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# ASSESSING SEISMIC BEHAVIOR IN MEDIUM AND HARD SOIL CONDITIONS FOR A THREE-DIMENSIONAL RCC FRAME WITH DIFFERENT ZONE CONSIDERATIONS

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## ABSTRACT

Earthquake engineering utilizes equivalent lateral forces to design structures capable of withstanding seismic events. In India's seismically active regions, the impact of seismic waves on the Earth's movement underscores the necessity for earthquake-resistant structures. This research delves into the seismic performance of multi-story reinforced concrete building frames, considering diverse loading conditions, varying soil types, and seismic zones III and IV. The analysis encompasses seismic responses like base shear, shear force, bending moment, axial load, and story displacement for an 11-story building. The study explores the influence of soil variations within seismic zones III and IV, as well as the effects of different seismic zones on the building's response. Both time history analysis and response spectrum analysis techniques were utilized to assess the building's natural time periods. These findings offer valuable insights into the intricate relationship between soil type, seismic zone, and structural behavior.

## I. INTRODUCTION

### General

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 behavior 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 2002 code 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.

### 1.1 Seismic Analysis

Seismology is the study of vibrations of earth, mainly caused by earthquakes. The study of these vibrations by various techniques, understanding the nature and various physical processes that generate them from the major part of seismology. From the seismic history of our country, it is observed that majority of the devastating earthquakes have been occurred in northern and north-eastern states of India. Most of this region is the hilly area which lies in the seismically active belt of Himalaya Range. In the last decade, all these regions have gone under rapid changes due to economic development. Being the frontier states rapid urbanization is going on these boundary of country, states with growing real estate development. Due to this, population density in hill region has increased enormously and all types of construction practices are followed [1]. During past earthquakes reinforcement concrete frame buildings that have columns of different heights within one storey, suffered more damage in shorter columns as compared to taller columns in the same storey.

## II. LITERATURE SURVEY

According to **Choudhary, S. N., &Bokare, P. S. (2018), [1]** the frequency of earthquakes has increased, causing severe damage to human life and property. As a result, the necessity for precise seismic evaluation of structures emerges. The seismic co-efficient methodology and response spectrum method are two of the static and dynamic seismic investigation methodologies employed in this study. These methodologies are linked in this study for seismic investigation of a G+10 multistory building. Building response spectrum analysis is performed using the advanced version of software STAAD-PRO-V8i, whilst seismic coefficient analysis is performed by hand using the Codal formula. These earthquake methodologies have been studied in comparison, presented, and explained.

According to **Rajashree S. Kulkarni et al., (2018) [2],** the orientation of structures according to climatology is highly essential in lowering the quantity of carbon impact in the environment. This research examines the effect of seismic load combined with vertical load on reinforced concrete structures oriented by $30^0$,$45^0$,$60^0$,$90^0$ and $180^0$ degrees while keeping the structure's CG constant with respect to the global x-z plane. A G+11 multi-story commercial building was evaluated in Staad pro v8i by orienting it at five various angles with respect to the global x-z plane and observing the structure's behavior, performance, and response in terms of storey drift, displacement, bending moment, and shear force. The results showed that maximum storey drift in the global "x" direction is greater for structures oriented by $180^0$. Except for the structure orientated by $90^0$ angle, the maximum top nodal displacement in the global "x" direction exceeds the allowable limit in all cases. Greatest bending moment was reported for structures orientated by $90^0$ and greatest shear force for structures oriented by $180^0$. As a result, the orientation of a structure is significant from both an environmental and design perspective. As the height of the structure rises, so will the design parameter values.

According to **Dessai, et al., (2023) [3],** Nature offers numerous benefits, but it may also produce hurdles and issues that have a big impact on human civilizations and the environment. Earthquakes, tsunamis, floods, and other natural calamities have resulted in property damage and loss of life. It is vital to identify and address these natural-caused difficulties through proactive actions. People are increasingly moving to high-rise buildings, which give better ventilation, more natural light, and reminiscing views. However, because the magnitude and direction of the earthquake cannot be foreseen, seismic analysis of structures is required to protect against collapse and to securely design the structure in opposition to earthquakes it may encounter over its lifetime. Traditional seismic design methodologies have recently been superseded by performance-based seismic design. The primary goal of this paper is to establish an earthquake-resistant structure by conducting a seasonal study of a G+11 structure exposed to ground excitations while taking into account recent earthquakes in India, employing FOUR different seismic zones (II, III, IV, & V), utilizing Time History Analysis method of research, analyzing and designing the building using ETABS software, and employing non-linear dynamic analysis.

## III. OBJECTIVES

**Objectives of the Research**

- Comparison of results of earthquake load applied on the structure for different Zone (iii and iv and different soil (Hard and medium).
- Comparison of results of earthquake load applied on the structure for two different zones and different soil by two different methods (response spectrum analysis and time history analysis)
- Studying the base shear, shear forces, bending moment, axial force natural time period, and Storey displacement.

# IV. METHODOLOGY

**General**

This studies is targeted towards presenting the comparative evaluation of different zone, different soil and different method for G+11 story structure considering seismic zones of iii and iv and soil type hard and medium kind to recognize the behaviour of the structure while dead load, live load and seismic load are carried out at the structure. The modelling and analysis are completed using staad. pro software program.

**Structure**

The four different height G+11 RCC multi storey framed building is considered for analysis to know the realistic behaviour during an earthquake with the general plan and elevation. RCC multi-storey framed building is modelled for zone iii and iv. The building models using Response spectrum seismic analysis and time history analysis method with fixed support using Staad Pro. The height of all floors is 3m and height of plinth is 3m. soil type is Hard and medium. Modal damping 5% is assumed with SMRF and I=1. The columns are assumed to be fixed at the base. Material concrete grade is M25 and while steel Fe415 is used.

