Parametric Study on the Behavior of Various Dome Structures under Different Parameters.

Mr. Aniket G. Sawant, Prof. Pandurang S. Patil
PG Student, Rajarambapu Institute of Technology, Maharashtra, India.
Professor, Rajarambapu Institute of Technology, Maharashtra, India.

Abstract

The behavior of braced type dome structures will be evaluated by a thorough examination of critical design parameters. This dissertation work presents comparative study on behavior of various dome structures for different parameters. The research is focused on conventional dome, ribbed dome, Schwedler dome, kiewitt dome and kiewitt-ribbed dome. The domes are compared with conventional dome for 15m, 20m, 25m and 30m span in earthquake zone IV and Zone V. The study provides a better understanding of the domes performance involving the types of bracings.

Key Words*: - Ribbed Dome, Schwedler Dome, Kiewitt Dome, lattice system, reticulated domes*

1. Introduction:

A dome is one of the distinguished structural arrangements that acquired strength and stiffness based on their shape and form. Traditionally, stone masonry domes were constructed and are now mostly made of RCC Steel because of its re- usability. Traditionally, a dome is a hollow upper half of a sphere, made of various materials, with a history dating from prehistory. It encompasses the maximum volume with the smallest sized volumes without interruption by columns.

The main goal of architects and engineers has always been to solve the problem of space enclosure. Architects and engineers look for new structural forms to accommodate large unobstructed areas. As a result, space structures, in which the three dimensional function is realized, are of considerable importance. These structure are increasingly used in construction. They entail essentially analysis and design in three dimensions, as opposed to two dimensions.

2. Types of braced domes :

a. Ribbed Dome

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.

Fig .1: **Ribbed Dome**

b. Schwedler Dome

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.

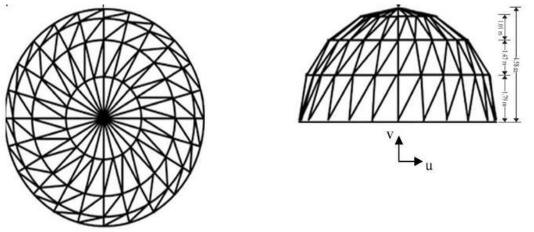

Fig .2: **Schwedler Dome**

c. Kiewitt Dome

Kiewitt dome structure is commonly used in spatial structures Reticulated domes (i.e., domes composed of bars) with various patterns have been built to span large surfaces, demonstrating their material efficiency.The pattern of a Kiewitt dome consists of a series of subdivided triangles.

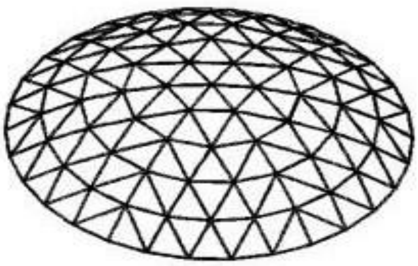

Fig .3: **Kiewitt Dome**

d. Kiewitt-Ribbed Dome

This dome combines the Kiewitt dome with ribbed domes. The crown part of the dome has Kiewitt type bracings and the bottom part has ribs.

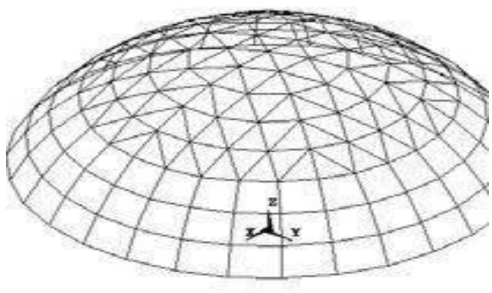

Fig .4: **Kiewitt-Ribbed Dome**

3. Research Objectives:

The following are the main objectives of the project work.

1. To analyse and design Ribbed dome, Schwedler dome, Kiewitt dome and Kiewitt- ribbed dome structures using STAAD Pro software for different spans in zones 4 and 5.
2. To compare the behavior of dome structures for axial forces, bending moment, shear forces, deformations and stresses developed.
3. To select an optimal dome structure based on performance and economy criteria
4. To provide detailed drawings and design of the optimal dome structure.

4. Methodology:

The parameters of the braced dome has been selected and modelling of the domes is done for different spans. In this phase the ribbed dome and Schwedler dome are analyzed and designed. The results of analysis and design are compared with conventional dome.

After Analysis and Design of Kiewitt and kiewitt-ribbed dome are analyzed and designed. The results of analysis and design are compared with conventional dome. Detailed drawings and design are prepared. The results are gathered and compared to find optimal dome structure and reports were prepared. The succeeding approach is adopted for this thesis to accomplish the objectives.

