Study of Optimised Sectional Shape for Geodesic Domes

Aabhas Shrivastava
M.E. Computer Aided Structural Design and Drawing, Student
Ujjain Engineering College, Ujjain, Madhya Pradesh, India

Umesh Pendharkar
Prof. of Civil Engineering Department
Ujjain Engineering College, Ujjain, Madhya Pradesh, India

Abstract— This Paper gives a study on Icosahedron geodesic domes where the members in domes are assigned three different cross sectional shapes i.e. Rectangular, Square and Circular, to look for the variation in stresses. The geodesic domes are much important for the force distribution point of view the force put onto the corner of a triangle gets directly transmitted to the base of triangle, as icosahedron is made up of triangles the force gets distributed throughout the shape. The study looks over finding out cross sectional shape with lesser stress values leading to higher degree of optimization for the dome members. The models of geodesic domes are generated with help of CADRE GEO 7.0 software and analysis is carried out with STAAD.PRO V8i SS6 software.

***Keywords*- Geodesic dome, Breakdown method, Frequency, Icosahedron.**

I. INTRODUCTION

From the early old days dome had a special keen interest as capable of covering large span with least interference. Geodesic domes were first specially designed from the great efforts of a well-known scientist named Buckminster Fuller in early 1950's. He had a great emphasis over the force distribution for these domes to be similar for that of atoms and molecules, then finally came out with the results stating the pattern of load distribution to be similar to that of the truss members i.e. only axial forces tension and compression. Such domes came out to be the lightest and most efficient form of structures covering large volume with the least surface area. These domes in recent times have brought out special light in the structure for engineers as they are very different from the regular plan forms. The geodesic domes can be made from three kind of platonic solids tetrahedron, octahedron, icosahedron all of these are just the approximation of spheres and icosahedron are very close to it and much simpler. A icosahedron is a regular polyhedron with 20sides, each of which is an equilateral triangle.

II. STUDY OF DOMES

A geodesic domes are defined as hemispherical thin shell structure made up of various geodesic polyhedron shape, where the line elements of the polyhedron are been pushed outwards to get the spherical dome shapes. Thus these are light weight structural elements forming up the interlocking polygon.

Class of Geodesic domes defines the main geodesic face of polyhedron, which is divided into two,

1) Class I the main geodesic face is full natural polyhedron face.
2) Class II the main geodesic face is not the natural polyhedron face but combination of 2 portion of adjacent polyhedron face.

ISSN No : 1006-7930

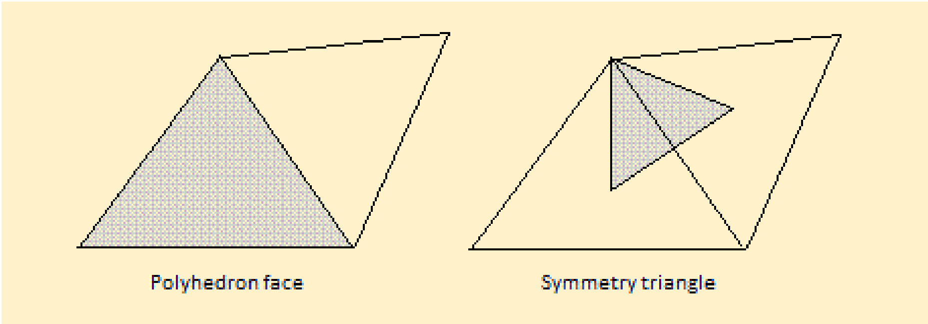

Fig. 1: Showing Class of Division

According to the type of triangulation for main polyhedron the geodesic domes are sub classified, these breakdown method are defined as the geometric technique for breaking down the geodesic face into smaller facets.

1) **Method I** accomplished by breaking down the flat triangular geodesic face sides by evenly spaced lengths (d, e and f in the picture below) then creating the mesh over the triangle in the manner shown, Then the face is projected onto the sphere. After projection, the lengths of the segments in the sides (a, b, and c) will *not* be equal nor will the spherical angles (A, B, C).

2) **Method II** accomplished by breaking down the edges of the geodesic face by equally spaced spherical angles so that d, e, and f on the flat triangle would not equal. Once projected onto the sphere the edges (a, b, c) will be equal and the spherical angles (A, B, C) will be equal.

