Seismic Performance Enhancement of Irregular RCC Structure Using Bracing System

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***Abstract*—Irregular reinforced concrete (RCC) buildings are highly susceptible to seismic damage due to abrupt variations in mass, stiffness, and geometry, which induce excessive lateral displacement and torsional effects. While seismic standards like IS 1893 provide general design guidelines, comparative research on the effectiveness of different bracing configurations for irregular structures remains limited. This study evaluates the seismic performance of a G+15 irregular RCC building—incorporating mass, stiffness, and geometric irregularities—strengthened with three steel bracing systems: X-bracing, V-bracing, and inverted V-bracing.**

Using ETABS, it is performed in compliance with IS 1893 to compare braced and unbraced models. Structural responses were evaluated based on story displacement, inter-story drift, and natural time period. Results indicate that integrating steel bracing significantly enhances seismic resistance and structural stability. Among the configurations, X-bracing exhibited superior performance, providing the highest lateral stiffness and the greatest reduction in displacement and time periods. V-bracing and inverted V-bracing also demonstrated effective drift control. These findings offer practical guidance for structural engineers designing or retrofitting irregular RCC buildings in active seismic zones.

***Index Terms*—Irregular RCC building, Seismic performance, Bracing systems, ETABS, X-bracing, V-bracing, Inverted V- bracing.**

I. INTRODUCTION

In the modern era of construction, Reinforced Cement Concrete (RCC) has emerged as one of the most widely used construction materials due to its strength, durability, and adaptability to different structural forms. With rapid urbanization and increasing demand for innovative architectural designs, buildings are often constructed with complex geometries and configurations. These structures frequently exhibit irregularities in plan and elevation, making them structurally vulnerable when subjected to dynamic loads such as earthquakes.

Earthquakes are among the most destructive natural disasters, causing significant loss of life and property. The behavior of structures during seismic events depends largely on their design, geometry, material properties, and construction practices. While regular structures tend to perform relatively better due to uniform distribution of mass and stiffness, irregular structures experience complex responses including torsion, stress concentration, and uneven displacement patterns.

The need to improve the seismic performance of such irregular RCC structures has become a critical area of research and engineering practice. One of the most effective and economical methods for enhancing seismic resistance is the incorporation of bracing systems, which improve lateral stiffness and load-carrying capacity.

II. OBJECTIVE OF THE STUDY

The primary objective of this study is to evaluate the seismic performance of an irregular high-rise RC building and determine the most effective bracing configuration to mitigate lateral loads.

The specific objectives are to:

- Model and Design: Develop a 3D finite element model of a high-rise (G+15) irregular RCC structure using ETABS.
- Investigate Configurations: Simulate and analyze the seismic behavior of the unbraced frame

against frames integrated with X, V, and Inverted-V bracing systems.
- Parametric Evaluation: Evaluate the impact of these bracing types on Maximum Displacement, Storey Drift, and Fundamental Time Period.
- Comparative Analysis: Contrast storey drift and displacement profiles using quantified analytical data and response graphs.
- Optimization: Identify the most structurally efficient bracing configuration for mitigating plan and vertical irregularities.

III. NEED OF STUDY

Modern construction frequently prioritizes architectural aesthetics over optimal structural configurations, leading to an increased deployment of complex, irregular geometries that are highly vulnerable to seismic failure. This research addresses this critical safety risk through the following areas:
- Structural Safety in Irregular Architecture: Mitigates the high vulnerability of complex buildings prone to localized failures and torsional responses under dynamic seismic loading.
- Demand for Economical Retrofitting: Establishes structural bracing as a low-cost, highly effective alternative to expensive seismic mitigation systems like base isolation or active dampers.
- Software-Driven Performance Mapping: Utilizes ETABS 2021 to simulate and accurately quantify the behavior of braced versus unbraced irregular frameworks.
- Bridging the Research Gap: Resolves the lack of comparative literature by directly contrasting the performance of X, V, and Inverted-V bracing topologies to determine the most structurally optimal configuration.

IV. SCOPE OF THE STUDY

The current study looks at different types of bracings and their effects on irregular building of shape and load combinations of mass and stiffness irregularity. For Analysis, twenty-five Models of twenty stories were considered.

The scope of this study includes:

1. Modeling of irregular RCC structures
2. Application of different bracing systems
3. Seismic analysis using software tools
4. Comparison of results based on key parameters

V. METHODOLOGY

This study evaluates the seismic performance of multi-storied RCC buildings with irregular shape Structure using bracing systems like Unbraced, X – bracing, V-bracing, Inverted V- bracing.

Structure Models
- 15-storey RCC irregular shape structure.
- Material properties include M30-grade concrete and Fe500-grade steel.

