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# Assessment of Steel-Braced Frame Structures' Stability

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**ABSTRACT:** In this paper, an attempt is made to evaluate the seismic performance of 15-storey steel-braced frame structures having different configurations of bracing, which includes X-bracing, zipper bracing, V-bracing, Chevron bracing, and eccentric bracing. The various structures, for lateral displacement, storey drift, and storey shear under critical parameters, have been analysed along with a natural time period in seismic zones 2 and 5 in India using ETABS 2016 software. The results show that including bracing largely enhances structural stability. Zipper and X-bracing show the most efficient reduction in lateral displacement and drift. The outcome will indicate that Zipper bracing resists seismic loads more effectively than others; thus, it will be the best option to enhance earthquake resilience in tall structures.

**KEYWORDS:** Steel Braced Frame, Seismic Performance, X-Bracing, Zipper Bracing, V-Bracing, Chevron Bracing, Eccentric Bracing, Lateral Displacement, Storey Drift, Storey Shear, Seismic Zones, ETABS 2016, Structural Stability.

## I. INTRODUCTION

In the current project, we consider braced frame structures applied for enhancing the lateral stiffness of buildings, aimed at reducing the sway index. This means the relation of maximum deflections at the top to the total height of the building. This is very critical to ensure stability and safety during seismic events where lateral/tensional deflections might lead to appreciable occupant discomfort or even serious distress. Bracing systems introduce diagonal members into the frame, thus rigidifying it into a vertical cantilever truss that can efficiently resist horizontal forces. Diagonal bracings work essentially under axial tension or compression; hence, the frame structure would be efficient in resisting seismic loads with a minimum increase in the size of members. Our study is on the comparison of different bracing configurations and their effect on reducing the sway index, a critical factor in design in tall structures, which aims for better earthquake resilience. By improving the frame's stiffness, we enhance its ability to prevent total collapse of the building and hence to save lives and reduce damage due to earthquakes. Performance-based methods place as much emphasis on life safety and prevention of collapse as they provide help in producing new design norms for uniform reliability among many classes of structural systems and seismic conditions.

ETABS 2016 is a Specialized Software Program for Analysing and Designing Building Structures, Offering Capabilities for Nonlinear Static and Dynamic Analysis. It Allows Structural Engineers to Create Complex Analytical Models Efficiently. The Software Integrates modelling, Analysis, Design, And Optimization Within a Single Microsoft Windows Interface. ETABS Provides Graphical Presentations of Results and Offers Easy Access to Printed Outputs or Saved Reports for Selected or All Elements.

In current U.S. practice, most of the concentrically braced frames are designed based on elastic analyses that essentially treat various configurations like V Bracing, Eccentric Back bracing, chevron, cross-braced, or zipper frames similarly. The post elastic behaviour of such frames depends, however, on brace configuration, impacting deformation modes and brace fracture life. Building codes view these configurations as a single system but recognize peculiar issues with chevron bracing and include provisions to bring its post-elastic performance in line with the others. Braces are typically designed for compression resulting from reversible lateral loading. V bracing is favoured for its shorter braces. The fully triangulated bracing types have the distinct advantage of girders not being subjected to any lateral loads, which facilitates the repetitive and economical design of floor framing.

## II. RELATED WORK

S. Naeimi et al. (2012) have mentioned that the buckling of compressive braces in the inverted-chevron braced frames causes unbalanced vertical pressure at the brace-beam intersection, which eventually generates mid-span beam displacement and loss of lateral resistance. This problem can be compensated for using zipper struts, as they redistribute the forces. Ali Paseban et al. (2013) have compared Chevron with Zipper braced frames. It was noticed that Zipper Frames have enhanced seismic performance, as they cause the unbalanced force to be transmitted at the upper floors. M. Pourbabaa et al. (2013) investigated Zipper Braced Frames. They illustrated that with the additional vertical elements in ZBF, it performs better than conventional Chevron frames. Nasim Irani Sarand et al. (2013) gave confirmation that zipper struts enhance the seismic performance by inhibiting failure localized. R. Rahimi et al. (2013) used numerical simulation to show that zipper and Suspended zipper braced frames improve the lateral capacity. J. Vaseghi Amiri et al. (2015) presented a seismic design procedure to distribute the structural damages uniformly for ZBFs. Acxa Kuriakose et al. (2017) has shown that Zipper Braces avoid early failure of braced frames linear and nonlinear performance is better than other models.

