Seismic Performance of Single Bay RCC Framed Building and Its Improvement Technique

MADHAV SHARMA[1], SURENDRA BAHADUR SHAHI[2]
[1]*Graduate School of Engineering, Mid-West University, Nepal*
[2]*Assist Prof. Graduate School of Engineering, Mid-West University, Nepal*

ABSTRACT- The major purpose of this study is to analyze the single-bay RCC Framed building and its improvement techniques. Total number of 36 models were selected. The models are 4 bay, 6 bay, 8 bay and 10 bay each with 3 storey, 5 storey and 7 storey. The model types are (i) Without bracing and shear wall, (ii) With Bracing and (iii) with shear wall. All the model was analyzed using Etabs software. Response spectrum analyses was carried out as per NBC code. The analysis was performed to understand the seismic performance of the single bay RCC building and compare its performance with that of the single bay RCC building with bracing and the RCC building with shear wall. The result shows that the size structural member increases significantly with the increase in number of bays and number of storeys, Bracing effectively reduces drift and displacement along the bracing direction while increasing stiffness and reducing overturning moments. Shear wall shows more effective than Bracing in reducing the drift and displacement.

Keywords: Single bay, Bracing, Shear wall, Response Spectrum, Etabs, NBC.

I. INTRODUCTION

Nepal is in the most seismically active areas on earth[1]. Earthquakes are the most unpredictable and devastating natural disasters. Since the earthquake forces are random in nature and unpredictable, the engineering tools need to be sharpened for analyzing structures under the action of these forces [2]. The behaviour of a building during an earthquake depends on several factors, stiffness, adequate lateral strength, ductility, and simple and regular configurations [3]. The selection of the building plan configuration plays a crucial role in the structural design for resisting earthquake ground shaking. Along with gravity load structure has to withstand lateral load which can develop high stresses [4]. Majority of damaged building during earthquake were not properly designed and are not constructed as per NBC[5]. Most of the buildings are constructed without considering the earthquake Resistance Criteria. For the most part, it is the poorly designed or constructed buildings that claim so many lives during and immediately after the earthquake.

A single-bay building has only one structural division marked by elements like columns or walls. It's a simpler structure compared to buildings with multiple bays, which have repeated units of these elements. The minimum number of bays suggested by NBC 205 is 2 and to account for maximum allowable floor area, 6 bays were taken with maximum allowed bay length i.e. 4.5m. As a result, Urbanization, there is the problem of face length of the land, due to this building are constructed with single bay. Such building is weak in lateral dynamic forces such as Earthquake loading in the direction of single bay. Hence, lateral load resisting element is needed for the construction of Single bay RCC building.

RCC bracing is more advantageous for higher Stability and stiffness that other bracing[6]. Bracing increases, the resistance of the structure against side sway or drift [7]. To resist the lateral load acting on building, different types of steel or RCC bracing systems are provided. It is found that the seismic performance of the building model is improved considerably by providing bracings [8]. Hence, strengthening Single bay RCC buildings along the single-bay direction can be done by providing the bracing system.

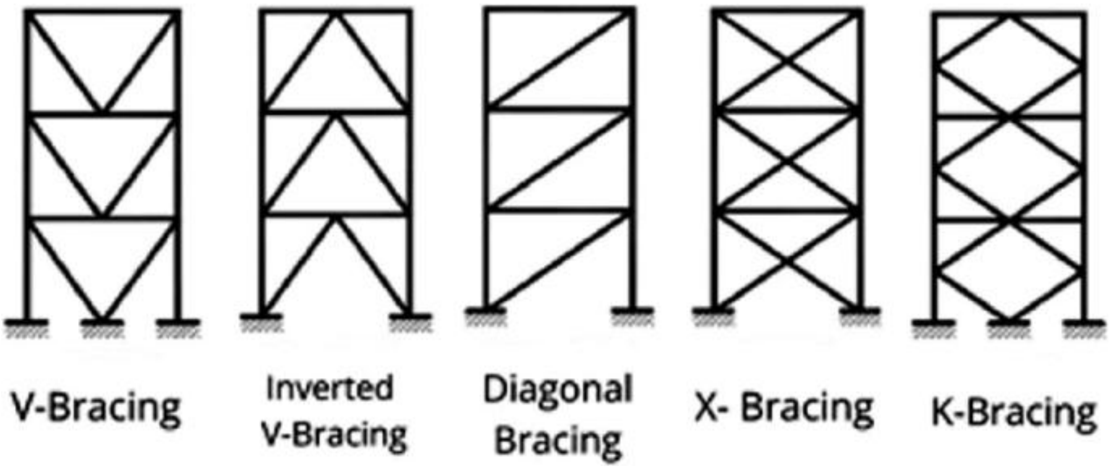


Figure 1: Single bay RCC Building With diagonal Bracing

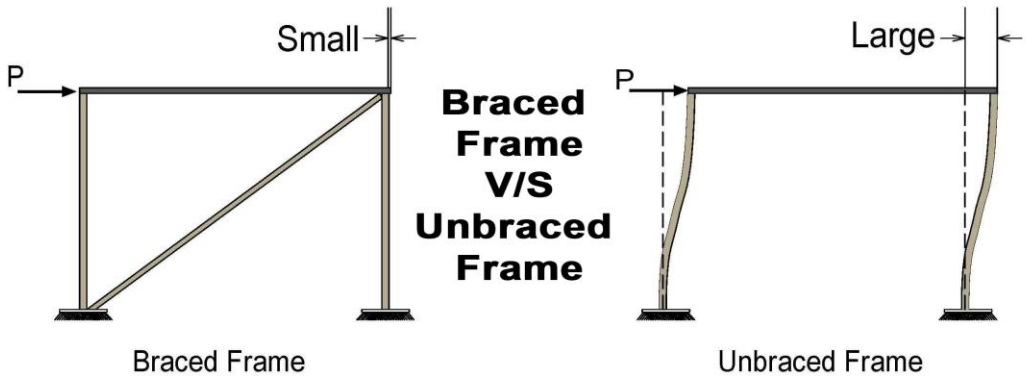


Figure 2: Braced Frame VS Unbraced Frame

Shear walls are the main vertical structural elements with a dual role of resisting both the gravity and lateral loads [7]. To reduce the effect of earthquake reinforced concrete shear walls are used in the building [9]. RCC shear walls at Proper locations, reduces the displacements due to earthquake[10]. So we can also use shear wall for better seismic performance for Single bay RCC building. The provision of shear walls in building to achieve rigidity has been found effective and economical [9]

Single-bay RCC buildings are constructed due to its Simplicity, Cost-effectiveness and limited plot dimension. However, there is concern for the seismic performance. The structures are highly vulnerable to lateral forces and may exhibit large drift, displacement, and overall instability under Seismic loading.

The research addresses the exciting gap by studying the seismic performance of single bay RCC building. It addresses the seismic performance of single bay RCC building and the critical parameters like Drift, displacement, storey stiffness and overturning moment for Single bay RCC building. The research evaluates the seismic performance of single bay RCC building by lateral load resisting element such as bracing and shear wall along the direction of bay. The study also focus on the improvement of seismic performance of Single bay RCC building with Bracing and with shear wall. .

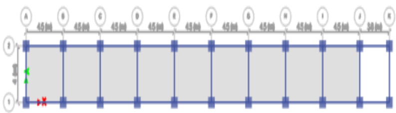
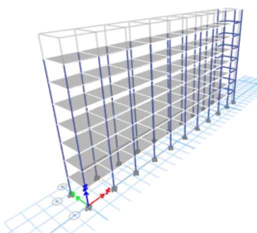
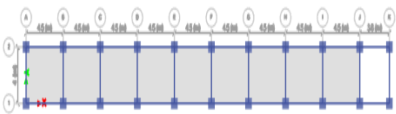
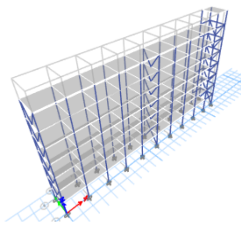
II. RESEARCH METHODOLOGY

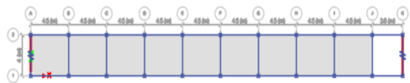
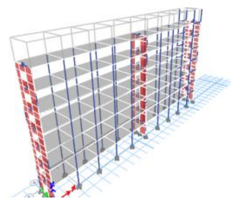
As per the research objective and research question we need sample selection and know their seismic performance, the process began with problem identification based on literature review. The model with varying number of bay in one direction and number of storey are selected. Modeling is done using Etabs 2018 software. The model type vary with 4 bay, 6 bay, 8 bay, 8 bay, 10 bay and varying storey are 3, 5, 7. All the model as classified as (i) without Bracing and shear wall, (ii) with RCC bracing, (iii) with RCC shear wall. The analysis of all model is done using Response Spectrum as per NBC. The result based on seismic analysis like Drift, Displacement, Storey stiffness, overturning moment, and Structural member size are compared . finally the result were interpreted, and the conclusion are made a per findings.

2.1 Sampling technique
In this study 4 model of single bay RCC building is selected i.e. 4 Bay, 6 Bay, 8 Bay and 10 Bay for each 3 storey, 5 storey and 7 storey. These all model are analyzed by Response spectrum method of analysis. The result for Drift, Displacement, Stiffness and Overturning moment are taken for Further analysis. Similarly, these all model are analyzed with shear wall and Bracing at both ends of single bay by Response spectrum method of analysis using User Coefficient Method. The models are shown below:

Table 1: All types of model

BAY →	4			6			8			10		
Storey ↓	Without bracing and shear wall	With shear wall	With bracing	Without bracing and shear wall	With shear wall	With bracing	Without bracing and shear wall	With shear wall	With bracing	Without bracing and shear wall	With shear wall	With bracing
3	3S4B	S3S4B	B3S4B	3S6B	S3S6B	B3S6B	3S8B	S3S8B	B3S8B	3S10B	S3S10B	B3S10B
5	5S4B	S5S4B	B5S4B	5S6B	S5S6B	B5S6B	5S8B	S5S8B	B5S8B	5S10B	S5S10B	B5S10B
7	7S4B	S7S4B	B7S4B	7S6B	S7S6B	B7S6B	7S8B	S7S8B	B7S8B	7S10B	S7S10B	B7S10B

S.N	Discription	Notation	Plan	3D
1	7 Storey 10 bay without bracing and shear wall	7S10B		
2	7 Storey 10 bay with bracing at two ends and mid	B7S10B		

3	7 Storey 10 bay with Shear wall at two ends and mid	S7S10B		

Sample Models are shown above in the table, all other model are similar, bracing and shear wall are placed at two ends.