**Geometrical Specifications for G+11**

**Table 4.1** Geometrical Specifications of the Structure

| Geometrical Specification | |
|---|---|
| Particulars of Item | Properties |
| Number of Storey | G+11 |
| Total height of Structure | 36m |
| Typical Storey height | 3m |
| Bottom Storey Height | 3m |
| Floor Diaphragm | Rigid |
| Number of bays along length | 5 |
| Number of bays along width | 6 |
| Spacing of bays along length | 3m |
| Spacing of bays along width | 3m |
| Beam Size | 300x450mm |
| Beam Shape | Rectangular |
| Column Size | 600x600mm |
| Column Shape | Rectangular |
| Slab Depth | 150mm |
| Slab Type | Thin Shell |
| Yield strength of distribution bar (fysec) | Fe415 |
| Yield strength of main bar (fymain) | Fe415 |
| Grade 0f Concrete | 15 for P.c.c and M25 forstructure |

Step-3: Property Definition: Using General-Property command define the property as per size requirement to the respective building on staad-Pro. So, beam and columns have been generated after assigning to selected beam and columns

Defining section properties for Beam, Column. Beam size of 300x450mm, Column size of 600x600mm and Slab size of 150 mm is considered in the study

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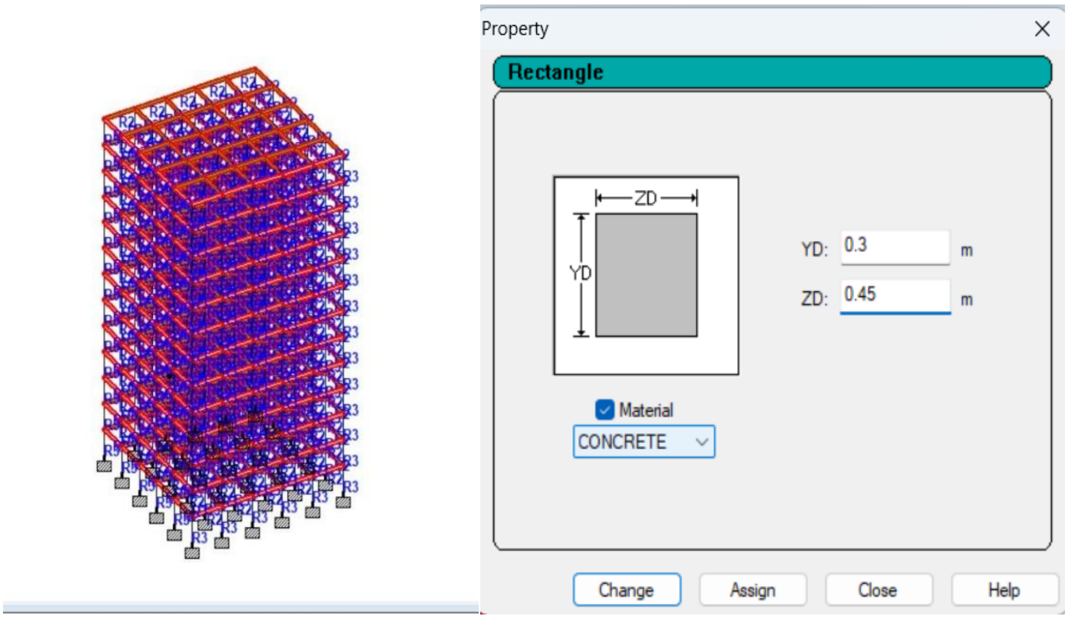


**Fig. 4.1** Defining the Properties of Beam

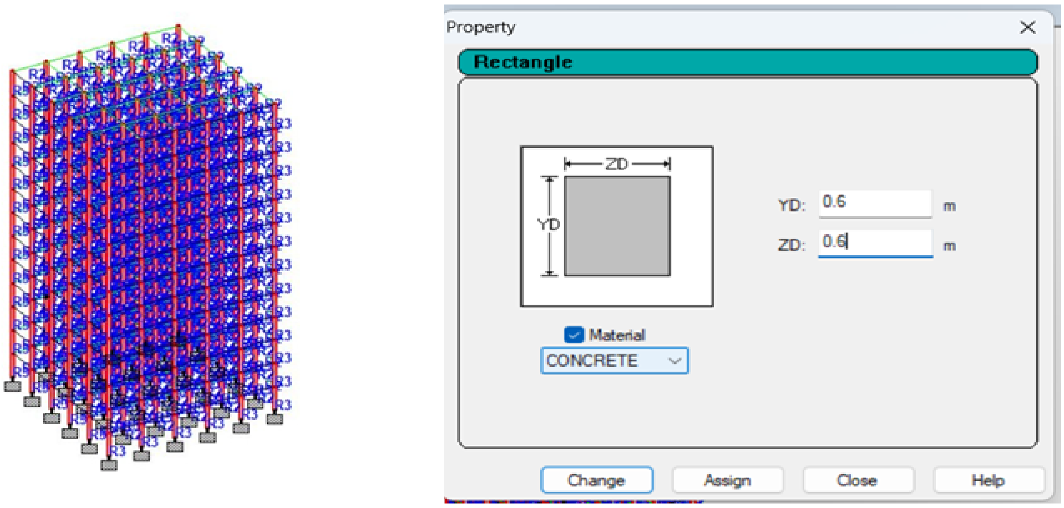


**Fig. 4.2** Defining the Properties of Column

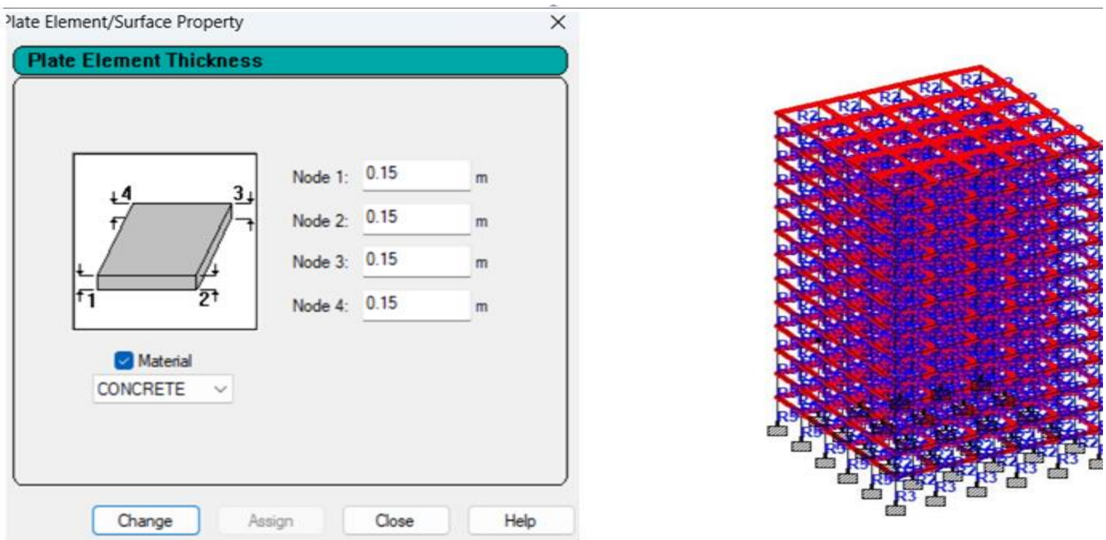


**Fig. 4.3** Defining the Properties of Shell-thin Slab

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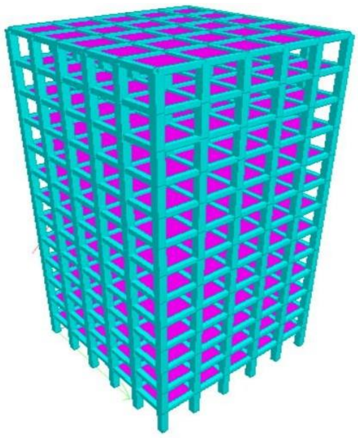

