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Sustainable Seismic Performance Evaluation of G+15 RCC High-Rise Building on Varying Soil Conditions Using ETABS

Ramatai B. Somwanshi*, Manisha Sawant, Urmila Mahadik, Nilima Pote, Vishwaraj Mokashi and Neha Muddamwar

JSPM's Rajarshi Shahu College of Engineering, Pune - 411033, Maharashtra, India; rama09somwanshi@gmail.com

Abstract

This study investigates the seismic performance of a G+15 Reinforced Concrete (RCC) high-rise building situated on varying soil types—hard, medium, and soft—across seismic zones II, III, IV, and V in India. Employing ETABS software and IS codes (IS 1893:2016, IS 875:1987/2015, IS 456:2000), the seismic responses analysed include storey drift, displacement, base shear, storey shear, and period. The analysis reveals that seismic parameters are significantly influenced by both soil type and seismic zone, with softer soils exhibiting increased seismic demand. The study underscores the importance of soil classification in earthquake-resistant design and proposes optimised structural solutions to maintain performance within permissible limits.

Major Findings: *Studies reveal that when considering Soil–Structure Interaction (SSI), softer soil significantly increases inter-story drift and fundamental period, reducing overall lateral stiffness and requiring tailored design strategies for high-rise RCC buildings to maintain resilience. Dynamic ETABS models of G+15 (or similar) RCC frames show that base shear and story displacements worsen on soft soils, while medium to firm soils yield more stable seismic performance, emphasising the need for soil-specific foundation design to boost sustainability. Incorporating soil conditions via SSI in ETABS simulations is crucial—softer soils amplify drift and vibration in G+15 RCC towers, demanding reinforced design measures for sustainable seismic resilience.*

Keywords: *Base Shear, ETABS, RCC Building, Seismic Analysis, Seismic Zones, Soil Type, Storey Drift*

1.0 Introduction

Earthquakes are natural disasters characterised by the sudden release of energy beneath the Earth's surface, resulting in ground motion that can significantly impact buildings. India, as per IS 1893 (Part 1): 2016, is divided into four seismic zones. Soil plays a critical role in the response of structures to seismic loads. This study investigates the impact of three soil types—Type I (hard), Type II (medium), and Type III (soft)on the seismic performance of a G+15 RCC high-rise building. Due to a lack of space in urban areas, vertical growth has resulted in the development of low-rise, medium-rise, and tall buildings. These buildings are usually made of framed structures. They are loaded vertically and laterally. The design is governed by lateral loads caused by the wing and earthquakes rather than vertical loads. Buildings designed to withstand vertical loads may not be able to withstand lateral loads. The lateral loads are the most important because, unlike vertical loads, which are

*Author for correspondence

expected to increase linearly with height, lateral loads are highly variable and rapidly increase with height. Vertically designed structures may not be able to withstand lateral loads. Because, unlike vertical loads, which are expected to increase linearly with height, lateral loads are highly variable and rapidly increase with height, they are the most important[1].

2.0 Literature Review Summary

Several studies have explored seismic analysis of high-rise structures using tools like ETABS and STAAD. Pro. Previous research highlights that storey displacement and drift increase with the severity of seismic zones and softening of soil types[2]. Tools like the Response Spectrum Method and Time History Analysis are commonly used to estimate seismic responses. However, gaps remain in evaluating high-rise buildings across all four seismic zones and three primary soil types in a systematic framework[3].

3.0 Research Objectives

1. To evaluate the seismic response of a G+15 RCC building with isolated pad footing for soil types 1, 2, 3 lying in zones II, III, IV, V by using ETABS software.
2. To compare seismic response (storey drift, storey displacement, storey shear, base shear, and period) of high-rise RCC buildings lying in four seismic zones with soil types 1, 2, and 3.
3. Comparing the design output of high high-rise RCC building lying in a type 3 seismic zone with soil types 1, 2, and 3.
4. To analyse the impact of different soil types (hard, medium, and soft) on the structural response.

