Comparative Seismic Performance of Multi-Storey Reinforced Concrete Building with Different Shear Wall Configurations Using ETABS

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Abstract:
The arrangement of lateral load-resisting elements can considerably influence the seismic response of multi-storey reinforced concrete buildings. The present study investigates the effect of shear wall location on the seismic performance of a G+10 reinforced concrete building using ETABS. A regular 20 m × 20 m building plan with four bays in each principal direction, 5 m bay spacing and a uniform storey height of 3 m was considered. Three structural configurations, namely Bare Frame, Core Shear Wall and Corner Shear Wall, were developed while maintaining identical geometric, material and loading parameters. M30 grade concrete and Fe500 reinforcement were adopted, and the seismic analysis was performed for Seismic Zone IV using the Response Spectrum Analysis method in accordance with IS 1893 (Part 1):2016. The seismic response of the three configurations was evaluated in terms of storey displacement, inter-storey drift and base shear. The comparative results demonstrate that the location of shear walls has a significant influence on lateral deformation and seismic force response. The Core Shear Wall configuration exhibited the most favorable overall response among the investigated arrangements, while the Corner Shear Wall configuration also provided substantial improvement compared with the Bare Frame. The study highlights the importance of considering shear wall location during the seismic design of multi-storey reinforced concrete buildings.

Keywords— Reinforced Concrete Building, Shear Wall Configuration, Seismic Performance, Response Spectrum Analysis, ETABS, Storey Displacement, Storey Drift, Base Shear.

1. Introduction

Earthquake-induced lateral actions can produce significant deformation and force demand in multi-storey reinforced concrete structures. As the height of a building increases, its dynamic characteristics become increasingly important in determining structural response. Lateral displacement, inter-storey drift and the distribution of seismic forces therefore become important considerations in the design and assessment of multi-storey buildings.

In reinforced concrete construction, beams and columns provide the primary structural framework, but additional lateral resistance may be required when a building is subjected to substantial seismic actions. Reinforced concrete shear walls are commonly introduced to increase lateral stiffness and provide an efficient mechanism for resisting horizontal earthquake forces.

The effectiveness of a shear wall system is not governed only by the presence or quantity of wall elements. Their position within the building plan can also influence the distribution of stiffness and the resulting structural response. A centrally positioned wall system and a wall system located near the building perimeter may produce different deformation characteristics because their contribution to the overall structural response is different.

This issue becomes particularly relevant for multi-storey buildings because the lateral response is influenced by the interaction between structural stiffness, mass distribution and dynamic characteristics. An unsuitable arrangement may result in greater lateral deformation, whereas an appropriately positioned wall system can provide improved control of structural movement.

India is divided into seismic zones according to the provisions of IS 1893. The present investigation considers Seismic Zone IV with a zone factor of 0.24. The selected seismic condition provides a suitable basis for comparing the response of different lateral load-resisting arrangements.

The present study considers a regular G+10 reinforced concrete building and compares three structural configurations: a Bare Frame without shear walls, a Core Shear Wall arrangement and a Corner Shear Wall arrangement. The geometry, material properties and principal loading parameters are maintained consistently so that the seismic response associated with different structural arrangements can be compared.

ETABS is used to develop the three-dimensional structural models and perform the seismic analysis. Response Spectrum Analysis is adopted to evaluate the dynamic response of the multi-storey building. The principal response parameters considered in the study are storey displacement, inter-storey drift and base shear.

The objective of the study is to examine how the placement of shear walls affects the seismic response of the selected G+10 reinforced concrete building and to compare the relative performance of central and corner shear wall arrangements with respect to the Bare Frame configuration.

2. Methodology

A numerical modeling and analysis procedure was adopted for the comparative investigation. The complete analytical procedure consisted of defining the building geometry, assigning material and member properties, developing the three structural configurations, applying gravity and seismic loading, performing Response Spectrum Analysis and extracting the required response parameters.

2.1 Building Geometry

The selected structure is a regular residential reinforced concrete building consisting of Ground plus ten storeys. The building has a plan dimension of 20 m × 20 m and four bays in both the X and Y directions. Each bay is 5 m wide and the storey height is maintained at 3 m, giving a total structural height of 33 m.

