ROOPA M
PRIYANKA V
and
H VENUGOPAL

Dynamic behaviour of geodesic dome structure for different time histories

Earthquake is caused by a sudden release of energy in the earth's crust, which causes seismic waves. The most significant effects of earthquakes are ground shaking and rupture. It has both social and economic effects, such as causing death and injury to creatures, including humans, and may damage the natural and build environment. It is critical to comprehend the loss of life and damage to structures caused by ground motion. So, the ground motion characteristics are to be studied keenly on any structure in the design process. In the present study different time histories are used to perform dynamic analysis of a geodesic dome using the analytical approach. The results like base shear and joint displacements are obtained with respect to the ground motion time period.

***Keywords**: Time histories, geodesic dome, FEA, dynamic analysis.*

1.0 Introduction

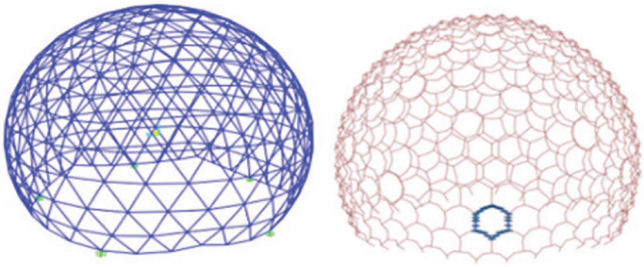
For venues that require wide, column-free areas, long-span structural solutions are required. It is found in places such as sports stadiums, auditoriums, hangars, exhibition centres, and assembly halls. A cost-effective long-span structural system is a space structure (Ramaswamy, 2002). In linguistic terms, the terms "space frame" and "space truss" are sometimes used interchangeably. space frames are believed to have fixed joints, whereas space trusses are pin-linked [1]. In mediaeval and late Latin, the term "doma" meant "house" or "roof." During the middle ages and renaissance periods, the expression "domus dei" came to denote "important or well-known home." This idea has stood the test of time. In Italian, the word "duomo" means "cathedral" or "church," for example (Makowski, 1984). In German, Icelandic, and Danish, the word "dom" also refers to a cathedral. In old English, the term "dome" was used to describe structures that acted as a town house, guild hall, or important gathering place (Makowski, 1984). All of these idioms hint at the dome's growing symbolic importance. Its supposed to represent a religious, civic, or communally significant site. Many researchers have used the time history approach to investigate the structural behaviour of geodesic domes [2,3,4]. Dominika Pilarska et al [2]. studied geodesic dome behaviour through maximum displacements, axial force, velocities, and accelerations utilising seismic analysis on two proposed geodesic domes using distinct ground motions. F. Fan et al. [10] are a group of researchers who came up with a novel way to solve a observed and reported on the behaviour of various steel domes that had been subjected to large earthquake loads. The development and spread of flexibility throughout these structures have received significant attention.

Severe earthquake ground motions are investigated on a single layer geodesic dome utilising SAP 2000 software to investigate the dome's dynamic behaviour through base shear and joint displacements.

2.0 Finite element modelling

2.1 Geodesic Dome Modelling

The CADRE Geo was used to model a geodesic dome with a diameter of 31 metres and a height of 23 meters, which was inspired by the SSIT library. For time history analysis, the geodesic dome is imported into SAP2000 V22. The steel elements of a geodesic dome are designed using the codebooks IS 800:2007-code of practice for general steel building and IS 1893 (Part 1): 2016. The dynamic analysis is based on the criteria for earthquake resistant design of structures. The outside and inner tube structures of the geodesic dome are shown in Fig.1.



(a) (b)

Fig.1: Outer tubular structure (a) and inner tubular structure (b) of the geodesic dome

---

Mss. Roopa M, Reasearch Scholar, Department of Civil Engineering, Sri Siddhartha Academy of Higher Education, Priyanka V, PG student, CADS, SSIT, Department of Civil Engineering and Dr. H Venugopal, Professor & HoD, Department of Civil Engineering, SSIT, Tumakuru, India. Email: roopam@ssit.edu.in / priyankav100198@gmail.com / venugopalh@ssit.edu.in

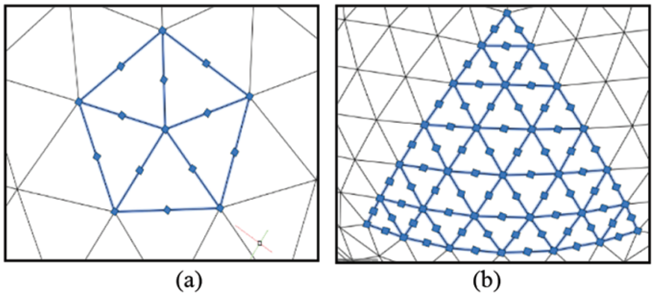


Fig.2: The pattern configuration of the geodesic dome is K5 (a) and the geometrical frequency of the dome is V6 (b)

