United States Patent

Georgiev et al.

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[54] BUOYANT STRUCTURE

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[52] **U.S. Cl.** ..... **114/0.5 F**, 114/43.5

[51] **Int. Cl.** **B63b 35/00**, B63b 35/44

[58] **Field of Search** ..... 114/0.5, 0.5 F, 43.5; 61/48; 14/27; 52/79, 10, 81

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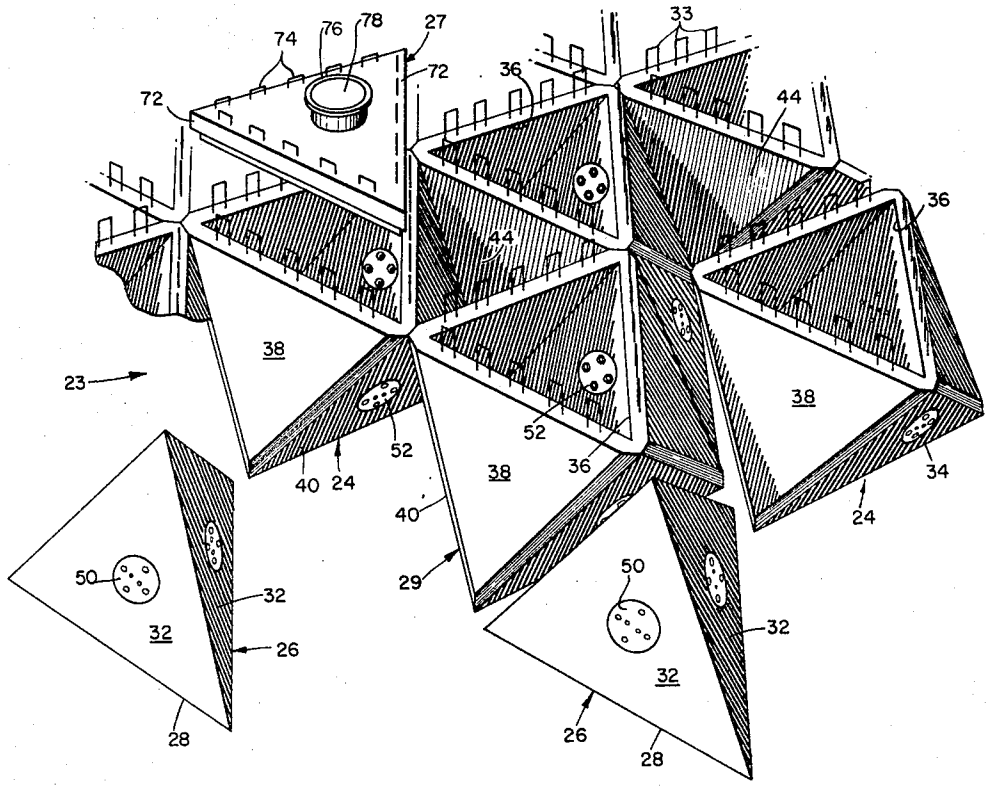
Primary Examiner—Trygve M. Blix

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[57] **ABSTRACT**

A buoyant structure suitable for use as a floating island of very large dimensions, e.g. an airport, and constructed of polyhedral modules fastened one to another. Some of these modules can be hollow to form a base having compartments suitable for housing mechanical systems, offices or the like. A particularly advantageous structure is formed of adjoined octahedral and tetrahedral modules with one side of each of these modules defining a lower plane, and one face of each octahedron defining the upper plane to which a platform is integrally fastened.