**Fig. 4.4** 3D Structure of the Building

**Defining Support**

Step 5: Assigning supports to the structure

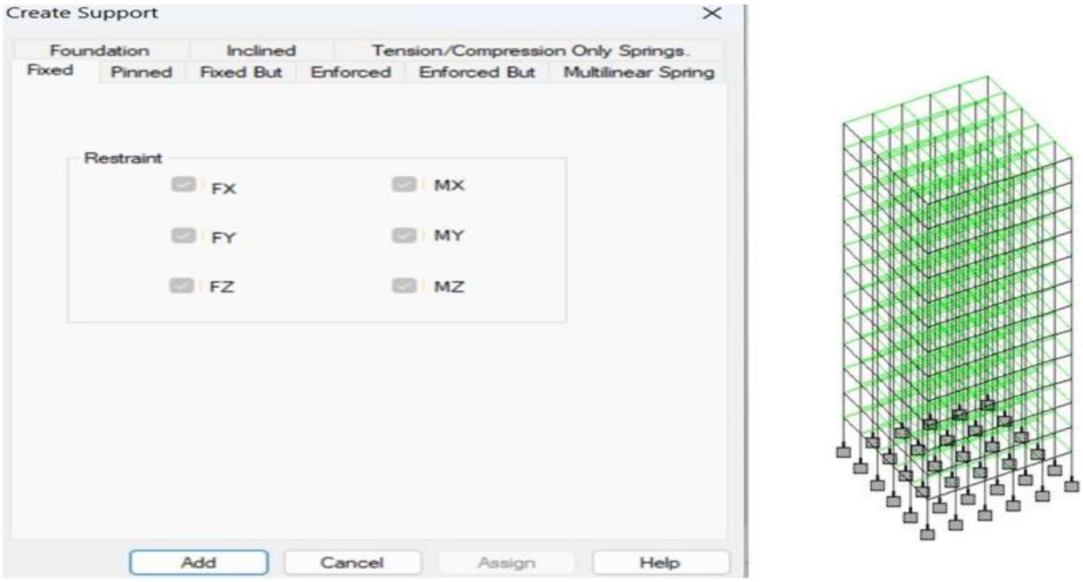


**Fig. 4.5** Assigning Supports

**Defining Load**

Step 6: Defining Load cases for dead load, live load and seismic analysis for X and Y Direction.

