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SEISMIC PERFORMANCE OF CONCENTRIC BRACED STEEL FRAMES FROM PUSHOVER ANALYSIS

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ABSTRACT**:** *The present study focuses on the effect of a provision of concentric bracings on the seismic performance of the steel frames. In the present study two different types of concentric bracings (viz. X and inverted-V type bracing) have been considered for the different storey levels. For this purpose, ETABS, Finite Element software has been used and the comparison between the performances of 1- bay X and inverted–V type and unbraced frames is made using pushover curves. Base shear carried, roof displacement generated and the number of hinges formed are the parameters used to identify the seismic performance of the frames. It is inferred that the effect of a provision of bracing will increase the strength of the steel frames and roof displacement undergone by the frame gets reduced considerably in braced frame.*

Keywords: *Concentric bracings, Inverted-V braces, Pushover analysis, Steel Frame, X braces.*

1. INTRODUCTION

Bracing is an effective upgrading strategy to enhance the global stiffness and strength of steel frames. It can increase the energy absorption of structures or decrease the demand imposed by earthquake loads. With the inclusion of bracings, structures with augmented energy dissipation may safely resist forces and deformations caused by strong ground motions. Generally, global modifications to the structural system are conceived such that the design demands, often denoted by target displacement, on the existing structural components, are less than their capacities.

Lower demands may reduce the risk of brittle failures in the structure and avoid the interruption of its functionality. The present work assesses the seismic performance of steel frames with X and inverted-V type bracing and that of the structure without bracing. The inelastic seismic response has been quantified in terms of global deformation parameters derived by means of nonlinear static pushover analysis.

The concentric bracings increase the lateral stiffness of the frame and usually decrease the lateral drift. However, the increase in the stiffness may attract a larger inertia force due to earthquake. Further, while the bracings decrease the bending moments and shear forces in columns, they increase the axial compression in the columns to which they are connected [1]. Tafheem et. al., made a study on a six storied steel building and analyzed the structure for lateral earthquake and wind loading, dead and live load. The performance was investigated for different types of bracing system such as concentric (crossed X) bracing and eccentric (V-type) bracing using HSS sections. It was found that the concentric (X) bracing reduces more lateral displacement and thus significantly contributes to greater structural stiffness to the structure [1]. Luigi et. al., studied on the seismic performance of steel moment resisting frames (MRFs) retrofitted with different bracing systems such as special concentrically braces (SCBFs), buckling-restrained braces (BRBFs) and mega-braces (MBFs). It was shown that MBFs are the most cost-effective bracing systems. Maximum storey drifts of MBFs are 70% lower than MRFs and about 50% lower than SCBFs. The amount of steel for structural elements and their connections in configurations with mega-braces are 20% lower than in SCBFs [2]. Madhusudan et. al., has highlighted the effect of a provision of bracings in structural frames to strengthen the frame against lateral dynamic forces. It was inferred that the effect of a provision of bracing is to strengthen the frames against lateral dynamic load and the effects are more pronounced in taller structures [3]. Poluraju et al., using nonlinear pushover analysis evaluated the performance of G+3 building using SAP-2000.The results obtained from the study show that properly detailed and designed frame will perform well under seismic loads [4]. Krawinkler H et. Al., suggested that carefully performed pushover analysis will provide insight into structural aspects that control performance during severe earthquakes. For structures that vibrate primarily in the fundamental mode, the pushover analysis will very likely provide better estimates of global, as well as local inelastic, deformation demands. This analysis will also expose design weaknesses that may remain hidden in an elastic analysis [5].

2. PUSH OVER ANALYSIS

In earthquake resistant design, structures are generally designed for a lower level of seismic forces and allowed to undergo nonlinear response due to severe ground motion. It is therefore important to understand the performance of these structures during failure and their ductility characteristics. Rigorous dynamic analysis is very difficult and sometimes not feasible. Hence, a nonlinear static pushover analysis has become popular in recent years to determine parameters such as initial stiffness, yield load, yield displacement, maximum base shear and maximum displacement. In the pushover analysis, the nonlinear load-deformation characteristics of individual components are modeled. A computer model of the structure incorporating inelastic material response is displaced to a target displacement or for a target force in monotonically increasing order and resulting internal deformations and forces in structural members is determined. Pushover analysis may be classified as displacement controlled pushover analysis when lateral displacement is imposed on the structure and its equilibrium determines the forces. Similarly, when lateral forces are imposed, the analysis is termed as force-controlled pushover analysis. The target displacement or target force is intended to represent the maximum displacement or the maximum force likely to be experienced by the structure during the design earthquake. Response of structures beyond maximum strength can be determined only by displacement-controlled pushover analysis. Hence, in the present study, displacement-controlled pushover method is used for analysis of structural steel frames with and without bracings. A structural analysis software package ETABS 9.7.2 version has been used for the purpose. A typical pushover curve is shown in Fig. 1. Base shear versus roof displacement is plotted for gradually increasing lateral loads till failure. Beyond elastic limit, different states such as Immediate Occupancy, Life Safety Collapse prevention and collapse are defined as per ATC 40 [6] and FEMA 356 [7].