5. Results and Discussion:

Table.1: Variation of axial forces in braced type domes

Max Axial forces in kN				
bracing type	15m	20m	25m	30m
conventional dome	164.777	264.86	409.173	550.445
ribbed dome	171.68	283.66	397.247	564.133
schwedler dome	192.933	283.665	397.247	578.235
kiewitt dome	180.643	284.903	397.207	788.483
kiewitt-ribbed dome	169.838	270.545	397.207	511.757

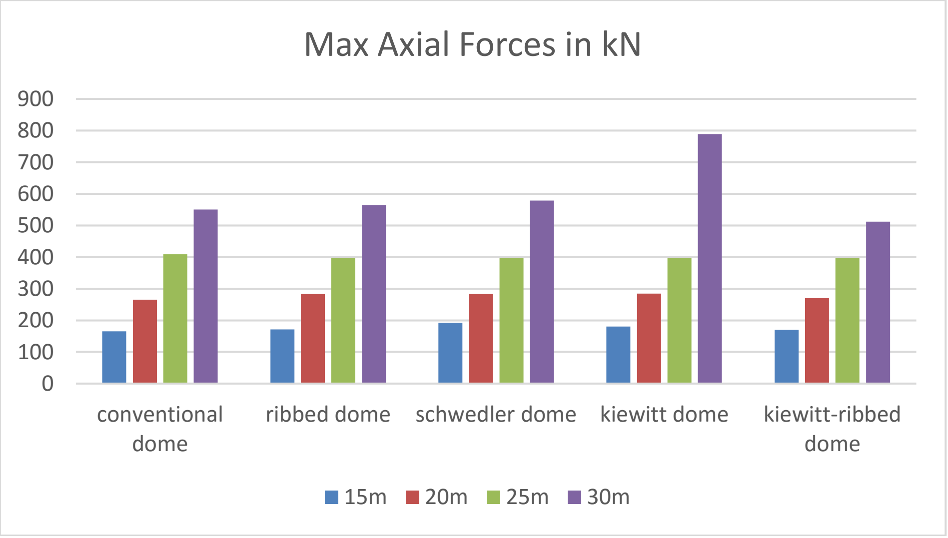

Fig.5: Max axial forces

The percentage change of axial forces of 15m span of ribbed, Schwedler, kiewitt, kiewitt-ribbed dome are 4.18%, 17.08%, 9.62%, 3.07% respectively when it is compared with the conventional dome.The percentage change of axial forces of 20m span of ribbed, Schwedler, kiewitt, kiewitt-ribbed domes are 7.09%, 7.09%, 7.56%, 2.14% respectively when compared with conventional dome.The percentage change in axial forces of 25m span of ribbed, Schwedler, kiewitt, kiewitt-ribbed dome are 2.91%, 2.91%, 2.92%, 2.92% respectively.The percentage change in axial forces of ribbed, Schwedler, kiewitt, kiewitt-ribbed domes of span 30m span are 2.48%, 5.048%, 43.24%, 7.028% respectively.

Table.2: Variation of shear forces in braced type domes

Max Shear Forces in kN				
bracing type	15m	20m	25m	30m
conventional dome	11.604	15.036	30.35	30.49
ribbed dome	12.39	25.34	22.5	32.03
schwedler dome	13.211	25.34	22.5	33.576
kiewitt dome	14.28	33.81	33.75	67.63
kiewitt-ribbed dome	12.97	23.4	33.75	41.16

