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Comparative Seismic Analysis Of A G+12 Building On Soil Type 1& 2 In Seismic Zones IV & V.

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Abstract: Rapid urbanization has pushed construction into high-risk seismic zones, making it crucial to understand how specific soil conditions influence the stability of high-rise structures. This project analyzes the seismic performance of a G+12 reinforced concrete building under varying earthquake intensities as defined by IS 1893:2016. Using STAAD.Pro, the structure was modeled and tested across four distinct scenarios, specifically comparing the transition from Seismic Zone IV to Zone V on both Hard (Type 1) and Medium (Type 2) soils. The study focused on quantifying the increase in lateral displacement, story drift, and base shear to determine at what point a standard frame becomes unsafe.

The results indicate that soil type acts as a significant magnifier for seismic forces. Shifting the building from a hard rock base in Zone IV to medium soil in Zone V caused the lateral displacement to surge by over 50%, pushing the story drift beyond the permissible safety limits. The analysis confirms that for a G+12 structure in severe seismic zones, relying solely on a moment-resisting frame is dangerous. To ensure stability and code compliance, the design requires the introduction of shear walls to control the sway, alongside a robust foundation upgrade to handle the drastically increased support reactions.

I. INTRODUCTION

With the rapid growth of cities and increasing demand for space, high-rise buildings have become a common sight in modern urban landscapes. These tall structures not only help in utilizing limited land efficiently but also symbolize technological progress. However, their safety during earthquakes has always been a matter of concern. Unlike low-rise buildings, high-rise structures are more flexible and tend to sway more under lateral forces, making their behavior under seismic loads complexFor this study secondary data has been collected. From the website of KSE the monthly stock prices for the sample firms are obtained from Jan 2010 to Dec 2014. And from the website of SBP the data for the macroeconomic variables are collected for the period of five years. The time series monthly data is collected on stock prices for sample firmsand relative macroeconomic variables for the period of 5 years. The data collection period is ranging from January 2010 to Dec 2014. Monthly prices of KSE -100 Index is taken from yahoo finance.

India lies in a seismically active region, with a large part of the country classified under moderate to high earthquake hazard zones. Past earthquakes in Bhuj (2001), Nepal (2015), and elsewhere have shown how vulnerable tall buildings can be if proper earthquake-resistant design is not followed. Therefore, it becomes essential to study how high-rise buildings perform in different seismic zones and on different types of soil, since the foundation soil has a direct influence on how the structure responds during ground shaking.

This project, focuses on understanding this behavior. By modeling a typical tall building on different soil conditions and subjecting it to earthquake forces as per codal provisions, the study aims to bring out the variation in response parameters such as base shear, story drift, and Strey Displacement. The findings can be useful for designing safer and more economical tall structures in earthquake-prone areas.
India is divided into different earthquake zones based on how strong and frequent the seismic activity is in each region. These zones range from Zone II to Zone V, where Zone II experiences the least shaking and Zone V faces the highest risk. The classification helps engineers and planners design buildings that can withstand expected ground movements. By knowing the zone of an area, safer construction practices can be followed to reduce damage during an earthquake.

1.1 Different Seismic Zone in India: As per IS 1893 Part I.
As per Indian Slandered Code IS 1893:2002, the Vibration and Intensity due to seismic waves are calculated, where the design horizontal seismic coefficient Ah can be calculated by the expression:

$$A_h = \frac{Z I S_a}{2 R g}$$

Where Z = zone factor given in **table 2 in IS 1893:2002**
1.2 Objectives
The primary objective is to analyze and compare the seismic structural response under four distinct scenarios:

Zone IV and Zone V, utilizing both Type 1 (Hard/Rocky) and Type 2 (Medium) soil conditions for each zone.

