Structural Analysis of Kiewitt Dome by using ETABS Software

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Abstract — Dome is a structural element in architecture that has changed its shape, functions and materials from time to time representing the advancement of human beings in mathematics and technology. Kiewitt dome consists of a series of subdivided triangles along the circumferential direction, which have common vertex at the crown of dome. On the basis of the lattice forms of upper single-layer reticulated shell, they can be called as rib-ring type, sunflower type and bird-nest type of suspen-dome. Kiewitt domes commonly used in spatial structures. Kiewitt Dome has better progressive collapse resistance than other dome. In this paper, we have analyzed 100 m kiewitt dome by using Extended Three-dimensional Analysis of Building System (ETABS) software and compared the results of maximum storey displacement, storey drifts, Stress and overturning moments. Structural performances under load combinations of bending moment, shear force and axial force are also being studied in this paper.

Keywords: Dome, Kiewitt, ETABS, Analysis, Storey Drift

I. INTRODUCTION

A. *Background of Study:*

According to evolution of building technology, especially in science of construction and materials, new functions appeared for domes. Dome is a structural element that has changed its shape, functions and materials from time to time representing the advancement of human being in technology. Shell structures have beautiful appearance, appropriate mechanical property and large coverage. As many characteristics of both rod system and thin shell construction, hence it possesses broad application prospect and developing potential. It is widely used in Airport, Railway station and other public buildings in recent years. Domes have been constructed over the centuries from mud, stone, wood, brick, concrete, metal, glass, steel and plastic. In modern period, with the industrial revolution, domes are used all over the world in different styles. The size of it became wider than any other domes built previously. The fields of engineering and architecture have few common languages for domes. Engineering focused on structural behavior of dome and architecture focused on form and symbolism of dome. Advancement in mathematics, materials and production techniques resulted in new dome types. Kiewitt dome consist of a series of subdivided triangles along the circumferential direction, which have common vertex at the crown of dome. On the basis of the lattice forms of upper single layer reticulated shell, they can be called as rib-ring type, sunflower type and bird-nest type of suspen-dome (Cao et al., 2020). Kiewitt dome is commonly used in spatial structure. It has better progressive collapse resistance than other dome. There are many studies related to geodesic dome and kiewitt dome to determine which dome type is superior in terms of material efficiency, the minimized weight of each variant is compared for various subdivision frequencies.

B. *Objective of the Study:*

In this paper, Structural analysis of 100 m Kiewitt dome with loads and load combination as per IS code has been analyzed. The specific objectives of this project were defined as the following:

- To study the kiewitt dome will reacts due to gravity load on ETABS-2017 software as per IS code.
- Compared the analysis results which include maximum storey displacement, storey drifts and stress.
- Structural performance under load combination which includes dead load (IS code-875 Part-1), live load (IS code-875 Part-2) and seismic load (IS code-1893-2016).
- Analysis of study is being done on the basis of maximum storey displacement, storey drifts, stress, overturning moments, bending moments, shear forces and axial forces.

II. LITERATURE REVIEW

A. *Willem Gythiel et al., (2020)*

Compared the three commonly built different types of reticulated dome subjected to distributed loads. This paper aims to determine which type of reticulated dome is superior in terms of material efficiency by comparing the minimized weight of different dome types, taking into account stress and buckling constraints. The study includes hemispherical Schwedler, Kiewitt and Geodesic domes with a diameter of 16 m and a gravity load of 2 KN/m².

B. *Tiantian li et al., (2019)*

In this paper, a transient time-history analysis of a long-span dome structure has been performed to systematically investigate its dynamic responses induced by a translating tornado. Long-span dome structures are widely used for public assembly venue because of their large column-free space and efficient use of materials. Static effects of tornadoes on civil structures have been extensively studied; their dynamic impact has not been sufficiently investigated. In this study, non-stationary characteristics of tornadoes and their dynamic impact on a long-span dome structure are systematically investigated.

