COMPARATIVE STUDY FOR GEODESIC DOME OF CLASS 1 SUBDIVISIONS

[1]Divyesh G. Mandali, [2]Satyen D. Ramani

[1]PG Student, Department of Civil Engineering, [2]Asst. Professor, Department of Civil Engineering,
SAL Institute of Technology and Engineering Research, Ahmedabad, Gujarat, India

Abstract- In this paper, comparison of geodesic dome is carried out for 20 meter diameter and class 1 division methods. Class1 method1 and class1 method2 both are used for different frequencies. Model of dome is generated in CADRE GEO 7.0 software. Analysis and design is carried out by STAAD Pro V8i SS5. Optimization is performed using STAAD in-built optimization tool.

Keywords: Geodesic dome, cadre geo, braced domes, wind load.

I. INTRODUCTION

A dome is one of the oldest structural forms and it has been used in architecture from earliest times. Domes are of special interest to engineers and architects as they enclose a maximum amount of space with a minimum surface and have proved to be very economic in the consumption of construction materials. A dome is been proved as a most efficient self supporting structure for a large area due to its two curved direction.

Domes can be exceptionally suitable for covering sports stadia, assembly halls, exhibition centers, fish-farming aqua pods, swimming pools and industrial buildings, for getting large unobstructed areas with minimum interference from internal supports.
Domes are given different names depending upon the way their surface is formed. Geodesic dome is a typical example of braced dome. Nowadays it is widely adopted for construction of exhibition hall all over the world.
Geodesic domes constitute an important family of braced domes offering high degree of regularity and evenness in stress distribution. Data preparation and handling of graphics for geodesic forms are difficult and time consuming tasks and are the stages of analysis where mistakes are most commonly made.

Architect and engineers have been excited about the possibilities of space structures for the past many years. They offer opportunities for variation in plan form and building profile, large uninterrupted spans, excellent distribution of loads, optimum utilisation of materials and prefabrication and mass production of easily transportable components. Hugh Kenner [1] studied and described all the mathematical information about division of geodesic features with explanations. M.P. Saka [2] studied for optimum geometry design for geodesic domes using harmony search algorithm. Eltayeb Elrayah Kralafalla [3] prepared computer aided processing of geodesic structural forms with detailed information about geometry division and results. Marek Kubik [4] studied and prepared excel sheet for design of pabal dome for Maharashtra where people were affected by 1993 killari earthquake to provide economic shelter to them.

Breakdown system provides some of the criteria for choosing the polyhedron. All system starts with triangular polyhedron face and subdivide it with a three way grid. Then push all vertices of the grid outward till they are a common distance from the center. By this way we will get division method. In the present study class1 method1 and class1 method2 domes with different frequency is carried out for analysis and design.

II. PRESENT STUDY

Geometry of class1 method1 and class1 method2 type geodesic domes for frequency 4, 6, 8, 10 and 12 for 20 meter diameter of geodesic dome are carried out and imported it to STAAD Pro for analysis and design. Generation of geometry is shown in Fig1. All Models of class 1 division for required frequency are given below.

Table 1 Generation Details

Sr no.	Models	Diameter(m)	Height(m)	Method	Frequency
1	Model11-4-10	20	10	Class1 Method1	4
2	Model12-4-10	20	10	Class1 Method2	4
3	Model11-6-10	20	10	Class1 Method1	6
4	Model12-6-10	20	10	Class1 Method2	6
5	Model11-8-10	20	10	Class1 Method1	8
6	Model12-8-10	20	10	Class1 Method2	8
7	Model11-10-10	20	10	Class1 Method1	10
8	Model12-10-10	20	10	Class1 Method2	10
9	Model11-12-10	20	10	Class1 Method1	12
10	Model12-12-10	20	10	Class1 Method2	12

Where, Model11-6-10 suggests that it is generated by class1 method1 with 6 frequency division and having radius 10 meter. Figure 1 shows geodesic Model11-6-10 geometry.

