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Analysis and Design of Geodesic Dome to Resist Wind Load

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Abstract:- The world is facing a very challenging and difficult civil engineering structures such as geodesic structures. Quite, often geodesic structures are more helpful in area with more earth quake and stroms. A wide amount of research is going on in the field of design of geodesic domes. it is also noted that the geodesic domes are fully capable of resisting wind loads due to its shape. The geodesic is also an eco friendly. In this present paper, a geodesic dome is modelled using staad.pro and analysed for wind loads. After being analyzed ,the maximum axial forces, maximum bending moment ,maximum deflection of geodesic dome will be found out.

Keywords:- *Geodesic domes, wind load, STAAD. Pro.*

I. INTRODUCTION

Engineers and architects have always had a special interest on structural systems such as frame models and domes that enable them to create large area spans with minimal interference from internal supports. dome structures are capable of obtaining maximum volume of area with minimum surface area. Domes are one of the oldest and cheapest forms of structural frames and have been used in architecture since earlier times. The earliest model of geodesic dome was designed by Walter Bauersfeld and he built the model in Jenaon the year 1922. The dome model was not popular on those days. The dome model became popular on 1950s,it was due to the work of Buckminster Fuller an American born architect. He developed a new design of geodesic domes and filed for a patent in 1951 for his improved Version.the designed model Has been used in structures such as the Tacome Dome (WA,USA) Poliedro de Caracas (Caracas, Venezuela) and The Eden Project (Cornwall, UK).

Geodesic domes original design,designed by Buckminster Fuller on the sphere was an division of icosahedron,but divisions such as octahedron and dodecahedron have been used in construction of symmetry systems to circmvent Buckminster Fuller patent. The aforementioned shapes are all part of the family of platonic solids. A entirely congruent regular polygons makes up polyhedron shape . if an icosahedron shape exploded onto the surface of a sphere, it produces twenty equilateral spherical triangles.The vertices of icosahedron which can also be described by the intersection of three great circles (circles with a diameter equal to that of the sphere) and are referred to as geodesic points. A group of fifteen great circles define the primary bracing of a geodesic dome. If the chords that join the vertices should be straight lines rather than curves it lead to the formation of planar triangles and this creates strongest network known as geodesic domes commonly used in structures.

As the diameter of the dome increases,the members of the dome quickly devolp excessive slenderness ratio.Due to this circumstances the primary bracing cannot be used in pratical.it lead to the introduction of secondary bracing.

To obtain a more strength and regular network of dome a secondary bracing is introduced in the dome. A dome can be modularly dividing each equilateral spherical triangle into a number of “subdivisions” of dome which is also known as “frequency”. geodesic subdivision are classified into two classes; Class I subdivision, Class II subdivision.

In the Class I subdivision the edges are parallel to dividing lines of the primary bracing; in Class II subdivision , the edges are perpendicular to dividing lines of the primary bracing.Class I subdivision produces geometry where the edges of the triangle lie on a great circle, it leads to simple hemisphere design with planar connections; this may not be possible with a Class II subdivision. Class II subdivisions domes require a smaller number of strut lengths, which is a great advantage for fabrication purpose. If the differences between two individual classs strut lengths are taken,it resultantly greater in a Class II dome because the dome produces a less uniform stress distribution. Additionally, Class II domes can only be achieved with an even frequency of subdivision.

A subdivision, or “frequency” can be defined as the number of triangles at each edge of the primary bracing in divide. The frequency is often referred short term as a number, or with the prefix letter “V”. It is noted that if secondary bracing is introduced in the dome, the triangles used in domes are no longer perfectly equilateral ,the bars or strut forming the skeleton show variations in both length, and the number of strut lengths required to fabricate the dome, as the dome size increases, there will be the increase frequency of subdivision. hemispherical shape cannot be formed by odd frequency order of domes, the equatorial spherical perimeter ring is the only form for even order frequenciesof domes. Odd order frequency of domes subdivisions are generally referred to with the suffix 5/8ths or 3/8ths, to indicate respectively if the ground ring is below or above the equator line of the geodesic sphere of dome.

II. LITERATURE REVIEW

A geodesic dome uses Self-bracing triangles, it is highly Stabe structures with the least useage of material for its theory creating. In addition with that it meets many of visual attractions that are important in architectural. Design. The Omni-triangulated structure of the geodesic domes provides inherently a very stable form. To counteract wind load the most stable H/D ratio is 0.4 among all diameters and H/D ratios analyzed and 0.2 is least suitable.