Table No. 1 Analysis Cases

Case No.	**Seismic Zone**	**Soil Type**	**Soil Description**
1	**Zone IV**	**Type 1**	Hard / Rocky Soil
2	**Zone IV**	**Type 2**	Medium Soil
3	**Zone V**	**Type 1**	Hard / Rocky Soil
4	**Zone V**	**Type 2**	Medium Soil

2 .Review of Relevant Studies

Thakur, R. K., et al. (2019) This study is highly relevant as it analyzed a **G+13 building**—very similar to the G+12 structure proposed in this project—using STAAD.Pro. They compared results across Zones II through V and three soil types. Their data showed a massive jump in structural demand: maximum node displacement in the X-direction surged from **54.36 mm** in Zone II (Hard Soil) to **325.62 mm** in Zone V (Soft Soil). Similarly, shear forces more than doubled between the best and worst-case scenarios. This establishes a clear baseline for the expected behavior of high-rise frames in severe zones.

Devi, K. and Petal, S., et al. (2023) Focusing on a **G+8 structure** using ETABS, this research quantified the economic impact of seismic zones. They found that shifting from Zone III to Zone V increased the Base Shear significantly, which directly impacted the design. Specifically, the requirement for longitudinal steel reinforcement in columns and beams rose by approximately **35%** to handle the increased intensity. This highlights the need for careful reinforcement detailing in higher zones.

3.Methodology

The work was carried out in a clear step-by-step manner starting from planning to final comparison of results.

Step 1: Preparing floor plan and modelling in STAAD.Pro

First, the architectural floor plan was prepared and converted into a structural layout. Using this layout, the building model was created in STAAD.Pro by placing columns, beams, slabs, and the shear wall in their exact positions.

Figure 2. GF

Figure 1. F1 to F12

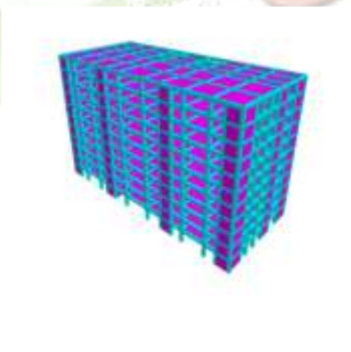

Figure 3. 3D Render Staad Model

Step 2: Finalizing member dimensions

The structural sizes were fixed as follows: columns 600×600 mm, L-shaped shear wall of 3700×3000 mm with 400 mm thickness, beams 230×350 mm and slab thickness 150 mm. These dimensions were assigned to the model.

Step 3: Selection of earthquake zones and soil types

Different seismic zones and soil types were chosen to study how the building behaves under varying conditions. Separate analysis cases were created in STAAD.Pro for each zone–soil combination.

Step 4: Load generation and load cases

All necessary loads such as dead load, live load, wind load, and seismic load were applied on the structure. Load combinations were then created as per code requirements.

Table No.2 Load Cases

Load Case No.	Load Type	Title	Details
1	Seismic	EQX	1893 LOAD X 1
2	Seismic	EQZ	1893 LOAD Z 1
3	Dead	DL	Selfweight Y –1, Member Load –24.3, Floor Load –1
4	Live	LL	Floor Load –3

Table No.3 Load Combinations

Load Case No.	Description	Details (Factors)
5	Generated Combination 1	1.5 DL + 1.5 LL
6	Generated Combination 2	1.2 DL + 1.2 LL
7	Generated Combination 3	1.2 DL + 1.2 LL + 1.2 EQX
8	Generated Combination 4	1.2 DL + 1.2 LL + 1.2 EQZ
9	Generated Combination 5	1.2 DL + 1.2 LL – 1.2 EQX
10	Generated Combination 6	1.2 DL + 1.2 LL – 1.2 EQZ
11	Generated Combination 7	1.5 DL
12	Generated Combination 8	1.5 DL + 1.5 EQX
13	Generated Combination 9	1.5 DL + 1.5 EQZ
14	Generated Combination 10	1.5 DL – 1.5 EQX
15	Generated Combination 11	1.5 DL – 1.5 EQZ
16	Generated Combination 12	0.9 DL + 1.5 EQX
17	Generated Combination 13	0.9 DL + 1.5 EQZ
18	Generated Combination 14	0.9 DL – 1.5 EQX
19	Generated Combination 15	0.9 DL – 1.5 EQZ

Step 5: Extracting analysis data
After running the analysis, important results like storey displacement, base shear, bending moments, shear forces and axial forces were extracted from the software.