22 Claims, 10 Drawing Figures



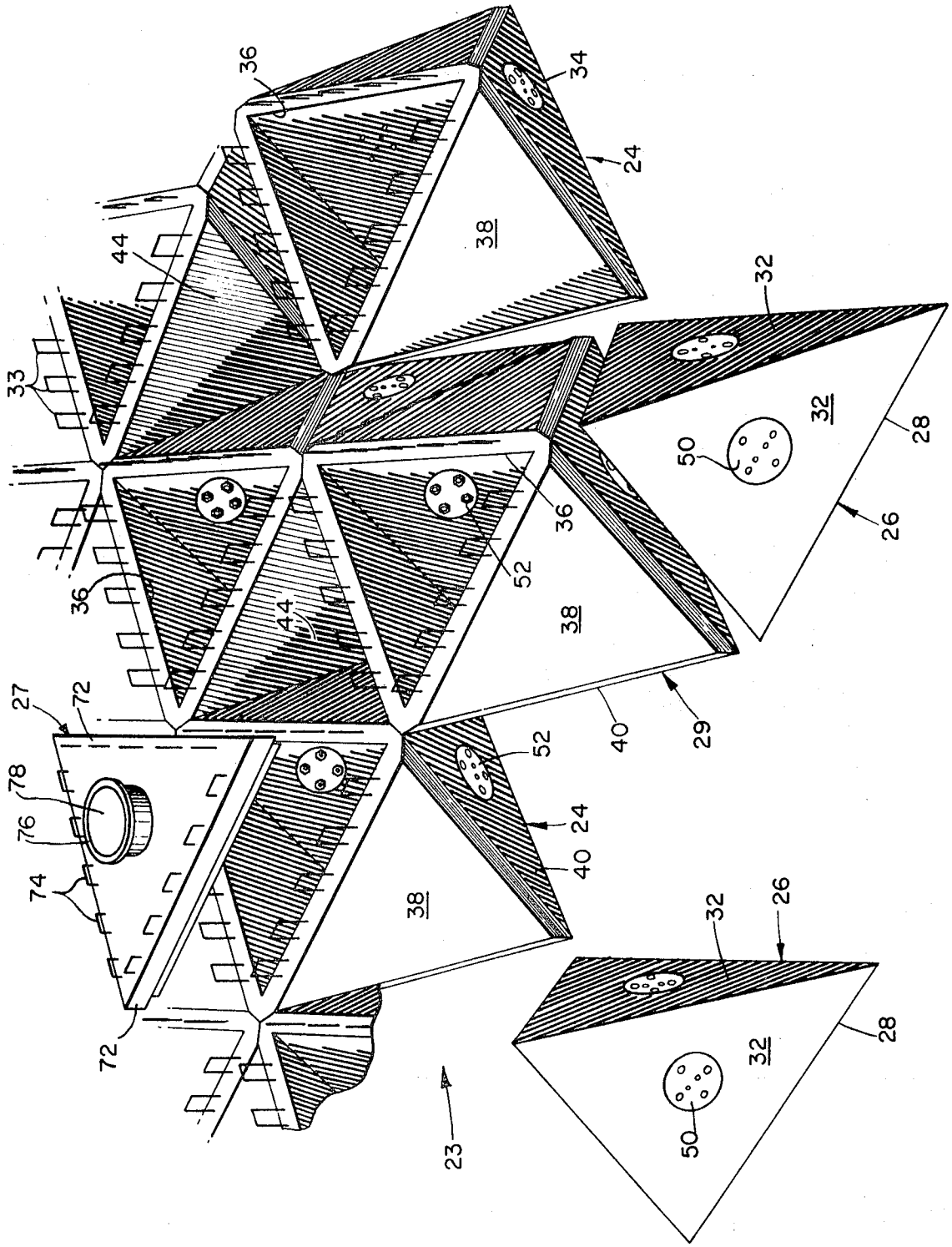


FIG. 1

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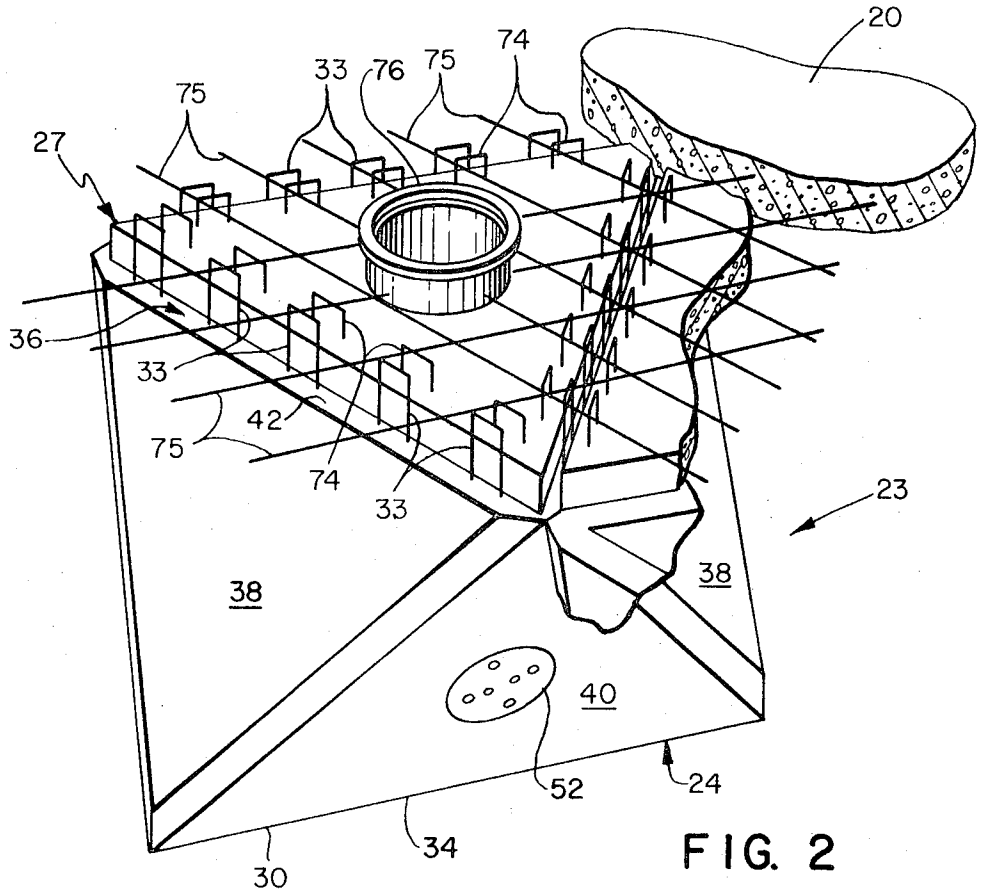


