International Journal For Technological Research In Engineering
Volume 4, Issue 2, October-2016 ISSN (Online): 2347 - 4718

# A PARAMETRIC STUDY ON STEEL DOME STRUCTURES

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***Abstract: In the recent years, there have been an increasing number of structures using steel domes as one of the most efficient shapes in the world to cover large spans. Dome structures are lightweight and elegant structures that provide economical solutions for covering large areas with their splendid aesthetic appearance. Dome covers the maximum volume with the minimum material volumes with no interrupting columns in the middle with efficient shapes. The behavior of flexible dome is nonlinear under the external loads which make it necessary to consider the geometrical non-linearity in their analysis to obtain realistic response of these structures. The analysis of steel dome will be carried by the use of computer software STAAD.Pro. For the analysis different diameters and rise of dome will be used as parameters.***
***Keywords: component; formatting; style; styling; insert (key words)***

## I. INTRODUCTION

Domes are one of the oldest magnificent structural systems. They consist of one or more layers of elements that are arched in all directions. Domes are used to cover large areas such as exhibition halls, stadium and concert halls. They provide a completely unobstructed inner space and economy in terms of materials. They are lighter compared with the more conventional forms of structures. Structural systems, which enable the designers to cover large spans, have always been popular during the history. Beginning with the worship places in the early times, sports stadia, assembly halls, exhibition centres, swimming pools, shopping centres and industrial buildings have been the typical examples of structures with large unobstructed areas nowadays. Dome structures are the most preferred type of large spanned structures.

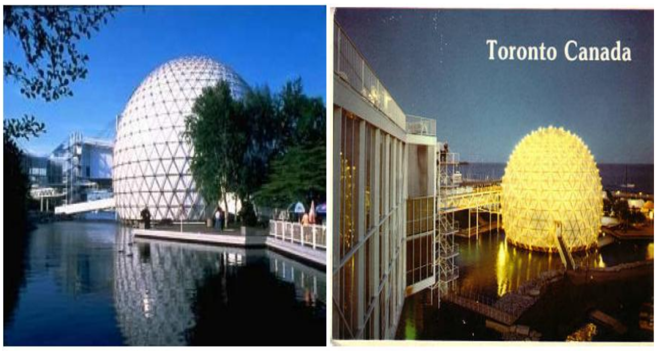
Domes have been of a special interest in the sense that they enclose a maximum amount of space with a minimum surface. This feature provides economy in terms of consumption of constructional materials. The development of domes has been closely associated with the development of available materials. Although, stone was the only structural material to use in the ancient times, brickwork gradually replaced the stone masonry. Later, timber was used in the middle Ages for the same purpose. But the great improvements in dome structures commenced with the development of the steel industry beginning in the 19th century. This enabled the engineers to design large spanned and multi-storey structures using steel. Nowadays it is very common to use steel in order to enclose large spans such as 200 m length.

## II. BRACED DOMES

Existing Braced Domes

Braced steel dome structures have been widely used all over the world during last three decades. Some examples of braced steel domes in the world are shown in Figure.

Nagoya Dome, Japan




Ontario Place, Toronto/Canada

Astrodome (Steel Lamella Dome), Houston/USA

Types of Braced Domes

Braced domes which have been built within the last few years can be mainly classified in five groups.

