International Journal of Scientific Research in Civil Engineering
© 2023 | IJSRCE | Volume 7 | Issue 1 | ISSN : 2456-6667

Analysis of a Tall Structure Under Seismic Loading of Two Different Regions Using ETAB

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Article Info

Publication Issue :
Volume 7, Issue 1
January-February-2023

Page Number : 29-47

Article History
Accepted : 01 Jan 2023
Published : 07 Jan 2023

ABSTRACT

Structural developments are increasing rapidly now-a-days throughout the world. Natural calamities like earthquake are happening frequently around the world, hence, the structure has to be designed for the same. The critical seismic analysis of reinforced concrete building, specifically involves the understanding behavior of structure under lateral loads unlike the usual gravity loads such as dead loads and the live loads. Multistorey building would be the greater part influenced by quake constrains to seismic prone areas. The major concern in the design of the multi-storey building is the structure to have enough lateral stability to resist lateral forces, buckling, to control lateral drift and displacement of the building.
In order to design an earthquake resistant structure, the analysis of the structure G+11 story is done using ETABS 2020.
G+11 story is analyzed for two different seismic zones, one location at Bhuj Gujarat and other location at Jabalpur, Madhya Pradesh and soil types as per IS 1893:2016. Further the behavior of the structure was investigated for the parameters such as Natural period, Displacement, Base shear, Story Stiffness and Story Drift.
Keywords — Base shear, storey displacement, special moment resisting frame, static analysis and Etabs.

I. INTRODUCTION

The unique concept used in earthquake engineering is the equivalent lateral force. In structures maximum displacement or member stresses are determined by the Dynamics analysis which further changes to partly dynamic and partly static analysis. There are different types of lateral loads in buildings like wind loads and earthquake loads and their behaviour varies with the type of soil. These types are Hard soil, Medium soil and Soft soil. When seismic waves pass through these soil layers their effects are different .When structure is exhibited to earthquakes it is influenced with the foundation and soil mass. Thus, it changes the movement of the earth .This indicates that the type of soil ,and also depends on the type of structure ,influences the movement of the entire system of ground structures. Because seismic waves are generated from the ground, they consist of changes in the properties of the soil and work in different ways in accordance with the correlate to the properties of the soil. Vibrations that distract the earth's surface caused due to waves generated in the earth are called earthquakes. It is mentioned that earthquakes do not kill human life, but structures that are not built taking into account the forces of an earthquake. Earthquake resistant structures in India currently attach great importance to human life and its security. India's geographical location is such that it comes under the subcontinent area so that's why India is having more than 60% earthquake prone area. Generally buildings are constructed in India design with permanent ,semi – permanent moving loads keeps in mind.

According to IS 1893 2016 code (Clause 6.3.5.3) soil condition is classified into following three types

Type I - Hard Soil: Sand gravel and well graded gravel and sand gravel mixtures without or with clay binder, and poorly graded clayey sands or sand clay mixtures (GB, CW, SB, SW, and SC) having value of N above 30, where N indicates the : standard penetration value.

Type II - Medium Soil :All soils having N between 10 and 30, and gravelly sands or poorly graded sands with little or no fines (SP) with N>15.

Type III - Soft Soil :All soils except SP with N

II. Seismic Analysis

The latest version of seismic zoning map of India given in the earthquake resistant design code of India [IS 1893 (Part 1) 2002] assigns four levels of seismicity for India in terms of zone factors. In other words, the earthquake zoning map of India divides India into 4 seismic zones (Zone 2, 3, 4 and 5) unlike its previous version which consisted of five zones for the country. According to the present zoning map, Zone 5 expects the highest level of seismicity whereas Zone 2 is associated with the lowest level of seismicity. Table I shows the Zone factors.

Table 1 Zone Factor

Zone Factor	
Zone Type	Zone Factor
V	0.36
IV	0.24
III	0.16
III	0.1

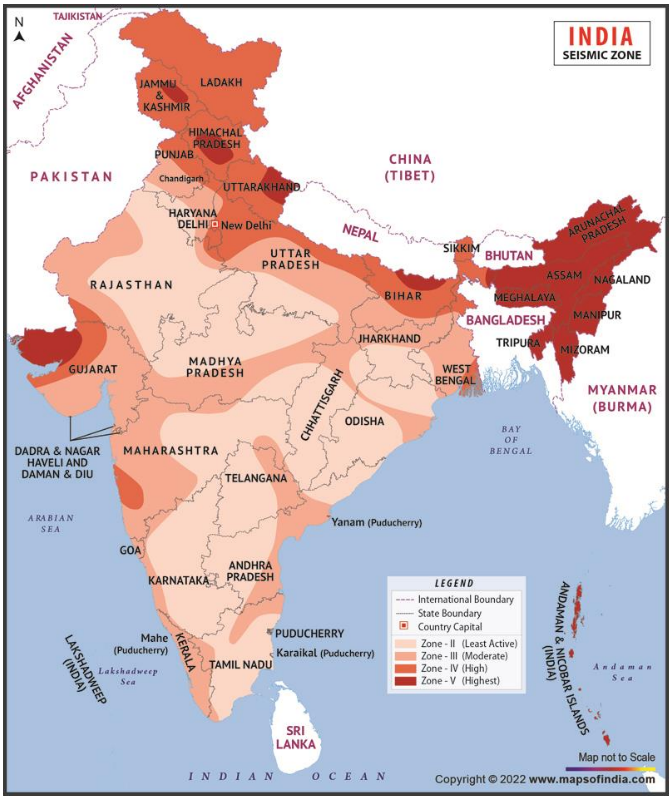


Fig 1 Seismic Zone of India

Objectives of the Research

- The main goal is to estimate and assess the building's seismic response, then evaluate and design using ETABS considering two different soil condition namely Hard soil and Medium soil.
- G+11 building modelling and application of various loads on ETABS, load calculations

owing to various loading combinations, analysis, and structure design on ETABS.

- Comparison of results of earthquake load applied on the structure for two different zones by ETABS and manual calculations both by an equivalent static method.
- Studying the responses, shear forces, bending moment, seismic forces, and node displacement, and restricting them by applying appropriate properties and materials, then assigning them again.

III. Literature Survey

Abhishek Mishra et.al (2022) research paper analyzed and compared the seismic response of a G+15 storey RCC frame structure with variable soil conditions (Hard and Soft soil) for seismic Zone IV. Both models were analysed in STAAD Pro V8i software using the Equivalent Static method of seismic analysis and the response of the model was examined in terms of the maximum storey displacement, base shear and story drift.

When compared to both Soft and Hard soil, the base shear value was more in the soft soil. When compared to both soft and hard soil the story drift value is more in the soft soil. The value of storey displacement increases as the stiffness property of the soil stratum decreases, so it was highest for model M1 with soft soil and lowest for model M2 with hard soil.

B. Ramakrishna et.al (2022) research paper aimed to present the analysis of a multi-stored building [G+5] using STAAD Pro by considering different seismic zones for all type of loads (Seismic load, Dead load, Live load and Wind load) and possible load combinations was performed as per Indian codes. The seismic analysis was done under different zones which are Zone-II, Zone-III, Zone-IV, Zone-V and also zone factor values was considered as per IS 1893-2002 (Part-1). Results were compared on the values of shear, bending moment and deflection for different zones.

Results stated that shear force, bending moment and deflection values for Zone III increased by 60% when compared to Zone II. Shear force, bending moment and deflection values for Zone IV increased by 24% when compared to Zone III. Shear force, bending moment and deflection values for Zone V increased by 50% when compared to Zone IV. For the same loading condition Zone V having more shear force, bending moment and deflection values. As comparing the results zone II having lower shear force, bending moment and deflection values.

Gourav B N et.al (2021) research paper conducted time history, response spectrum and p-delta analyses using Etabs software to study the effects of different soil types and seismic zones for a high-rise building of G+ 30 storey. In the research, a total of 12 models were analyzed for various soils types and seismic zones are systematically compared and discussed for a seismic performance of multistory building. The obtained results were analyzed and compared to determine the most suitable condition for the construction of a given high-rise building to have maximum service life.