**OBJECTIVES:** By comparing results from two seismic zones in India, the study seeks to determine the most stable and effective steel buildings with various bracing systems for withstanding lateral loads and seismic action. It also evaluates these structures' effectiveness in terms of tale shear, displacement, drift, and time period.

## III. METHODODLGY

Different bracing arrangements, including X-Bracings, V-Bracings, Chevron Bracings, Zipper Bracings, and Eccentric Backward Bracings, were modelled in ETABS 2016 for the seismic analysis of a 15-storey steel structure. In the latter, the analysis shall consider the seismic zones of India: Zone 2 and Zone 5, against storey displacement, storey drift, storey shear, and natural time period, all under lateral loads. The base model was a normal steel moment-resisting frame with no bracing provided in it. All the combinations of loads as per IS 1893:2002 were applied, and equivalent static method was followed to calculate the natural period of the building. Performance of each type of bracing was compared to determine the most feasible and effective system regarding its addition for improving seismic resiliency, with results tabulated for analysis.

### Details of the Structure

In this research, a 15-story steel structure of 45 meters height is considered with different configurations of bracing at various seismic zones in India. A regular steel moment-resisting frame has been taken as the base model. The storey height was kept constant, which is drawn as 3 meters. The behaviour of lateral loads follows as per IS 1893:2002. The analysis is carried out in ETABS 2016 with parameters like lateral displacements, story drift, and story shear taken into consideration for linear evaluations, while nonlinear evaluations consider plastic hinge formation, performance points, and capacities. This is based on the Equivalent Static Method, wherein the natural period of building is calculated as  $T=0.075h^{0.75}$ . Seismic weights include full dead load and 25% of live load; earthquake loads are applied in both X and Y directions. Results are tabulated to make comparisons between the different types of bracing and seismic zones, which result in conclusions regarding the most effective and stable structures.

Building Data	
Type of Structure	Steel Moment Resisting, Chevron, Zipper, X, V, Eccentric bracing.
Number of Stories	5, 10 and 15 stories
Height of each floor	3 m
Height of building	15, 30 and 45 m
Building type	Office Building

Material Properties	
Grade of concrete for deck fck	M25
Grade of steel	fe -345

Material Property Design Data Section Properties	
Column Sections	ISHB 450
Beam Sections	ISMB 250
Deck slab	100 mm thick.
Bracings	ISHB 150.

**GRAVITY AND LATERAL LOADS: IS 1893: 2002**

- A. LIVE LOAD - 3KN/M2
- B. FLOORS FINISH - 1.5 KN/M2
- C. WALL LOAD - 12.65 KN/M.
- D. PARAPET WAL - 2 KN/M.

LOCATION OF BUILDING-MODERATE INTENSITY (Z-II) AND (Z-V)