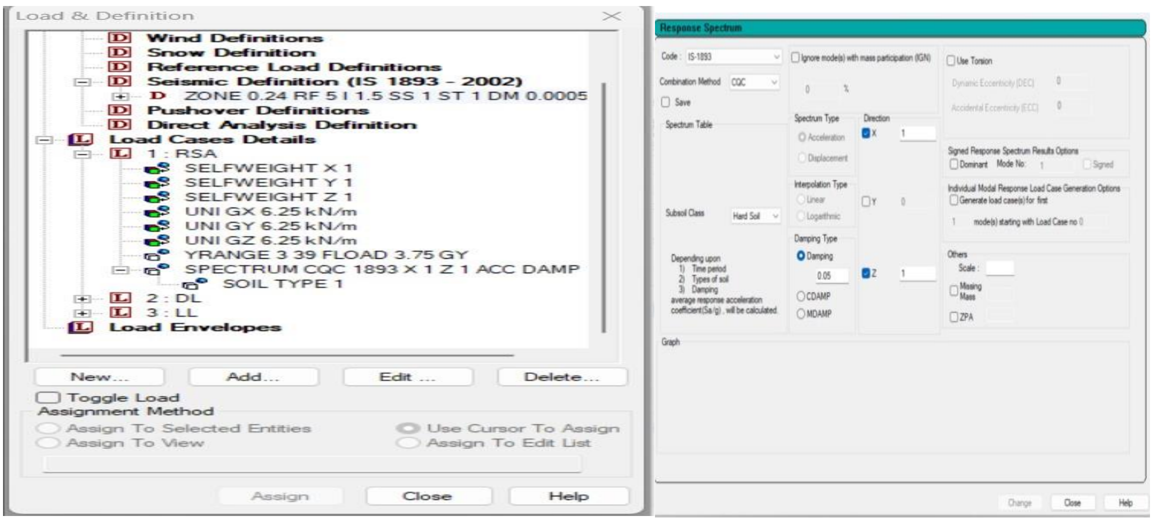


**Fig. 4.6** Defining Load Cases

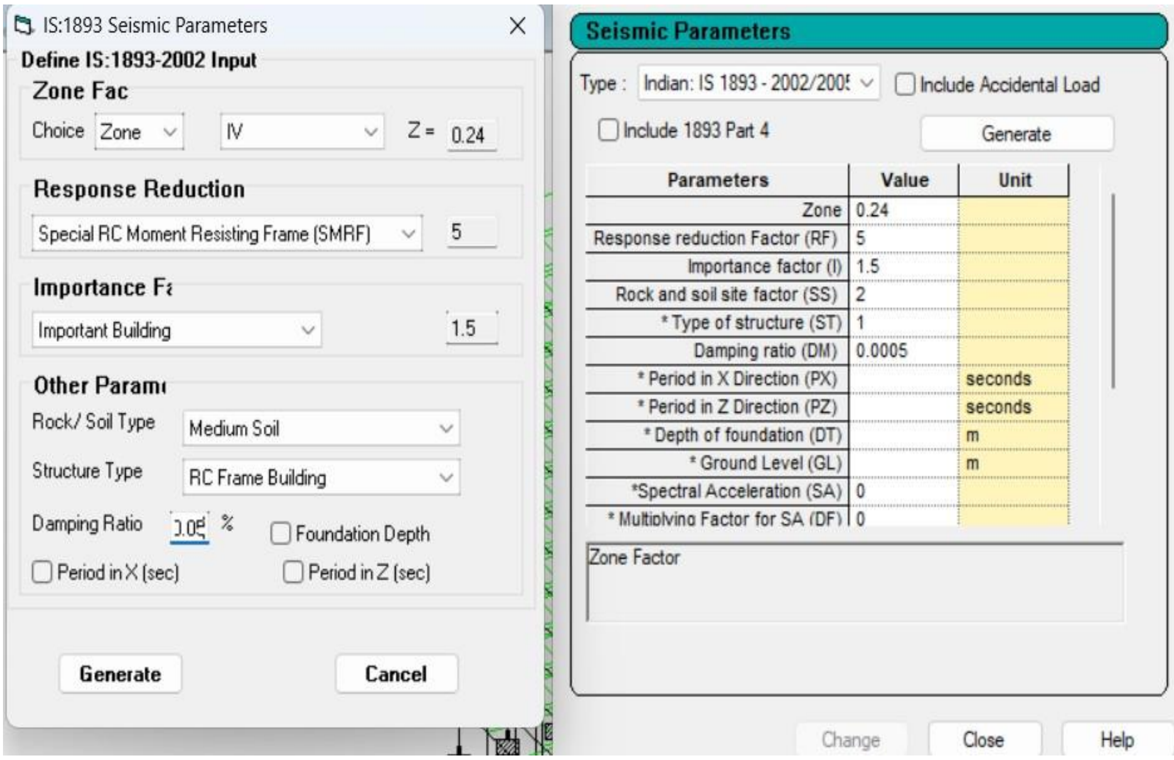


**Fig. 4.7** Defining Seismic Analysis as per IS 1893-2002 For Zone iv

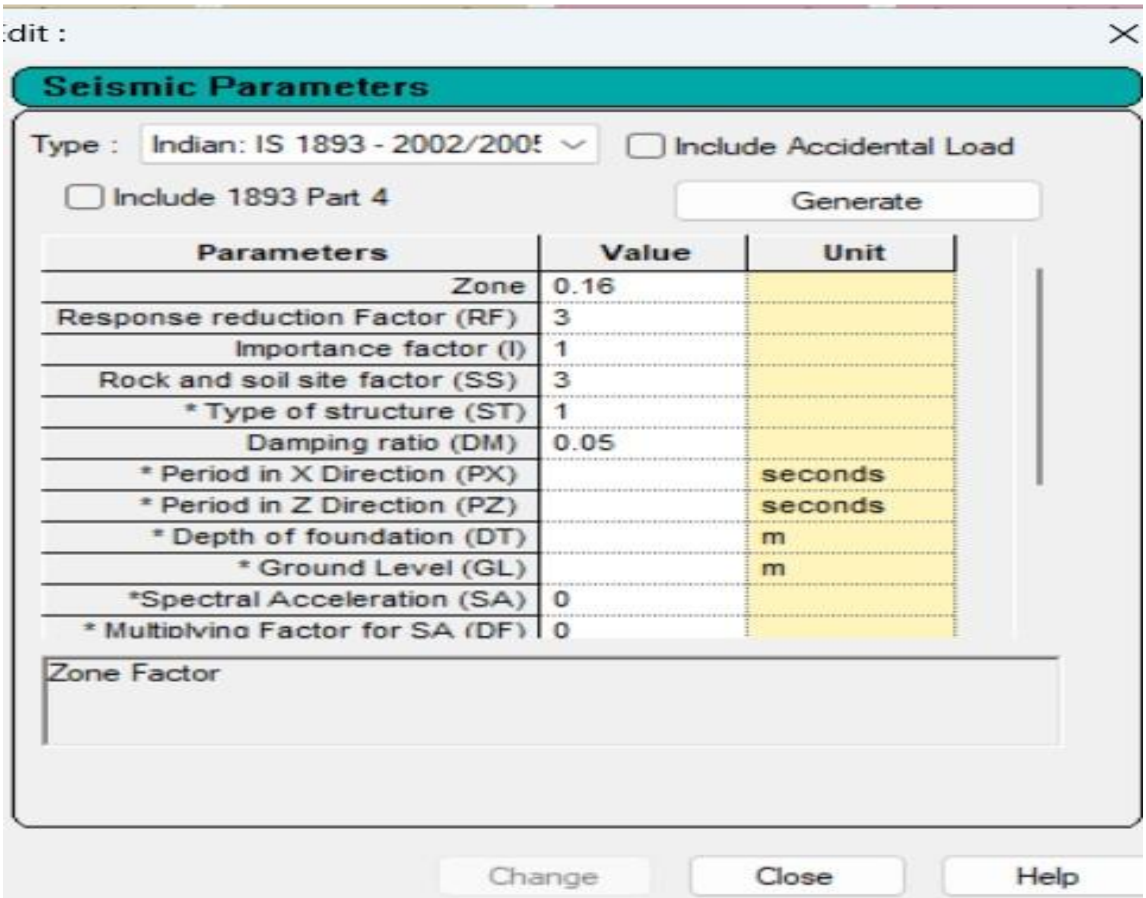


**Fig. 4.8** Defining Seismic Analysis as per IS 1893-2002 for Zone III

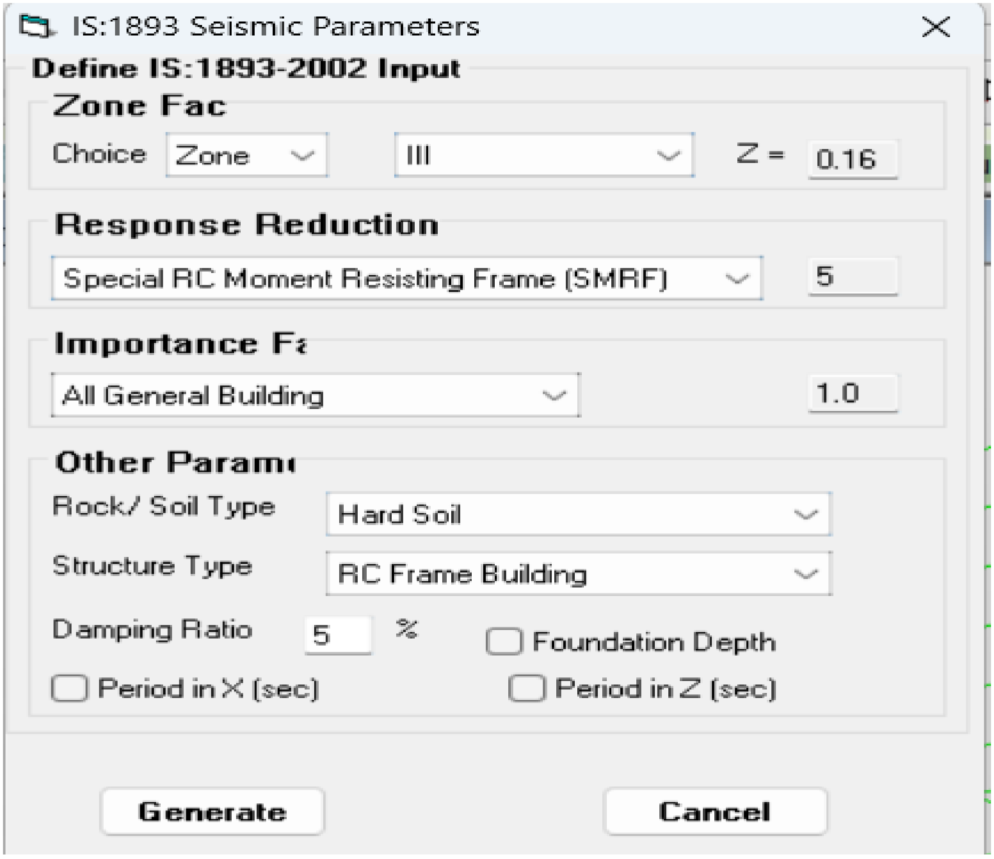


**Fig. 4.9** Defining Seismic Analysis as per IS 1893-2002 for Hard soil

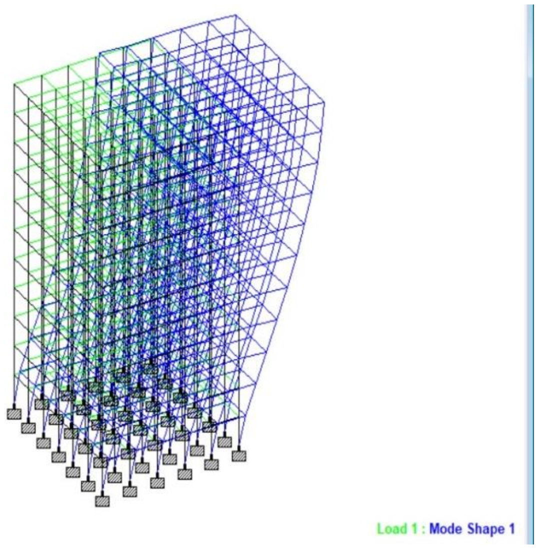


**Fig. 4.10** Storey Displacement

## V. RESULT AND ANALYSIS

**General**

The comparative study of different soil and different zone for high rise building structure the study of storey displacement, base shear, maximum shear force, bending moment, axial force of building response spectrum analysis is performed. The results obtained from analysis are given below and comparative study is carried out which is stated below.

**Results for G+11 RCC Building Located at Zone IV with Soil Type Hard, and Medium**

**Base shear evaluation for hard soil in G+11 Structure**

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**Table 5.1** Results of Base Shear for G+11 RCC Building Located at Zone iv with Soil Type-Hard

| Story | Level In Meter | Peak Story Shear In KN | |
|---|---|---|---|
| | | X | Y |
| 12 | 36.00 | 160.58 | 161.22 |
| 11 | 33.00 | 323.57 | 325.57 |
| 10 | 30.00 | 455.16 | 458.92 |
| 9 | 27.00 | 551.64 | 557.31 |
| 8 | 24.00 | 617.86 | 625.35 |
| 7 | 21.00 | 666.78 | 675.78 |
| 6 | 18.00 | 714.40 | 724.48 |
| 5 | 15.00 | 771.06 | 781.78 |
| 4 | 12.00 | 835.07 | 846.17 |
| 3 | 9.00 | 854.67 | 906.02 |
| 2 | 6.00 | 935.99 | 947.54 |
| 1 | 3.00 | 951.87 | 963.52 |
| BASE | 0.00 | 951.87 | 963.52 |

**Storey Displacement Evaluation for Hard Soil in G+11 Structure**

**Table 5.2** Results of Storey Displacement for G+11 RCC Building Located at Zone iv withSoil Type-Hard

| Storey | Level In Meter | Storey Displacement Inmm |
|---|---|---|
