SEISMIC ASSESSMENT OF A TWENTY-STORY MULTISTORY STRUCTURE WITH SHEAR WALL SUPPORT

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Abstract
This study investigates the seismic assessment of a twenty-story multistory structure reinforced with shear wall support, aimed at evaluating its structural integrity and performance under seismic loading. Utilizing advanced computational models and dynamic analysis methods, the research examines the effectiveness of shear walls in enhancing the building's resistance to seismic forces. The structure's response to various earthquake scenarios is analyzed, focusing on key parameters such as lateral displacement, story drift, and overall stability. The study also compares the seismic performance of the shear wall-supported structure with that of a similar building lacking shear walls, highlighting the significant improvements in seismic resilience. The findings underscore the critical role of shear walls in mitigating seismic risks, providing valuable insights for the design and construction of high-rise buildings in seismically active regions. This comprehensive assessment not only confirms the advantages of incorporating shear walls but also identifies potential areas for optimization in the structural design. The results contribute to the ongoing development of seismic design codes and practices, emphasizing the need for robust engineering solutions to ensure the safety and durability of tall buildings exposed to seismic hazards. Overall, this study offers a detailed evaluation of shear wall-supported structures, advancing the understanding of their behavior under earthquake conditions and supporting the advancement of safer construction methodologies.

Keywords: *Seismic Assessment, Shear Wall Support, Multistory Structure, Dynamic Analysis, Earthquake Resilience.*

1. Introduction

The seismic assessment of high-rise buildings is crucial for ensuring their resilience and safety in earthquake-prone regions. This study focuses on a twenty-story multistory structure, evaluating its performance under seismic forces with an emphasis on shear wall support. Shear walls are critical components in high-rise buildings, providing essential lateral stiffness and strength to resist seismic loads and prevent catastrophic failures during earthquakes. The analysis investigates two types of shear wall configurations: traditional reinforced concrete (RC) shear walls and advanced composite shear walls (steel-plated). With the increasing complexity of building designs and the growing demand for taller structures, it becomes imperative to evaluate how different shear wall materials impact the overall seismic performance. Composite shear walls, which incorporate steel plating, offer potential benefits over conventional RC shear walls, such as reduced thickness and lighter weight, which can significantly lower the building's dead load.

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This study employs advanced modeling techniques using ETABS-2017 to analyze the seismic performance of the structure. By comparing various models with different shear wall configurations, the research aims to identify key parameters that influence the building's response to seismic forces. The assessment includes evaluating base shear, story-shear forces, and inelastic drifts. These factors are critical for understanding how well the building can withstand earthquake-induced stresses and maintain structural integrity.

2. Research Objective

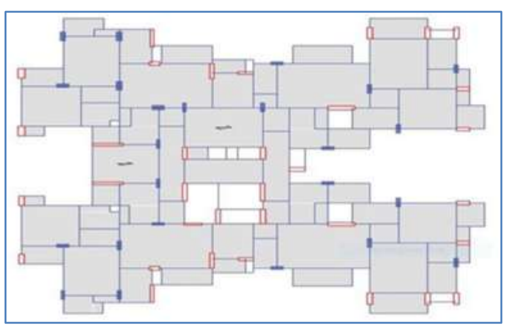
1. To analyze and design a twenty-story high-rise building incorporating steel plate shear walls using ETABS.
2. To compare the seismic behavior of reinforced concrete structures of varying heights, with and without shear walls.
3. To evaluate the performance of coupled shear walls versus framed structures without shear walls in seismic conditions.
4. To compare the displacement, story drift, overturning moment, and story shear by varying the thickness of steel plate shear walls.

3. Models Considered for Analysis

This study evaluates the seismic performance of a twenty-story multistory building supported by shear walls. Two distinct models, representative of contemporary construction practices, have been analyzed:

1. **Type A**: A hybrid framed structure featuring a reinforced concrete (RCC) shear wall located at the center, complemented by RCC columns.
2. **Type B**: A hybrid framed structure incorporating a composite shear wall at the center, coupled with composite columns.

