from a different angle;

FIG. 3 is a side elevational view of the structure shown in FIG. 2 and illustrating the relative disposition of cables of one group forming the cabling system;

FIG. 4 is a side elevational view illustrating the large domed structure of the present invention installed as a permanent covering over an athletic stadium or the like;

FIG. 5 is a top plan view of the structure shown in FIG. 4;

FIG. 6 is an enlarged fragmentary view within the area designated as 6 in FIG. 4, with portions broken away for clarity;

FIG. 7 is an enlarged fragmentary view of the area designated as 7 in FIG. 6;

FIG. 8 is a sectional view taken generally along the line 8-8 in FIG. 7;

FIG. 9-9b are sectional views taken generally along the line 9-9 in FIG. 6 and showing various devices sus-
ceptible for use in attaching envelope panels to the ca-
blng system;
FIG. 10 is a perspective view of a clip device adapted
to connect the envelope panels to the cable joining de-
vice;
FIG. 11 is a perspective view illustrating an inflated
work access structure anchored to the exterior of the
domed structure;
FIG. 12 is a sectional view taken generally along the
line 12—12 in FIG. 11;
FIGS. 13 and 13a are fragmentary views illustrating
various arrangements, which may be employed to de-
tachably anchor the inflated work access structure to
the cable joining devices;
FIG. 14 is a fragmentary plan view illustrating an al-
ternative envelope panel configuration adapted to be
employed with a cabling system of the type illustrated
in FIG. 4;
FIG. 15 is a top plan view illustrating an alternative
cabling system;
FIG. 16 is an enlarged view of the area designated as
16 in FIG. 15;
FIG. 17 is an end elevational view of the joining de-
vice shown in FIG. 16;
FIG. 18 is a top plan view showing the utilization of
the cabling system of the present invention in forming
an air supported structure of the type having a cylindri-
cal section and a pair of spherically shaped end sec-
tions;
FIG. 19 is a side elevational view of the structure
shown in FIG. 18; and
FIG. 20 is a view showing a modified form of the
dome structure shown in FIGS. 1—3.

DETAILED DESCRIPTION

Now referring particularly to FIGS. 1, 2 and 3, it will
be understood that the large, air supported structure
according to the present invention, which is generally
designated as 1, is in the form of a spherically shaped
dome adapted to provide a permanent cover for a sta-
dium or athletic field, not shown, having a diameter or
width measured in hundreds of feet. The structure may
be provided, if desired, with a relatively large access
opening in the form of an air lock 2 for vehicles or the
like and relatively smaller personnel access openings 3,
which are air sealable by conventional means, such as
rotolving doors.
Structure 1 generally includes an air inflated enve-
lope 4, suitably sealed relative to the ground or struc-
ture support, and a cabling system 5, the envelope
when inflated being adapted to support the full weight
of the structure, together with the aerodynamic and
snow loads imposed thereon, and the cabling system
being adapted to both transmit loading from the enve-
lope into the ground or other structure support or base
and maintain the envelope in a desired configuration.
Envelope 4, when inflated may be considered as bal-
looning upwardly over the base support, whereby to
support cabling system 5 in an upwardly arched and
loaded or tensioned condition, as will be apparent from
viewing for instance FIGS. 1 through 4.

In accordance with the preferred embodiment of the
present invention, cabling system 5 is formed from a
plurality of cables arranged in an intersecting relation-
ship, so as to define a pattern, lattice work or matrix
consisting of three groups of essentially parallel cables
6, 7 and 8, attached together at their points of intersec-
tion by cable joining devices 9, which will be more fully
hereinafter described. As will be best seen by viewing
FIGS. 2 and 3 in the case of cable group 6, the cables
within the three groups include a central-most, center
or main cable 6a, which lies along a great circle arc
within a great circle plane 6a' passing through the
crown of structure 1, and secondary cables 6b, which
lie along non-great circle arcs substantially within sec-
ondary planes 6b'. Planes 6b' are arranged at an acute
angle with respect to great circle plane 6a' and inter-
secting therewith along substantially a common line,
not shown, spaced vertically below the center of curva-
ture R of structure 1. The central cables 6a—8a
intersect at the crown of structure 1 at approximately
60° angles so as to divide the surface of structure 1 into
six equal segments. The secondary cables, for example
7b and 8b, intersect with the central cable of the other
group, for example cable 6a, at common points spaced
substantially equally apart in a direction lengthwise
thereof. As a result, the cables of groups 6—8s cooper-
ate to define a lattice work or matrix of interstices 10,
which approximate equalateral triangles, which are
uniformly distributed over the surface of the structure.
It will be understood that although the interstices 10 vary
slightly in size in a direction outwardly away from the
crown of the structure, there are however, a series of
duplications of identically sized interstices and the
whole of such interstices may be considered as being
of relatively uniform size.

