Sept. 19, 1967 D. G. EMMERICH 3,341,989

CONSTRUCTION OF STEREOMETRIC DOMES

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Fig. 1

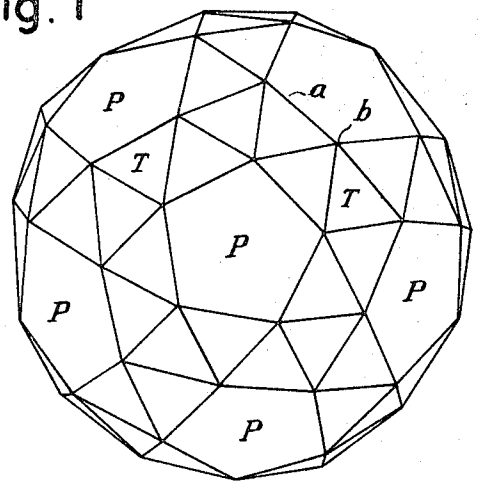


Fig. 2

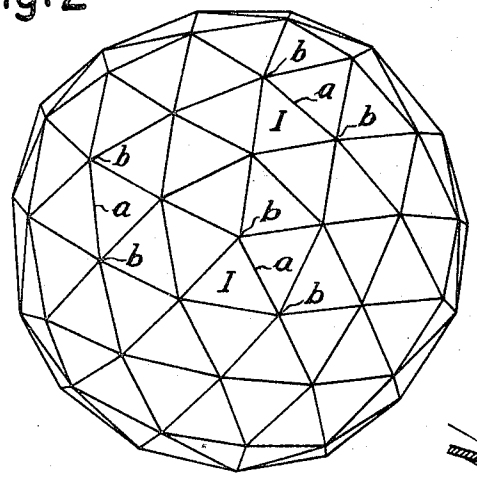


Fig. 3

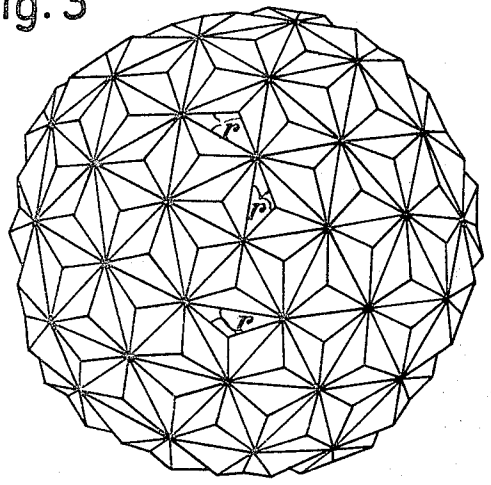


Fig. 12

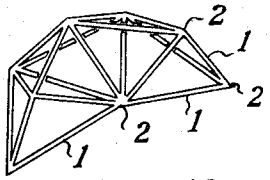


Fig. 13

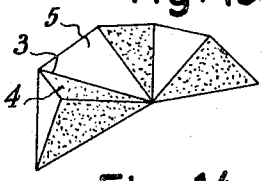


Fig. 14

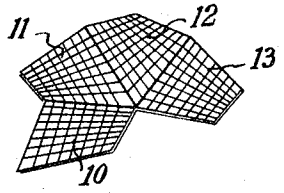
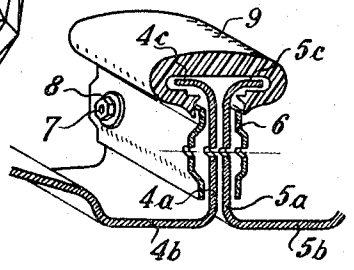


