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Dynamic Analysis of High Rise Normal and Unsymmetrical Steel Building with Eccentric Bracing System

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ABSTRACT: Eccentrically braced frames (EBFs) are commonly used in steel structures as lateral load-resisting systems. These systems are designed to undergo inelastic deformations during strong seismic events, allowing them to absorb and dissipate earthquake energy. Most seismic design codes account for this energy dissipation by introducing a strength reduction factor, which reduces the calculated earthquake loads to better reflect the actual behavior of structures under seismic forces. This reduction is achieved by dividing the base shear obtained from analysis by the strength reduction factor. The factor itself is influenced by three main components: ductility, over strength, and redundancy, which depend on both the structural system and the properties of the construction materials. In this study, a parametric analysis was conducted to determine the strength reduction factor values for eccentrically braced steel frames. Key parameters such as storey height, number of bays, length of the shear link, and location of the braced bay were varied across different 2D models. Both static analysis and response spectrum analysis were used to evaluate the strength reduction factor for each configuration. The results were then compared with values recommended in various design codes to assess the influence of the considered parameters on structural performance.

KEYWORDS: Steel Building, Ductility, ETABS.

I. INTRODUCTION

Eccentrically Braced Frames (EBFs) are a type of steel structural system designed for seismic resistance, combining the strength of braced frames with the ductility of moment frames. Unlike concentrically braced frames, EBFs feature a deliberate offset (or eccentricity) between the brace and the beam-column connection, creating a short beam segment called a "link." This link is designed to yield and deform under seismic loads, dissipating energy while the rest of the frame remains elastic. Depending on its length, the link may behave in shear, bending, or a combination of both. EBFs offer excellent seismic performance, controlled damage in replaceable links, and flexibility in architectural design, making them ideal for earthquake-prone regions.

Lateral loads have an effect on the structural integrity of buildings. As a result, lateral loading must be avoided by the use of lateral load resistance devices such as shear walls and bracing. The structural components that brace the structure are either isolated or clustered. If the above requirement is not met, bracing is referred to as concentration if it is attached to the column beam junction or directly to the column beam junction in the beam's center. The G + 21 multi-story steel building model with the same design is used for this purpose, but with different bracing methods. This project compares disconnected high-rise steel frame structures and exhibits novel bracing techniques, as well as each frame inside a single structure, such as transverse V and single diagonal bracing. The connection system performs effectively in terms of lateral displacement, base shear, and overall weight.

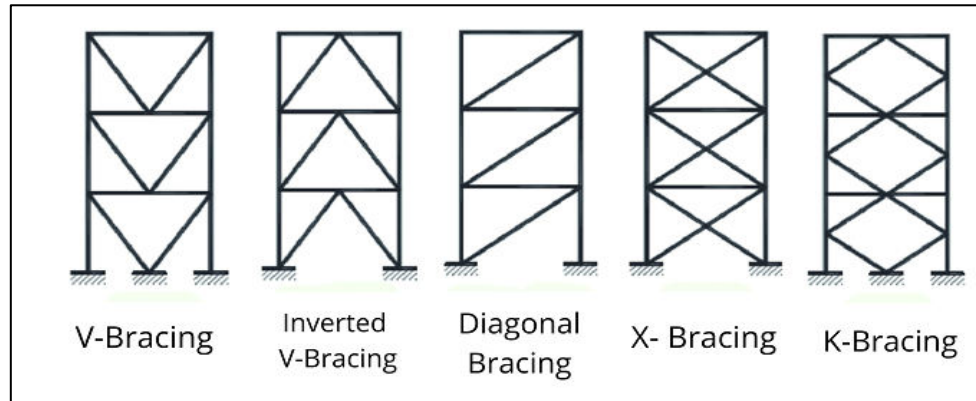


Fig 1 Bracing Details

V Bracing

The two diagonal members forming a V-shape extend downward from the first two corners of a horizontal member and meet at a focal point on the lower horizontal member (left hand diagram). Inverted V-bracing (right hand diagram, also known as chevron bracing) is a meeting of two members at a focal point on the upper horizontal member.