Results stated that as the seismicity of the building increases care should be taken by the structural engineers to counter the seismic energy and to safeguard the building. With the change in soil property from hard to medium and from hard to soft the lateral deflection was increased. In Seismic Zone - 2, 3 & 5 the values of maximum Shear forces & maximum bending moment are decreasing in hard soil strata when compared with soft soil strata & found the least for the same.

IV. METHODOLOGY

Step 1: Research paper from different authors are summarized in this section who have focused towards analyzing multi storey high rise structures considering seismic loads with different zones and soil condition

Step 2: In order to initiate the modelling of the case study, firstly their's need to initialize the model on the basis of defining display units on metric SI on region India as ETABS supports the building codes of different nations. The steel code was considered as per IS 800:2007 and concrete design code as per IS 456:2000.

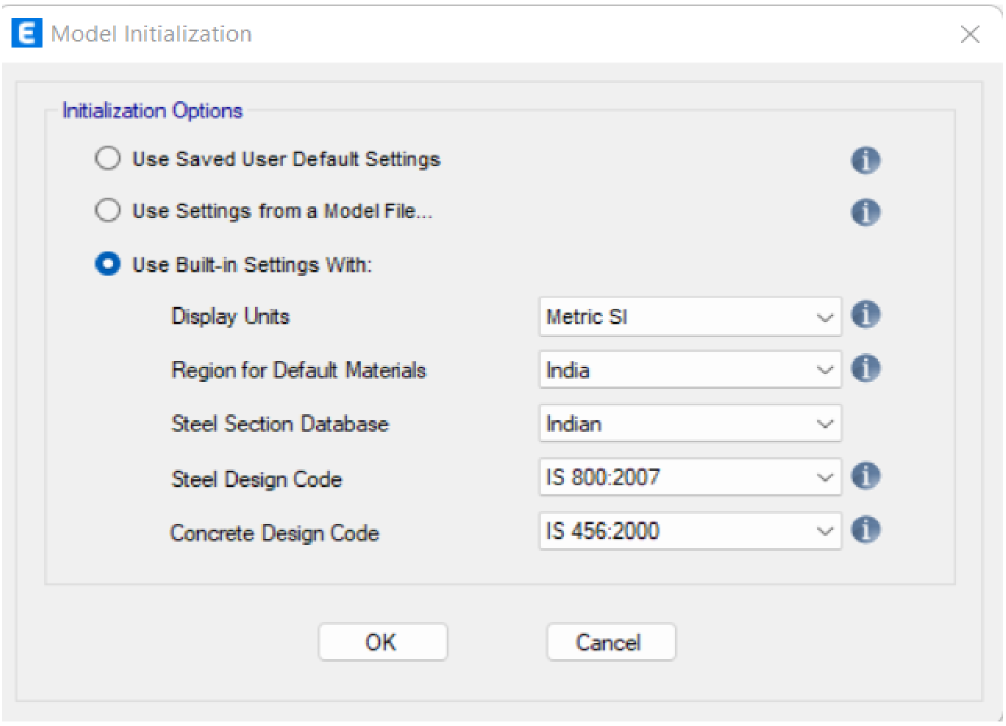


Fig 2 Model Initialization

Step 3: ETABS provides the option of modelling the structure with an easy option of Quick Template where the grids can be defined in X, Y and Z direction. Here in this case, 5 bays in considered in both X and Y direction with a constant spacing of 4m making the model symmetrical in nature. G+ 11 storey structure is considered with typical storey height of 3.2 m and Bottom storey height of 3.2 m.

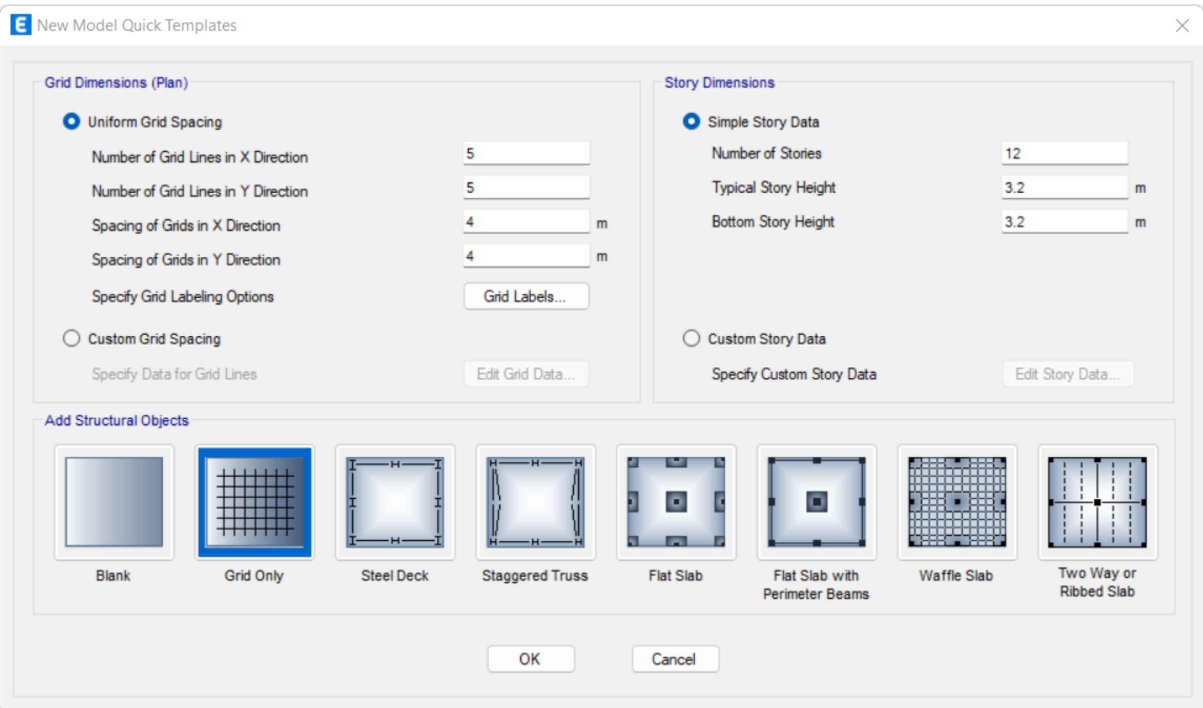


Fig 3 New Model Quick Template

Step 4: Next step is to define material properties for concrete and steel. Here in this case study, M30 concrete and rebar HYSD 415 is considered and its predefined properties are available in the ETABS application.

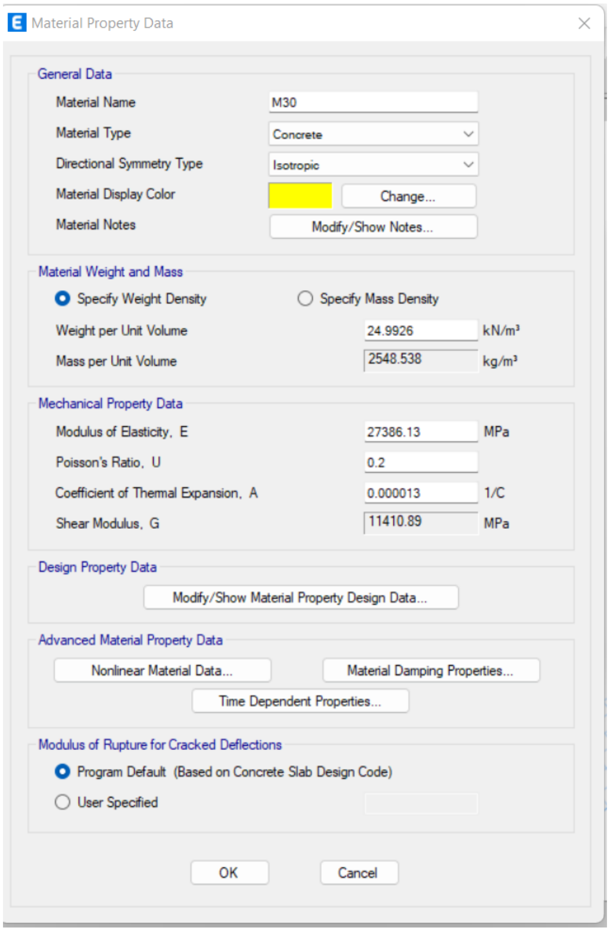


Fig 4 Defining Properties of Concrete M30.

