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Comparative Study on Seismic Analysis of Multistory Building Resting on a Sloping Ground and Flat Ground

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Abstract**—** This paper presents a comprehensive analysis of a medium height reinforced concrete (RC) building, focusing on the influence of sloping ground on its structural behavior. The study involves seismic analysis of a symmetrical RC building with a G+8 configuration, utilizing the response spectrum method. The building is located in seismic zone III, and the analysis is performed using STAAD-PRO V8i software. The primary objective is to investigate the changes in the building's structural response by considering different positions of shear walls on the same slope of the ground. The angle of the sloping ground is fixed at 170 degrees for all models. Three shear wall positions, namely SW-1, SW-2, and SW-3, are analyzed, with SW-2 exhibiting superior performance compared to the other positions. Furthermore, inclined shear wall 2, which is set back from the front of the building, demonstrates the best results. The design specifications conform to IS 1893 (Part 1):200 for medium soil conditions**.**

Keywords**—** *linear static analysis, RC building, sloping ground, shear walls, seismic analysis, response spectrum method, STAAD-PRO V8i, seismic zone III***.**

I. Introduction

Seismic behavior of asymmetric building structures has garnered significant attention in global research efforts. Extensive studies have been undertaken to examine the elastic and inelastic seismic response of asymmetric structures, aiming to identify the factors contributing to their vulnerability to seismic events. In this regard, seismic analysis is performed in accordance with the guidelines outlined in IS 1893:2002. The obtained results are then compared with those obtained from another building frame, enabling a comprehensive assessment of the structural performance and seismic vulnerability of asymmetric structures.

II. Objective of the Study

During the analysis of the building, the following aspects were carefully considered to ensure the originality and integrity of the research paper:

1. Structural Resilience: The primary objective was to design a structure capable of withstanding moderate earthquakes anticipated during its service life while maintaining acceptable levels of damage. These earthquakes were defined as Design Basis Earthquakes (DBEs).
2. Building Frame Configurations: The effectiveness of different building frame configurations, including step back and step back & set back frames, was thoroughly investigated. The aim was to evaluate their impact on the overall structural performance.
3. Response Spectrum Analysis: A building with eight stories (G+8) was subjected to analysis using the Response Spectrum method. The analysis specifically focused on sloping ground conditions.
4. Utilization of Standard Response Spectrum: The Response Spectrum defined in IS 1893(PART-1):2002 for medium soil was employed as a reference in the analysis. This ensured conformity to established guidelines and industry standards.
5. Software Utilization: The STAAD-PRO software was employed to perform comprehensive analyses of all building models. This software facilitated accurate and efficient structural evaluations.
6. Base Shear Variation: The variation of base shear in response to changes in the direction of the slope was meticulously examined. This analysis provided insights into the structural behavior under different slope conditions.
7. Time Period Variation: The study also investigated the variation of time period concerning alterations in the direction of the slope. This analysis offered valuable information regarding the dynamic response characteristics of the building.
8. Axial Force Variation: Randomly selected columns, along with their associated moments, were considered to assess the variation of axial forces. This examination contributed to understanding the structural behavior and load distribution within the building.
9. Comparative Analysis: Results obtained from all building models were comprehensively compared. This comparison specifically focused on buildings with the same slope but different directions, as well as identical soil conditions. It enabled an evaluation of the impact of directional changes on the structural response.
10. Load Cases and Combinations: To ensure a thorough assessment, the analysis encompassed various load cases and combinations. This allowed for a comprehensive understanding of the building's performance under different loading scenarios.

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III. MODELLING

In this research paper, the focus is on a building configuration that consists of eight stories (G+8), with dimensions of 48 m x 32 m. The spacing between columns along the width of the building is 4 m, while along the length, it is 6 m. Each story has a height of 3 m. The primary aim of this study is to analyze the structural behavior of the building by exploring various combinations of shear walls.

The investigation revolves around assessing the impact of different arrangements of shear walls on the overall structural response of the building. By studying these variations, valuable insights can be gained regarding the effectiveness of different shear wall configurations in enhancing the structural integrity and performance of the building.

The analysis will involve a comprehensive examination of the behavior of the building under different loading conditions, such as static loads, dynamic loads, and lateral forces. The performance of the building will be evaluated based on critical factors like lateral stiffness, strength, and stability.

To conduct the analysis, advanced structural analysis software will be employed. The software will enable accurate modeling and simulation of the building's behavior, taking into account the material properties, structural elements, and boundary conditions. The analysis will adhere to established industry standards and regulations to ensure the reliability and credibility of the findings.