Structural Member size:

Table 2: Beam Column Size For Model without Bracing and Shear wall

STOREY	BAY	COLUMN	BEAM
3	4-BAY	400*400	400*350
	6-BAY	450*450	450*300
	8-BAY	500*500	500*400
	10-BAY	800*800	800*650
5	4-BAY	450*450	460*350
	6-BAY	500*500	520*450
	8-BAY	600*600	600*500
	10-BAY	900*900	900*750
7	4-BAY	500*500	500*450
	6-BAY	500*500	520*450
	8-BAY	700*700	750*600
	10-BAY	1200*1200	1250*1000

Table 3: Beam Column Size For Model with Bracing

STOREY	BAY	COLUMN	BEAM D*B	Bracing Size
3	4-BAY	350*350	360*300	300*300
	6-BAY	400*400	400*350	350*350
	8-BAY	450*450	450*400	400*400
	10-BAY	750*750	760*650	500*500
5	4-BAY	400*400	400*350	300*300
	6-BAY	450*450	450*400	350*350
	8-BAY	550*500	550*450	350*350
	10-BAY	850*850	850*750	500*500
7	4-BAY	500*500	500*450	300*300
	6-BAY	500*500	520*450	350*350
	8-BAY	700*700	750*600	400*400
	10-BAY	1200*1200	1250*1000	550*550

Table 4: Beam Column Size For Model with Shear wall

STOREY	BAY	COLUMN	BEAM D*B	Shear wall
3	4-BAY	350*350	350*300	150
	6-BAY	400*400	400*300	150
	8-BAY	400*400	400*350	150
	10-BAY	450*450	450*350	150
5	4-BAY	400*400	400*350	150
	6-BAY	450*450	450*400	150
	8-BAY	550*550	550*450	150
	10-BAY	850*850	850*750	150
7	4-BAY	450*450	450*400	150
	6-BAY	450*450	450*400	150
	8-BAY	550*550	550*500	150
	10-BAY	1000*1000	1000*900	150

Analysis of data

All types of models were analyzed using the Response spectrum method as per NBC. The data are represented in the following. Here the comparison of storey Drift, Displacement, Storey stiffness and overturning moment in 3-storey, 4 Bay for EQX(ULS) IS done. The comparison between without shear wall and bracing, with bracing and with shear wall.

4.1.1 Inter-storey Drift, Displacement, Storey stiffness, overturning moment Index of Frames Due to EQX (ULS) and EQY (ULS) For 3-storey

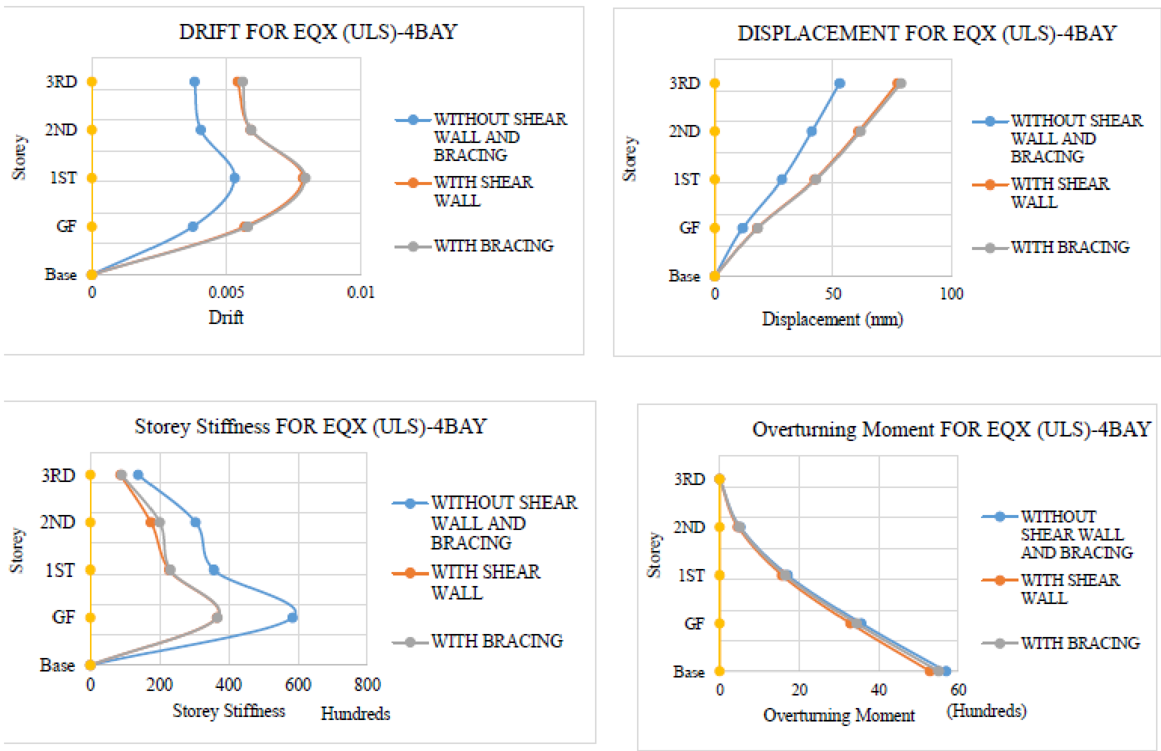


Figure 3: Comparision of storey Drift, Displacement, storey stiffnesss and overturning moment for 3 Storey 4 Bay for EQX (ULS)

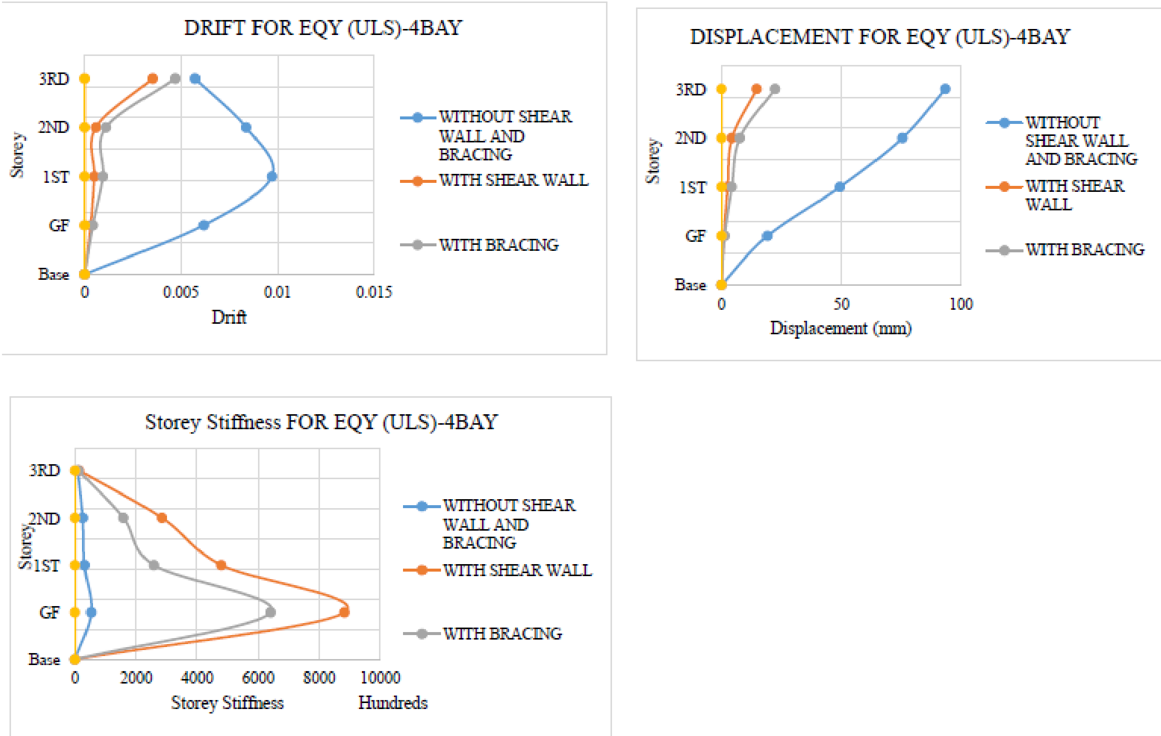


Figure 4: Comparision of storey Drift, Displacement, storey stiffnesss for 3 Storey 4 Bay for EQY (ULS)

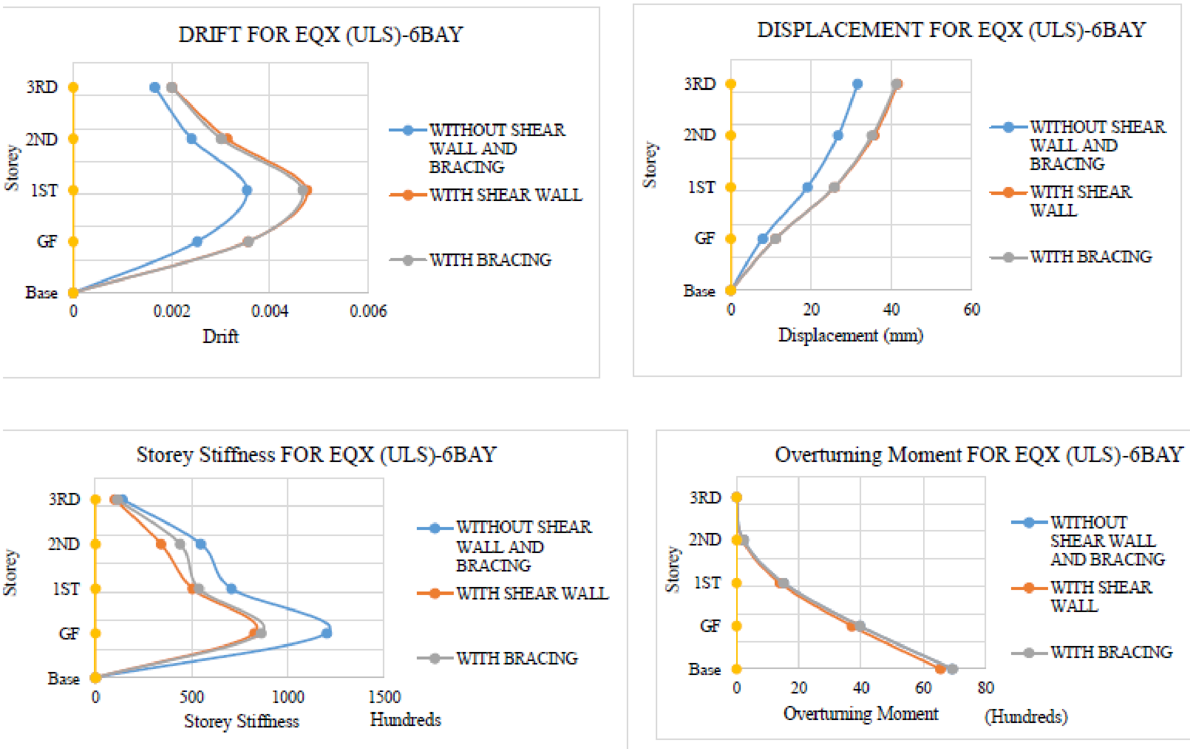


Figure 5: Comparision of storey Drift, Displacement, storey stiffnesss and overturning moment for 3 Storey 6 Bay for EQX (ULS)