III. BEHAVIOR OF GEODESIC DOMES

The configuration of the members of dome decides the manner in which a braced dome have to be. Fully triangulated domes have higher stiffness when compared to semi triangulated domes, since geodesic dome is also a fully triangulated dome it also have high stiffness in all direction.the geodesic domes are kinematically stable,when it has no mechanism it is idealised as space truss.a dome will not be kinematically stable when it is not fully triangulated and it will be idealised as truss.

The stiffness of the dome s may vary greatly on domes surfaces in all directions.the forces acts on the network of dome was an equilibrated combination of compression forces and tension forces. The compression forces are discontinuous and cesarelocal,while the tension forces are contionous and global. Buckminster Fuller coined the term tensegrity as an "a portmanteau of tensional integrity, to convey the concept of coherence and resilient elasticity of geodesic networks".

IV. STRENGTHS AND WEAKNESSES OF GEODESIC DOMES

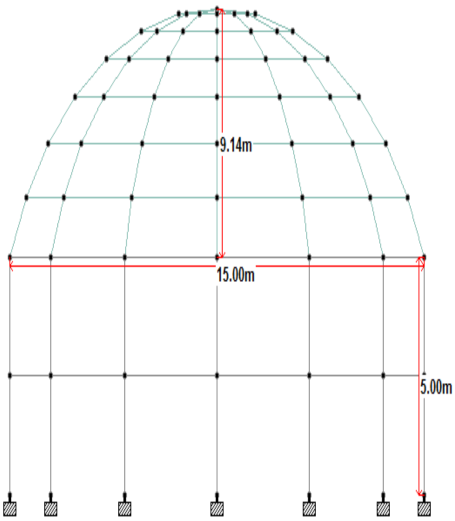
The resistance against seismic shock co-relates with the degree of compaction of the building. The most geometrical form of constructon is a hemispherical structure,which encloses a minimum surface area with maximum volume. The reinforcing elements should be locating close to the building and distributed uniformly all over the structure of the dome.the reinforcing elements are symmetrical and rigid.the frame of the geodesic dome follows the same. The geodesic domes has low centre of gravity,it is lower than mass point of any cubiod structure of similar proportions. The core grid of construction should be deformable and elastic to a certain extent,since the geodesic domes follows the same concept of core grid, it is proven that geodesic domes can survive stroms, severe earthquakes with few cracks in the cladding. For geodesic domes ,deep foundations are generally not required. Because of the light weight, round shape and uniform load distribution shallow foundations are used.the use of shallow foundation in construction generally reduces both time and money than deep foundation.

The geodesic dome to has its own disadvantages, one of the important and difficult in the construction of geodesic domes are perimeter chords with the shape of an icosahederon has irregular or raggedline that may be difficult in architectural grounds. The outside apperence of geodesic dome depends on how the closures are treated. Due to the hemispherical shape of geodesic dome structure, it is difficult to achieve effective sound isolation during the portioning of rooms. This leads to the loss of privacy and disturbances from other rooms. The furniture are custom designed one,which increases the cost for desining and executing. Due to the curved walls of the structure, there will loss in space in rooms.

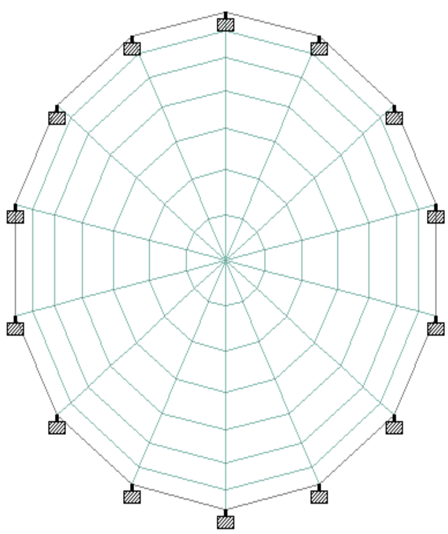
V. ANALYTICAL MODEL OF GEODESIC DOME USING STAAD.Pro

A plan for model to be analysed is drawn.

A model of geodesic dome with diameter of 15 metre is drawn.



Elevation



Plan

Fig 1:- Dome of 15m span

VI. LOADS APPLIED:

Loading criteria for dead load, live load and wind load are applied. For dome shaped type structures are having wind load as a dominating force. Wind load is calculated by ASCE-7-2010 and applied on models. Load combinations are considered as per IS 456(part1):2000. Which are, Load combination 4 :- 1.2 (Dead Load + Live Load(imposed load) + Wind Load)

Dead Load (Self weight):
Dead load in terms of self weight is considered as weight of members and covering material. Here we are considering covering concrete as structural element, which also transfer the load to the members

Live load (imposed load):
A vertical imposed load of 0.5 kN/m2 is applied and it is taken based on the codal provision IS:875 – part 2.

