Comparative Analysis of Concentric Steel Braced Frame Structures Impact of Aspect Ratio Using Pushover Analysis

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Abstract: This research explores how different ratios affect a structure's ability to withstand earthquakes. One such ratio is the H/B ratio, where H is the building frame's overall height and B is its base width. steel frame. Here, the height of the building remains the same, the width of the foundation varies. In this study, seven different aspect ratios ranging from 1.0 to 3.75 have been considered for a ten-story steel frame building with fence protection, i.e., X fence with no protection system. Two types of slabs are considered for this study, one with the same steel sections for the high strength required for the beam and column and the other with different steel sections according to the strength and performance requirements. carrying out assigned duties. For this analytical study, ETABS has been used and a comparison has been made between the performance of the empty slabs and different conditions using push curves. Roof displacement, foundation shear and yield strength are parameters used to define the seismic performance of floors. It has been determined that providing reinforcement to the frame has increased load capacity, transmission capacity and reduced roof movement for all types of conditions.

Keywords: Aspect ratio, load analysis, steel frame, X-stiffened frame, 1-section type, 2-section type.

1. Introduction

Steel structures are important in construction and need to be designed to perform well under seismic loads. The installation of steel girders improves shear strength and energy absorption and increases seismic resistance. Analysis and other properties are evaluated, as nonlinear static analysis can predict failure modes and redistribution. Previous studies have focused on pressure analysis for RC slabs and different bracing models, but not on the proportionality of steel slabs and bracing systems. This study investigates this gap using ETABS for X-ray steel plates with different deformation characteristics. Steel is by far most useful material for building construction in the world. Today steel industry is the basic or key industry in any country. Its strength of approximately ten times that of concrete, steel is the ideal material of modern construction.

Its mainly advantages are strength, speed of erection, prefabrication, and demount ability. Structural steel is used in load-bearing frames in buildings and as members in trusses, bridges, and space frames. Steel, however, requires fire and corrosion protection. Steel has been known from 3000 BC steel was used during 500-400 BC in China and then in Europe. In India, the Ashokan pillar is made with steel and the iron joints used in Puri temples are more than 1500 years old.

The modern blast-furnace technology which was developed in AD1350 (Guptha 1998). The large-scale use of iron for structural purposes started in Europe in the latter part of the eighteenth century. The first major application of cast iron was in the 30.4–m–span Coalbroakadale Arch Bridge by Darby in England, constructed in 1779 over the River Severn.

2. Literature Review

Khan and Khan (2014) studied a typical 15-story steel-framed building with examples of an insulation system. This structure is designed for various types of concentric insulation such as V, X, diagonal, and external X, and the operation of each frame is carried out by a push-free filter. **Kalibhat et al (2014)** compared three parameters (ISA, ISMC, ISMB) for bracing models and investigated the effect of concentric bracing on the seismic performance of steel slabs. They found that the addition of concentric bracing increased the shear strength of the foundation and reduced roof movements and flow between floors. The movements of the side panels of the building are reduced by using the inverted V-bracket compared to the X-bracket system. **Vijayakumar and Babu**, (2012) determined the behaviour of G+2 reinforced concrete, bare frame under seismic forces in Zone III. The reinforced concrete structures were analyzed using SAP2000 software by the non-static analysis method the results related to pressure requirements, strength range, and plastic strains show the properties of the structures.

Most of the inches in the beams are designed for continuous use, life safety, anti-collapse, and small columns, The analysis is complete. **Polu Raju P. and Rao N. P.V.S., (2011)**, For analysis purposes, they considered three and six-story RC buildings with different insulation systems and different cross-sections as described above. The decision showed that the addition of roofers affects the total strength of the buildings in terms of resistance, flexibility, and flexibility compared to a bare frame. They found that the X and Zipper brace systems performed better than other braces depending on the type and size of the cross-section. **Inel and Ozmen, (2006)** performed compression analysis using SAP [2000] and compared building performance for standard hinge conditions and user-defined hinge properties. They have concluded that the results obtained from user-defined hinge functions are more accurate than standard hinges. **Mahri and Hajipour (1382)** conducted tests on scale models of RC ductile slabs with X-steel and knee brace systems.