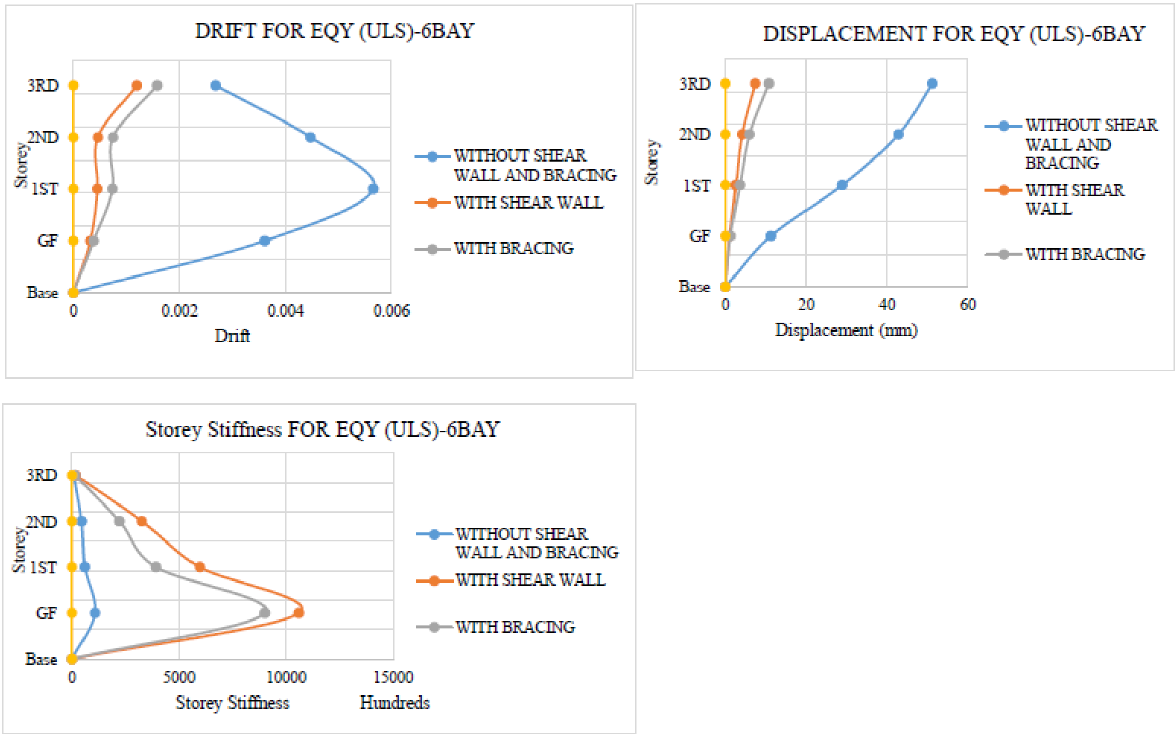


Figure 6: Comparision of storey Drift, Displacement, storey stiffnesss for 3 Storey 6 Bay for EQY (ULS)

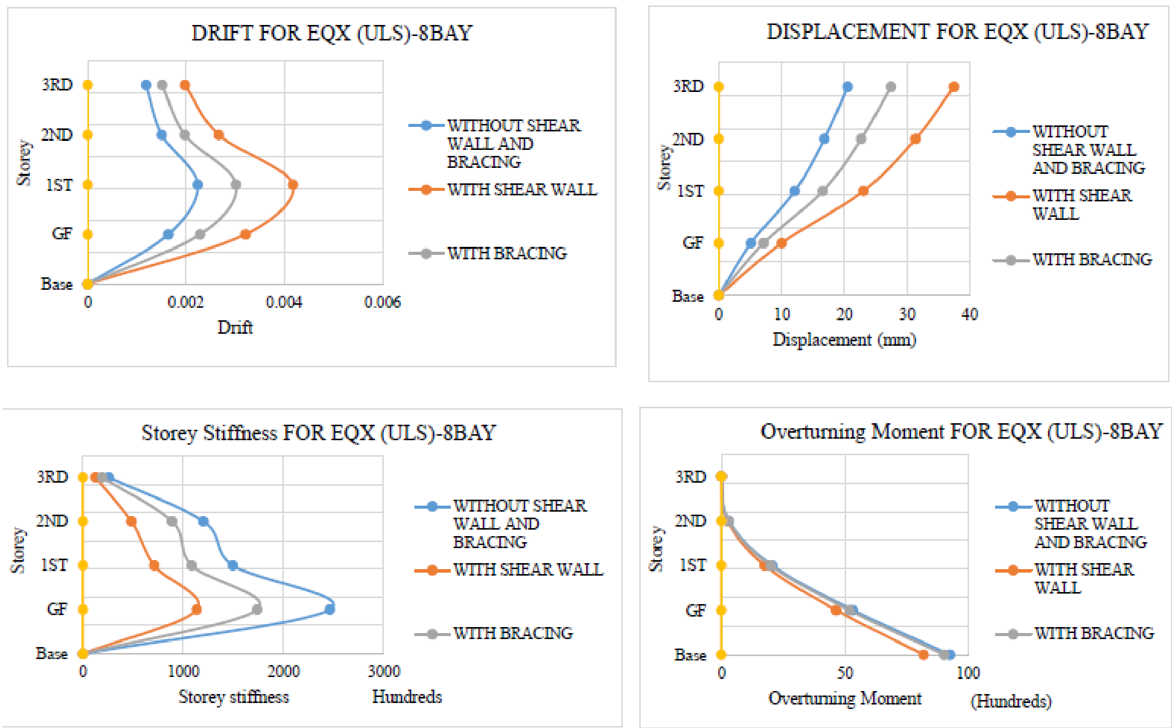


Figure 7: Comparision of storey Drift, Displacement, storey stiffnesss and overturning moment for 3 Storey 8 Bay for EQX (ULS)

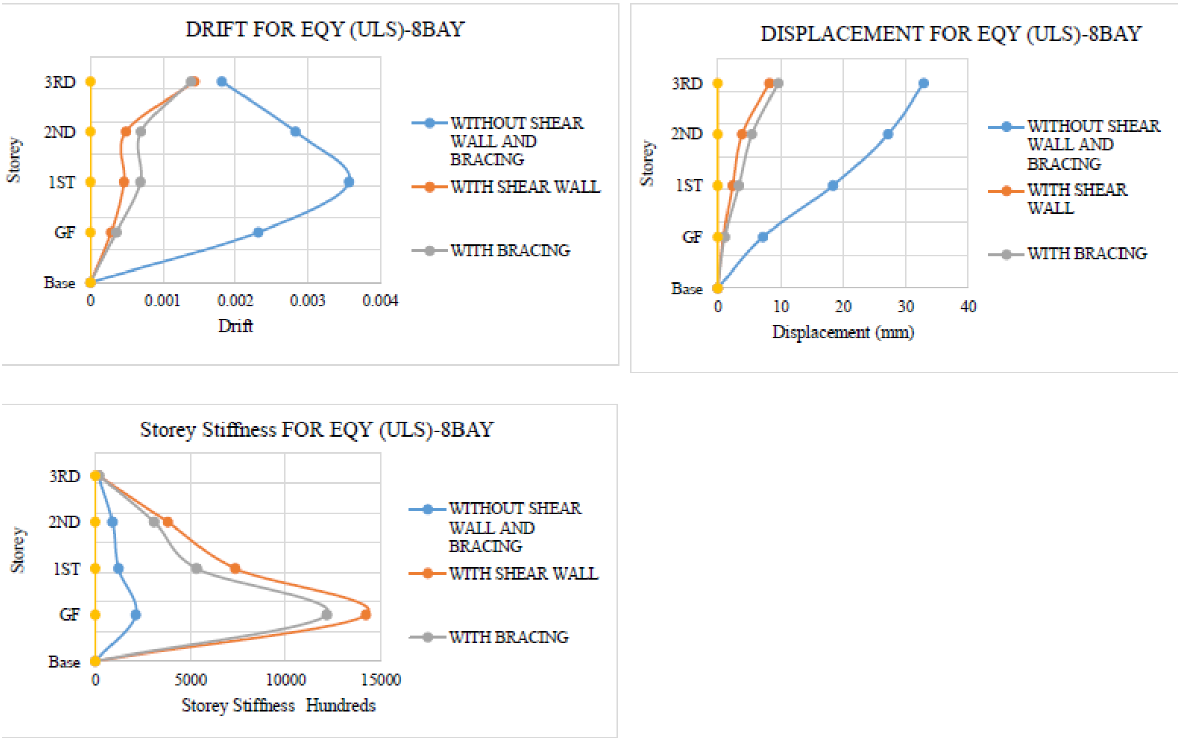


Figure 8: Comparision of storey Drift, Displacement, storey stiffnesss for 3 Storey 8 Bay for EQY (ULS)

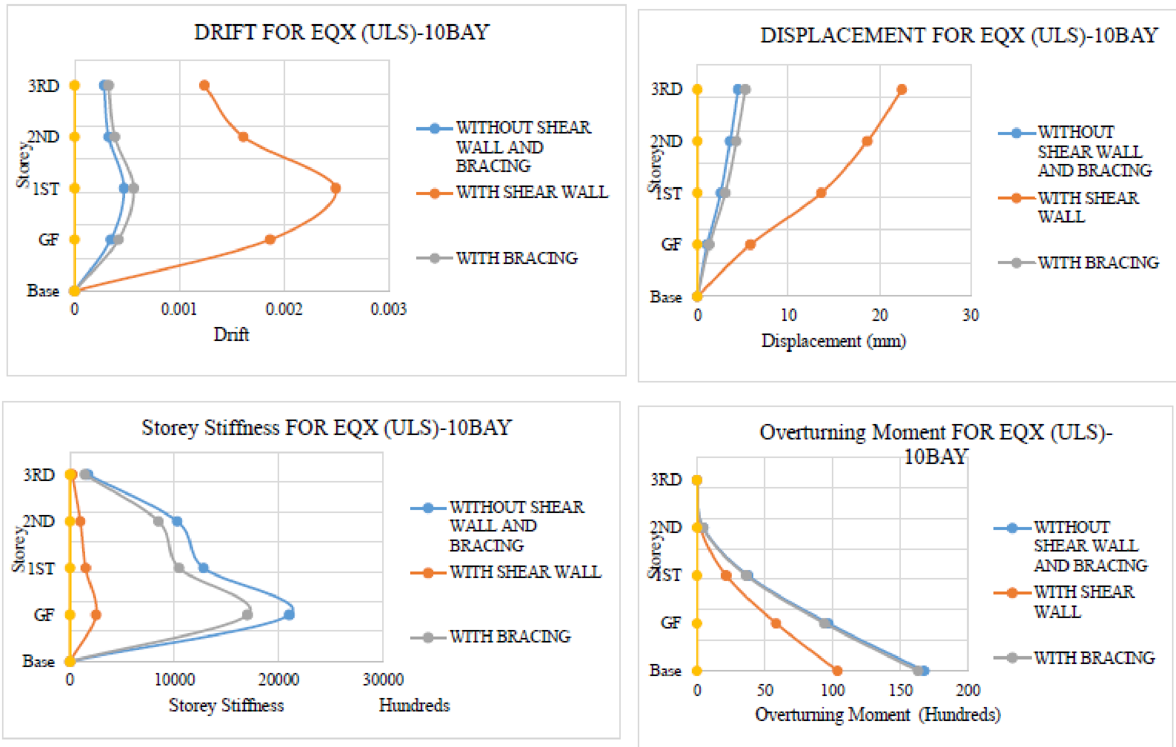


Figure 9: Comparision of storey Drift, Displacement, storey stiffnesss and overturning moment for 3 Storey 10 Bay for EQX (ULS)