The selection of these models aims to reflect actual building types prevalent in modern construction, ensuring the study's relevance and applicability.



Type A: hybrid framed structure with RCC shear wall in center and columns

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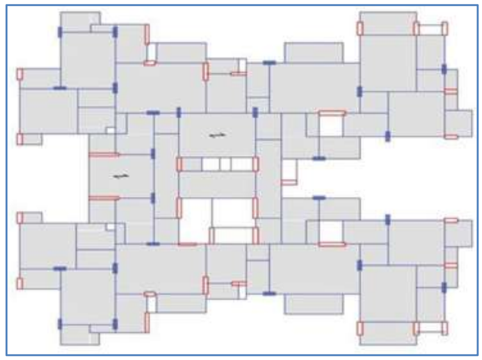

Type B: hybrid framed structure with Composite shear wall in center and columns.

4. Method of Analysis

A. Static Analysis

The static method is the simplest form of seismic analysis, requiring less computational effort and relying on formulae provided in building codes. Initially, the design base shear for the entire building is computed and subsequently distributed along the building's height. The resulting lateral forces at each floor level are then allocated to the individual lateral load-resisting elements.

B. Dynamic Analysis

Dynamic analysis is performed to determine the design seismic forces and their distribution across different levels of the building's height, as well as to various lateral load-resisting elements. This analysis is crucial in the following scenarios:

1. **Regular Buildings**: Structures exceeding 40 meters in height in seismic zones IV and V, and those taller than 90 meters in zones II and III.
2. **Irregular Buildings**: All framed buildings taller than 12 meters in zones IV and V, and those exceeding 40 meters in height in zones II and III.
3. **Irregular Buildings (Under 40 meters)**: For buildings shorter than 40 meters in height in zones II and III, dynamic analysis is not mandatory but recommended.

C. Response Spectrum Method

The response spectrum method involves plotting the peak or steady-state response (displacement, velocity, or acceleration) of a series of oscillators with varying natural frequencies, all subjected to the same base vibration or shock.

D. Pushover Analysis (Non-linear Static Method)

The pushover analysis technique models a structure with non-linear properties, such as steel yield and plastic hinges. It applies a permanent gravity load and subjects the structure to an incremental lateral load, starting from zero and increasing until a prescribed ultimate displacement is reached or the structure becomes unstable and unable to withstand further forces.

E. Non-linear Time History Analysis

This analysis evaluates the dynamic response of a structure at each time increment when its base is subjected to a specific ground motion time history, using compatible time histories for medium soil as per IS-1893:2002-Part 1.

5. ETABS

ETABS is a sophisticated yet user-friendly analysis and design software specifically developed for building systems. It features an intuitive graphical interface and integrates advanced modeling, analytical, design, and detailing procedures within a unified database. While ETABS is quick and efficient for simple structures, it is also capable of handling the most complex building models, including those with a wide range of nonlinear behaviors, making it a preferred tool for structural engineers in the building industry.

A. Building Geometry: Most buildings have straightforward geometries consisting of horizontal beams and vertical columns. ETABS simplifies the definition of building geometry by allowing users to establish a grid system with horizontal floors and vertical column lines, minimizing the effort required to model the structure.

B. Floor Level Commonality: In many buildings, the floor levels are similar. ETABS leverages this commonality to significantly reduce both modeling and design time by applying similar properties across repetitive floor levels.

C. Input and Output Conventions: ETABS uses input and output conventions that align with common building terminology. Models are defined logically in terms of floors, columns, bays, and walls, rather than as a series of abstract nodes and elements. This approach ensures that the structural definition is straightforward, concise, and meaningful.

