Optimizing A Building For Seismic Resilience

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Abstract- *This study delves into the critical issue of seismic resilience for structures founded on soft soil conditions in a highly seismic region – Zone V. Leveraging the capabilities of ETABS software, a comprehensive analysis is undertaken to evaluate the structural response under earthquake loads. The focus is on quantifying key parameters that directly influence seismic performance: maximum story displacement, story shear force, overturning moment, and story drift.*

The comprehensive findings of this study will be instrumental in establishing design guidelines and retrofitting techniques specifically tailored for structures on soft soils in high seismic zones. The analysis will be further enriched by incorporating a suite of earthquake ground motions representative of Seismic Zone V. This will ensure the validity and applicability of the results to real-world scenarios with high seismic risk.

Keywords- Seismic resilience, seismic analysis, G+13 story building, Building Response Simulation

I. INTRODUCTION

Buildings that are designed and built to withstand earthquakes are crucial in areas of the world where seismic activity is a serious threat. Because of their unpredictable and devastating nature, earthquakes have the potential to cause extensive damage, which could lead to fatalities, population displacement, and serious economic consequences. In order to ensure the safety and sustainability of communities exposed to seismic hazards, it is imperative that building design strive for seismic resilience. Many parts of the world are seriously threatened by earthquakes. The design of a building with seismic resilience goes beyond simply keeping it intact during an earthquake.

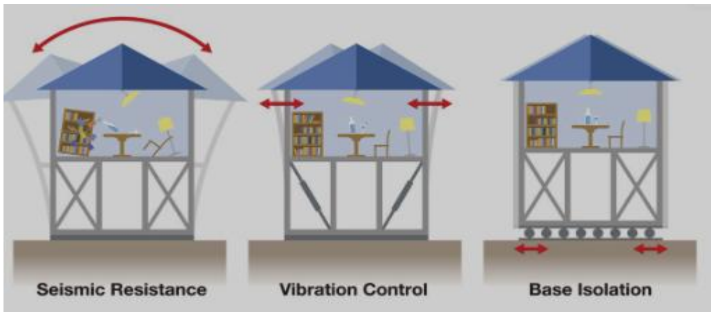


Fig 1. Seismic resistance structure

Objective Functions for Resilience

Building design resilience's goal function is to measure and maximize a structure's performance under seismic loading so that it can endure and bounce back from seismic events with the least amount of damage and downtime. This function prioritizes the resilience of buildings by integrating multiple criteria, such as structural integrity, functionality, and post-event recovery.

Hazard and Ground Motion Selection

The choice of suitable ground motion parameters and hazard scenarios is crucial in seismic-resilient building design in order to precisely evaluate the structural response and guarantee strong performance against seismic forces. The process of choosing a seismic risk entails locating possible seismic sources, figuring out their size, frequency, and location as well as evaluating the risks of ground shaking they pose.

The ground motion selection process can be formalized using a formula:-

$$GM(t) = \sum_{i=1}^{n} A_i \cdot F_i(t)$$

where (GM(t)) represents the ground motion at time (t), (Ai) represents the amplitude of the (i)-the ground motion component, and (Fi(t)) represents the time history function of the (i)-the ground motion component.

Building Response Simulation

Because it offers important insights into how structures behave under seismic loading conditions, building response simulation is a critical component of seismic resilience building design. Engineers are able to forecast the dynamic response of buildings including their deformations, stresses, and vibrations during seismic events by using sophisticated computational models and simulations. Through the use of these simulations, one can evaluate the performance of the structure, spot possible weak points, and optimize design parameters to increase resilience.

II. LITERATURE REVIEW

Elaina J. Sutley et. at.(2017), this study stated the multiobjective optimization part of the framework, which was demonstrated to determine the ideal set of seismic retrofit plans for a community's stock of woodframe buildings, was presented and demonstrated in this companion article, Part II. The investigation revealed that at a design basis earthquake (DBE) seismic intensity, there was the most variation in the overall financial damage. The study emphasizes how crucial it was to take into account social, economic, and engineering factors when estimating losses.

As per the result, it was demonstrated that it is significantly more crucial to incorporate community-specific SED factors into loss projections when computing loss estimates for a less robust building stock. In actuality, depending on the magnitude of the earthquake, different estimates of the expected economic damage varied by millions or even billions of dollars.

Giulia Cere et. al.(2022), In this study, we show how artificial neural networks enhanced with evolutionary computation may be used to assess structural robustness in order to suggest optimization approaches. In order to understand intricate multi-aspect structural dynamics, these calls for effective multi-layer computational models that are abstracted at several levels.