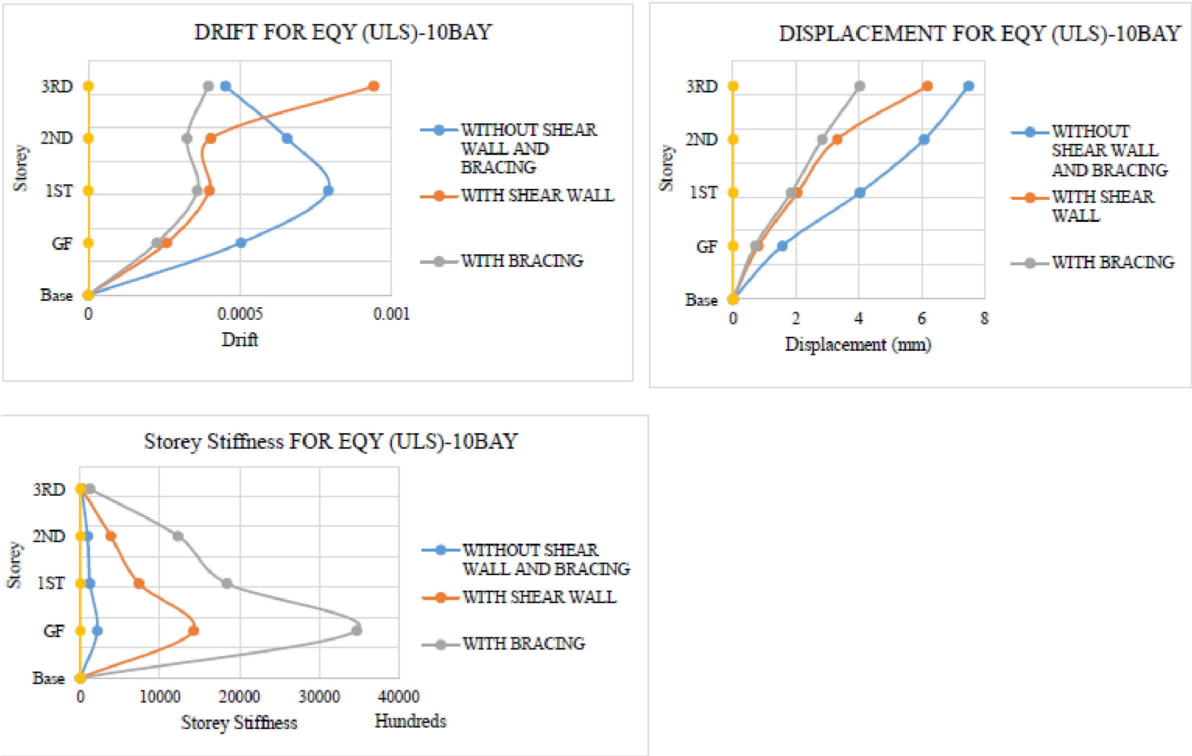


Figure 10: Comparision of storey Drift, Displacement, storey stiffnesss for 3 Storey 10 Bay for EQY (ULS)

4.1.2 Inter-storey Drift, Displacement, Storey stiffness, overturning moment Index of Frames Due to EQX (ULS) and EQY (ULS) For 5-storey

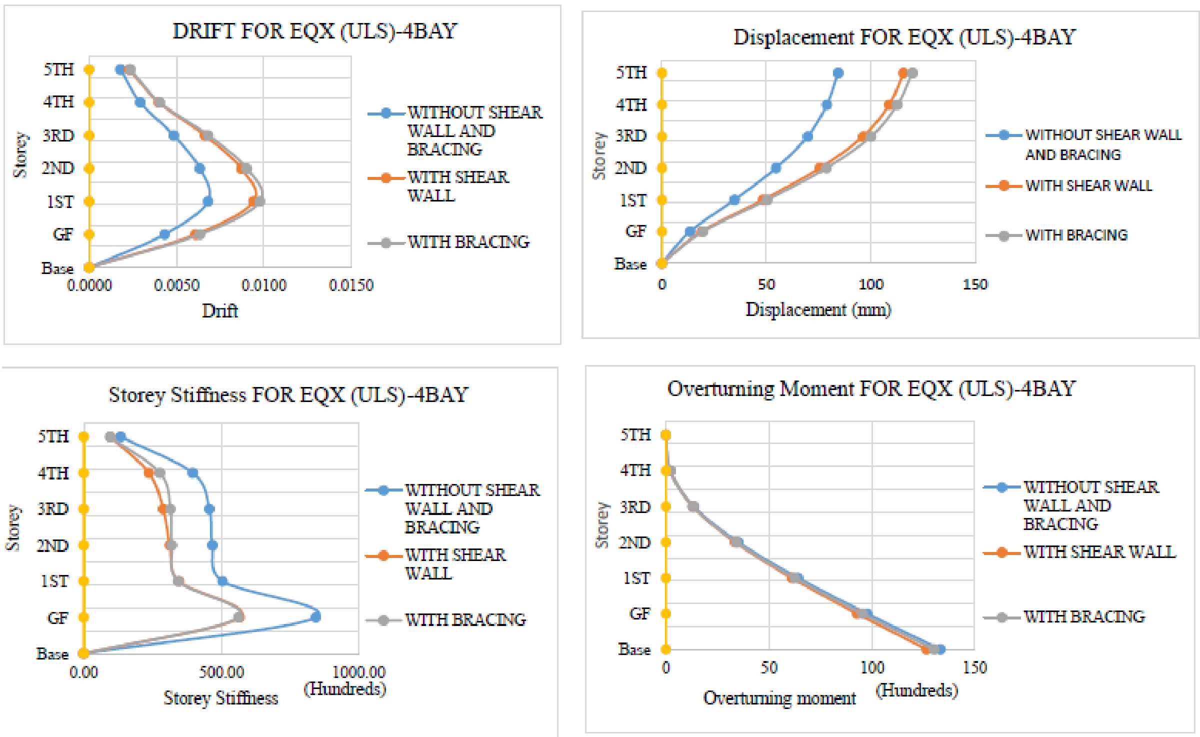


Figure 11: Comparision of storey Drift, Displacement, storey stiffnesss and overturning moment for 5 Storey 4 Bay for EQX (ULS)

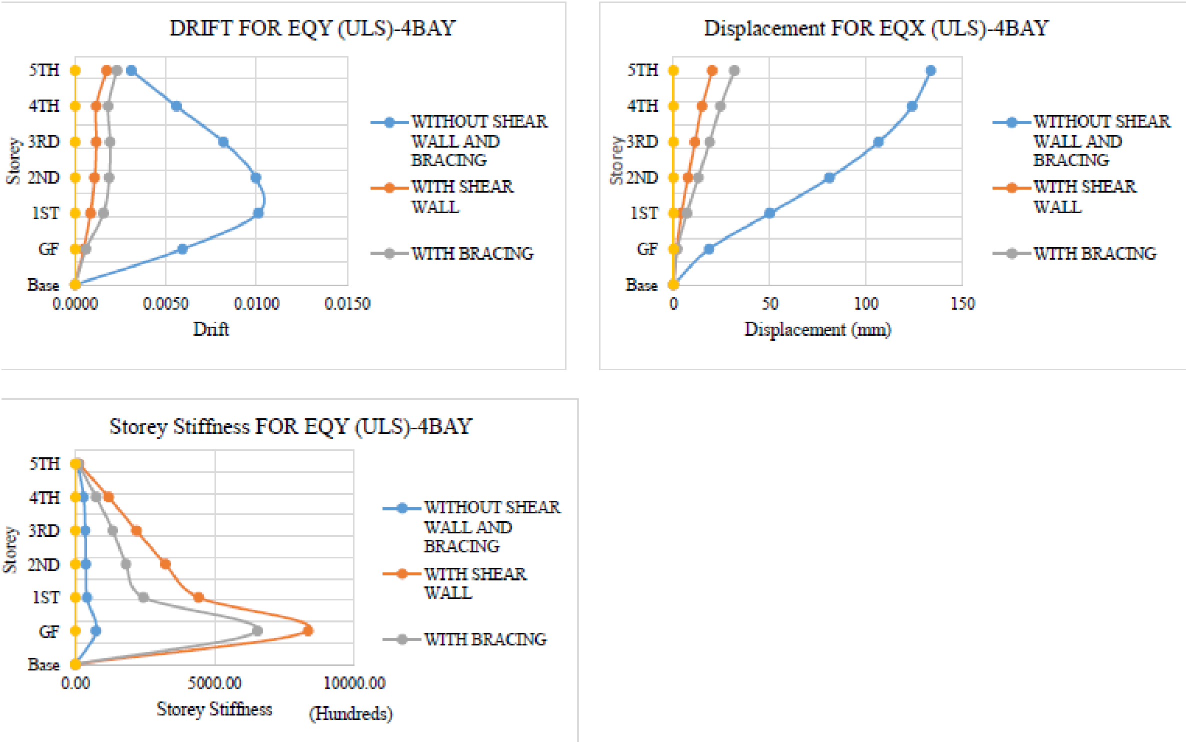


Figure 12: Comparision of storey Drift, Displacement, storey stiffnesss for 5 Storey 4 Bay for EQY (ULS)