4.0 Methodology

The study is divided into four phases:

Phase I: Literature review and problem formulation.

Phase II: Modelling of a G+15 residential RCC building using ETABS software[4].

Phase III: Seismic analysis using IS code-based load combinations for four seismic zones and three soil types.

Phase IV: Comparative analysis and discussion of results including storey drift, displacement, base shear, and period[5].

5.0 Building Specifications

Height: 59.5 m
Storeys: G+15
Concrete: M30; Steel: Fe 500
Plan: 19.5 m × 10.2 m
Load considerations: IS 875 (Parts 1–3), IS 1893 (Part 1): 2016

6.0 Analysis of High-Rise Building

The analysis of HRB is done using ETABS software, and the various sequential steps involved in the process of analysis are shown in Figure 1.

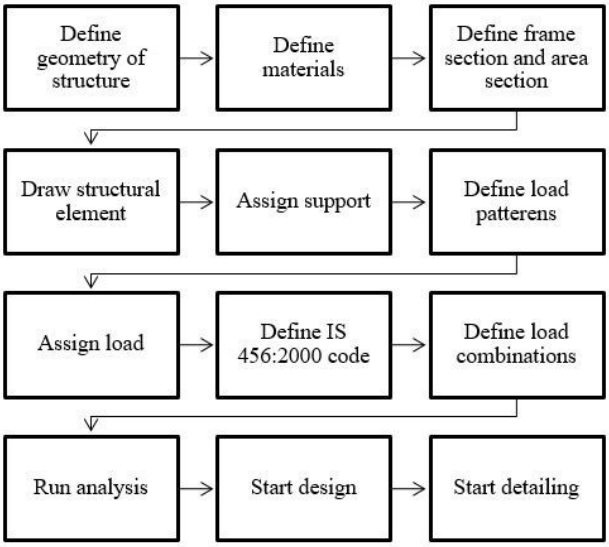


Figure 1. Process of analysis.

7.0 Geometrical Details

Table 1. The geometrical details considered for the analysis of HRB

Parameters	Particulars
Type of Building	Residential
Number of storeys	G+15
Height of HRB	59.50m
Height of each storey	3.5m
Size of structure in plan	19.50 m x 10.20 m
Base to ground level	3 m
Wall size	150 mm and 230 mm