C. *Xiaoyang Lu et al., (2012)*

Discuss about parametric modeling of six typical reticulated domes which are Ribbed, Schwedler, Lamella, Kiewitt, Three way grid and Geodesic dome based on the structure features and a method for node generation for which macro program is designed by using ANSYS Parametric Design Language (APDL). This six typical reticulated dome modeling are realized under parameters such as span, high rise, grid number in circular and radial direction.

D. Zhi-hong zhang & Shi-lin Dong (2011)

Discuss about large-span hybrid spatial structures specially design for Gymnasium steel roof using structural system. According to the latticed forms of the upper single layer reticulated shell they can be called as Rib-ring type, Sunflower type, Kiewitt type and Bird-nest type of suspend domes. The paper utilized force density method for shape determination analysis. Dynamic relaxation method has been used in numerical analysis fields such as for load analysis of spatial or planar frames, linear elastic analysis of thin shells or load analysis of tensile structures. The pseudo mass or pseudo damping is used to change a static problem into dynamic problem. Therefore, it is called as Pseudo transient analysis method. The conclusion is load or action effects are thoroughly summarized for member section design.

III. METHODOLOGY

A. Software version and details-

1) AutoCAD 3D-2016

For the modeling of kiewitt dome AutoCAD 3D-2016 has been used. AutoCAD is software for computer-aided design by Autodesk. AutoCAD 3D modeling is often used in architecture for designing 3D models, floor plans, buildings, etc.

2) ETABS-2017

For the analysis of the dome ETABS-2017 software, has been used. ETABS stands for Extended Three- dimensional Analysis of Building System. The dxf file from AutoCAD is imported in ETABS. ETABS is 3D modeling software for any kind of structural analysis and design. The advantages of ETABS are lots. Using this program you can perform both steel structure and RC structure design.

B. Layout-

Type	Span (m)	Rise (m)	Ratio (Rise/Span)	Figure number
Kiewitt dome	100	20	1/5	Fig. 1

Table 1: Geometric parameters of kiewitt dome

The layout for kiewitt dome is carried out in the Autodesk AutoCAD 3D-2016 software as shown in figure below.