The test results show that by adding an X or knee support system to the frame, it is possible to increase the strength and power of the simple RC frame and reduce its total movement to the required levels. he. X-bracing and knee bracing systems can be used to design or retrofit for severe-level earthquakes, and the knee brace is a useful system when designing or retrofitting for fall-level earthquakes. From the previous works, it can be seen that many experimental and analytical works have been done in pressure analysis of RC slabs and less works on steel slabs and different types of insulation systems. Since the condition of the steel plates and various types of insulation systems is not working.

Therefore, this work focuses on the effect of different conditions on the seismic performance of steel slabs and X-bracing systems using ETABS, and the results are analyzed by push analysis. **Kadid and Yahiaoui (2011)** conducted a study on the seismic performance of reinforced concrete (RC) frames with various bracing configurations. Published in *Procedia Engineering*, their research involved finite element analysis to assess the effectiveness of different bracing types under seismic loads.

The findings demonstrated that bracing significantly enhances the seismic resistance of RC frames by reducing lateral displacements and increasing structural stability. X-bracing, in particular, was identified as the most effective configuration. This study underscores the importance of incorporating optimal bracing designs to improve the earthquake resilience of RC structures.

3. Pushover Analysis

Linear elastic analysis shows elastic strength and initial yield points but does not show failure modes or redistribution. The non-static compression analysis described in ATC-40 is simpler and more accurate in estimating deformation requirements. Compression analysis involves increasing structural loads to determine response. The controlled high-pressure analysis, used in this study, evaluates, in addition to the total strength response, a plot of the total foundation shear and roof movement to identify weaknesses and collapse stresses.

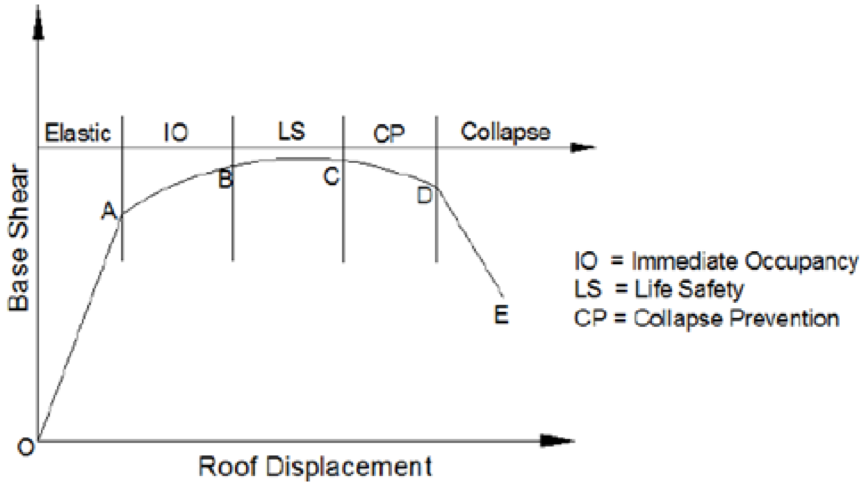
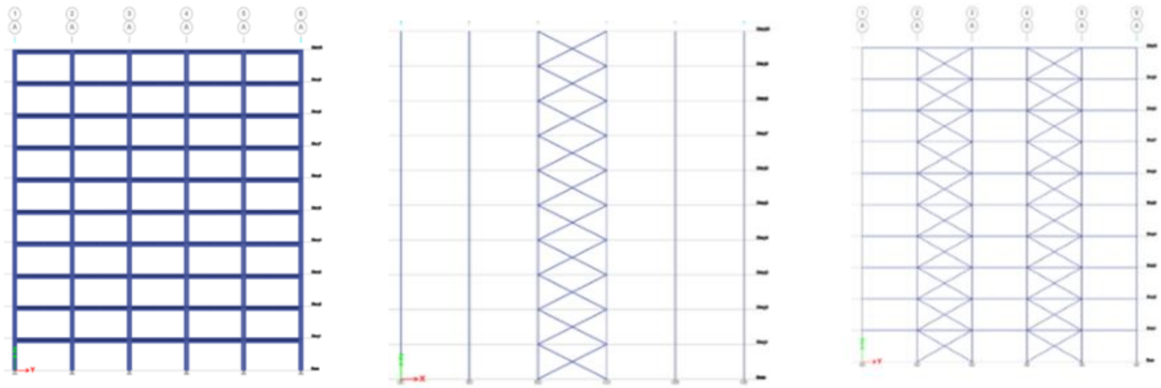