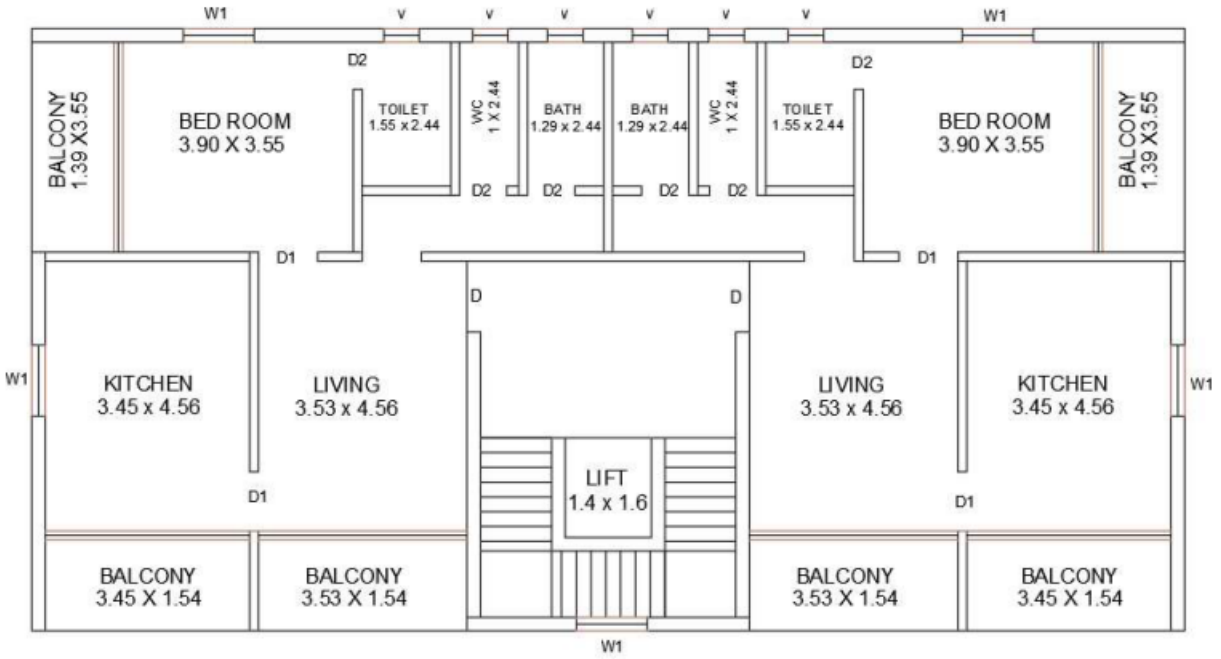


Figure 2. Typical floor plan in AutoCAD.

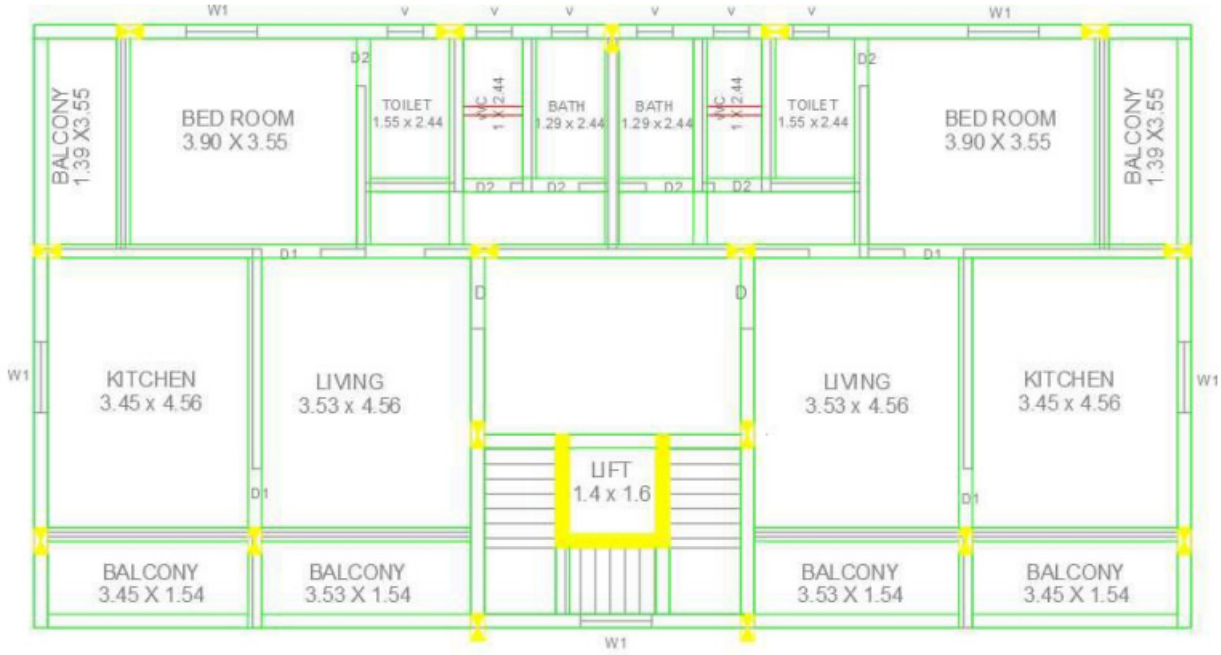


Figure 3. Column position and beam framing plan.