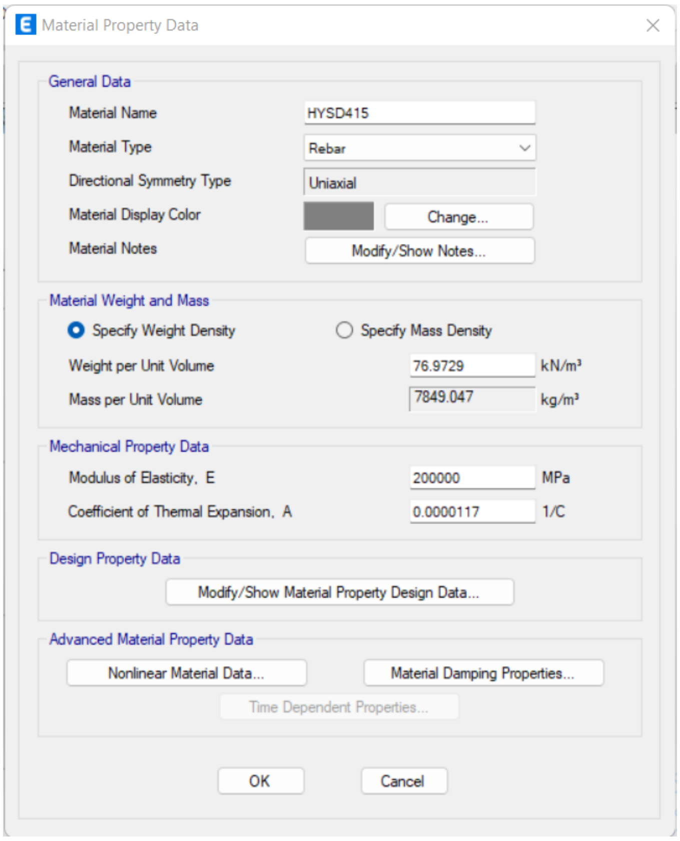


Fig 5 Defining Properties of Rebar HYSD 415

Step 5: Defining section properties for Beam, Column. Beam size of 400x300mm, Column size of 500x300mm and Slab size of 150 mm is considered in the study.

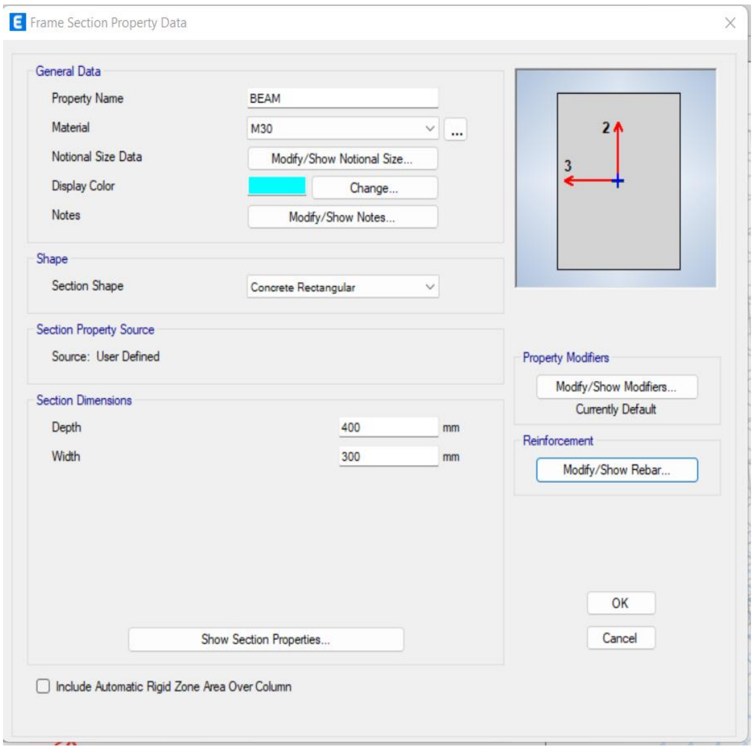


Fig 6 Defining the section properties of Beam

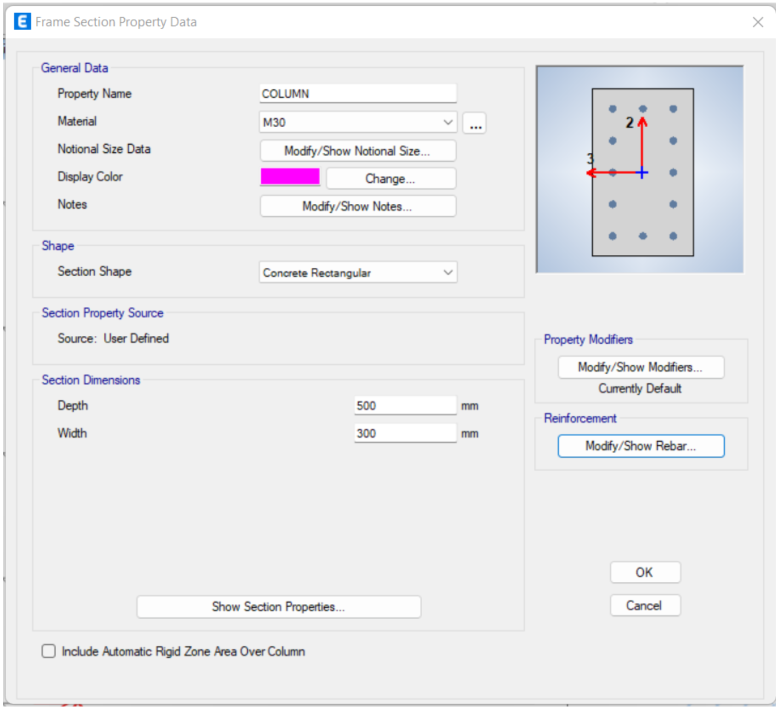


Fig 7 Defining Properties of Column

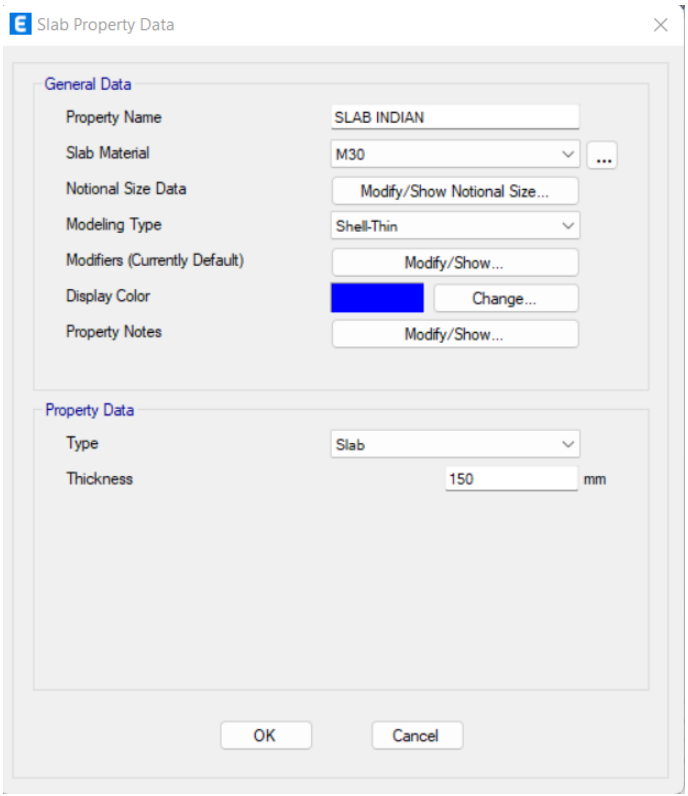


Fig 8 Defining the Properties of Shell-thin slab

Step 6: Assigning Fixed Support at bottom of the structure in X, Y and Z direction in both the considered cases.