Figure No.1: Typical pushover curve

4. Description OF Steel Frame Structure



(i) (ii) (iii)

Figure No.2: (i) Steel bare frame, (ii) One Bay X Braced Frame, (iii) Two Bay X Braced Frame for aspect ratio1.0.

In this study, a path -two-dimensional frame A steel frame and an X-frame frame, two X-frame frames, and a free-standing structure with different dynamic properties are modeled and analyzed by use of ETABS. Two types of slabs are considered for this study, one with the same steel sections (type 1) for the maximum beam and column strength and the other with different steel sections (type 2) to measure the requirements for strength and ability to carry assigned responsibilities. The structural configuration of various frame structures and the shape of 1.0 is shown in Figure 2. The building consists of G+9 floors. All columns in all models are assumed to be down for convenience. The height of each floor is 3.0 meters. The live load on the floor is 3 kN/m2 and on the roof is 1.5 kN/m2. The floor level on the floor is 1kN/m2. The weathering stress on the roof is 2kN/m2. When calculating the seismic load, only 25% of the existing floor load is considered. Concrete and concrete weights are 25kN/m3 and 20kN/m3 respectively. The building is a strong steel anchor frame with an important protection evaluated in the seismic region V. The type of soil is called medium and the period of the building in the X direction is evaluated according to the dimensions of the building foundation as per IS code 1893-. 2016. The dimensions used for the beams are beam 1, column beam 2, and X bracket for section type 1 ISWB600. Beam and column dimensions for type 2 sections as per SP 6 (1) 1964 are given in Table 1.

Table No.1: Beam, column, and bracing sizes of Type 2 section for different aspect ratios.

Aspect Ratio	Base Width B in m	Type 2 Section		
		Beam Size	Column Size	X Brace
1.00	30	400*230mm	400*400mm	ISWB 600
1.25	24	400*230mm	400*400mm	ISMB 600
1.50	20	400*230mm	400*400mm	ISMB 500
2.00	15	400*230mm	400*400mm	ISMB 450
2.50	12	400*230mm	400*400mm	ISMB 450
3.00	10	400*230mm	400*400mm	ISMB 450
3.75	08	400*230mm	400*400mm	ISMB 400

5. Results and Discussion

TableNo.2: Base Shear (B.S) Type 1 Section.

Type-1 section			
Aspect Ratio	Bare Frame	One Bay X Braced Frame	Two Bay X Braced Frame
	B.S in KN	B.S in KN	B.S in KN
1.00	206.14	520.53	555.43
1.25	145.79	422.46	445.15
1.50	129.17	312.40	335.25
2.00	094.51	202.38	217.99
2.50	070.43	145.53	162.93
3.00	062.52	113.23	118.31
3.75	038.99	78.35	84.24