The cabling system, as thus far described, is a partic-
ularly important feature of the present invention, since
it allows the cables of groups 6—8s to extend continu-
ously across the surface structure 1 and be anchored at
their respective ends to the ground or other structure
base or support, not shown. Otherwise, expensive and
relatively heavy machine fittings, of the type conven-
tionally provided to ground anchor the ends of the re-
spective cables, would have to be provided at each
cable intersection with the result that the overall cost
and difficulty of erecting the structure would be sub-
stantially increased.

In its simplest form, envelope 4 is of unitary construc-
tion and disposed inwardly of the cabling system such
that generally triangularly shaped elements of the enve-
lope protrude outwardly through cable interstices 10.
As best shown in FIG. 1, the envelope elements are
preferably formed with a double curvature configura-
tion, whose radii of curvature is substantially smaller
than the radius of curvature of structure 1. By forming
the envelope elements in this manner lower fabric
stresses are encountered, than would be the case if the
envelope elements were to conform to a smooth spheri-
cal contour. An envelope suitable for use in this ar-
grangement, particularly when used on relatively small
domes, would be of material of limited stretchability,
which would be shaped by inflation pressures to deform
or balloon outwardly through the cable interstices. Al-
ternatively, the individual envelope elements could be
fabricated from a plurality of contoured panel elements
edge joined to each other to permit the element to ac-
quire its desired curvature configuration upon inflation
of the envelope. In these arrangements, the envelope
would preferably be fixably attached to the cabling sys-
tem, so as to assure transfer of envelope loads into the
cables and to prevent propagation of rips and tears
from one panel element to another.
In FIG. 4, structure 1 is shown as being modified by positioning cabling system 5 inwardly of envelope 4 and as being installed as a permanent covering over a circular or bowl shaped stadium 21 having tiers of seats 22 and any desired number of suitable access openings, not shown. A suitable anchoring arrangement for structure 1 may be provided by a ring of girders or truss member 23, positioned peripherally of stadium 21 above the uppermost tier of seats. While in this instance, the ring of girders or trusses 23 would preferably form the base or support of structure 1, cables of groups 6–8 could however be directly anchored to the ground. A suitable cover device 24 would be provided to form a suitable weather and air seal interconnecting structure 1 to stadium 21.

Cable joining devices 9 are best shown in FIGS. 7 and 8 as including top and bottom cable clamping plates or discs 37 and 38, respectively, and a pair of identically configured intermediate cable clamping plates or discs 39. Plates 37, 38 are each provided on one surface thereof with transversely extending generally semi-circular cable receiving recesses or grooves 41, 42, centrally disposed threaded openings 43, 44 and annularly arranged equally spaced through bore openings 45, 46, respectively. Intermediate plates 39 are each provided with a pair of transversely extending semi-circular cable receiving recesses or grooves 47a, 47b, which are disposed on opposite sides of such plates in substantially a 60° offset relationship, and six annularly arranged equally spaced through bore openings 49. When plates 37–39 are arranged in the manner shown in FIG. 8, such that grooves 41, 47a are aligned to receive cables 6, grooves 47b, 47a of adjacent intermediate plates are aligned to receive cable 7, and grooves 47b, 42 are aligned to receive cable 6 and plate bore openings 45, 46 and 49 are aligned for receipt of clamping bolts 51. Preferably, the grooves are patterned to accommodate for slight angular variations in alignment between intersecting cables, so as to permit a single clamping device configuration to be employed for joining cables at all points of intersection thereof throughout the cabling system.

Bolts 51 are threadable into nuts 52 for the purpose of clamping plates 37–39 together, such that cables 6–8 are in turn attached together at their point of intersection so as to provide an angular spacing between adjacent cables of substantially 60°. Preferably, nuts 52 are welded or otherwise affixed to the lower surface of bottom plate 38 in alignment with openings 46, so as to permit bolts 51 to be threadably secured in clamping position without need for gaining access to the interior of the domed structure. Alternately, nuts 52 may be dispensed with and bottom plate opening 46 threaded to receive bolts 51. As a further alternative, fully threaded rods may be substituted for bolts, so that pairs of nuts can be used to securely clamp cables between mating pairs of plates.

Threadably received within top and bottom plate openings 43, 44 are eye shaped anchoring and suspending bolts 53, 54, respectively, whose purpose will hereinafter be more fully described.

Now referring particularly to FIG. 6, it will be understood that in the preferred embodiment of the present invention envelope 4 is formed by a plurality of triangular panels 60, which are dimensioned so as to substantially conform with the interstices 10 defined by groups of cables 6–8 and attached to their respective bounding cables to provide for transfer of envelope loads into such cables. Since, as mentioned above, interstices 10 are formed in a series of duplicate sizes, only a limited number of differently sized panels need be employed. Furthermore, in structures of the type shown in FIGS. 1 and 4, wherein only a relatively small portion of a spherical surface is used in forming the dome, interstices 10 are of substantially equal size, thereby permitting a single sized panel to be effectively used within the interstices without encountering substantial variations of stress levels within the several panels. Also, in structures of this type, inflation pressures on the envelope panels or elements tends to produce relatively uniform loading of the several cables throughout their lengths in order to minimize distortion of the surface of the structure from its essentially spherical configuration.

