WIND AND SEISMIC ANALYSIS OF BUILDING WITH BRACING SYSTEM RESTING ON SLOPING GROUND

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Abstract - *Hillside buildings face challenges due to limited flat land, leading to irregular foundations and unsymmetrical structures. The varying stiffness and mass distribution cause the center of mass and center of stiffness of each floor to misalign, resulting in significant torsional response to lateral loads. Unequal column heights in these buildings lead to varying stiffness within the same storey, causing damage to shorter, stiffer columns. To address these issues, bracing systems are used. The study focuses on Step back buildings with different bracing types, analyzed using ETABS v 9.0 finite element code through response spectrum analysis. Dynamic parameters like time periods, top storey displacements, drifts, and base shear are compared among various hill building configurations. The most effective bracing type is identified for Step back buildings on sloping ground, specifically X bracing, providing better results in all dynamic parameters. The chosen bracing is then applied in Step back buildings and compared with Step back setback buildings using wind and seismic analysis. X bracing proves to be the preferred choice. The software analysis is validated against other research papers.*

Key Words: Hillside buildings, Bracing systems, Torsional response, Sloping ground, Dynamic parameters, X bracing.

1.INTRODUCTION

Constructing buildings on hill slopes presents unique challenges and considerations for architects and engineers. The scarcity of flat land necessitates irregular foundations and unsymmetrical structures, resulting in varying stiffness and mass distributions. As a consequence, the center of mass and center of stiffness of each floor may misalign, leading to significant torsional response when exposed to lateral loads. To address these structural complexities and ensure stability, bracing systems play a crucial role in hillside buildings. This introduction explores the dynamic parameters involved, the impact of sloping ground, and the effectiveness of X bracing, as it offers valuable insights into optimizing construction techniques and enhancing seismic resilience in such terrains.

1.1 Bracing System

Bracing systems are essential components in building construction, designed to provide lateral stability and resist forces that result from various loads, such as wind, earthquakes, or other lateral movements. They help prevent excessive lateral deflection and ensure the overall structural integrity of the building.

There are several types of bracing systems commonly used in construction:

1. X-Bracing: X-bracing consists of diagonal members that form an "X" pattern between beams or columns. This configuration effectively resists lateral forces from different directions and offers symmetrical bracing to counteract torsional moments.

2. K-Bracing: K-bracing is similar to X-bracing but forms a "K" shape. It provides lateral stiffness and can be an aesthetically pleasing choice for architectural purposes.

3. V-Bracing: V-bracing involves diagonal members arranged in a "V" shape, connecting beams or columns. It is a simple and efficient bracing system that provides stability against lateral forces.

4. Chevron Bracing: Chevron bracing uses a series of diagonal members in a zigzag pattern, resembling chevrons (∧). This system offers good stiffness and strength while minimizing material usage.

5. Eccentric Bracing: Eccentric bracing employs diagonal members that do not intersect at a common point, creating an eccentric configuration. This system enhances energy dissipation during seismic events.

6. Inverted V-Bracing: In this bracing type, diagonal members form an inverted "V" shape. It provides lateral stiffness and can be suitable for architectural preferences.

Each bracing system has its advantages and limitations, and the selection depends on various factors, such as building height, architectural design, seismic zone, and local building codes. Engineers carefully assess these factors to choose the most appropriate bracing system to ensure the safety and stability of the structure.

1.2 Aim

This research aims to compare the response of building frames on sloping ground under seismic and wind loads, considering various parameters such as the number of bays, angle of sloping ground, and number of stories. The study focuses on two building configurations: step back frames with bracing and step back setback frames.

1.3 Objectives

1. Investigate different types of bracing systems to identify the most effective one for enhancing the structural properties of step back buildings.

2. Analyze the dynamic response of both step back buildings with bracing and step back setback buildings on sloping ground under wind and earthquake excitations.

3. Examine the impact of changing the number of bays along and across the slope direction while considering the chosen bracing system.

4. Conduct a detailed comparative study based on key response quantities, including maximum top storey displacement, maximum storey drifts, and maximum base shear.