Fig. 16



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Fig. 5

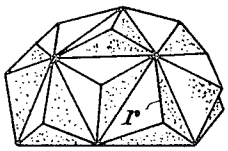


Fig. 4

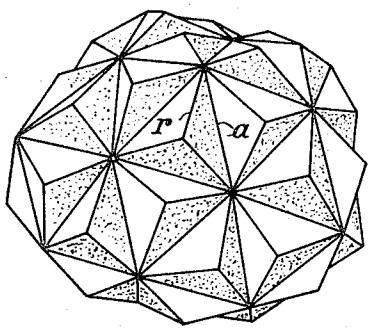


Fig. 6

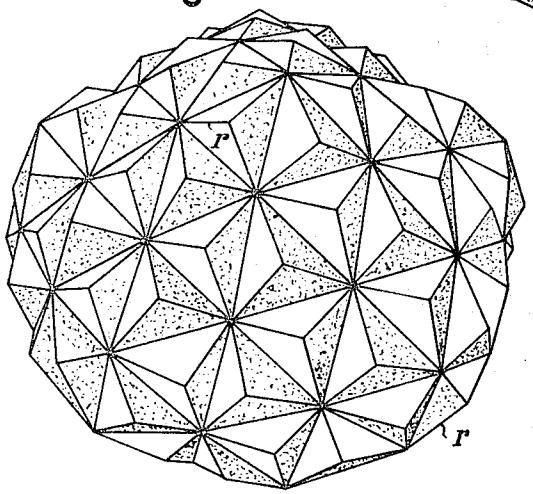


Fig. 7

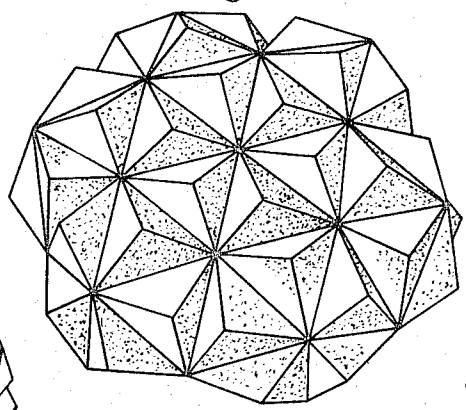
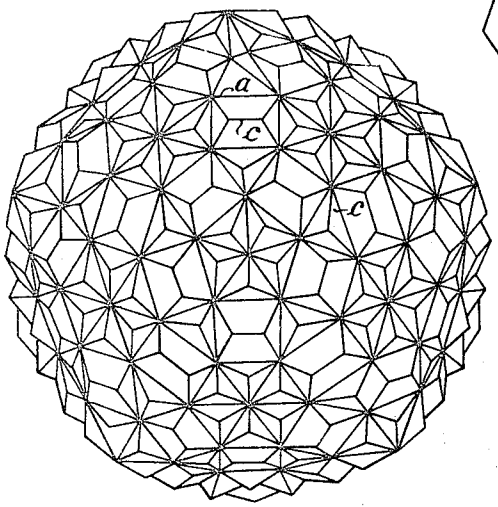