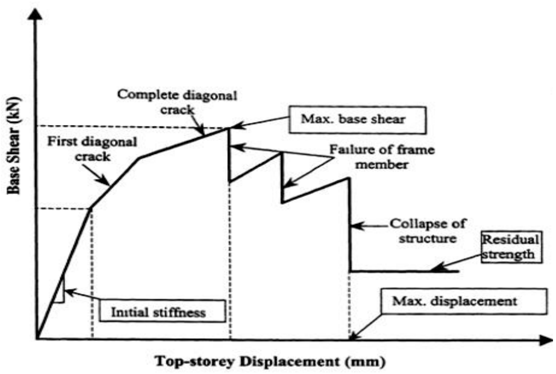
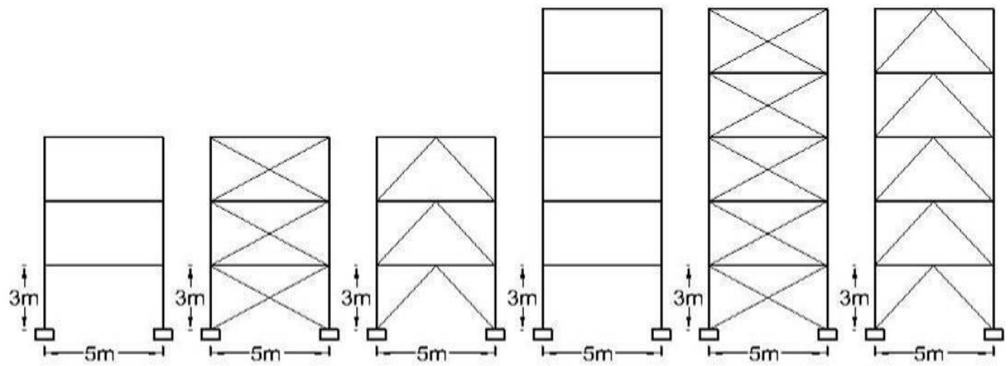


Fig. 1: Idealized pushover curve with salient features

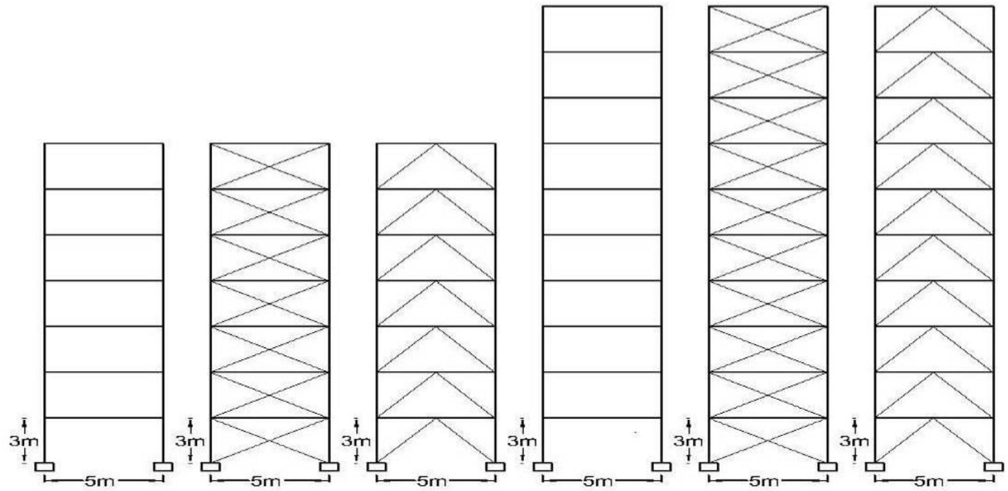
3. PROBLEM STATEMENT

In the present paper, a 1- bay 2D steel structural frame with different concentric bracings (viz. X and inverted-V type bracing) and structures without bracing has been modeled and analyzed using ETABS. Different structural configuration is shown in the Fig. 2. The results obtained from the pushover analysis are plotted in the graph, and performance of the structure is tabulated for zone III.