2.2 Structural and Material Properties

The structural members were modeled using M30 grade concrete and Fe500 reinforcing steel. The principal member dimensions adopted in the final model were a 600 mm × 600 mm column section, a 300 mm × 500 mm beam section and a 150 mm thick slab. The shear wall thickness was 200 mm. The unit weight of concrete was taken as 25 kN/m³.

PARAMETER	DESCRIPTION
Building Type	Reinforced Concrete Building
Number of Storeys	G+10
No. of Bays	4 × 4
Bay Spacing	5m
Storey Height	3m
Column Size	600mm×600mm
Beam Size	300mm×500mm
Slab Thickness	150 mm
Shear Wall Thickness	200 mm
Structural Software	ETABS v20
Seismic Zone	Zone IV
Design Codes	IS 1893(Part 1): 2016, IS 456:2000

Table 2.1 Building Description

2.3 Seismic Parameters

The building was analyzed for Seismic Zone IV. The seismic zone factor was taken as 0.24, with an importance factor of 1.0 and a response reduction factor of 5 corresponding to the SMRF system. Medium soil condition and 5% damping were considered. The selected analysis type was Linear Dynamic Response Spectrum Analysis.

2.4 Load Considerations

The structural models were subjected to gravity and seismic loading. Dead load and live load were considered for the building, while seismic loading was applied in the X and Y directions through the Response Spectrum Analysis procedure. The self-weight of structural members was included through the appropriate dead-load definition in ETABS. The seismic load cases were defined in accordance with the provisions of IS 1893 (Part 1):2016.

The principal load combinations used in the analysis included gravity loading and seismic loading in both principal directions. The thesis lists combinations including 1.5(DL+LL), 1.2(DL+LL±EQX), 1.2(DL+LL±EQY), 1.5(DL±EQX), 1.5(DL±EQY) and stability combinations involving 0.9DL and seismic action.

3. Structural Modeling and Analysis

3.1 Bare Frame Model

The Bare Frame was developed as the reference structural configuration. The model consists of the reinforced concrete beam-column framing system and floor slabs without the addition of shear walls. This configuration represents the lateral response of the selected building when resistance to earthquake-induced lateral action is provided by the frame system alone.

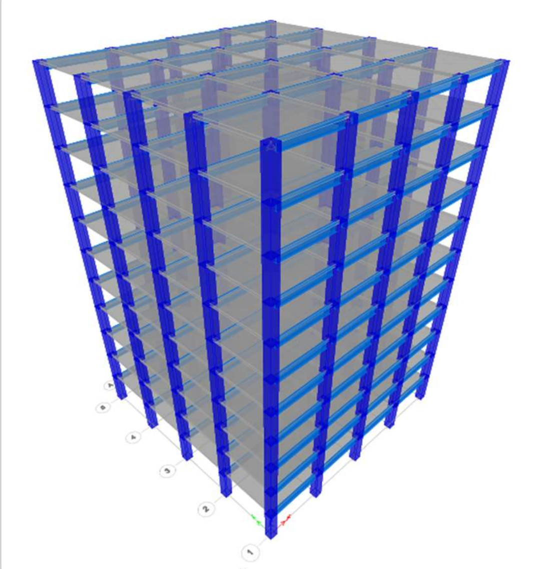

Figure 3.1 3D View of Bare Frame Model
[Source: Developed by using ETABS Software]

3.2 Core Shear Wall Model

The Core Shear Wall configuration incorporates reinforced concrete shear walls in the central portion of the building plan. The wall elements extend through the building height and form the principal additional lateral load-resisting system.

The purpose of this configuration is to evaluate the response associated with a centrally concentrated stiffness arrangement. The structural geometry and principal material properties remain unchanged relative to the Bare Frame model.

