Analysis of Framed Structure In Hard And Soft Soil In Different Earthquake Zones

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Abstract- *This study investigates the influence of building height, seismic zones, and soil types on the structural behavior of building frames, focusing on maximum node displacement, shear forces, and bending moments. The analysis reveals that as the building height increases, the maximum node displacements and beam end forces (shear and bending moment) also increase, particularly in soft and medium soil strata. Across Seismic Zones II, III, and IV, the percentage variation in maximum node displacements remains nearly consistent, with hard soil strata exhibiting the least displacements compared to soft soil. Notably, in Seismic Zone IV (Model-3), no significant variation in node displacement was observed across different soil types. Similarly, shear forces and bending moments decrease in hard soil compared to soft soil, with the lowest values recorded in hard strata for Seismic Zones II, III, and IV. However, in Seismic Zone IV (Model-3), both shear forces and bending moments remain unaffected by soil type. The findings highlight the critical role of soil-structure interaction in seismic performance, emphasizing that hard soil conditions generally lead to reduced structural responses. These insights can aid in optimizing seismic design strategies for multi-story buildings in varying seismic zones.*

Keywords- Seismic zones, soil-structure interaction, node displacement, shear force, bending moment, building height, structural response.

I. INTRODUCTION

Multistory buildings are preferred in cities. Building laws of many cities permitsconstruction of ground plus three storey building without lift. Constructions of such building are possible only by going to a set of rigidly inter-connected beams and columns. These rigidly interconnected beams and columns of multi bay and multistory are called framed structure.

When loads from walls and floors are transferred to beams, rotation of beams takes place. Since beams are rigidly connect to columns , the rotation of columns also takes place. Thus any load applied anywhere in building is shared by entire network of beams and columns

LOADS ON STRUCTURE

The nature of loading governs the kind of analysis to be performed on the structure. The loads are divided into two basic categories

1. **Static Loads** are the loads which changes gradually (the increasing speed of load is not as much as the regular recurrence of the structure)
2. **Dynamic Loads** are the loads which changes with time decently fast in contrast with the structure's common recurrence.

II. LITERATURE REVIEW

The reviewed literature focuses on the seismic analysis and design of multi-story buildings, considering different seismic zones, soil types, and structural systems. Key findings include:

1. Seismic Response of Buildings – Studies by V. Ratna Priya & N. Jitendra Babu (2017) and GirumMindaye& Shaik Yajdani (2001) highlight the influence of seismic zones and support conditions (flexible vs. rigid) on structural behavior, emphasizing the need for ductile detailing in higher seismic zones.
2. Comparative Analysis of Load Effects – Ashis Debashis Behera & K.C. Biswal (2012) found that seismic load combinations require more steel reinforcement than wind loads, but wind loads cause higher deflections and shear bending.
3. Ductile Detailing and Design Considerations – Sudhir K. Jain & R.K. Ingle (2004) provided detailed examples for ductile detailing in different seismic zones, while Jain & Shah (2005) demonstrated the design of a six-story building in Zone III, considering medium soil and masonry infill walls.
4. Comparative Performance of RCC vs. Composite Structures – Ashiru Muhammad et al. (2015) observed that reinforced concrete (RCC) structures exhibit higher seismic responses compared to

composite steel-concrete structures, making composites more efficient for high-rise buildings.

5. Software-Based Analysis & Design – Several studies (Raj et al. 2017, Aman et al. 2016, Kumawat &Kalurkar 2014) utilized software like STAAD.Pro, SAP2000, and Revit for structural modeling, revealing variations in deflection and bending moment results across different platforms.
6. Cost and Structural Efficiency – Kumawat &Kalurkar (2014) and Varalakshmi et al. (2014) concluded that composite structures are more economical and efficient than conventional RCC structures, especially in seismic zones.

Key Observations:

- Soil-structure interaction significantly affects seismic response, with hard soil reducing displacements and forces.
- Ductile detailing is crucial in high-seismic zones to ensure structural resilience.
- Composite structures offer better performance and cost efficiency compared to RCC.
- Software tools like STAAD.Pro and SAP2000 are widely used, but results may vary slightly between programs.

III. METHODOLOGY

Conventional structural design is primarily governed by strength (ultimate limit state) and rigidity (serviceability limit state) criteria. However, seismic design introduces an additional requirement: ductility, ensuring structures can withstand inelastic deformations without catastrophic failure. Based on these principles, seismic design methodologies can be categorized as follows:

1. Lateral Strength-Based Design

This traditional approach, as per IS 13920:1993, ensures that structures possess minimum lateral strength to resist seismic forces while allowing controlled nonlinear behavior. Key features include:

- Compliance with material ductility, member slenderness, and cross-sectional detailing.
- Assumes adequate inelastic performance without explicit ductility checks.

2. Displacement (Ductility)-Based Design

Recognizing that structures cannot remain elastic under severe earthquakes, this method focuses on energy dissipation through yielding. Unlike strength-based design, it directly evaluates deformation limits, offering better performance predictability.

