DRISHTI

A Revolutionary Concept

Geodesic Dome

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AIM:

To study, analyse and design a two-frequency (2v)

Geodesic dome

Abstract

The idea behind making a geodesic dome was so that we can study and analyse about it. A geodesic dome is a spherical structure that formed of five platonic geometry (icosahedron) used in construction. The dome utilises more volume with less surface area and materials. Of all the structures built from linear elements, Geodesic spheres are the arrangement of polygons in great circles that approximate a true sphere.

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GEODESIC DOME

1. Introduction

Geodesic - Related to or denoting the shortest possible line between two points on a sphere or curved surface.

A geodesic dome is a hemispherical thin-shell structure made out of triangles connected to form a true sphere.

The triangular elements of the dome are structurally rigid and distribute the structural stress throughout the structure, making geodesic domes able to withstand cumbersome loads for their size and weight.

The triangles are put as hexagons and pentagons to form the dome eventually.

The first dome was designed after World War I by Walther Bauersfeld for a planetarium to house his planetarium projector.

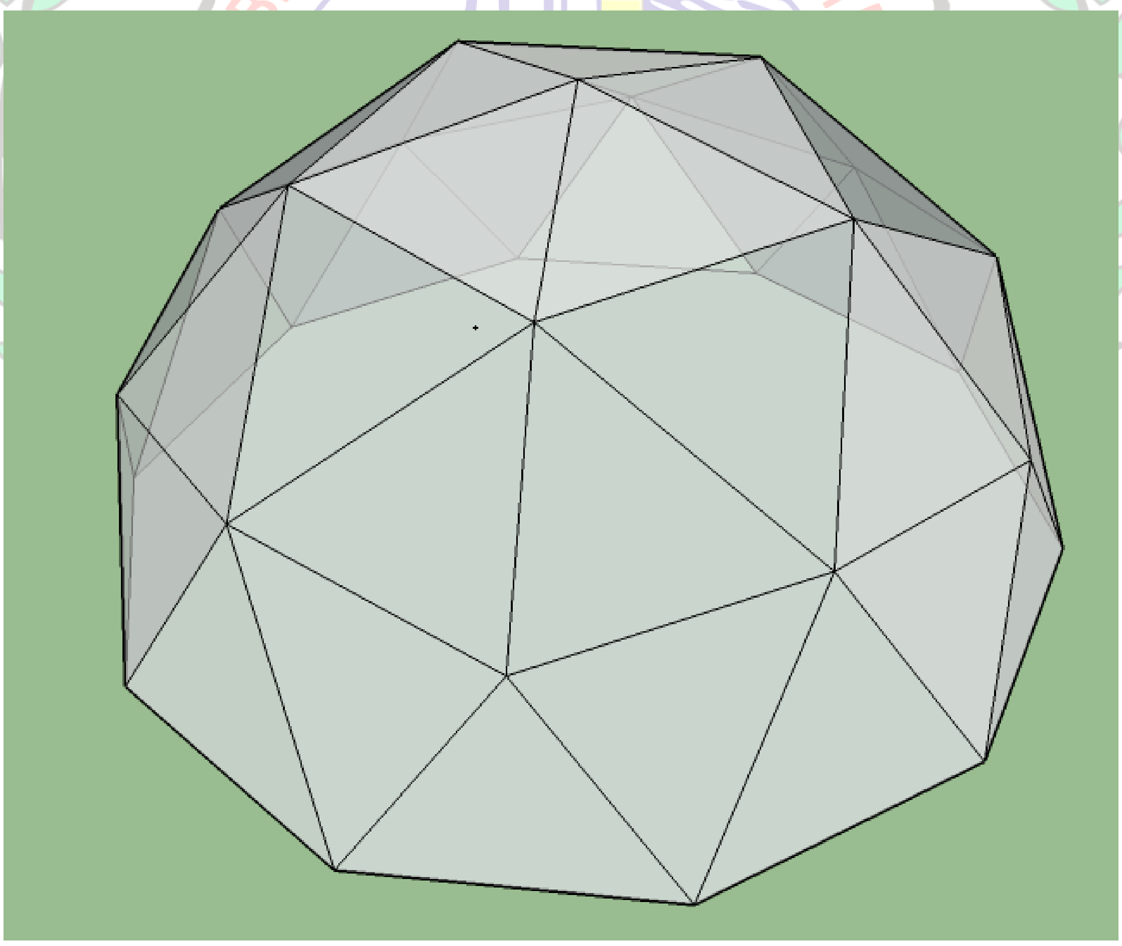


Fig 1

2. Merits and Demerits:

➢ Merits:

a) Domes are very energy efficient.
b) As there are no corners, domes are beneficial to even temperature throughout the structures and provide more efficient air circulation.
c) High volume to surface area ratio means that less building materials used, and more space is available inside the dome.
d) Geodesic domes are efficient architectural designs, and they are more durable, lighter and quicker to construct.
e) Transportation is easy as we can dismantle it.
f) The even distribution of weight throughout the structure is stable to earthquake and storms.