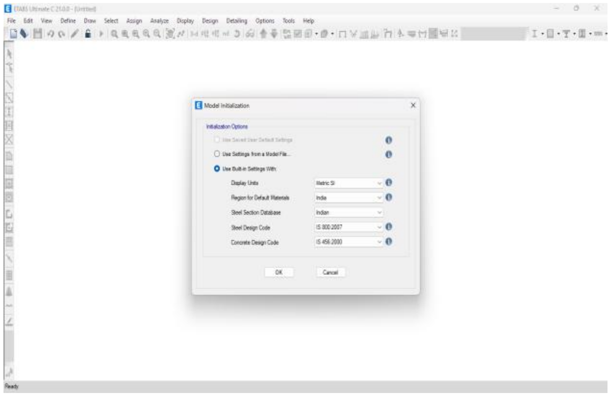
An existing structural system was modeled with more than 98% accuracy using single- and multi-objective optimization to simulate its structural loading behavior.

Findings show that a 20% increase in predicted structural design costs can result in up to a 75% decrease in damage, which significantly lowers the probability of mortality.

III. METHODOLOGY

Step 1: Initialization of the model which is focused towards analyzing multi storey high rise structures considering seismic loads with same seismic zones and soil condition.

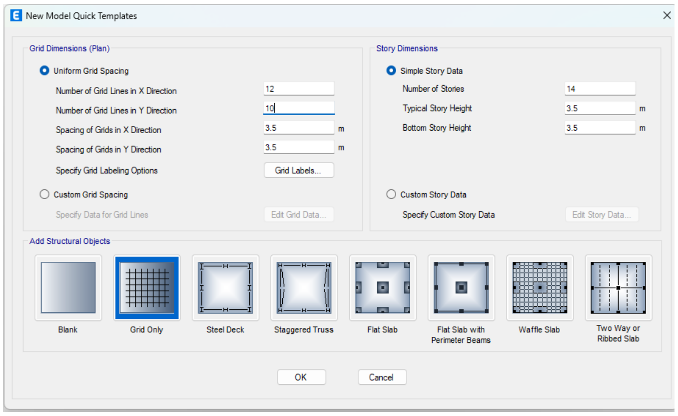
Step 2: Since ETABS supports the building codes of various countries, the first step in starting the case study modeling process is to initialize the structural model based on defining display units on metric SI in the Indian region.



○ Use Settings from a Model File...
● Use Built-in Settings With:
Display Units: Metric SI
Region for Default Materials: India
Steel Section Database: Indian
Steel Design Code: IS 800:2007
Concrete Design Code: IS 456:2000

Fig 2. Model Initialization

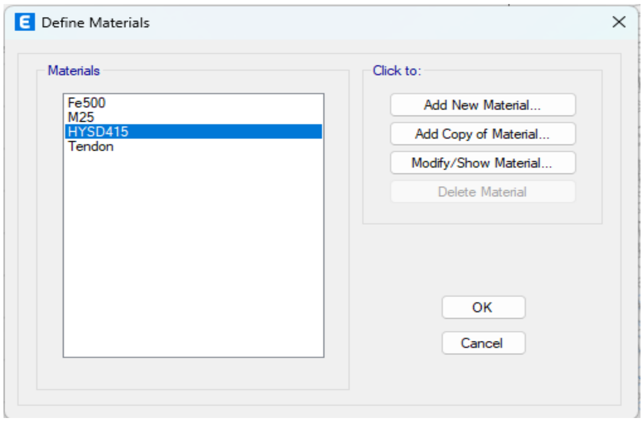
Step 3: With the help of the simple Quick Template feature, which allows grid definition in the X, Y, and Z directions, ETABS offers the ability to model a structure.



● Uniform Grid Spacing
Number of Grid Lines in X Direction: 12
Number of Grid Lines in Y Direction: 10
Spacing of Grids in X Direction: 3.5 m
Spacing of Grids in Y Direction: 3.5 m
○ Custom Grid Spacing
● Simple Story Data
Number of Stories: 14
Typical Story Height: 3.5 m
Bottom Story Height: 3.5 m
○ Custom Story Data

Fig 3. New Model Quick Template

Step 4: Next step is to define the material properties of concrete and steel. Here in this case study, M25 concrete and rebar HYSD 415 is considered and its predefined properties are available in the ETABS application.