Preferably, as mentioned above in connection with the unitary envelope construction, panels 60 are fabricated to provide a double curvature configuration when inflated, which has substantially smaller radii of curvature than the radius of curvature of the dome. This permits a reduction in the maximum stress in the envelope material, since the smaller the radius, the lower the load. Patterning of the envelope panels in this manner results in a flatwise pattern size, which is substantially greater than the size of the interstices formed by the cables.

For purposes of illustration, panels 60 are shown as being provided with reinforcing means, such as rope or cable edging 61, which is continuous along the marginal edges of the panels. Rope edging 61 facilitates attachment of the panels to the cabling system, while minimizing stress concentrations at the points of panel attachment.

Representative of devices having utility in attaching panels 60 to the cabling system are those designated as 65–65b in FIGS. 9–9b, respectively. Attaching device 65 is in the form of a rope or cable 67, which is laced through apertures 68 of adjacent panels, such that intermediate portions of the rope are looped about the supporting cable. Apertures 68 are positioned adjacent rope edging 61 and arranged in an equally spaced relationship lengthwise of the marginal edges of the panels. The ends of rope 67 may be suitably tied or clamped together in any suitable manner, not shown, after the facing operation has been completed. This arrangement permits a considerable degree of adjustability of the panel and when desired permits panels of slightly differing size to be used in the same interstice in order to further reduce the number of panel sizes necessary for forming a given dome structure.

In FIG. 9a, attaching device 65a is shown as being in the form of a generally U-shaped clip 69, which is formed to provide an enlarged base portion 70 adapted to clamp over cable 6 and end socket portion 71 adapted to releasably receive rope edging 61. Rope edging 61 may be clamping secured within socket 71 by tightening a bolt 72, which is adapted to be threadably received within nut 73. Preferably, nut 73 is welded or otherwise affixed to the clip so as to permit the rope edging to be clamped or released from a position exteriorly of the structure. It will be understood that clamping devices 65a, which are employed to secure adjacent panels to cable 6, are staggered lengthwise of the cable between adjacent joining devices 9 and are made in a width and provided in sufficient number so as to insure
that the transfer of load from the panels to the cable is substantially uniform along the facing marginal edges of the adjacent panels.

In FIG. 9b, attaching device 65b is shown as being in the form of wire clips 75, which are bent around cable 6 and have their respective ends passed through apertures 68 and thereafter deformed as at 76a, 76b. As in the case of attaching devices 65a, devices 65b are staggered along cable 6 between joining devices 9.

Referring particularly to FIGS. 7 and 8, it will be understood that, in order to insure against movement of the marginal edges of panels 60 lengthwise of their adjoining cables, to position the panels properly within the cable interstices and to maintain tension on the rope edging 61 in order to obtain uniform distribution of load in the panel, the apexes of the panels are connected to cable joining devices 9. The preferred mode of attaching the panel apaxes to cable joining devices 9 is to employ generally U-shaped clip devices 80 of the type shown in FIG. 10 having aligned through bore openings 81 adapted to freely receive clamping bolts 51. Referring particularly to FIGS. 8 and 10, it will be understood that a panel apex may be attached to a cable clamping device 9 by first positioning rope edging 61 within the base of clip device 80 and thereafter employing clamping bolt 51 to secure the clip device either in a straddled relationship to one of the stacked plates or between adjacent plates forming cable joining device 9 in a position located centrally of adjacent cables. It will be understood that by providing each of the cable clamping devices with a plurality of clamping bolts 51, one or more may be temporarily removed as necessary to permit replacement of a damaged or worn panel without reducing the capability of such joining device to maintain the cables attached at their point of intersection.

While panels 60 have been described as being attached at their apexes to joining devices 9, it will be understood that this arrangement is unnecessary where cable affixed devices, not shown, are provided to clampingly engage substantially the entire edge of each panel so as to prevent stress concentrations occurring therein and constrain the panel edge from movement lengthwise of its bounding cable.

Again referring to FIGS. 6, 8 and 9b, it will be understood that installation of envelope 30 is completed by edge seal devices 90, which serves as flashing and forms a fluid seal between marginal edges of adjacent panels 60, and cap seal devices 91, which form a fluid seal about each of cable joining devices 9. Seal devices 90, which are made of a flexible material similar to that used in panels 60, are shown for purposes of illustration as consisting of edge flaps 93, which are permanently affixed to panels 60 as by stitching, adhesive or heat sealing at 94. A suitable fluid seal is completed between flaps 93 by adhesive, as indicated at 95 in FIG. 9, or by mechanical devices, such as clip device 96, shown only in FIG. 9a.

