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SEISMIC ANALYSIS OF MULTI-STORY REINFORCED CONCRETE BUILDINGS WITH VARIOUS BRACING SYSTEMS

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ABSTRACT

In modern urbanization, the demand for high-rise structures is increasing, necessitating advanced seismic design to ensure safety. This study evaluates the seismic performance of a G+17 story reinforced concrete building using various bracing configurations—X, V, Inverted V, and Eccentric Forward—under different seismic zones (Zone II and Zone V). The analysis is performed using ETABS 2016 software employing Response Spectrum Analysis (RSA) and Equivalent Static Method (ESM). Results indicate that the incorporation of bracing significantly enhances the lateral stiffness and reduces story drift and displacement. Specifically, X-bracing was found to be the most effective, reducing lateral story movement by approximately 40% compared to a bare frame structure. The study concludes that braced systems provide superior resistance against horizontal seismic forces, with the X-brace system demonstrating the highest efficiency in minimizing seismic responses.

KEYWORDS: Seismology, Seismic Design, Bracing Systems, ETABS, Story Drift, Base Shear, Response Spectrum Analysis

INTRODUCTION

Seismology involves the study of vibrations in the earth, primarily caused by earthquakes, which are best explained by the Elastic Rebound Theory. In high-rise construction, engineering quality is critical as structural failure, rather than the earthquake itself, is the primary cause of casualties. For tall structures, traditional static force distribution is often insufficient, requiring more robust seismic designs.

Previous research suggests that shorter columns often suffer more damage than taller columns in the same story, a phenomenon known as the short column effect. Bracing systems offer a cost-effective modification method to increase both the stiffness and strength of buildings with minimal added weight. This study aims to assess how different bracing types influence the seismic response of multi-storied RC buildings.

LITERATURE REVIEW

Anusha K[1], Raghu K[2] [2018][1] evaluated the seismic response of a 15-story steel moment-resisting frame in Zone-II (medium soil) using bracing systems at various angles. By analyzing parameters such as story drift, displacement, and shear, the study demonstrated that steel bracing effectively resists lateral shifts through axial tension and compression, similar to truss behavior, thereby enhancing the structure's earthquake resistance.

Md. Ahasan – ul – Haque [1] , Md. Atik Masum[2] [2018][2] investigated the stability of a ten-story commercial steel structure under lateral stress using various bracing configurations, including X-type, V-type, and eccentric systems. The comparative analysis revealed that transverse (cross) bracing provided the most significant structural improvement, reducing lateral displacement by 41% and offering superior rigidity compared to other designs.

Research Paper

K. S. K. Karthik Reddy [2015][3] analyzed a 16-story tower in Zone-II under high wind speeds (220 kmph) using STAAD Pro to evaluate four bracing types. The study found that X-type steel bracing significantly enhanced lateral stiffness and minimized inter-story drift compared to unbraced and concrete-braced frames. While adding 3.5% to the total structural weight, steel X-bracing proved 2.15% more efficient than concrete alternatives and effectively reduced stresses on outer columns.

Adithya. M[1] , Swathi rani K.S[2] [2015][4] utilized ETABS to analyze a 20-story 3D frame, focusing on the cost-effectiveness and structural impact of various bracing types and their placements. The study specifically limited bracing to auxiliary columns (maximum four per story) to optimize the drift index and inter-story drift under earthquake and wind loads while maintaining a minimal structural load.

Anes Babu[1] , Dr. Chandan KumarPatnaikuni[2] [2015][5] investigated steel bracing as a retrofitting solution for G+9 reinforced concrete (RC) buildings across multiple seismic zones. Comparing models with shear walls, steel bracings, and unbraced prototypes, the research found that steel bracing effectively reduces lateral drift compared to shear walls. Notably, zigzag bracing performed better in Zones II and III, while X-type bracing proved more effective for the higher intensities of Zones IV and V.

Masood Ahmed Shariff[1] , Owais M[2] [2016][6] examined the seismic retrofitting of an H-shaped asymmetric reinforced concrete building (36m x 36m) in Zone IV using ETABS. Through a static linear earthquake analysis, the study compared a standard frame with an X-braced frame. The results indicated that steel bracing significantly increased structural stiffness and base shear capacity while effectively reducing horizontal deflection and potential earthquake damage.

Objectives

Structures on flat terrain are uniform and uniform in vertically horizontal directions, and they are sensitive to lateral pressures. There has been an increased need for structures that can withstand lateral pressures well. To withstand lateral forces, other structural parts, such as supports, might be utilized.

The primary aims of this investigation are outlined below:

- To examine the performance of multi-storied RC building structure with various varities of bracing systems applying to tremour loading and to choose the proper brace frame for upholding the shaking of ground force efficiently.
- To check the performance of various bracing configurations on seismic performance of building resting on sloping ground.
- To check the variations of BaseShear with respect to different configurations of bracings.
- Identify the variations of mode period with respect to different configurations of bracings.
- Examine the variation of storey displacements with respect to different configurations of bracings.