D. Member Stiffness Considerations: In most buildings, member dimensions are large relative to bay widths and story heights, which affects the frame's stiffness. ETABS accounts for these effects in its member stiffness calculations, unlike general-purpose programs that may use centerline-to-centerline dimensions, thus providing more accurate results.

6. Design Basis

A. Design Philosophy

The Limit State Method is employed for design, involving:

1. Assessing dead and external loads.
2. Determining design loads from various combinations.
3. Estimating structural responses (bending moments, shear forces, etc.).
4. Calculating concrete sections and reinforcement requirements.

Uncertainties in load estimation and material properties are addressed using appropriate safety factors.

B. Analysis and Design

Initial analysis includes gravity load combinations:

- **Dead Load**: Weight of structural components.
- **Live Load**: Movable components and occupant loads.

Two load combinations analyzed:

1. Dead Load + Live Load
2. 1.5 × (Dead Load + Live Load)

Designs for beams and columns were based on STAAD Pro, while slab panels were designed manually. Calculations for slabs and staircases were also included.

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C. Analysis of Gravity Loads

Dead and live loads are calculated based on architectural plans and IS:875-Part 1.

D. Dead Loads and Live Loads

Dead load calculations follow IS:875-Part 1, with densities provided in the relevant table.

E. Design Philosophy per IS1893:2002

IS1893:2002 mandates:

- Structures should withstand minor earthquakes without damage, moderate earthquakes with minimal damage, and major earthquakes without collapse.
- Response spectrum analysis is recommended, with simplified Static Analysis for regular and moderately irregular low-rise buildings, and Dynamic Analysis for irregular and high-rise structures.

F. Static Analysis

The horizontal seismic coefficient A_h is calculated as:

$$Ah= \frac{Z \cdot S_a}{2Rg}$$

where:

- **Z**: Zone factor.
- **I**: Importance factor.
- **R**: Response reduction factor.
- **S_a**: Response acceleration coefficient.
- **g**: Acceleration due to gravity.

Design base shear V_B is determined by:

$$V_B = A_h \cdot W$$

where W is the seismic weight. The fundamental period of vibration T_a is estimated based on building type, and base shear VB is distributed along the building height.

G. Dynamic Analysis

Required for:

1. Regular buildings over 40 meters in zones IV and V, and over 90 meters in zones II and III.
2. Irregular buildings over 12 meters in zones IV and V, and over 40 meters in zones II and III.
3. Irregular buildings under 40 meters in zones II and III (recommended but not mandatory).

H. Static and Dynamic Parameters

1. **Design Parameters**: Analysis conducted using ETABS software.
2. **Design Characteristics**: Considered for multistory rigid jointed frames.

7. Analysis for seismic loads

According to IS: 1893, Noida falls within Seismic Zone IV. The design base shear VVV is calculated using the formula:

$$V= \frac{Z \cdot I \cdot W \cdot S_a}{2 \cdot R \cdot g}$$

The values for the key coefficients are provided in the table below:

Table 1 Seismic parameters

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SI.	Description	Value	Reference
1	Seismic Factor for Zone: IV	0.24	IS-1893
2	Structure importance	1.0	IS-1893
3	Response reduction factor, R	5.00	IS-1893
4	Damping	5%	IS-1893
5	Time period	Variable	IS-1893

A. Wind Load Parameters

The basic wind speed V_b for a site is determined according to IS 875 (Part 3). This value is adjusted to obtain the design wind speed V_z at any height z for the structure using the formula:

$$Vz=V_b\cdot K_1\cdot K_2\cdot K_3\cdot K_4$$

For Gurgaon, the wind velocity is 47 m/s. Additional wind load parameters according to IS: 875 (Part-3) are summarized below:

Table 2 Wind parameters

Sl.	Description	Value	Reference
01	Terrain category.	3	IS-875
02	Class of structure.	C	IS-875
03	Probability factor, k1.	1.0	IS-875
04	Terrain, height and structure size factor, k2.	As/Height	IS-875
05	Topography factor, k3.	1.0	IS-875
06	Importance factor, k4 for the cyclonic region	1.0	IS-875