FIG. 2

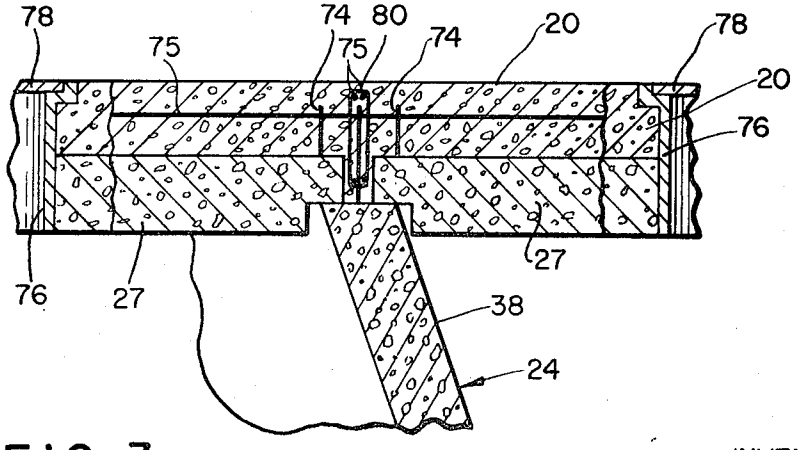


FIG. 3

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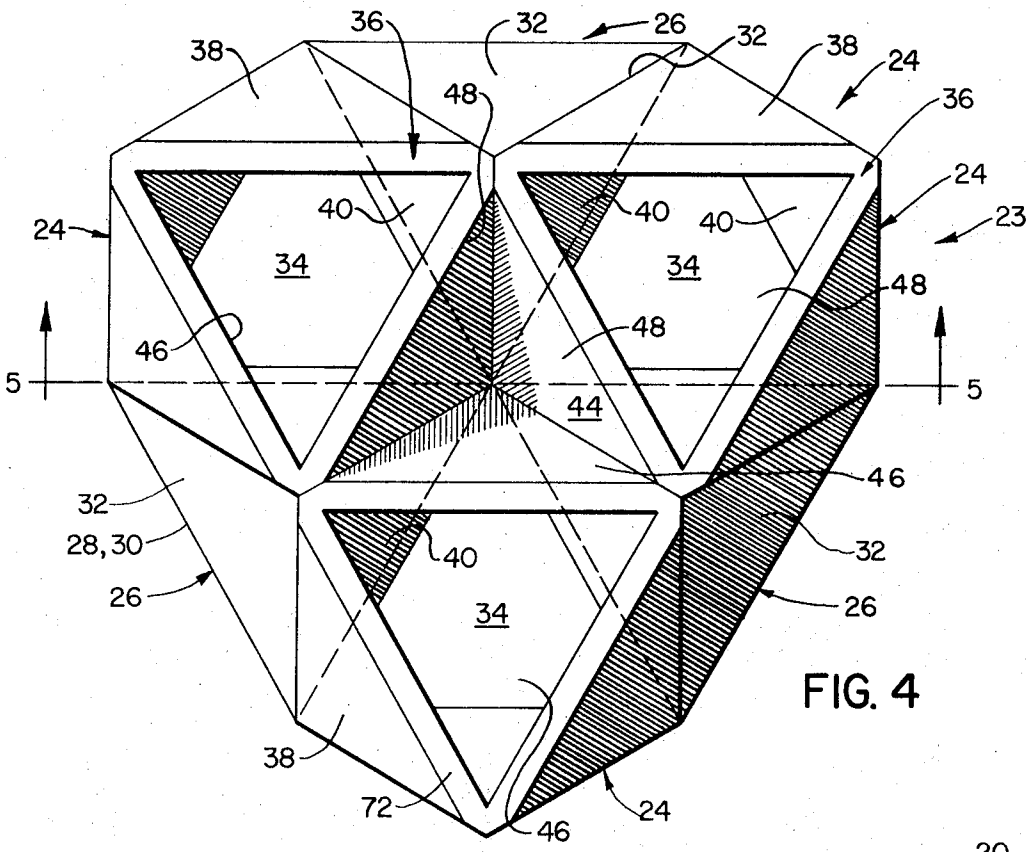