SOIL TYPE - TYPE II

IMPORTANCE FACTORS - 1.0

RESPONSE REDUCTION FACTORS -5

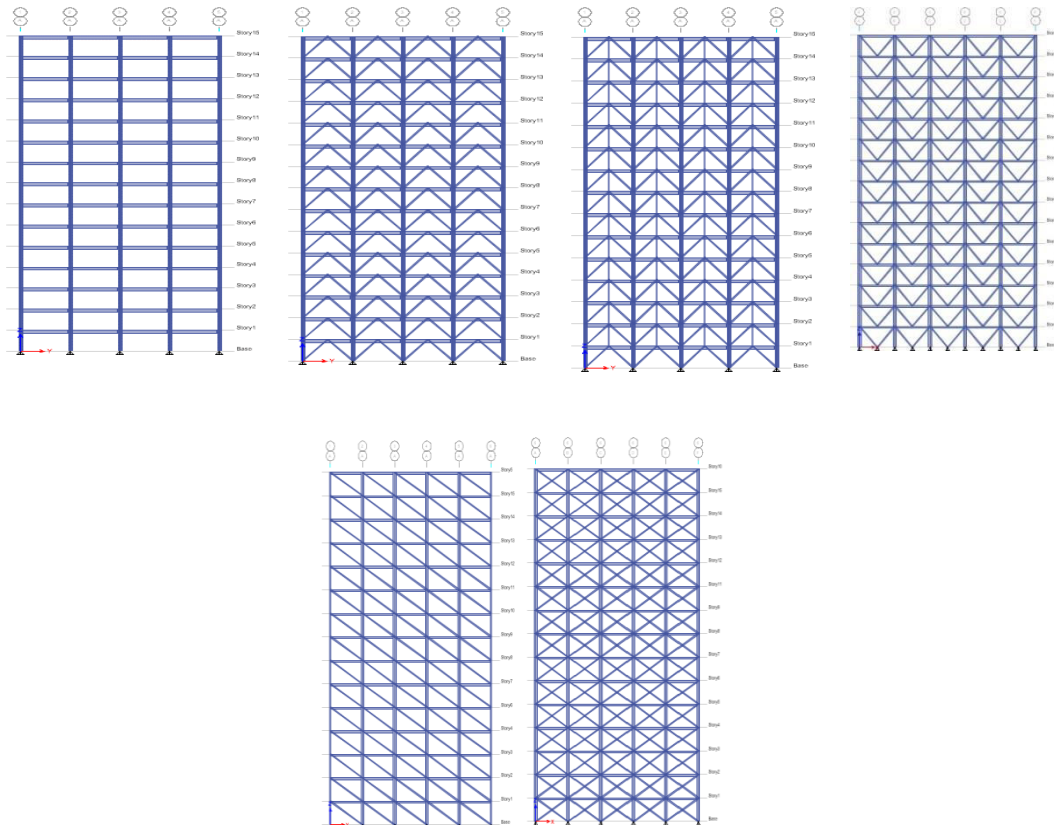
Load Combinations

Type	Design Load Combinations
Gravity analysis	1.5 (Dead Load + Live Load)
	1.2 (Dead Load + Live Load + EQX)
	1.2 (Dead Load + Live Load - EQX)
	1.2 (Dead Load + Live Load + EQY)
	1.2 (Dead Load + Live Load - EQY)
	1.5 (Dead Load + EQX)
Equivalent Static Analysis	1.5 (Dead Load - EQX)
	1.5 (Dead Load + EQY)
	1.5 (Dead Load - EQY)
	0.9 (Dead Load + EQX)
	0.9 (Dead Load - EQX)
	0.9 (Dead Load + EQY)
	0.9 (Dead Load - EQY)
Wind Analysis	1.2 (Dead Load + Live Load + WINDX)
	1.2 (Dead Load + Live Load - WINDX)
	1.2 (Dead Load + Live Load + WINDY)
	1.2 (Dead Load + Live Load - WINDY)
	1.5 (Dead Load + WINDX)
	1.5 (Dead Load - WINDX)

	1.5 (Dead Load - WINDY)
	0.9 (Dead Load + WINDX)
	0.9 (Dead Load + WINDY)
	0.9(Dead Load - WINDY)

**MODELLING**

1. FRAMED STEEL STRUCTURE WITHOUT BRACINGS.
2. STEEL STRUCTURE WITH ZIPPER BRACED FRAMES.
3. STEEL STRUCTURE WITH INVERT V BRACINGS.
4. STEEL STRUCTURE WITH CHEVRON BRACINGS.
5. STEEL STRUCTURE WITH ECCEN BACKWARD BRACINGS.
6. STEEL STRUCTURE WITH X- BRACINGS.



**Fig 1:** Bare Frame, Inverted V Frame, Zipper Braced Frame, V-Braced Frame, Eccentric Braced Frame and X-Braced Frame Structure.