X bracing

Cross-bracing (or X-bracing) is when two diagonal members cross each other. They should only be resistant to stress, acting to prevent one weed side at a time depending on the loading direction. As a result, steel cables can also be used for cross-bracing.

Y bracing

The interconnect on each floor (in horizontal planes) provides a load path to transfer horizontal forces to the planes of the vertical interconnect. Horizontal bracing is required at each floor level; however, the floor system also provides adequate resistance. The roofs need to be connected to each other.

Diagonals Bracing

Trussing, or triangle, is made by inserting diagonal structural members into the rectangular areas of the structural frame, which helps to stabilize the frame. If a weed is used, it must be sufficiently resistant to tension and compression.

II. AIM AND OBJECTIVE

Aim

To analyze and compare the performance of steel buildings using different bracing systems (e.g., X-bracing, V-bracing and Diagonal-bracing) under lateral and vertical loads. The study aims to identify the most efficient bracing system in terms of structural behavior, displacement control, and overall stability while considering the economic feasibility.

Objective

- To study the role of bracing system in high rise steel structure.
- Analysis and design different parameter in high rise steel structure by using ETABS
- To study the behavior of high-rise steel structure with and without bracing system in different load condition.
- To investigate efficient bracing system in high rise steel structure by following point of view - Lateral displacement

III. LITERATURE REVIEW

The reviewed literature presents an extensive analysis of seismic performance in steel-framed structures with various bracing systems. **Muhammed Tahir Khalee (2016)** utilized ETABS to study regular and irregular frames in Seismic Zone V and concluded that cross bracing is the most effective in minimizing lateral displacement and base shear.

Thasneem Yaseen (2016) focused on X-bracing in ten-story buildings using different IS steel sections, finding it improved stiffness and reduced floor drift. **B.M. Broderick (2012)** combined experimental hybrid testing with numerical modeling to assess the seismic response of plan-irregular braced frames and identified displacement ductility demand as a key performance metric. **Gayatri Thakre (2016)** analyzed wind-induced lateral forces on different bracing types using STAAD Pro and found structural stiffness and bracing configuration significantly influence performance. **Yatendra Singh (2016)** compared K, V, and X bracings in G+9 structures using static analysis, highlighting how bracing reduces displacements and enhances frame capacity.

Sina Kazemzadeh Azad (2017) provided a detailed review of Eccentrically Braced Frames (EBFs), addressing energy dissipation, connection behavior, and design challenges at both component and system levels. **Chaitanya CVK (2017)** conducted pushover analysis to evaluate response reduction factors (R-values) across various aspect ratios and bracing locations, using ETABS. **Man Mohan Singh (2017)** compared concentric, eccentric, and moment-resisting frames across 3, 6, and 9-story buildings, demonstrating that different frame systems yield varying seismic responses. **Amol Patil (2018)** focused on optimizing eccentric bracing in high-rise (G+20) structures, confirming that innovative bracing solutions significantly improve seismic resistance.

Jorge Ruiz-García (2018) examined the effect of seismic sequences on EBFs on soft soils and found increased interstory drift post-link failure, along with non-uniform hysteretic energy distribution. **Pei Chi (2019)** explored self-centering tension-only braces (SC-TOB) in tall buildings, discovering that adjusting visibility attenuation and axial force improved structural response and energy dissipation. **Arshia Keivan (2019)** evaluated K-type and D-type self-centering EBFs, noting minimal residual drift and successful tuning of seismic performance through post-tensioning cables. **Md. Zeshan Danish (2019)** analyzed steel bracing types (D, K, V) in six-story structures using pushover methods and emphasized retrofitting as an effective strategy. **T.Y. Yang (2020)** compared traditional design with the Equivalent Energy Design Procedure (EEDP) for EBFs, finding EEDP yielded better seismic performance and cost efficiency. Lastly, **Quanxi Ye (2020)** assessed prefabricated steel frames with recentering energy-dissipative braces using ABAQUS, highlighting the impact of bolt tendon size and brace detailing in enhancing seismic resilience. Overall, these studies collectively demonstrate that appropriate bracing systems significantly enhance the seismic performance, ductility, and energy dissipation of steel structures.