Fe500
M25
HYSD415
Tendon

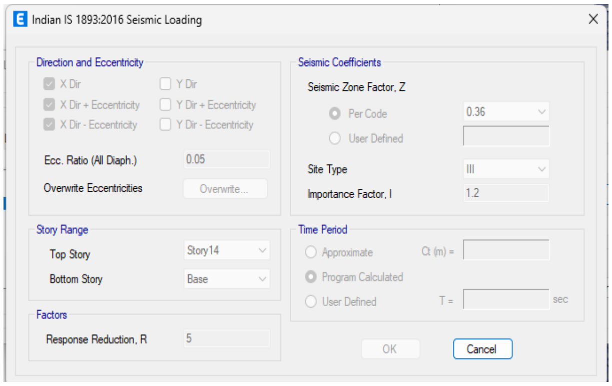
Fig 4. Defining Materials

Step 5: Defining section properties for Beam, Column. Beam size of 500x450mm, Column size of 450x350mm and Slab size of 175 mm is considered in the study.

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

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

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



Indian IS 1893:2016 Seismic Loading

Direction and Eccentricity

☑ X Dir ☐ Y Dir

☑ X Dir + Eccentricity ☐ Y Dir + Eccentricity

☑ X Dir - Eccentricity ☐ Y Dir - Eccentricity

Ecc. Ratio (All Diaph.) 0.05

Overwrite Eccentricities

Seismic Coefficients

Seismic Zone Factor, Z

● Per Code 0.36

○ User Defined

Site Type III

Importance Factor, I 1.2

Story Range

Top Story Story14

Bottom Story Base

Time Period

○ Approximate Ct (m) =

● Program Calculated

○ User Defined T = sec

Factors

Response Reduction, R 5

Fig 5. Seismic Loading

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

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

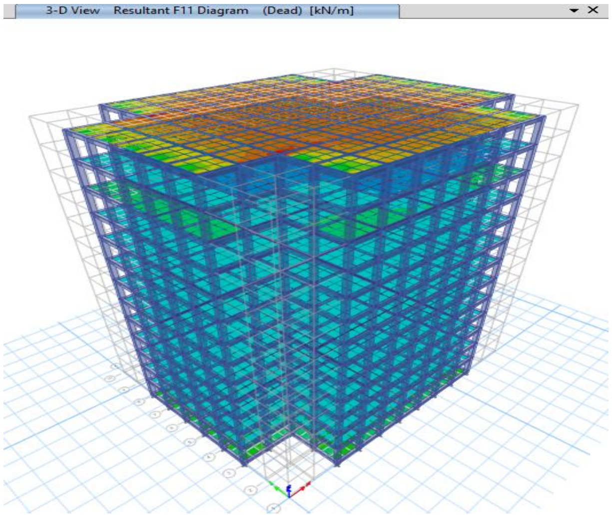


Fig 6. Stress Analysis

IV. PROBLEM IDENTIFICATION

Table 1. Geometrical Specifications of the Structure

Geometrical Specification	
Particulars of Item	Properties
Number of Storey	G+13
Typical Storey height	3.5m
Bottom Storey Height	3.5m
Floor Diaphragm	Rigid
Shape of the Building	RCC Structure
Beam Size	450x350mm
Beam Shape	Rectangular
Column Size	500x450mm
Column Shape	Rectangular
Slab Depth	175mm
Slab Type	Thin Shell

4.4 Properties of Material

Table 2. Properties of Concrete

Properties of Concrete	
Grade of Concrete	M25
Directional Symmetry Type	Isotropic
Weight per Unit Volume	24.9926 kN/m3
Mass per Unit Volume	2548.538 kg/m3
Modulus of Elasticity, E	27386.13 MPa
Poisson's Ratio, U	0.2
Coefficient of Thermal Expansion, A	0.000013 1/C
Shear Modulus, G	11410.89 MPa

Table 3. Properties of Steel

Properties of Steel	
Material Name	Fe500
Directional Symmetry Type	Isotropic
Weight per Unit Volume	76.9729 kN/m3
Mass per Unit Volume	7849.047 kg/m3
Modulus of Elasticity, E	210000 MPa
Coefficient of Thermal Expansion, A	0.0000117 1/C
Poisson's Ratio	0.3
Shear Modulus,G	80769.23 MPa

Load Calculation

Dead Load

The dead load is considered as per IS 875-1987 (Part I-Dead loads)
Self-weight = 1kN
Slab load = 4.375 kN/m2
Wall load = 16.1 kN/m

Imposed load (LL)

The imposed load is considered as per IS 875-1987 (Part II-Imposed loads)".
Live load on slab = 3 kN/m2

Earthquake load (EL)

The earthquake load is considered as per the IS 1893-2002 (Part I). The factors considered are
Zone factor = 0.36 (Zone V)
Importance factor = 1
Response reduction factor = 1.2
Soil condition = Soft soil
Damping = 5 %