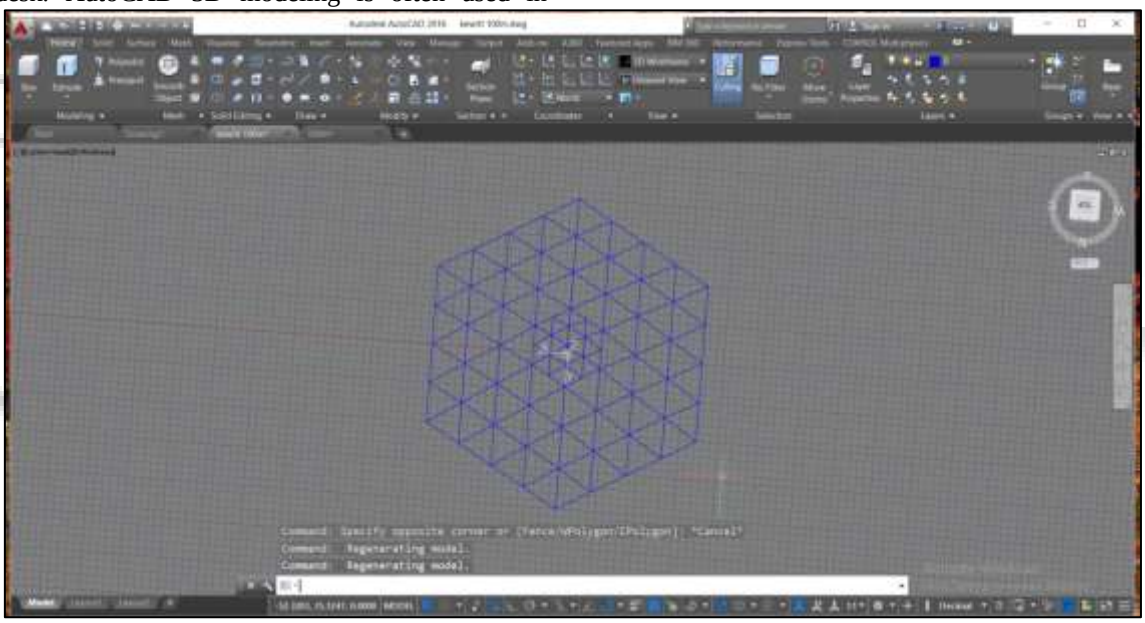

Fig. 1: Modeling of Kiewitt dome in AutoCAD-2016

C. Structural Modeling-

Kiewitt dome are exported from AutoCAD 3D in .dxf file format and then this file imported in ETABS-2017 then by providing material properties, load combinations and loadings for kiewitt dome then analysis has been done to check results. Fe345 Steel has been used for kiewitt dome. As per Indian steel table, ISLC 100 and ISLB 125 have been used for frame sections.

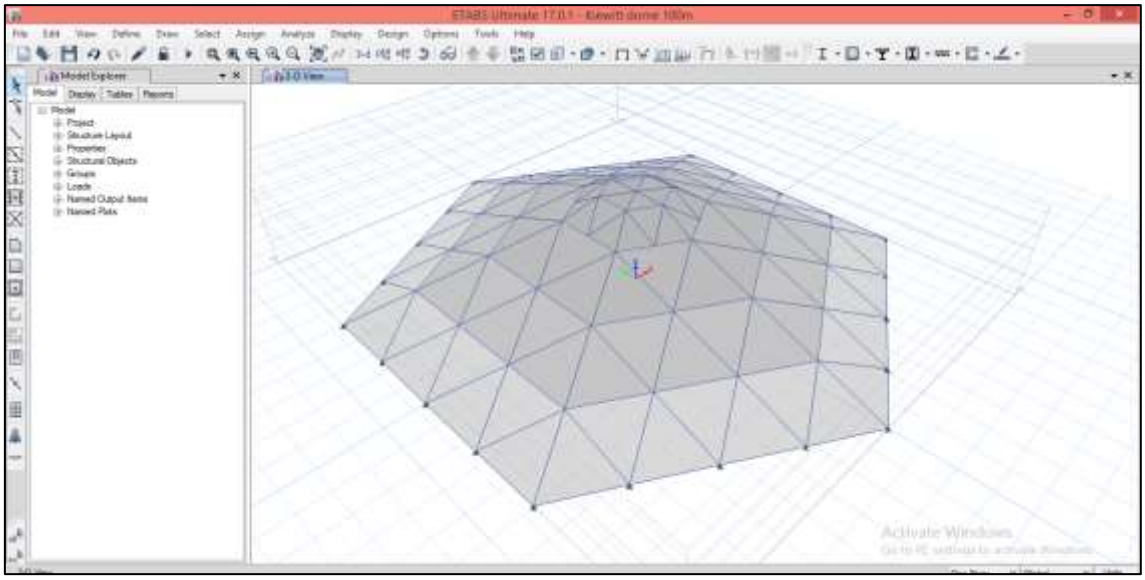

Fig. 2: Structural Modeling of Kiewitt dome in ETABS-2017

D. Loadings-

For overall analysis considering the loads are dead load, live load and seismic load are generated by using ETABS-2017 software. Dead load is self-weight of the structure and these are permanent loads which are always present. IS 875-1987 (Part-1) has used for dead load for kiewitt dome. We considered overall 4 KN/m² for both dome. Live load may vary over the time. It is weight of people and movable objects. We considered 1.50 KN/m² live load as per IS 875-1987 (Part-2). There are 4 seismic zones in India as per IS 1893-2016 (Part-1). The code gives recommendations for earthquake resistant design of structures. It is mandatory to follow these recommendations for design of structures.