2. LITERATURE SURVEY

Over the past several decades, structural engineers have prioritized making structures earthquake-resistant, leading to numerous research efforts aimed at finding innovative and effective ways to enhance seismic performance on sloping ground. Extensive experimental work has been conducted to explore various approaches in earthquake-resistant design for structures situated on sloping terrain.

2.1 Review of Literature

In Ashwani Kumar's research (2018), the focus is on the issues and problems related to the development and building regulations of hill towns. The study involves a comparative analysis of existing building regulations in various Himalayan hill towns, with the aim of gaining a deeper understanding of safety measures against natural hazards in such areas [1].

In the study conducted by B.G. Birajdar and S.S. Nalawade (2004), seismic analyses were performed on 24 reinforced concrete buildings with three different configurations: Step back building, Step back Set back building, and Set back building. Using a 3-D analysis with consideration for torsional effects using the response spectrum method, the researchers studied the dynamic response properties, including fundamental time period, top storey displacement, and base shear action induced in columns. The findings indicated that Step back Set back buildings are more suitable for construction on sloping ground [2].

Zaid Mohammada et al.'s research (2017) involved modeling and analyzing two different configurations of hill buildings using ETABS v 9.0 finite element code. A parametric study was conducted, varying the height and length of the hill buildings in eighteen analytical models. The dynamic parameters obtained from the analysis, such as shear forces induced in columns at the foundation level, fundamental time periods, maximum top storey displacements, storey drifts, and storey shear, were compared among the different hill building configurations to suggest their suitability [3].

3. METHODOLOGY

The methodology adopted to achieve the research objectives is as follows:

1. Initial Stage: The first stage involves selecting the most effective type of bracing for step back buildings on sloping ground. The determination is based on response spectrum analysis conducted in ETABS. Different types of bracing, including X bracing, V bracing, Inverted V bracing, Diagonal bracing, and a Bare frame, are analyzed. Key parameters such as maximum storey displacement, maximum storey drift, maximum base shear, and fundamental time period are compared to identify the optimal bracing configuration.

2. Analysis Stage: In the second stage, dynamic response analysis is carried out for three building configurations:

a. Step back building with the finalized effective bracing

b. Step back building without any bracing (Bare frame)

c. Step back setback building on sloping ground

The analysis includes both earthquake and wind excitations. Additionally, the impact of varying the number of bays along and across the slope direction is studied for earthquake and wind loads.

By following this methodology, the study aims to determine the most suitable bracing system for step back buildings on sloping ground, assess the seismic and wind response of different building configurations, and understand the influence of varying bay numbers on the structural behavior. The findings from this comprehensive analysis will contribute to enhancing the seismic and wind resilience of buildings in hilly terrains.

Table -1: Different properties considered for Step back building with 8 Storey

Material Properties	
Grade of Concrete	M25
Modulus of Elasticity of concrete	25000 N/mm^2
Poisson's ratio	0.2
Yield stress of main steel	500 MPa
Yield stress of distribution steel	415 MPa
Steel used for bracing	Fe 250
Floor system Diaphragm	Rigid Frame
Torsional effect & Accidental eccentricity	As per IS 1893:2016

Geometrical Properties	
Inclination of Ground	26º
Inter storey Height	3.5 m
Foundation depth	1.75 m
Length of building along slope	7 m
Width of building across slope	5 m
Thickness of slab	150 mm
Beam size	230 × 400 mm
Column size	300 × 500 mm
Section for bracing	ISMB 300
Foundation Supports	Fixed
Seismic parameters and loads	
Seismic Zone	V
Importance Factor	1.5
Response Reduction Factor	5
Soil Type	Medium
Dead load	5 kN/m²
Live load	3 kN/m²
Frame load on floor slabs	15 kN/m
Frame load on roof slabs	7.5 kN/m