| 12 | 36.00 | 25.47 |
| 11 | 33.00 | 24.33 |
| 10 | 30.00 | 23.24 |
| 9 | 27.00 | 21.80 |
| 8 | 24.00 | 20.04 |
| 7 | 21.00 | 18.00 |
| 6 | 18.00 | 15.71 |
| 5 | 15.00 | 13.16 |
| 4 | 12.00 | 10.38 |
| 3 | 9.00 | 7.40 |
| 2 | 6.00 | 4.34 |
| 1 | 3.00 | 1.53 |
| BASE | 0.00 | 0.00 |

Shear Force Evaluation for Hard Soil in G+11 Structure

**Table 5.3** Results of Shear Force for G+11 RCC Building Located at Zone iv with Soil Type-Hard

| BEAM | L/C | Max Shear Force in KN |
|---|---|---|
| 1 | RSA | 190 |
| 4 | RSA | 145 |
| 13 | RSA | 130 |

| | | |
|---|---|---|
| 19 | RSA | 115 |
| 25 | RSA | 105 |

**Bending Moment Evaluation for Hard Soil in G+11 Structure**

**Table 5.4** Results of Shear Force for G+11 RCC Building Located at Zone iv with Soil Type-Hard

| BEAM | L/C | Max Bending Moment |
|---|---|---|
| 1 | RSA | 291 |
| 4 | RSA | 146 |
| 13 | RSA | 124 |
| 19 | RSA | 119 |
| 25 | RSA | 114 |

**Axial force Evaluation for Hard Soil in G+11 Structure**

**Table 5.5** Results of Axial Force for G+11 RCC Building Located at zone iv with Soil Type-Hard

| BEAM | L/C | Max axial force |
|---|---|---|
| | | FX KN |
| 1 | RSA | 2920 |
| 4 | RSA | 2650 |
| 13 | RSA | 2315 |
| 19 | RSA | 1980 |
| 25 | RSA | 1660 |

**Base shear Evaluation for Medium Soil in G+11 Structure**

**Table 5.6** Results of Base Shear for G+11 RCC Building Located at Zone iv with Soil Type-Medium

| **Story** | **Level In Meter** | **Peak Story Shear In KN** | |
|---|---|---|---|
| | | **X** | **Y** |
| 12 | 36.00 | 189.55 | 189.74 |
| 11 | 33.00 | 387.19 | 388.50 |
| 10 | 30.00 | 555.42 | 558.67 |
| 9 | 27.00 | 690.96 | 696.74 |
| 8 | 24.00 | 797.88 | 806.45 |
| 7 | 21.00 | 886.26 | 897.47 |
| 6 | 18.00 | 967.52 | 980.84 |
| 5 | 15.00 | 1048.21 | 1062.88 |
| 4 | 12.00 | 1126.25 | 1141.61 |
| 3 | 9.00 | 1192.50 | 1208.14 |
| 2 | 6.00 | 1236.31 | 1252.06 |
| 1 | 3.00 | 1252.78 | 1268.58 |
| BASE | 0.00 | 1252.78 | 1268.58 |