Step 6: Comparison and conclusion
Finally, the results from all cases were compared to understand how the structure performs in different conditions. Based on this comparison, conclusions were drawn regarding the safety and behavior of the building.

4. RESULTS AND DISCUSSIONS

4.1 This chapter presents the results of the seismic analysis performed on the G+12 RC frame structure using STAAD.Pro. The analysis was conducted for four distinct cases to evaluate the structural response under varying Seismic Zones (IV and V) and Soil Types (Type 1: Hard and Type 2: Medium). The parameters compared include Maximum Nodal Displacement, Shear Force, Bending Moment, Support Reactions, and Storey Displacement profiles.

4.2 Dimensional Details

Plan Configuration: U-Shaped (Symmetric layout with two lateral wings).

Overall Plan Dimensions: 54.1 m x 60.2 m (Maximum Width x Maximum Depth).

Number of Storeys: G + 12 (13 Floors total).

Total Building Height: 39 m (Above Plinth level).

- Storey Heights:
- Typical Floors: 3.0 m
- Ground Floor (General): 3m
- Ground Floor (Reception): 6 m (Double-Height area).
- Column Spacing (Grid): 6m.
- Structural Member Sizes:
- Columns: 600 x 600 mm (Uniform square section).
- Beams: 350 x 230 mm (Depth x Width).
- Slabs: 150 mm (Uniform thickness).
- Structural Shear Walls: 400 mm Thick (Located at wing ends & re-entrant corners).
- Lift Core Walls: 230 mm Thick (Located around lift shafts).

4.3 Applied Loads (for STAAD.Pro)

- Dead Load (DL):
- Self-Weight: Applied with a -1 Factor (Auto-calculated using density 25 kN/m3).
- Floor Finish: 1 kN/m2 (Applied as floor load on all plates).
- External Wall Load: 24.3 kN/m (Applied on peripheral beams).
- Internal Wall Load: 24.3 kN/m (Applied on internal partition beams).
- Live Load (LL):
- Typical Office Floors: 3.0 kN/m2 (As per IS 875 Part 2 for commercial office usage).

- Seismic Load (EL):
- Analysis Method: Response Spectrum Method (Manual Input).
- Zone Factors (Z): 0.24 (for Zone IV) and 0.36 (for Zone V).
- Soil Types: Type I (Hard Rock) and Type II (Medium Soil).
- Response Reduction Factor (R): 5.0 (Dual System: SMRF + Shear Walls).