FIG. 4

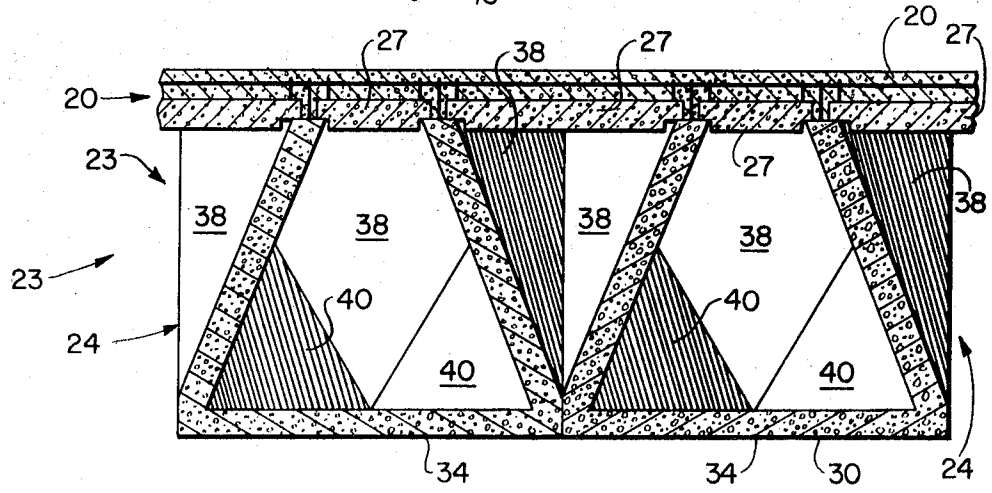


FIG. 5

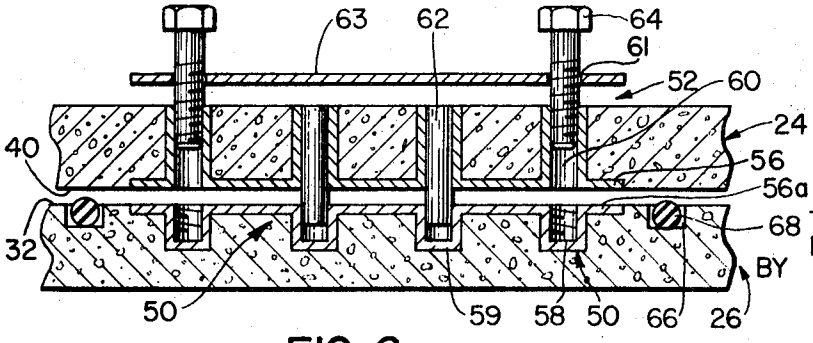


FIG. 6

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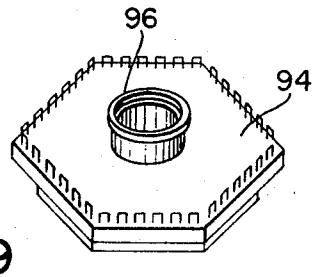


FIG. 9

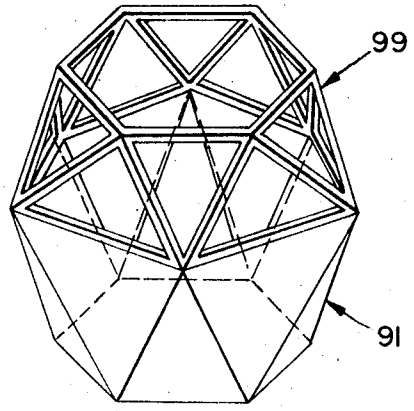


FIG. 10

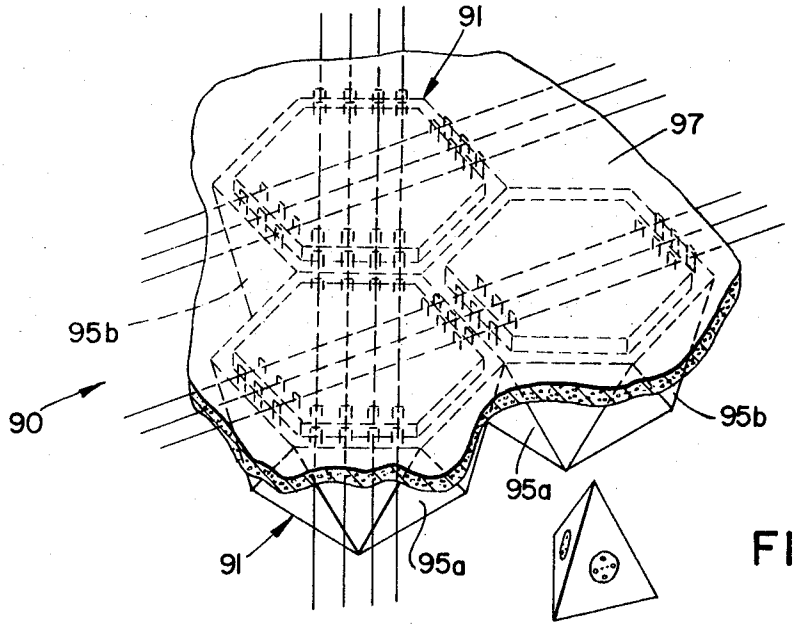


FIG. 7

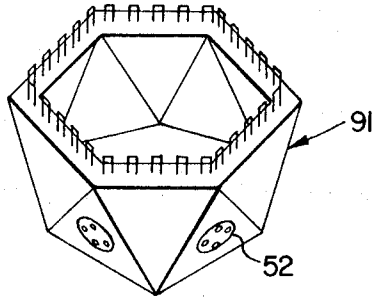


FIG. 8

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BUOYANT STRUCTURE

BACKGROUND OF THE INVENTION

The building of large floating platforms often has been suggested for providing space for airplanes to land. The aircraft carrier is a familiar example of a dynamic floating airport. However during the pre-jet aircraft era, numerous novel designs of static floating platforms were suggested by inventors who understood the value of utilizing the buoyant properties of water to provide airdromes which would be accessible to metropolitan areas.