Cap seal devices 91 are shown as being in the form of flexible coated fabric discs, which are preferably cut from the fabric from which panels 60 are formed, and centrally apertured as at 97 to receive anchoring bolt 53. Cap seal devices 91 are sealably joined, as by adhesive, peripherally thereof to seal devices 90 on panels 60 to complete sealing of the envelope.

Panels 60', which peripherally bound the envelope, may be affixed and sealed with respect to sealing device 25 by any conventional clamping device, not shown.

The structure shown in FIG. 4 may be assembled by first installing pre-stretched cables between appropriate anchor points on the ring of girders or truss members 23, in such a manner as to allow the cables to drape downwardly into the stadium. The attaching devices would then be installed at each cable intersection at positions or points previously marked on the respective cables. Alternatively, where space permits, the cable system could be assembled by laying the groups of cables on the ground and thereafter connecting same together prior to raising the cable system into position for attachment on the ring of girders. Thereafter, conventional scaffolding or cranes could be employed to lift the panels and hold them in place during attachment thereof. After attachment of the panels, sealing device 90 would be joined so as to provide an essentially air tight envelope. The envelope would then be inflated and necessary adjustments be made in the cables and position of the panels to insure proper alignment of parts. It will be understood that by the utilization of pre-stretched cables, the cable system is not readily susceptible to stretching under load with the result that the cable system tends to become rigid under envelope inflation pressures. The greater the pre-load imposed on the cable system as a result of envelope inflation pressure, the less likelihood there is that the surface of the structure will deform under non-uniform loading conditions, such as produced by high wind and snow loadings. The envelope would be fully air sealed by the attachment of cable sealing device 91.

Preferably, a hoisting arrangement would be used, which consists of platforms arranged in an essentially triangular configuration and suspended from the cable clamping devices. These platforms would be arranged to support the panels as they are raised into position and clamped, and would be disposed so that they could be moved readily from one support point to another throughout the cable system.

When structure 1 is to be anchored directly to the ground or some other non-elevated base or support, as shown in FIG. 1, it may be assembled by a procedure wherein the cables are laid out on the ground, interconnected in their desired pattern, the panels attached to the cables and the various sealing devices fixed in place. Subsequently, the envelope would be inflated to elevate the cable system above the base support and air support the structure. In an instance wherein the envelope is of unitary construction, the envelope would be placed upon the ground prior to laying out the cables. The resultant structure may have diameters measured in hundreds of feet with panels having marginal edges measured in tens of feet.

Preferably, simultaneously with the attachment of panels 60, support cables or the like, not shown, would be attached to suspension bolts 54 to facilitate subsequent placement of desired equipment, such as liners, sound equipment, lighting devices, etc., which are to be suspended from the completed dome structure.

To facilitate replacement or repair of any of panels 60, there is provided a generally hemispherically shaped air inflatable work access shelter 100 employed to facilitate replacement or repair of panels 60. The work access shelter would be essentially at air supported shelter consisting of an envelope 101, which is
joined to a tie down cabling system 102 having six arcuate cable sections, whose adjacent ends are anchorable to cable joining devices by anchoring bolts 53. In the arrangement illustrated, shelter 100 is sized so as to fully cover only one of panels 60 and the alternate junctions of the cable sections are anchored to the three cable joining devices adjacent the apexes of such panel. The remaining junctions of the cable sections are connected by cables 103 to joining devices disposed intermediate the apexes of the panel. It will be understood, however, that the size and attaching arrangements of shelter may be varied, as desired.

As in conventional air inflated structures, envelope 101 may be provided with an access door 104 and be air sealed with respect to dome envelope 4 by circumferentially extending inturnd sealing flap 105.

Various cable section designs and arrangements for attaching same to anchoring bolts 53 are susceptible of use. As by way of illustrating, however, reference may be had to FIG. 13, wherein the cable sections are shown as being continuous webbing and the arrangement for attaching same to anchoring bolts 53 is shown as being a conventional hook device 106. Alternatively, as indicated in FIG. 13a, the cable sections may be formed from separate cables attached to a bolt 107.

It will be understood that when one of panels 60 must be replaced due to damage or wear, workmen would climb onto the top of the dome using suitable safety harnesses attached to cable joining devices 9. The replacement panel would be hoisted into position and placed over the panel to be replaced. Shelter 100 would then be attached in place above the defective panel by means of anchoring bolts 53. Suitable guide or emergency ropes, which may be permanently or temporarily attached to anchoring bolts 53, may be provided to facilitate movement of the workmen and materials onto the dome and prevent their falling through an open cable interstice when a panel is removed therefrom. An ancillary air blower, not shown, may be employed to initially inflate shelter 100, or in the alternative, the seal devices 90 around the defective panel would be opened to allow air from inside the dome to inflate the shelter. After anchoring and inflating shelter 100, the defective panel could be removed, while simultaneously attaching the replacement panel, without any further loss of air from the dome, and the workmen would be able to perform their duties therein fully protected from external weather conditions.