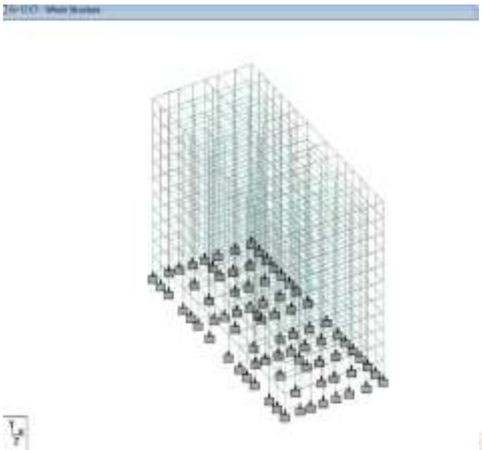

Fig 4. ***Line Model in Staad***

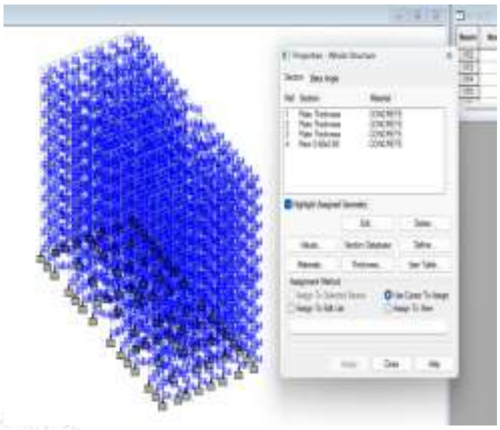

Fig 5. ***Sectional Properties Applied in Staad***

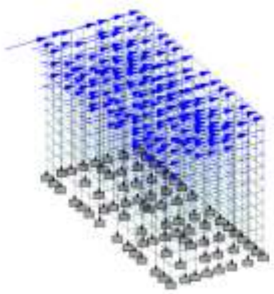

Fig 6. ***Earthquake load in X direction.***

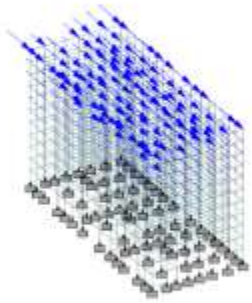

Fig 7. ***Earthquake load in Z direction.***

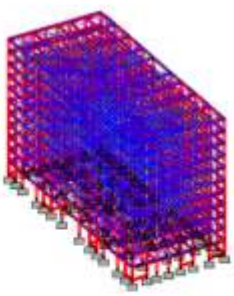

Fig 8. ***Member loads on Beam***

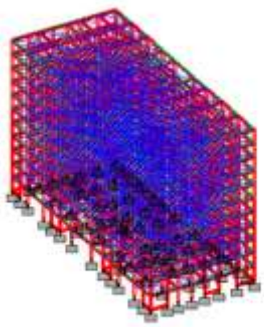

Fig 9. ***Floor Loads On Each floor***

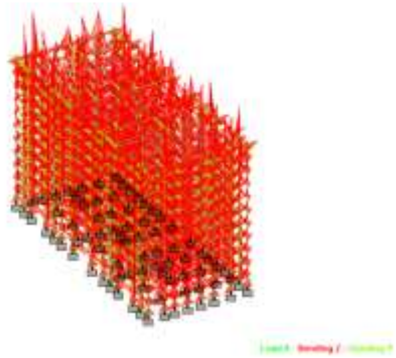

*Fig 10.**Bending Moment Diagram***

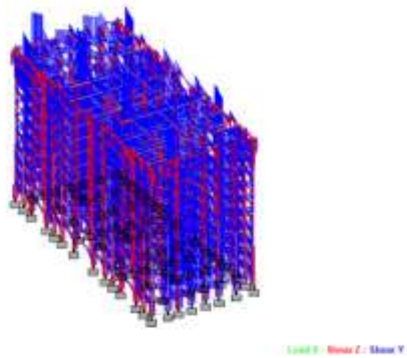

*Fig11.**Shear Force Diagram***

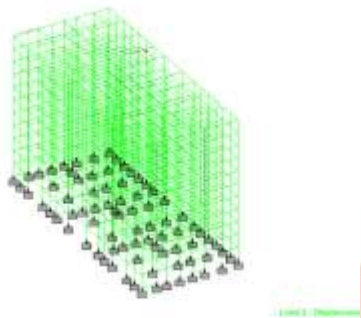

*Fig 12. **Displacement Diagram***

The maximum lateral displacements in the X-direction were extracted for all four cases to evaluate the global stiffness of the structure. The results are presented in Table 4.1.

Table No. 4 Maximum Nodal Displacement (mm)

Case	**Seismic Zone**	**Soil Type**	**Displacement (mm)**
Case 1	IV	Type 1 (Hard/Rocky soil)	23.801
Case 2	IV	Type 2 (Medium soil)	27.566
Case 3	V	Type 1 (Hard/Rocky soil)	29.248
Case 4	V	Type 2 (Medium soil)	36.151

Discussion

The nodal displacement results clearly demonstrate the sensitivity of the structure to both seismic intensity and soil flexibility.