IV. PROBLEM STATEMENT

Analyse a multi-storey commercial/residential building using an Eccentrically Braced Frame (EBF) structural system. The building is to be constructed in a seismic zone, requiring both strength and ductility for optimal performance under lateral loads.

Model Details

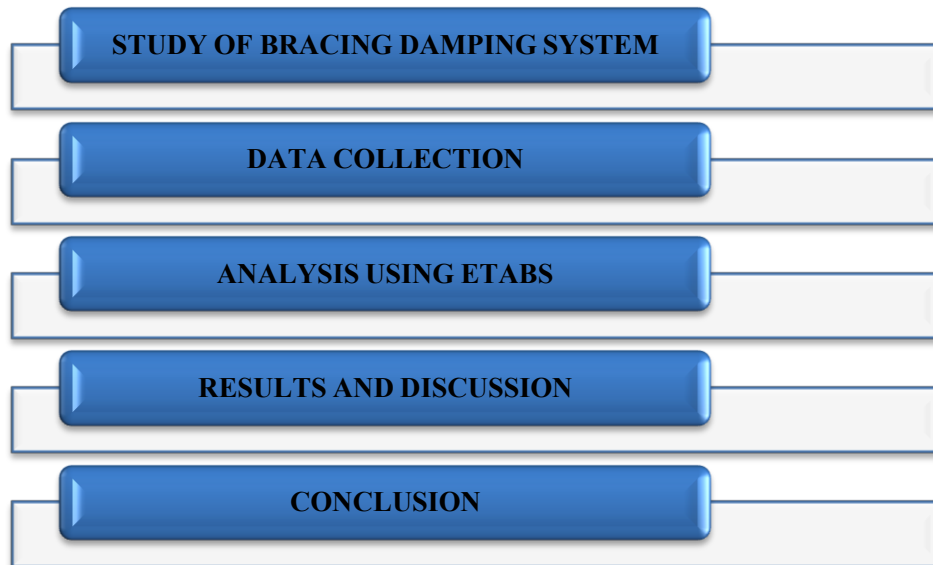
Table 1 Model Details

Number of Stories	G+21
Total Height Of building	68.7 m
Height of Each Stories	3.2 m
Dimension of building	50 m x 50 m
Size of Beam	Primary- ISMB 500, Bracing- ISLC 200
Size Of Column	ISMB 600
Slab Thickness	150 mm
Bracing Type	V bracing , Diagonal Bracing , X Bracing
Location	Pune
Seismic Zone	Zone III
Response Reduction Factor	5.0
Importance Factor	1.2
Grade Of Steel	Fe345
Density Of Concrete For Slab	M25

Supports at base	Fixed
Diaphragm	Rigid
Load Description	DL-Dead Load LL-Live load SDL- Super Dead load EQX- Earthquake in X direction EQXN- Earthquake in X Negative direction EQY- Earthquake in Y direction EQYN- Earthquake in Y Negative direction WDX- Wind Load In X direction WDY- wind load in Y direction
Earthquake Analysis	Response Spectrum Analysis

IV. METHODOLOGY

To analyze and compare the performance of steel buildings using different bracing systems (e.g., X-bracing, V-bracing and Diagonal-bracing) under lateral and vertical loads. The study aims to identify the most efficient bracing system in terms of structural behavior, displacement control, and overall stability while considering the economic feasibility.



The methodology for the study of the bracing damping system focuses on evaluating the seismic performance of steel structures using three bracing types: X-bracing, V-bracing, and Diagonal-bracing. The process begins with data collection for a typical G+9 steel-framed building, incorporating design parameters based on IS 800:2007 and IS 1893:2002, including material properties, loading conditions, and seismic zone data. The structure is modeled in ETABS, and three separate configurations are created—each with one of the selected bracing systems. Seismic analysis is performed using both the Equivalent Static Method and the Response Spectrum Method to assess how each bracing type affects structural behavior under lateral loads.