➢ Demerits:

a) Complex geometry shape demands more advance mathematics for structural analysis and computer modelling.
b) Getting planning permission is difficult in many places; people think that geodesic dome is not fitting with the inherent design and often object to their construction.
c) The dome shape makes various items very difficult to accommodate – chimneys, soil vents, fire escapes, windows, doors.
d) Thermal cycles from day to night stretch and stress the structure.

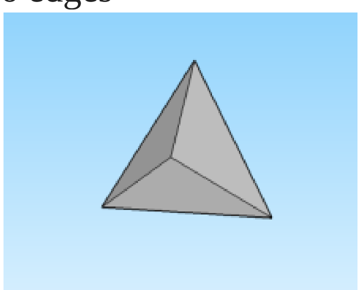
3. Platonic solids:

In three dimensional spaces, a platonic solid is a regular, convex polyhedron. It constructed by a congruent, regular polygon with the same number of faces meeting at each vertex. From all the vertices of the icosahedron, a sphere can draw.

Five solids meet these criteria:

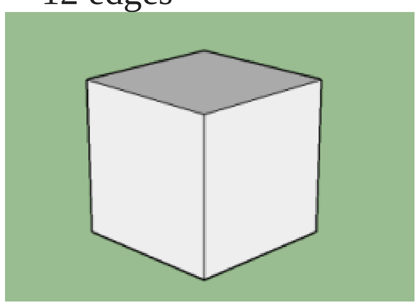
TETRAHEDRON

4 faces
4 vertices
6 edges



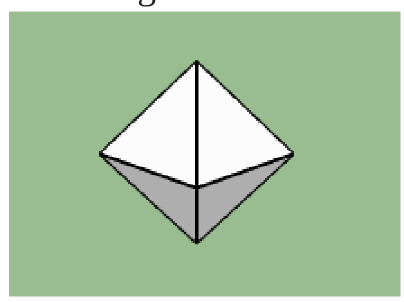
CUBE

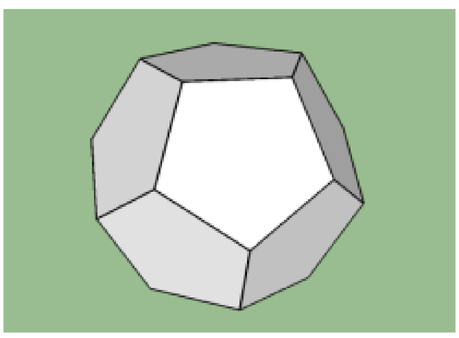
6 faces
8 vertices
12 edges



OCTAHEDRON

8 faces
6 vertices
12 edges



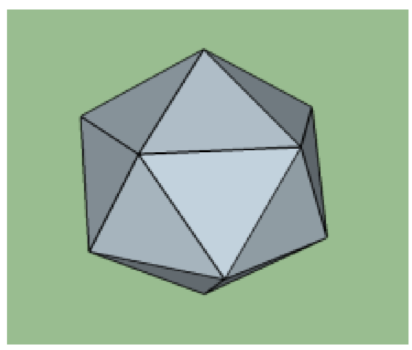


DODECAHEDRON

12 faces

20 vertices

30 edges



ICOSAHEDRON

20 faces

12 vertices

30 edges

Fig 2

Why only five platonic solids?

- Suppose P is the no. of edges of each face and Q is the no. of faces that meet at each vertex then by Euler's formula $1/P + 1/Q < ½$.
- When we add up the internal angle that meets at a vertex, it must be less than 360 degrees, because at 360-degree shape flattens out.
- It must follow Euler's formula that is for any convex polyhedron (which include the platonic solids) the no. of faces plus the no. of vertices minus no. of edges always equals to 2.

$F+V-E = 2$

3.1) Icosahedron:

An icosahedron is a polyhedron that has 20 faces, 12 vertex and 30 edges.

