SEISMIC ANALYSIS OF A GEODESIC DOME USING TIME HISTORY METHOD

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Abstract - *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 ground motion data are used to perform dynamic analysis of a geodesic dome using the Time history method. The results like base shear and joint displacements are obtained with respect to the ground motion time period

1. INTRODUCTION

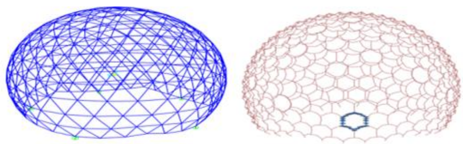
For venues that demand vast column-free areas, long-span structural solutions are required. Sports constructions, auditoriums, hangars, exposition centers, and assembly halls are among the places where it is used. One form of efficient long-span structural system is space structures (Ramaswamy, 2002). In linguistic terms, the phrases "space frame" and "space truss" are frequently interchanged. While both have comparable 3-dimensional characteristics, space frames are considered to have fixed joints in this thesis, whereas space trusses are pin-linked [1]. The term "doma" signified "home" or "roof" in middle and late Latin. The phrase "domus dei" evolved to mean "important or renowned house" during the Middle Ages and Renaissance periods. This concept has endured to this day. The word "duomo" in Italian, for example, implies "cathedral" or "church" (Makowski, 1984). The word "dom" also refers to a cathedral in German, Icelandic, and Danish. The term "dome" was used in old English to describe constructions that served as a town house, guild hall, or significant gathering place (Makowski, 1984). All of these language terms allude to the dome's growing symbolic significance. It is thought to be symbolic of a religious, civic, or communally significant location. Time History technique was utilized in many studies to analyze the structural behaviour of geodesic domes [2,3,4]. Dominika Pilarska et al [2]. performed seismic analysis on two proposed geodesic domes using different ground motions to study geodesic dome behaviour through maximum displacements, axial force, velocities, and accelerations. F. Fan et al. [10] Studied the behavior of several steel domes subjected to significant earthquake loads and reported. A special focus has been placed on assessing the development and dissemination of plasticity throughout these structures.

In the present study, severe earthquake ground motions are studied on a single layer geodesic dome using the SAP 2000 software to study the dynamic behaviour of the dome through base shear and joint displacements.

2. FINITE ELEMENT MODELING

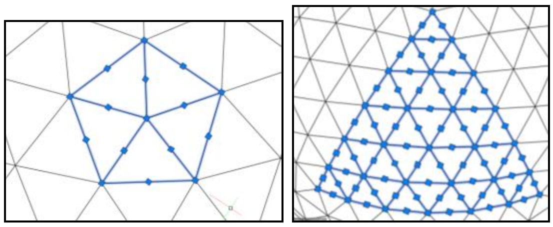
2.1 Geodesic Dome Modeling

The geodesic dome of 31-meter diameter and 23-meter height which is inspired by Infosys training center, Mysore and SSIT library is modeled in CADRE Geo. The Geodesic Dome is imported into SAP2000 V22 for time history analysis. The codebook IS 800:2007-code of practice for general steel construction is used to design the steel elements of a geodesic dome and IS 1893(Part 1):2016 Criteria for Earthquake Resistant Design of Structures is used for the dynamic analysis. Fig-1 shows the outer and inner tubular structures of the geodesic dome



(a) (b)

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



(a) (b)

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

Pattern configuration and frequency details of the geodesic dome are shown in Fig.2, and the 3D view of the geodesic dome model of SAP2000 is shown in Fig. 3.