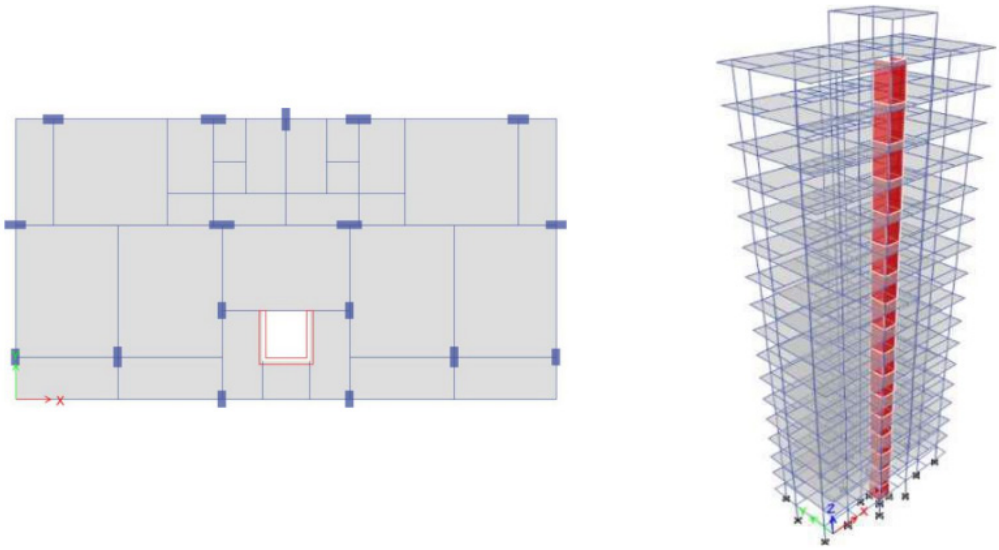


Figure 4. Typical floor plan and 3D elevation view of the structure.

Table 2. Material properties

Concrete grade	M30
Reinforcement grade	Fe 500 HYSD
Density of AAC brick	7.5 kN/m^3
Density of concrete	25 kN/m^3

8.0 Material Properties

In this section, material (e.g., grade of concrete and steel) and section properties of the structural members, viz., slab, beam and column, are defined[6]. Figures 5 and 6 show the snapshots giving details of the materials and sectional properties defined for the structural members considered for the G+15 RCC frame building[7]. Table 2 shows the material properties of the HRB.

9.0 Load Details

The various loads and load combinations for linear static analysis were considered in this 3D analysis[8]. Dead load and imposed load are designed as per the Indian Standard Code IS:875 Part I and IS:875 Part II. The details of the various areas considered in this work are specified in Tables 3 to 5.

a) Dead Load, live load, and superimposed load
b) Earthquake load
c) Wind load

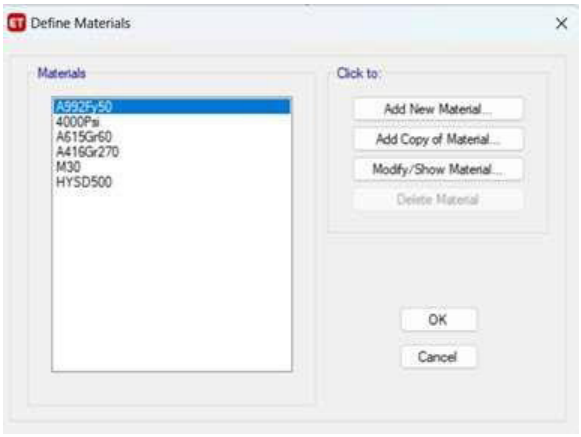


Figure 5. Defining material properties.

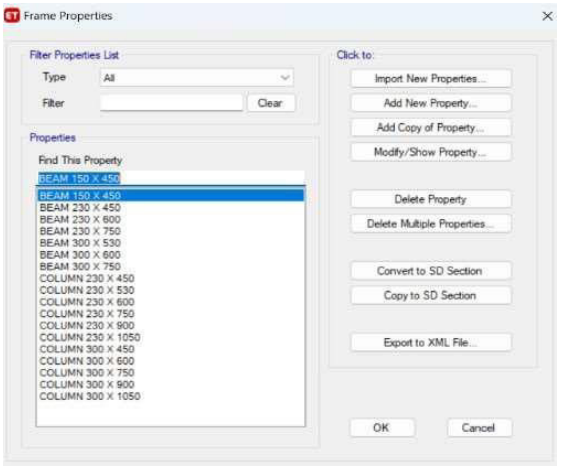


Figure 6. Defining section properties.