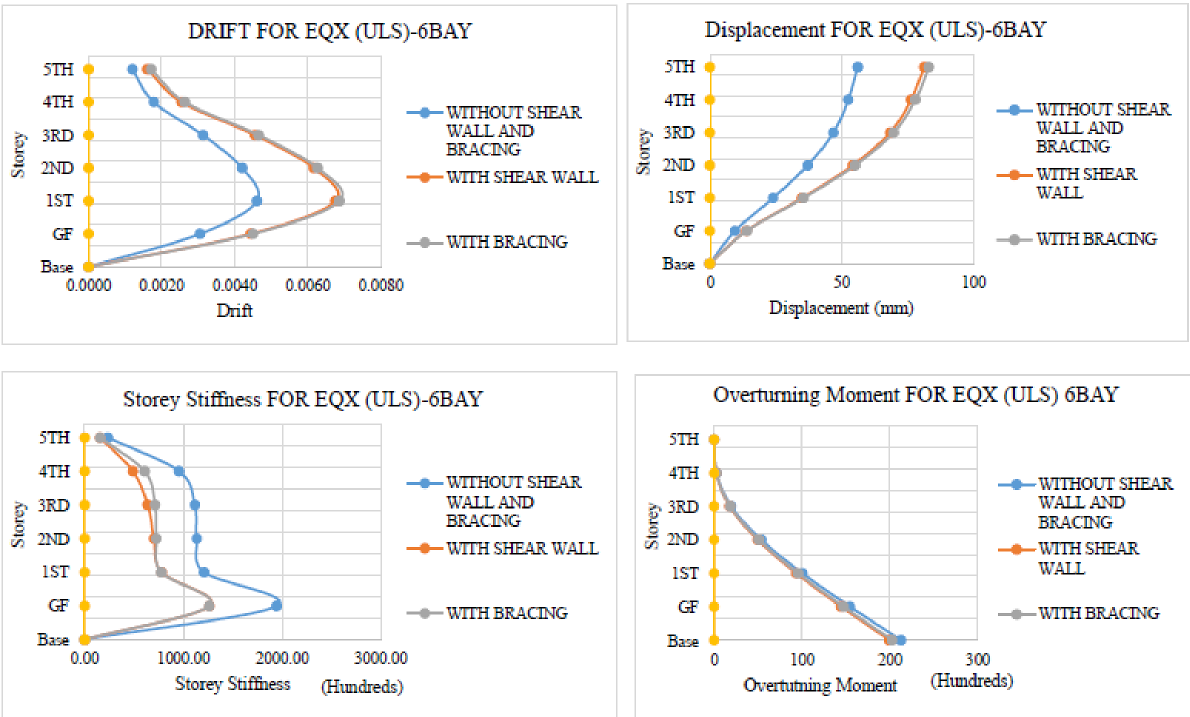


Figure 13: Comparision of storey Drift, Displacement, storey stiffnesss and overturning moment for 5 Storey 6 Bay for EQX (ULS)

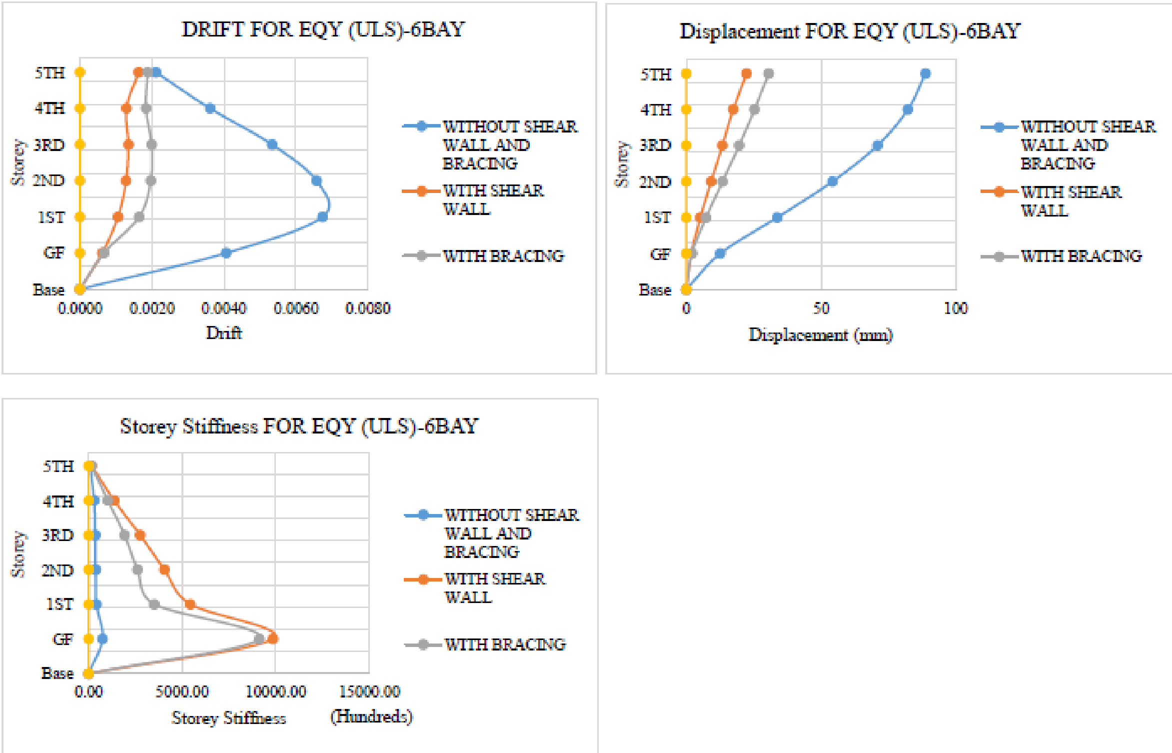


Figure 14: Comparision of storey Drift, Displacement, storey stiffnesss for 5 Storey 6 Bay for EQY (ULS)

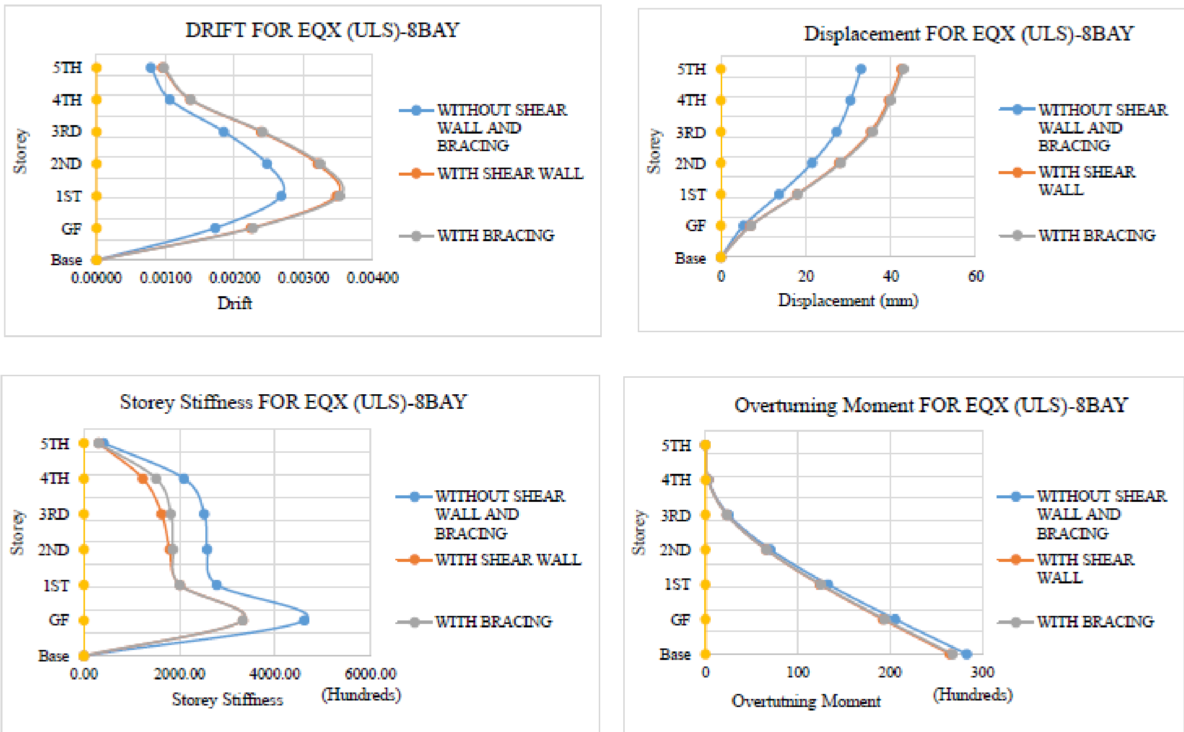


Figure 15: Comparison of storey Drift, Displacement, storey stiffness and overturning moment for 5 Storey 8 Bay for EQX (ULS)

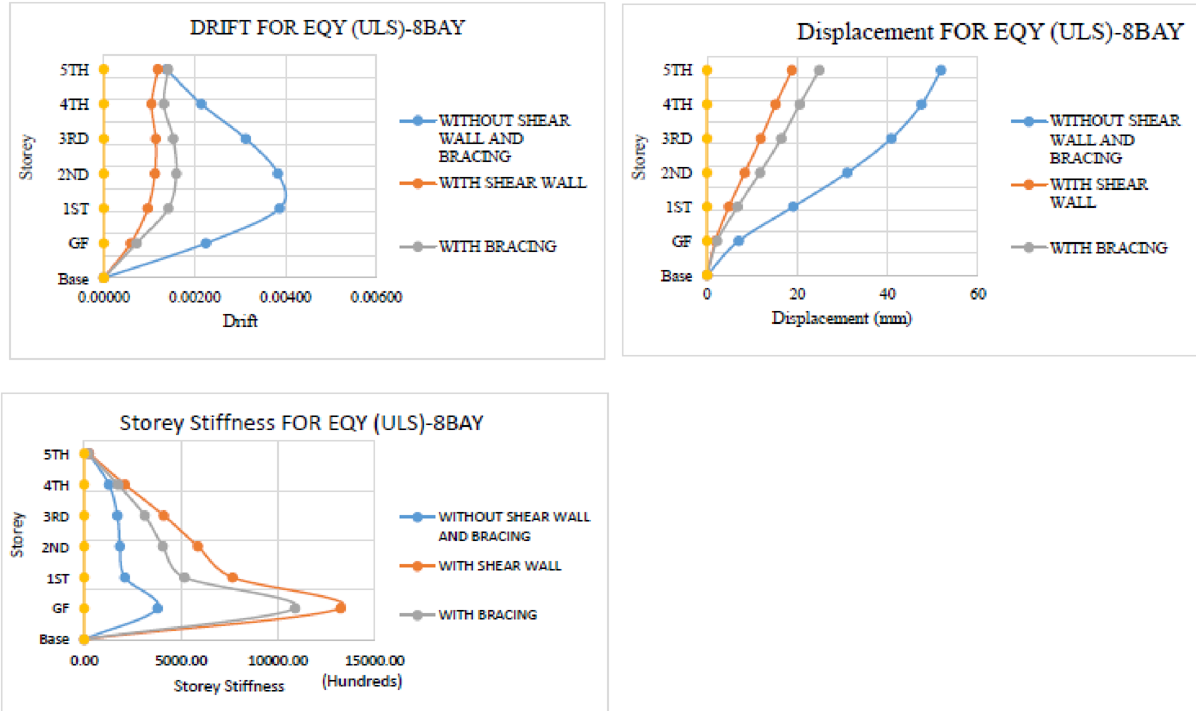


Figure 16: Comparision of storey Drift, Displacement, storey stiffnesss for 5 Storey 8 Bay for EQY (ULS)