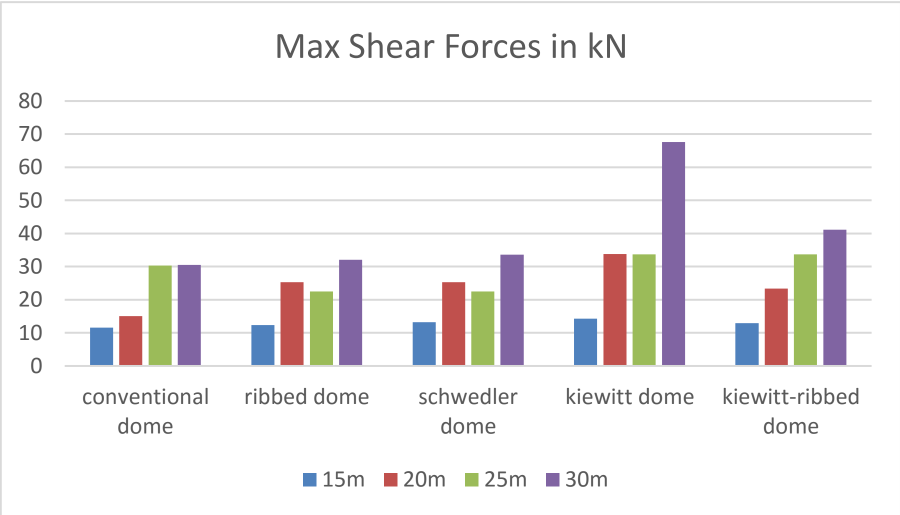

Fig.6: Max shear forces

The shear forces in 15m span of ribbed, Schwedler, kiewitt, kiewitt-ribbed dome are increased by 6.77%, 13.48%, 23.06% and 11.77% respectively when compared to conventional dome.The shear forces in 20m span of ribbed, Schwedler, kiewitt, kiewitt-ribbed dome are increased by 68.52%, 68.52%, 24.86%, 55.62% respectively when compared to conventional dome.The percentage change of 25m span of shear forces in ribbed, Schwedler, kiewitt, kiewitt-ribbed dome are 25.86%, 25.86%, 11.20%,11.20% respectively.The percentage change of 30m span of shear forces in ribbed, Schwedler, kiewitt, kiewitt-ribbed dome are 5.05%, 10.12%, 21.81%, 34.99% respectively

Table.3: Variation of bending moments in braced type domes

Max Bending Moments kNm				
bracing type	15m	20m	25m	30m
conventional dome	29.167	35.916	75.672	85.642
ribbed dome	31.075	60.56	56.12	90.166
schwedler dome	33.23	60.56	56.12	94.79
kiewitt dome	42.8	80.76	84.09	118.46
kiewitt-ribbed dome	38.97	55.9	84.09	106.29

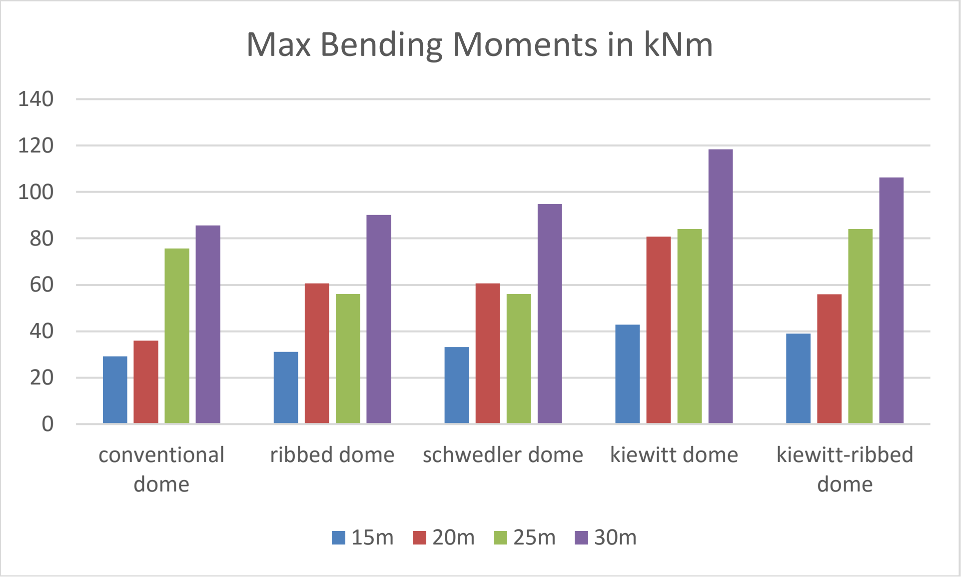

Fig. 7: Max Bending moment

The bending moment in 15m span of ribbed, Schwedler, kiewitt, kiewitt-ribbed dome are increased by 6.54%, 13.93%, 46.74% and 33.60% respectively when compared to conventional dome.The bending moment in 20m span of ribbed, Schwedler, kiewitt, kiewitt-ribbed dome are increased by 68.61%, 68.56%, 24.85%, 55.64% respectively when compared to conventional dome.The percentage change of 25m span of bending moment in ribbed, Schwedler, kiewitt, kiewitt-ribbed dome are 25.83%, 25.83%, 11.12%, 11.12% respectively. The percentage change of 30m span of bending moment in ribbed, Schwedler, kiewitt, kiewitt-ribbed dome are 5.28%, 10.68%, 38.32%, 24.10% respectively.