Alternatively, the defective panel may be first removed by separating its sealing flaps 93 from those of adjacent panels and from adjacent cap seal devices 91. Thereafter, the defective panel would be detached from the adjacent cables 6–8 and cable joining devices 9, and when fully detached lowered by suitable means, not shown, onto the floor of stadium 21. The panel installation platforms could then be employed to elevate a replacement panel into position under shelter 100, whereafter such panel would be attached in place, as described above, and the shelter removed.

Reference is now made to FIG. 14, wherein there is illustrated a modified envelope configuration formed of diamond shaped panels 120. Panels 120 may be attached to the cabling system in the same manner described with reference to panels 60, except that panels 120 are not attached to cables extending transversely or diagonally of the panels in each sixty degree segment of the dome. Thus, it will be understood that panels positioned in segments I–IV, segments II–V, and segments III–VI, are unattached to cables 6, 7 and 8, respectively. This panel arrangement is particularly advantageous when interstices 10 are relatively small.

In FIG. 15, a modified cabling system is illustrated, wherein four central or main cables 132a–132d are joined at the crown or center of the dome by means of a ring or load plate, not shown, such as to divide the dome when viewed in plan into eight equal sized segments. The cabling system is completed by a secondary cabling system formed from eight sets of secondary cables 134, which are connected at their respective ends to the main cables by joining devices 137 and to a truss ring or the like, not shown, by conventional machine fittings. Secondary cables 134 are connected to each other intermediate their respective ends by joining devices 9', which are similar in construction to that shown in FIGS. 7 and 8.

By again referring to FIG. 15, it will be seen that in any given segment of the domed surface, two sets of essentially parallel secondary cables, for example 134a and 134b, are arranged essentially parallel one to each of a pair of segment bounding main cables, for example 132a and 132b, and intersect the other of the pair of bounding cables and each other. A third set of secondary cables, for example cables 134c, extend between the pair of main bounding cables from adjacent their point of intersection with sets of cables 132a, 132b and intersect with such sets of cables at the points of intersection thereof.

Joining devices 137 are shown in FIGS. 16 and 17 as including a pair of plates 138a, 138b having facing recesses 139a, 139b adapted to clampingly receive one of main cables 132a–132d. Bolts 140, which pass through the plates 138a and 138b, serve both to clampingly secure the plates on its main cable and to receive an eye type machine fitting 141 carried on the ends of the secondary cables. If desired, joining devices 137 may be fitted with clip devices 80 for the purpose of attaching triangular shaped panels of the envelope construction described above in reference to FIG. 4. However, envelopes of the type described above with reference to FIG. 1 may be employed with the cabling system shown in FIG. 15.

FIGS. 18 and 19 illustrate the manner in which the cabling system of FIGS. 1 and 4 may be employed in forming an air supported structure of ellipsoidal configuration or one having a pair of spherically shaped end sections 144, 144' joined to a central section 145. In this structure, the central cable 6a of one of the groups of cables forming the system lies within a plane which vertically bisects each of sections 144, 144' and 145; secondary cables 6b being positioned in the end sections in the manner shown in FIG. 2, and lying along straight lines extending lengthwise of the cylindrical surface of central section 145. The main cable 7a–8a', which are arranged to intersect with central cable 6a at the crowns of the end sections continue onto the cylindrical surface of the central section, such as to extend diagonally of the axis thereof. By assuring that the secondary cables 7b–8b' intersect central cable 6a at common, equally spaced points lengthwise thereof throughout both the end and cylindrical sections, the cylindrical section cable interstices are equilateral triangles approximating the size of the interstices formed in the end sections.
When employing the cabling system illustrated in FIGS. 18 and 19, the air inflated envelope 4 may be of any desired construction, and arranged either interiorly or exteriorly of the cabling system.

FIG. 20 illustrates how the cabling system of the preferred embodiment of the present invention may be modified to produce a six sided domed structure. In this construction, the sides of the domed structure are defined by vertically rising walls or the like 150, whose upper surface follows the arc defined by secondary cables 6b-8b. The ends of the cables may be fixed in a suitable manner to the upper surfaces of walls 150. Alternatively, the ends of the cables may be fixed to vertically raising trusses or extended to the ground, and wall 150 formed as a non-load bearing member, such as a curtain, whose primary purpose is to provide an air seal. Walls 150 serve to both fluid seal the dome with respect to the ground and to afford convenient locations for access openings into the domed structure.