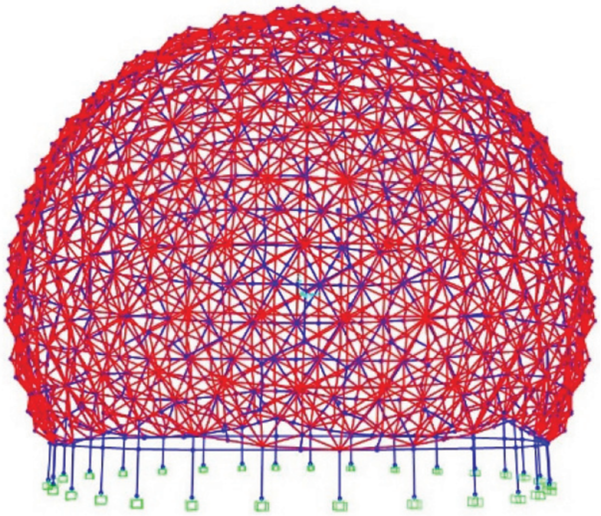


Fig.3: A 3D view of the geodesic dome in SAP2000

Fig.2 depicts the geodesic dome's pattern configuration and geometrical frequency, while Fig.3 depicts a 3D image of SAP2000's geodesic dome model.

3.0 Time history analysis

Time history analysis is the study of a structure's dynamic response at each increment of time when its base is subjected to a certain ground motion. The ground motion data is taken from the CESMD strong-motion center. The response spectrum curve in SAP2000 is used to match the acceleration data. The ground motion records from the Kachchh, Uttarkashi, and El Centro earthquakes were utilized to perform a linear time history analysis on the geodesic dome, results like base shear and joint displacements with respect to time period are obtained and discussed.

Fig.5 shows the spectrum matching of Kachchh acceleration data to spectrum curve according to IS 1893-2016. Similarly, all the earthquake acceleration data are matched.

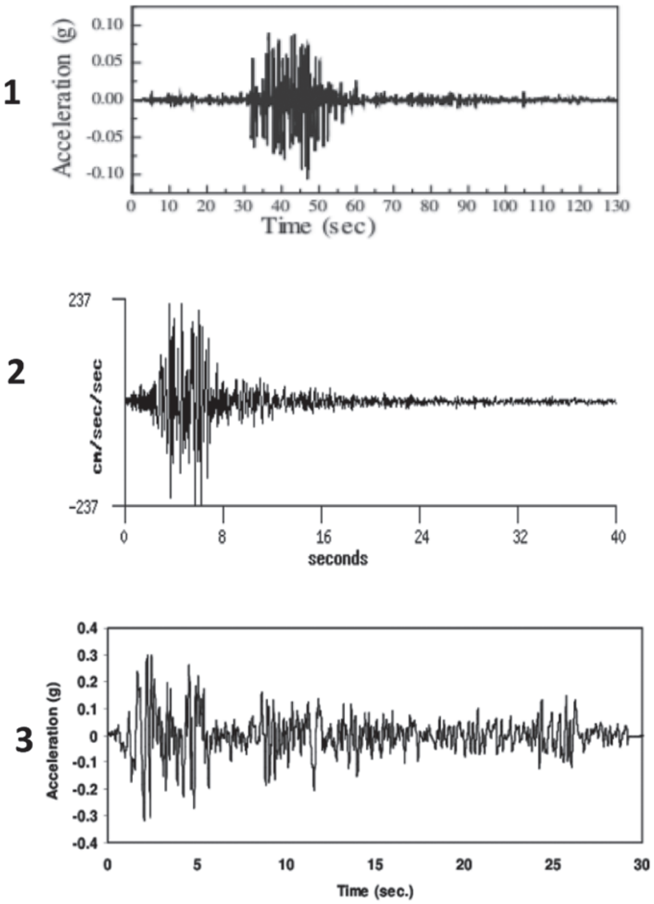
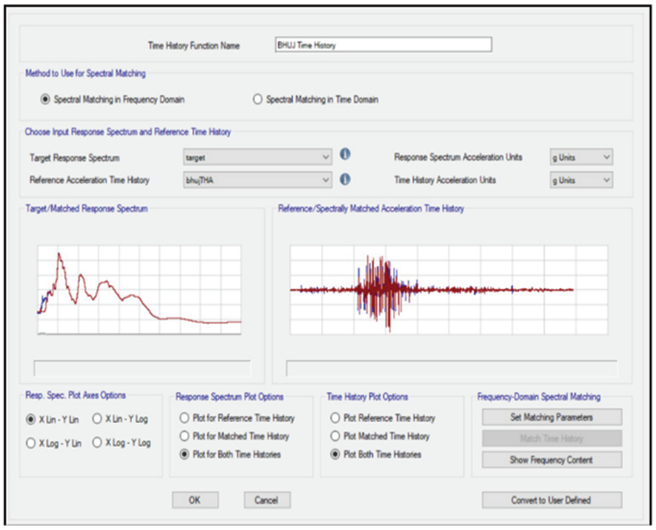