MATERIALS AND METHODS

The study models a G+17 story RC building with 5 bays in both X and Y directions, each 4m wide, with a story height of 3m. The materials used include M30 grade concrete and Fe500 steel. The analysis is conducted using ETABS 2016 for two seismic zones (Zone II and Zone V) on Type III (soft) soil.

Loading Conditions

Load Type	Value
Wall Load	10.25 kN/m
Live Load	3.00 kN/m^2
Floor Finish	1.50 kN/m^2
Seismic Zones	Zone II (0.1) & Zone V (0.36)

RESULTS:

Lateral Displacement Analysis

Bare Frame Vulnerability: The bare frame structure exhibited the highest lateral displacement values across all seismic zones, peaking at 10.773 mm at the 18th story in Zone II.

Efficiency of X-Bracing: The introduction of X-bracing significantly reduced lateral story movement by approximately **40%** compared to the bare frame.

Comparative Performance: While all bracing types (V, Inverted V, and Eccentric) reduced movement, the X-brace system consistently provided the lowest displacement values across both X and Y directions.

Storey Drift and Stiffness

Safety Compliance: All braced models maintained story drift within the permissible limit of **0.004 times the story height** as specified by IS 1893-2002.

Stiffness Peaks: The Inverted V bracing system demonstrated the highest story stiffness, while the bare frame showed the lowest resistance to lateral forces.

Drift Progression: Story drift values generally increased from the base up to level 10 before gradually decreasing toward the upper storeys.

Base Shear and Natural Time Period

Energy Dissipation: The base shear for the X-braced structure was **50% higher** than the bare frame, indicating a much stiffer and more earthquake-resistant assembly.

Rigidity Impact: The natural time period of the building was cut by nearly **half** when X-bracing was employed, a direct result of the increased structural rigidity.

Dynamic Response: The response spectrum analysis confirmed that the structural mass and stiffness were the primary drivers of the building's modal period.

DISCUSSION

The comparative analysis reveals that a **bare frame structure** lacks the necessary lateral stiffness for a G+17 story building, resulting in maximum displacement and story drift. The introduction of bracing systems fundamentally transforms the structural response by creating a more rigid load path. Among the configurations, **X-bracing** proved most effective, reducing lateral movement by **40%** and the natural time period by nearly **50%**.

While the **Inverted V system** provided the highest story stiffness, the X-brace system offered a more balanced reduction in inter-story drift. The **50% increase in base shear** observed in braced models confirms that while these structures attract higher forces due to increased stiffness, they undergo significantly less deformation. This tradeoff is critical for ensuring structural integrity and preventing shear failure during high-magnitude seismic events.

TABLES AND FIGURES

Lateral Displacement Analysis

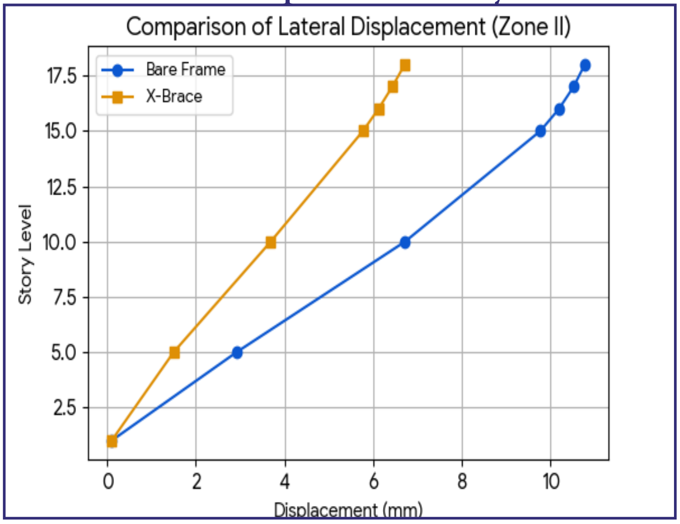

Table 1.1: Horizontal Deflection at Top Story (Elevation 18)

Seismic Zone & Direction	Normal Structure	X-Brace	V-Brace	Inverted V	Eccentric Forward
Zone II (X & Y)	10.773	6.717	7.270	7.098	7.852
Zone V (X & Y)	38.784	24.180	26.171	25.552	28.269

Table 2.1: Maximum Storey Drift (at Mid-Level/ Story 10)

Seismic Zone & Direction	Normal Structure	X-Brace	V-Brace	Inverted V	Eccentric Forward
Zone II (X & Y)	0.000244	0.000150	0.000160	0.000160	0.000175
Zone V (X & Y)	0.000880	0.000539	0.000584	0.000576	0.000631

Table 3.1: Total Base Shear (kN)

Seismic Zone & Direction	Normal Structure	X-Brace	V-Brace	Inverted V	Eccentric Forward
Zone II (X & Y)	730.89	1395.57	1232.82	1262.74	1134.52
Zone V (X & Y)	2631.20	5024.06	4438.17	4545.86	4084.27

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