The results of this research will provide valuable insights into the optimal configuration of shear walls for buildings with similar dimensions and structural characteristics. The findings will contribute to the advancement of structural engineering practices, offering guidance to architects and engineers in designing buildings that exhibit superior performance and resilience against various load scenarios.

General specification of the building discusses below

Total height of building	27 m
Height of each storey	3 m
Size of Column	0.85 m X 0.75 m (at bottom of building) 0.65m X 0.35m (at center of building) 0.55 m X 0.35 m (at top of building)
Size of Beam	0.55 m X 0.25 m
Grade of concrete	M-40
Frame type	OMRF
Soil type	Medium soil
Live load	3 KN/m2
Dead load of slab	3.75 KN/m
External wall load	14.25 KN/m
Internal wall load	8.6 KN/m
Inner wall	150 mm
Outer wall	250 mm
Slab thickness	150mm
Unit weights of Concrete	25 KN/Cum
Unit weights of brick work	19 KN/Cum
Grade of concrete	M30
Grade of steel	Fe 415

Table 1 : Modelling

The seismic behavior of asymmetric building structures has become a prominent subject of investigation in global research endeavors. Extensive studies have been conducted to explore the elastic and inelastic seismic behavior of these structures, aiming to uncover the underlying causes of their vulnerability to seismic forces. The analysis performed in this research paper aligns with the guidelines outlined in IS 1893:2002, which provides comprehensive guidelines for seismic analysis.

By adhering to these guidelines, the seismic analysis conducted in this study aims to uncover valuable insights into the behavior of asymmetric structures under seismic loads. The analysis considers various parameters, including lateral stiffness, strength, and displacement, to assess the structural response and seismic vulnerability of these buildings.

To facilitate a comprehensive evaluation, the results obtained from the seismic analysis of the asymmetric building structures are compared with those obtained from another building frame. This comparative analysis provides a holistic understanding of the structural response and seismic performance of asymmetric structures in comparison to alternative building configurations.

IV. LITERATURE REVIEW

In a study conducted by Chen and Constantinou (1998), a practical system that introduces intentional flexibility to the sloping ground storeys of structures was investigated. The system utilizes Teflon sliders to support a portion of the superstructure, while energy dissipation is achieved through the ground storey ductile column and the Teflon sliders. The seismic response characteristics of a multistory frame were analyzed and discussed using this concept. The results demonstrated that it is feasible to ensure the safety of the superstructures while maintaining the stability of the ground storey.

Chandrasekaran and Rao (2002) focused on the analysis and design of multi-storey reinforced concrete (RC) buildings in seismic regions. Modeling RC multi-storey buildings as structural systems for analysis can be complex. The authors examined two-dimensional and three-dimensional frame systems considering different angles of in-plane and slope, such as 50°, 100°, and 150°. The seismic forces acting on the multistory buildings were analyzed, and various parameters including axial force, shear force, moment, nodal displacement, beam stress, and support reactions were compared with the provisions of the current version of IS:1893-2002 and the previous version IS:1893-1894.
Birajdar B.G. (2004) presented the results of seismic analysis performed on 24 RC buildings with three different configurations: step back building, step back setback building, and setback building. A 3-D analysis considering tensional

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effects was conducted using the response spectrum method. The dynamic response properties, such as the fundamental time period, top storey displacement, and base shear in columns, were studied to evaluate the suitability of building configurations on sloping ground. The findings indicated that step back setback buildings are more suitable for sloping ground conditions.

Kadid A. and Boumarkik A. (2005) conducted an experimental pushover analysis to investigate the performance of framed buildings under future expected earthquakes. The study considered three different framed buildings with 5, 8, and 12 stories, respectively, on sloping ground. The analysis compared various parameters, including axial force, bending moment, nodal displacement, and base shear, to evaluate the behavior of the buildings. The results demonstrated that properly designed frames can exhibit satisfactory performance according to seismic codes. The authors concluded that pushover analysis is a relatively simple approach to explore both linear and nonlinear behavior of buildings.