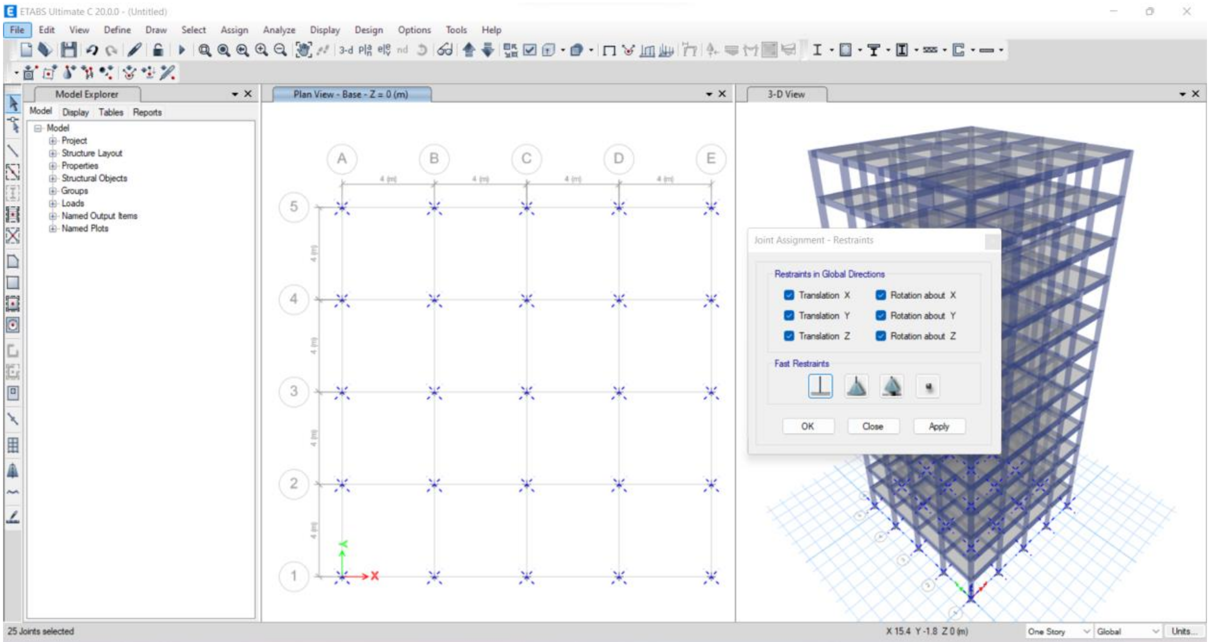


Fig 9 Assigning Fixed Support

Step 7: Defining Load cases for dead load, live load and seismic analysis for X and Y Direction.

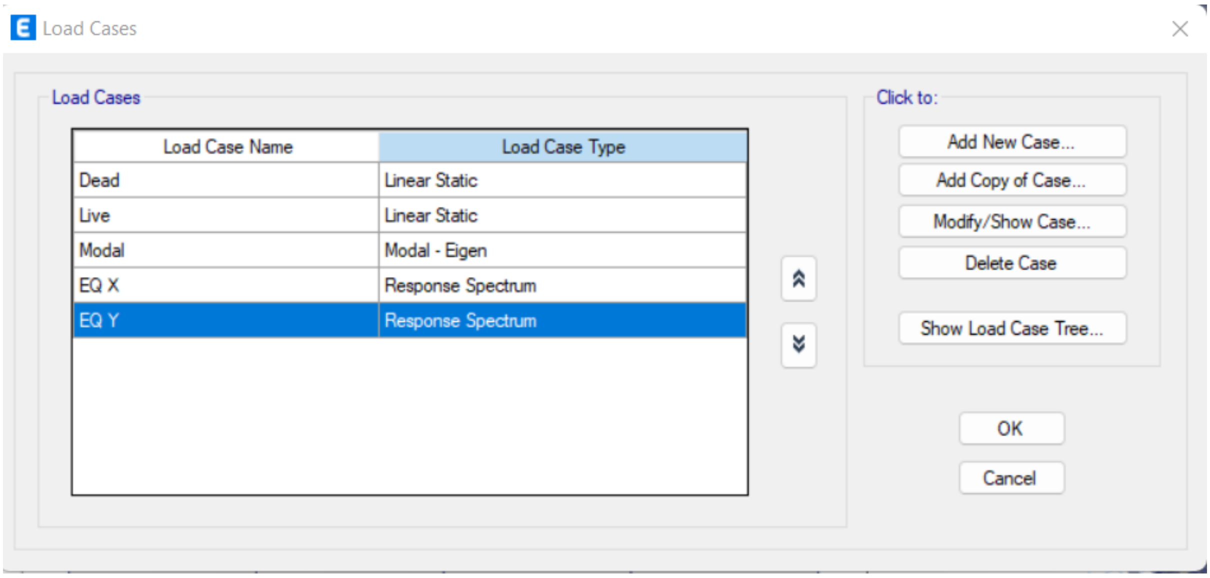


Fig 10 Defining Load Cases

Step 8 Defining Seismic Loading as per IS 1893: 2016 Part I.