IV. EXPERIMENTAL RESULTS

In the present study, the seismic performance of various models has been compared with respect to different parameters like storey displacement, drift, shear, natural time period, and overturning moment to find out the best model based on the comparative results. The results show the model with optimum configuration which resists seismic loads optimally.

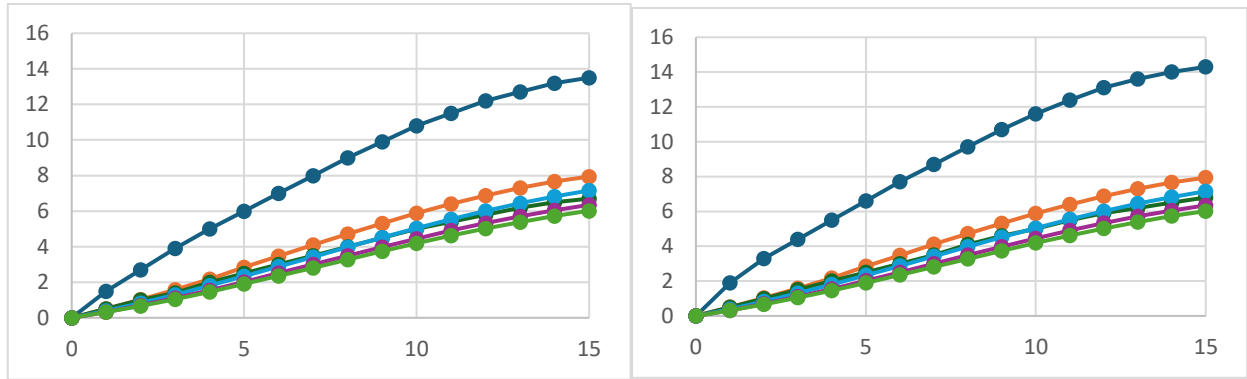


Fig 2: Displacement Plot for 15 storey structure in X and Y direction (zone-II)

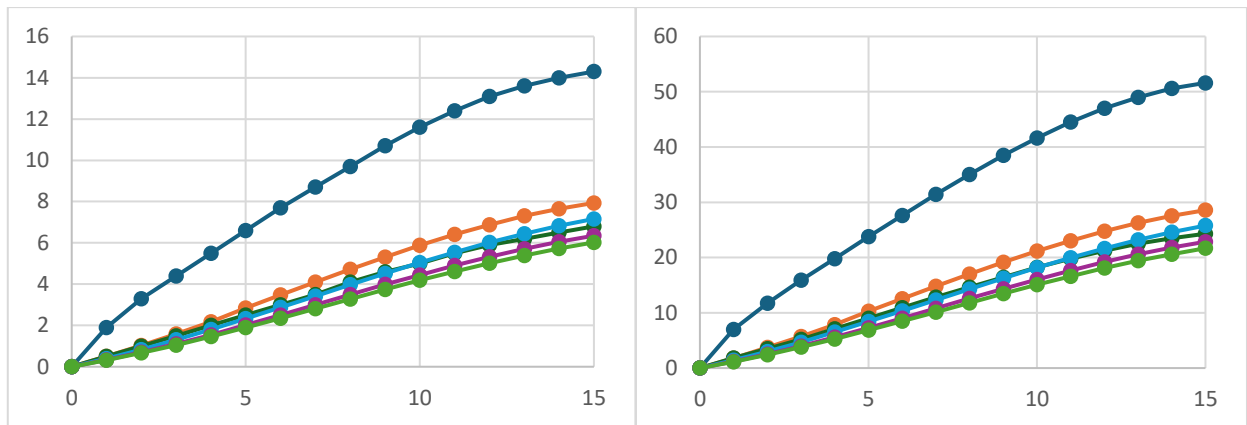


Fig 3: Displacement Plot for 15 storey structure in X and Y direction (zone-V)

In the displacement analysis carried out for a 15-storey building in both zones 2 and 5, this maximum displacement occurred in the Y-direction of the bare frame in zone 5 with a value of 51.6 mm at the top storey, which is storey 15. The configuration for X-Bracings shows the minimum displacement in both zones. It has the lowest value of 0.32 mm at the base (storey 1) in zone 2. Comparing the two zones, obviously, displacements in zone 5 were considerably higher due to the higher seismic zone factor, thus pointing out that bracing systems, especially X-Bracings and Zipper Bracings, play a vital role in reducing displacement.