Load Combinations

1. 1.5 (DL+LL)
2. 1.2 (DL + LL + EQX)
3. 1.2 (DL + LL + EQY)
4. 1.5 (DL + EQX)
5. 1.5 (DL + EQY)
6. 0.9DL + 1.5EQX
7. 0.9DL + 1.5EQY

V. RESULTS & DISCUSSION

Maximum story displacement

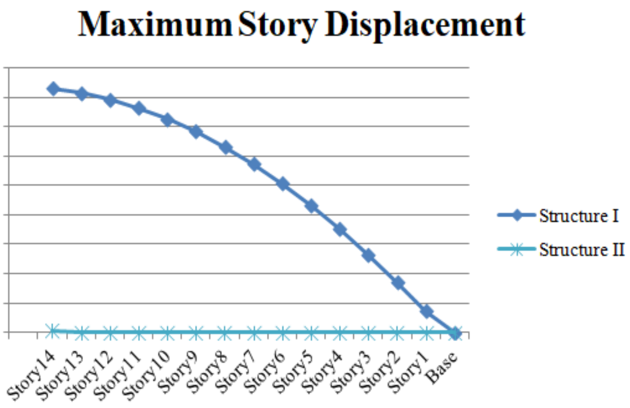


Fig 7. Maximum story displacement in mm

Story drift

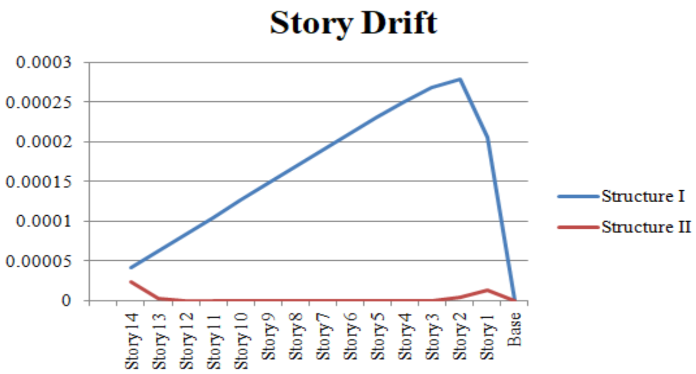


Fig 8. Story Drift

Story shear

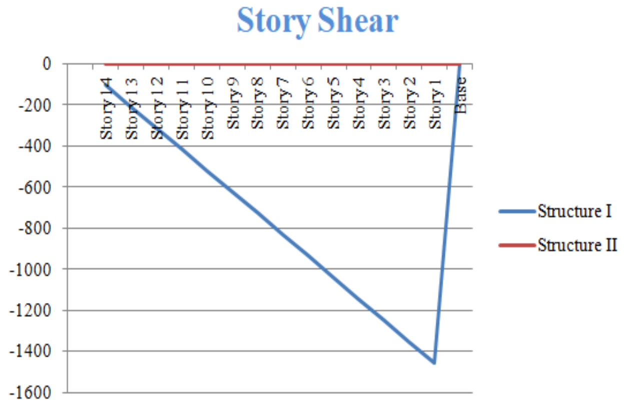


Fig 9. Story in kN

Overturning moment

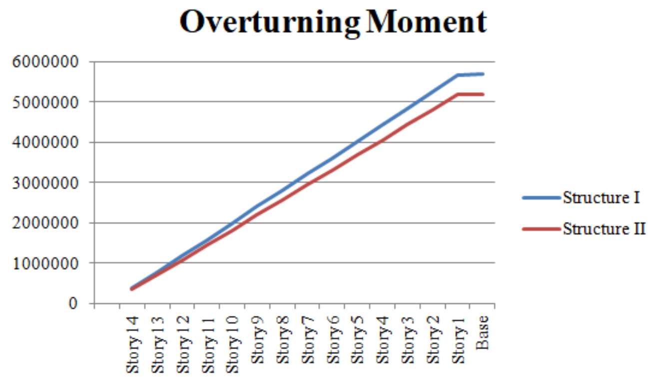


Fig 10. Overturning Moment in kN-m

VI. CONCLUSION

- As the maximum displacement value for structure I is observed approx. 8.297mm and for structure II is observed approx. 0.068mm, so the structure I is shown higher value by approx. 99% as compare to structure II.

- As the maximum displacement value for structure I is observed approx. 0.000041 and for structure II is observed approx. 0.000023. Hence there is minor difference found between structure I and structure II.
- The story shear for structure I is observed between 0 to -104 kN and for structural case 2 it is observed 0kN for each story.
- The overturning moment for structural case I is observed approximately 5000000kN-m and for structural case II it is observed approximately 4500000kN-m, hence structure I shown 8% higher value of overturning moment.

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