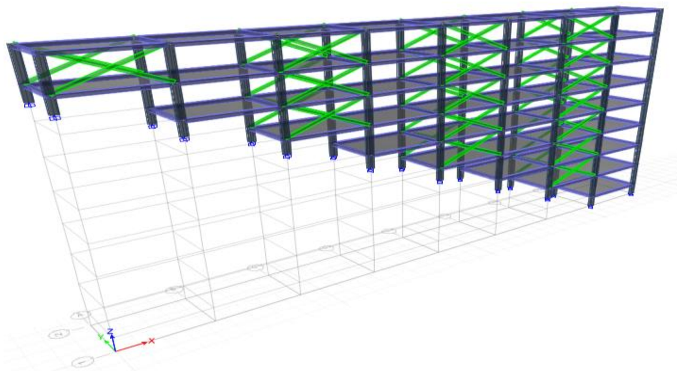

Fig -1: Structural Model of X-braced frame

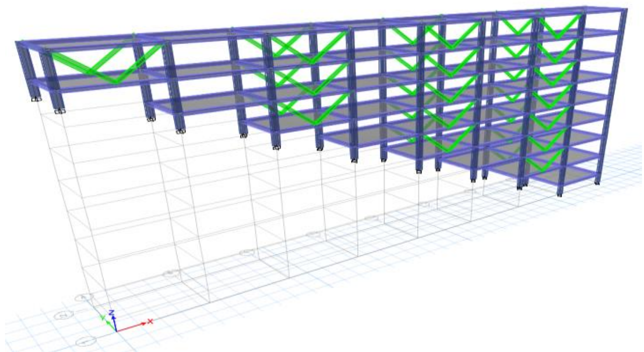

Fig -2: Structural Model of V-braced frame

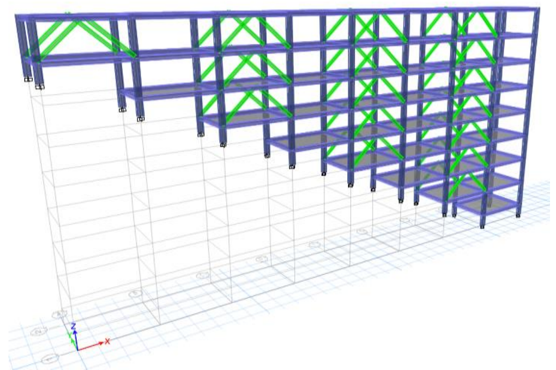

Fig -3: Structural Model of Inverted V-braced frame

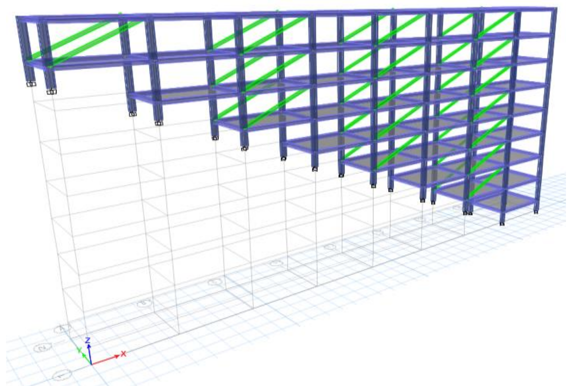

Fig -4: Structural Model of Diagonal braced frame

4. RESULTS

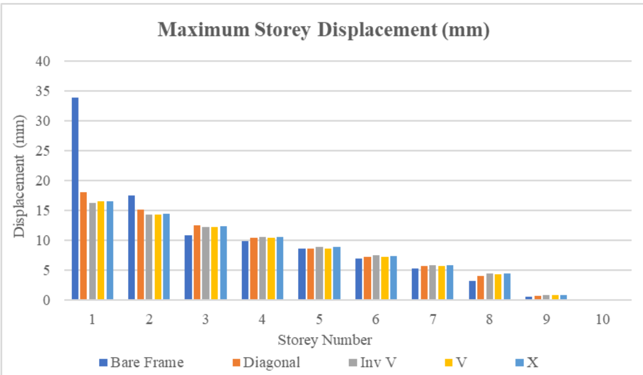

Chart -1: Graph of displacement vs storey number

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 10 Issue: 10 | Oct 2023 www.irjet.net p-ISSN: 2395-0072