With the dawning of the age of jet aircraft and the consequent emphasis on very large commercial aircraft, interest in design of so-called seadromes dwindled. In fact, however, it is the supersonic jet aircraft, along with the diminishing availability of land for airports near large cities, that has stimulated new interest in seadromes. This time the interest in large seadromes is of high, even critical, importance. This is because, unless some landing field is provided over areas where sonic booms are not bothersome, the number of cities served by supersonic transports may be severely limited.

A consideration of the problem encountered in providing a buoyant structure large enough to accommodate such modern aircraft rules out the general approaches taken in the prior art wherein stresses are normally borne by a superstructure erected upon a buoyant platform or wherein the buoyant structure comprises moving parts to accommodate wave action or other variations in stress distribution across the platform surface. It has, therefore, been a considerable challenge to provide high strength structures which are both economical and durable under the conditions imposed by the present situation.

Floating platforms may also be used to support various architectural structures such as dwellings and commercial and industrial buildings, and this may in the long run be the most important use for the platforms. In many coastal cities there is a serious need for more land, a problem that is aggravated by the fact that landward expansion can take place on only one side of a city so situated. In the past, more land has been made available by the simple process of filling in large water tracts. However, this can be rather expensive, especially when costly foundations are required for the buildings erected on the reclaimed land.

Moreover, land filling has recently come under attack because of its widespread ecological implications. By interferring with normal waterflow and underwater wildlife movement it may adversely affect natural processes far from the location of the fill. The substitution of a floating structure for land fill will serve to diminish or eliminate some of these undesirable effects.

SUMMARY OF THE INVENTION

Therefore, it is an object of the invention to provide an improved load-bearing buoyant structure.

Another object of the invention is to provide a buoyant structure incorporating an integral platform and which is capable of bearing and dissipating large loads exerted on the platform.

Another object of the invention is to provide a buoyant, load-bearing structure which comprises compartments suitable for housing equipment and/or personnel.

Another object of the invention is to provide a novel process for forming a buoyant structure by the use of prefabricated building units.

Still another object of the invention is to provide means whereby the aforesaid units can be fastened together into an integrated platform.

Another object of the invention is to provide unique polyhedral units suitable for use in forming the buoyant structure of the invention.

Other objects of the invention will be obvious to those skilled in the art on reading this application.

The above objects have been substantially achieved by building a buoyant structure comprising mated polyhedral modules, fastened together in such a way that stresses exerted on any portion of the structure are transmitted therethrough and adequately absorbed therein by a plurality of polyhedral modules.

Most advantageously, there will be two different polyhedron configurations utilized to construct a buoyant base. This base is a structure which, although quite capable of bearing loads itself in many cases, is usually covered with a platform which is preferably fastened to and integral with the base.

The polyhedron-shaped modules will normally include a lower polyhedron, that is a polyhedron with fewer polygonal faces, and a higher polyhedron, that is a polyhedron with more faces. It will usually be more convenient to select a tetrahedron as the lower polyhedron, and to use the tetrahedron with its three upwardly canted side faces to provide surfaces to attach a higher polyhedron such as an octahedron or other polyhedron having downwardly canted, mating triangular side faces. Specifically, in combination with octahedrons, a tetrahedron will have its apex at approximately the upper surface of the buoyant base structure; its lower face will be at the bottom of the structure; and its three other faces will be canted upwardly, and separated by 120 angular degrees, to bear against abutting faces of the octahedrons.

The above-described tetrahedral-to-octahedral arrangement can be reversed, with the buoyant structure turned upside down so that the three upwardly canted faces of the octahedrons will be the faces abutting the tetrahedron whose apex points downward. Nevertheless, it will be seen from a description of the process of assembling the structure that the position of the tetrahedron in which its apex is on top and its center of gravity low is usually the more advantageous position.

Convenient access to these spaces, advantageously, will be through either the top of the buoyant structure or through adjacent surfaces of the adjoining polyhedrons of the higher order.

A particular feature of the invention is the ease by which the polyhedral modules can be brought into position and attached to one another to form the buoyant base. Each polyhedron may be weighted so that it will displace just that amount of water appropriate to enable the polyhedrons to be floated together with fastening units on each polyhedron being thereby brought into exact register with fastening units on adjoining polyhedrons to which it is to be attached. Normally smaller polyhedrons will be prefabricated to a constant mass while the larger polyhedrons, where required, will be provided with ballast to make whatever fine adjustment in water displacement is required to obtain precise register of the fastening units. Such ballast might be required, for example, when differences in water density are caused by temperatures changes or by salinity changes as in tidal areas. In one advantageous mode of connecting the various polyhedral units, differences in displacement can be caused by varying weight of workmen who tighten the bolts securing together adjacent polyhedrons while within the polyhedron.

While the invention is generally described as involving the use of equilateral or regular polyhedral structures, it is to be understood that variations in the classical polyhedral shapes may also be used. In any case, the side faces should be triangular, although in some situations they may advantageously be truncated somewhat. Moreover, since polyhedrons may be formed by combining two or more polyhedrons, it is possible to build a structure according to the invention in which the polyhedral modules are themselves assembled from polyhedral units.