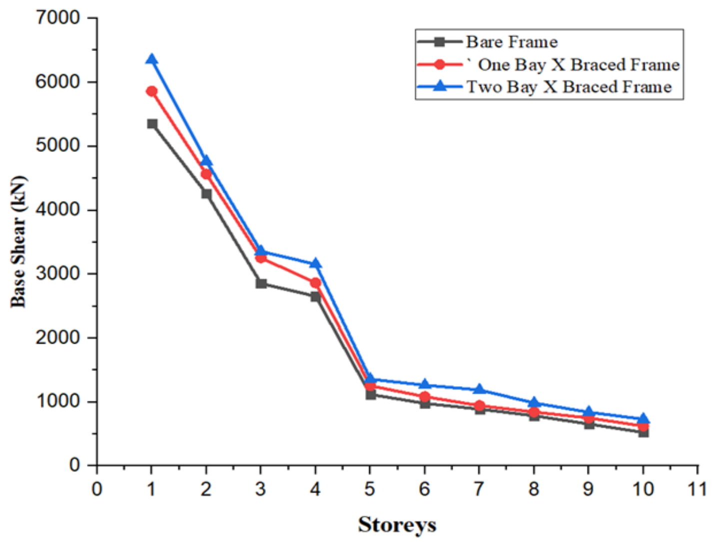


Figure No.3: Storey Base Shear @ section-1

The above table and graph show the values of base shear for different aspect ratios from 1 to 3.75. The base shear values are decreasing with an increase in the aspect ratio from 1 to 3.75. The maximum values of the base shear are shown for the two bay X braced frame model when we compared with other models because of the extra weight from the base frame model the base shear values are increasing this indicated the higher stiffness for the structure in section 1 case.

Table No.3: Base Shear (B.S) Type 2 Section.

Type-2 section			
Aspect Ratio	Bare Frame	One Bay X Braced Frame	Two Bay X Braced Frame
	B.S in KN	B.S in KN	B.S in KN
1.00	209.14	544.53	565.43
1.25	168.64	408.97	423.03
1.50	141.64	303.61	311.29
2.00	107.87	194.81	199.10
2.50	087.63	133.26	136.44
3.00	074.07	100.66	103.19
3.75	060.59	71.54	73.19

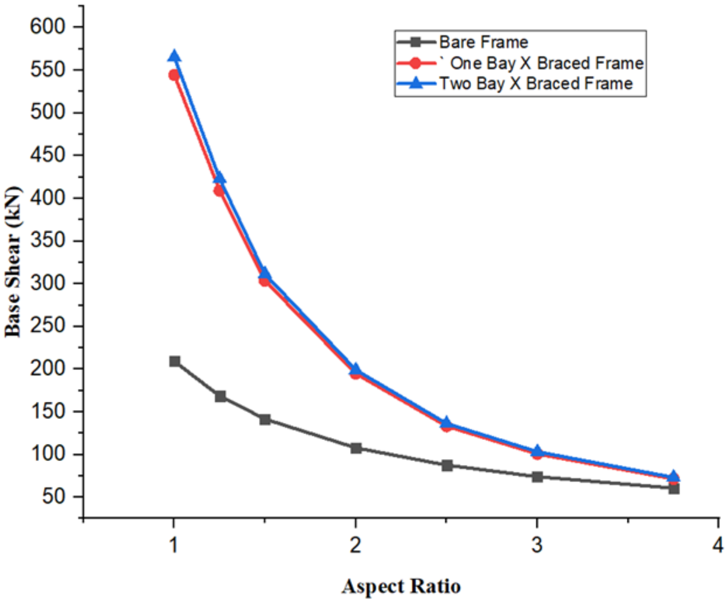


Figure No.4: Storey Base Shear @ section-2

The above table and graph show the values of base shear for different aspect ratios from 1 to 3.75. The base shear values are decreasing with an increase in the aspect ratio from 1 to 3.75. The maximum values of the base shear are shown for the two bay X braced frame model when we compared with other models because of the extra weight from the base frame model the base shear values are increasing this indicated the higher stiffness for the structure in section 2 case.

Roof Displacement:

Table No.4: Roof Displacement (R.D) Type 1 Section.