Various modifications of the above described embodiments will likely occur to those skilled in the art. Exemplary thereof, would be to modify the preferred embodiment of the cabling system by displacing the centralmost cables thereof from the center or crown of the dome, so as to place the center of one triangular interstice at the center of the crown. In this arrangement the centralmost cables would not lie along great circle arcs and there would be produced a lack of symmetry between opposing sides of the structure, which might be desirable in the case of sloping terrain.

1. A large air supported structure of at least spherical sectioned configuration for use as a stadium cover or the like, comprising in combination:
   a base support for said structure;
   a reinforcing cable system anchored to said base support, said cable system being formed of a plurality of cables arranged in an intersecting relationship so as to define a pattern consisting of three groups of cables wherein centermost cables of said groups intersect at approximately 60° angles adjacent the crown of said structure and said groups of cables cooperate to define interstices approximating mutually uniformly sized equilateral triangles, and joining means fixedly interconnected said cables at all the points of intersection thereof; and
   an air inflatable envelope for supporting said cables above said base support in an upwardly arched and loaded condition, said envelope having elements thereof closing said cable interstices and said envelope being arranged in a substantially fluid sealed relationship relative to said base support so as to form a substantially air tight enclosure reinforced by said cabling system, and attaching means for attaching said envelope to said cables, whereby to retain said envelope elements in registration with their associated cable interstices and transfer envelope loads into said cable system.

2. A structure according to claim 1, wherein said cables are continuous along the surface of said structure and anchored at their respective ends to said base support.

3. A structure according to claim 1, wherein said envelope is formed by a plurality of panels, at least some of said panels are of diamond shaped configuration and define two envelope elements for closing two adjacent interstices, said panels of diamond shaped configuration being marginally attached to cables bounding said adjacent interstices, and said envelope includes means for sealing between marginal edges of adjacent panels.

4. A structure according to claim 1, wherein said envelope is formed by a plurality of panels of essentially triangular shaped configuration, each of said panels defining one of said envelope elements and being marginally attached to said cables bounding an associated interstice by said attaching means, said panels having double curvature configuration wherein the radii of curvature thereof are substantially smaller than the radii of curvature of said structure, and said envelope includes seal means for sealing between marginal edges of adjacent panels.

5. A structure according to claim 16, wherein said envelope is formed by a plurality of panels of essentially triangular shaped configuration, each of said panels defining one of said envelope elements and being marginally attached to said cables bounding an associated interstice by said attaching means, said panels having double curvature configuration wherein the radii of curvature thereof are substantially smaller than the radii of curvature of said structure, and said envelope includes seal means for sealing between marginal edges of adjacent panels.

6. A large air supported structure for use as a stadium cover or the like, comprising in combination:
   a base support for said structure;
   a reinforcing cable system anchored to said base support, said cabling system being formed of a plurality of cables arranged in an intersecting relationship so as to define a pattern consisting of three groups of cables wherein centermost cables of said groups intersect at approximately 60° angles adjacent the crown of said structure and said groups of cables cooperate to define interstices approximating equilateral triangles of relatively uniform size and joining means fixedly interconnecting said cables at all the points of intersection thereof; and
   means for supporting said cables above said base support in an upwardly arched and tensioned condition, said means for supporting said cables comprising an inflatable envelope arranged in a substantially fluid sealed relationship relative to said base support so as to form a substantially air tight enclosure reinforced by said cabling system, said envelope comprising a plurality of triangular panels, each of flexible, air inflatable material and each aligned with a particular interstices with which it is associated, attaching means attaching each panel along its marginal edges to the portions of the intersecting cables which bound the interstice with which each panel is associated for obtaining relatively uniform distribution of load in said cables, and seal means for sealing between marginal edges of adjacent panels.

7. A structure according to claim 6, wherein said cables are continuous along the surface of said structure and anchored at their respective ends to said base support.

8. A structure according to claim 6, wherein said structure additionally includes in combination:
   an air inflated, work access shelter, said shelter being dimensioned so as to provide an enclosure covering a plan view area of said envelope in excess of at least one of said panels, said shelter including tie down means removably attachable to said cabling
system and means adapted to form a fluid seal with said envelope, whereby said shelter may be selectively anchored to said structure above one of said panels in a fluid seal relationship to portions of said envelope bounding said one panel such that when inflated, said shelter provides a weather protection enclosure for workmen on the exterior of said structure and reduced differential in pressure across said one panel so as to facilitate repair or replacement thereof.

9. A structure according to claim 6, wherein said cabling system includes anchoring devices, said anchoring devices being adapted to extend outwardly of said structure through said envelope, and said structure additionally includes in combination:

an air inflated work access shelter, said shelter being dimensioned so as to provide an enclosure covering a plan view area of said envelope in excess of at least one of said panels, said shelter including tie down means removably attachable to said anchoring devices and means adapted to form a fluid seal with said envelope, whereby said shelter may be selectively anchored to said structure above one of said panels in a fluid sealed relationship to portions of said envelope bounding said one panel such that when inflated said shelter provides a weather protection enclosure for workmen on the exterior of said structure and reduces differential in pressure across said one panel so as to facilitate repair or replacement thereof.