Models in ETABS

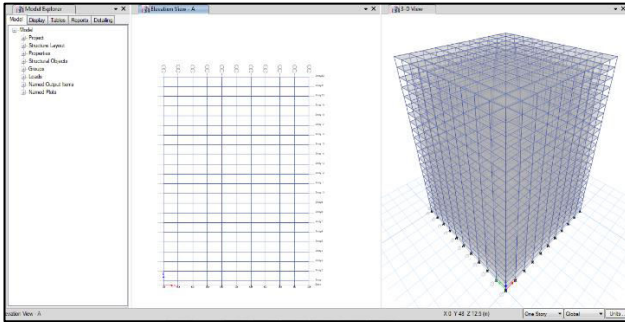


Fig 2 Normal Building Model

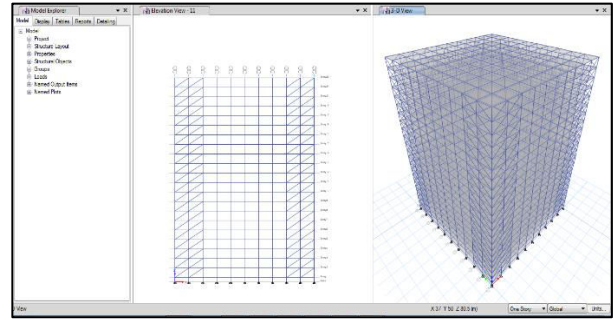


Fig 3 Diagonal Bracing Model

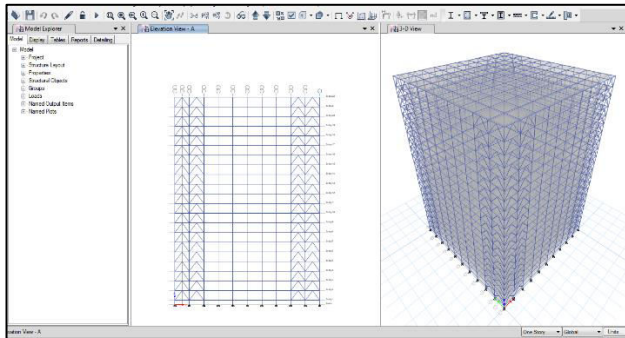


Fig 4 V Bracing Model

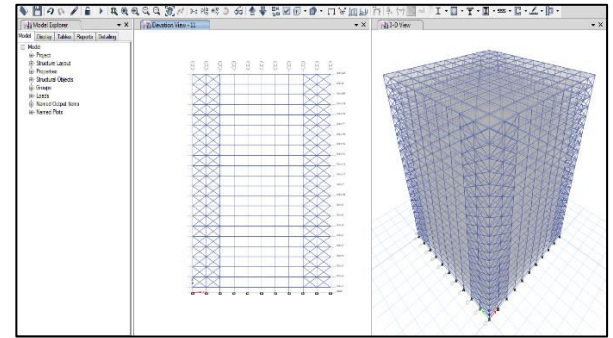
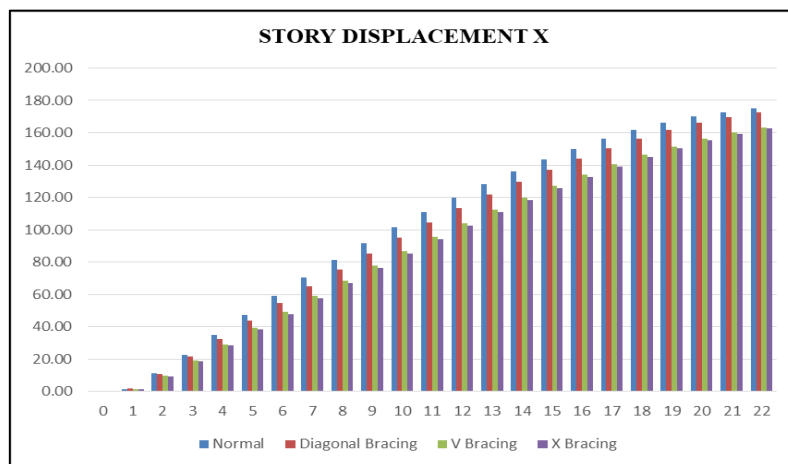