The results after the analysis of kiewitt dome are as follows-

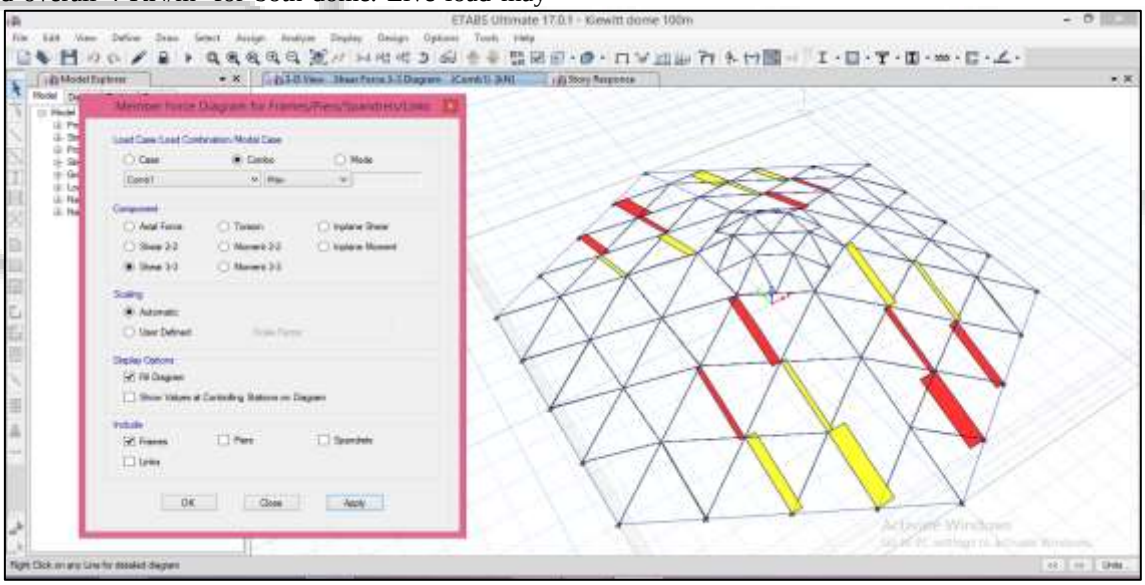

Fig. 3: Maximum Shear force of Kiewitt dome

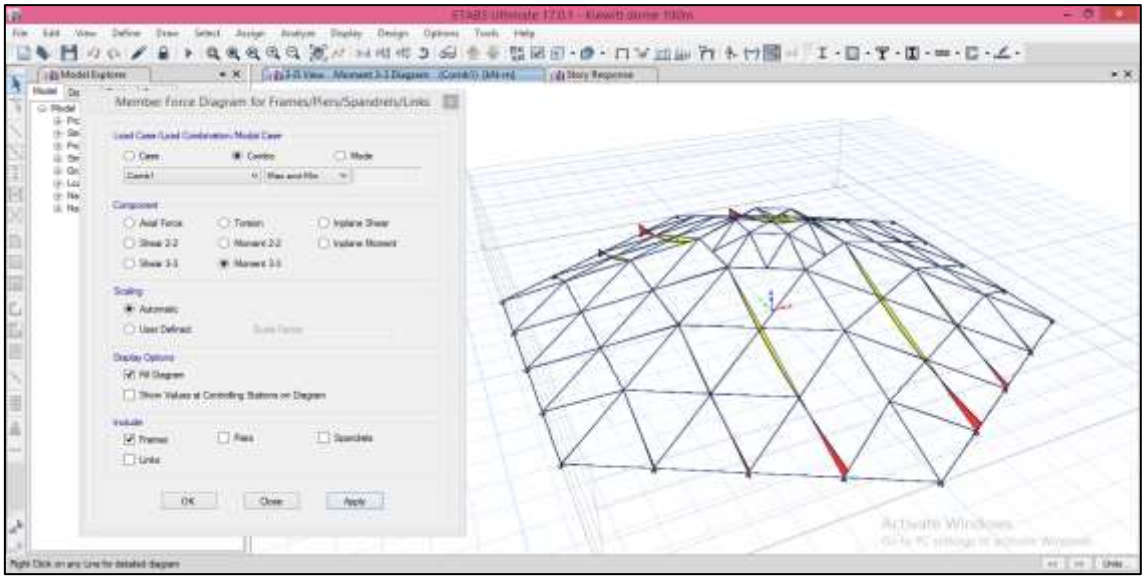

Fig. 4: Maximum Bending moment of Kiewitt dome

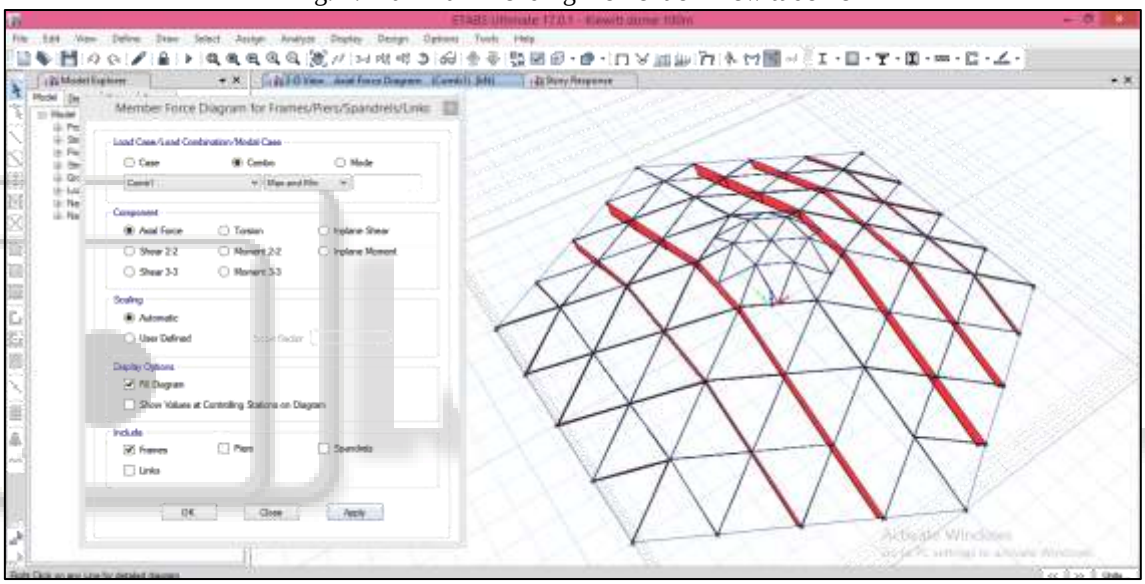