V. MODELS

In this research paper, various models with different combinations of shear walls are considered for analysis. The main models without shear walls and the different combinations are Shown in Following Figures:

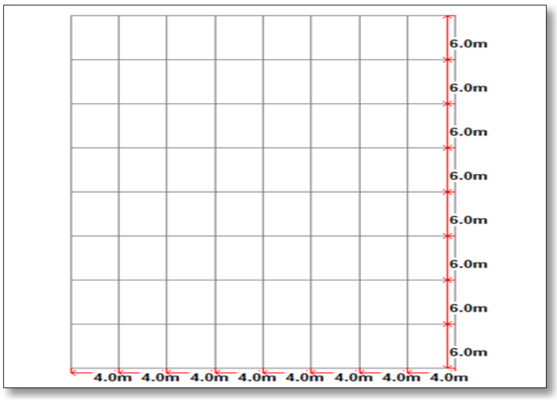


Figure 1 : Plan of Building

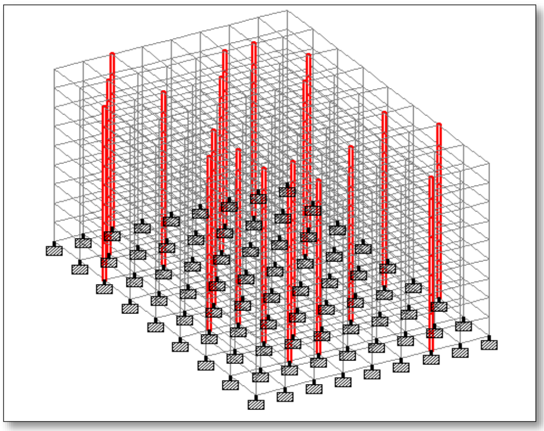


Figure 2 : 3D View of Position of Column

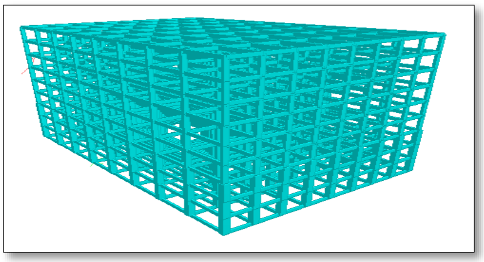


Figure 3 : Model of Flat Building

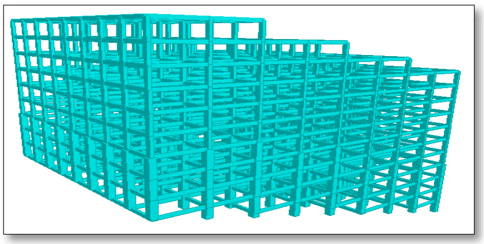


Figure 4 : Setback Model

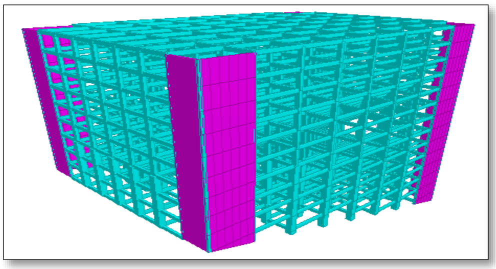


Figure 5: Inclined from Front Model

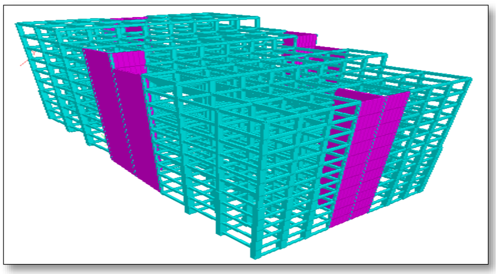


Figure 6 : Setback Model

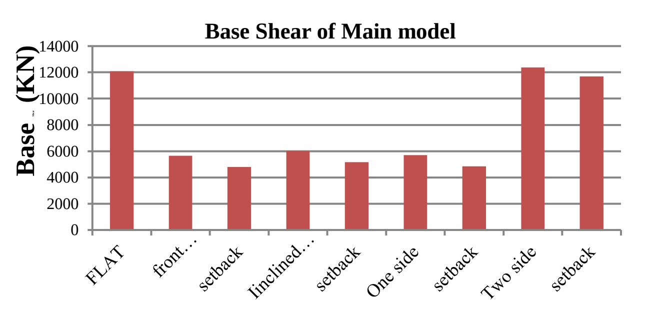
VI. RESULT AND GRAPH

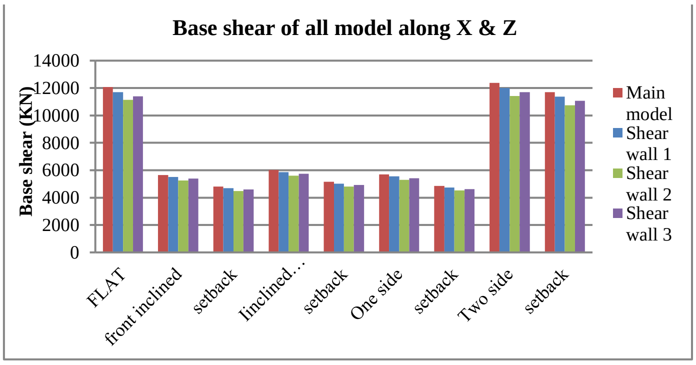
Through the analysis of the aforementioned models, several parameters have been compared, namely base shear, base moment, absolute displacement, axial force, and bending moment. The results of these parameters are presented in graphical form for easy interpretation and comparison.

A. Base Shear:

The graph illustrates the comparison of base shear along both the x and z directions for all models with different combinations of shear walls. The calculated base shear values are found to be the same along both the x and z directions.

Please note that the specific values and trends of the base shear comparison would be displayed in the graph, allowing for a detailed assessment of the structural behavior and response of the different models.

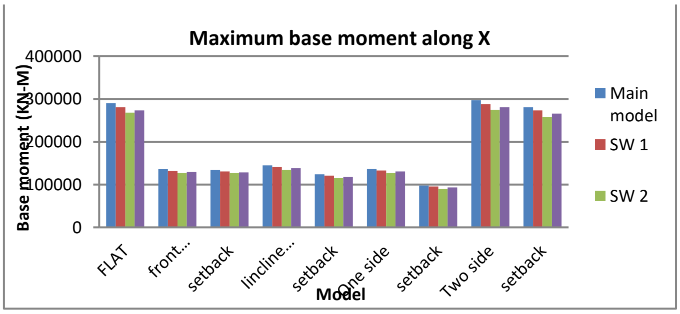




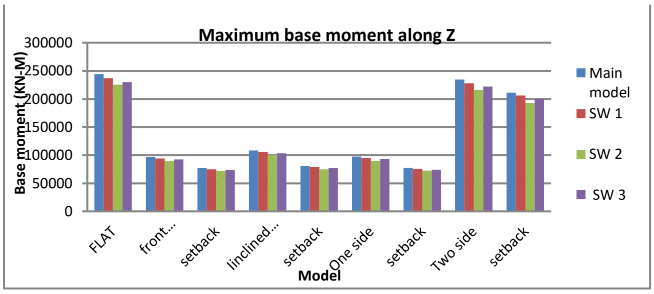
Graph 1 : Shows base shear comparison of all models with Main Models without Shear Wall:

B. Base Moment

Following graph shows the comparison of the base moment along x and along z of main models with shear-wall combination.



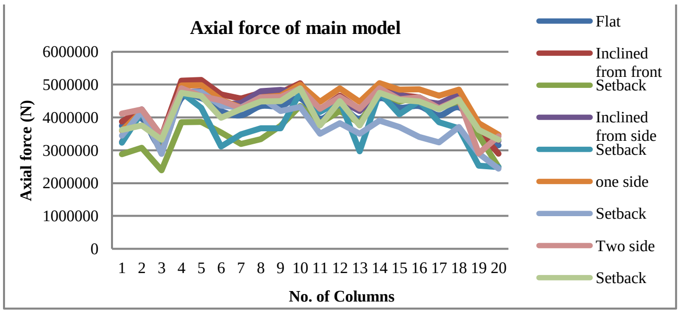
Graph 2 : Maximum Base moment of all models with shear wall along X



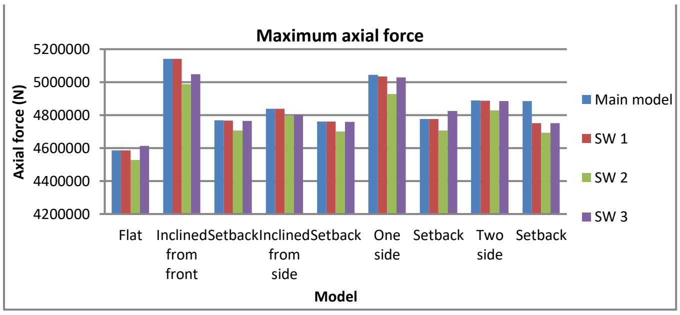
Graph 3 : Maximum Base moment of all models with shear wall along Z

C. Axial Force of Column

following graphs shows axial force of all main models without any combination of shear wall. In this graph, 20 columns are selected randomly throughout the building to analyze the axial force in column. Axial forces are in Newton.