Table 3. Load details

Live load at typical Floor	3 kN/m²
Floor Finish	1.5 kN/m²
External Wall load	5.26 kN/m²
Internal wall load	3.43 kN/m²
Parapet wall load	1.72 KN/m²

Table 4. Seismic factors as per IS: 1893 (Part 1)-2016

Parameters	Particulars
Type of Sesmic Zone	Zone II III IV and V
Sesmic Zone factor	01,0.16,0.24,0.36
Importance Factor	1.2
Soil type	Hard,Medium and soft
Response reduction factor	5
Damping Ratio	0.05
Type of frame	Special Moment Resiting Frame

Table 5. Wind Load Parameters as per IS: 875 (Part 3)-2015

Parameters	Particulars
Location of Project	Mysore(II), Pune(III), Delhi(IV) and Bhuj(V)
Wind Speed	33,39,47 and 50 m/s
Risk Coefficient(K1)	1
Terrain height and structure size factor K-2	As per building Height and wind speed
Topography Factor k3	1
Factor for Cyclonic regionk4	1
Geometry of building for deciding kd	0.9
Tributary area for deciding ka	0.8
load combination factor	0.9
Design life of Building	50
Percentage of openings in the building	5-20%

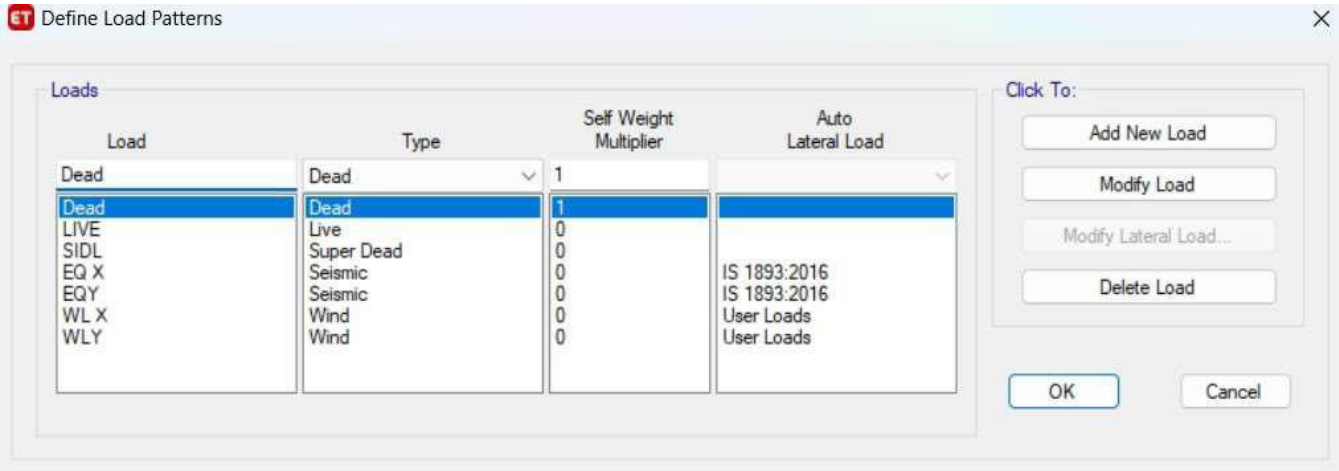


Figure 7. Defining load patterns.

10.0 Defining Response Spectrum Function

In this step, the response spectrum function is selected for HRB under consideration as per IS Code 1893: 2016, Part I. The values of input parameters viz. seismic zone, soil type, importance factor and response reduction factor[9] are provided in the slots given in the response spectrum function window shown in Figure 8.