Fig. 5: Maximum Axial force of Kiewitt dome

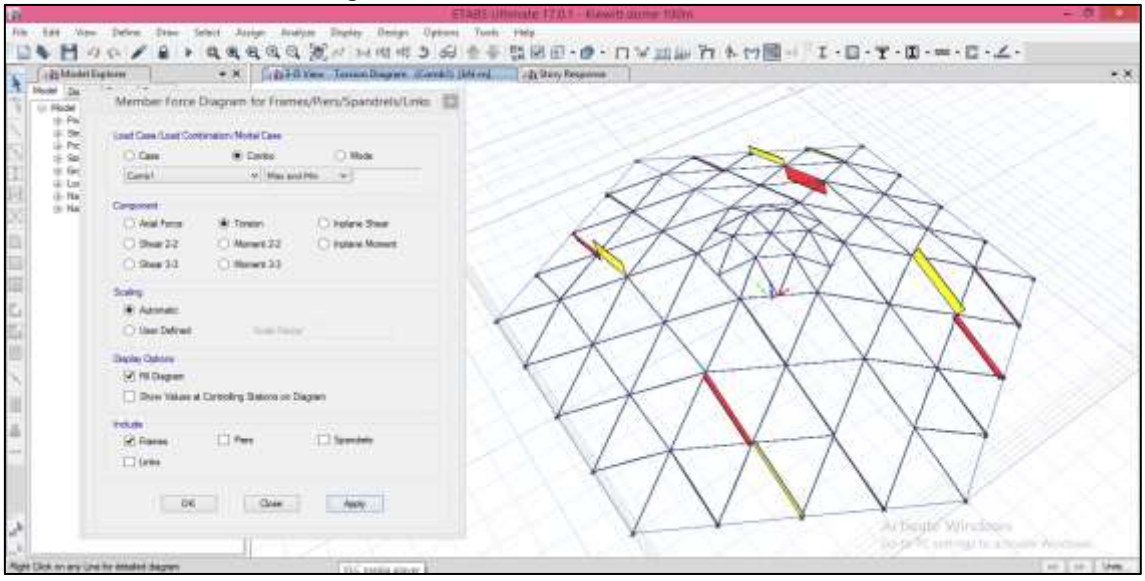

Fig. 6: Maximum Torsion of Kiewitt dome

IV. RESULTS AND COMPARISON

After the analysis on ETABS-2017, the results are obtained and the following assumptions are made-