Type -1 section			
Aspect Ratio	**Bare Frame**	**` One Bay X Braced Frame**	**Two Bay X Braced Frame**
	R.D in KN	**R.D in KN**	**R.D in KN**
1.00	7.6	7.3	4.3
1.25	9.0	7.3	4.0
1.50	10.9	7.3	3.8
2.00	10.6	7.0	3.6
2.50	11.9	8.2	4.2
3.00	18.3	9.4	4.2
3.75	19.6	11.1	5.4

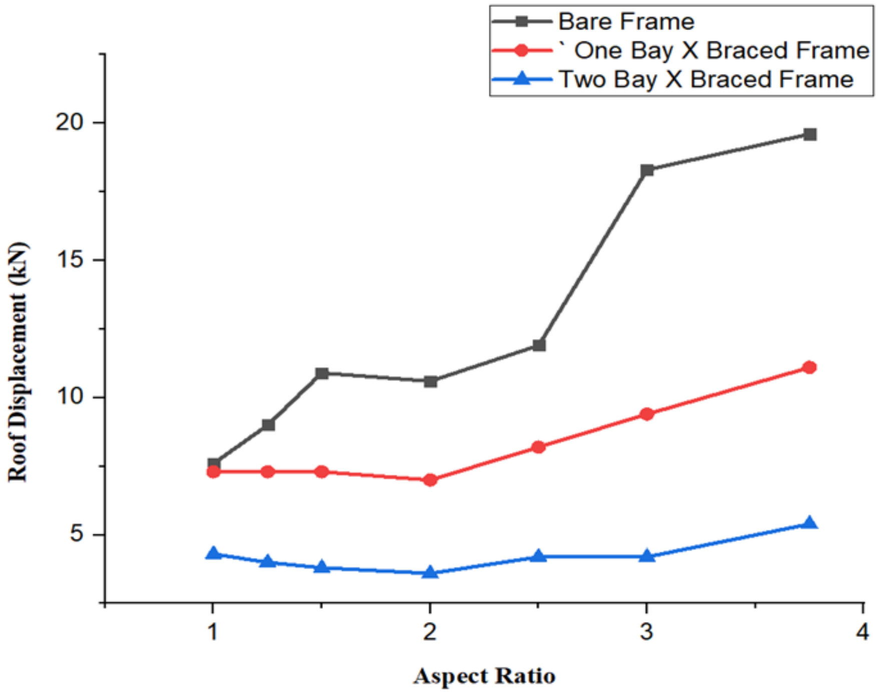


Figure No.5: Roof Displacements @ section-1

The Roof displacements are shown in the above graph and table for various aspect ratios from this results it is observed that with increase in the aspect ratio the values of base shear are increases, the maximum values of base shear are seen in the aspect ratio 3.75. and it is also observed that the values of base shear are less for the two bay X bare frame model when we compared with one bay frame X type and without bare frame, so by providing bare frame the displacement values are reducing here in Section 1.

Table No.5: Roof Displacement Type 2 Section

Type -2 section			
Aspect Ratios	Bare Frame	One Bay X Braced Frame	Two Bay X Braced Frame
	R.D in KN	R.D in KN	R.D in KN
1.00	7.6	7.3	4.3
1.25	5.6	5.6	3.2
1.50	4.5	4.4	2.5
2.00	3.3	3.2	1.9
2.50	2.8	2.7	1.7
3.00	2.6	2.4	1.6
3.75	2.4	2.3	1.5