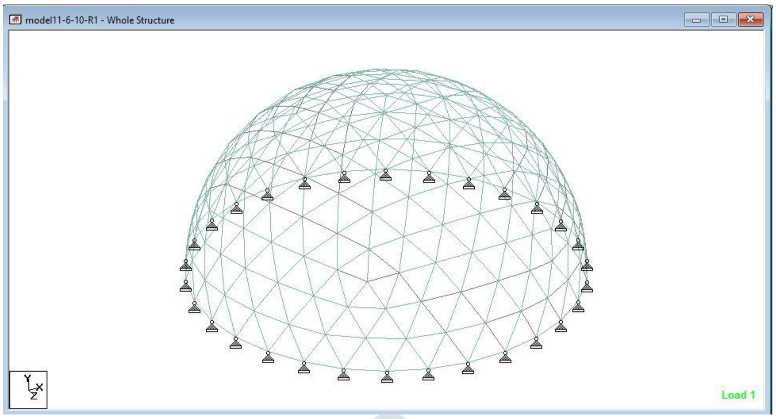

Figure 1 Geometry of Model11-6-10

III LOADING CRITERIA AND GROUPING

Loading criteria for dead load, live load and wind load are applied. For hemispherical shaped type structures are having wind load as a dominating force. Wind load is calculated by IS-875-3(1987) and applied on models. Application of wind load on structure is shown in Fig 2 and Fig 3.

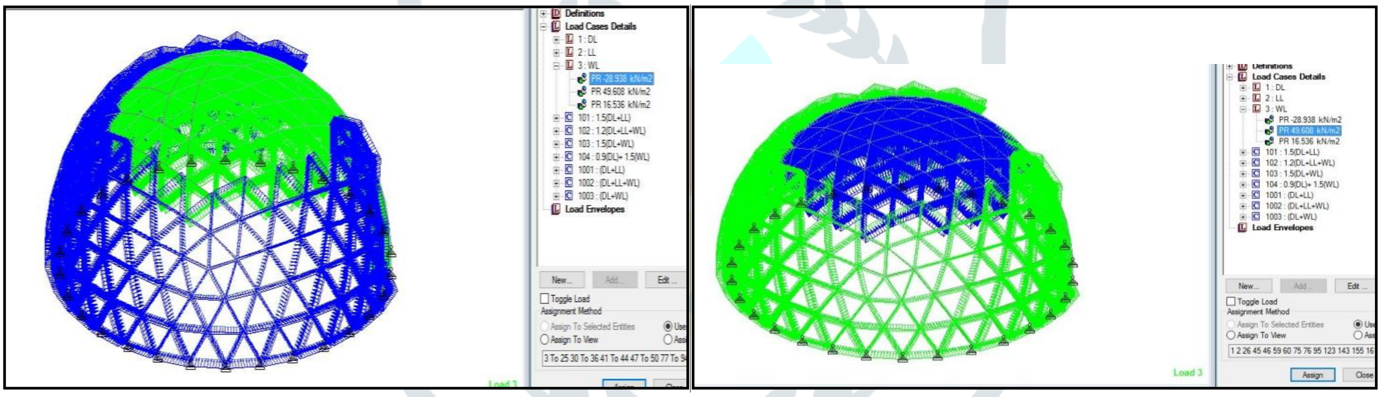

Figure 2 Application of Wind load pressure Pz_1 and Pz_2

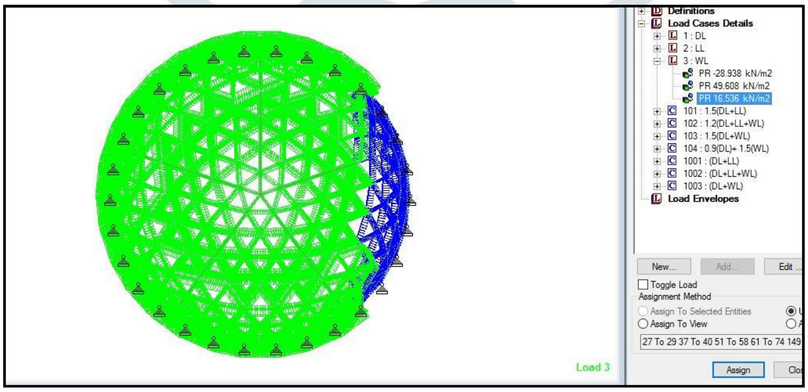

Figure 3 Application of Wind load pressure Pz_3

Load combinations are considered as per IS 1893(part1):2002 (clause 6.3.1.2). Which are,