- Adopted in modern seismic codes worldwide.
- Ensures controlled plastic hinge formation and post-yield stability.

3. Capacity-Based Design

This approach predefines plastic hinge locations to ensure a controlled failure mechanism. Key aspects include:

- Strength hierarchy to prevent brittle failures (e.g., strong-column weak-beam concept).
- Force overstrength in critical elements to maintain elastic behavior where needed.

4. Energy-Based Design (Emerging Approach)

A forward-looking method that balances input seismic energy with dissipation mechanisms:

- Accounts for kinetic, elastic, plastic, and damping energy.
- Aims for optimized structural performance under dynamic loading.

IV. PROBLEM FORMULATION

GENERAL REQUIREMENT

The following clauses from section 2 of IS 456:2000 are considered by the program:

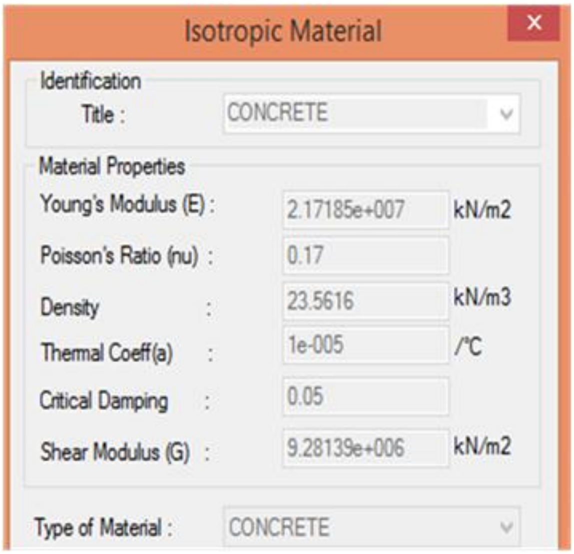
Cl 5.3.3 – The size of aggregate is considered as 20 mm.

Cl. 5.6 – This implementation assumes that the reinforcement specified conforms to Cl. 5.6 of the code. The modulus of elasticity of the reinforcement is taken as 200,000 N/mm2 as per clause 5.6.3 of the code.

Cl. 6.2 – The program will only consider the design of elements that use ordinary concrete or Standard concrete.
If you specify a high strength concrete grade (i.e., compressive strength greater than 55 N/mm2), the program will issue a warning alert you that there might be additional considerations that need to be taken into account in the design. The design strengths of concrete shall be as given in Table 2 of IS 456:2000.

Cl 6.2.2 – The tensile and flexural strength of concrete shall be taken as:Fcr = 0.7√fck
Where, fck = the characteristic compressive strength of concrete.

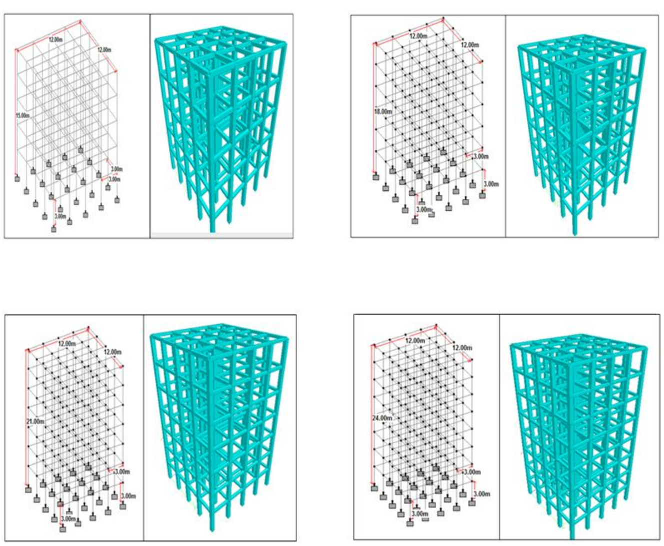
Cl. 6.2.3.1 – The modulus of elasticity of concrete is taken:Ec = 5000√ fck



3.6 MODELING OF STRUCTURES

A structure is an assembly of individual components such as beams, columns, slabs, plates etc.. In STAAD, frame elements and plate elements may be used to model the structural components.

The current models of this work are shown below,



(a) Model of 15m heights(b) Model of 18m heights
(c)Model of 21m heights (d) Model of 24m heights
Figures 3.4: Models of different heights

The structure consisting of all models symmetrical reinforced concrete frame shown in earlier with four bays in both x & z horizontal directions and analyzed it in Staad Pro. V8i (series 4) software package. The storey height is 3 meters and the horizontal spacing between bays is also 3 meters in both x & z directions.