1. Ribbed domes
2. Schwedler domes
3. Lamella domes
4. Two- and three-way (also four-way) grid domes
5. Geodesic domes

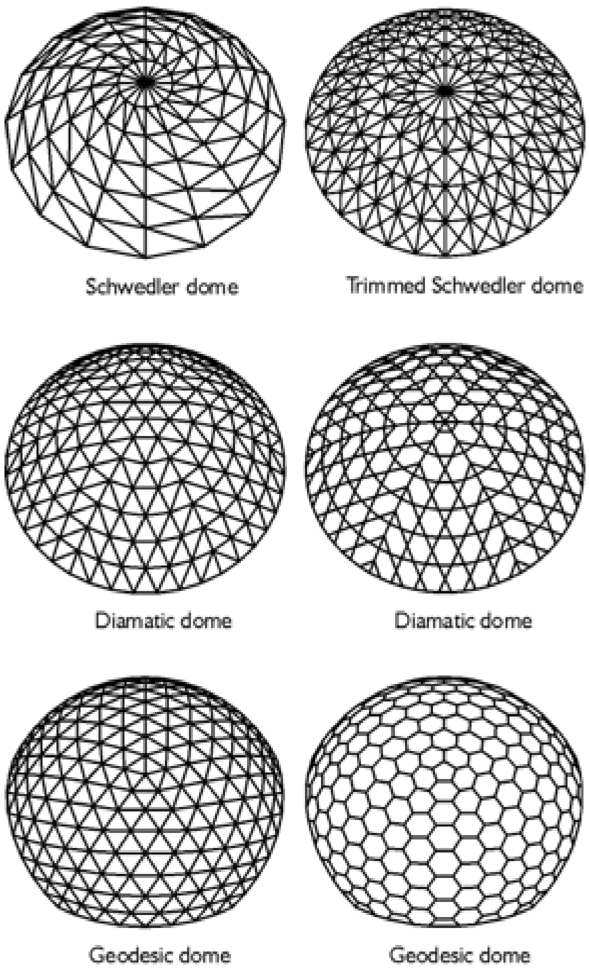



Figure 1 Types of Domes (1)

Ribbed Domes

Ribbed dome consists of a number of intersecting “ribs” and “rings”. A “rib” is a group of elements that lie along a meridional line and a “ring” is a group of elements that constitute a horizontal polygon. Ribs can be radial trussed or solid. They generally interconnect at the crown and a tension ring at the foundation stiffens the ribs. A ribbed dome will not be structurally stable unless it is designed as rigidly-jointed system, since it does not have diagonal elements.

Schwedler Domes

J.W. Schwedler, a German engineer, who introduced this type of dome in 1863, built numerous braced domes during his lifetime. A Schwedler dome, one of the most popular types of braced dome, consists of meridional ribs connected together to a number of horizontal polygonal rings. To stiffen the resulting structure so that it will be able to resist unsymmetric loads, each trapezium formed by intersecting meridional ribs with horizontal rings is subdivided into two triangles by introducing a diagonal member. Many attempts have been made in the past to simplify the analysis of Schwedler domes, but it is only during the last decade that precise methods of analysis using computers have finally been applied to find the actual stress distribution in these structures.

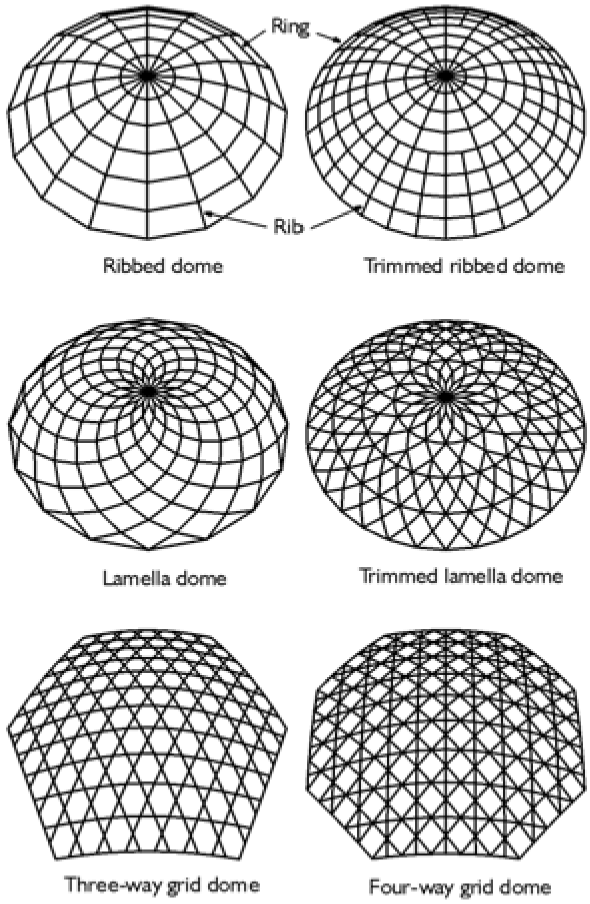



Figure 2 Types of Domes (2)