B. Load Cases

Table 3 Load case

Load case	Description
Dead	Dead Load
Finish	Floor Finish Load
Services	Service load on floor
Wall	Wall Load
Live	Live Load
Roof Live	Roof Level Live Load
EQX	Static Earthquake Load In X Direction
EQX	Static Earthquake Load In X Direction

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SPECX	Dynamic Earthquake Load In X Direction
SPECY	Dynamic Earthquake Load In Y Direction
Wind X	Along Wind Load In X Direction
Wind Y	Along Wind Load In Y Direction

C. Load Combinations

Table 4 Load combination

S No.	Load combination
1	1.5 (DL + LL)
2	1.2 (DL + LL + EQX)
3	1.2 (DL + LL – EQX)
4	1.2 (DL + LL + EQY)
5	1.2 (DL + LL – EQY)
6	1.5 (DL + EQX)
7	1.5 (DL – EQX)
8	1.5 (DL + EQY)
9	1.5 (DL - EQY)
10	1.2 (DL + LL + WLX)
11	1.2 (DL + LL -WLX)
12	1.2 (DL + LL + WLY)
13	1.2 (DL + LL-WLY)

8. Analysis

The analysis of various building models with different heights generated extensive data sets. Microsoft Excel was utilized for tabulating, plotting, and analyzing the results from the ETABS analysis. The primary goal was to identify the key parameters influencing the building's performance. A sample tabulation for Type A structures with 20 storeys is provided below.

A. Computational Modelling

Three-dimensional (3D) geometric models of the buildings were developed using ETABS-2017. Initial dimensions of the structural elements were estimated based on gravity loads and imposed loads. For residential buildings, the imposed load was taken as 2 kN/m², and the load due to floor finish and partitions was 1.5 kN/m², in accordance with IS 875 (Part 2): 1987. Lateral loads due to earthquakes were calculated using the seismic coefficient method outlined in IS 1893 (Part 1): 2016, which considers the full dead load (DL) plus 25% of the imposed load (IL), excluding the imposed load on the roof.

The total base shear V_B was calculated using:

$$VB= A_h \cdot W$$

where:

- W is the seismic weight of the building.
- A_h is the design horizontal seismic coefficient, determined by:

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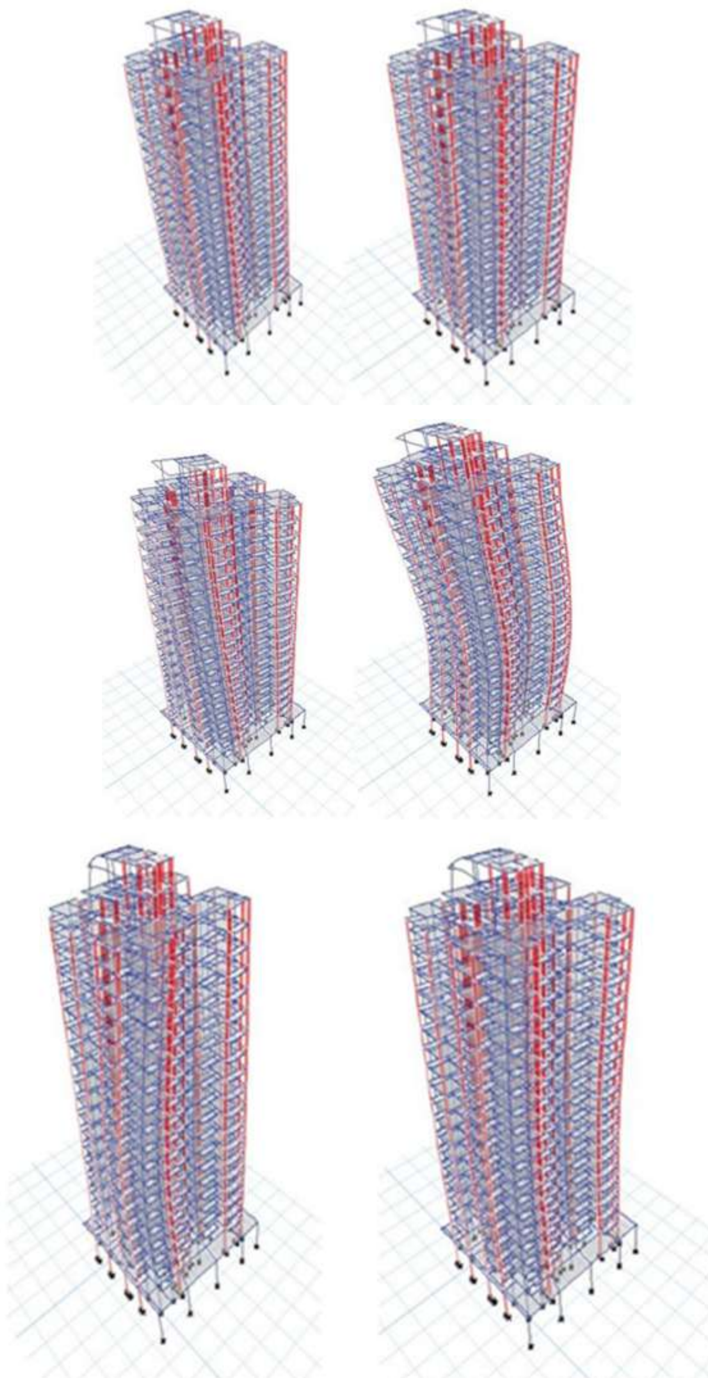
$$A_h = \frac{Z \cdot I \cdot S_a}{2 \cdot R \cdot g}$$

9. Mode Shape



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The same above parameters have been tabulated for all other types, Type A- reinforced concrete shear walls (RCSW) and Type B- steel-plate shear walls (SPSW). for 20 storeys. The results were tabulated and plotted as below

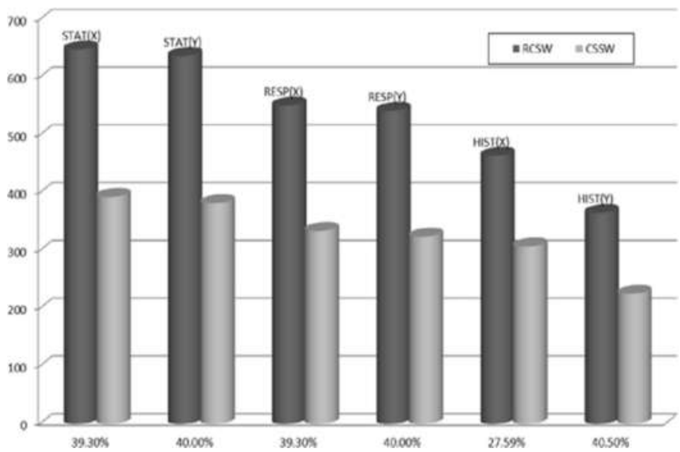
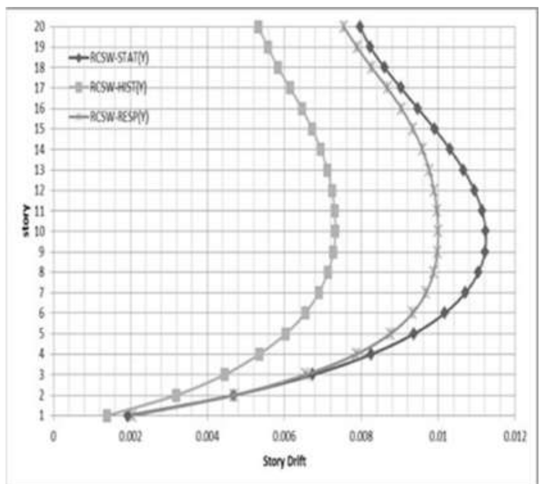
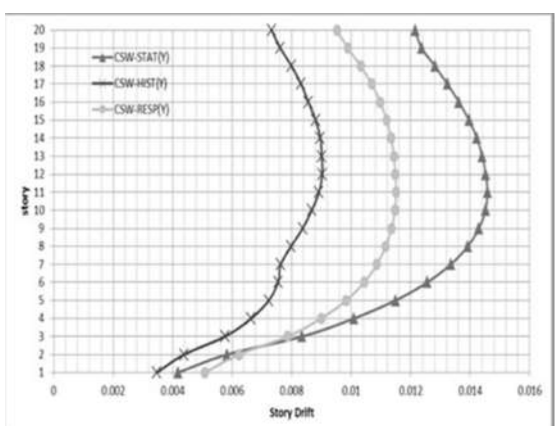