4.2 THE PRELIMINARY DATA :

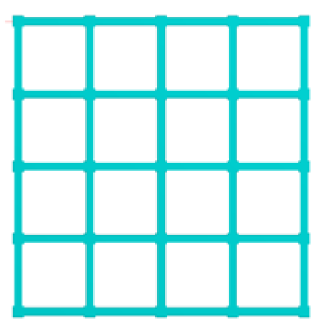
The preliminary data of problem is given in Table 4.1

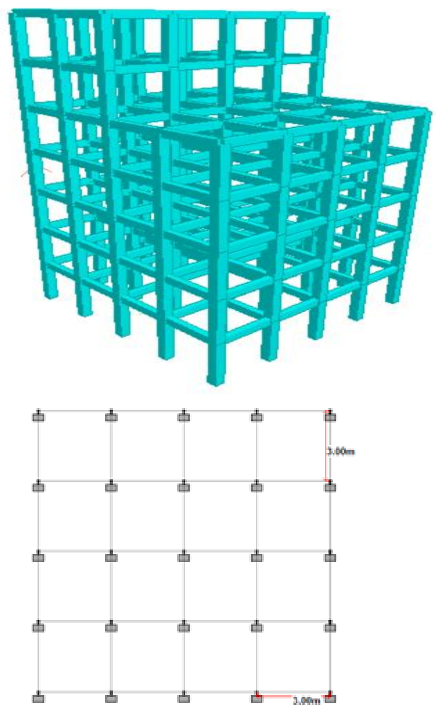
All dimensions are in mm unless specefied

SIZE OF PLAN	12 M X 12M
COLUMN SIZE	450 X 450
BEAM SIZE	300 X 450
WALL THICKNESS	230
THICKNESS OF SLAB	125
HEIGHT OF FRAMES	15M,18M,21M & 24M
HEIGHT OF EACH FLOOR	3M
GRADE OF CONCRETE	M25
GRADE OF PRIMARY STEEL	FE415
GRADE OF SECONDARY STEEL	FE415
SUPPORT CONDITION	FIXED
OUTER WLL THICKNESS	230
INNER/PARTITION WALL THICKNESS	100
SEISMIC ZONES	I ,II , III & IV
SOIL TYPE	HARD

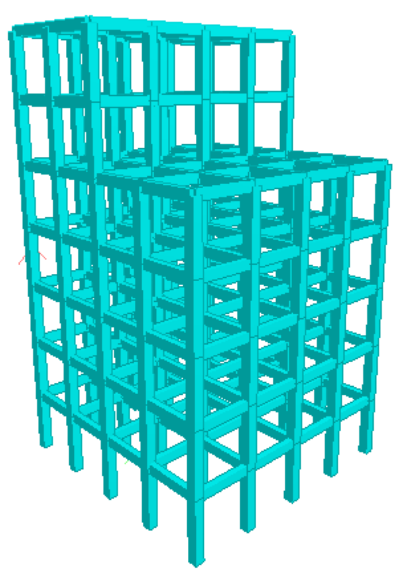
Table 4.1: Preliminary Data

The plan of current model is shown below in figure 4.1





(a)Plan in 3-D rendering
(b) Plan with bay width



Figures 4.1: Plan of current models

IV. AND OBSERVATIOBS:

This study investigated the seismic response of building frames under varying heights, soil conditions, and seismic zones. Key findings are summarized as follows:

1. Height vs. Structural Response
   - Maximum node displacements increase with building height.
   - Similarly, shear forces (Shear-Y) and bending moments (Moment-Z) in beams escalate with height, particularly in soft and medium soil conditions.
2. Effect of Seismic Zones
   - Zones II, III, and IV exhibit nearly identical percentage variations in maximum node displacements.
   - Zone IV (Model-3) showed no significant variation in node displacement across different soil types (soft, medium, hard).
3. Influence of Soil Strata
   - Hard soil consistently results in the lowest displacements, shear forces, and bending moments compared to soft soil.
   - In Zone IV (Model-3), shear forces and bending moments remained unaffected by soil type.
4. Comparative Analysis
   - Zones II and IV demonstrated similar percentage increases in shear forces and bending moments for medium and hard soils (Model-4).
   - Zones II, III, and V exhibited reduced shear forces and bending moments in hard soil, confirming its superior stability.

V. FOR FUTURE WORK

To extend this research, the following areas are recommended:

1. Material-Specific Analysis
   - Investigate steel building frames under similar seismic and soil conditions.
   - Conduct a comparative study between RC and steel frames for different:
     - Soil types
     - Seismic zones
     - Heights and plan configurations

2. Structural Systems Optimization
   - Evaluate the performance of different bracing systems.
   - Compare Ordinary Moment-Resisting Frames (OMRF) and Special Moment-Resisting Frames (SMRF) under dynamic loading.

3. Advanced Modeling Techniques

- Incorporate nonlinear dynamic analysis for more accurate seismic assessments.
- Explore energy-based design approaches for improved earthquake resilience.

Final Remarks

This study highlights the critical role of soil-structure interaction and seismic zoning in structural design. Future research should focus on alternative materials, advanced framing systems, and refined analytical methods to enhance earthquake-resistant construction practices.