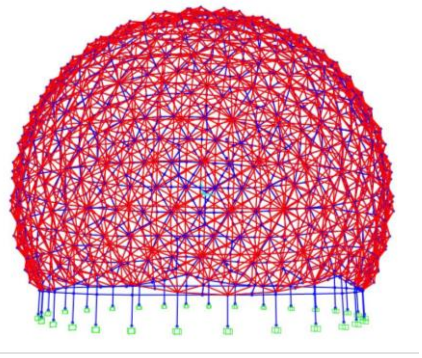


Fig-3 A 3D view of the geodesic dome in SAP2000

3. TIME HISTORY ANALYSIS

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

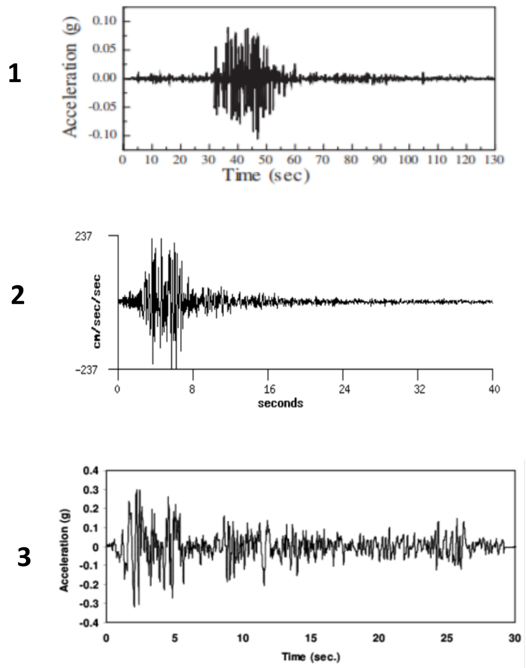


Fig-4 Acceleration data for 1. Kachchh 2. Uttarkashi 3. El Centro 4. Kobe 5. Northridge earthquakes

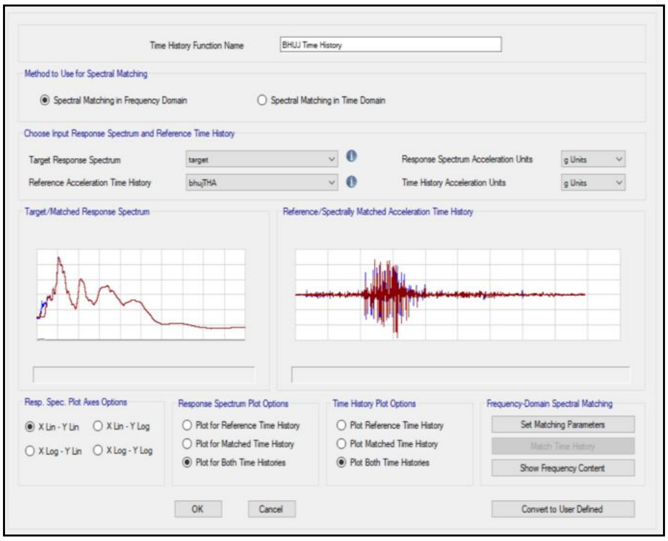


Fig-5 Spectrum matching for Kachchh Earthquake in SAP2000 according to IS1893-2016

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.

4. RESULTS AND DISCUSSION

Base shear is an estimate of the greatest predicted lateral stress on the structure base as a result of seismic activity. The seismic zone, soil material, and building code lateral force formulae are used to compute it. In this work, the base shear of the geodesic dome is estimated using the fundamental period of vibration when subjected to dynamic loads. The other results like Joint displacements and Frame axial force with respect to the time period are obtained for each acceleration data which are used to perform time history analysis of the geodesic dome.

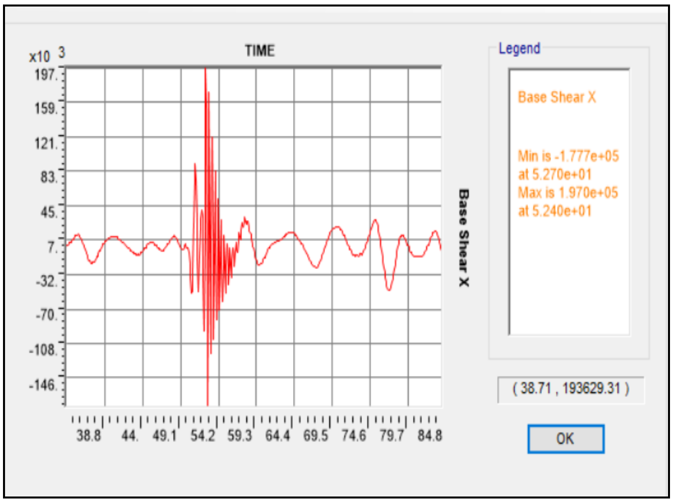


Fig-6 Base shear time history response of geodesic dome in the X direction for Kachchh earthquake acceleration data.