Load combination 101:- 1.5 (Dead Load + Live Load)
Load combination 102:- 1.2 (Dead Load + Live Load + Wind Load)
Load combination 103:- 1.5 (Dead Load + Wind Load)
Load combination 104:- 0.9 Dead Load + 1.5 Wind Load

Other loads to fulfill serviceability criteria are provided are,
Load combination 1001:- Dead Load + Live Load
Load combination 1002:- Dead Load + Live Load + Wind Load
Load combination 1003:- Dead Load + Wind Load

Here we have considered dome covered by non structural covering roof. It has no stiffness and can only pass the load into members of the structure. Deflection criteria and strength criteria are considered for design parameter. The modulus of elasticity is taken as 205KN/mm^2. The circular hollow pipe sections given in Indian standard section database are selected to be used for the design purpose. The sectional designations are varying from the PIP213L to PIP3556H.

For designing Model11-6-10, it is decided to group the members of structure by observing axial force diagram of dominating load combinations. Here combination of wind load is dominating and its axial force diagram is shown in Fig 4.

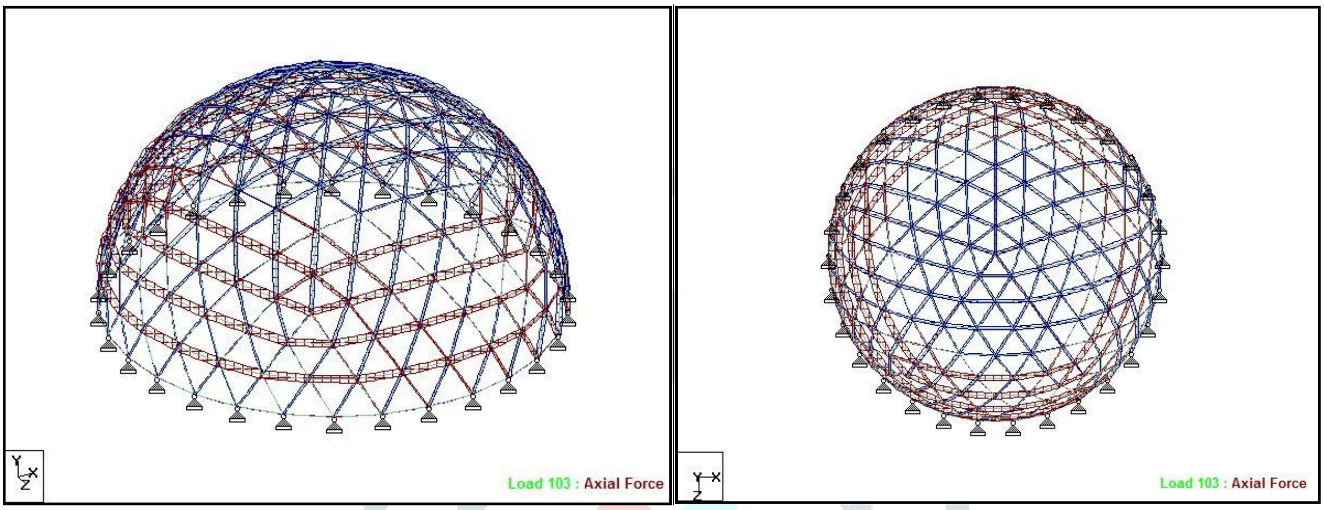

Figure 4 Isometric view and top view of axial force diagram for Model11-6-10

It is decided after observation that bottom rings are having maximum compressive axial force and can be grouped together. For example, bottom 4 numbers of rings are having maximum compressive axial force are grouped individually and named as RING2 , RING3, RING4 and RING5 respectively. From crown to RING5 members are grouped as a TOP-PENTAGON. Remaining bottom diagonal members between horizontal rings are grouped as BOTTOM. Hence in this case total 6 groups are derived. Sectional properties of all members will be different after optimizing the model. Grouping of dome is shown below in Fig 5, Fig 6and Fig 7.

