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Seismic Behaviour of Steel Building with And Without Bracing System by Performance Point

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Abstract

Steel structures have been playing an important role in the construction industry in recent years. It is necessary to create a model that performs well under seismic loading. Seismic performance of multi-storey steel framed buildings is designed as per the provisions of the Indian Code (IS 800 -2007). The ductility of the structure can be increased by adding steel support to the structure. There are different types of support for retrofitting. X-brace, diagonal brace, V-shaped brace, inverted V-shaped brace etc. There are many ways to prepare steel supports such as: The frame of the building is designed with or without different types of connections such as diagonal, X-brace, V-brace and inverted V-brace, which will be considered in this study. The performance of each frame was examined by nonlinear static analysis (pushover analysis) using the ETABS-2021 software package. The comparison of braced and unbraced frames was based on the examination of base shear forces, hinge consequences and lateral displacements of different frames. Compare the response curves and performance points of different frames with and without support systems to know the relationship between the various frames involved.

Keywords: *Non-linear behaviour of structure; Performance point; Pushover analysis; Steel structure; Seismic analysis.*

1. Introduction

Nonlinear static pushover analysis can provide a better understanding of structural behavior during seismic events. Seismic performance of multi-storey steel frame buildings are designed as per IS 800 (2007) requirements. Steel structures are more elastic than RCC buildings but expand laterally than RCC buildings. Bracing is an arrangement used to reduce the deflection of a structure. Braced frame is a structural design designed to withstand wind and seismic forces.

1.1. Pushover Analysis

Pushover analysis is a static, nonlinear procedure using the simplified nonlinear technique to estimate seismic structural deformations. It is an incremental static analysis used to determine the force-displacement relationship, or the capacity curve, for a structure or structural element. The analysis involves applying horizontal loads, in a prescribed pattern, to the structure incrementally, i.e. pushing the structure and plotting the total applied shear force and associated lateral displacement at each increment, until the structure or collapse condition [1][2].

1.2. Capacity Curves

The results of the static non-linear pushover analysis show the relationship between base shear and displacement as shown in Figure 1. The relationship between displacements is proportional to the base

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shear plotted into a curve called the Curve of Structure Capacity.[2]

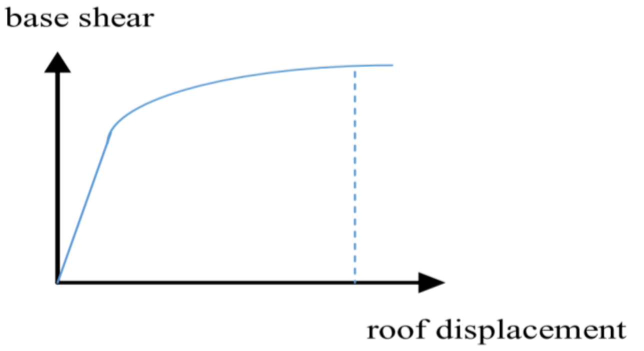

Figure 1 Capacity Curve

1.3. Performance Point

The performance point is the point where the curve of capacity intersects the spectrum response curve as used in the capacity spectrum method [2]. The illustration of the performance point can be seen in Figure 2.