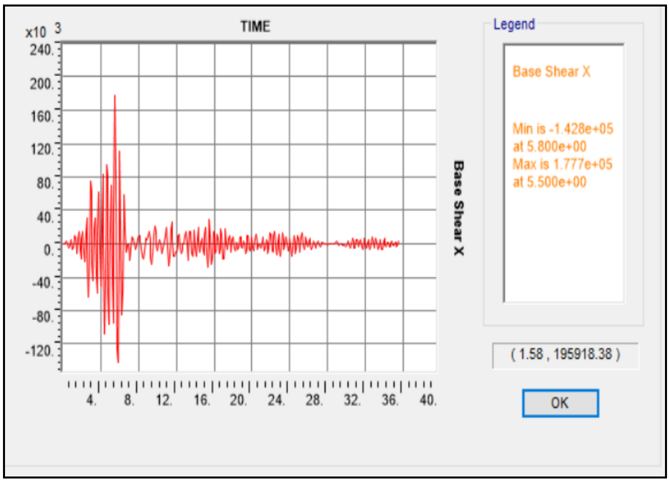


Fig-7 Base shear time history response of geodesic dome in the X direction for Uttarkashi earthquake acceleration data.

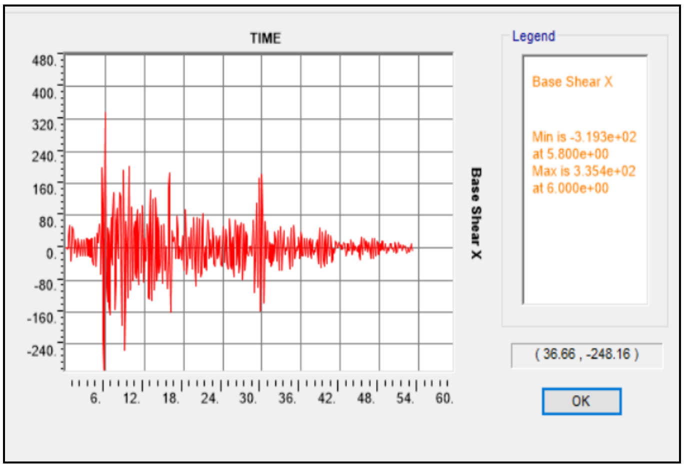


Fig-8 Base shear time history response of geodesic dome in the X direction for El Centro earthquake acceleration data.

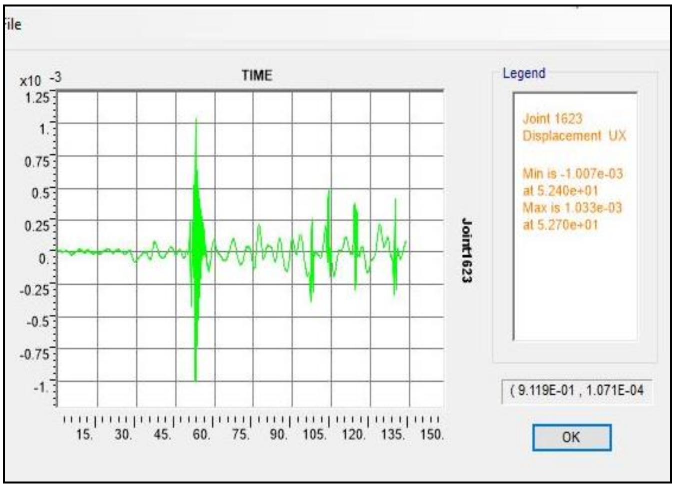


Fig -9 Joint displacement for geodesic dome due to Kachchh earthquake ground motion