Beam size: ISMB500
Column size: ISHB400
Bracing size: ISLB200



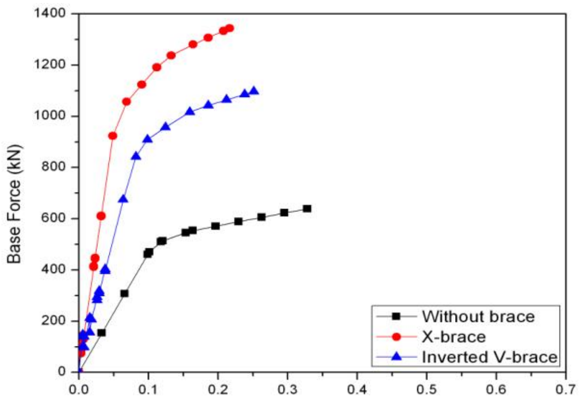
(i) 3 storey (ii) 5 storey

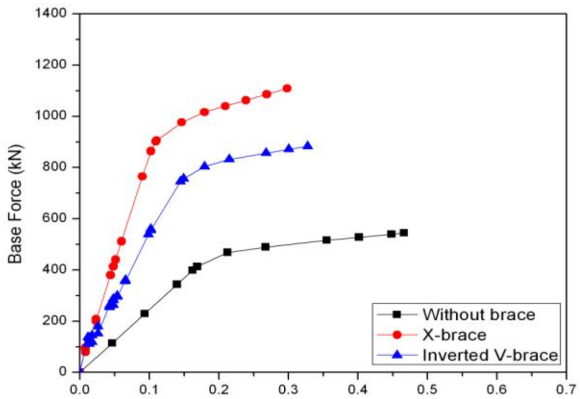


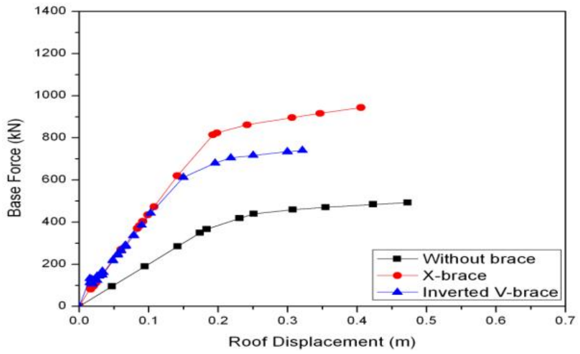
(iii) 7 storey (iv) 10 storey

Fig. 2: Typical steel frame used in the present study

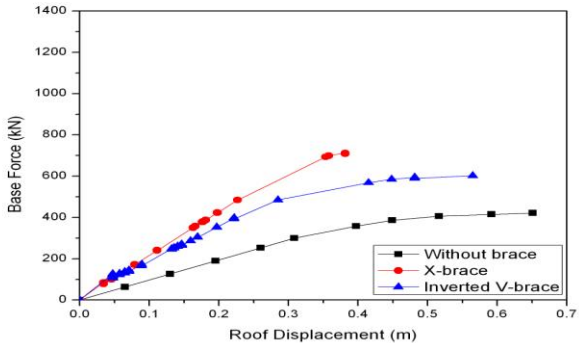
4. RESULTS AND DISCUSSION







(iii) 7 storey



(iv) 10 storey

Fig. 3: Pushover curves for 1-bay steel frames with X and inverted-V type bracing and without bracing

Fig. 3 shows the pushover curves for two dimensional 1- bay frames with X and inverted-V type bracing and structures without bracing. It can be observed that the effect of bracing increase the base shear carrying capacity and roof displacement. Also, the base shear carrying capacity of the X bracing is more than that of the inverted-V bracing. Table 1 presents the percentage increase in base shear carrying capacity in X and inverted-V type braced steel frame

Table 1: Percentage increase in base shear carrying capacity in X and inverted-V type braced steel frame

	Without brace	X brace		Inverted-V brace	
	Base Shear carried	Base Shear carried	Percentage increase	Base Shear carried	Percentage increase
3 storey	638.40	1344.13	110.55	1097.17	71.86
5 storey	544.25	1108.47	103.67	883.45	62.32
7 storey	492.38	943.71	91.66	740.30	50.35
10 storey	421.58	889.67	111.03	602.26	42.86