Seismic Analysis
- The Non-Linear Time History Analysis (NLTHA) method is used to study the buildings' response under earthquake loads.
- Ground motion data from the Bhuj Earthquake (2001) is used.
- Models are analyzed as per IS1893:2016 for Zone V seismic conditions.

Bracing Systems
- Each building is first analyzed without bracing to establish a baseline.
- Then, the four bracing types are applied to study their effect on building performance.

Analysis Tools
- ETABS 2021 software is used for modeling and seismic analysis.

Performance Metrics
- Story Displacement: Measures lateral movement of stories.
- Story Drift: Checks the relative movement two between adjacent floors.
- Time Period: Studies the impact of bracing on building vibration.

Comparison and Results
- Results are compared to find the best bracing system for irregular shape Structure.
- Inverted V bracing is specifically assessed for its innovative energy dissipation properties.

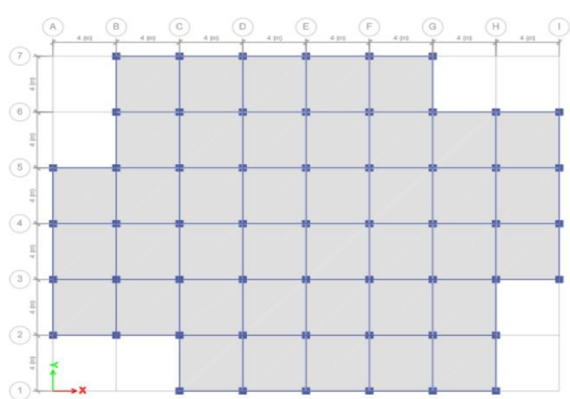
- This methodology provides insights into improving the safety and stability of irregular Structure during earthquakes.

VI. MODEL INFORMATION

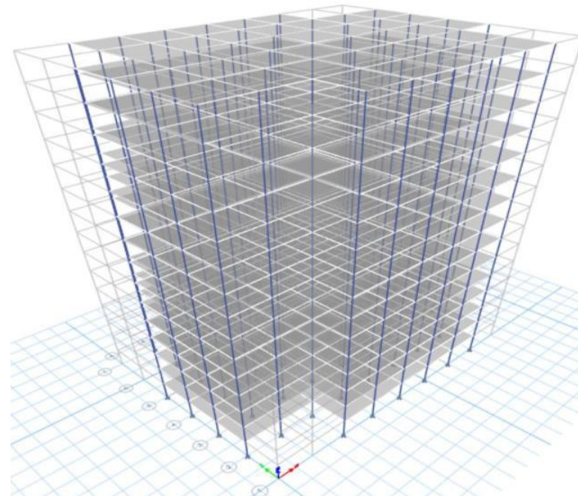
S.No	Variable	Data
1	Type of structure	Irregular structure
2	No. of stories	15
3	Floor height	3m
4	Live load	3kn/m^2
5	Wall load	External wall= 13.8kn/m^2 Internal wall = 7.5kn/m^2 Parapet wall = 3kn/m^2
6	Materials	M30, Fe500
7	Size of column	500x500mm
8	Size of beam	350x450mm
9	Size of Bracings	ISA 200X200X25mm
10	Depth o slab	150mm
11	Specific weight of RCC	25kn/m^3
12	Zone	V
13	Importance factor	2
14	Response reduction factor	5
15	Type of soil	Medium (II)

For analysis, the following four models of fifteen stories were considered in this study.

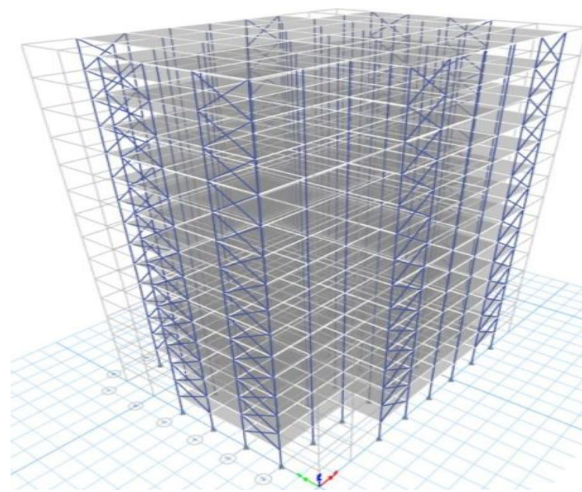
- Model1–Irregular Shape plan view
- Model2–Irregular shape unbraced structure
- Model3–Irregular shape X- Bracing structure
- Model4–Irregular shape V- Bracing structure
- Model5– Irregular shape Inverted V- Bracing structure.