Fig. 1 Comparison of Base Shear for 20-Story Buildings



A.RCSW



B. CSSW

Fig. 2 Story Drifts for the 20-Story Buildings.

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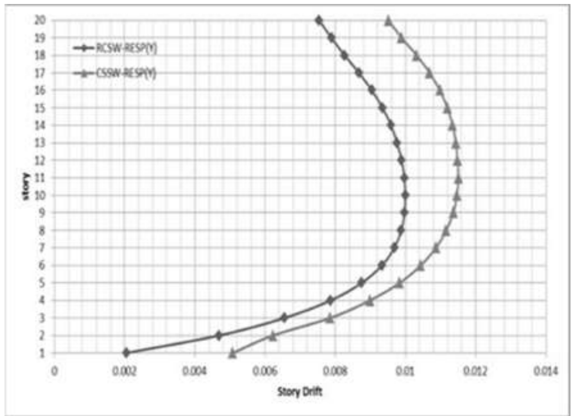
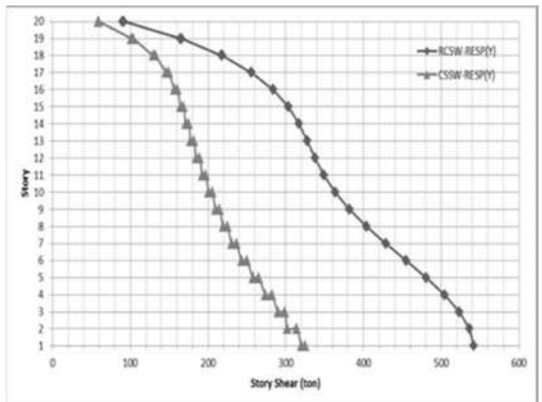


A. RCSW



B. CSSW

Story Shear and Drift for the 20-Story Buildings.

10 Conclusions

The seismic assessment of a twenty-story multistory structure reveals that substituting traditional reinforced concrete (RC) shear walls with composite shear walls (steel-plated) offers substantial benefits in earthquake-prone areas. One of the primary advantages is the significant reduction in the building's total dead load due to the thinner profile of steel-plated walls compared to RC shear walls. This reduction in dead load translates into a decrease in story-shear forces and base shear, with reductions of 46% observed in eight-story buildings and 38% in twenty-story buildings. These reductions enhance the overall seismic performance of the structure by lowering the lateral forces that the building must resist during an earthquake. However, it is important to note that while composite shear walls improve efficiency and reduce base shear, they also lead to increased inelastic drifts. In twenty-story buildings, the inelastic drifts are 26% higher with composite shear walls compared to RC shear walls. This increased drift must be carefully managed, as it can affect the building's response to seismic events. Despite this, the reduced dead loads and improved structural performance make composite shear walls an attractive option for modern high-rise buildings in seismically active regions.

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