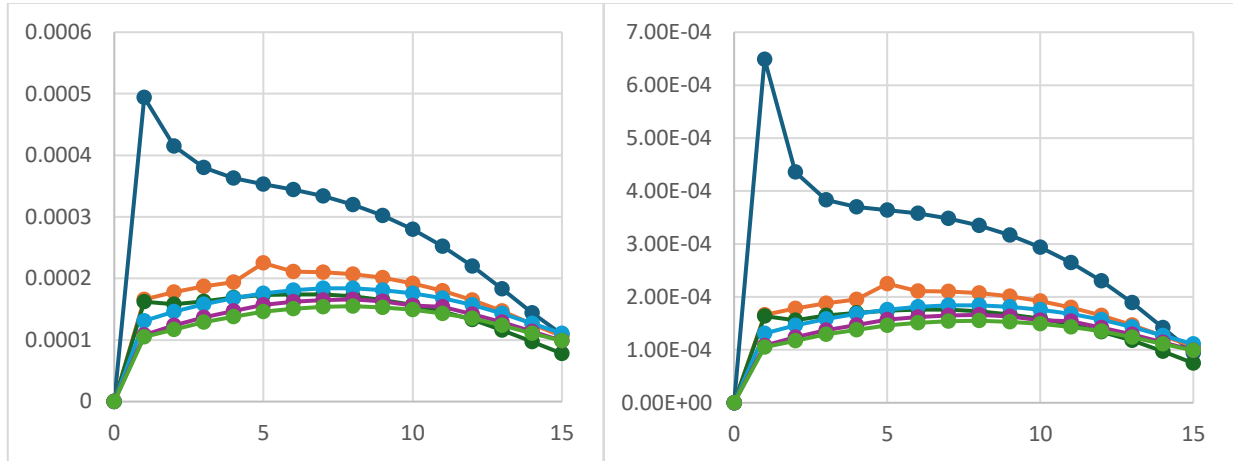


Fig 4: StoreyDrift Plot for 15 storey structure in X and Y direction (zone-II)

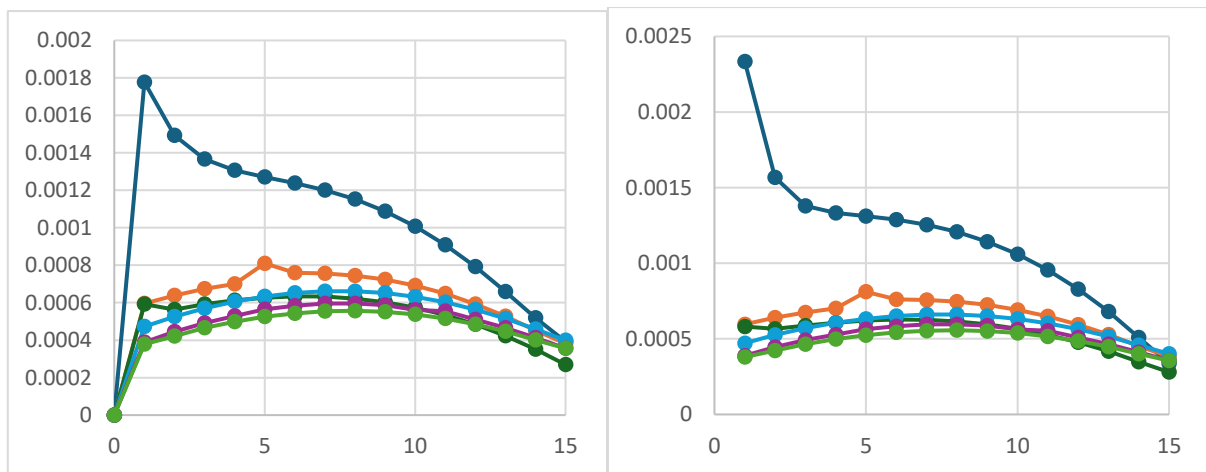


Fig 5: StoreyDrift Plot for 15 storey structure in X and Y direction (zone-V)