One way in which the buoyant structure may be defined is a platform having a superstructure engaging with, and supported by, a stress-distributing array of polyhedron modules, having both downwardly and upwardly canted adjoining faces facing in various directions in order to assure the multi-

directional dissipation of stresses applied to the platform. From one point of view the tetrahedral modules, which have upwardly canted faces, can collectively be considered as the basic module. All the modules mated and adjoined to these tetrahedral modules can be considered as part of the supported structure, it being understood that because all modules will generally be buoyant, they all provide a substantial part of the supportive function of the system. All other elements of the structure are advantageously structurally integrated to these modules.

The foregoing descriptive material has been largely referenced to the building of floating airports. Nevertheless, the unique structures of the invention can be utilized in solving any number of other construction problems. Thus in building of bridges, it may be desirable to float or otherwise transport the modules, constructed according to the invention, to the bridge site, and then connecting and elevating them into position to form a bridge structure. On the other hand, in some instances a buoyant, relatively inexpensive structure of the type described herein can be used directly as a highway bridge without the need for elevated structure. A structure made according to the invention can also form a highly suitable highway and, in some environments such as swampy regions, will have considerable advantage over the present highway construction procedures. If so desired, the loads from the platform can be transferred from the initial supporting surface of water or muds to piles sitting on bedrock. Our platforms can also be used as platforms on which to erect buildings of various kinds, or they can be used as habitational structures themselves. Other uses for the platforms include the construction of floating drydocks, floating marinas, and barges.

In constructing a lower polyhedron module, e.g. the tetrahedron of choice, it is desirable to form a pyramid of reinforcing rods having one side open and placing a buoyant core therein, or forming the core in place. After the core, preferably an organic resin foam with a closed cell configuration, has been placed in the open pyramid, the pyramid is closed and a rigid shell, e.g. a concrete envelope, is formed therearound.

The higher polyhedron module, e.g. an octahedron, may also be formed of a steel reinforcing frame and an envelope of concrete molded about the frame.

At least some of the higher polyhedrons are advantageously formed with an essentially hollow interior which can be suitably utilized to form office space, space for drainage, and other mechanical systems, etc. Access to the interiors of these polyhedrons will usually be from the platform above, by means of manholes or through interconnecting passageways between adjacent vertical faces of polyhedrons of higher order.

ILLUSTRATIVE EXAMPLE OF THE INVENTION

In this description and accompanying drawings we show and describe a preferred embodiment of our invention and suggest various alternatives and modifications, but it is to be understood that these are not intended to be exhaustive and that other changes and modifications will also be made within the scope of the invention.

IN THE DRAWINGS

FIG. 1 is an exploded view of the substructure of a platform embodying the invention;

FIG. 2 is a fragmentary view of the platform illustrating the manner in which the upper pad is connected to the substructure;

FIG. 3 is a section in elevation along the upper part of the platform showing how reinforcing rods from the substructure are tied into the reinforcing of upper pad;

FIG. 4 is a plan view of part of the substructure of the platform of FIGS. 1–3;

FIG. 5 is a section in elevation of the structure shown in FIGS. 1–4;

FIG. 6 is a fragmentary section of a tetrahedron and adjoining octahedron of FIG. 1 showing in detail the arrangement by which one is attached to the other;

FIG. 7 is a fragmentary view of another platform embodying the invention;

FIG. 8 is a perspective view of a polyhedron, having two parallel hexagonal surfaces and 12 side faces incorporated in the platform of FIG. 7.

FIG. 9 shows a cover useful for closing the polyhedron shown in FIG. 8.

FIG. 10 is a perspective view of a polyhedron of the type shown in FIG. 8, combined with an inverted open lattice structure similar to the same polyhedron, which can be used for habitation or storage purposes.

FIGS. 1, 2 and 3 depict a part of a floating platform comprising a steel-reinforced concrete pad **20** supported on, and structurally integral with, a buoyant base **23** consisting of interfitting octahedrons **24**, tetrahedrons **26** and covers **27**.

The tetrahedrons **26** are formed of water resistant, reinforced concrete shells molded around buoyant filler cores to provide overall buoyancy.

Each tetrahedron has a plane-forming surface provided by its bottom face **28**. This face **28** coincides with, and partly forms one portion of a lower plane **30** of the platform, as seen in FIGS. 2 and 5. The tetrahedron **26** also has three bearing faces **32** which are adapted for joining, positioning and/or supporting neighboring octahedrons **24**.

With further reference to FIGS. 1 and 2, each octahedron **24** has a triangular bottom face **34** in the plane **30** and an open top face **36**. The faces **34** and **36** are offset so as to define triangular, upwardly canted side faces **38** and downwardly canted side faces **40**.

As shown in FIG. 2, each octahedron **24** is formed of concrete cast on a steel reinforcing frame. This frame is partly visible in the drawing only to the extent that portions thereof form a series of steel loops **33** that protrude upwardly from the rim **42** around the top face **36**.

The modules **24** and **26**, and indeed the entire structure, may alternatively be made of any other suitable materials, e.g. plastic or metal.