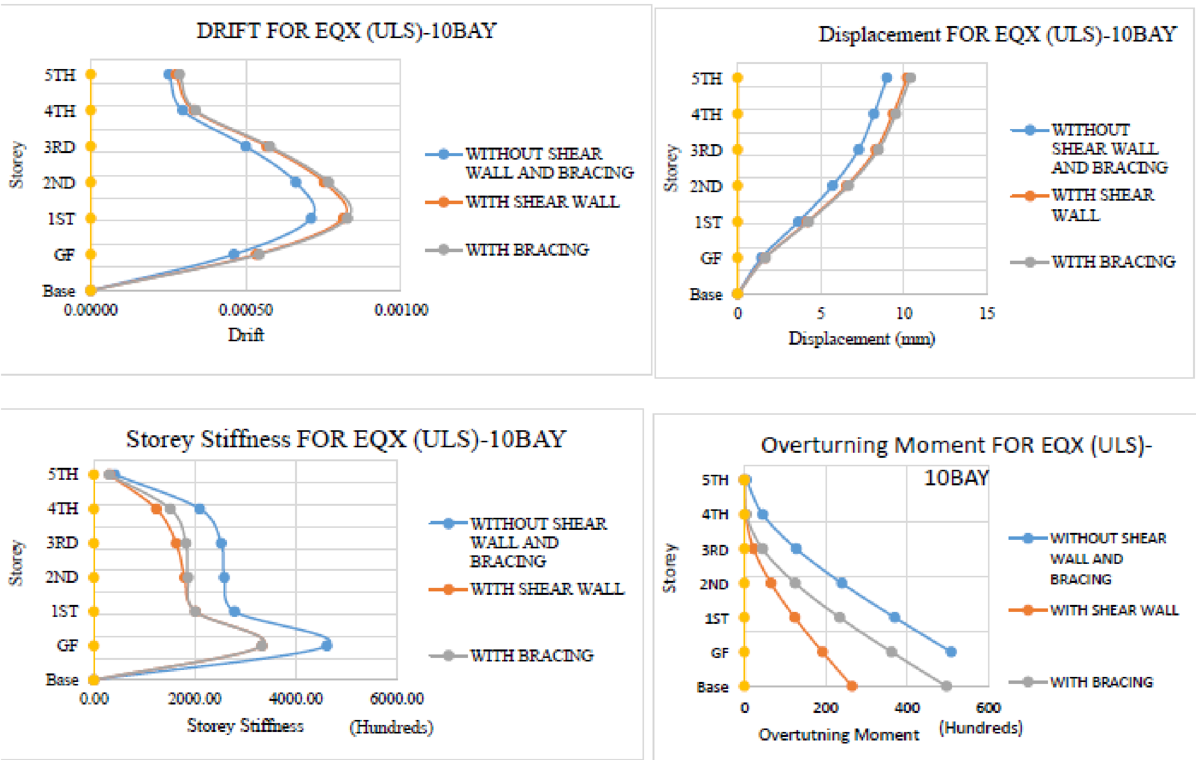


Figure 17: Comparision of storey Drift, Displacement, storey stiffnesss and overturning moment for 5 Storey 10 Bay for EQX (ULS)

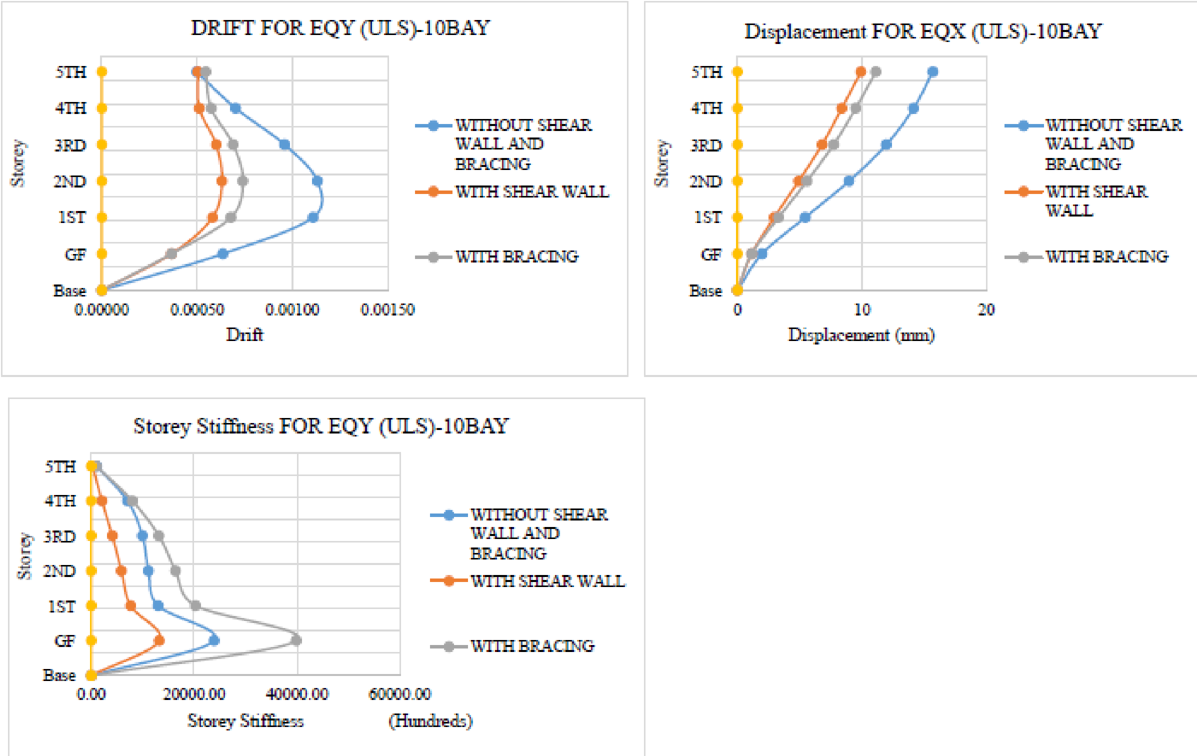


Figure 18: Comparision of storey Drift, Displacement, storey stiffnesss for 5 Storey 10 Bay for EQY (ULS)

4.1.3 Inter-storey Drift, Displacement, Storey stiffness, overturning moment Index of Frames Due to EQX (ULS) and EQY (ULS) For 7-storey

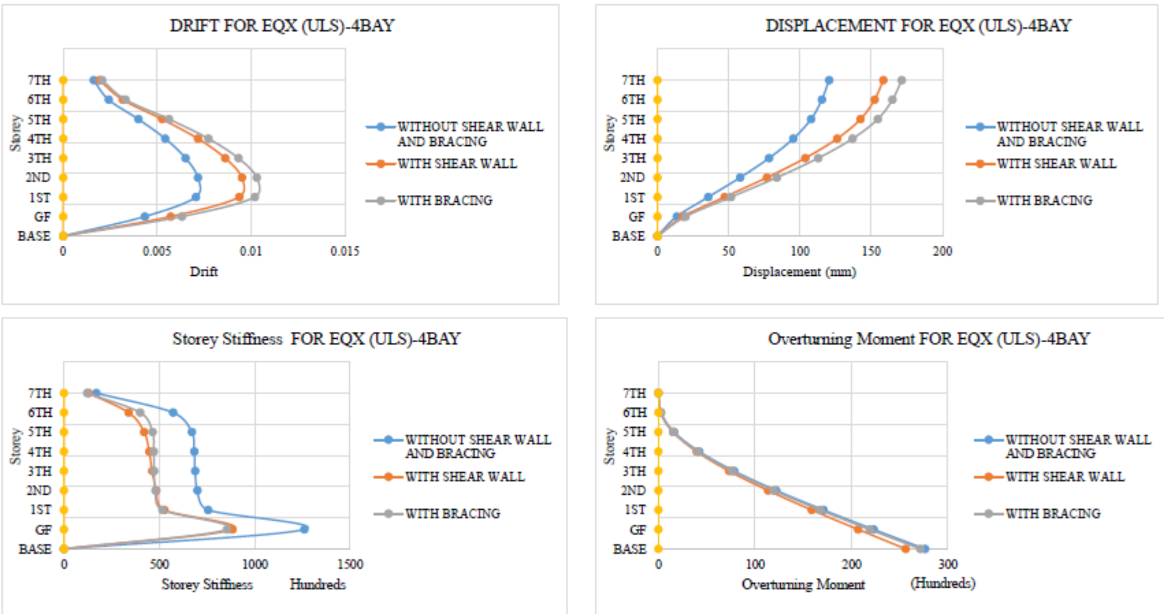


Figure 19: Comparision of storey Drift, Displacement, storey stiffnesss and overturning moment for 7 Storey 4 Bay for EQX (ULS)

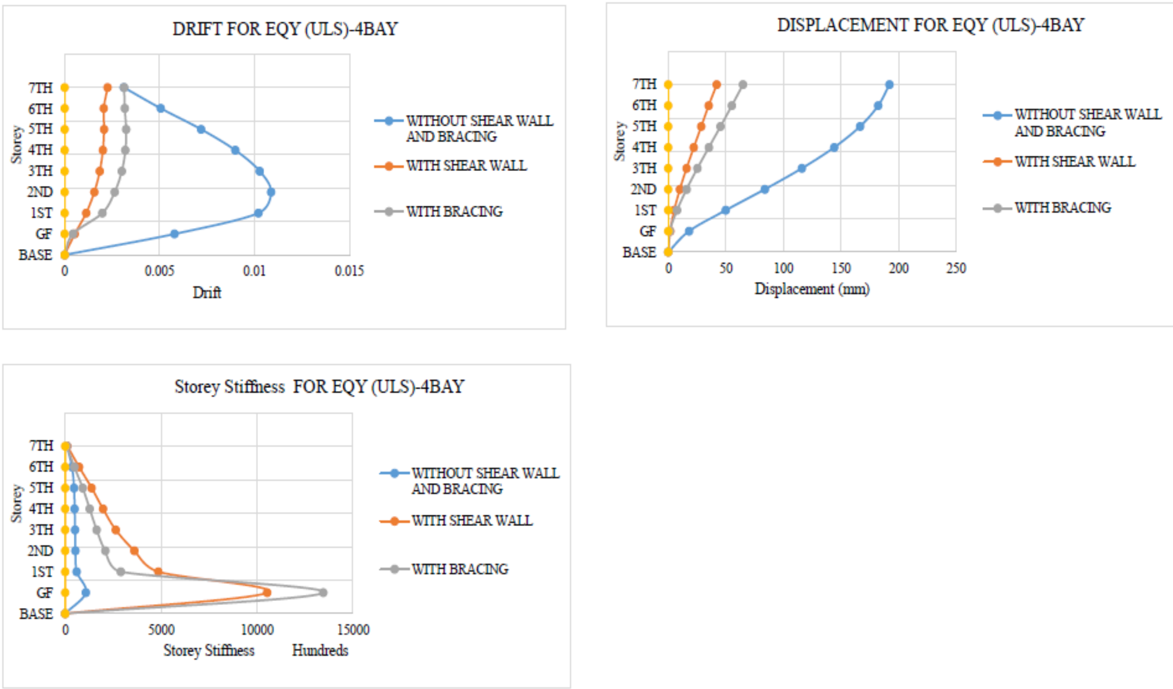


Figure 20: Comparision of storey Drift, Displacement, storey stiffnesss for 7 Storey 4 Bay for EQY (ULS)