Lamella Domes

The lamella system was invented in Europe in 1906 by Mr. Zollinger, a German city architect. The lamella dome consists of a large number of similar units, called lamellas, arranged in a diamond or rhombus pattern. Each lamella unit has a length which is twice the length of the side of a diamond. Roof covering or purlins used to triangulate the diamond complete the stability requirement of the surface of the dome. A lamella dome has a diagonal pattern and may involve one or more rings. The great popularity of lamella domes is due to their exceptionally good behaviour under excessive wind loadings, as well as in fire and seismic disturbances.

Two- and- Three-Way Grid Domes

A grid dome is obtained by projecting a plane grid pattern onto a curved surface. Grid domes are normally rather shallow with their rise to span ratios being smaller than the other types of domes. The intersection of three-way grid dome members forms a triangular space lattice. A modified type of three-way grid is four-way grid dome which has denser pattern.

Geodesic Domes

Richard Buckminster Fuller, the inventor of geodesic domes, has made a phenomenal impact on architects since 1954.

International Journal For Technological Research In Engineering
Volume 4, Issue 2, October-2016 ISSN (Online): 2347 - 4718

Nature – said Buckminster Fulleralways builds the most economic structures. He claimed that geodesic domes based on mathematical principles embodying force distributions similar to those found in atoms, molecules and crystals will be the lightest, strongest and cheapest constructions ever made.

Double Layer Grids
A review of the developments in the field of space structures shows clearly that the most remarkable progress has been made in prefabricated double layer grids. These systems are of special importance as they are frequently used in roof construction. Successful attempts have been made in various countries to apply them to floor construction in multi-storey buildings. Double layer grids consist of two plane grids forming the top and bottom layers, parallel to each other and interconnected by vertical and diagonal members. Double layer grids may be lattice grids, or true space grids. In lattice grids, each set of bottom horizontal member is set in the same vertical plane under the top horizontal member, as in normal lattice trusses; but in space grids they do not lie in the same vertical plane. True space grids consist of a combination of prefabricated tetrahedra, octahedra or 'skeleton pyramids having triangular, square or hexagonal bases. The grid pattern of the top layer may be identical with that of the bottom 'layer, or it may differ.

## III. PROBLEM

Different types of dome models can be analyzed. Four different diameters of 70, 80, 90, 100 meters for h/d ratios of 0.2, 0.3, and 0.4 are modeled for geometry of Schwedler dome.
Following results are compared from analysis result
- Max Nodal Displacement
- Max Support Reaction
- Max Member Axial Forces

Based on these result comparisons best suitable height to diameter ratio can be selected for required diameter and expected loading conditions like dead load and wind load. Analysis is carried out using software STAAD Pro.

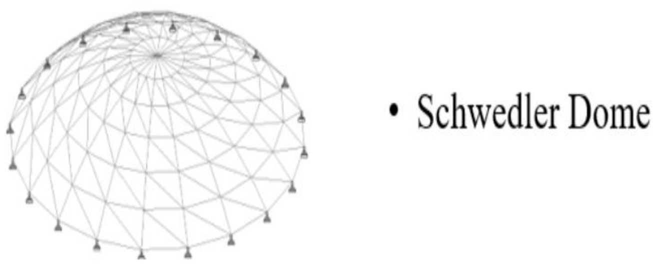
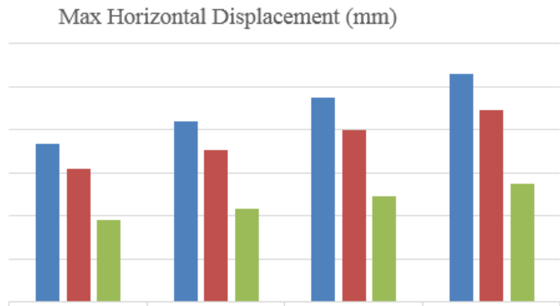



Figure 3 Modelling in STAAD Pro

Wind load and dead load are considered. Wind load is applied according IS 875 (Part 3) 1987.Sections of ISMB 150 provided in all models.