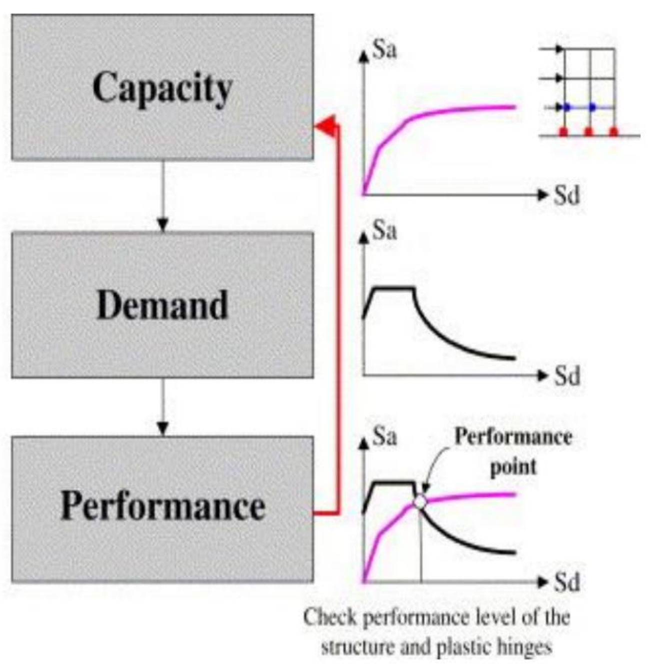

Figure 2 Performance Point

At the performance of point, it can be obtained regarding the period of building structure and effective structural stiffness due to changes in the shape of the elements after the plastic joint occurs. Based on this information, other structural responses such as the degree of deviation and the position of plastic joint (hinges) points can be identified. [3]

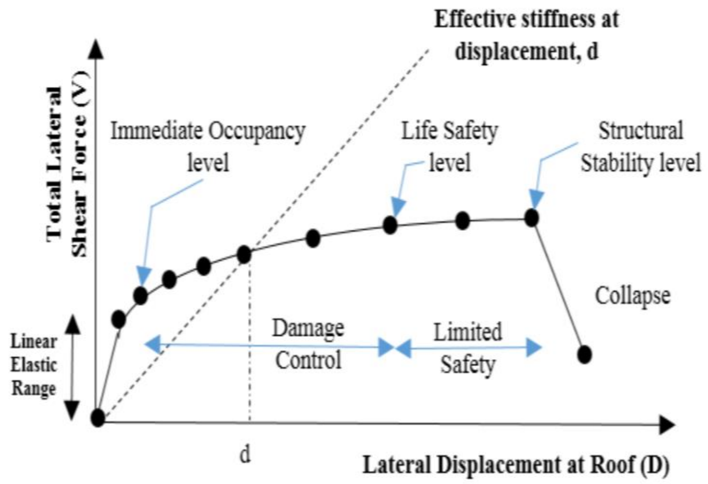

Figure 3 Performance Levels

Immediate Occupancy (IO) category is a structural condition that can withstand, the structure does not suffer structural and non-structural damage during an earthquake. In this category of IO, structures can be re-functional after the earthquake. Life Safety (LS) is a condition where the structure is still able to withstand, there is little structural damage, people who live or are inside a building are safe from earthquakes when an earthquake occurs. Collapse Prevention (CP) is a structural condition that suffered very heavy structural damage, but did not collapse during an earthquake. Structural Stability (SS) is a condition in which a structure experiences partial or total damage, the damage has caused a decrease in strength and stiffness in the lateral force retaining system [2].

1.4. Scope of The Present Study

The structures with bracing have performance points at less vulnerable damage states than structure without bracing. Also, hinges formed during pushover analysis for structures with and without bracing revealed that higher percentage of hinges reached more vulnerable damage states in case of structures without bracing [6]. When the number of storey decreases corresponding base shear increases and also number of storeys increases corresponding displacement increases [7]. Modelling of the steel

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frame structure under the push-over analysis using ETABS software and the results so obtained has been compared. Conclusions are drawn based on the target displacement of the structure by using an idealized Force-Displacement curve. [4]

1.5. Objective

- To investigate the seismic performance of a multi-story steel frame building with different bracing arrangements such as diagonal bracing, X bracing, V bracing and inverted V bracing, using the Nonlinear Static Pushover analysis method.
- To evaluate the performance factors for steel frames with various bracing arrangements designed according to the Indian Earthquake Code.