To construct the platform, the substructure or base **23** (FIG. 1) is first assembled. Individual modules in the form of octahedrons **24** and tetrahedrons **26** are floated into place and fastened together in a nesting arrangement best seen in FIGS. 1 and 4. The downwardly canted side faces **40** of each octahedron **24** are joined to correspondingly upwardly canted side faces **32** of tetrahedrons **26**. Each tetrahedron is thus joined to three octahedrons and each octahedron to three tetrahedrons (except, of course at the edges of the base **23**).

The upwardly canted octahedron faces **38**, which do not adjoin the tetrahedrons, define tetrahedrally shaped void compartments **44**. It should be noted that ordinarily the compartments **44** will not be sealed along their edges and thus they do not contribute to the buoyancy of the platform.

As shown in FIG. 4, the upper surface of the resulting structure is cellular, being comprised of adjacent equilateral openings **46** and **48** in the faces **36** of the octahedrons and the tops of the void compartments **44**.

The tetrahedrons **26** and adjacent octahedrons **24** are joined together in a face-to-face relationship by means of one or more mating fastening units **50** and **52** (FIGS. 2 and 6). The construction of the fastening units is depicted in detail in FIG. 6. As shown therein, each fastening unit **52** comprises a plate **56** provided with clearance holes **60** and each fastening unit **50** comprises a plate **56***a* provided with drift pin alignment holes **59** and threaded sockets **58**. Each of the units **52** also includes a drift pin locking plate **63** having bolt clearance holes **61**. The plates **56** and **56***a* should be directly secured to the reinforcing in the respective modules, as by welding, etc.

To assemble a tetrahedron **26** to an octahedron **24**, the two modules are floated together and drift pins **62** are driven from the interior of the octahedron, through the holes **60** and into the holes **59**. With the fastening units **50** and **62** thereby aligned, the locking plate **63** is put in place. Bolts **64** are then

inserted through the holes 61 and threaded into the sockets 58.

When the bolts 64 are tightened they sandwich the octahedron face 40 between the tetrahedron fastening unit 50 and the drift pin locking plate 63, thereby holding the face 40 securely against a tetrahedron face 32. The bolts 64 also combine with the drift pins 62 to resist shear between the faces 32 and 40. In this regard it should be noted that, except at the edges of the platform, these shears are the only forces tending to separate the octahedrons 24 from the tetrahedrons 26 (FIGS. 1 and 4).

With further reference to FIG. 6, the fastening units 50 and 52 are sealed by O-ring gaskets 68 in grooves 66 from water that seeps in between the joined octahedrons 24 and tetrahedrons 26.

Other fastening arrangements may be desirable in some applications; for example, the modules might be cemented together with a suitable adhesive.

FIGS. 1, 2 and 3 illustrate a convenient arrangement for closing the equilateral openings 46 and 48 forming the cellular upper plane of the substructure prior to laying a reinforced concrete surface thereover. The triangular cover plates 27 (FIG. 1) are cast to fit on and into these openings, with flanges 72 resting on the upper rims 42 of the octahedrons 24. Steel loops 74 extending from reinforcing in the cover plates 27 provide means to tie the cover plates into reinforcing rods 75 (best seen in FIGS. 2 and 3) running through the concrete pad 20 (FIG. 3). Some of the cover plates 27 are provided with manhole rings 76 which allow access to the compartments within underlying polyhedrons and receive manhole covers 78.

The reinforcing rods 75 in concrete pad 20 are also threaded through both the steel loops 33 extending from the reinforcing frames within the concrete walls of the octahedrons 24. Rods 75 are also combined with stirrups 80 (FIG. 3) to form reinforcing ribs extending along the upper edges of the polyhedrons, between the cover plates 27.

With this arrangement, the pad 20 is an essentially integral part of the underlying polyhedral substructure.

FIG. 5 strikingly shows the structural strength of a platform embodying the invention. In the illustrated vertical cross-section, the walls and bottoms of the various polyhedrons define triangular truss-like members. Moreover, these triangular configurations will be found in cross-sections extending in different directions from the section shown in FIG. 5. Since the triangular form provides maximum strength, the existence of manifold cross-sections of this type imparts great strength to the overall structure.

The triangular cross-sectional configurations result from the canting of the side faces of the polyhedrons, as do the triangular shapes of the faces themselves. The structure may be truncated somewhat, in which case the various triangles will be converted to trapezoids. However, since the trapezoidal form is not as strong, truncating should be minimized, so that the resulting trapezoidal sections are so close to triangular as to be considered essentially triangular.

FIGS. 7–9 depict the construction of a platform 90 in which the higher order polyhedrons 91 whose top and bottom faces are regular hexagons are offset, as viewed from above, to provide downwardly-canted triangular side faces 95*a* interfitting with the faces 32 of tetrahedrons 26 and fastened thereto by means of the fastening units 50 and 52 described above.

Moreover, the bottom faces are "inscribed" in the top faces so that each apex in the bottom face lies directly below the midpoint of an edge of the top face. Consequently, the remaining side faces 95*b* of the polyhedron 90 are vertical, and adjacent polyhedrons 90 therefore adjoin each other face-to-face at the faces 95*b* as shown in FIG. 7. Accordingly, the polyhedrons 91 can be directly joined together and furthermore they can be provided with apertures leading from one to another. This facilitates interior access throughout the system, both for personnel and the mechanical subsystems (i.e. plumbing, electrical, etc.). It should also be noted that the platform 90 has no void compartments corresponding to the compartments 44 of FIGS. 1 and 4.