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**Storey Displacement Evaluation for Medium Soil in G+11 Structure**

**Table 5.7** Results of Storey Displacement for G+11 RCC Building Located at Zone iv with Soil Type-Medium

| Storey | Level In Meter | Storey DisplacementIn mm |
|---|---|---|
| 12 | 36.00 | 35.12 |
| 11 | 33.00 | 34.11 |
| 10 | 30.00 | 32.63 |
| 9 | 27.00 | 30.62 |
| 8 | 24.00 | 28.15 |
| 7 | 21.00 | 25.24 |
| 6 | 18.00 | 21.95 |
| 5 | 15.00 | 18.32 |
| 4 | 12.00 | 14.37 |
| 3 | 9.00 | 10.19 |
| 2 | 6.00 | 5.95 |
| 1 | 3.00 | 2.09 |
| BASE | 0.00 | 0.00 |

**Shear Force Evaluation for Hard Soil in G+12 Structure**

**Table 5.8** Results of Shear Force for G+11 RCC Building Located at Zone iv with Soil Type-Hard

| BEAM | L/C | Max ShearForce in KN |
|---|---|---|
| 1 | RSA | 265 |
| 4 | RSA | 195 |
| 13 | RSA | 175 |
| 19 | RSA | 160 |
| 25 | RSA | 150 |

**Bending Moment Evaluation for Hard Soil in G+11 Structure**

**Table 5.9** Results of Shear Force for G+11 RCC Building Located at Zone iv with Soil Type-HardSource: Staad Pro OUTPUT

| BEAM | L/C | Max BendingMoment |
|---|---|---|
| 1 | RSA | 397 |
| 4 | RSA | 198 |
| /13 | RSA | 169 |
| 19 | RSA | 160 |
| 25 | RSA | 154 |

**Axial force Evaluation for Hard Soil in G+11 Structure**

**Table 5.10** Results of Axial Force for G+11 RCC Building Located at Zone iv with Soil Type-HardSource: Staad Pro OUTPUT