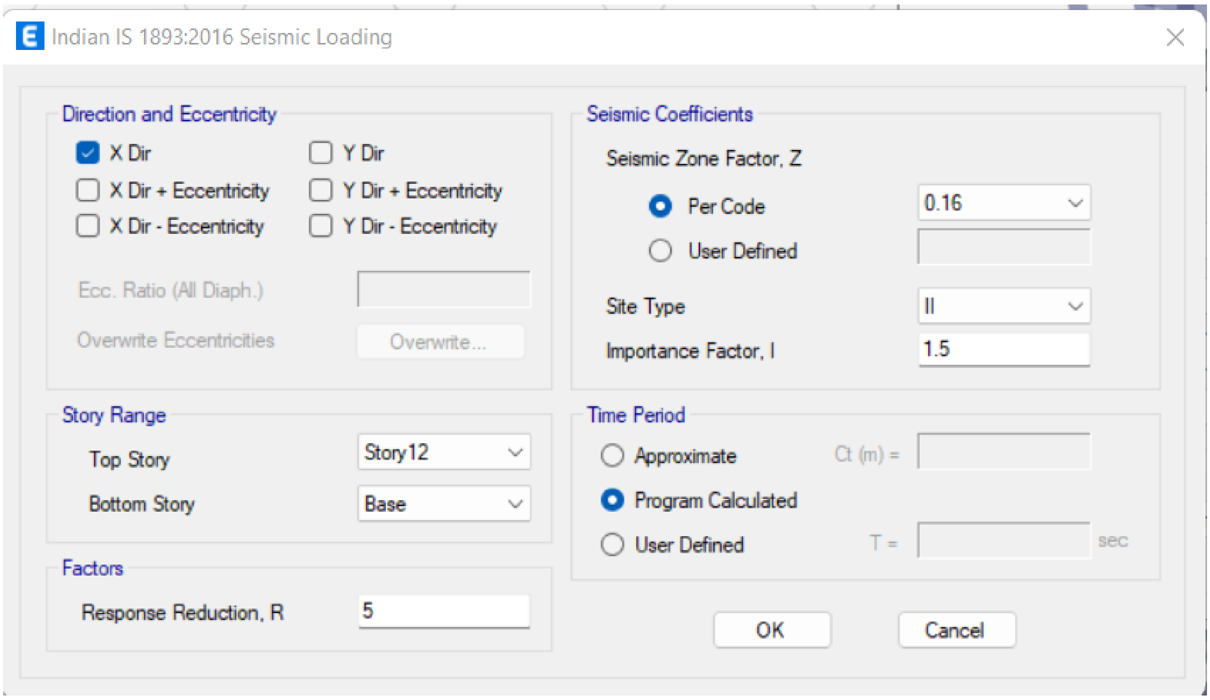


Fig 11 Seismic Loading for the Case Jabalpur for Soil Type II

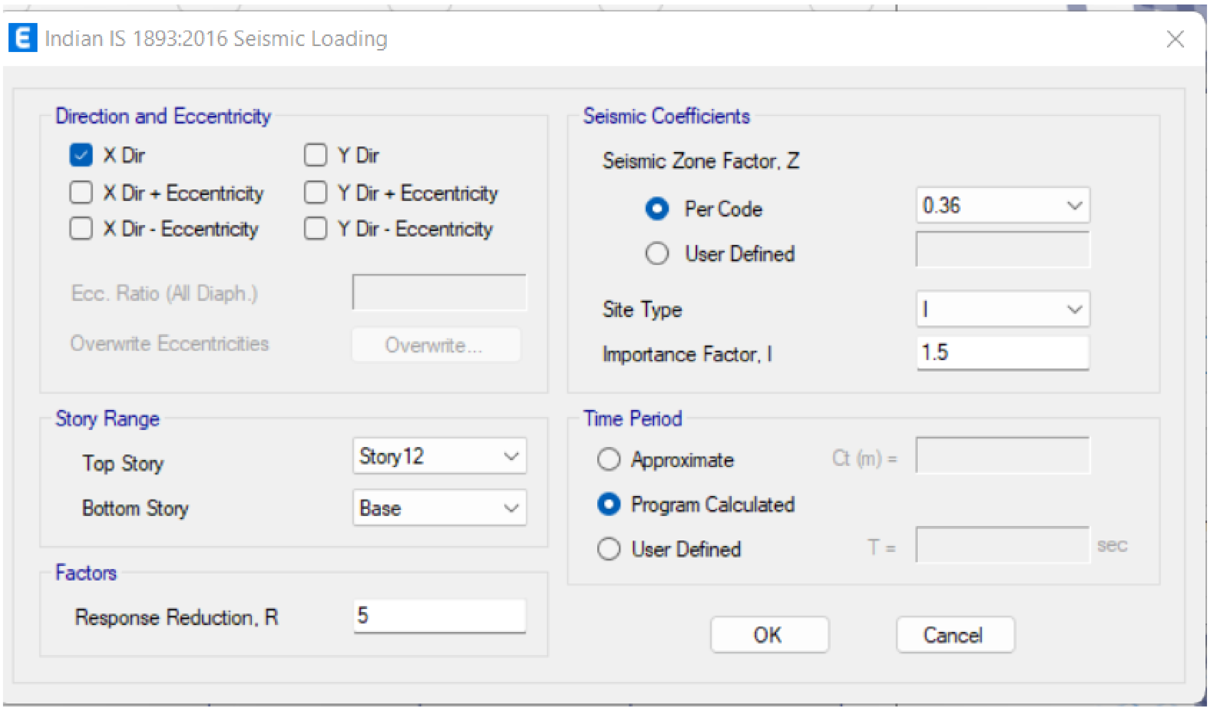


Fig 12 Seismic Loading for the Case Bhuj for Soil Type I

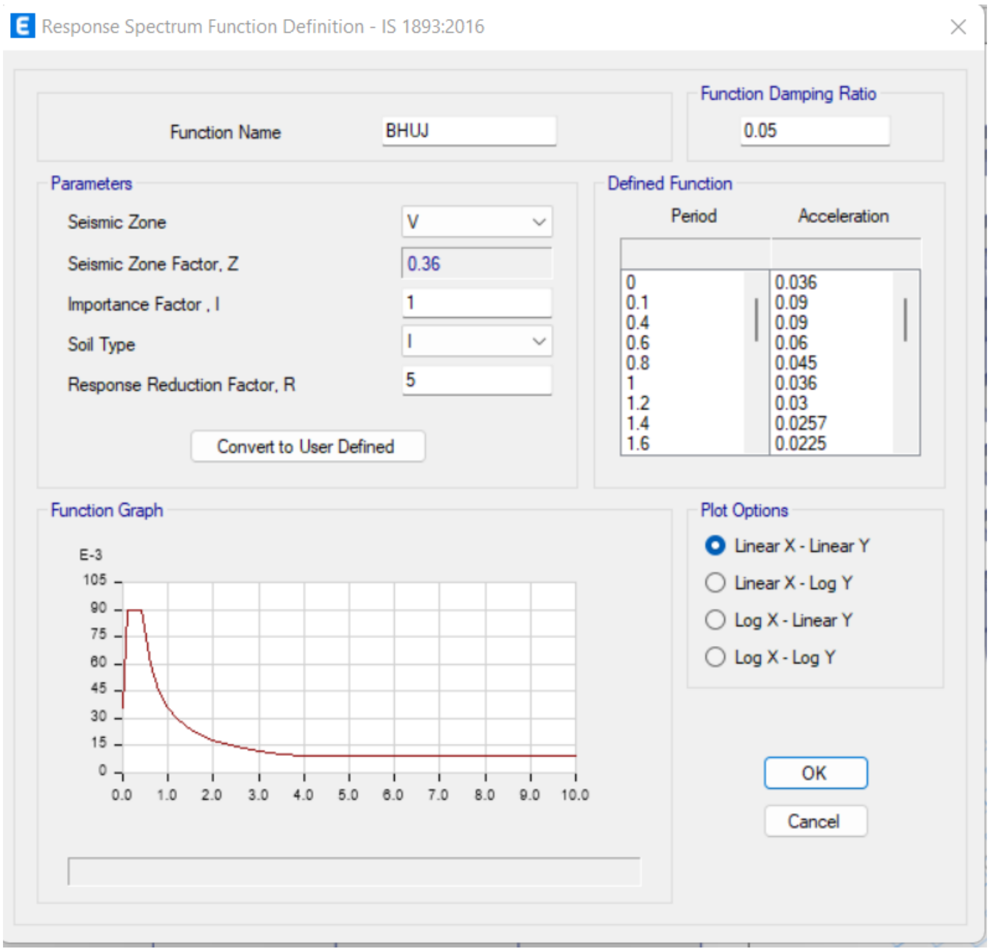


Fig 13 Defining Response Spectrum Analysis as per IS 1893-2016.