2. Method

The present study is based on a nonlinear analysis of typical multi-story (G+20 and G+24) steel frame buildings with and without different types of bracing models. Different configurations of frames are selected such as Diagonal, X, V and inverted V bracing frames. [5]

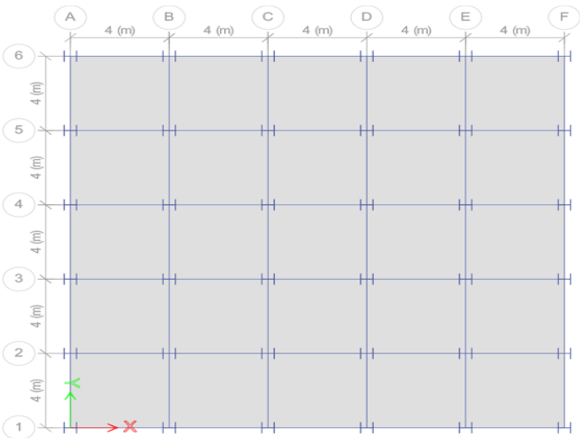

Figure 4 Plane View of Structure

2.1. Properties of Structures

For the analysis work, nine models of the building (G+24) floors and nine models of the building (G+20) are made to know the realistic behavior of the building during an earthquake. In these studies diagonal bracings, V-bracings, inverted V-bracing, X-bracing and bare frame have been taken for the pushover analysis. Typically, bay width is taken 4m in both X and Y direction. No of bays in both directions are 5. A story height (floor to floor) of 3.25m was considered in this study. The models were analyzed as per Indian standard code and Fema356 and ATC 40. Different arrangements of steel braced frame and a bare frame are considered below. All columns are fixed from the base for the foundation.

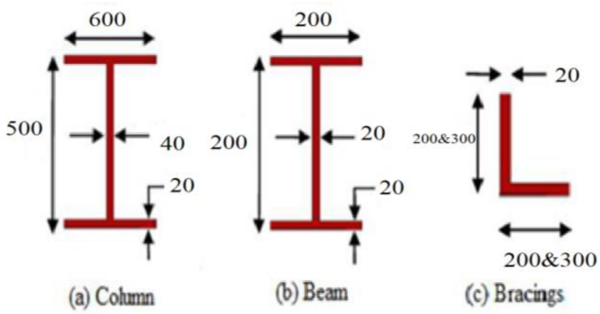

Figure 5 Structural Component

Table 1 Model Descriptions

No.	Name	Description
1	S1	G+24 Without bracing
2	S2	G+20 Without bracing
3	S1D1	G+24 With diagonal bracing (200)
4	S1D2	G+24 With diagonal bracing (300)
5	S1Λ1	G+24 With invert V-bracing (200)
6	S1Λ2	G+24 With invert V-bracing (300)
7	S1V1	G+24 With V-bracing (200)
8	S1V2	G+24 With V-bracing (300)
9	S1X1	G+24 With X-bracing (200)
10	S1X2	G+24 With X-bracing (300)
11	S2D1	G+20 With diagonal bracing (200)
12	S2D2	G+20 With diagonal bracing (300)
13	S2Λ1	G+20 With invert V-bracing (200)
14	S2Λ2	G+20 With invert V-bracing (300)
15	S2V1	G+20 With V-bracing (200)
16	S2V2	G+20 With V-bracing (300)
17	S2X1	G+20 With X-bracing (200)
18	S2X2	G+20 With X-bracing (300)

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The location of the bracing shows below figure 6. There was bare frame (A), structure with diagonal bracing (B), Invert V bracing (C), V bracing (D) and X bracing (E).

2.2. Assignment of Structures

For assigning a hinges for structural member, hinges are provide beams and column. For the column default hinge that yields based upon the interaction of the axial force and banding moment (P-M2-M3) is assigned and for the beam default hinge that yields based upon the flexure (M3).