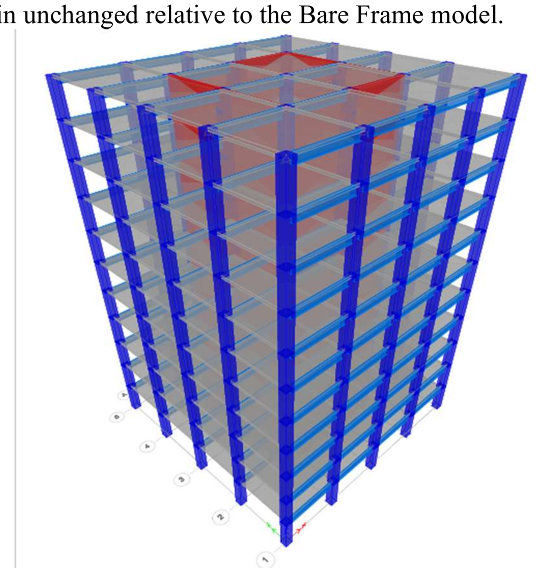

Figure 3.2 Core Shear Wall 3D Model Configuration
[Source: Developed by using ETABS Software]

3.3 Corner Shear Wall Model

The Corner Shear Wall configuration incorporates shear walls at the corner regions of the building plan. The walls are continued through the height of the building. This configuration represents a more peripheral distribution of the lateral load-resisting elements.

The three models are therefore distinguished primarily by the presence and location of the shear walls, allowing their seismic response to be compared under the same general building and seismic conditions.

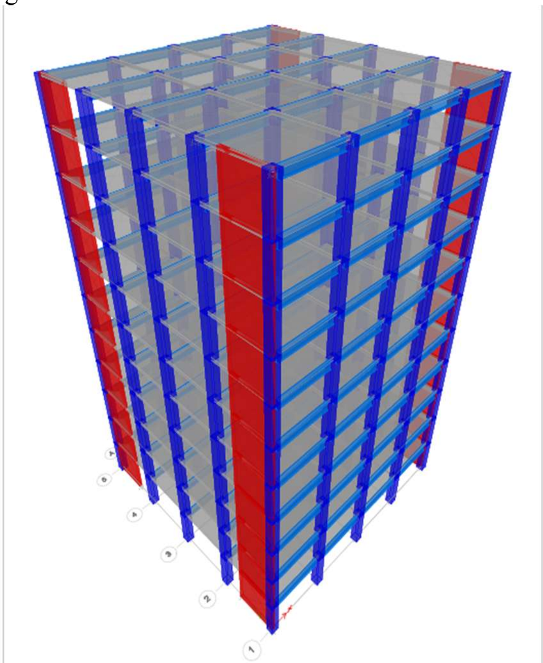

Figure 3.3 Corner Shear Wall 3D Model Configuration
[Source: Developed by using ETABS Software]

3.4 Response Spectrum Analysis

A linear dynamic Response Spectrum Analysis was carried out in ETABS. The seismic parameters corresponding to Zone IV and medium soil condition were incorporated into the response-spectrum function. Modal analysis was performed to determine the dynamic characteristics of the structure, including natural time periods and mode shapes. The thesis states that sufficient modes were included to achieve at least 90% mass participation.

After analysis, the principal response parameters extracted from the models were story displacement, inter-storey drift and base shear. These parameters were used for the comparative assessment of the three structural configurations.

4. Results and Discussion

The results obtained from the ETABS analysis were compared to identify the influence of shear-wall arrangement on the seismic response of the selected G+10 building.

4.1 Story Displacement

Story displacement represents the lateral movement of a structural level under seismic excitation. It provides an indication of the flexibility of the structural system and is particularly useful when comparing different lateral load-resisting arrangements.

The final thesis reports maximum displacement values of 12.1109688 for the Bare Frame, 0.109888 for the Corner Shear Wall model and 0.01961688 for the Core Shear Wall model.

STRUCTURAL CONFIGURATIONS	MAXIMUM DISPLACEMENT
Bare Frame	12.1109688
Corner Shear Wall	0.109888
Core Shear Wall	0.01961688

Table 4.1 Comparison of Storey Displacement for Bare Frame, Core Shear wall, Corner Shear Wall Models

Taking the Bare Frame as the reference, the numerical results indicate a substantial reduction in the maximum reported displacement after the introduction of shear walls. The reduction for the Core Shear Wall model relative to the Bare Frame is approximately 99.84%, while the reduction for the Corner Shear Wall model is approximately 99.09%.