In the drift analysis for a 15-storey structure, it is observed that for the bare frame in zone 5, the maximum drift is in the Y direction, with a value of 0.002335 at the base, storey 1. Then, the minimum drift happens in zone 2 with the Zipper bracing in the X-direction, which shows a value of 7.50E-05 at the top storey, storey 15. In comparison with the zones, zone 5 obtains considerably higher drift values for all the configurations; this is due to its high seismic zone factor. For both the zipper bracings across different zones, this gives the lowest drift values; hence, it is proven to be most effective in minimizing structural drift under seismic loads.

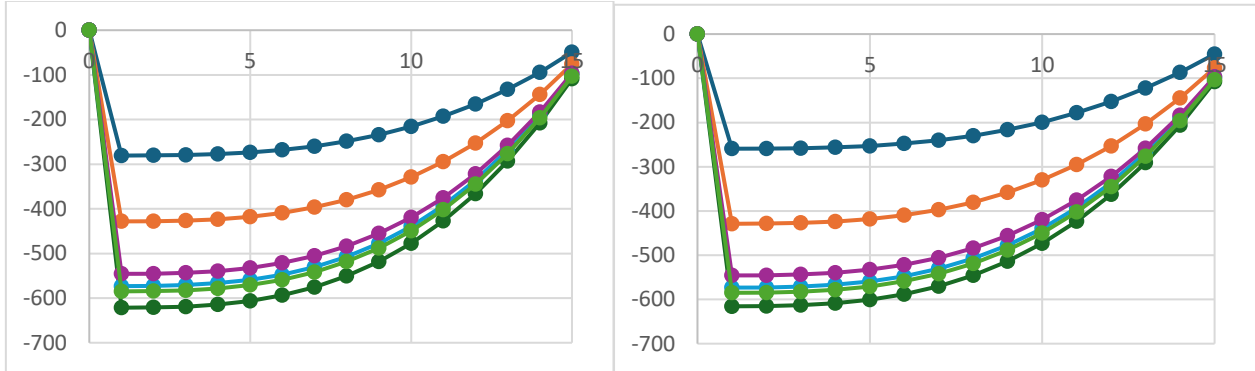


Fig 6: Storey Shear Plot for 15 storey structure in X and Y direction (zone-V)

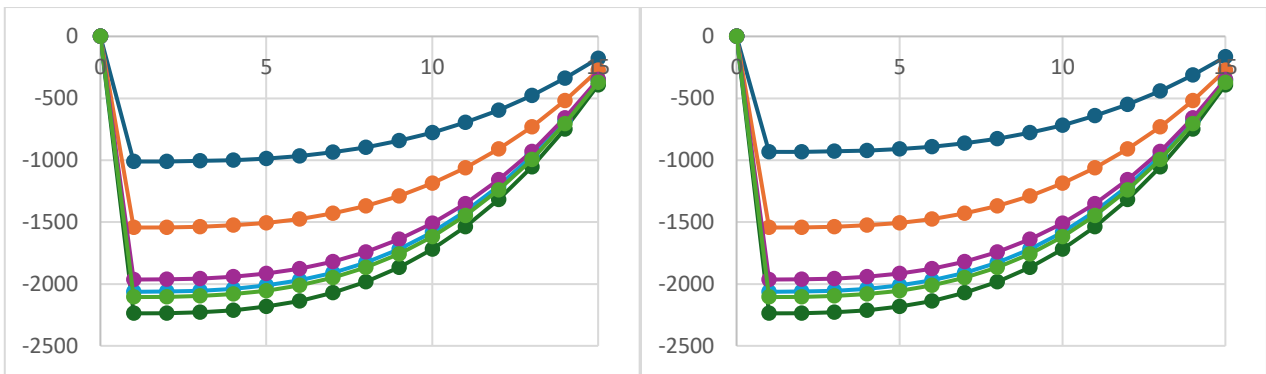


Fig7: Storey Shear Plot for 15 storey structure in X and Y direction (zone-V)