For a description of the polyhedron, Schlafly symbol used.

Suppose P is the no. of edges of each face of polyhedron and Q is the no. of faces that meet at each vertex of polyhedron then {P, Q} is the Schlafly symbolisation.

For icosahedron, it is {3, 5}.

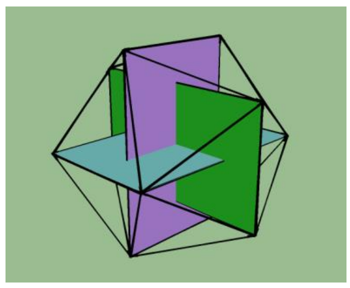


Fig 3

The figure shows an icosahedron made up of three golden rectangles placed perpendicular to each other. Then the vertices of the rectangles are joined to form equilateral triangles. The resulting figure is an icosahedron.

3.1.1) Golden ratio;

Two quantities are in the golden ratio if their ratio is the same as the ratio of their sum to the larger of the two numbers.

From Fibonacci sequence:

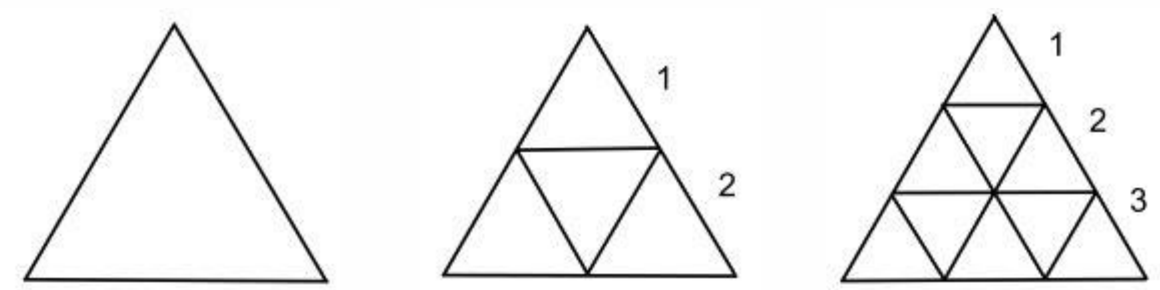
There is a special relationship between the Golden Ratio and the Fibonacci Sequence
0, 1, 1, 2, 3, 5, 8, 13, 21, 34, ...
When we take any two successive Fibonacci numbers, their ratio is very close to the Golden Ratio.

B	A	A/B
144	233	1.618055556
233	377	1.618025751

A golden rectangle is a rectangle whose side lengths are in the golden ratio of 1:1.618.

3.2) Frequency explanation:

The concept of frequency is defined as the number of parts or segments into which a principle part is subdivided. For instance, 2v means the edge of the principle triangle is equally divided into two segments; 3v means three equal segments, and so on. Higher the "v", or frequency, the more triangles there are in the geodesic dome. A higher frequency dome is more spherical than a lower frequency dome. Bigger you build a dome, the higher the frequency needs to be. But the higher frequency dome will be more complicated to build, as it will have more struts.



1 frequency,	2 frequency	3 frequency,
1 part each side	2 parts each side	3 parts each side
1 triangle	4 triangles	9 triangles

Fig 4

4.Design:

A dome of 3 feet diameter designed using SketchUp software.

Then we measured struts length, dihedral angles and axial angle from the dome design we made in software.

Verified these measurements and by calculations.

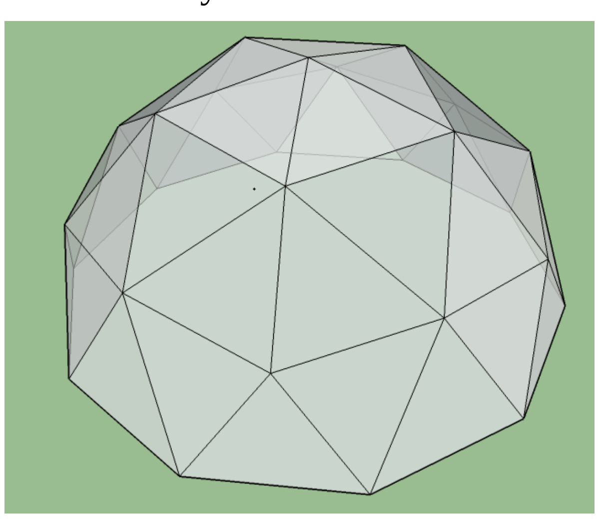


Fig 5

5. Load Distribution:

Suppose a force applied at the top of the dome: the force distribution would be like:

1. All the struts in between the layers (shown by red lines) are in compression.
2. All the struts in the layers (shown by blue lines) are in tension.