Fig. 10



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Fig. 11

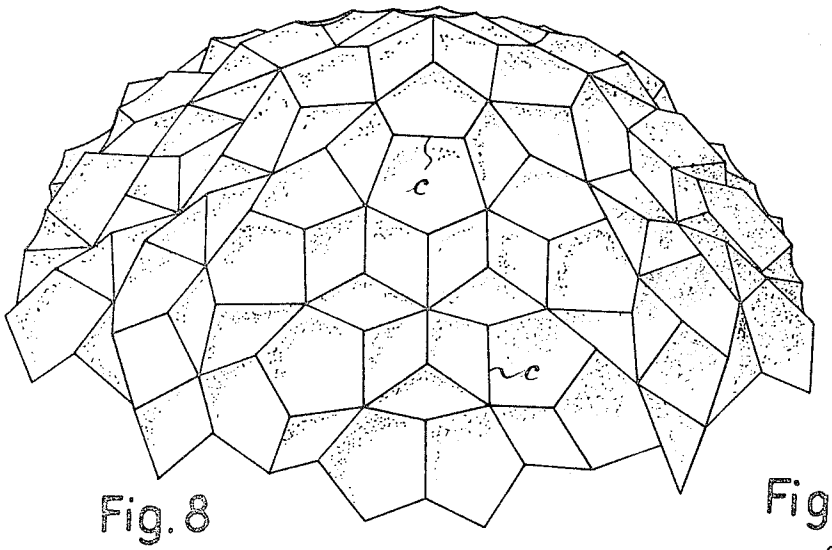


Fig. 8

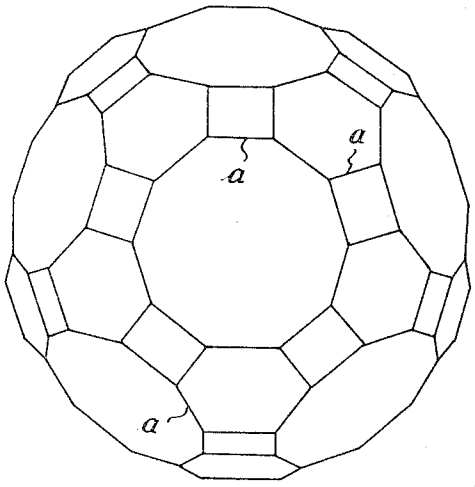


Fig. 15

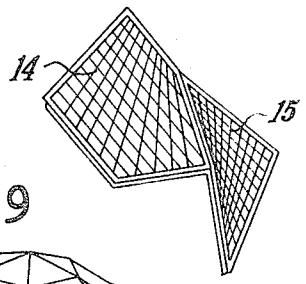
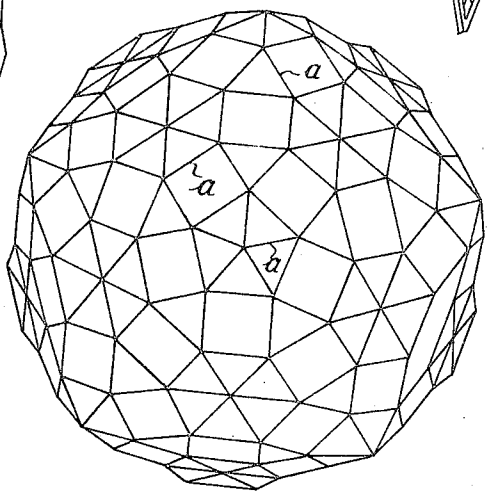


Fig. 9



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CONSTRUCTION OF STEREOMETRIC DOMES

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Continuation of abandoned application Ser. No. 364,253, May 1, 1964. This application July 16, 1965, Ser. No. 472,534
Claims priority, application France, May 2, 1963, 933,363, Patent 1,379,636
2 Claims. (Cl. 52—81)

This is a continuation of my copending application Ser. No. 364,253, filed May 1, 1964, now abandoned.

The present invention relates to improvements in building dome-shaped structures constituted by complex polyhedra whose homologous points may define a sphere, an ellipsoid or other surfaces of revolution.

Such surfaces of revolution have great stability and, therefore, are advantageously used as a building configuration. However, they have the disadvantage of not being capable of formation by simple plane structural components while mass production of relatively large dome-shaped structures makes it imperative to use only a limited number of different standardized components, such as rods, sheets and the like.

For example, a polyhedral tesselation may be obtained by subdividing a spherical surface into a plurality of polygonal segments but this tesselation will be irregular because it is not readily possible to divide the sphere into identical polygons or at least a small number of different types of polygons which are as regular as possible. Furthermore, it is desirable to make the surface of the structure three-dimensional because, as is known, this increases the ability of the structure to sustain stresses.

It has been proposed to build domes of a spherical configuration in which the main structural elements are interconnected in a geodesic pattern of approximate great circle arcs intersecting to form a three-way grid defining substantially equilateral triangles. However, this construction requires a rapidly increasing number of different types of structural components as the number of sub-divisions increases, making mass production with a small number of different-sized components impossible and further requiring the design of arbitrary profiles.

It is the principal object of the present invention to overcome these disadvantages and to provide a mass production method for building dome-shaped structures, which makes use of the principles of solid geometry. This method may be carried out with a minimum number of different structural components, using often no more than one or two standardized components and, at the same time, providing a three-dimensional surface capable of sustaining considerable stresses not obtainable by a smooth surface of revolution, the homologous points of the three-dimensional surface forming the desired surface of revolution, such as spheres, ellipsoids and the like.

This and other objects of this invention are accomplished by departing from a fictitious regular or semi-regular polyhedron as a structural pattern and so interconnecting structural components on this pattern as to form a multitude of regular polygonal faces defining alternately reentrant and salient angles therebetween. The regular polygonal faces are grouped to form polyhedra having regular polygonal bases and each polygonal face corresponds in space with a face of the fictitious polyhedron. In a preferred embodiment of the invention, a multitude of polyhedral frusta are built on successive patterns.

Such dome-shaped building structure may be composed of one or two types of standard structural components, such as rods forming merely a network or flat or skew sheets or plates forming a solid covering which is very stable and self-supporting.

The structural patterns are preferably fairly complex semi-regular solids, symmetrical solids composed of regular polygons being used. Non-spherical domes are obtained if the vertices of the polygons are not on a sphere.