Step 9: Conducting the model check for both the cases in ETABS

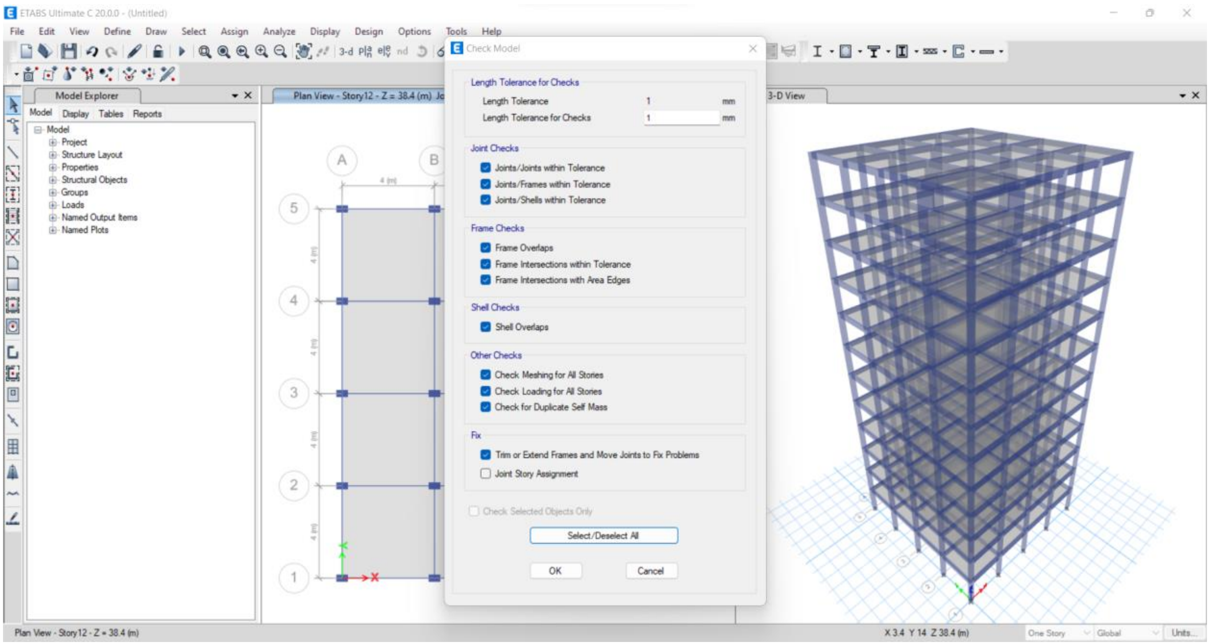


Fig 14 Model Check

Step 10: Analyzing the structure for dead load, stress analysis and displacement.

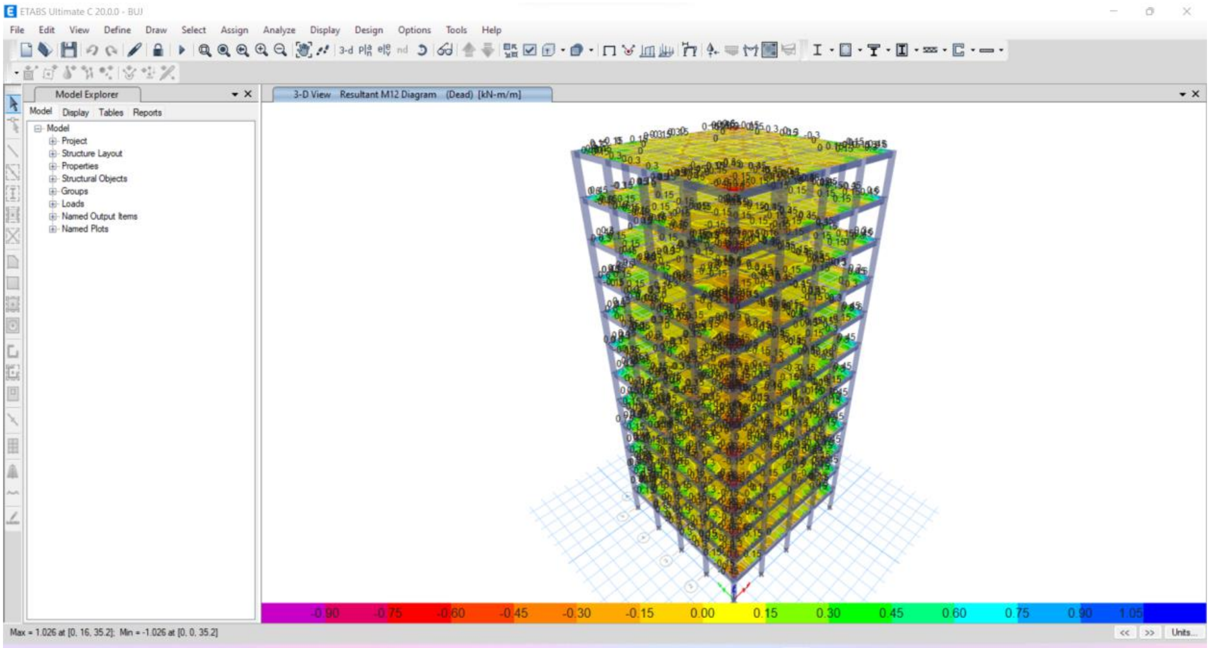


Fig 15 Stress Analysis for Dead Load

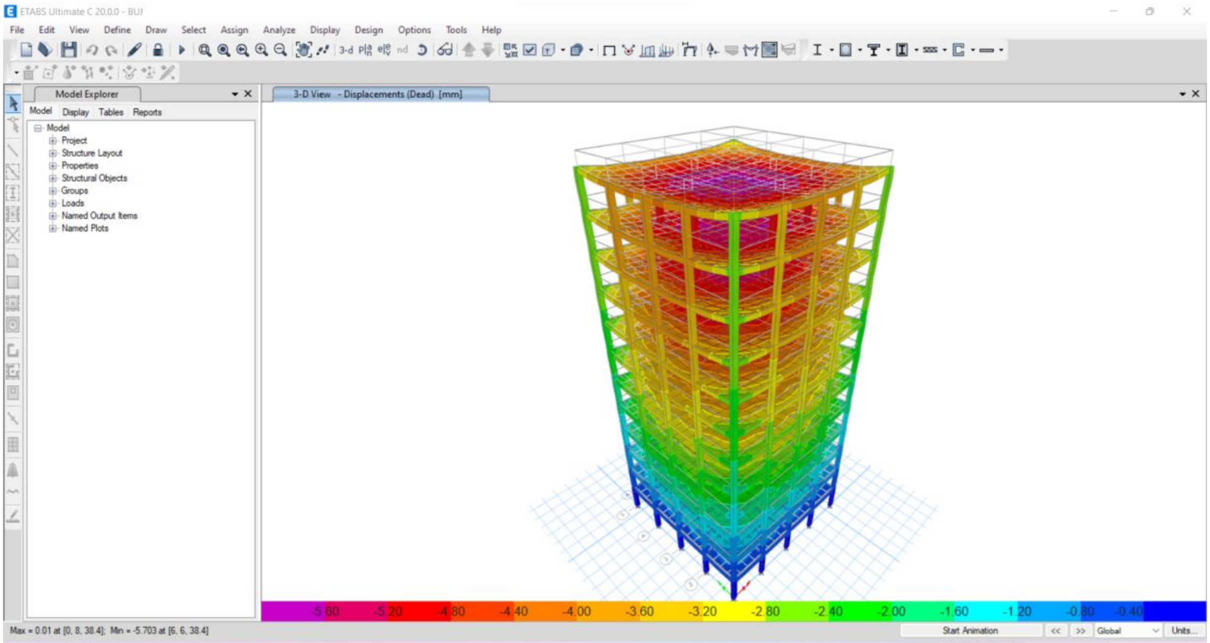


Fig 16 Storey Displacement

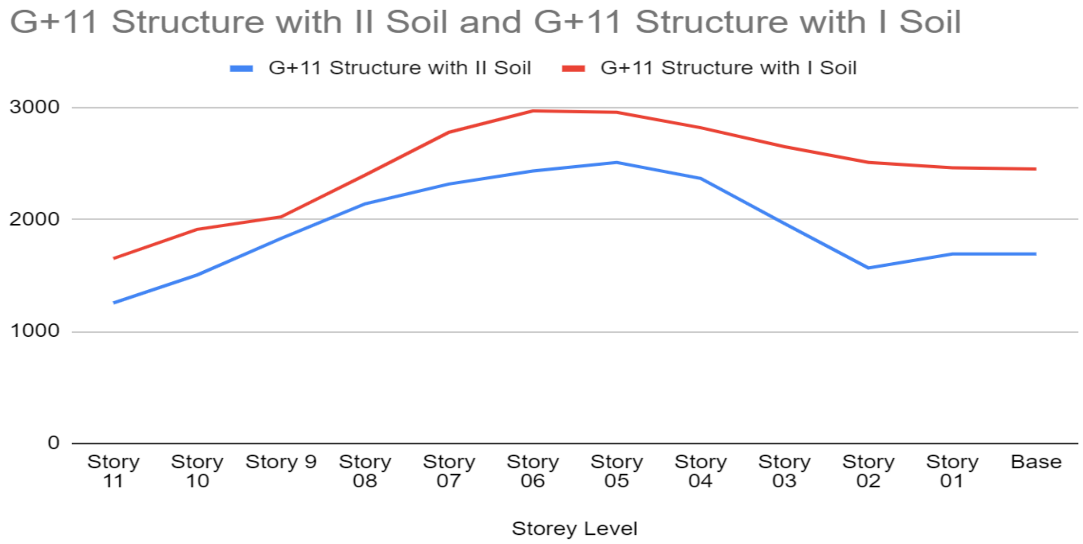
Table 2 Geometrical Specifications of the Structure