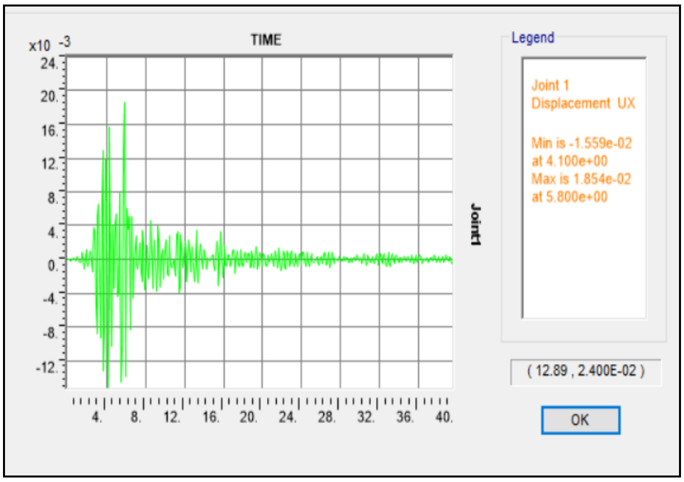


Fig -10 Joint displacement for geodesic dome due to Uttarkashi earthquake ground motion

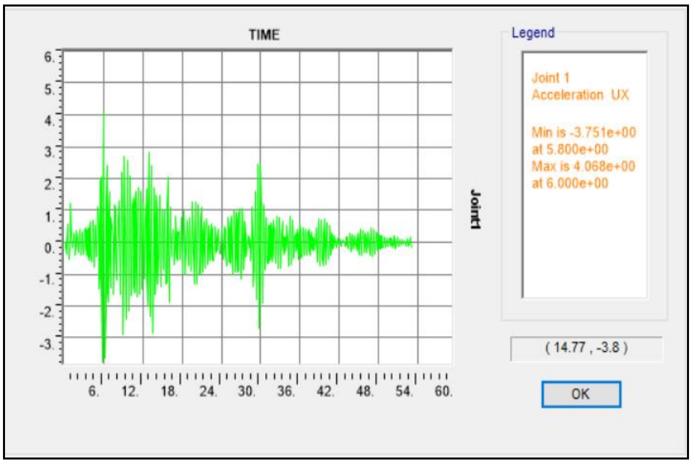


Fig -11 Joint displacement for geodesic dome due to El Centro earthquake ground motion

Fig. 6, 7, 8 shows the Maximum base shear values of the Geodesic dome for the ground accelerations of the Kachchh, Uttarkashi, and El Centro earthquakes respectively. It is clearly observed that the geodesic dome exhibit maximum base shear with El Centro earthquake acceleration and it is inferior to the other two ground accelerations. Fig. 9,10,11 shows the maximum joint displacement of the geodesic dome under the seismic excitations of the Kachchh, Uttarkashi, and El Centro earthquakes. It is clearly observed from the figures that Maximum joint displacement in the geodesic dome occurred with El Centro acceleration data. It is mainly due to the strong acceleration data of El Centro earthquake which was having a magnitude of 7.1 and a hammering acceleration of 0.319g.

5. CONCLUSIONS

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

- Modal analysis is performed to know the initial and final frequencies which are 2.512 Hz to 11.052 Hz. These frequencies are used to match the ground motion frequency to the geodesic structure soil and seismic conditions.
- Ground motion data of recent earthquakes are obtained and time history analysis has been performed on the geodesic dome to study the structural behavior.
- The base shear in the geodesic dome is found maximum for the El Centro earthquake motions as this was a severe earthquake that happened in the 19th century. Base shear for other ground motions is inferior to this ground motion.
- Joint displacement of geodesic also found maximum for El Centro earthquake and less for other ground motions.
- Time history analysis on space structures like a geodesic dome is an important process in designing, as different Ground motion characteristics affect the structural behavior.

REFERENCES

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

[2] S. Excitations, D. Pilarska, and T. Maleska, "Numerical Analysis of Steel Geodesic Dome under," 2021.

[3] Y. G. Li, F. Fan, and H. P. Hong, "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, "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, R. Dalledone Machado, and L. Barbieri, "Dynamic Analysis of a Geodesic Dome," no. July, pp. 1425–1432, 2018, doi: 10.26678/abcm.cobem2017.cob17-5951.

[6] L. Lin, F. Fan, X. Zhi, and H. Yin, "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, F. Fan, X. D. Zhi, and J. W. Dai, "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, S. Z. Shen, and G. A. R. Parke, "Study of the Dynamic Strength of Reticulated Domes under Severe Earthquake Loading," pp. 235–244, 2004.

[9] Sariyar, O., & 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 modeling 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., & 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.