Table.4: Variation of shear stresses in braced type domes

Max Shear stresses in kN/m2				
bracing type	15m	20m	25m	30m
conventional dome	67.57	51.04	66.87	69.916
ribbed dome	65.66	77.93	75.36	72.79
schwedler dome	80.48	74.001	60.383	74.8
kiewitt dome	103.96	91.29	74.54	73.31
kiewitt-ribbed dome	93.98	68.1	69.068	66.42

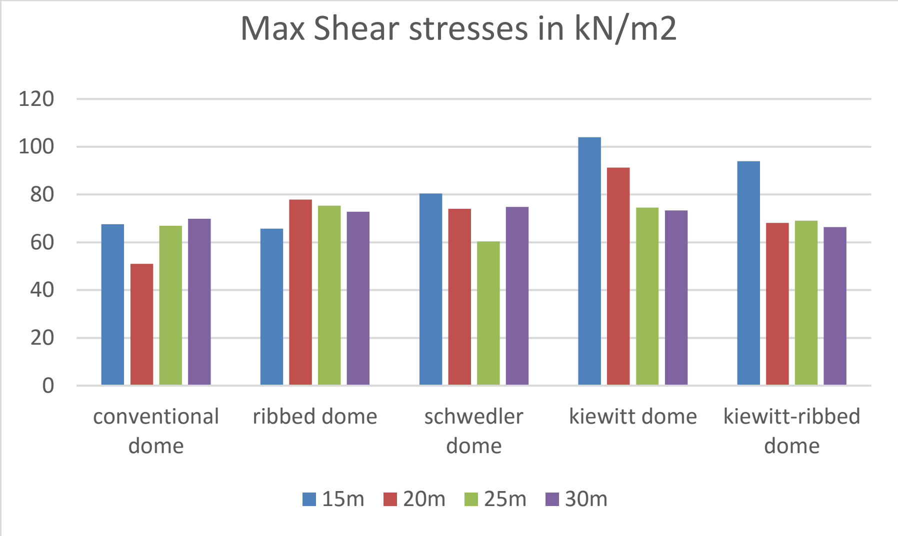

Fig. 8: Max shear stresses

The shear stresses in 20m span of ribbed, Schwedler, kiewitt, kiewitt-ribbed dome are increased by 52.68%, 44.98%, 78.85%, 33.42% respectively when compared to conventional dome. The percentage change of 25m span of shear stresses in ribbed, Schwedler, kiewitt, kiewitt-ribbed dome are 12.69%, 9.70%, 11.47%, 3.28% respectively. The percentage change of 30m span of shear stresses in ribbed, Schwedler, kiewitt, kiewitt-ribbed dome are 4.11%, 6.98%, 4.85%, 5.29% respectively.

Table.5: Variation of displacements in braced type domes

Max Displacement in mm Zone IV				
bracing type	15m	20m	25m	30m
conventional dome	8.371	9.93	21.61	27.913
ribbed dome	12.8	16.1	34.8	40.9
schwedler dome	9.54	16.44	21.3	30.64
kiewitt dome	14.12	18.5	21.7	24.017
kiewitt-ribbed dome	10.33	12.93	22.36	31.49