11.0 Load Combinations

The following design load combinations are considered for seismic static analysis and design[10]. In ETABS 2018, the default load combinations are provided for static load, imposed load and lateral load[11]. There is also a provision for defining load combinations. The load combinations as per IS:1893-2016 are shown in Table 6.

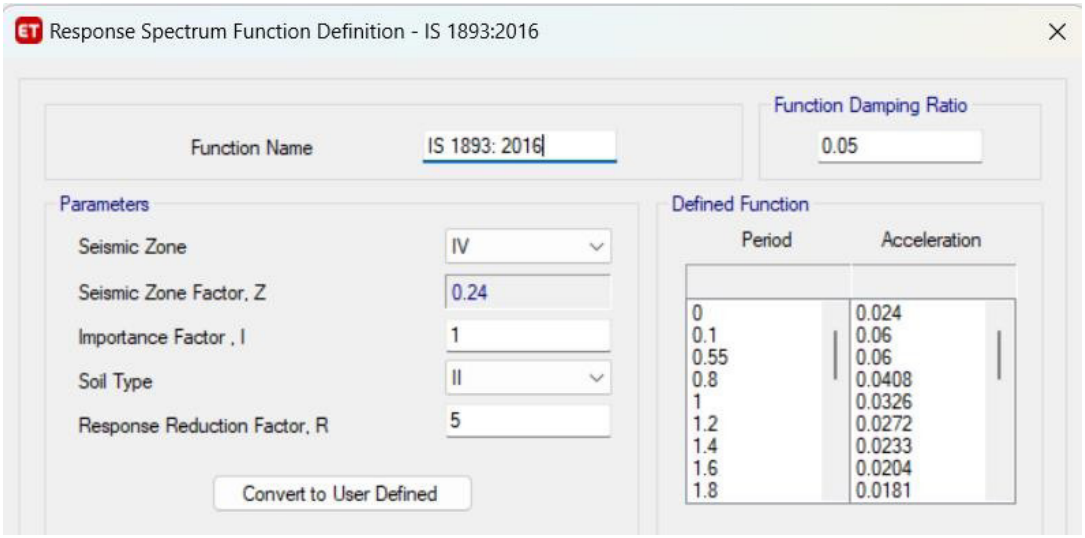


Figure 8. 1 Response spectrum definition.