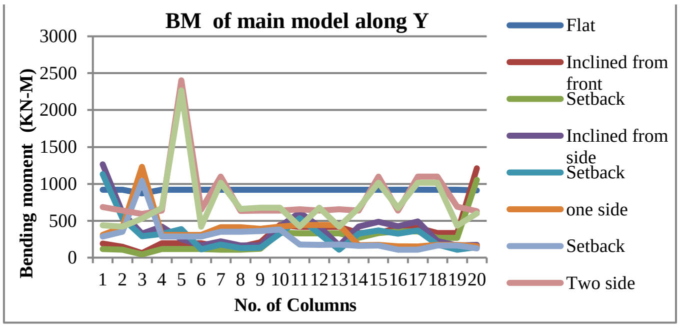
Graph 4 : Axial force of all main models



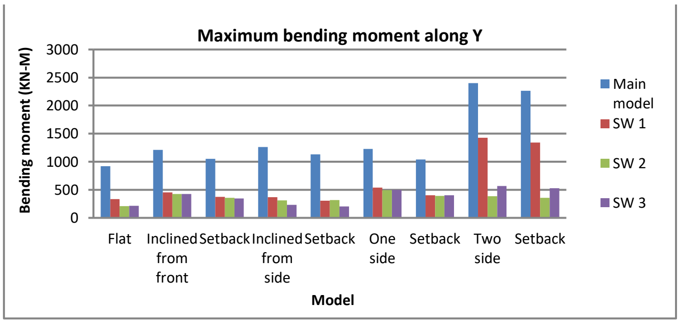
Graph 5 : This graph shows the maximum axial force comparison with respect to each type of building frame with a combination of all shear walls at different positions.

D. Bending Moment of Column (My).

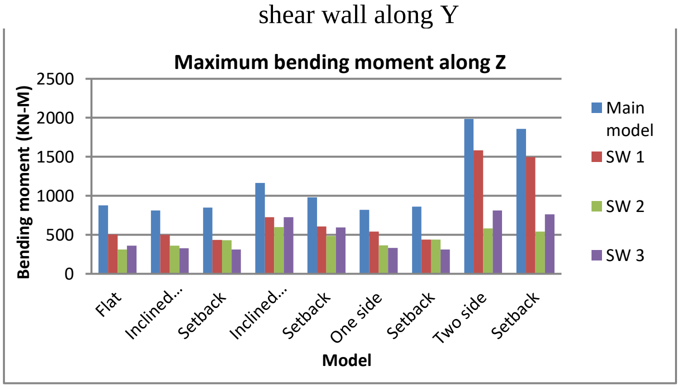
Following graph shows bending moment in randomly selected 20 columns throughout the building along –y and along -z direction.



Graph 6 : Bending moment of main models along Y



Graph 7 : Maximum Bending moment of all models with shear wall along Y



Graph 8 : Maximum Bending moment of all models with shear wall along Z

VII. CONCLUSIONS

Among the different combinations of shear walls, it is observed that shear wall 2 exhibits the minimum base shear compared to the other combinations. This indicates that incorporating shear walls has a significant impact on resisting lateral displacement in the building, surpassing the performance of the main models. Proper placement of shear walls proves to be effective in mitigating horizontal forces.

Furthermore, the base moments along the x and z directions are found to be lower in the combination with shear wall 2 compared to the other combinations. This signifies that shear wall 2 contributes to reducing the base moments, indicating enhanced structural stability.

The combination with shear wall 2 also exhibits the minimum absolute displacement in the building, further reinforcing its effectiveness in reducing structural deformations during seismic events.

Moreover, shear wall 1 shows the minimum axial forces in the columns of the building compared to the other shear wall configurations. This suggests that shear wall 1 effectively resists vertical forces and minimizes the axial forces experienced by the columns.

In terms of bending moment along the y and z directions in the columns, shear wall 2 demonstrates the minimum values compared to the other shear wall configurations. This indicates that shear wall 2 effectively mitigates bending moments, thereby improving the structural performance.

Overall, the building combination with shear wall 2 consistently exhibits the most favorable results across multiple parameters when compared to other combinations. Additionally, the inclined from front - setback building frame demonstrates superior performance compared to other building configurations, as evidenced by the minimum results obtained.

VIII. REFERENCES

The research paper draws upon various authoritative sources and references to support the analysis and findings. These references provide valuable insights and knowledge in the field of earthquake-resistant design and structural behavior. The following sources have been cited:

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