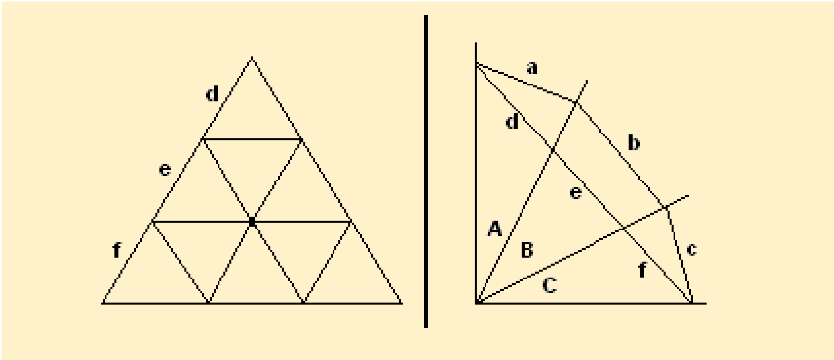

Fig. 2: Breakdown Method-I

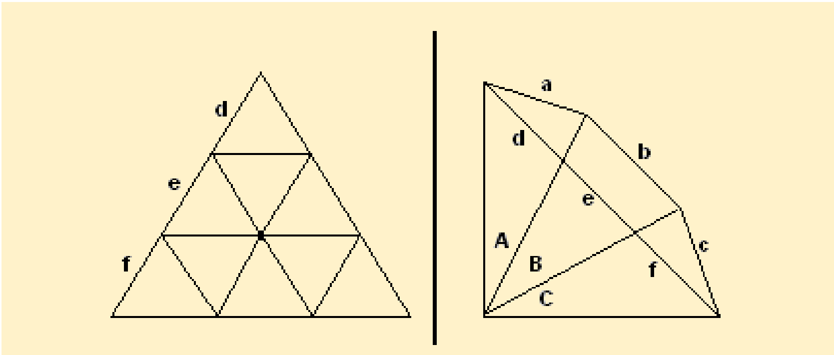

Fig. 3: Breakdown Method-II

A geodesic dome frequency can be defined as the number of parts each main edge gets divided into, the subdivision of main edges lead to increase of the strut members due to which the stability of domes also increases. The domes for even frequency are normally taken into account as the perimeter rings are evenly produced only for them.

These domes play an important role in making structure stable against forces with help of interconnected triangles which distribute the force evenly along its three sides, to enclose an enough amount of space without the help of any column. They can be used up for covering up assembly halls, planetarium, aqua pods for fish farming, swimming pools, defense shelter, green houses and various tourist attraction living places.

III. MODELING AND ANALYSIS

A. Model

1) Dome having a radius of 12m with frequency 2υ, 4υ, 6υ, 8υ, 10υ

2) Dome having a radius of 18m with frequency 2υ, 4υ, 6υ, 8υ, 10υ

3) Dome having a radius of 24m with frequency 2υ, 4υ, 6υ, 8υ, 10υ

4) Dome having a radius of 30m with frequency 2υ, 4υ, 6υ, 8υ, 10υ

The geodesic domes been modelled with the help of the CADRE Geo 7.0 software and were imported on Staad Pro V8i SS6 software for modelling and analysis purpose. Basic requirement for geodesic domes is equilateral triangle, with all same size, and making equal angles with each other this can be achieved only with three mathematical platonic solids i.e. the tetrahedron, the octahedron and the icosahedron. So are these solid shapes only approximation to spheres. Thus the models are generated by sub dividing the platonic solid into number of triangles and then pushing the vertices out to the surface of sphere from the center. Breaking the triangular face of icosahedron into small triangles leads to increase of geodesic dome frequency.

Dividing a triangle into 2 number of edges on each side produces 4 triangles calling it 2frequency, dividing a triangle into 3 number of edges on each side produces 9 triangles calling it a 3frequency, similarly division of 4 number of edges on each produces 16triangle calling it a 4frequncy and so on. The member forces in geodesic domes are purely axial forces, only compression and tension and so this force passing the vertex reaches the bottom member of the beam leading to major accumulation on bottom member. Nowhere the analysis looks for design of connection thus assuming cent precent force transmission. The bottom ring beam members (highlighted in fig. 4) of domes are analyzed over variation in stresses for different sectional types but having same cross sectional area.

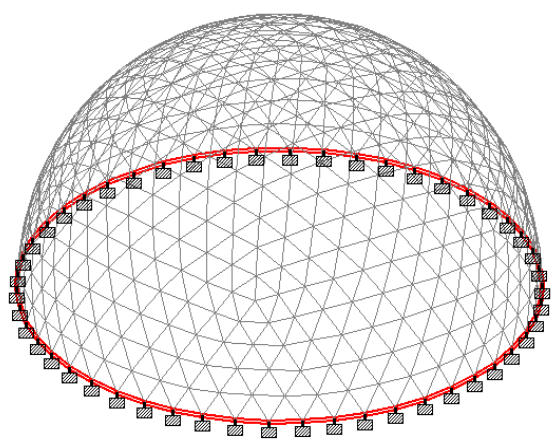

Fig. 4: Highlighted Bottom Ring Beam of Geodesic Dome

Table 1: Material Properties of Member

Member material	Fy (KN/mm^2)	Density (Kg/m^3)	Poisson's Ratio
Steel	253.2 X 10^{-3}	7833.409	300 X 10^{-3}

B. Cases
1) Assigning rectangular hollow tubular section to members.
2) Assigning square hollow tubular section to members.
3) Assigning circular hollow tubular section to members.