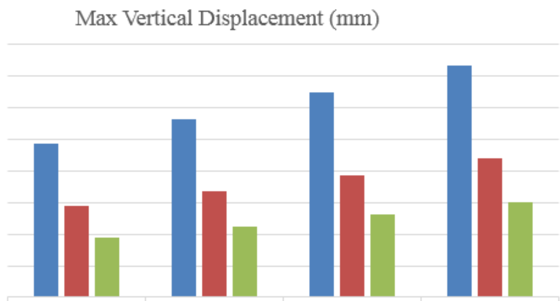
## IV. RESULTS

Results of all models are compared and presented in bar form. Results of Maximum nodal displacement, Maximum axial force, Minimum Axial force, Support reactions



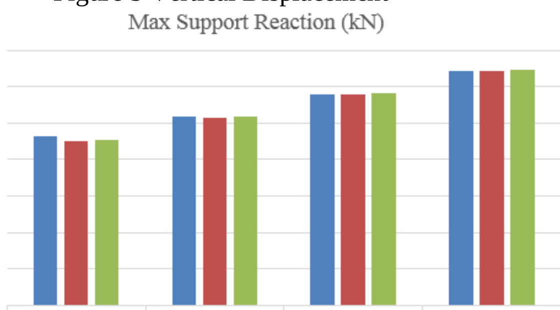

| | dia 70 | dia 80 | dia 90 | dia 100 |
|---|---|---|---|---|
| H/D 0.2 | 18.331 | 21.042 | 23.774 | 26.492 |
| H/D 0.3 | 15.421 | 17.692 | 19.976 | 22.25133333 |
| H/D 0.4 | 9.496 | 10.902 | 12.319 | 13.72866667 |

Figure 4 Horizontal Displacement



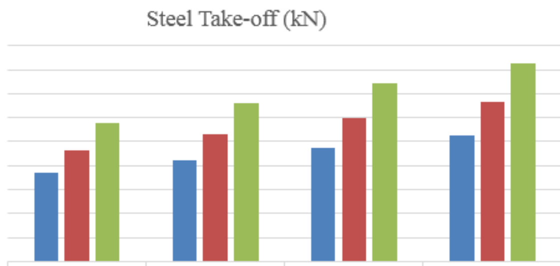

| | dia 70 | dia 80 | dia 90 | dia 100 |
|---|---|---|---|---|
| H/D 0.2 | 24.216 | 28.242 | 32.403 | 36.7 |
| H/D 0.3 | 14.389 | 16.833 | 19.372 | 22.005 |
| H/D 0.4 | 9.393 | 11.187 | 13.093 | 15.118 |

Figure 5 Vertical Displacement




| | dia 70 | dia 80 | dia 90 | dia 100 |
|---|---|---|---|---|
| H/D 0.2 | 0.928 | 1.036 | 1.159 | 1.283 |
| H/D 0.3 | 0.902 | 1.029 | 1.157 | 1.284 |
| H/D 0.4 | 0.908 | 1.037 | 1.165 | 1.294 |

Figure 6 Max Support Reactions




| | dia 70 | dia 80 | dia 90 | dia 100 |
|---|---|---|---|---|
| H/D 0.2 | 368.728 | 421.404 | 474.079 | 526.754 |
| H/D 0.3 | 465.51 | 532.014 | 598.513 | 665.014 |
| H/D 0.4 | 579.666 | 662.475 | 745.285 | 828.094 |

Figure 7 Steel Take off

## V. CONCLUSIONS

Analysis was carried out for schwedler geometry for different diameters and different H/D ratios. By analyzing the results, we can conclude that best suited h/d ratio can be selected for schwedler dome according to the parameters. 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. As such complex geometry of schwedler dome the section size can be decreased, because of such diagonal members provided this geometry is one of best suited geometry for lateral loads.