Maximum equivalent shear force is observed in storey 1, or at the base in zone 5, with the Zipper bracings configuration, amounting to -2237.5788 kN in the Y direction, in the storey shear analysis of a 15-storey building. The minimum shear force is observed in zone 2. The Bare frame configuration showed a value of -45.6928 kN at the top storey, storey 15, in the Y direction. Comparison of both zones shows that zone 5 has very high shear force for all different configurations due to its high seismic intensity; however, it is the Zipper bracings that reveal the highest shearing resistance throughout its configurations, making it the most rugged configuration for seismic loads.

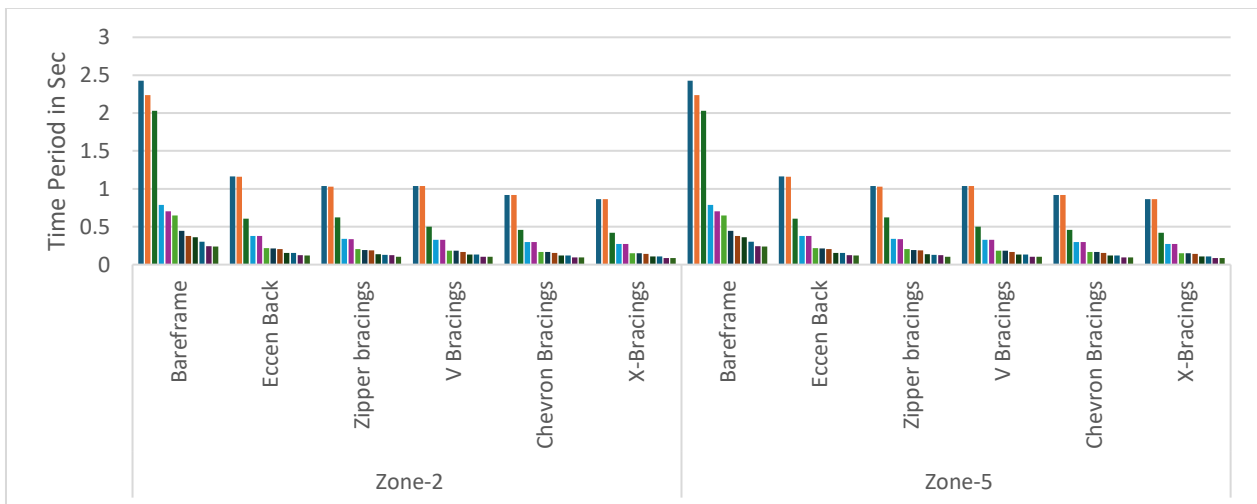


Fig8: Time period Plot for 15 storey structure. (zone-II and V)



In the time period analysis of a 15-storey structure in Zone-2, a maximum time period of 2.426 seconds is recorded under the Bareframe configuration; it has shown that the structure is most flexible and vulnerable to seismic loads. The minimum time period was seen in X-Bracings where the drop in time period was drastically 0.088 seconds; therefore, it is an indication of maximum stiffness and least vulnerability to seismic loads. Zipper Bracing and V Bracing decrease time periods compared to the Bare frame thus, they have effectiveness in improving the seismic performance of a structure.

## V. CONCLUSION

In this paper, comparisons have been made of the structural behaviour of 15-storey buildings under lateral earthquake loads, considering the effectiveness of adding bracings to bare frame structures. Parameters such as lateral storey displacement, storey drift, storey shear, natural time period, and overturning moment have been compared. The addition of X-bracings and zipper bracings to the bare frame structure reduces lateral displacement effectively; among them, zipper bracings give the maximum reduction. With bracings, storey drift is reduced, especially in the centre of the structure, and storey shear decreases with height and is maximum at the base. Time period is maximum in bare frames and increases in taller structures but is reduced with bracings. Zonal comparison the effects are maximum in zone 5 because of the higher seismic zone factor. Overall, zipper bracing performs better in resisting lateral loads on all parameters studied.

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