Table 2 Structure Details

Particular	Details
No. of Bays in X Direction	5
No. of Bays in Y Direction	5
Plan Size	20 m × 20 m
Storey Height	3.25 m
Grade Of Concrete	M30
Grade of steel	Fe345 Structure steel
Slab Thickness	125 mm
Live Load	3 kN/m^2 At Typical Floor 1.5 kN/m^2 On Terrace
Floor finish load	1.25 kN/m^2 At Typical Floor 3 kN/m^2 On Terrace
Earthquake Load	As Per IS-1893 (Part 1) – 2016
Zone	V
Soil type	Type II, Medium As Per IS:1893
Building Importance Factor	1.5
Response Reduction Factor for concentric and eccentric respectively	3 (Model-A) 5 (Model-B, C, D, E)

For research, 18 model create and all model described in table1, and By use of earthquake code IS 1893(part1):2016 below graph created which was response spectrum curve generated by ETABS. This curve depending factor on zone, soil type, importance factor, response factor and damping ratio.

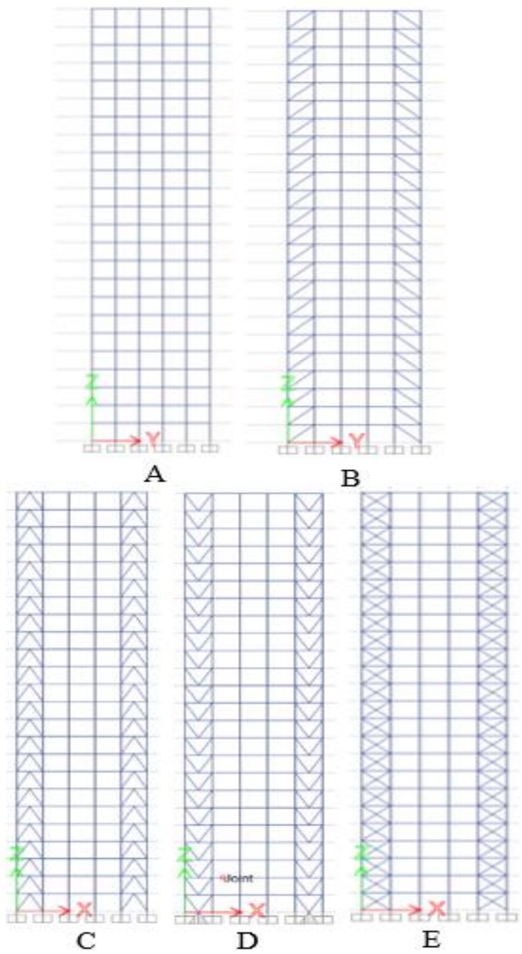

Figure 6 Elevation of Structure G+24 And G+20

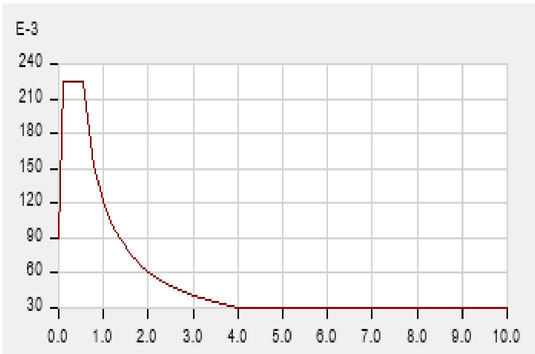

Figure 7 Response Curve

3. Results and Discussion

The comparison of base shear of the building and displacement at the performance point is shown in Figure 7-1 and Figure 7-2 respectively, also value was indicated in Table 3. The results obtained from

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this study show that buildings with re-entrant corners are inherently vulnerable to collapse due to earthquake load.