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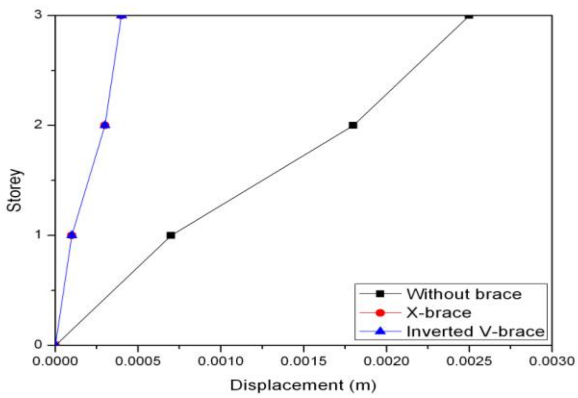
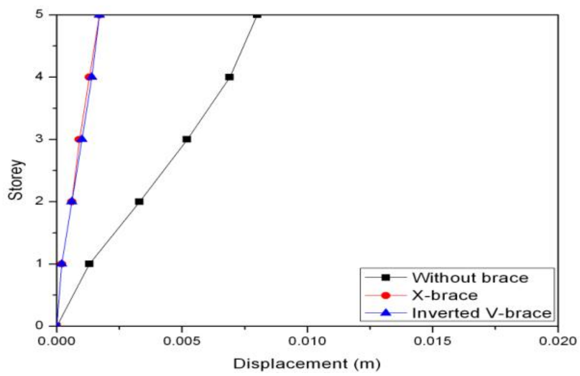
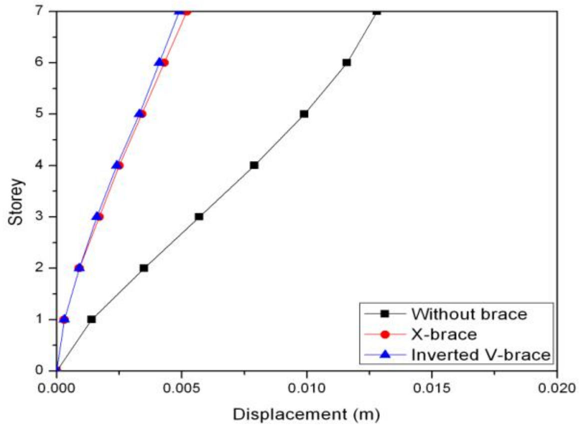