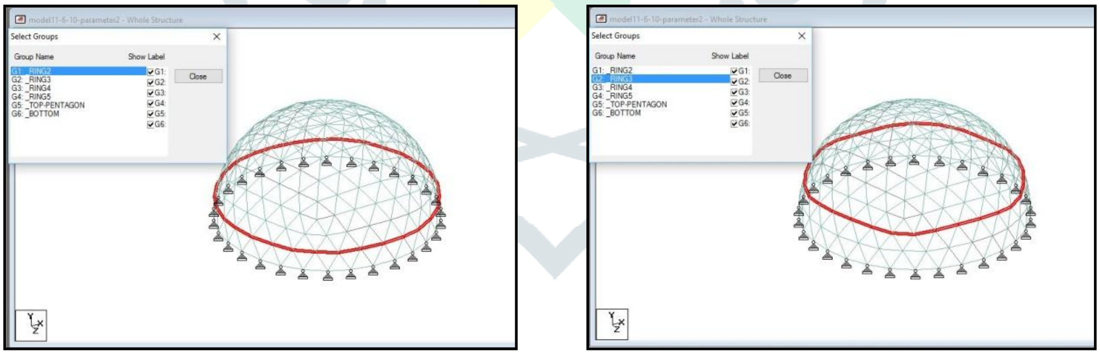

Figure 5 Grouping members RING2 and RING3

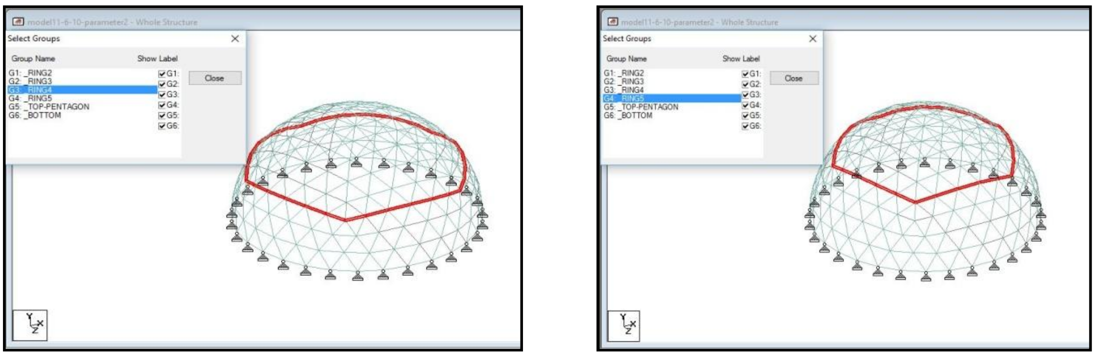

Figure 6 Grouping members RING4 and RING5

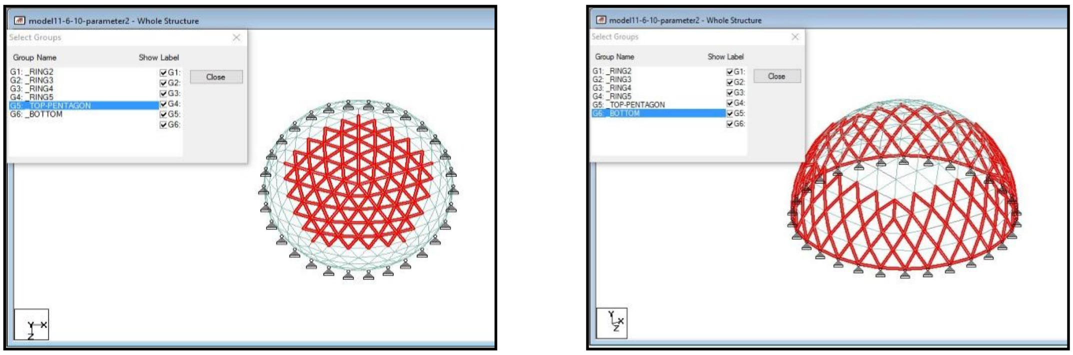

Figure 7 Grouping members TOP-PENTAGON and BOTTOM

Section obtained for each group for all models are given in result.

IV RESULTS COMPARISON

Section obtained for groups after optimizing the structure for models are tabulated in Table 2 to Table 6. These members are related to optimized design based on both strength and deflection criteria as mentioned before.