Type	Maximum displacement (mm)		Allowable displacement (mm)	Maximum storey drift (m)		Allowable storey drift (m)	Maximum stress (MPA)	Allowable stress (MPA)
	X	Y		X	Y			
Kiewitt	36.6	52.4	61.5	0.024	0.042	0.08	275.02	300

Table 2: Maximum and Allowable displacement, storey and stress

The maximum displacement, maximum storey drift and maximum stress of kiewitt dome has listed in Table 2. From the above data following conclusions can be obtained,

1) The maximum displacement of kiewitt dome appears at story-1 for X and Y direction. As per IS code 800-2007, the allowable displacement is 61.5 mm for kiewitt dome. Therefore, Kiewitt dome satisfy the condition.
2) As per IS code 1893-2016, storey drift shall not exceed 0.004 times storey height. The maximum storey drift for kiewitt dome appears at storey-1 in X and Y direction. The allowable storey drift for kiewitt dome is 0.08 m. Therefore, as per results kiewitt dome satisfies the condition of maximum storey drift.
3) The above table clearly shows that the maximum stress for kiewitt dome the maximum stress value is 275.02 MPA which is less than the allowable stress i.e. 300 MPA. From the above we can conclude that the dimension and loads applied to the dome adopted are sufficient and within the permissible limits.
4) Overturning moment maximum at storey at storey-1 and minimum at storey-4.
5) Graphical representation of maximum storey displacement, storey drift and overturning moments for kiewitt dome as below.