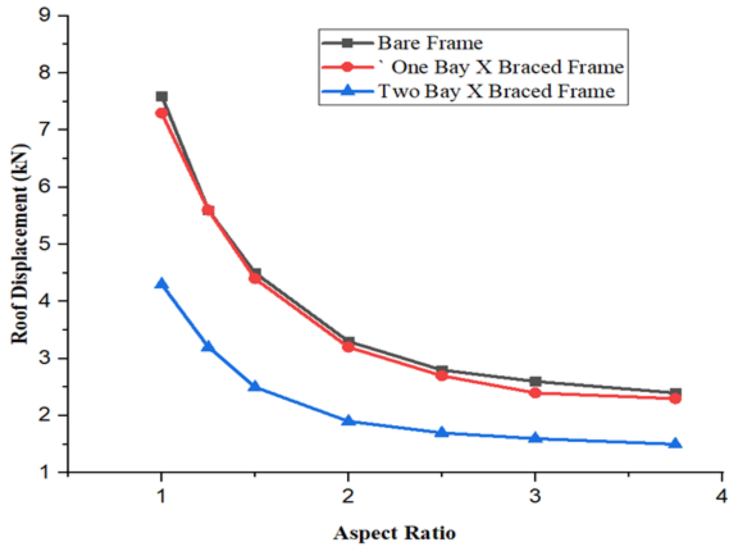


Figure No.6: Roof Displacements @ section-2

The Roof displacements which are shown in the above graph and table for various aspect ratios from this results it is observed that with increase in the aspect ratio the values of base shear are increases, the maximum values of base shear are seen in the aspect ratio 1. And it is also observed that the values of base shear are less for the two bay X bare frame model when we compared with one bay frame X type and without bare frame, so by providing bare frame the displacement values are reducing here in Section 2.

Table No.6: Performance Point (P.P) Type 1 Section

Type -1 section			
Aspect Ratio	Bare Frame	One Bay X Braced Frame	Two Bay X Braced Frame

	P.P in KN	P.P in KN	P.P in KN
1	725.31	987.04	1106.12
1.25	671.24	853.79	1038.09
1.5	630.25	726.49	988.37
2	584.62	669.74	873.44
2.5	540.28	589.4	687.98
3	478.62	487.44	568.46
3.75	364.63	398.75	455.31

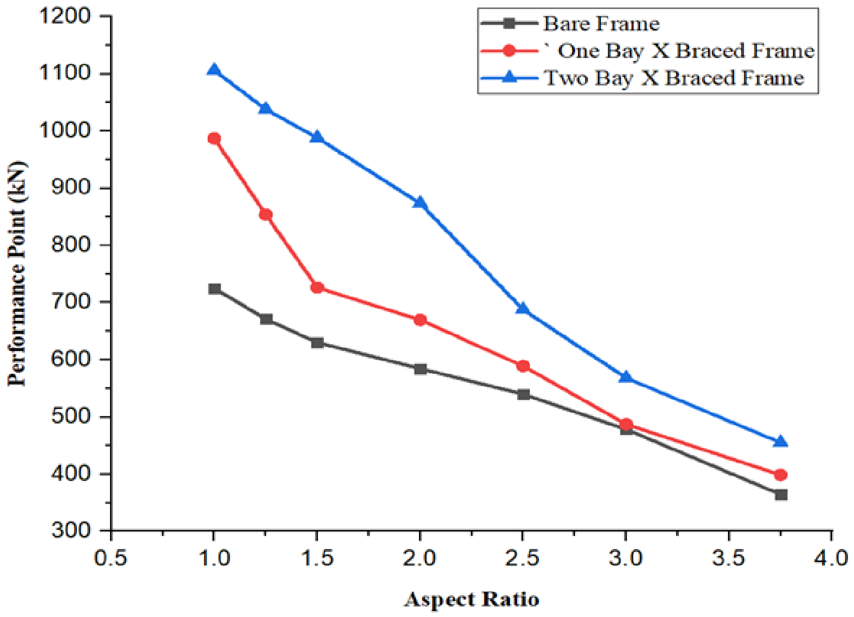


Figure No.7: Performance point @ section-1

The above table and graph show the values of base shear for different aspect ratios from 1 to 3.75. The Performance point values are decreasing with an increase in the aspect ratio from 1 to 3.75. The maximum values of the Performance points are shown for the two bay X braced frame model when we compared with other models because of the extra weight from the base frame model the base shear values are increasing this indicated the higher stiffness for the structure in section 1 case.