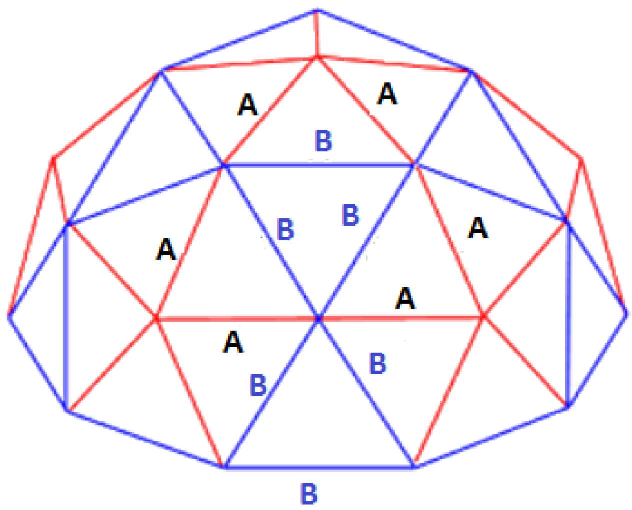


Fig 6

The load acting is evenly distributed at the bottom surface of the dome symmetrically.

6. CALCULATIONS:

a. Diameter: 3 feet

b. Number of triangle:

   1st layer: 5,

   2nd layer: 15,

   3rd layer: 20

c. Dihedral angle: 151.9 degrees and 162 degrees.

d. There is a total of 6 pentagons, 5 in the base and one at the top.

Length calculation:

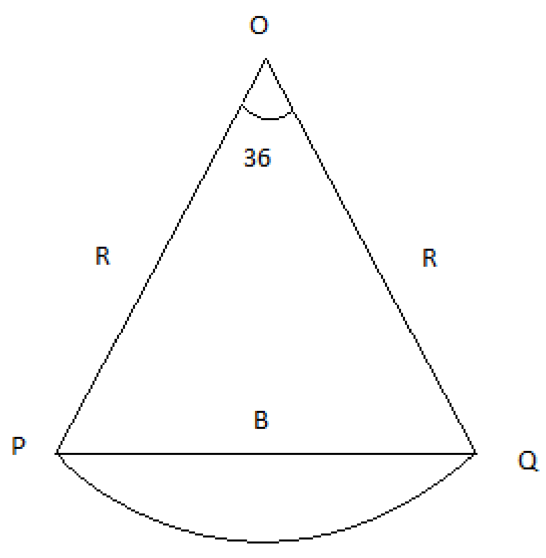


Fig.8

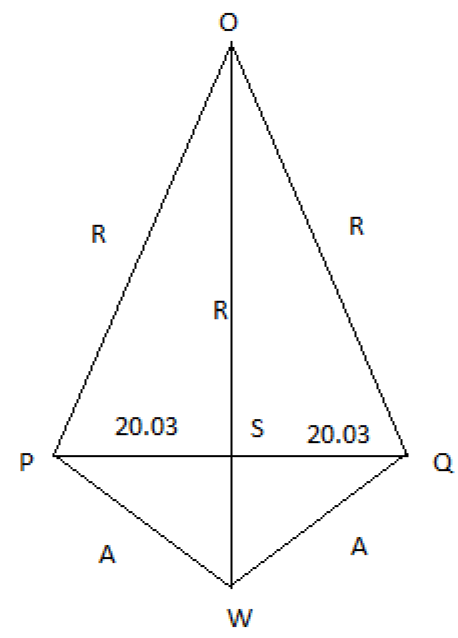


fig.9

For fig 8,

It is the triangle in which B is the base strut of the geodesic dome. And **'r'** is the radius of the base of the geodesic dome. Here P and Q are the joints.

The base of the geodesic dome is decagon so that the angle made by base strut at the centre is 36 degree.

So, by cosine formula,

$$\cos 36 = \frac{r^2 + r^2 - B^2}{2 \times r^2}$$

So we get B = 28.23 cm.

From fig 9,

A is second strut length, and **'r'** is the radius of the geodesic dome.