These values indicate that the centrally positioned shear-wall arrangement provides the strongest control of the reported lateral displacement among the three configurations considered. The result is consistent with the role of a concentrated central lateral-resisting system in increasing the stiffness available against lateral deformation. The comparison also shows that the mere inclusion of shear walls is not the only consideration; their position within the structural plan can materially influence the resulting response.

4.2 Story Drift

Story drift is the relative lateral movement between consecutive storeys. It is an important indicator of seismic deformation because excessive inter-storey movement can affect both structural and non-structural components.

The maximum drift values obtained from the final thesis are 0.0015288 for the Bare Frame, 0.000398 for the Corner Shear Wall model and 0.000078 for the Core Shear Wall model.

STRUCTURAL CONFIGURATION	MAXIMUM DRIFT
Bare Frame	0.0015288
Corner Shear Wall	0.000398
Core Shear Wall	0.000078

Table 4.2 Comparison of Storey Drift for Bare Frame, Core Shear wall, Corner Shear Wall Model

Compared with the Bare Frame, the Corner Shear Wall arrangement reduces the maximum reported drift by approximately 73.97%, whereas the Core Shear Wall arrangement produces a reduction of approximately 94.90%.

The Core Shear Wall therefore provides the greatest reduction in the maximum drift value among the three configurations. The numerical comparison suggests that the centrally arranged wall system provides a more effective mechanism for controlling inter-storey deformation in the investigated building.

4.3 Base Shear

Base shear represents the resultant horizontal seismic force developed at the base of the structure. It is an important response quantity because it reflects the overall lateral force obtained from the seismic analysis. The ETABS results

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reported in the thesis are presented separately for the X and Y directions.

MODEL	X DIRECTION(KN)	Y DIRECTION(KN)
Bare Frame	1700.82	1680.43
Core Shear Wall	157.79	120.36
Corner Shear Wall	615.42	596.87

Table 4.3 Base Shear Obtained from ETABS

The Bare Frame produces the largest reported base-shear values, whereas the Core Shear Wall model gives the smallest values in both principal directions. The Corner Shear Wall model lies between the two.
Relative to the Bare Frame, the reported X-direction base shear is reduced by approximately 90.72% for the Core Shear Wall and 63.82% for the Corner Shear Wall. In the Y direction, the corresponding reductions are approximately 92.84% and 64.48%, respectively.
The difference between the two shear-wall arrangements demonstrates that changing the wall location changes the global dynamic response of the structural system. The central wall arrangement produced the lowest reported base-shear values in the analyzed models.
However, base shear should not be interpreted independently of the complete seismic design process. The values reported here are the ETABS analysis outputs for the specific modeling assumptions, seismic parameters and structural configurations adopted in the study.

4.4 Comparative Assessment

The displacement and drift results provide the clearest indication of the influence of shear-wall placement.

PARAMETER	CORE SHEAR WALL	CORNER SHEAR WALL
Maximum Displacement Reduction	99.84%	99.09%
Maximum Drift Reduction	94.90%	73.97%
X- Direction Base Shear	90.72%	63.82%
Y- Direction Base Shear	92.84%	64.48%

Table 4.4 Percentage Reduction Relative to Bare Frame

The Core Shear Wall model provides the largest reduction for all four compared response measures. The displacement and drift reductions are particularly pronounced, indicating a substantial change in the lateral deformation characteristics of the structure.
The Corner Shear Wall model also provides a substantial improvement over the Bare Frame, but the magnitude of improvement is lower than that obtained with the Core Shear Wall arrangement for the reported results.
The comparison therefore indicates that, for the specific G+10 building investigated, shear-wall location has a measurable influence on seismic response, and the Core Shear Wall arrangement provides the most favorable response among the three tested configurations.

4.5 Engineering Interpretation

The numerical results can be interpreted in terms of the distribution of lateral stiffness within the building. The Bare Frame does not contain dedicated wall elements and therefore exhibits the largest reported deformation response.
Adding shear walls introduces a stiffer lateral load-resisting mechanism. The difference between the Core and Corner configurations demonstrates that the location of this additional stiffness is relevant to the overall structural response.
The Core Shear Wall configuration produces the lowest displacement and drift values in the final dataset. This indicates that the central arrangement is particularly effective for controlling lateral deformation in the selected regular building.
The Corner Shear Wall configuration also improves the response substantially compared with the Bare Frame, but its reported displacement and drift remain higher than those of the Core configuration.
These observations should be considered specific to the investigated geometry and modeling assumptions. Changing the building height, plan irregularity, wall dimensions, wall length, soil condition or seismic parameters may alter the relative response of the different arrangements.