The top faces of the polyhedrons 91 are open initially to permit access to the interiors of these units. They are then closed by hexagonal cover plates 94 (FIG. 9) which may be provided with manholes 96 and covers 78. The platform 90 is provided with an integral pad or deck 97 similar to the pad 20 of FIGS. 1–4.

The structure illustrated in FIG. 7 thus has more usable space in the interiors of its higher order polyhedrons 90 and greater buoyancy than does the structure illustrated in FIGS. 1–4, although with some decrease in structural strength, which can be compensated for by additional structure reinforcement. Also the polyhedrons 91 can readily be matched with superstructures 99, as seen in FIG. 10, to provide a multi-storied facility.

In summary, a structure embodying our invention provides sufficient strength for the most demanding applications such as aircraft landing facilities. Yet it is easily constructed by fabricating individual modules, floating or otherwise transporting them into place and quickly fastening them together, after which an integral upper pad is monolithically formed in place.

What is claimed is:

1. A structure suitable for use as a floating platform and formed of:
   - A. a buoyant base of mating higher and lower polyhedrons
     1. defining upper and lower generally horizontal planes;
     2. having mating faces between upper and lower polyhedrons canted with respect to the horizontal planes and to planes orthogonal with respect to each other and to the horizontal planes; and
   - B. a platform fastened to, and extending along at least one of, said horizontal planes.

2. A structure as defined in claim 1 wherein said lower polyhedron is a tetrahedron.

3. A structure as defined in claim 2 wherein said higher polyhedron is an octahedron.

4. A structure as defined in claim 1
   - A. wherein at least some of said polyhedrons form hollow compartments, and
   - B. including passage means providing access to said compartments from said platform through integrated cover plates containing manholes.

5. A structure as defined in claim 1
   - A. wherein at least some of said polyhedrons form hollow compartments, and
   - B. including passage means providing interconnecting access between said compartments.

6. A structure as defined in claim 2, wherein said higher polyhedron has twelve side faces extending between two parallel hexagonal surfaces of different perimeter.

7. A structure as defined in claim 2 in which further faces of the higher polyhedrons are perpendicular to said planes, said further faces providing mating surfaces at which higher polyhedrons are fastened to each other.

8. Buoyant structural modules in the shape of higher and lower order polyhedra nestable to form a platform having bottom and side surfaces and a horizontal top surface, each polyhedron having a plurality of faces with fastening means thereon positioned to join mating faces of pairs of higher and lower order polyhedra in face to face contact with the faces of the mating higher order polyhedra forming an obtuse angle with said top surface.

9. The buoyant structural module as defined in claim 8 wherein each face comprises a rigid shell formed of concrete reinforced with steel-reinforcing members.

10. A buoyant structural unit as defined in claim 8 wherein a groove in the outer surface of said shell encircles said fastening means, said groove forming means to hold and protect a gasket.

11. A buoyant structural module as defined in claim 8 wherein said core is hollow and the fastening means in said module are accessible from the interior of the module.

12. A buoyant structure having a platform integral with, and supported by, a plurality of polyhedral modules, having canted faces in supporting contact with said platform to providing means for dissipating stresses exerted on said platform in a plurality of directions.

13. A structure as defined in claim 12 wherein said polyhedrons are octahedrons.

14. A structure as defined in claim 12 wherein said deck mates with and is integrally fastened to said polyhedrons.

15. A process for forming a buoyant structure, said process comprising the steps of:

A. Assembling polyhedrons

1. of both higher and lower orders,
2. having upper faces defining a generally planar load-bearing surface when so assembled,
3. each polyhedron having one of said upper faces also having at least three faces adjoining said upper face and canted with respect to each other and said upper face; and

B. Integrally fastening a deck to the top of said load-bearing surface.

16. A process as defined in claim 15 wherein said integral fastening is accomplished by placing an array of downwardly-canted polyhedron faces against matching upwardly-canted faces.

17. A process as defined in claim 16 wherein said polyhedrons are tetrahedrons and octahedrons.

18. A process as defined in claim 17 wherein upwardly canted surfaces of said tetrahedrons and the downwardly canted surfaces of said octahedrons are fastened to one another.

19. A process as defined in claim 15 wherein said structure is formed of concrete, reinforced with steel members, and wherein said deck is integrally connected to steel-reinforcing members protruding from the tops of higher order polyhedrons.

20. A process as defined in claim 16 wherein said polyhedrons are relatively weighted, prior to fastening one to another, to float in proper position for said fastening step.

21. A buoyant structure comprising mating tetrahedra and octrahedra joined together face-to-face to form at least one generally planar load-bearing surface, the faces of selected ones of the tetrahedra and octahedra forming a generally continuous outer surface for buoyantly supporting said structure in a fluid.

22. A buoyant structure according to claim 21 in which the faces at which the octahedra are joined to the tetrahedra are canted with respect to the load bearing surface.

* * * * *