Fig 5 X Bracing Model

V. RESULTS AND ANALYSIS

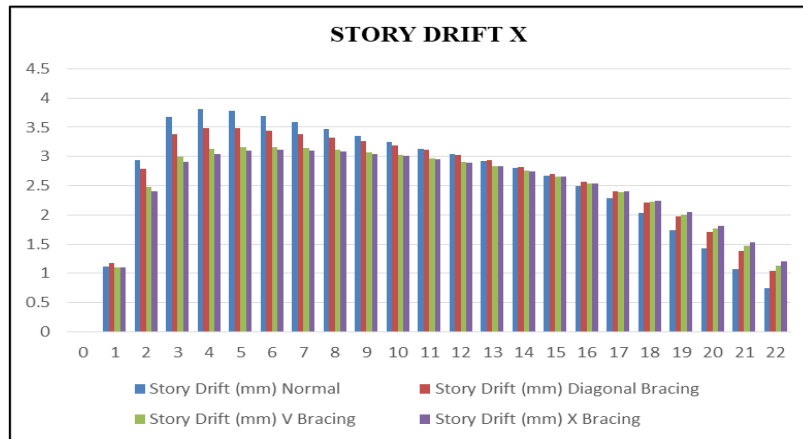
Story Displacement X



Graph 1 Story Displacement X

The above graph shows results for story displacement for normal structure. For story displacement, normal bracing to x bracing show story show 0- 200 and bracing result show from 0-22 in that final x bracing is 170.

Story Drift X



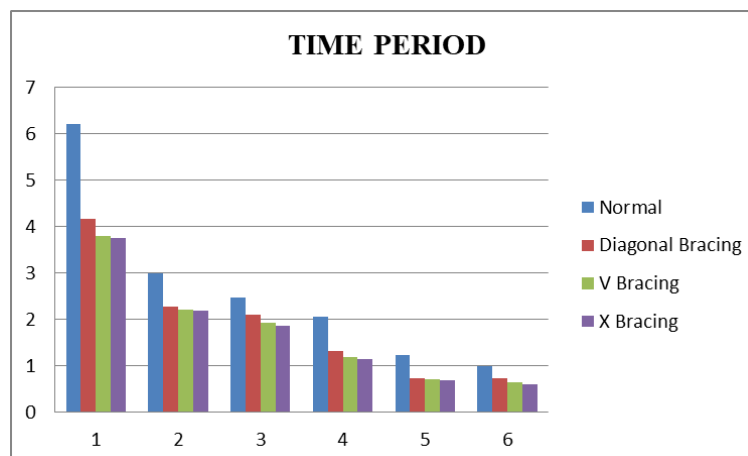
Graph 2 Story Drift (X)

The above graph shows results for story drift for normal structure. For story displacement, normal bracing to x bracing show story show 0- 4.5 and bracing result show from 0-22 in that final story drift normal bracing is 3.7.