Fig.4: Acceleration data for 1. Kachchh 2. Uttarkashi 3. El Centro 4. Kobe 5. Northridge earthquakes



Time History Function Name: BHUJ Time History

Method to Use for Spectral Matching

● Spectral Matching in Frequency Domain ○ Spectral Matching in Time Domain

Choose Input Response Spectrum and Reference Time History

Target Response Spectrum: target

Reference Acceleration Time History: bhujTHA

Response Spectrum Acceleration Units: g Units

Time History Acceleration Units: g Units

Resp. Spec. Plot Axes Options

● X Lin - Y Lin ○ X Lin - Y Log ○ X Log - Y Lin ○ X Log - Y Log

Response Spectrum Plot Options

○ Plot for Reference Time History ○ Plot for Matched Time History ● Plot for Both Time Histories

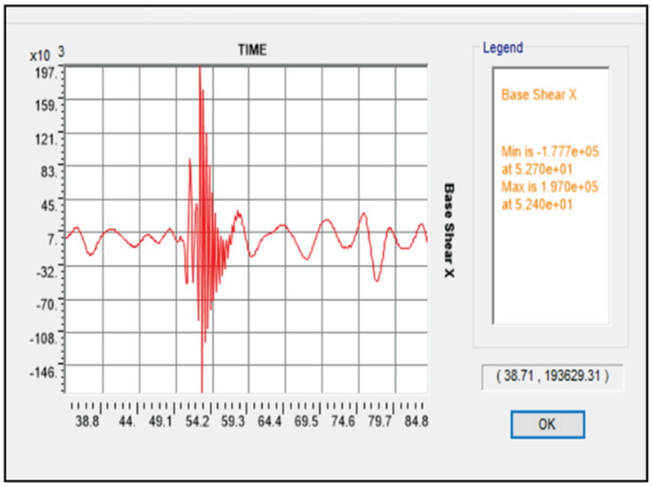
Time History Plot Options

○ Plot Reference Time History ○ Plot Matched Time History ● Plot Both Time Histories

Fig.5: Spectrum matching for Kachchh Earthquake in SAP2000 according to IS1893-2016

4.0 Results and discussion

The largest expected lateral stress on the structural base as a result of seismic activity is called base shear. It is calculated using the seismic zone, soil material, and building code lateral force equations. The fundamental period of vibration when subjected to dynamic stresses is used to estimate the base shear of the geodesic dome in this study. For each acceleration data that is used to perform time history analysis of the geodesic dome, various results such as joint

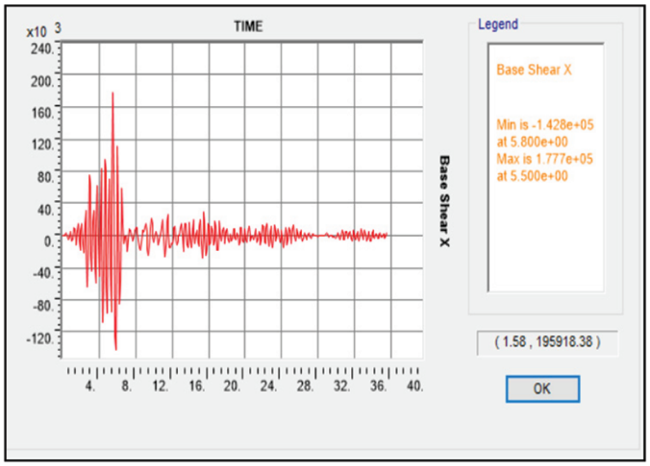


Base Shear X

Min is -1.777e+05
at 5.270e+01
Max is 1.970e+05
at 5.240e+01

(38.71 , 193629.31)

Fig.6: Base shear time history response of geodesic dome in the X direction for Kachchh earthquake acceleration data