5. Discussion

The main finding of the investigation is that the seismic response of the building changes significantly when shear walls are introduced and their position within the plan is altered.
The Bare Frame provides the highest reported displacement and drift values. This establishes a useful reference condition for assessing the contribution of the shear-wall systems.
The Corner Shear Wall arrangement reduces both deformation parameters substantially. Its performance indicates that placing lateral-resisting elements toward the perimeter can provide a significant increase in the seismic resistance of the building compared with a frame-only system.
The Core Shear Wall arrangement produces the lowest reported displacement and drift. The maximum displacement decreases from 12.1109688 in the Bare Frame to 0.01961688 in the Core configuration. Similarly, the maximum drift decreases from 0.0015288 to 0.000078.
The base-shear results follow the same comparative ordering in the final thesis dataset, with the Bare Frame producing the largest values and the Core Shear Wall producing the smallest values.
These findings reinforce the importance of considering shear-wall location during the conceptual and preliminary stages of seismic structural design. Wall placement should be selected not only on the basis of structural strength but also with consideration of stiffness distribution, deformation control and compatibility with the building layout.
At the same time, the present investigation is based on a single regular G+10 building configuration. Therefore, the results should not be generalized to every building type. Further

numerical studies involving irregular plans, different heights, alternative wall thicknesses and additional wall arrangements would be useful for establishing broader design trends.

6. Conclusions

Based on the numerical investigation of the G+10 reinforced concrete building, the following conclusions are drawn:

- The location of shear walls has a significant influence on the seismic response of the investigated reinforced concrete building.
- The Bare Frame configuration exhibited the highest reported maximum displacement of 12.1109688 and the highest reported maximum drift of 0.0015288.
- The introduction of shear walls substantially reduced the reported lateral deformation response.
- The reported base shear was highest for the Bare Frame and lowest for the Core Shear Wall model in both principal directions.
- The Core Shear Wall configuration produced the lowest maximum displacement, with a reported value of 0.01961688, representing an approximately 99.84% reduction relative to the Bare Frame result.
- The Corner Shear Wall configuration produced a maximum displacement of 0.109888, corresponding to an approximately 99.09% reduction relative to the Bare Frame.
- The Core Shear Wall model produced the lowest maximum drift value of 0.000078, approximately 94.90% lower than the Bare Frame result.
- The Corner Shear Wall model reduced the maximum drift by approximately 73.97% relative to the Bare Frame.
- The X-direction base shear values were 1700.82 kN, 615.42 kN and 157.79 kN for the Bare Frame, Corner Shear Wall and Core Shear Wall models, respectively. The corresponding Y-direction values were 1680.43 kN, 596.87 kN and 120.36 kN.
- Among the three configurations investigated, the Core Shear Wall arrangement produced the most favorable overall response according to the displacement, drift and base-shear values reported in the final thesis.
- The results indicate that shear-wall design should consider not only the provision of wall elements but also their location within the building plan.
- Since the investigation is based on a regular G+10 building and a fixed set of material, geometric and seismic parameters, the conclusions should be applied within the scope of the adopted analytical model.

7. Limitations and Future Scope

The study is based on a regular G+10 reinforced concrete building with a 20 m × 20 m plan and fixed member and wall dimensions. Only three structural arrangements were investigated. The analysis was carried out using linear dynamic Response Spectrum Analysis under the selected Zone IV and medium-soil conditions.

Future investigations may extend the study by considering:

- Different building heights
- Irregular building plans
- Different shear-wall thicknesses and lengths
- Additional wall locations and combinations
- Different soil conditions
- Nonlinear static or nonlinear dynamic analysis
- Torsional response and accidental eccentricity
- Performance-based seismic assessment
- Comparison of additional lateral load-resisting systems.

Such extensions would help determine whether the response trends observed for the present G+10 configuration remain applicable to a wider range of reinforced concrete building systems.

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