- Impact of Soil: In Zone IV, changing the soil from Hard (Type 1) to Medium (Type 2) resulted in a displacement increase from 23.80 mm to 27.56 mm (approximately 15.8%). This aligns with the findings of Kale et al. (2022)[1], who reported that softer soil strata significantly amplify seismic waves, leading to higher structural demand.
- Impact of Zone: The transition from Zone IV to Zone V on Medium soil (Case 2 to Case 4) caused the displacement to jump by 31% (27.56 mm to 36.15 mm).
- Comparison: The maximum observed displacement of 36.151 mm in Case 4 is consistent with the trend observed by Thakur et al. (2019)[2], where maximum displacements were recorded in the highest seismic zones on softer soils. However, the absolute value is well within the permissible limit of H/500 (approx. 78 mm), indicating the frame possesses adequate stiffness.

4.5 Maximum Shear Force

The base shear is the total design lateral force acting at the base of the structure. It is a critical parameter for the design of the foundation and ground-floor columns.

Table No. 5 Maximum Shear Force in X-direction (kN)

Case	Seismic Zone	Soil Type	Shear Force (kN)
Case 1	IV	Type 1 (Hard/Rocky soil)	1025.271
Case 2	IV	Type 2 (Medium soil)	1116.773
Case 3	V	Type 1 (Hard/Rocky soil)	1152.375
Case 4	V	Type 2 (Medium soil)	1289.610

Discussion

The shear force data indicates a direct correlation between the seismic zone factor (Z) and the lateral force generated.

- The shear force increased by 25.7% between the best-case scenario (Case 1) and the worst-case scenario (Case 4).
- This increase is significant for the design of shear reinforcement (stirrups). As noted by Shashidhar prasad and Shivakumar (2019) [3] in their analysis of G+15 buildings, base shear is directly proportional to the seismic intensity. The increase observed here necessitates tighter spacing of ties in the columns for Zone V to prevent shear failure.

4.6 Maximum Bending Moment

The governing bending moment (Mz) determines the requirement for longitudinal reinforcement in the columns.

Table No. 6 Maximum Bending Moment in X-direction (kN-m)

Case	Seismic Zone	Soil Type	Bending Moment (kN-m)
Case 1	IV	Type 1 (Hard/Rocky soil)	1350.883
Case 2	IV	Type 2 (Medium soil)	1497.405
Case 3	V	Type 1 (Hard/Rocky soil)	1553.905
Case 4	V	Type 2 (Medium soil)	1773.224

Discussion

- The bending moment demand escalated by 31.2% in Case 4 compared to Case 1.
- This implies that a column section designed for Zone IV may be under-reinforced for Zone V. This corroborates the study by Devi and Petal (2023)[4], who found that the percentage of steel required in columns increases drastically (from 1.1% to 3.1%) as the seismic zone severity increases. To resist the moment of 1773 kN-m, the G+12 columns will likely require Fe500D steel and potentially a concrete grade of M30 or higher.

4.7 Maximum Support Reaction

The vertical reactions at the supports were extracted to understand the load transfer to the footing.

Table No. 7 Maximum Support Reaction (kN)

Case	Seismic Zone	Soil Type	Reaction (kN)
Case 1	IV	Type 1 (Hard/Rocky soil)	12584.89
Case 2	IV	Type 2 (Medium soil)	14086.51
Case 3	V	Type 1 (Hard/Rocky soil)	14670.68
Case 4	V	Type 2 (Medium soil)	16923.74

Discussion

- The foundation load increased by 34.4% in Zone V (Medium Soil) compared to Zone IV (Hard Soil).
- This increase is attributed to the higher overturning moments generated by the increased lateral seismic forces. This result aligns with Thakur et al. (2019)[5], who observed that support reactions increase significantly when shifting zones, necessitating larger footing dimensions for buildings in Zone V.

4.8 Storey Displacement Profiles

The storey-wise displacement behavior of the building was analyzed for all four cases.

(Note: The values below represent cumulative nodal displacement at each floor level relative to the base).