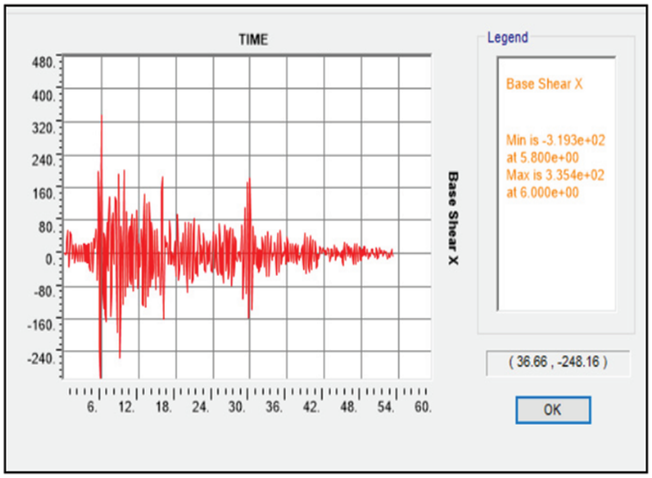


Base Shear X

Min is -1.428e+05
at 5.800e+00
Max is 1.777e+05
at 5.500e+00

(1.58 , 195918.38)

Fig.7: Base shear time history response of geodesic dome in the X direction for Uttarkashi earthquake acceleration data

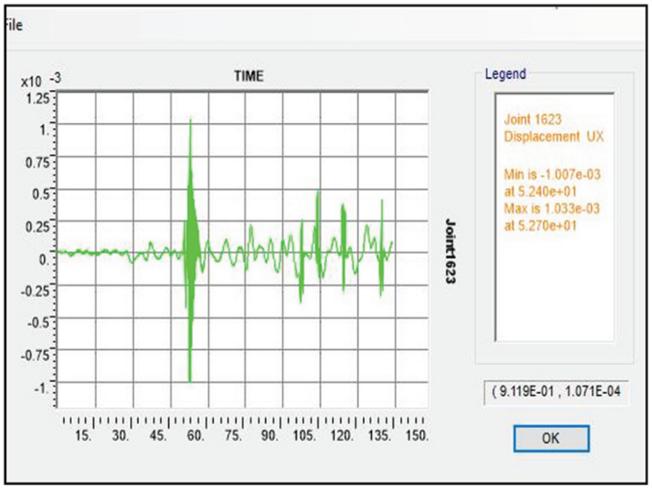


Base Shear X

Min is -3.193e+02
at 5.800e+00
Max is 3.354e+02
at 6.000e+00

(36.66 , -248.16)

Fig.8: Base shear time history response of geodesic dome in the X direction for El Centro earthquake acceleration data

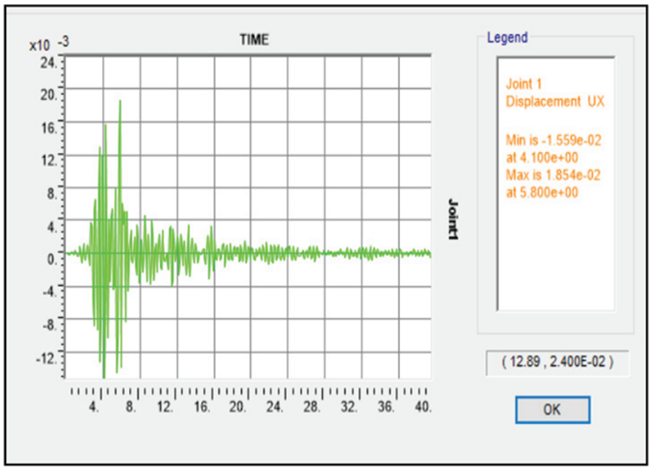


Joint 1623
Displacement UX

Min is -1.007e-03
at 5.240e+01
Max is 1.033e-03
at 5.270e+01

(9.119E-01 , 1.071E-04)

Fig.9: Joint displacement for geodesic dome due to Kachchh earthquake ground motion

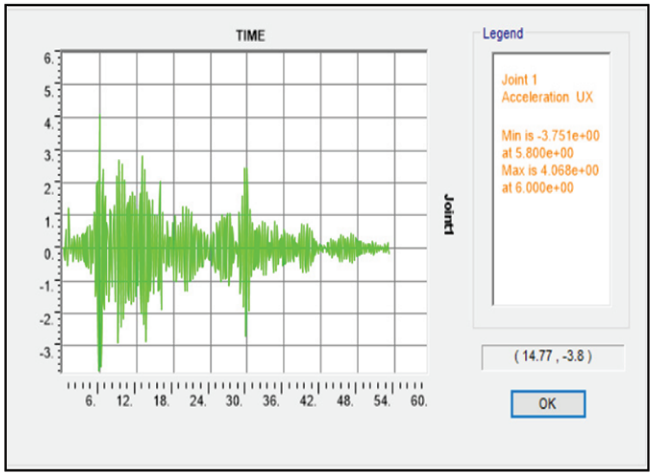


Joint 1
Displacement UX

Min is -1.559e-02
at 4.100e+00
Max is 1.854e-02
at 5.800e+00

(12.89 , 2.400E-02)