The above and other objects, advantages and features of the invention will become more apparent in connection with the following detailed description of certain embodiments thereof, taken in conjunction with the accompanying drawing wherein:

FIG. 1 shows a semi-regular polyhedral structural pattern;

FIG. 2 shows a first development of this pattern by building regular pyramids having five equilateral triangular faces on the regular pentagonal faces of the pattern;

FIG. 3 illustrates a subsequent development of the pattern of FIG. 2, wherein regular pyramids having three isosceles triangular faces are built on the bases formed by the equilateral triangular faces of the pattern of FIG. 2;

FIG. 4 shows a hemispherical dome composed of ninety faces of identical isosceles triangles derived from a dodecahedral structural pattern in the general manner illustrated by FIGS. 1 to 3;

FIG. 5 is similar to FIG. 4 but has only 30 faces forming a hemispherical dome derived from an icosahedral structural pattern;

FIG. 6 is a perspective view of a dome being half that of FIG. 3;

FIG. 7 is a perspective view of a dome with 108 faces provided by six regular frusta built on each of a plurality of pentagons derived from an icosahedral structural pattern;

FIGS. 8 to 11 illustrate the step-by-step development of a complex polyhedron derived from the structural pattern of a rhombicosidodecahedron by successively building polyhedra on bases provided by the faces of each preceding polyhedron;

FIG. 12 diagrammatically shows the use of rods as structural components of a building structure according to the invention;

FIG. 13 illustrates the use of flat sheets as such building components;

FIGS. 14 and 15 show the use of skew sheets as building components; and

FIG. 16 is a perspective view, partly in section, showing one manner of interconnecting building component sheets according to the invention.

It will be obvious from a mere glance at the illustrative structural patterns and the manner of building them up, that an almost infinite variety of configurations of the final structure may be obtained by continuously building on the faces of the preceding polyhedron and always using the same, or possibly one or two other, additional structural component. It is also possible to continue such step-by-step build-up on some faces of the structural pattern only while leaving other such faces undisturbed.

Also, it is possible to retain the structural components of each structural pattern or to retain only those of the last-built structure and to remove the components of each preceding structural pattern as the next pattern is built on it. The vertices of the successive polyhedra will lie on two or more concentric surfaces of revolution, thus creating a three-dimensional surface of great structural strength. Thus, the subdivisions produced by the method of the present invention is "stereometric" and does not follow a geodesic pattern, the successive polyhedra being formed without regard to the great circles of a sphere. In this manner, domes of a variety of shapes may be constructed with identical structural components or, at most, a very limited number of different-sized components.

FIGS. 1 to 3 illustrate the building of one embodiment of a structure according to the present invention. FIG. 1 shows a snub dodecahedron constructed from rods *a* connected at junctures *b* to define a total of 92 plane faces, i.e. 12 pentagons P and 80 equilateral triangles T. In FIG. 2, the framework has been built up by connecting five rods *a* of the same length as the length of the rods of FIG. 1 to the juncture points *b* of each pentagon so as to form five like equilateral triangles on each pentagon so that the resultant solid has 140 equilateral triangular faces. Finally, in FIG. 3, three isosceles triangles are built up on each triangular face of the solid of FIG. 2 to produce a structure with 420 plane faces defined between connected rods. The length of the rods *r* forming the isosceles triangles is such that they enclose an angle of 109° 28′.

If a regular dodecahedron is used as the starting structural pattern, i.e. a solid with 12 equal regular pentagonal faces using rods *a*, and this pattern is built up by connecting five rods of the same length to the juncture points of each pentagon to form five equilateral triangles on each pentagon so that the resultant polyhedron has 60 equilateral triangular faces, it may finally be built into the structure of FIG. 4 by building on each triangular face three isosceles triangles with rods *r* to obtain a structure with 180 plane faces of like isosceles triangles.

FIG. 5 shows another embodiment wherein an icosahedron is the starting pattern and three isosceles triangles are built on each equilateral triangle of the icosahedron with rods *b* to form a structure with 60 plane faces of the same isosceles triangles as are formed in the solids of FIGS. 3 and 4.

In FIG. 6, half of the structures of FIG. 3 is shown in perspective, the dome of this figure having 210 faces, i.e. half the number of faces of the spherical structure of FIG. 3. The homologous points of the structure, i.e. the apices of the outermost triangular polyhedra, are located on a sphere.

On the other hand, in the similar structure of FIG. 7, these homologous points are inscribed on an ellipsoid.

FIGS. 8 to 11 illustrate embodiments of a structure having more than one kind of face. FIG. 8 shows the basic structural pattern constituted by structural elements *a* constituting a rhombicosidodecahedron consisting of a total of 12 decagonal, 20 hexagonal and 30 quadratic faces. FIG. 9 shows the development of this pattern into a structure composed of a total of 330 equilateral triangles and squares produced by building 11 faces (five quadratic, five triangular and one pentagonal) on each decagonal face of the basic pattern, and by building six equilateral triangles on each hexagon of the basic pattern and five equilateral triangles on each pentagon.