Geometrical Specification	
Particulars of Item	Properties
Number of Storey	G+11
Total height of Structure	38.4m
Typical Storey height	3.2m
Bottom Storey Height	3.2m

Floor Diaphragm	Rigid
Number of Grid Lines in X-direction	5
Number of Grid Lines in Y-direction	5
Spacing of Grids in X-direction	4m
Spacing of Grids in Y-direction	4m
Beam Size	400x300mm
Beam Shape	Rectangular
Column Size	500x300mm
Column Shape	Rectangular
Slab Depth	150mm
Slab Type	Thin Shell

Story Shear in kN

Storey Shear in kN		
Storey Level	G+11 Structure with II Soil	G+11 Structure with I Soil
Story 11	1254.304	1650.849
Story 10	1504.689	1910.848
Story 9	1830.732	2022.298
Story 08	2138.652	2394.417
Story 07	2315.94	2777.447
Story 06	2432.479	2968.719
Story 05	2508.256	2956.351
Story 04	2366.272	2818.154
Story 03	1962.451	2648.438
Story 02	1566.039	2508.267
Story 01	1691.523	2460.222
Base	1691.523	2450.222

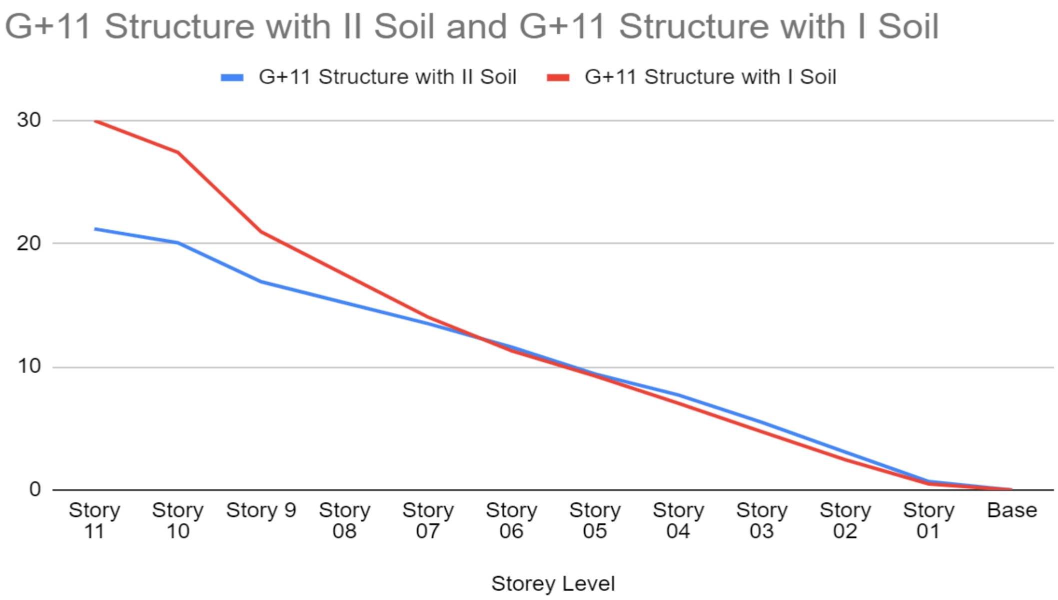


Story Shear in kN

Discussion: Story shear is the graph showing how much lateral (read: horizontal) load, be it wind or seismic, is acting per story. The lower you go, the greater the shear becomes. Story Shear was maximum at 6th Story in both the cases.

Story Displacement in mm

Storey Displacement in mm		
Storey Level	G+11 Structure with II Soil	G+11 Structure with I Soil
Story 11	21.187	29.98
Story 10	20.063	27.404
Story 9	16.898	20.939
Story 08	15.198	17.484
Story 07	13.503	14.017
Story 06	11.589	11.291
Story 05	9.415	9.252
Story 04	7.714	7.038
Story 03	5.497	4.732
Story 02	3.077	2.451
Story 01	0.681	0.492
Base	0	0

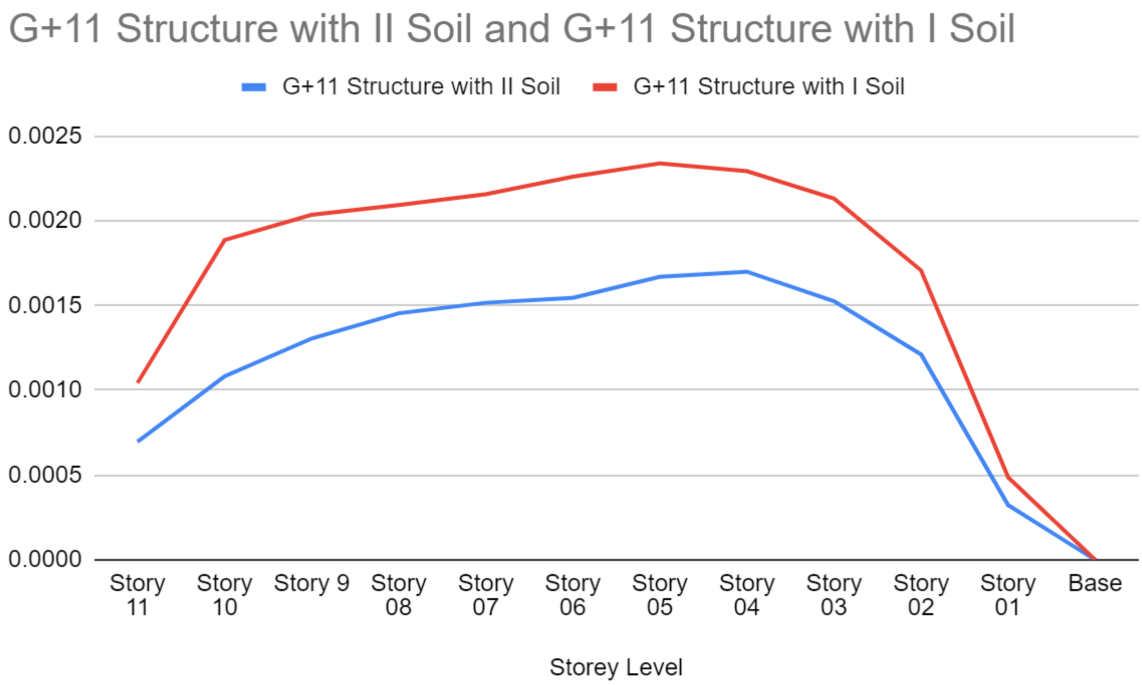


Story Displacement in mm

Discussion: It is found that with the increase in zones the displacement also increases for each soil type. The maximum value of displacement for hard soil is 8.7,13.9, 20.8, 29.8mm. For medium Soil 11.8, 18.9, 28.3, 42.4mm while for Soft soil it is 13.6, 21.7, 32.6, 48.9mm. It is observed that for zone II to zone III the increment is by around 37% while for zone III t to V the percentage reduces by 22.8%

Story Drift in m

Story Drift in m		
Storey Level	G+11 Structure with II Soil	G+11 Structure with I Soil
Story 11	0.000697	0.001044
Story 10	0.001083	0.001887
Story 9	0.001306	0.002036
Story 08	0.001455	0.002094
Story 07	0.001517	0.002157
Story 06	0.001546	0.002261
Story 05	0.00167	0.002339
Story 04	0.0017	0.002293
Story 03	0.001526	0.002131
Story 02	0.001212	0.001708
Story 01	0.000323	0.000486
Base	0	0