Fig.10: Joint displacement for geodesic dome due to Uttarkashi earthquake ground motion



Joint 1
Acceleration UX

Min is -3.751e+00
at 5.800e+00
Max is 4.068e+00
at 6.000e+00

(14.77 , -3.8)

Fig.11: Joint displacement for geodesic dome due to El Centro earthquake ground motion

displacements and frame axial force with regard to time period are obtained.

Figs, 6, 7, and 8 illustrate the geodesic dome's maximum base shear values for the ground accelerations of the Kachchh, Uttarkashi, and El Centro earthquakes. The geodesic dome exhibits the maximum base shear with the El Centro earthquake acceleration, which is lower than the other two ground accelerations. The maximum joint displacement of the geodesic dome during the seismic excitations of the Kachchh, Uttarkashi, and El Centro earthquakes is shown in Figs. 9, 10 and 11. The maximum joint displacement in the geodesic dome occurred with El Centro acceleration data, as seen in the figures. It is mostly because of the El Centro earthquake's significant acceleration data, which had a magnitude of 7.1 and a hammering acceleration of 0.319g.

5.0 Conclusions

The following conclusions are drawn from the present study and are listed below.

- Modal analysis is used to determine the initial and end frequencies, which range from 2.512 Hz to 11.052 Hz. These frequencies are used to adjust the frequency of the ground motion to the geodesic structure, soil, and seismic conditions.
- To analyze the structural behaviour of the geodesic dome, ground motion data from previous earthquakes were gathered and a time history analysis was performed.
- Base shear and joint displacements were observed maximum for El Centro ground motion, other ground motions show inferior values.
- Time history analysis on space structures such as a geodesic dome is a vital design process since variable ground motion factors affect structural behaviour.

References

[1] C. W. A. I. Hung, (2009: "A Comparative Study of Structural Material for Dome Construction,"

[2] D. Pilarska et al. (2021): "Numerical Analysis of Steel Geodesic Dome under,"

[3] Y. G. Li et al. (2017): "Reliability of lattice dome with and without the effect of using small number of ground motion records in seismic design," *Eng. Struct.*, vol. 151, pp. 381–390,2017,doi: 10.1016/j.engstruct. 2017.07.038.

[4] D. M. Wei and S. F. Gao, (2017): "Seismic response analysis of K8 pattern single-layer reticulated domes under vertical rare earthquakes," Procedia Eng., vol. 210, pp. 417–424, 2017, doi: 10.1016/j.proeng. 2017.11.096.

[5] N. Barbieri et al. (2017): "Dynamic Analysis of a Geodesic Dome," no. July, pp. 1425–1432,2018,doi: 10.26678/abcm.cobem2017.cob17-5951.

[6] L. Lin et al. (2013): "Size Effect and Material Property Effect of the Impactor on the Damage Modes of the Single-Layer Kiewitt-8 Reticulated Dome," vol. 2013, 2013.

[7] D. Z. Wang et al. (2013): "Impact response and failure mode for single-layer geodesic spherical domes under impact load," Appl. Mech. Mater., vol.351–352,pp.80–84,2013,doi: 10.4028/www.scientific.net/AMM.351-352.80.

[8] F. Fan et al. (2004): "Study of the Dynamic Strength of Reticulated Domes under Severe Earthquake Loading," pp. 235–244, 2004.

[9] Sariyar, O., and Ural, D. N. (2010): "Expert System Approach for Soil Structure Interaction and Land Use." *Journal of Urban Planning and Development,* 136(2), 135–138.=https://doi.org/10.1061/(asce)0733 9488(2010)136:2(135)

[10] Provenzano, P. (2003): A fuzzy-neural network method for modelling uncertainties in soil-structure interaction problems. *Computer-Aided Civil and Infrastructure Engineering,* 18(6), 391–411. https://doi.org/10.1111/1467-8667.00326

[11] Levine, E. R., Kimes, D. S. and Sigillito, V. G. (1996): Classifying soil structure using neural networks. Ecological Modelling, 92(1), 101–108.https://doi.org/10.1016/0304 3800(95)00199-9

[12] IS 1893: Part 1 (2002): "Criteria for earthquake resistant design of structures", *Bureau of Indian Standards*, New Delhi.