| BEAM | L/C | Max axial force |
|---|---|---|
| | | FXKN |
| 1 | RSA | 4105 |

| | | |
|---|---|---|
| 4 | RSA | 3705 |
| 13 | RSA | 3214 |
| 19 | RSA | 2710 |
| 25 | RSA | 2235 |

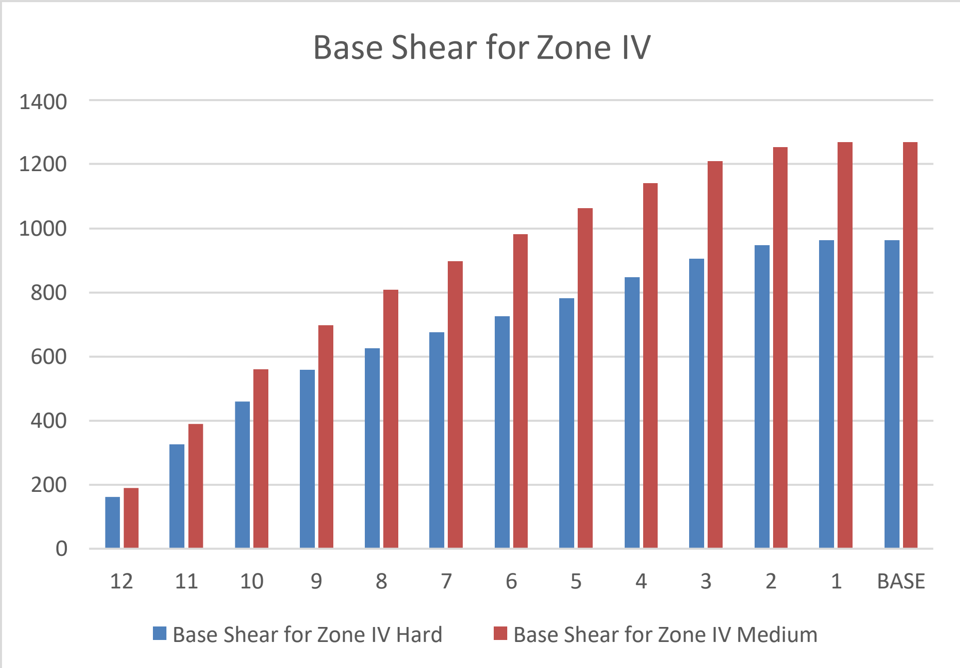


**Fig. 5.1** Base Shear for Hard and Medium Soil in Zone IV

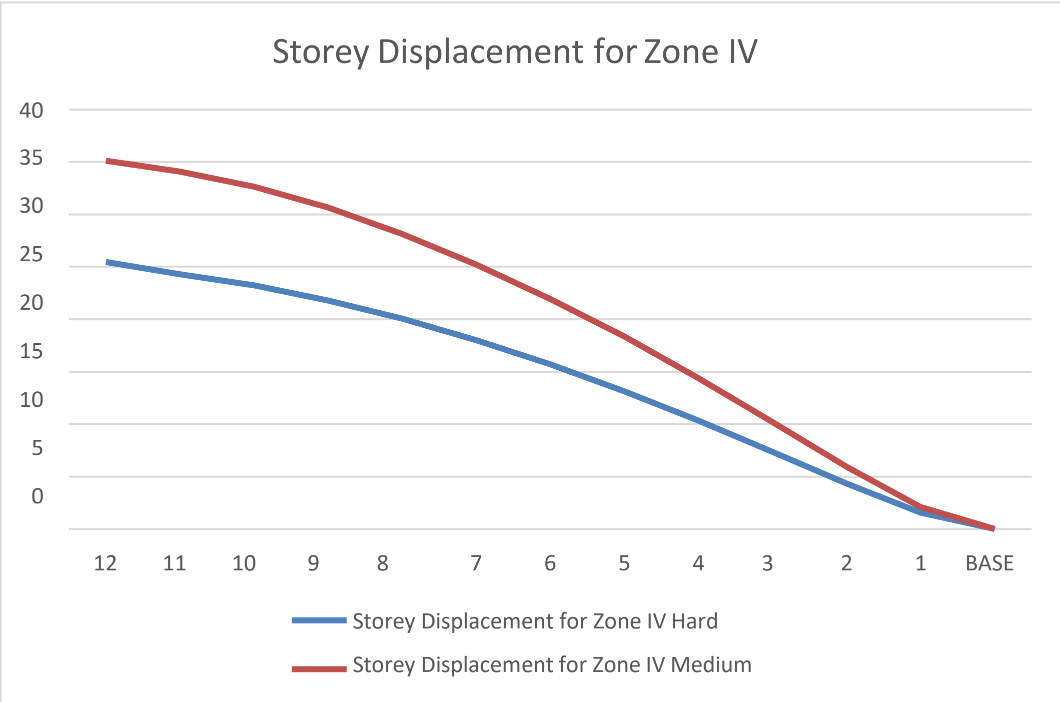


**Fig. 5.2** Displacement for Hard and Medium Soil in Zone IV

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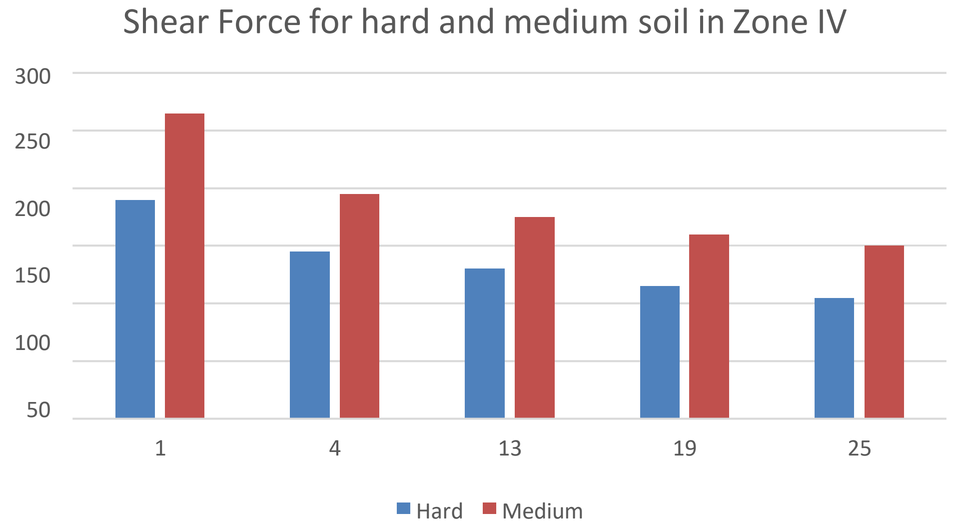


**Fig. 5.3** Shear Force for Hard and Medium Soil in Zone IV

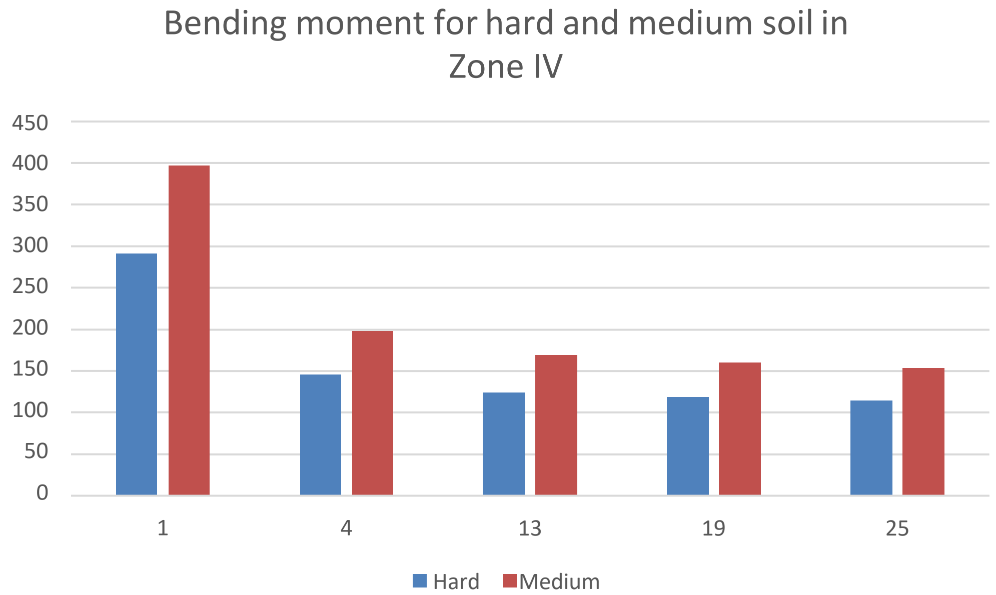


**Fig. 5.4** Bending Moment for Hard and Medium Soil in Zone IV

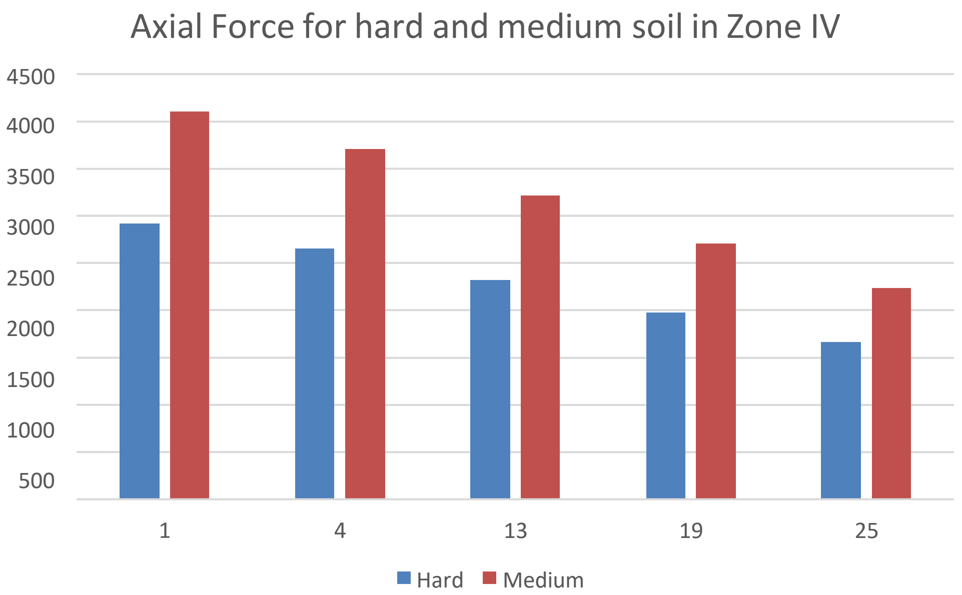


**Fig. 5.5** Axial Force for Hard and Medium Soil in Zone IV

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**Results for G+11 RCC Building Located at Zone III with Soil TypeHard, And Medium**