10. A structure according to claim 6, wherein said panels include marginal edge portions and apex portions formed by intersecting marginal edge portions thereof, said marginal edge portions being disposed adjacent said cables bounding said interstices and said apex portions being disposed adjacent said joining means interconnecting said bounding cables, and said attaching means includes first means adapted to removably attach said panel marginal edge portions to said bounding cables and second means adapted to attach said panel apex portions to said cable joining means.

11. A structure according to claim 10, wherein said panels include load transmitting means extending along said marginal edge portions and through said apex portions thereof, and said first and second means removably attaching said load transmitting means to said bounding cables and said cable joining means.

12. A structure according to claim 6, wherein said joining means comprise an upper plate, a lower plate and two intermediate plates, said plates being clampingly secured in a stacked relationship by clamping bolts removably received within aligned plate apertures, facing surface portions of adjacent plates defining recesses in which said cables are clampingly secured.

13. A structure according to claim 12, wherein anchoring devices are adapted to be removably affixed to said upper plates, said anchor devices extending outwardly of said structure through said envelope, and said structure additionally includes in combination:

an air inflated work access shelter, said access shelter being dimensioned so as to provide an enclosure covering a plan view area of said envelope in excess of at least one of said panels, said access shelter including tie-down means removably attachable to said anchoring device and means adapted to form a fluid seal with said envelope, whereby said access shelter may be selectively anchored to said structure above one of said panels in a fluid sealed relationship to portions of said envelope bounding said one panel such that when inflated said shelter provides a weather protection enclosure for workmen on the exterior of said structure and reduces differential in pressure across said one panel so as to facilitate repair or replacement thereof.

14. A structure according to claim 13, wherein said seal means include overlapping flap seal devices carried along marginal edges of adjacent panels and cap devices, said cap devices being secured to said joining means, and said anchoring devices extending upwardly through said cap devices.

15. In an air supported structure of the type including a base support, an air inflated envelope peripherally attached and sealed to balloon upwardly above said base support and assume a predetermined shape having at least a portion of spherical section, and a cabling system attached to said base support and maintained in tension by said envelope whereby to assume said predetermined shape, the improvement wherein:
said cabling system consists of at least three main cable sections each anchored at one end to said base support and each extending from such anchor point to the crown of the spherical section along a great circle arc thereof, the anchor points of said main cable sections being spaced to provide included angles between any pair of adjacent main cable sections, said cabling system including groups of further cable sections in which the cable sections of each group are parallel and in which at least some of said groups are parallel with said three main cable sections, said three main cable sections and said groups of cable sections being arranged to provide a network of cable sections criss-crossed to define similar relatively uniform triangular interstices, and means fixing said cable sections in said network at all of the points of cable crossings whereby to limit and control the distribution of stresses in said envelope within said spherical section; and

said envelope comprising a plurality of triangular panels, each of flexible material and each aligned with a particular interstice with which it is associated, attaching means attaching each panel along its marginal edges to the portions of the intersecting cables which bound the interstice with which each panel is associated for obtaining relatively uniform distribution of load in said cables, and said means for sealing between marginal edges of adjacent panels.