Time Period

Table 1 Time Period

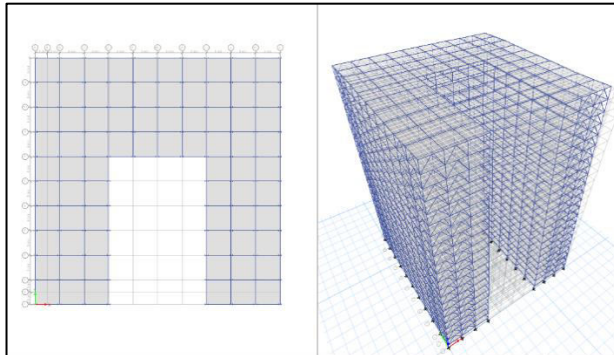
Mode No	Time Period Sec			
	Normal	Diagonal Bracing	V Bracing	X Bracing
1	6.204	4.159	3.804	3.742
2	2.99	2.278	2.211	2.195
3	2.465	2.104	1.919	1.87
4	2.067	1.321	1.189	1.136
5	1.235	0.737	0.711	0.698
6	0.985	0.729	0.641	0.6



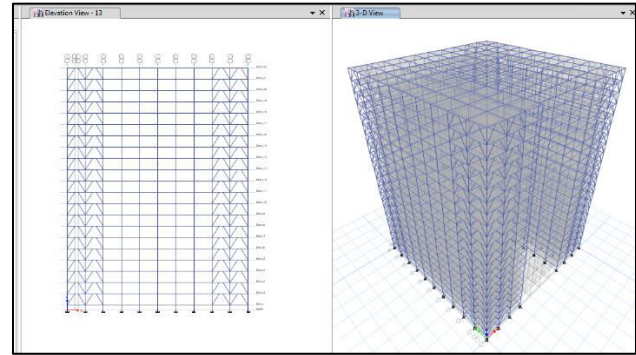
Graph 3 Time Period

The above graph shows results for Time Period for normal structure. For Time Period, normal bracing to x bracing show story show 0- 7 and bracing result show from 1-6 in that final Time Period Normal bracing is 6.2.

Eccentric Bracing Model- C Shape



Normal Building Model



Eccentric Bracing Model

Table 2 Time Period

Time Period		
Mode No	V Bracing	Eccentric Bracing
1	3.451	3.717
2	2.223	2.3
3	1.918	2.107
4	1.073	1.196
5	0.967	0.733
6	0.6	0.681

The time period data for the building with V bracing and Eccentric Bracing (EBF) systems shows that EBF generally results in slightly higher time periods across most vibration modes, indicating a more flexible structure due to the presence of deformable links designed to dissipate seismic energy. For example, in Mode 1, the time period increases from 3.451 seconds in V bracing to 3.717 seconds in EBF, reflecting reduced stiffness and enhanced ductility. This trend continues through Modes 2 to 4, while slight variations in later modes (e.g., Mode 5) may be due to localized stiffness or mode shape differences. Overall, the data confirms that EBF systems provide better energy dissipation and controlled flexibility compared to the stiffer V bracing system, making them advantageous in seismic design.

VI. CONCLUSION

We created a G+21 steel structural structure using ETABS Software and then investigated it for response spectrum analysis utilizing a variety of bracing methods, including X, V, and diagonal bracing. According to the research, X bracing produces high-quality results, while V bracing produces results that are almost equal to X bracing; thus, V bracing is recommended for eccentric bracing systems. We evaluate unsymmetrical models of V bracing and Eccentric bracing with a 1 m eccentricity in order to obtain more accurate results, and based on our findings, we conclude that increasing the eccentricity of the structure results in the structure acting uneconomically. The following points serve to bolster the aforementioned findings:

- Overall, all X, V, and diagonal bracing giving better results in terms of Story Displacement and Story Drift against seismic load in X and Y direction
- Base shear after comparison with soil structure interaction along X and Y direction it was observed that decreases between 15%-20% for normal, diagonal and V bracing as compared to X bracing

- After comparison for story drift along X and Y direction it was observed that Story drift Decreases between 15%-40% for different story in X bracing as compared to normal, diagonal and V bracing.
- To restrict the excessive deformation in any seismic zone, by using X bracing we get better performance than V and Eccentric bracing.
- Seismic weights in case of X bracing are found to be more than V and diagonal bracing so the natural frequency of the structure will be more in case of X bracing. This has been proved by lower time period in case of X bracing system.
- Overall X bracings perform better than V and Eccentric bracing and helps us to trace actual behavior of frame system.

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