The purpose behind carrying out this study work is to look for which section type is the least stressed among them so that we can switch to a lower dimension one leading to the reduction in weight and ultimately for cost reduction.

Table 2: Section Properties of Member

Section type	Dimension (mm)	Thickness (mm)	Area of cross-section (cm^2)	Unit weight (kg/m)
Rectangular hollow	80 X 40	4.0	8.55	6.71
Square hollow	60 X 60	4.0	8.55	6.71
Circular hollow	88.9 (dia)	3.2	8.60	6.71

IV. RESULTS

Stress value due to dead weight of the structure with radius of 12m, 18m, 24m, 30m, 36m are tabulated below

Table 3: Stress Values for Different Cross Sectional Shape with Radius of Dome 12m

Dome frequency	Stress values for Cross-sectional shape (N/mm^2)		
	Circular	Rectangular	Square
2	4.25	4.647	5.185
4	1.091	1.191	1.329
6	0.473	0.516	0.575
8	0.269	0.285	0.318
10	0.165	0.180	0.201

Table 4: Stress Values for Different Cross Sectional Shape with Radius of Dome 18m

Dome frequency	Stress values for Cross-sectional shape (N/mm^2)		
	Circular	Rectangular	Square
2	9.581	10.455	11.665
4	2.455	2.679	2.989
6	1.063	1.160	1.295
8	0.587	0.640	0.715
10	0.371	0.404	0.451

Table 5: Stress Values for Different Cross Sectional Shape with Radius of Dome 24m

Dome frequency	Stress values for Cross-sectional shape (N/mm^2)		
	Circular	Rectangular	Square
2	17.032	18.586	20.739
4	4.365	4.763	5.315
6	1.891	2.063	2.302
8	1.043	1.138	1.250
10	0.659	0.719	0.802

Table 6: Stress Values for Different Cross Sectional Shape with Radius of Dome 30m

Dome frequency	Stress values for Cross-sectional shape (N/mm^2)		
	Circular	Rectangular	Square
2	38.223	41.819	46.662
4	9.821	10.717	11.958
6	4.254	4.642	5.180
8	2.347	2.561	2.858
10	1.482	1.618	1.805

V. CONCLUSION

From the above table it is observed that

a) Stress values are maximum for square hollow tubular sectional shape.
b) Minimum stress value is obtained for circular tubular sectional shape.
c) It could be stated that a lower cross section member can be used for circular hollow tubular ultimately leading to reduction in deadweight of the structure and cost effective.

REFERENCES

1. Laxmipriya S, Ragavi G, Sakthisree M. (2017), “The Concepts behind the Design of Geodesic Domes – An Overview” in Imperial Journal of Interdisciplinary Research (IJIR) Vol-3, Issue-3.
2. D. Mandali, (2016), "Comparative Study for Geodesic Dome of Class 1 Subdivisions," JETIR, Vol. 3.
3. Saka, M. P., (2007), “Optimum Design of Steel Frames using Metaheuristic Search Techniques Based on Natural Phenomena: A Review”, Civil Engineering Computations: Tools and Techniques, Ed. B. H. V. Topping, Saxe-Coburgh Publications, pp.: 105-147.
4. Ravi Manne, Snigdha Kantheti, (2020), "COVID-19 and Its Impact on Air Pollution", International Journal for Research in Applied Science & Engineering Technology (IJRASET), ISSN: 2321-9653, Vol. 08, Issue 11, pp. 344-346, DOI: https://doi.org/10.22214/ijraset.2020.32139
5. Kubic, M., (2009), Structural Analysis of Geodesic Domes. Durham University School of Engineering. Final Year Project.
6. Groza Othilia, (2013), “Geodesic Structures”, International Journal of Education and Research in Vol. 1 No. 5 May.
7. Davis, T. (2011), Geodesic Dome, Pacific Domes, California.
8. Hosseini, M., Hajnasrollah, S., and Herischian, M. (2012), "A Comparative Study on the Seismic Behavior of Ribbed, Schwedler, and Diamatic Space Domes by Using Dynamic Analyses." Proceedings of the 15WCEE, Lisbon, 24-28.