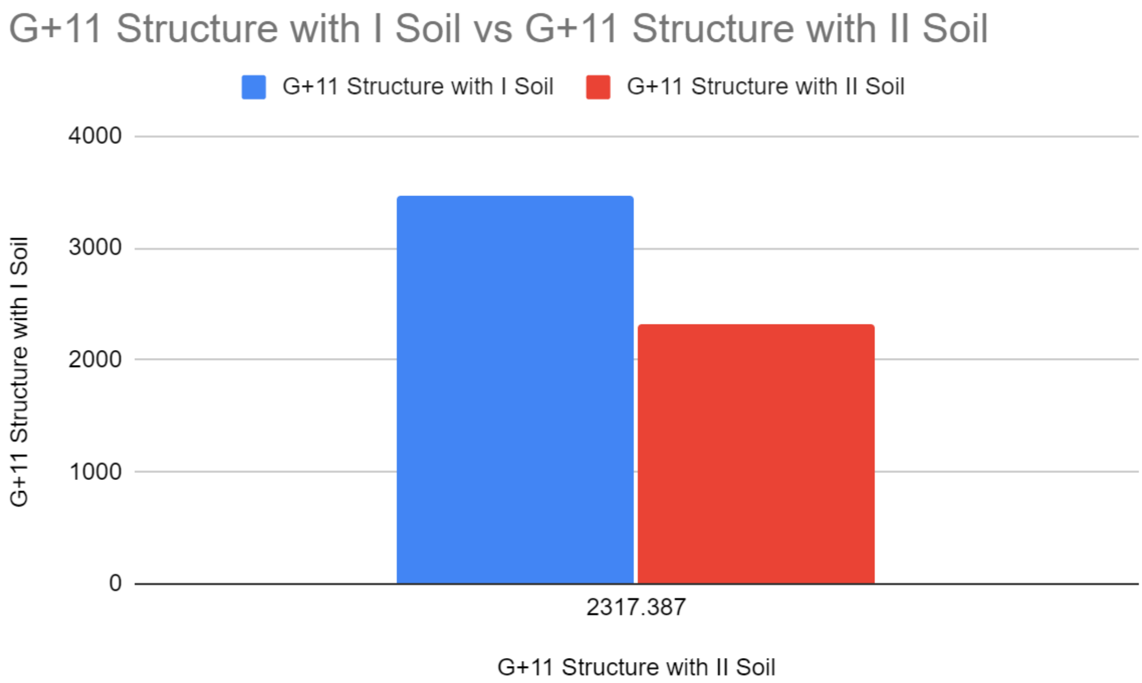


Story Drift in m

Discussion: Storey drift is considered as a drift of a particular level with respect to a level below. The above table shows the Zone wise comparison of storey drift with respect to the soil type. The result show that the value of storey drift increases with the increasing zones. It is observed that the Storey drift increases by more than 30% (zone to zone) for symmetric structure for all the soil types.

Base Shear in kN

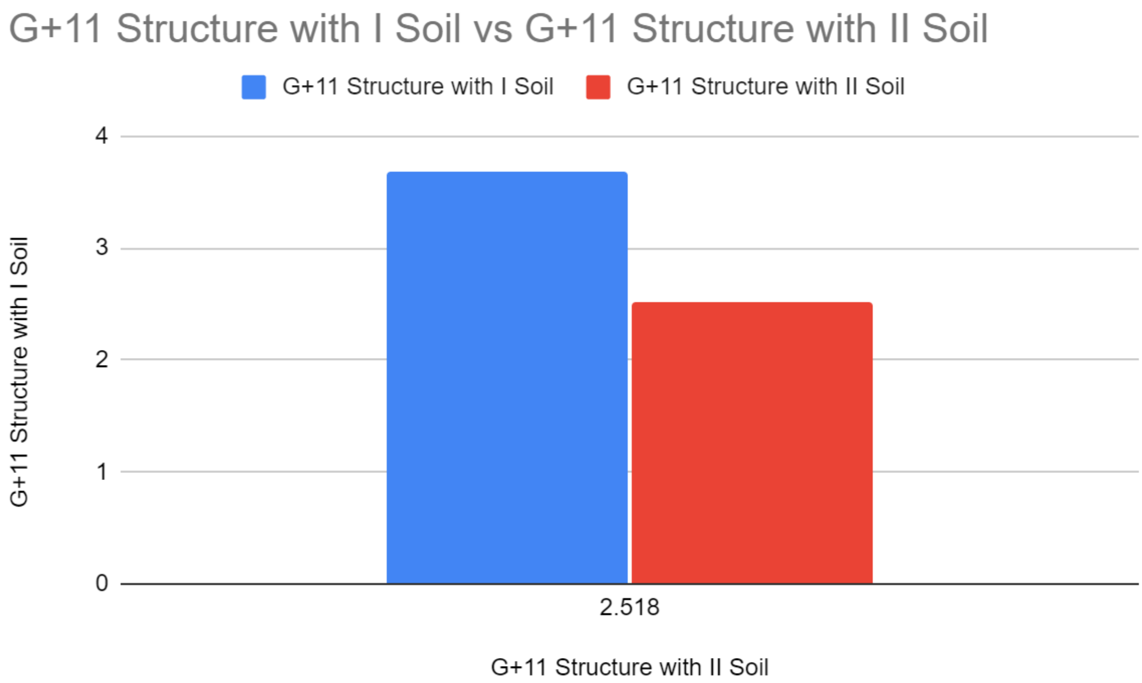
Base Shear in kN	
G+11 Structure with II Soil	G+11 Structure with I Soil
2317.387	3476.294



Base Shear in kN

Discussion: "Base Shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure". It is observed that the base shear of the building increases with the increasing seismic Zones. Base SHear was maximum fro Structure with Soil Type I as 3476.294 kN and 2317.387 kN for structure in II soil type.

Natural TIme Period in sec	
G+11 Structure with II Soil	G+11 Structure with I Soil
2.518	3.69



Discussion: Model with II soil was least affected in comparison to the other model

V. CONCLUSION

From the above results it is concluded that;

Base Shear

"Base Shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure". It is observed that the base shear of the building increases with the increasing seismic Zones. Base SHear was maximum for Structure with Soil Type I as 3476.294 kN and 2317.387 kN for structure in II soil type. The seismic response such as base shear for Bhuj earthquake are found to be more by 45.44% than Jabalpur earthquake by using time history analysis.

Story Displacement

It is found that with the increase in zones the displacement also increases for each soil type. The maximum value of displacement for hard soil is 8.7,13.9, 20.8, 29.8mm. For medium Soil 11.8, 18.9, 28.3, 42.4mm while for Soft soil it is 13.6, 21.7, 32.6, 48.9mm. It is observed that for zone II to zone III the increment is by around 37% while for zone III t to V the percentage reduces by 22.8%. The top story displacement of Jabalpur and Bhuj earthquake by response spectrum method is found to be 33.15% and 34.26% higher.

Story Drift

Storey drift is considered as a drift of a particular level with respect to a level below. The above table shows the Zone wise comparison of storey drift with respect to the soil type. The result show that the value of storey drift increases with the increasing zones. It is observed that the Storey drift increases by more than 30% (zone to zone) for symmetric structure for all the soil types. The values of the storey drifts for all the stories for all the effects are found to be within the permissible limits specified as per IS: 1893-2002 (Part I).

VI. Future Scope

- Further research can be extended to different zones of India.
- Further research can even be extended using different analytical tools such as SAP 2000 or STAAD.Pro and identify the most appropriate damping measure to understand the reaction of structure and recommend necessary damping measure.

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Cite this article as :

Abhishek Thakur, Ankita Singhai, "Analysis of a Tall Structure Under Seismic Loading of Two Different Regions Using ETAB", International Journal of Scientific Research in Civil Engineering (IJSRCE), ISSN : 2456-6667, Volume 7 Issue 1, pp. 29-47, January-February 2023.

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