P and Q are the centres of any two consecutive pentagons

Distance between centres of pentagons is equal to the edge length of icosahedrons, So the length of the edge can be derived from a co-ordinate of the icosahedron, which is 40.6 mm analytically.

Triangle PSW is right angle triangle so

$B^2 = S\,W^2 + 20.3^2$

So we get B = 24.98 cm

e. Length of strut A=24.98 cm & Length of strut B=28.23 cm

f. 30 AAB isosceles triangles & 10 BBB equilateral triangles

7. Manufacturing:

Aluminium is a lightweight, malleable metal. It has high strength as compared to other materials. Also, it does not get corroded and is a durable material.

We used the malleable property of aluminium in our project as we pressed and hammered it to get the desired shape as shown.

Fig 10

In manufacturing first, to make a geodesic dome, our material is aluminium hollow rods. As per calculations, 65 struts needed, in which 30 ‘A’ type struts and 35 ‘B’ type struts.

The ‘A’ and ‘B’ strut lengths are the joint to joint distance so we added 1cm to both the sides making it 26.98 and 30.23 cm long aluminium rods to cut.

Further to join the ends of the struts, first flattened 2cm of the struts from each side.

Make holes on strut on both the sides leaving 1 cm at the ends.

The next step was the formation of the geodesic dome. For this draw a decagon on a wooden surface. Next, connect the ‘B’ length struts to make the base of the geodesic dome.

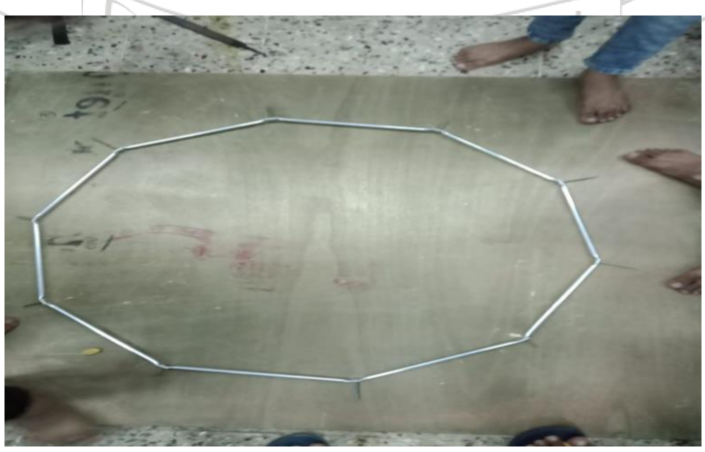


Fig 11

To make the AAB and BBB triangles, at every joint ‘A’ and ‘B’ struts are used in such a manner that the struts make the isosceles and equilateral triangles alternatively.

Fig 12

In the next step, the 1st horizontal layer (or connected the consecutive triangles) made using the ‘A’ struts.

Fig 13

Then make pentagons using ‘B’ struts and hexagons using ‘A’ struts.

Fig 14

The last step is connecting the vertex of the 2nd layer by the ‘A ’struts.

GEODESIC DOME

Fig 15

Fig 16

8. Applications & examples:

Examples	Places
1) Warehouses	Ford company, a geodesic dome by Fuller
2) Auditorium	Nevada, USA(golden turtle)
3) Greenhouses	Long Island, New York, with 70 feet diameter
4) Water Park	Sagaiga, Japan, 710 feet diameter, the world’s largest dome
5) Theatres	France, Paris
6) Temples	Maitri mandir, Tamilnadu , India
7) Laboratory	NASA, USA
8) Stadium	Fukuoka, Japan

9. FUTURE ASPECTS:

The world's first climate-controlled city built in Dubai- as in summer, the amount of heat generated in the city exceeds the maximum limit. Hence a dome is being constructed covering around 4.8 million square foot, and so the temperature can be regulated.

10. CONCLUSION:

After building the prototype of the geodesic dome, it concluded that pure mathematics required of polyhedron structure as well as specific manufacturing techniques and principles. Although geodesic domes are being ignored today, with further research and advancement, geodesic domes can gain popularity among the erudite of the construction industry.

11. REFERENCE:

Frequency explanation:https://www.ziptiedomes.com/faq/What-Is-Geodesic-Dome-Frequency-Explained.htm

Platonic solids: https://www.mathsisfun.com/geometry/platonic-solid-why-five.html

Merits and demerits: https://exinearticles.com/?Geodesic-Dome-Greenhouse:-Merits-and-Drawbacks&id=6529090

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