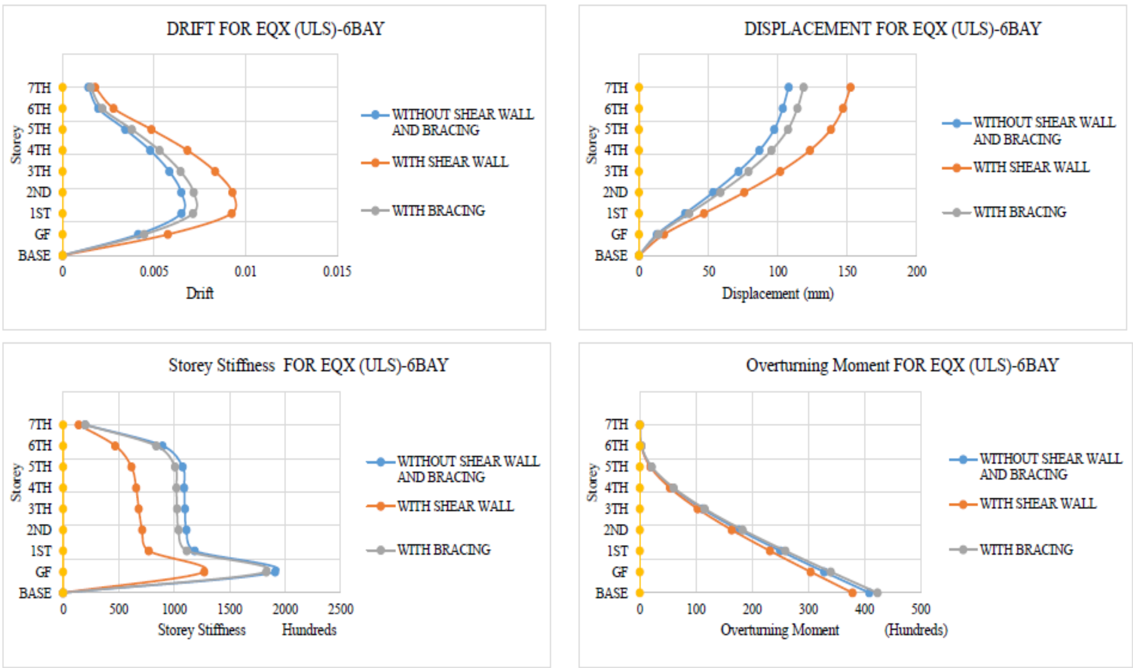


Figure 21: Comparision of storey Drift, Displacement, storey stiffnesss and overturning moment for 7 Storey 6 Bay for EQX (ULS)

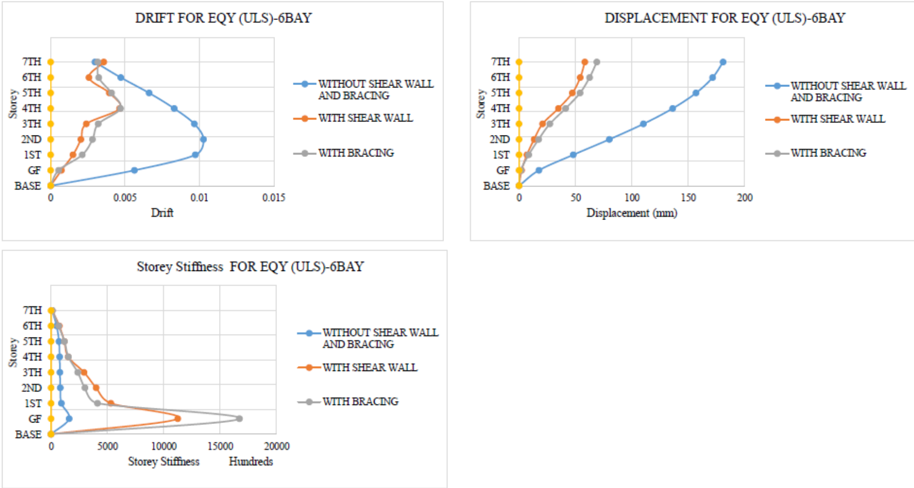


Figure 22: Comparision of storey Drift, Displacement, storey stiffnesss for 7 Storey 6 Bay for EQY (ULS)

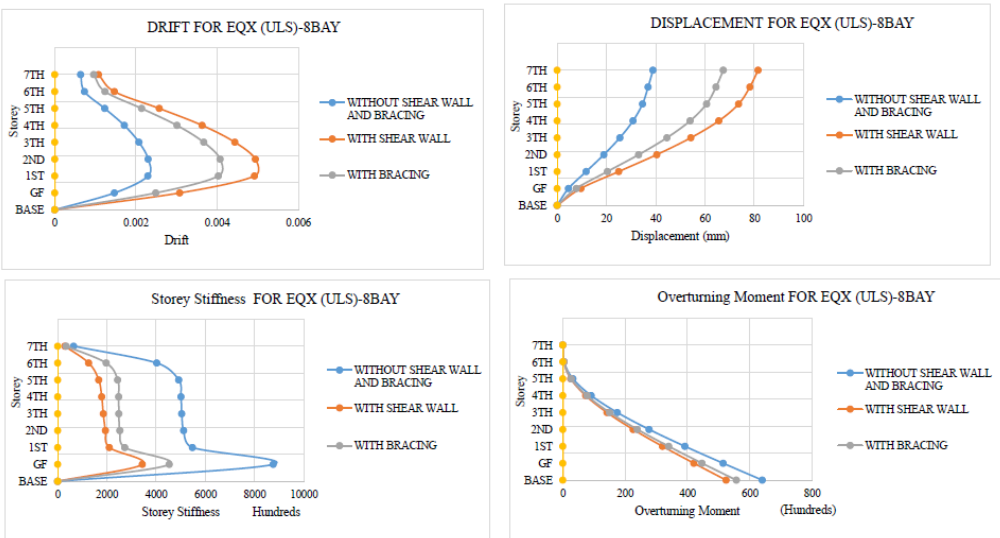


Figure 23: Comparision of storey Drift, Displacement, storey stiffnesss and overturning moment for 7 Storey 8 Bay for EQX (ULS)

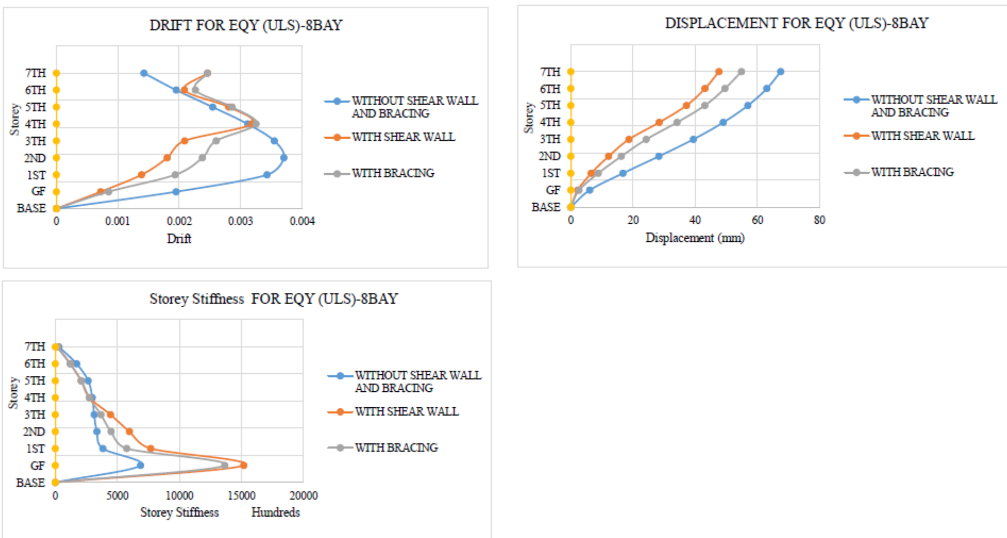


Figure 24: Comparision of storey Drift, Displacement, storey stiffnesss for 7 Storey 8 Bay for EQY (ULS)

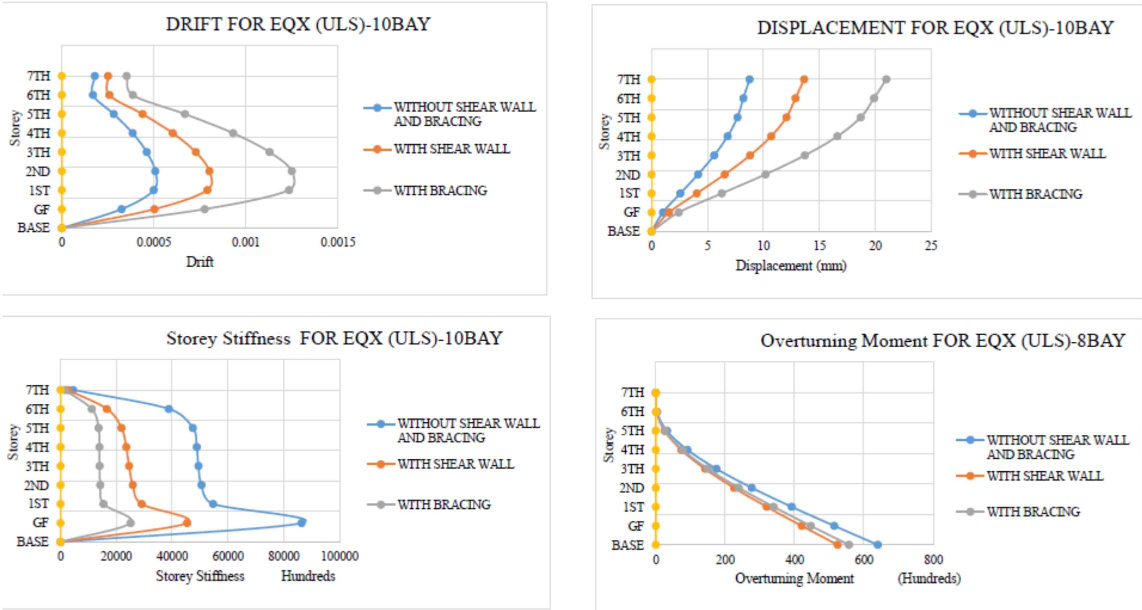


Figure 25: Comparision of storey Drift, Displacement, storey stiffnesss and overturning moment for 7 Storey 10 Bay for EQX (ULS)