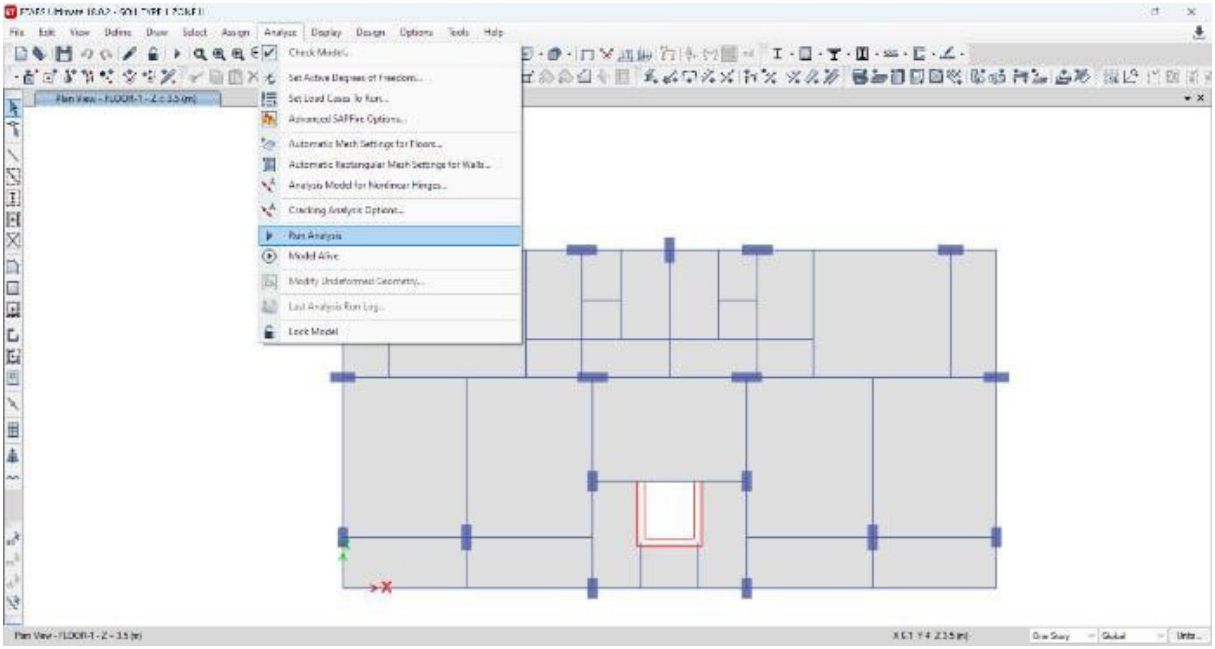


Figure 9. Model check and performed analysis of the model.

Table 6. Load combinations

Strength Design	Serviceability
1.5DL+1.5LL	1DL+1LL
1.2DL+1.2LL+1.2EL	1DL+0.8LL+0.8EL
1.5DL+1.5EL	1DL+1EL
0.9DL+1.5EL	

12.0 Analysis of HRB

After the modelling is over, the HRB[12] is analysed, and the analysis results are provided by the software gives the results for the seismic responses of the HRB. The figure below shows a snapshot giving the details of the analysis done for the HRB under consideration[12].

Table 7. Reaction check for different zones and soil types

Soil Type	Seismic Zone	EQ X9kN)	SPEC X (kN)	EQ Y (kN)	SPEC Y(kN)
Hard Soil	**II**	**278.32**	**278.32**	**215.72**	**215.72**
	III	446.81	446.8	346.31	346.31
	IV	686.09	686.09	531.77	531.76
	V	1050.56	1050.56	815.04	815.04
Medium Soil	**II**	**378.52**	**378.52**	**293.38**	**293.38**
	III	608.56	608.56	471.48	471.78
	IV	939.44	939.43	728.07	728.07
	V	1487.76	1487.75	1153.13	1153.13
Soft Soil	**II**	**464.8**	**464.8**	**360.25**	**360.25**
	III	747.28	747.28	579.2	579.19
	IV	1167.06	1167.05	904.56	904.56
	V	1849.78	1849.78	1433.71	1433.71

13.0 Reaction Check

Table 7 shows the reaction check for different zones and soil types. The earthquake force[13] in the x and y directions must be equal to the response spectrum forces in the x and y directions, receptively, for further seismic response.

14.0 Results and Discussion

14.1 Storey Displacement

Displacement increases with seismic intensity and soil softness. For example, from Zone II to V, displacement increased by 17% to 53% depending on soil type.

14.2 Storey Drift

Storey drift[14] follows a similar trend to displacement, highlighting greater deformation in soft soil under higher seismic loads.

14.3 Base Shear and Storey Shear

Base shear[15] increased to 74.67% when transitioning from hard to soft soil, especially in higher seismic zones, reflecting higher lateral force demand.

14.4 Period

Periods were found to increase with building flexibility, particularly on soft soil, emphasising the need for damping or base isolation in such conditions[16].

15.0 Conclusions

Seismic responses like storey drift, displacement[17], and base shear[18] increase significantly from Zone II[19] to Zone V[20] and from hard to soft soils. Structural optimisations ensured that seismic performance remained within permissible limits. ETABS[21] proved effective for integrated seismic analysis using IS code parameters.

16.0 Future Scope

Evaluate performance using nonlinear methods such as pushover and time-history analysis.[22] Consider alternate structural systems like shear walls,[23] bracing, and base isolation. Explore the impact of innovative materials (e.g., FRP composites)[24] in seismic design.

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