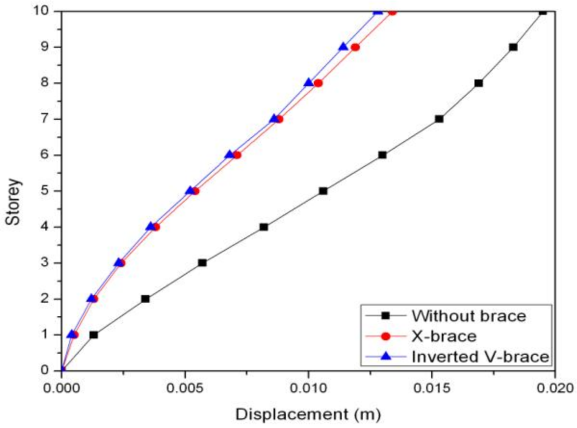
(i) 3 storey



(ii) 5 storey



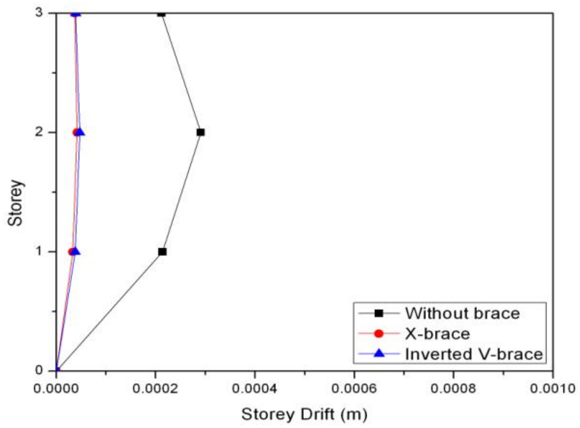
(iii) 7 storey



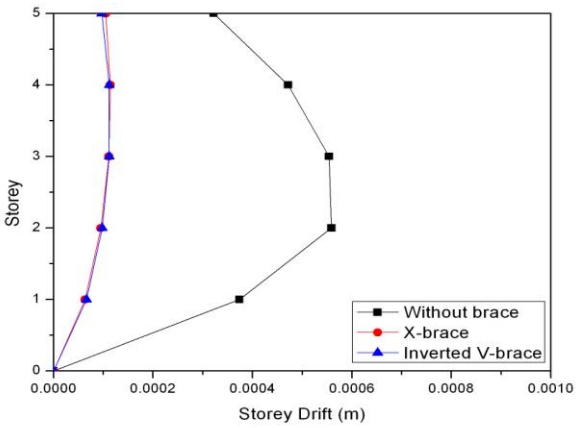
(iv) 10 storey

Fig. 5: Variation of lateral displacements with X and inverted-V type bracing and without bracing

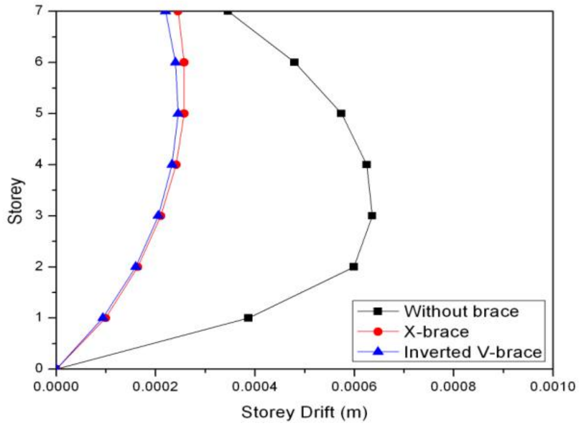
Fig. 5 shows a plot between the number of storey and roof displacement with and without bracings for different storey levels considered in the present study. It is found that the roof displacement is reduced considerably in braced steel frames. It can also be seen that the roof displacement for inverted-V braced frame gets reduced marginally with respect to X braced steel frames.



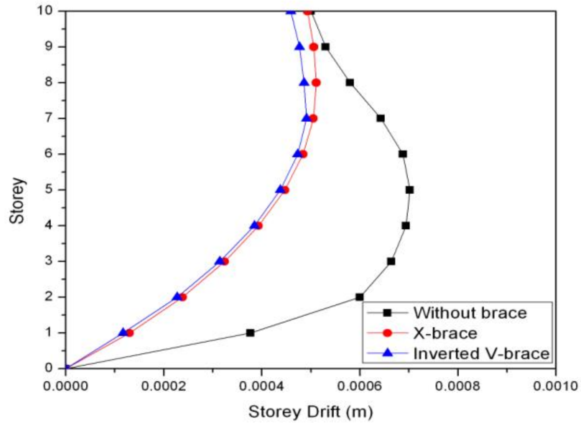
(i) 3 storey



(ii) 5 storey



(iii) 7 storey



(iv) 10 storey

Fig. 6: Variation of storey drift with X and inverted-V type bracing and without bracing

Fig. 6 shows the plot of storey drifts at different storey levels for different models considered in the study. It is observed that the storey drift reduces considerably in braced frames when compared to unbraced frames. Table 2 shows the roof displacement from elastic analysis and at performance point.

Table 2: Roof displacement from elastic analysis and at performance point

	Without brace		X brace		Inverted-V brace	
	RD at elastic limit (mm)	RD at performance point (mm)	RD at elastic limit (mm)	RD at performance point (mm)	RD at elastic limit (mm)	RD at performance point (mm)
3 storey	2.5	13.10	0.4	1.97	0.4	2.17
5 storey	8	39.20	1.7	7.70	1.7	7.80
7 storey	12.8	46.03	5.2	20.32	4.9	14.07
10 storey	19.5	89.10	13.4	49.35	12.8	51.11

RD: Roof displacement

5. CONCLUDING REMARKS

The following are the observations from the present analysis.

1. Steel bracings can be used to strengthen or to retrofit the existing structure.

2. The provision of bracing enhances the base shear carrying capacity of frames and reduces roof displacement undergone by the structures.

3. The lateral storey displacements of the building are reduced by the use of inverted-V bracing in comparison to the X bracing system.

4. Bracing acts as an extra redundant in frames there by reducing inter storey drift.

5. The present analytical work has shown that steel frames with insufficient lateral stiffness can be retrofitted with braces. Braces are the viable solutions to provide both global lateral stiffness and strength of the frame.

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