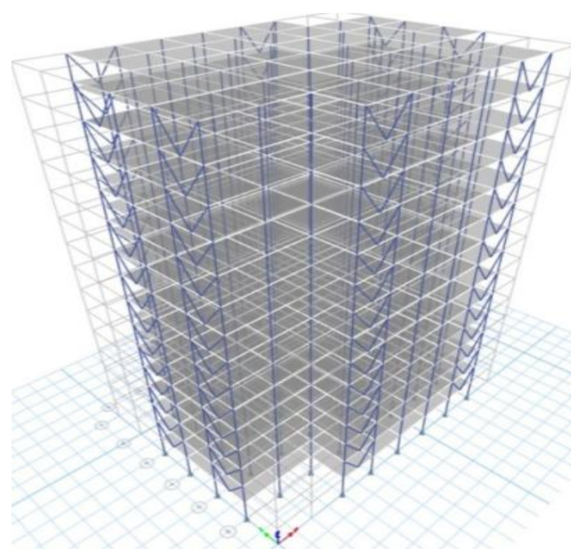
Model1–Irregular Shape plan view



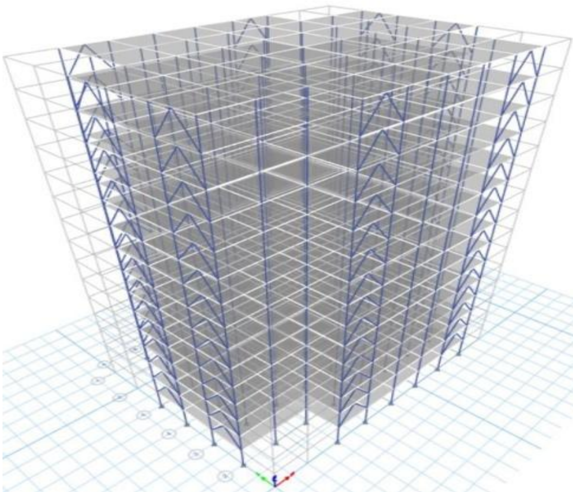
Model2–Irregular shape unbraced structure



Model3–Irregular shape X- Bracing structure



Model4–Irregular shape V- Bracing structure



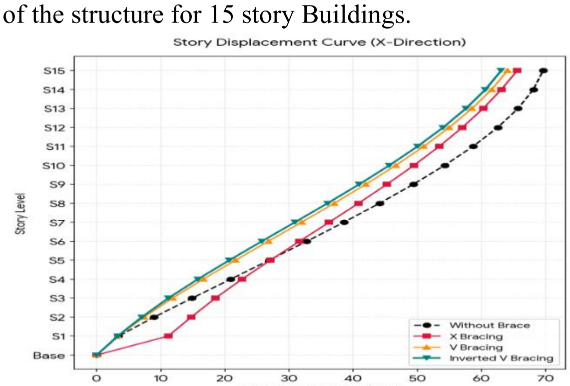
Model5 –Irregular shape Inverted V- Bracing structure.

VII. RESULTS AND DISCUSSION

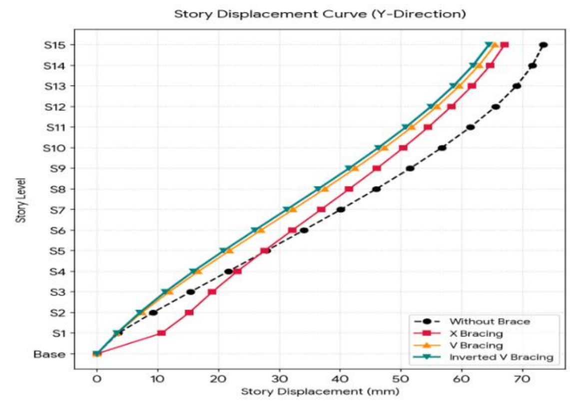
The results obtained are of different parameters such as story displacement, Storey drifts, Modal Periods, etc. The results obtained by carrying out by Response Spectrum Analysis for G+15, Storey Buildings as listed.

- Model1–Irregular-MaximumDisplacementinX-Direction
- Model2–Irregular-MaximumDisplacementinY-Direction
- Model3–Irregular-MaximumDriftinX-Direction
- Model4–Irregular-MaximumDriftinY-Direction
- Model5–MaximumTimePeriodofIrregularmodels

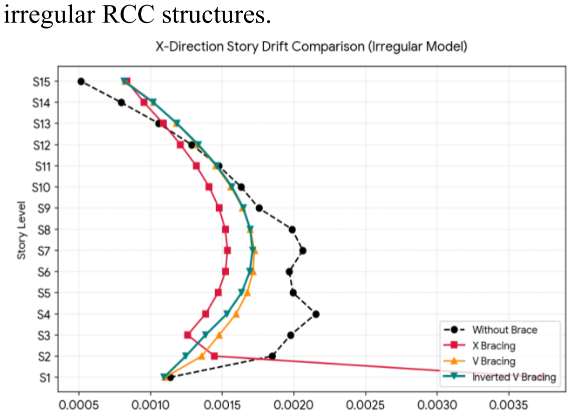
Subsequent Discussions are made about the Results obtained based on the story drifts, Story Displacement, etc. for buildings individually and also considering the Storey effect of buildings by comparing the responses of the structure for 15 story Buildings.