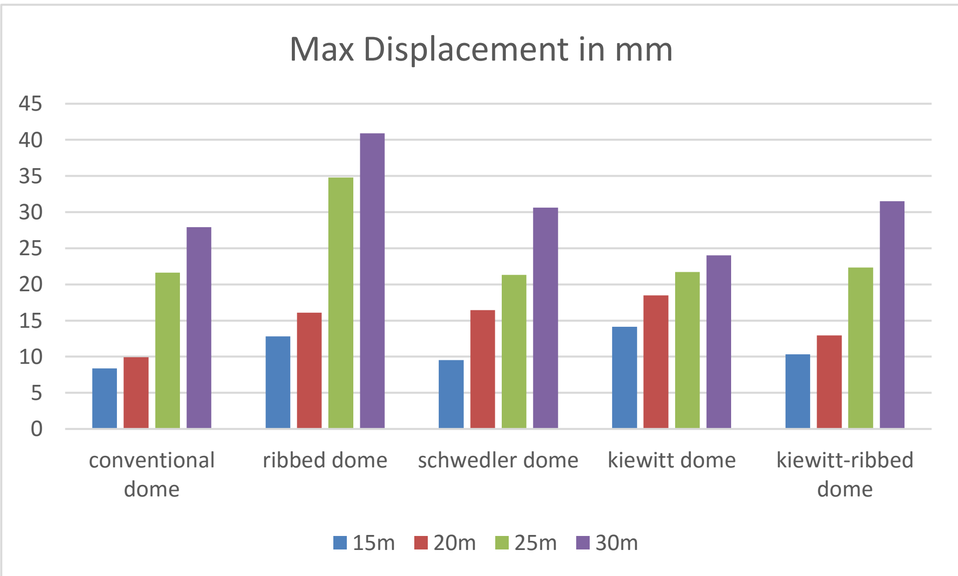

Fig. 9: Max displacement in Zone IV

Comparing the displacement of the ribbed dome of 15 m span to the conventional dome of 15 m span in zones IV and V, we see 14.04% and 5.57% increases, respectively. By comparing ribbed domes with 30m spans to conventional domes with 30m spans in zone IV and zone V, 3.78% and 3.73 % of the displacement are increased, respectively. Comparing Schewedler dome of 15 m span to conventional dome of 15 m span in zone IV and zone V, displacement increases by 14.05% and 13.2%, respectively. By comparing schewedler domes of 30m span to conventional domes of 30m span in zones IV and V, we can observe displacement increases of 9.79% and 9.7%, respectively. For zone IV, the displacement in Kiewitt dome of 15m, 20m, 25m, 30m are increased by 68.67%, 86.30%, 9.67% and 16.22% respectively when compared to conventional dome. For zone IV, the displacement in Kiewitt-ribbed dome of 15m, 20m, 25m, 30m are increased by 23.40%, 30.21%, 38.74% and 12.81% respectively when compared to conventional dome. For zone V, the displacement in Kiewittdome of 15m, 20m, 25m, 30m are increased by 49.22%, 82.34%, 29.19% and 8.31% respectively when compared to conventional dome. For zone V, the displacement in Kiewitt-ribbed dome of 15m, 20m, 25m, 30m are increased by 54.84%, 80.46%, 52.22% and 13.07% respectively when compared to conventional dome.

6. Conclusions

The following are the findings of the study about the behavior of a braced type domes:

1. Ribbed dome of 15m shows 4.19 % change in axial forces which is minimum and kiewitt dome of 30m span shows maximum increase of axial forces by 43.24% when compared to conventional dome.
2. Shear force percentage change in Ribbed dome of 15m span is minimum which is 6.51% and kiewitt dome of 30m span shows 68.52% increase when compared with conventional dome.
3. The bending moments in Ribbed dome of span 15m span shows least percentage change of 6.54% and kiewitt dome shows maximum increase of 68.56% compared to conventional dome.
4. The changes in stresses varies from 2.82% to 78.85% Ribbed dome shows least percentage increase when compared to conventional dome.
5. The displacement increase percentage varies from 5.57% to 86.36%. The ribbed dome and Ribbed dome shows least displacements compared to conventional dome.
6. The optimum volume of concrete and steel for ribbed dome of 15m span is 24.4 cum and 15 tonne.

REFERENCES:

1. Fu, Feng. (2005).“Structural behavior and design methods of Tensegrity domes.” Journal of Constructional Steel Research - J CONSTR STEEL RES. 61. 23-35. 10.1016
2. H. S. Jadhav, Ajit S. Patil, (2013) “Parametric study of double layer steel dome with reference to span to height ratio”, International Journal of Science and Research, Volume: 02, Issue:08.
3. Peter Chacko et al. (2014) “Finite element analysis of ribbed dome”. International Journal of Engineering Research and Applications (IJERA) ISSN: 2248- 9622.
4. Anuj Chandiwala, (2014) “Analysis and design of steel dome”, International Journal of Research in Engineering and Technology, Volume: 03, Issue: 03.
5. Taruna Desaria et al. (2015) “Modern building with erection of brace dome and space deck.” International Conference on: “Engineering: Issues, opportunities and Challenges for Development” ISBN: 978-81- 929339-1-7.
6. Shah Yash Jayminkumar, Vaibhav Doshi (2016) “A parametric study on steel dome

structures.” International Journal For Technological Research In Engineering.Volume 3, Issue 9, May-2016.
7. Riya Anna Abraham, G. Kesava Chandran (2016) “Study of dome structures with specific focus on monolithic and geodesic domes for housing.”International Journal of Emerging Technology and Advanced Engineering ISSN 2250- 2459.
8. Keyur R. Patel et al. (2016) “Earthquake analysis of different configuration of steel domes using computer programme.” IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163.
9. Hossein Kalantari et al. (2018) “Seismic vulnerability study of Soltaniyeh dome using nonlinear static and dynamic analyses.” International Journal of Advanced Structural Engineering 10, pages367–380 (2018).