## REFERENCES

[1] Akbar, V., Sassan, E., Jabbarzadeh, M.J. and Fariborz, N. (2004) 'Seismic Vulnerability Analysis of The Historic Sultaniya Dome' 13th World Conference On Earthquake Engineering Vancouver, B.C., Canada.

[2] Chandiwala, A. (2005) 'Analysis and Design of Steel Dome Using Software.' International Journal of Research in Engineering and Technology.

[3] Cipriani, B. and Lau, W. (2010) 'Construction Techniques in Medieval Cairo: the Domes of Mamluk Mausolea' (1250 A.D.-1517A.D.).

[4] Ameen, H. (2010) 'The Impact of Diameter, Number of Ribs, Percentage of Steel, Compressive Strength and Cover Thickness on the Large Concrete Dome.'.

[5] Feng, F. (2004) 'Structural Behaviour and Design Methods of Tensegrity Domes' Journal of Constructional Steel Research 61 pp. 23–35.

[6] Feng, F., Duozhi, W., Xudong, Z. and Shizhao, S. (2009) 'Failure Modes of Reticulated Domes Subjected to Impact and the Judgment' School of Civil Engineering, Harbin Institute of Technology,Harbin China.

[7] Rechard, J., Punniyakotty, N. M. and Shanmug, N. E. (2006) "Limit State Analysis and Design of Cable Tensioned Structure.' National University of Singapore Department of Civil Engineering.

[8] Subramaniyam Narayan, Space structures:Principles and Practice

[9] Kevin, D. and Matthew, P. (2012) 'Commercial Building Structural Design and Analysis' Worcester Polytechnic Institute1203.

[10] Marek, K. (2009) 'Structural Analysis of Geodesic Domes' Durham University School of Engineering.

[11] Masayoshi, N., Mutsuro, S., Yoshio T. and Hasozawa, O. (2003) 'Structural Concept Design and Construction of Sapporo Domes' Takenaka Research & Development Institute Takenaka Corporation.

[12] Mujde, A. (2001)'The Structural Analysis of Domes: From Pantheon Until Reichstag' Historical Constructions Guimaraes, 2001.

[13] Hasancebi, O., Erdal, F. and Saka, M. P. (2009) 'Optimum Design of Geodesic Steel Domes Under Code Provisions Using Metaheuristic Techniques' International Journal of Engineering and Applied Sciences (IJEAS) Vol.2, Issue 2 pp. 88-103.

[14] Peter, C, Dipu, V. S. and Manju, P. M. (2014) 'Finite Element Analysis of Ribbed Dome' Department of Civil Engineering, Sree Narayana Gurukulam College of Engineering, Kerala, India.

[15] Shiro, K., Jong, M. K., and Myung, C. C. (2003) 'A New Proportioning Method for Member Sections of Single Layer Reticulated Domes Subjected to Uniform and Non Uniform Loads' Engineering Structure 25 pp. 1265-1278.

[16] Yuan, X. F. and Dong, S. L. (2002) 'Nonlinear Analysis and Optimum Design of Cable Domes' Engineering Structure 24 pp. 965-977.

[17] Xingfei Y., Lianmeng C. and Shilin D. (2006) 'Prestress Design of Cable Domes' International Journal of Solids and Structures 44 pp. 2773–2782.

[18] Xudong, Z., Feng, F. and Shizhao, S. (2010) 'Elasto-plastic Instability of Single Layer Reticulated Shells Under Dynamic Actions' School of Civil Engineering, Harbin Institute of Technology,Harbin China.

[19] Zhi, W. Y., Dong, X. Z., Feng, F. and Chen, L. (2011) 'Effect of Substructures upon Failure Behaviour of Steel Reticulated Domes Subjected to Severe Earthquake' Department of Civil Engineering, Harbin Institute of Technology. China.