Table No. 8 Storey Displacement Data - Case 1 (Zone IV, Hard Soil)

Storey	Height (m)	Max Disp X (mm)	Max Disp Z (mm)
Base	0	0	0
1	0.00*	0	0
2	3	1.217	1.303
3	6	3.091	3.216
4	9	5.091	5.172
5	12	7.114	7.071
6	15	9.099	8.858
7	18	10.973	10.537
8	21	12.653	12.033
9	24	14.044	13.226
10	27	15.042	14.027
11	30	15.613	14.397
12	33	16.289	14.822

Table No.9 Storey Displacement Data - Case 2 (Zone IV, Medium Soil)

Storey	Height (m)	Max Disp X (mm)	Max Disp Z (mm)
1	0	0	0
2	3	1.65	1.76
3	6	2.52	2.54
4	9	2.67	2.66
5	12	2.69	2.62
6	15	2.61	2.51
7	18	2.45	2.31
8	21	2.17	2.01
9	24	1.77	1.59
10	27	1.23	1.05
11	30	0.64	0.46
12	33	0.77	0.52

Table No. 10 Storey Displacement Data - Case 3 (Zone V, Hard Soil)

Storey	Height (m)	Max Disp X (mm)	Max Disp Z (mm)
1	0	0	0
2	3	1.81	1.94
3	6	3.67	3.85
4	9	6.04	6.19
5	12	8.42	8.47
6	15	10.74	10.63
7	18	12.92	12.57
8	21	14.86	14.22
9	24	16.44	15.47
10	27	17.55	16.20
11	30	18.13	16.37
12	33	18.83	16.54

Table No. 11. Storey Displacement Data - Case 4 (Zone V, Medium Soil)

Storey	Height (m)	Max Disp X (mm)	Max Disp Z (mm)
1	0	0	0
2	3	2.3	2.1
3	6	5.1	5.21
4	9	8.9	8.39
5	12	12.4	11.5
6	15	15.6	14.44
7	18	18.4	17.17
8	21	20.9	19.56
9	24	23.0	21.81
10	27	24.6	23.19
11	30	26.0	23.86
12	33	27.9	24.67

Discussion on Storey Drift and Safety

The Storey Drift is the relative displacement between two consecutive floors. According to IS 1893:2016 (Clause 7.11.1)[6], the storey drift in any storey due to the minimum design lateral force shall not exceed 0.004 times the storey height.

- Allowable Drift: 0.004 x 3000 mm = 12 mm.

Analyzing the worst-case scenario (Table 4.6.4 - Zone V, Medium Soil):

- Max Cumulative Displacement: 27.9 mm at the top storey.
- Max Inter-Storey Drift: Calculating the difference between floors (e.g., Storey 3 vs Storey 2: 5.1 - 2.3 = 2.8 mm), the maximum drift observed is approximately 3.8 mm (between Storey 3 and 4).
- Conclusion: The maximum inter-storey drift of 3.8 mm is well below the permissible limit of 12 mm. This confirms that the G+12 bare frame structure possesses sufficient lateral stiffness to satisfy the serviceability requirements of IS 1893:2016, even in Seismic Zone V.

5.Conclusions

Based on the comparative seismic analysis of the G+12 RC frame structure under Seismic Zones IV and V with different soil conditions, the following conclusions are drawn:

- **Dominance of Soil-Structure Interaction:** The study conclusively proves that the soil type is a critical governing factor in seismic response. Shifting the same building from Hard Rock (Type 1) to Medium Soil (Type 2) amplifies the structural demand by approximately **15-16%**, regardless of the seismic zone.
- **Zone V Vulnerability:** The transition from Zone IV (Z=0.24) to Zone V (Z=0.36) results in a non-linear surge in forces. The combined effect of higher seismicity and softer soil causes the structural demand (displacement and forces) to increase by over **50%** in the worst-case scenario compared to the baseline.

- **Elastic Behavior:** Despite the significant increase in forces, the G+12 bare frame remains within the elastic safety limits defined by **IS 1893:2016** for all analyzed cases. The structure is sufficiently stiff to resist the lateral loads without immediate collapse, although the serviceability demand is high.