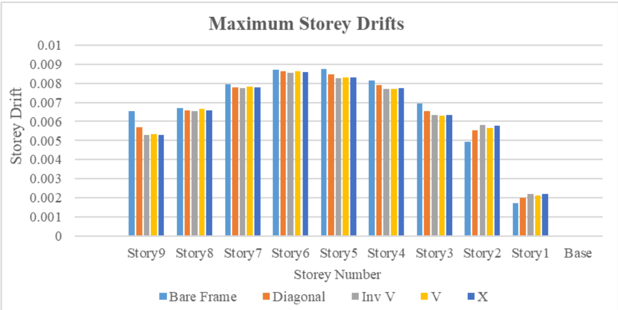

Chart -2: Graph of storey drift vs storey number

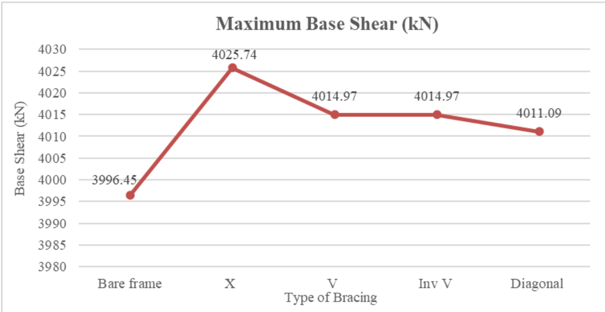

Chart -3: Graph of Maximum Base Shear vs Type of bracing

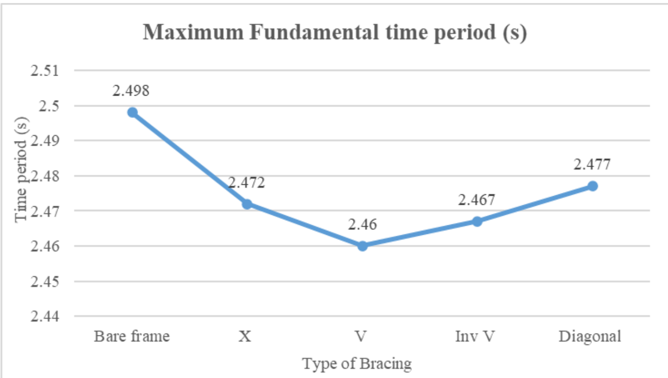

Chart -4: Graph of Maximum fundamental time period vs type of bracing

4.1 Summary of Results:

The frame models were analyzed using response spectrum analysis, starting with a bare moment resisting frame and then incorporating various bracing configurations, including diagonal bracing, V bracing, inverted V bracing, and cross bracing (X bracing). The introduction of bracing increased the stiffness and frequency of the frame, with the cross bracing (X bracing) demonstrating the highest stiffness among the braced models and the bare frame.

Comparing the braced models and the model without bracing, it was observed that the cross bracing (X bracing) resulted in the maximum base shear. Additionally, the incorporation of bracing systems led to a reduction in the lateral displacement of the moment resisting frame.

For step back buildings on sloping ground, the inverted V bracing and X bracing yielded better results compared to other bracing configurations.

Furthermore, the study also analyzed the performance of buildings with bracing systems by varying the number of bays. However, detailed findings related to this aspect are yet to be provided in the summary.

5. CONCLUSIONS

1. The analysis of different bracing types in step back buildings reveals that inverted V and X bracing are more effective compared to other bracing configurations. These bracing systems enhance the structural performance and seismic resilience of the buildings.
2. Step back buildings equipped with bracing systems demonstrate superior performance under both seismic and wind loading conditions when compared to step back setback buildings.
3. The research findings suggest that the effectiveness of bracing in step back buildings is limited up to 6 storeys when the number of bays increases along the slope. However, increasing the number of bays across the slope enhances the performance of buildings with bracing.
4. In both seismic and wind analyses, the lateral forces in the Y-direction are found to be the most critical. Step back buildings with X bracing prove to be more favorable, exhibiting better results across all dynamic parameters considered in the analysis.

5.1 Future Scope:

Based on the research outcomes, there are several potential areas for future exploration:

I. The effect of change in degree of slopes for step back buildings with bracing system can be found out.

II. Analysis methods like Time history analysis or Push over analysis can be carried out to get the accurate results.

III. Study can be continued further for finding the effective position of bracings for different configuration.

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