Wind Load:
The wind load calculations on the structure was calculated by ASCE-7-2010 shown in figure 6. The basic wind speed is considered as 85 mp/hr. The building classification category is II. The explosure category is "B". The above given data is used to calculate wind load in STAAD.Pro

Load combination:
Load combination are considered as per IS 456(part1):2000. Which are, Load combination 4 :- 1.2 (Dead Load + Live Load + Wind Load).

Design of model:
The whole structure is a concrete design based on codal provision Is 456:2000 . The concrete grade used in the structure is M_{25}. The steel grade used in the structure is Fe_{550}. The column was a circular column with diameter 0.4 metre. The beam was rectangular beam with size 0.23X0.23 metre. The following parameters given above is applied to the structure and then analysed to check whether the structure is stable or not. Analysis is carried out,and it is found that the structure is stable,the analyse report states that the structure is having 0 errors and 1 warning.

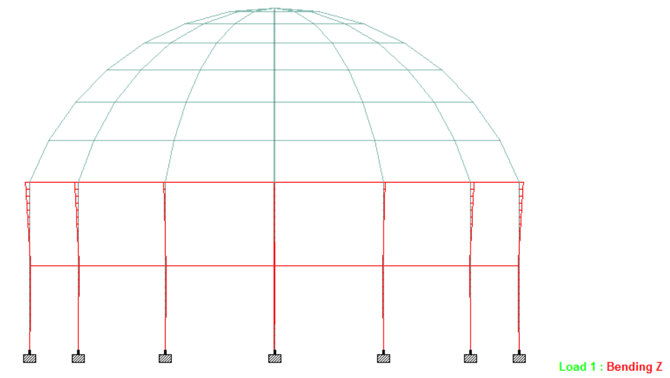


Fig 2:- Lateral Displacement

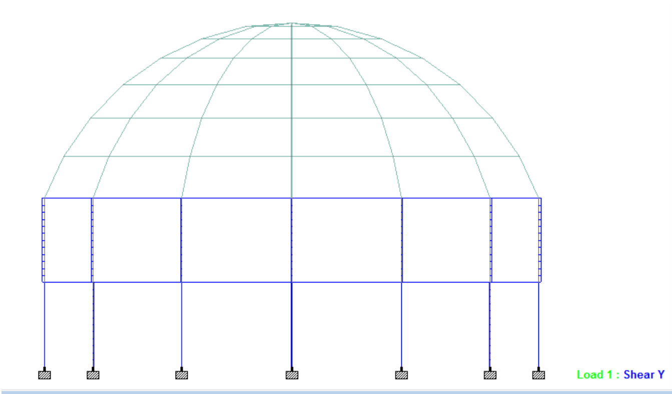


Figure 3: Shear Force

VII. RESULTS AND DISCUSSIONS

Beam forces

- The maximum fx values was 240.856 KN occurs on beam 105.
- The minimum fx values was -63.411 KN occurs on beam 101.
- The maximum fy values was 11.002 KN occurs on beam 119.
- The minimum fy values was -11.002 KN occurs on beam 154.
- The maximum fz values was 11.285 KN occurs on beam 99.
- The minimum fx values was -11.285 KN occurs on beam 134.
- The maximum My values was 22.081 KN occurs on beam 134.
- The maximum Mz values was 21.527 KN occurs on beam 114.

NODAL DISPLACEMENTS

- THE MAXIMUM DISPLACEMENT OF NODE IS 0.404MM AT X DIRECTION ON NODE 4.
- THE MINIMUM DISPLACEMENT OF NODE IS -0.404MM AT X DIRECTION ON NODE 11.
- THE MAXIMUM DISPLACEMENT OF NODE IS 0.700MM AT Y DIRECTION ON NODE 31.
- THE MINIMUM DISPLACEMENT OF NODE IS -0.900MM AT Y DIRECTION ON NODE 99.
- THE MAXIMUM DISPLACEMENT OF NODE IS 0.414MM AT Z DIRECTION ON NODE 1.
- THE MINIMUM DISPLACEMENT OF NODE IS -0.414MM AT Z DIRECTION ON NODE 8.

VIII. CONCLUSION

Dome shows good performance against the vertical loads.Due to its structural symmetry and shape,it provides good performance against vertical loading.it is observed that top plate are subjected to tensile forces,where as the bottom forces are subjected to compressive forces.The deflections of the members is very low The nodal displacements due to horizontal loads are also low..The dome have good resistant to wind loads at a H/D ratio of 0.6.

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