Table No.7: Performance Point (P.P) Type 2 Section

Type -2 Section			
Aspect Ratio	Bare Frame	` One Bay X Braced frame	Two Bay X Braced Frame
	P.P in KN	P.P in KN	P.P in KN
1	845.25	1087.45	1206.12
1.25	786.54	945.36	1138.9
1.5	680.25	756.49	988.37
2	574.62	699.74	873.44

2.5	430.28	589.4	798.78
3	358.62	487.44	698.46
3.75	294.63	428.75	565.31

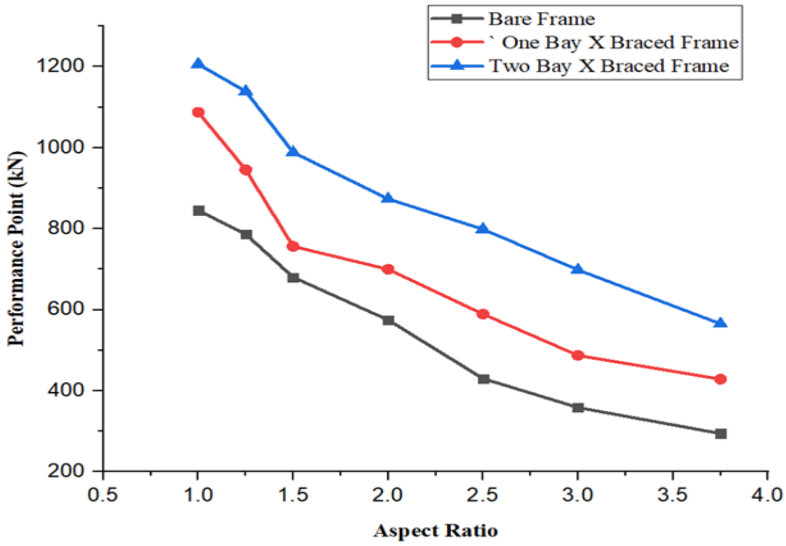


Figure No.8: Performance point @ section-2

The above table and graph show the values of base shear for different aspect ratios from 1 to 3.75. The performance point values decrease with an increase in the aspect ratio from 1 to 3.75. The maximum values of the Performance points are shown for the two bay X braced frame model when we compared with other models because of the extra weight from the base frame model the base shear values are increasing this indicated the higher stiffness for the structure in section 2 case.

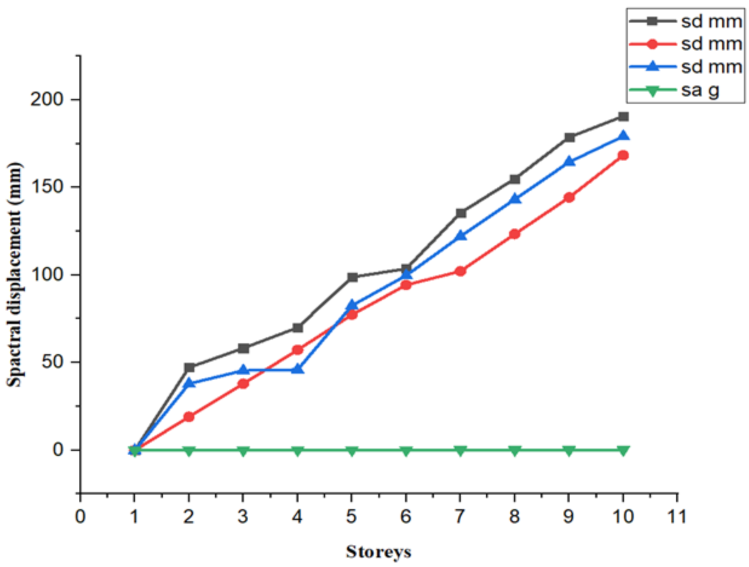


Figure No.9: Capacity and Demand spectrum curve for bare frame, one bay X braced frame structures of Type 1 section for different aspect ratios.