A further stage of the structure of FIG. 9 is illustrated in FIG. 10. In this structure, three isosceles triangles are built with rods *c* on each equilateral triangle of the structure of FIG. 9 to form regular pyramids, and two like trapezoids and two like isosceles triangles each are built with like rods *c* on each square of the structure of FIG. 9, producing a polyhedron with one thousand and eight faces. By joining together the faces forming reentrant angles, there is produced the polyhedron of FIG. 11 consisting of 360 rhombic and 180 pentagonal faces delimited by one thousand one hundred seventy identical arrises *c*.

A dome structure according to the present invention may be comprised of any portion of the described polyhedra, such as half, more than half or less than half of the complete polyhedron. It may be constructed in any suitable manner from separate components or in a single piece. Useful component parts for the construction of such domes are shown in FIGS. 12 to 16.

In FIG. 12, there is illustrated one type of structure made of individual metal rods **1**, for instance of steel or aluminum, all of the same length and joined together at joints **2**, for instance by welding, to form the arrises of a polyhedron. In another structural embodiment shown in FIG. 13, flat plates **4**, **5** are joined together along arrises **3** to form the polyhedron, all components being stamped metal sheets of like size.

Instead of using flat plates, as in the embodiment of FIG. 13, it is possible to use skew plates replacing each pair of adjacent faces **4**, **5** enclosing a reentrant angle. Such a modification is shown in FIG. 14 where hyperbolic paraboloid plates **10**, **11**, **12**, **13** are used to obtain a dome having fundamentally the geometric structure of the dome constituted by the flat plates of FIG. 13. In FIG. 5 hyperbolic paraboloid sheets **14**, **15** are used to replace pairs of adjacent faces of the polyhedron of FIG. 11, which enclose reentrant angles.

One suitable manner of joining together adjacent plates **4** and **5** is illustrated by way of example in FIG. 16. As will be noted from the drawing, each plate is stamped along its edges to form a recessed rim portion **4***b*, **5***b* and an upright flange portion **4***a*, **5***a* ending in an inwardly turned shoulder **4***c*, **5***c*. Profiled clamping plates **6** are mounted along each flange portion of adjacently assembled plates and interconnected by bolts **7** held in place by nuts **8**. In this manner, the two plates are securely joined together and the combined assembly be made fluid-proof by arranging a plastic sealing strip **9** over the inwardly turned shoulders **4***c*, **5***c* and sealing the edges of the sealing strip to the clamping plates.

It is also possible to make the components of the polyhedron of structural equilibria units such as disclosed and claimed in my copending application Serial No. 377,206, filed June 23, 1964. Furthermore, if desired, the polyhedral dome structure of this invention may be made in a single piece, for instance by casting, injection molding or any other suitable process.

The dome and its component parts may be made of any suitable structural material, such as metal, concrete plastics, plywood, glass or any combination of such materials. It may obviously be insulated, sealed, provided with desriable openings, such as windows and/or doors, stiffening members and other structural components. It may serve as a framework, a casing or a mere reinforcement to be embedded in concrete, for instance.

By way of example and without intending to be limited thereby, the hereinabove described structures may be used to build roofs, buildings, assembly halls or auditoriums, factories, warehouses, garages, sheds, greenhouses, barns and, generally speaking, any type of permanent or temporary building structure.

While the present invention has been described and illustrated in connection with certain specific embodiments, it will be clearly understood that many variations and modifications may occur to those skilled in the art without departing from the spirit and scope of this invention as defined in the appended claims.

I claim:

1. A complex polyhedral dome-shaped building structure, comprising structural components of equal length interconnected to form a multitude of polygonal faces defining alternately reentrant and salient angles therebetween, whereby one standardized component is used in the structure, said polygonal faces being grouped to form a multiple of polyhedral frusta having regular polygonal

bases and each polygonal base corresponding in space with a regular face of a polyhedron serving at least partially as a structural pattern for the building structure.

2. A complex polyhedral dome-shaped building structure as defined in claim 1, further comprising flat sheets mounted between the structural components to form the faces of the polyhedral dome-shaped building structure.

References Cited

UNITED STATES PATENTS

2,682,235	6/1954	Fuller	52—81
2,891,491	6/1959	Richter	52—81
2,914,074	11/1959	Fuller	52—81
2,978,074	4/1961	Schmidt	52—81
3,026,651	3/1962	Richter	52—81
3,061,977	11/1962	Schmidt	52—81
3,063,519	11/1962	Richter	52—81
3,114,176	12/1963	Miller	52—81
3,194,360	7/1965	Richter	52—81
3,203,144	8/1965	Fuller	52—81
3,220,152	11/1965	Sturm	52—81

OTHER REFERENCES

Modern Plastics, February 1957, p. 86. Copy in Group 350.

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