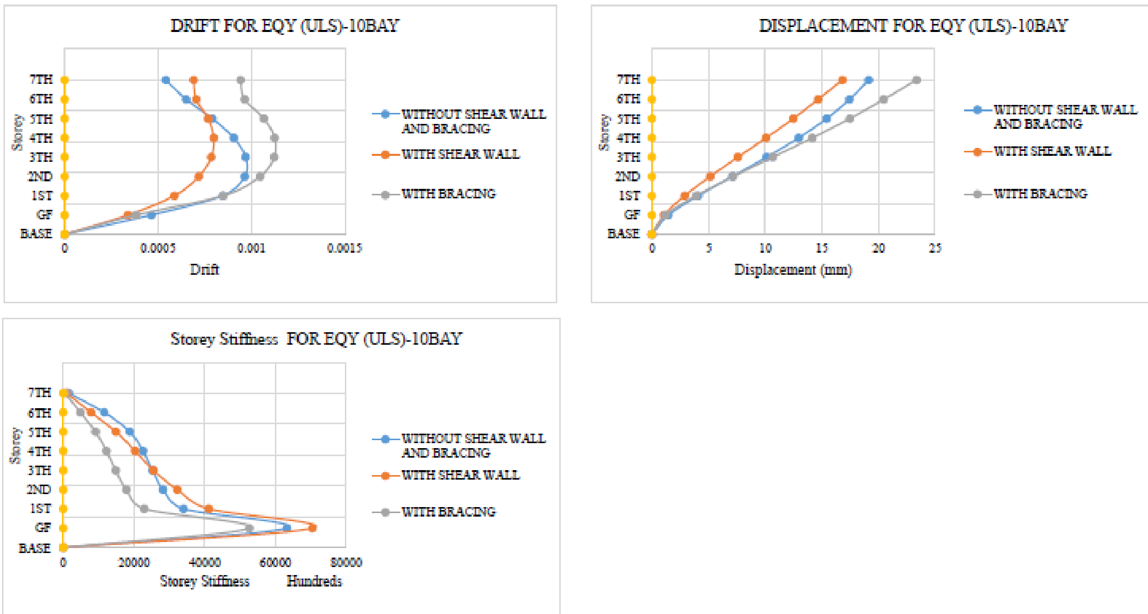


Figure 26: Comparision of storey Drift, Displacement, storey stiffnesss for 7 Storey 10 Bay for EQY (ULS)

From Fig. 5 it is observed that Drift increases by 48.81% in Bracing and increases by 47.67% in shear wall, displacement increases by 49.29% in bracing and increases by 46.23% in shear wall, storey stiffness decreases by 37.075% in bracing and decreases by 37.403% in shear wall and overturning moment decreases by 3.233% in bracing and decreases by 6.954% in shear wall.

From Fig. 6 it is observed that drift decreases by 53.481% in bracing and decreases by 63.775% in the shear wall, displacement decreases by 78.286% in bracing and decreases by 84.106% in the shear wall, stiffness increases by 1029.67% in bracing and increases by 1573.189% in the shear wall.

From Fig. 7, it is observed that drift increases by 33.94% in bracing and increases by 34.45% in the shear wall, displacement increases by 30.59% in bracing and increases by 31.76% in shear wall, Storey Stiffness decreases by 28.28% in bracing and decreases by 31.525% in shear wall, Overturning moment increases by 0.246% in bracing and increases by 5.34% in the shear wall.

From Fig 8, it is observed that drift decreases by 74.48% in the shear wall and decreases by 78.897% in the shear wall, displacement decreases by 65.524% in bracing and decreases by 74.779% in the shear wall, storey stiffness increases by 454.13% in bracing and increases by 497% in the shear wall.

From Fig. 9, it is observed that drift increases by 35.56% in bracing and increases by 86.21% in the shear wall, displacement increases by 33.81% in bracing and increases by 82.64% in the shear wall, storey stiffness decreases by 29.42% in bracing and decreases by 53.84% in the shear wall, overturning moment decreases by 2.48% in bracing and decreases by 11.49% in the shear wall.

From Fig. 10 it is observed that drift decreases by 64.66% in bracing and decreases by 59.73% in the shear wall, displacement decreases by 74.597% in bracing and 74.91% in the shear wall, storey stiffness increases by 439.63% in bracing and increases by 890.35% in the shear wall.

From Fig. 11 it is observed that drift increases by 20.06% in bracing and increases by 426.9% in the shear wall, displacement increases by 18.2% in bracing and increases by 403.5% in the shear wall, storey stiffness decreases by 19.121% in bracing and decreases by 17.409% in the shear wall, overturning moment decreases by 2.70% in bracing and decreases by 38.138% in the shear wall

From Fig 12 it is observed that drift decreases by 55.62% in bracing and increases by 18.96% in the shear wall, displacement decreases by 51.613% in bracing and decreases by 17.409% in the shear wall, storey stiffness increases by 101.72% in bracing and increases by 16.02% in the shear wall.

From Fig. 13, it is observed that drift increases by 43.8% in bracing and increases by 38.34% in the shear wall, displacement increases by 42.08% in bracing and increases by 37.07% in the shear wall, storey stiffness decreases by 33.33% in bracing and decreases by 32.791% in the shear wall, overturning moment decreases by 2.28% in bracing and decreases by 5.018% in the shear wall.

From Fig. 14, it is observed that drift decreases by 77.185% in bracing and decreases by 82.676% in the shear wall, displacement decreases by 76.341% in bracing and decreases by 84.957% in the shear wall, storey stiffness increases by 780.58% in bracing and increases by 1026.3834% in the shear wall.

From Fig. 15, it is observed that drift increases by 48.91% in bracing and increases by 48.07% in the shear wall, displacement increases by 65.524% in bracing and 74.779% in shear wall, storey stiffness decreases by 35.071% in bracing and 34.914% in the shear wall, overturning moment decreases by 4.68% in bracing and 6.24% in the shear wall.

From Fig. 16 it is observed that drift decreases by 70.492% in bracing and decreases by 75.845% in the shear wall, displacement decreases by 65.524% in bracing and 74.779% in the shear wall, storey stiffness increases by 454.134% in bracing and increases by 497.56% in the shear wall.

From Fig. 17 it is observed that drift increases by 31.63% in bracing and 29.8% in the shear wall, displacement increases by 30.44% in bracing and increases by 28.6% in the shear wall, storey stiffness decreases by 27.89% in bracing and 27.81% in the shear wall, overturning moment decreases by 5.423% in bracing and decreases by 6.505% in shear wall.

From Fig. 18 it is observed that drift decreases by 58.781% in bracing and decreases by 69.241% in the shear wall, displacement decreases by 51.979% in bracing and decreases by 63.678% in the shear wall, storey stiffness increases by 187.994% in bracing and increases by 250.460% in the shear wall.

From Fig 19. It is observed that drift increases by 16.48% in bracing and increases by 14.51% in the shear wall, displacement increases by 15.84% in bracing and increases by 13.51 in the shear wall, storey stiffness decreases by 16.75% in bracing and decreases by 16.757% in the shear wall, overturning moment decreases by 2.26% in bracing and decreases by 3.98% in the shear wall.

From fig 20. It is observed that drift decreases by 34.571% in bracing and 44.297% in the shear wall, displacement decreases by 29.128% in bracing and 36.768% in the shear wall, storey stiffness increases by 66.90% in bracing and decreases by 63.947% in the shear wall.

From Fig.21 it is observed that drift increases by 43.70% in bracing and increases by 32.63% in the shear wall, displacement increases by 42.33% in bracing and increases by 31.58% in the shear wall, storey stiffness decreases by 32.22% in bracing and decreases by 29.91% in the shear wall, overturning moment decreases by 1.75% in bracing and decreases by 7.23% in the shear wall.

From Fig. 22 it is observed that drift decreases by 70.19% in bracing and decreases by 79.17% in the shear wall, displacement decreases by 66.21% in bracing and decreases by 78.07% in the shear wall, storey stiffness increases by 1152.17% in bracing and increases by 880.03% in the shear wall.

From Fig. 23 it is observed that drift increases by 10.32% in bracing and increases by 42.97% in the shear wall, displacement increases by 9.98% in bracing and increases by 41.37% in the shear wall, storey stiffness decreases by 4.17% in bracing and decreases by 33.46% in the shear wall, overturning moment increases by 3.53% in bracing and decreases by 7.34% in shear wall.

From Fig. 24 it is observed that drift decreases by 54.28% in bracing and decreases by 54.90% in the shear wall, displacement decreases by 61.89% in bracing and decreases by 67.77% in the shear wall, storey stiffness increases by 945.3% in bracing and increases by 602.48% in the shear wall.

From Fig.25 it is observed that drift increases by 77.05% in bracing and increases by 114.73% in the shear wall, displacement increases by 73.51% in bracing and increases by 109.78% in the shear wall, storey stiffness decreases by 48.24% in bracing and decreases by 60.70% in the shear wall, overturning moment decreases by 13.01% in bracing and decreases by 18.14% in the shear wall.

From Fig.26 it is observed that drift decreases by 12.26% in bracing and decreases by 14.15% in the shear wall, displacement decreases by 18.67% in bracing and decreases by 29.38% in the shear wall, storey stiffness increases by 98.82% in bracing and increases by 121.05% in the shear wall.

From Fig. 27 it is observed that drift increases by 146.35% in bracing and increase by 57% in the shear wall, displacement increases by 139.66% in bracing and increases by 55.71% in the shear wall, storey stiffness decreases by 70.91% in bracing and decreases by 47.52% in the shear wall, overturning moment decreases by 30.85% in bracing and decreases by 18.64% in the shear wall.

From Fig. 28 it is observed that drift increases by 16.0% in bracing and decreases by 17.65% in the shear wall, displacement increases by 22.01% in bracing and 12.15% in the shear wall, storey stiffness decreases by 16.77% in bracing and increases by 11.36% in the shear wall.

Here, Drift and Displacement increase in the orthogonal direction of the shear wall and bracing plane as stiffness decreases in the direction and the structure remains more flexible.

III. CONCLUSION

From the analysis of the different models of single Bay RCC building the following points were concluded:

1. From the analysis of Single bay RCC buildings without bracing and shear wall, it is found that structural member size increases significantly with the increases in the number of bays and the number of the storey for the permissible limit of drift and displacement, hence the single bay RCC building may not be suitable with increases in the number of the bay in another direction and increase in the number of storeys.
2. From the analysis of Single bay RCC Building with Bracing, it is found that the drift and displacement reduced in the direction of bracing i.e. along the Y-direction. Stiffness increases and overturning moment decreases. Hence Bracing can be more Convenient in single-bay RCC Buildings
3. From the analysis of Single bay RCC Buildings with Shear wall, it is found that the drift and displacement reduce more than that in bracing along the Y-direction. Storey stiffness Increases and the Overturning moment decreases. Hence Shear walls can be more Convenient in Single bay RCC Buildings.
4. From the analysis of the Single Bay RCC building, it is found that drift and displacement increase along the direction of the bay and shear wall for both types of models of single bay with bracing and shear wall and Storey stiffness decreases.
5. From the analysis of Single bay RCC building with bracing and shear wall, it is found that drift and displacement significantly reduce in the bracing system and reduced more in the shear wall. Storey Stiffness increases and the overturning moment decreases more in the shear wall. Hence the shear wall is more effective than the Bracing system in the single bay RCC building with increases in the number of storeys.

5.1 Recommendation

1. Investigate the potential of combining bracing and shear walls in single-bay RCC buildings. This hybrid approach could potentially offer a balanced solution, leveraging the advantages of both systems to optimize seismic performance.
2. The study can be performed with Non-Linear Analysis Approach for further investigation.

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