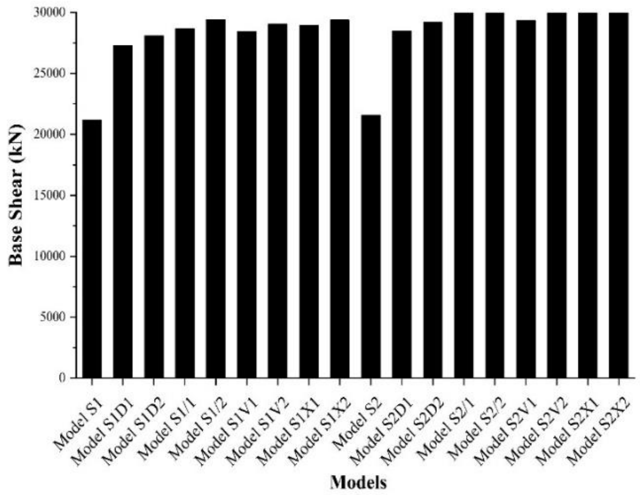

Figure 8 Base Shear of Models at Performance Point

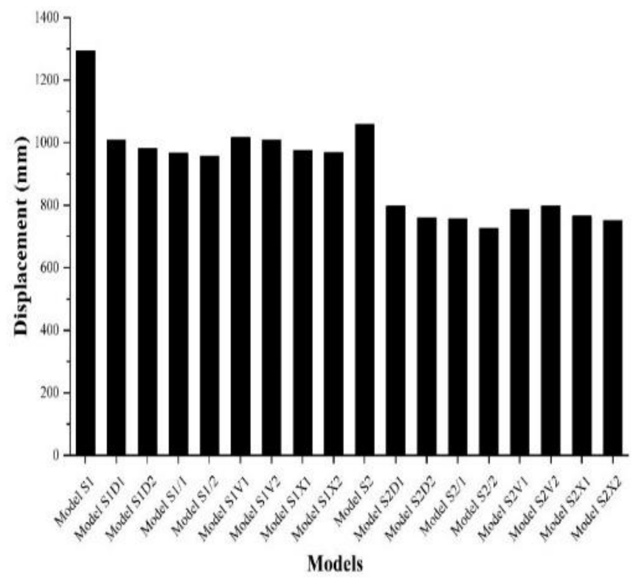

Figure 9 Top Displacement at Performance Point

In the above study, the behaviour of G+20 and G+24 storied steel frame buildings having different bracing, such as Diagonal bracing, Invert V-bracing, V-bracing and X-bracing located in seismic zone V has been analyzed under non-static response (Pushover Analysis) using ETABS software. The main objective of this study is to compare the regular building with the use of different bracing types using the non-linear static method. The analysis results in terms of load-carrying capacity, roof displacement hinge formation and performance level are studied.

Table 3 Model Result at Performance Point

Storyes	Description		Displacement mm	Shear kN
G+24 (S1)	without bracing		1294	21174
	D	1	1009	27286
		2	982	28082
	Λ	1	966	28647
		2	956	29406
	V	1	1016	28427
		2	1009	29051
	X	1	975	28941
		2	968	29380
G+20 (S2)	without bracing		1058	21568
	D	1	797	28474
		2	759	29219
	Λ	1	756	30081
		2	725	30624
	V	1	787	29341
		2	797	30869
	X	1	765	30659
		2	752	30893

Conclusion

1. The G+24 and G+20 structures provide different bracing systems and different bracing sizes, a max base shear caring capacity was X-bracing with a 300mm L section Model.
2. Whenever the structure storey was higher without bracing, the storey base shear was changed by 2% but the top storey displacement was changed by 18 %.
3. Whenever the structure storey was higher with bracing, the storey base shear was changed from 4 % to 6 % but the top storey displacement was changed from 30% to 24%.
4. Conclude that by providing bracing in the G+24 building, a base shear was increased and

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displacement was decreased by 30% to 40% and 21% to 25% respectively.

5. Also changing the bracing size from 200 to 300, change for all G+24 buildings, a base shear was increased and displacement was decreased by 1.5 % to 2.8 % and 0.6 % to 2.6% respectively.
6. Conclude that by providing bracing in G+20 building, a base shear was increased and displacement was decreased by 24% to 30% and 24% to 29% respectively.
7. Also changing the bracing size from 200 to 300, change for all G+20 buildings, a base shear was increased and displacement was decreased by 0.7 % to 5 % and 1.2 % to 5 %.

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