Table 2 Section designation for frequency 4 models

Method	Model Name	Group Name	Section Size
Class1 Method1	Model11-4-10	RING1	PIP3239H
		RING2	PIP3239H
		TOP PENTAGON	PIP2191L
		BOTTOM	PIP1937H
Class1 Method2	Model12-4-10	RING1	PIP3239H
		RING2	PIP3239H
		RING3	PIP2191M
		TOP PENTAGON	PIP2191M
		BOTTOM	PIP2191M

Table 3 Section designation for frequency 6 models

Method	Model Name	Group Name	Section Size
Class1 Method1	Model11-6-10	RING1	PIP1937H
		RING2	PIP1937H
		RING3	PIP2191H
		RING4	PIP1937H
		TOP PENTAGONE	PIP1651H
		BOTTOM	PIP1651M
Class1 Method2	Model12-6-10	RING1	PIP2191M
		RING2	PIP2191M
		RING3	PIP2191H
		RING4	PIP2191L
		TOP PENTAGONE	PIP1651H
		BOTTOM	PIP1524H

Table 4 Section designation for frequency 8 models

Method	Model Name	Group Name	Section Size
class1 method1	Model11-8-10	RING1	PIP1937L
		RING2	PIP1937L
		RING3	PIP1937M
		RING4	PIP1937M
		RING5	PIP1651H
		TOP PENTAGONE	PIP1524M
		BOTTOM	PIP603M

class1 method2	Model12-8-10	RING1	PIP1937L
		RING2	PIP1937L
		RING3	PIP1937L
		RING4	PIP1937M
		RING5	PIP1683H
		TOP PENTAGONE	PIP1397M
		BOTTOM	PIP1524L

Table 5 Section designation for frequency 10 models

Method	Model Name	Group Name	Section Size
class1 method1	Model11-10-10	RING1	PIP1524M
		RING2	PIP1524M
		RING3	PIP1524M
		RING4	PIP1524M
		RING5	PIP1651M
		RING6	PIP1937L
		RING7	PIP1397M
		TOP PENTAGONE	PIP1270M
		BOTTOM	PIP1270L
class1 method2	Model12-10-10	RING1	PIP1524M
		RING2	PIP1524M
		RING3	PIP1524M
		RING4	PIP1524M
		RING5	PIP1651L
		RING6	PIP1683M
		RING7	PIP1524M
		TOP PENTAGONE	PIP1397L
		BOTTOM	PIP1270L

Table 6 Section designation for frequency 12 models

Method	Model Name	Group Name	Section Size
class1 method1	Model11-12-5	RING1	PIP1270M
		RING2	PIP1270M
		RING3	PIP1270M
		RING4	PIP1397L
		RING5	PIP1397L
		RING6	PIP1397M
		RING7	PIP1524M
		RING8	PIP1397L
		TOP PENTAGONE	PIP483L
		BOTTOM	PIP1143M
class1 method2	Model12-12-5	RING1	PIP1270M
		RING2	PIP1270M
		RING3	PIP1270M
		RING4	PIP1397L
		RING5	PIP1397L
		RING6	PIP1397M
		RING7	PIP1524M
		RING8	PIP1524L
		TOP PENTAGONE	PIP1270L
		BOTTOM	PIP1270L

Tonnage of all models and its comparison is shown by graph below.

Table 7 Weight of class1 method1 domes

Models	Tonnage(KN)	Frequency
Model11-4-10	217.38	4
Model11-6-10	234.706	6
Model11-8-10	266.472	8
Model11-10-10	266.256	10
Model11-12-10	285.103	12

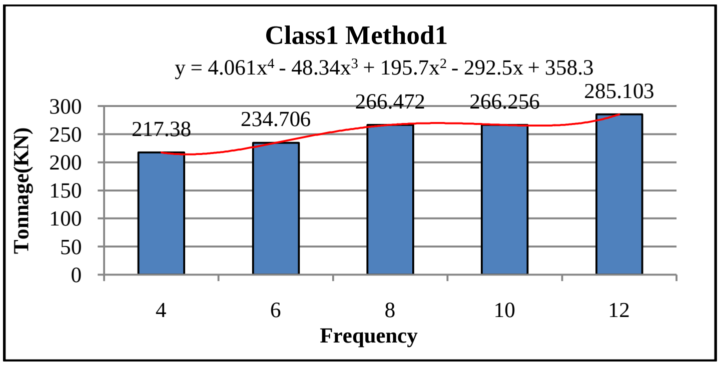

Figure 8 Tonnage comparison for Class1 Method1

Table 8 Weight of class1 method2 domes

Models	Tonnage(KN)	Frequency
Model12-4-10	238.328	4
Model12-6-10	240.185	6
Model12-8-10	253.113	8
Model12-10-10	269.418	10
Model12-12-10	299.567	12