As per the observation from the above figure it is found that the percentage decrease in lateral displacement the analysis shows that the introduction of bracing systems significantly reduces storey displacement in the structure. Among the considered configurations, inverted V –bracing 9.41% exhibits the best performance, followed closely by V- bracing 7.99% And X bracing 5.81%. The unbraced structure shows maximum displacement, indicating lower stiffness and higher susceptibility to lateral loads. in both Maximum Displacement X-Direction safe. Hence, the use of Inverted V or V bracing is recommended for improving seismic performance of irregular RCC structures.



As per the observation from the above figure it is found that the percentage decrease in lateral displacement the analysis shows that the introduction of bracing systems significantly reduces storey displacement in the structure. Among the considered configurations, Inverted V-bracing 12.19% exhibits the best performance, followed closely by V-bracing10.78% & X-bracing 8.67%. The unbraced structure shows maximum displacement, indicating lower stiffness and higher susceptibility to lateral loads. in both Maximum Displacement X-Y Direction safe. Hence, the use of Inverted V or V bracing is recommended for improving seismic performance of irregular RCC structures.



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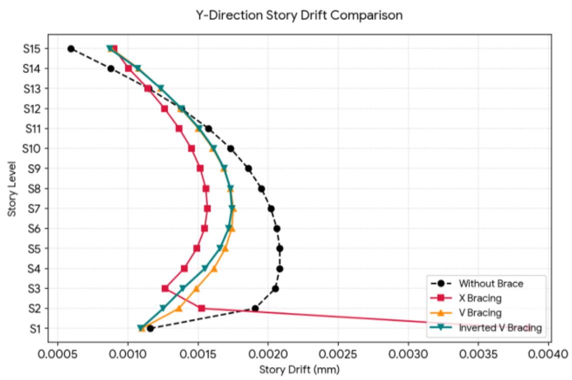
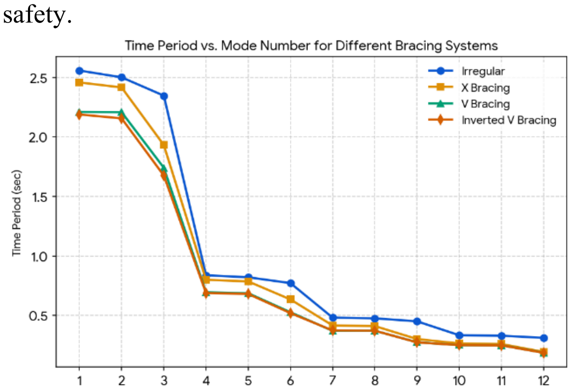


As per the observation from the above figure the storey drift analysis indicates that the incorporation of bracing systems significantly improves the structural performance by reducing inter-storey deformation. The maximum drift occurs in the mid-height of the structure. Among all configurations, IN V-bracing 46.8% shows the least drift, followed closely by V-bracing 48.8% and X-bracing 52.2%. The unbraced model exhibits the highest drift, making it more vulnerable to seismic damage. in both Maximum Drift in y direction safe. All models satisfy the permissible drift limits as per IS 1893, confirming structural safety.



The analysis shows that introducing bracing systems significantly reduces the natural time period of the irregular structure, indicating an increase in lateral stiffness. Among all configurations, Inverted V bracing (2.189sec) and V bracing (2.210sec) demonstrate superior performance, X bracing (2.458sec) while the unbraced model exhibits the highest flexibility and least seismic efficiency. Hence, bracing systems are highly effective for improving the dynamic behavior of irregular RCC buildings.

VIII. CONCLUSION

Based on the observations and the results obtained during the course of this study, the following conclusions are arrived:

- The present study evaluated the seismic performance of plan-irregular RCC buildings strengthened with various bracing systems using ETABS in accordance with IS1893.3
- The behavior of irregular buildings was assessed based on key response parameters such as storey displacement, storey drift, and time period.
- I have evaluated the seismic performance of reinforced concrete (RCC) irregular buildings with bracing system (X, V, & IN V) by using Response spectrum analysis.
- I have compared the effectiveness of different bracing System like X, V, & IN V for assumed irregular building models in terms of lateral displacement, storey drift, and time period.
- I have identified the most prominent bracing system among all this bracing system X, V, & IN V.

IX. FUTURE SCOPE

- Investigate the performance of other lateral force resisting systems, such as dampers, in mitigating the seismic response of irregular buildings.
- It can be studied by considering varying height of structure to get clear idea till which story height the effect of bracing will be significant.
- Further research can be carried by using the same system with soil interaction properties.

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