For structures with an aspect ratio of 1.0, pushover curves typically demonstrate a clear progression from elastic behavior to plastic deformation, with relatively uniform transitions due to the structural symmetry. The curve reflects the structure's balanced response to lateral loads, showing initial linear behavior, followed by yielding, plastic hinge formation, strength degradation, and eventual collapse. The equal height and width of these structures contribute to a more predictable and consistent pushover response.

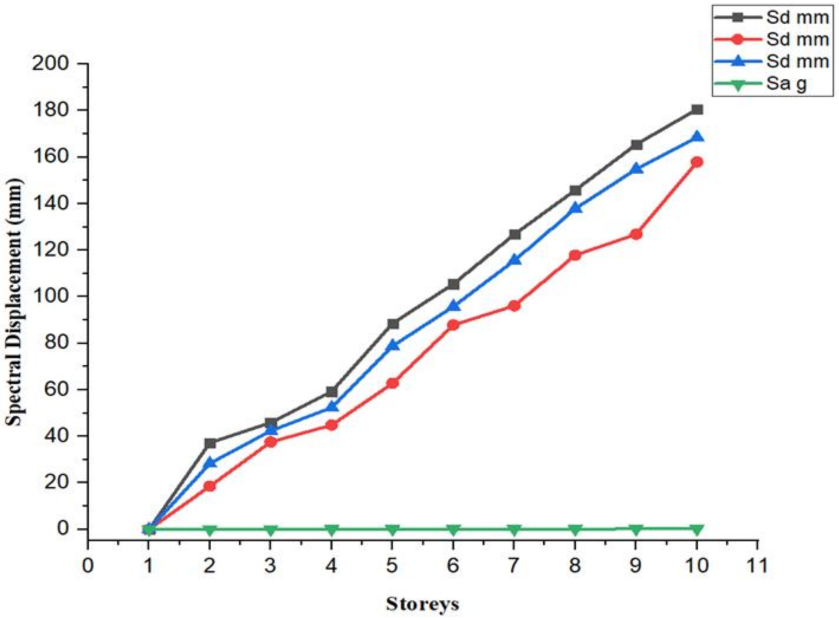


Figure No.10: Pushover curves for bare frame one bay X braced frame and two bay X braced frame structures of with different aspect ratios

Pushover curves are essential for understanding how a structure will perform under lateral loads. The aspect ratio helps in quantifying the relationship between displacement and force, which is crucial for evaluating the safety and stability of structures in seismic or wind load scenarios. An aspect ratio of 2.0 would be a specific criterion or characteristic used to interpret the structure's response and performance in the analysis.

6. Conclusions

The following are the observations from present analysis.

- As aspect ratio increases, base shear carrying capacity decreases for type 1 section considered in the study.
- As aspect ratio increases, base shear carrying capacity decreases for type 2 section considered in the study.
- As aspect ratio increases, roof displacement decreases for frames with Type 1 section it increases considerably the provision of bracing enhances the base shear carrying capacity of frames and reduces roof displacement undergone by the structures.
- As aspect ratio increases, roof displacement decreases for frames with Type 2 section it increases considerably the provision of bracing enhances the base shear carrying capacity of frames and reduces roof displacement undergone by the structures.
- The performance point is between base shear and displacement; it can be observed that as aspect ratio increased base shear at performance point decreased considerably from an aspect ratio of 1.0 to 3.75 for both type of sections. As aspect ratio increased roof displacement at the performance point decreased considerably from aspect ratio 1.0 to 3.75 for Type 1 section and that of Type 2 section increased considerably. Two bay X braced frame is showing better performance than bare frame and one bay X braced frame structures.
- Capacity and Demand spectrum curve for bare frame, one bay X braced frame and two bay X braced frame structures of Type 1 section for aspect ratios 3.75.

7. References

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