**Base shear evaluation for hard soil in G+11 Structure**

**Table 5.11** Results of Base Shear for G+11 RCC Building Located at Zone iii with Soil Type-Hard

| Story | Level In Meter | Peak Story Shear In KN | |
|---|---|---|---|
| | | X | Y |
| 12 | 36.00 | 107.05 | 107.48 |
| 11 | 33.00 | 215.71 | 217.05 |
| 10 | 30.00 | 303.44 | 305.95 |
| 9 | 27.00 | 367.76 | 371.54 |
| 8 | 24.00 | 411.91 | 416.90 |
| 7 | 21.00 | 444.52 | 450.52 |
| 6 | 18.00 | 476.27 | 482.98 |
| 5 | 15.00 | 514.04 | 521.19 |
| 4 | 12.00 | 556.71 | 564.11 |
| 3 | 9.00 | 596.45 | 604.01 |
| 2 | 6.00 | 623.99 | 631.69 |
| 1 | 3.00 | 634.58 | 642.34 |
| BASE | 0.00 | 634.58 | 642.34 |

**Storey Displacement Evaluation for Hard Soil in G+11 Structure**

**Table 5.12** Results of Storey Displacement for G+11 RCC Building Located at Zone iv withSoil Type-Hard

| Storey | Level In Meter | Storey Displacement Inmm |
|---|---|---|
| 12 | 36.00 | 16.72 |
| 11 | 33.00 | 16.22 |
| 10 | 30.00 | 15.49 |
| 9 | 27.00 | 14.53 |
| 8 | 24.00 | 13.36 |
| 7 | 21.00 | 12.00 |
| 6 | 18.00 | 10.47 |
| 5 | 15.00 | 8.77 |
| 4 | 12.00 | 6.92 |
| 3 | 9.00 | 4.93 |
| 2 | 6.00 | 2.89 |
| 1 | 3.00 | 1.02 |
| BASE | 0.00 | 0.00 |

**Shear Force Evaluation for Hard Soil in G+12 Structure**

**Table 5.13** Results of Shear Force for G+11 RCC Building Located at Zone iv with SoilType-Hard

| BEAM | L/C | Max Shear Forcein KN |
|---|---|---|
| 1 | RSA | 125 |
| 4 | RSA | 95 |
| 13 | RSA | 85 |
| 19 | RSA | 75 |
| 25 | RSA | 70 |

**Bending Moment Evaluation for Hard Soil in G+11 Structure**

**Table 5.14** Results of Shear Force for G+11 RCC Building Located at Zone iv with SoilType-Hard

| BEAM | L/C | Max Bending Moment |
|---|---|---|
| 1 | RSA | 193 |
| 4 | RSA | 96 |
| 13 | RSA | 83 |
| 19 | RSA | 80 |
| 25 | RSA | 76 |

**Axial force Evaluation for Hard Soil in G+11 Structure**

**Table 5.15** Results of Axial Force for G+11 RCC Building Located at Zone iv with Soil Type-Hard

| BEAM | L/C | Max axial force |
|---|---|---|
| | | FXKN |
| 1 | RSA | 1955 |
| 4 | RSA | 1765 |
| 13 | RSA | 1540 |
| 19 | RSA | 1320 |
| 25 | RSA | 1105 |

**Axial Force Evaluation for Hard Soil in G+11 Structure**

**Table 5.16** Results of Axial Force for G+11 RCC Building Located at Zone iv with Soil Type-Hard

| BEAM | L/C | Max axial force |
|---|---|---|
| | | FXKN |
| 1 | RSA | 2735 |
| 4 | RSA | 2470 |
| 13 | RSA | 2140 |
| 19 | RSA | 1805 |
| 25 | RSA | 1490 |

## VI. CONCLUSION

The effect of seismic for multi-storey reinforced concrete building frames with various load, different soil and different zone Variation in seismic responses of building such as base shear, shear force, bending moment, axial load, storey displacement were considered for the study. The results for & G+11 storey building are discuss in results section for the discussion it is concluded that.

The following general conclusions were drawn from the present study.

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**Comprehensively the Soil Effects on RCC Building ConsideringVariation in Soil in Presence Seismic Zone iii and iv**

**Comprehensively the Soil Effects on RCC Building Considering Variation in Soil in Presence Seismic Zone iii Base shear**

In case of G+11 RCC frame based on base shear of storey with soil type-Hard is obtained as 642KN. When the soil type change to medium base shear of storey is increased to 835KN.

**Displacement**

In case of G+11 RCC frame based on displacement of storey with soil type-Hard is obtained as 16.71mm. When the soil type change to medium displacement of storey is increased to 23.41mm

**Axial Force**

In case of G+11 RCC frame based on axial force with soil type-Hard is obtained as 1955KN When the soil type change to medium axial force is increased to 2735KN

**Shear Force**

In case of G+11 RCC frame based on shear force with soil type-Hard is obtained as 125kN When the soil type change to medium shear force is increased to 170KN.

**Bending moment**

In case of G+11 RCC frame based on bending moment with soil type-Hard is obtained as 193kN-m. When the soil type change to medium bending moment is increased to 268KN-m.

Comprehensively the Soil Effects on RCC Building Considering Variation in Soil in Presence Seismic Zone iv

**Base shear**

In case of G+11 RCC frame based on base shear of storey with soil type-Hard is obtained as951 KN. When the soil type change to medium base shear of storey is increased to 1252 KN.

**Displacement**

In case of G+11 RCC frame based on displacement of storey with soil type-Hard is obtained as 25.47mm. When the soil type change to medium displacement of storey is increased to 35.12mm

**Axial Force**

In case of G+11 RCC frame based on axial force with soil type-Hard is obtained as 2920KN when the soil type change to medium axial force is increased to 4105KN

**Shear Force**

In case of G+11 RCC frame based on shear force with soil type-Hard is obtained as 190kN when the soil type change to medium shear force is increased to 265KN.

**Bending moment**

In case of G+11 RCC frame based on bending moment with soil type-Hard is obtained as 291kN-m. When the soil type change to medium bending moment is increased to 397KN-m.

**Comprehensively Results for Natural Time Periods With ResponseSpectrum And Time History Analysis Method For G+11 RCC Frame Building**

- In case of G+11 RCC frame based on maximum natural time period with time history analysis obtained as 0.385sec. When the method changes to response spectrum analysis natural time increased to 0.386sec.
- Natural time period is less in Time History Analysis Method.
- Minor variation in both methods (time history analysis and response spectrum analysis)

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