16. A large air supported structure of at least spherical sectioned configuration for use as a stadium cover or the like, comprising in combination:
a base support for said structure;
a reinforcing cabling system anchored to said base support, said cabling system being formed from a plurality of cables arranged in an intersecting relationship so as to define a pattern consisting of three groups of cables wherein cables within each said group include a central cable lying along a great circle arc within a great circle plane passing through the crown of said structure and secondary cables lying along non-great circle arcs substantially within secondary planes, each said secondary plane of a group being arranged at an acute angle
with respect to said great circle plane of said group and intersecting therewith along a substantially
commom line spaced from the center of curvature
of said structure, said central cables of said groups
intersecting at said crown at approximately 60°
angles, said secondary cables of two of said groups
intersecting with said central cable of a third of said
groups at common points spaced substantially
equally apart in a direction lengthwise thereof such
that said groups of cables cooperate to define sub-
stantially equally sized interstices of triangular
shaped configuration, and joining means for fixedly
interconnecting said cables at all points of intersection
thereof, and
an air inflated envelope for supporting said cables
above said base support in an upwardly arched and
loaded condition, said envelope having elements
thereof closing said cable interstices and said enve-
lope being arranged in a substantially fluid sealed
relationship relative to said base support so as to
from a substantially air tight enclosure reinforced
by said cabling system, and attaching means for at-
taching said envelope to said cables, whereby to re-
tain said envelope elements in registration with the
cable interstices and transfer envelope loads into
said cable system.
17. A large air supported structure of the type having
generally cylindrical center section and generally
spherically shaped end sections for use as a stadium
cover or the like comprising in combination:
a base support for said structure;
a reinforcing cabling system anchored to said base
support, said cabling system being formed of three
groups of cables arranged in an intersecting rela-
tionship and fixedly interconnected at common
points of intersection by joining devices such that
said cables cooperate to define interstices of trian-
gular shaped configuration, one of said groups in-
cluding a central cable and secondary cables ex-
tending lengthwise of said structure between said
spherical end portions thereof, said central cable of
said one group lying within a plane vertically bi-
secting said structure through the crowns of said
end sections, said secondary cables of said one
group lying within secondary planes arranged at
acute angles with respect to said bisecting plane
and intersecting therewith along a substantially
common line extending lengthwise of said structure
and spaced from the center of curvature thereof;
said cables of the other of said groups of said cables
extending in opposite directions diagonally of said
structure and intersecting said central cable of said
one group at common points spaced substantially
equally apart in a direction lengthwise of said cylin-
drical section and said end sections, said cables of
said other groups intersecting with said center
cable intermediate said crowns being arranged at
substantially 60° angles relative thereto;
an air inflatable envelope for supporting said cables
above said base support in an upwardly arched and
loaded condition, said envelope having portions
thereof closing said cable interstices and said enve-
lope being arranged in a substantially fluid sealed
relationship to said base support so as to form a
substantially air tight enclosure reinforced by said
cabling system, and attaching means for attaching
said envelope to said cables, whereby to retain said
envelope portions in registration with their associ-
ated cable interstices and transfer envelope loads into
said cable system.
18. A large air supported structure for use as a sta-
dium cover or the like comprising in combination:
a base support for said structure;
a cabling system, said cabling system being formed of
a plurality of cables arranged in an intersecting re-
lationship so as to define a lattice work having in-
terstices of substantially like configuration and
joining means for fixedly interconnecting said ca-
bles at all the points of intersection thereof;
an air inflatable envelope for maintaining said cables
above said base support in loaded condition, said
envelope being formed from a plurality of separate
panels formed of flexible air inflatable material and
configured to substantially conform to said inter-
stices, attaching means for removably and separ-
ately attaching said panels to portions of said ca-
bling system bounding said interstices, and remov-
able sealing means disposed outwardly of said ca-
bling system and attaching means for providing a
fluid seal between adjacent envelope panels, said
panels individually representing a relatively small
surface area of said envelope;
anchoring devices, said anchoring devices being fixed
to said joining means and extending outwardly of
said structure through said envelope; and
an air inflated work access shelter, said shelter being
dimensioned so as to provide an enclosure out-
wardly covering a relatively small portion of said
surface area of said envelope suficient to bound at
least one of said panels, said shelter including tie
down means removably attachable to said anchor-
ing devices and means adapted to form a fluid seal
with said envelope, whereby said shelter may be se-
lectively anchored to said structure above one of
said panels in a fluid sealed relationship to portions
of said envelope bounding said one panel such that
when inflated said shelter provides a weather pro-
tection enclosure for workmen on the exterior of
said structure and reduces differential in pressure
across said one panel so as to facilitate repair or re-
placement thereof.
19. A large air supported structure having at least a
portion of a spherical section for use as a stadium cover
or the like, comprising in combination:
a base support for said structure;
a cabling system anchored to said base support, said
"cabling system being formed of a plurality of pre-
stretched cables arranged in an intersecting rela-
tionship so as to define a pattern consisting of three
groups of cables wherein cables within each said
group include a central cable lying essentially along
a great circle arc within a great circle plane passing
through the crown of said structure and secondary
cables lying essentially along non-great circle arcs
substantially within secondary planes arranged at
acute angles with respect to said great circle planes
of their associated groups, said central cables of
said groups intersecting at said crown at approxi-
mately 60° angles, said secondary cables of any two
of said groups intersecting with said central cable of
a third of said groups at common points spaced
apart in a direction lengthwise thereof whereby
said groups of cables cooperate to define substan-
tially uniformly sized interstices of triangular
3,744,191

shaped configuration, and joining means for fixedly interconnecting said cables at all points of intersection thereof, and
and air inflated envelope for supporting said cables above said base portion in an upwardly arched and loaded condition, said envelope having substantially uniformly sized elements thereof closing said cable interstices and said envelope being arranged in a substantially fluid sealed relationship relative to said base support so as to form a substantially air tight enclosure reinforced by said cabling system, and attaching means for attaching said envelope elements to said cables, whereby to retain said envelope elements in registration with their associated cable interstices and to permit the development of essentially uniform cable loadings under envelope inflation pressure.

20. A structure according to claim 19, wherein said envelope is formed by a plurality of panels of flexible material and of essentially triangular shaped configuration, each of said panels defining one of said envelope elements and being marginally attached to said cables bounding an associated interstice by said attaching means, and said envelope includes seal means for sealing between marginal edges of adjacent panels.

* * * * *