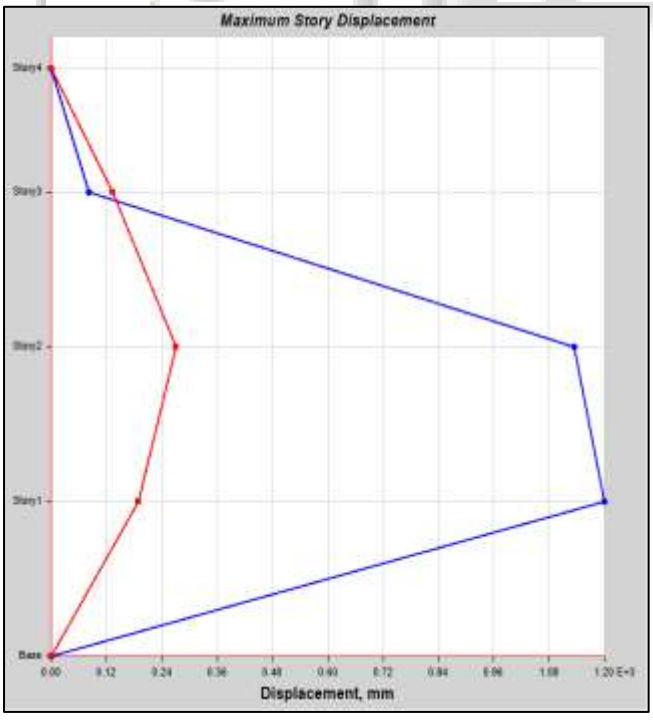

Fig. 7: Maximum storey displacement of Kiewitt dome

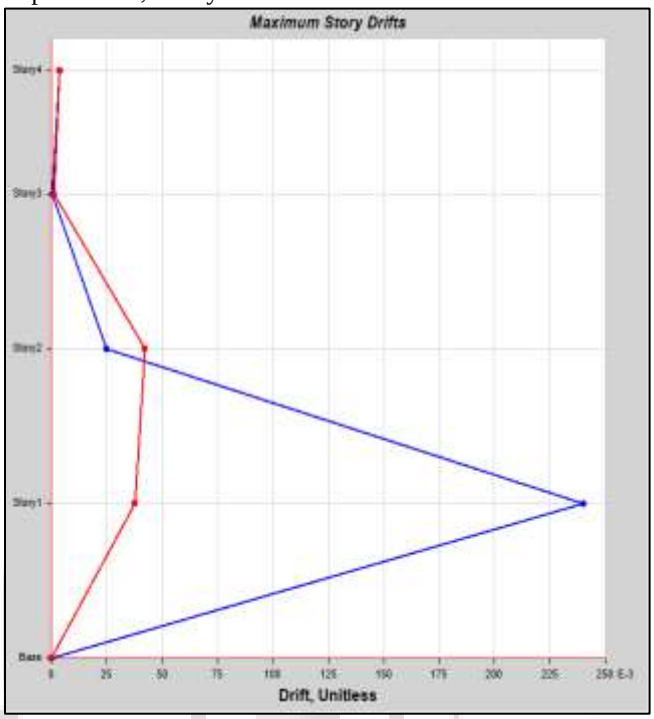

Fig. 8: Maximum storey drift of Kiewitt dome

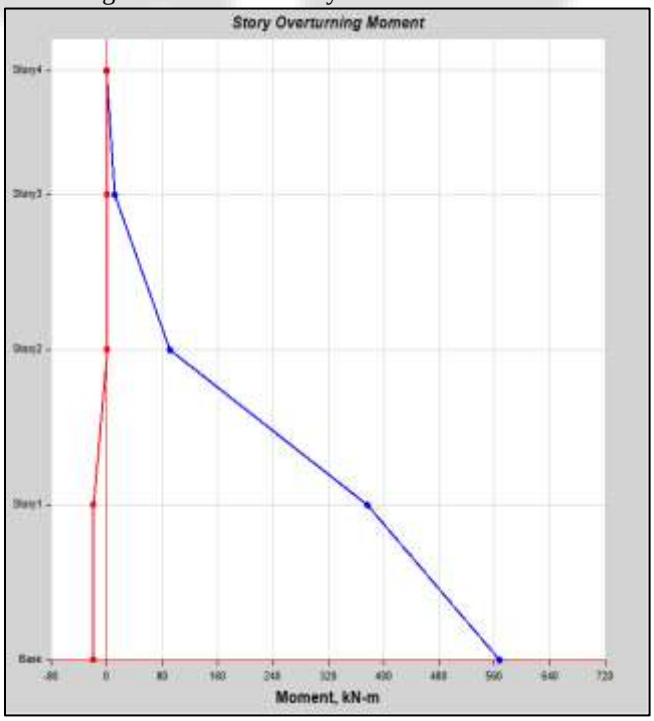

Fig. 9: Maximum Overturning moment of Kiewitt dome

V. CONCLUSION

This paper draws the following conclusions,

1) As per IS code 1893-2016, storey drift shall not exceed 0.004 times storey height. The maximum storey drift kiewitt dome maximum storey drift appears at storey-1 in X and Y direction. The allowable storey drift for kiewitt dome is 0.08 m. Therefore, as per results kiewitt dome satisfies the condition of maximum storey drift.
2) As per IS code 800-2007, the maximum displacement for a frame shall not exceed 1/325 of the span. The allowable displacement for kiewitt dome is 61.5 mm. Displacement obtained for kiewitt dome in X direction is 36.6 mm and in Y direction is 52.4 mm. Kiewitt dome satisfy the condition. While the maximum displacement value for kiewitt dome is far less than the allowable value. Therefore, Kiewitt dome has better mechanical performance which can apply to large-span structures.
3) Maximum Overturning moment appears at storey-1 which is 0.091 mm and minimum overturning moment appears at storey-4 which is 0.035 mm. Hence, Kiewitt dome perform better in overturning moment.
4) As per results, Kiewitt dome is more stable and uniform stressed as per combination loading which includes dead load, live load and earthquake load as per IS code.

VI. REFERENCES

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