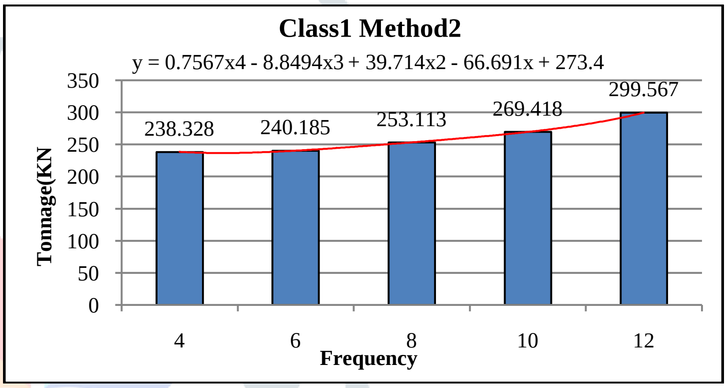

Figure 9 Tonnage comparison for Class1 Method2

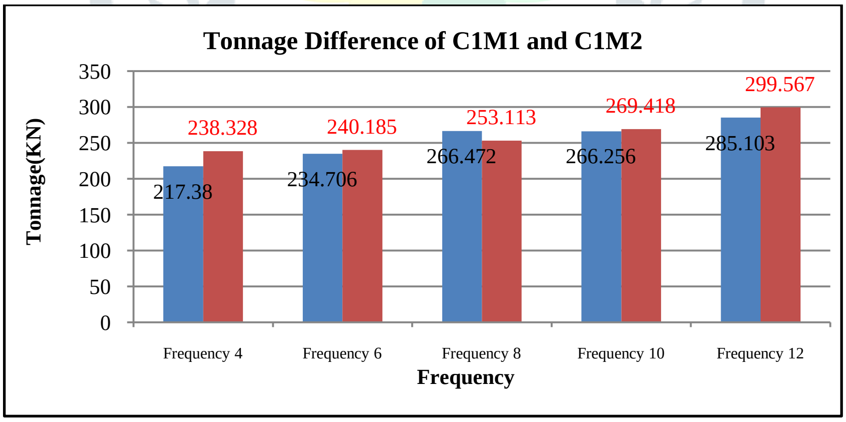

Figure 10 Tonnage comparisons of Class1 Method1 and Class1 Method2 for same frequency

V. CONCLUSION

From the graph shown in Fig 8 it is clear that the lowest tonnage for class1 method1 division is obtain for frequency 4. An empirical formula can also be suggested to estimate the tonnage particularly made from class1 method1.

$T = 4.0611f^4 - 48.348f^3 + 195.78f^2 - 292.5f + 358.38$

From the graph shown in Fig 9 it is clear that the lowest tonnage for class1 method2 division is obtain for frequency 4. An empirical formula can also be suggested to estimate the tonnage particularly made from class1 method2.

$T = 0.7567f^4 - 8.8494f^3 + 39.714f^2 - 66.691f + 273.4$

where, T=quantity in tonnes

f= frequency

As frequency increases tonnage is increasing simultaneously for class1 method2 but member sizes reduces as frequency increases as shown in comparison table 2 to table 6

From the graph shown in Fig 10 for frequency 4 class1 method1 division is preferable where for frequency 8 class1 method2 division is preferable for obtaining optimum tonnage.

REFERENCES

[1] Hugh Kenner "Geodesic math and how to use it", University of California Press Berkeley, Los Angeles, London

[2] Marek Kubik,"Structural analysis of geodesic domes", Durham university school of engineering, April 29,2009

[3] Eltayeb Elrayah Kralafalla, "Computer Added Processing Of Geodesic Structural Forms" A Thesis Submitted For The Degree Of Doctor Of Philosophy University Of Surrey Department Of Civil Engineering , August 1994

[4] IS 875 (Part 3) 1987- Code of Practice for design Loads (Other than Earthquake) for Building and Structures

[5] M. P. Saka, "Optimum Geometry Design of Geodesic Dome Using Harmony Search algorithm", Advances in structural engineering volume-10 No. 6 2007.

.