Seismic Evaluation of Building with Buckling Restrained Braces (BRB)

Nayana Surendran, Dr. K Subha

Abstract— In General, Civil engineering structures are susceptible to the severe damage when subjected to enormous cyclic forces during a seismic event. Many of the structural failures in buildings during strong earthquake shaking have indicated that sustainable strength and stable energy dissipation capability are most desirable to maintain inter story drifts and overall structural displacements within tolerable levels. The bracing is one of the best lateral load resisting systems and it will be the viable solution for enhancing earthquake resistance. A Bracing is a system that is provided to minimize the lateral deflection of structure. Steel bracing are the common type which mainly used to resist the lateral loads acting during a seismic activity. Conventional type of lateral load resisting systems are concentrically-braced frames (CBFs) and eccentrically braced frames (EBF). Buckling Restrained Braces(BRB) are the new generation of bracing which has a stable energy dissipation property Characteristic feature of BRB is its ability to yield both in tension and compression without buckling, thus obtaining a stable hysteresis loop. The BRB brace placed in a concentric frame is termed as BRBF system. In this paper behaviour of different configuration of BRB for different earthquake data is studied. Also, the effective location of bracing is discussed. Non linear time history analysis were carried out to assess the structural performance of different configuration of BRB under earthquake ground motions. These models are compared in different aspects such as inter storey drift, storey displacement and base shear.

Index Terms— lateral load resisting system, concentrically-braced frames, eccentrically braced frames, Buckling Restrained Braces(BRB), inter storey drifts,hysteresis loop, stable energy dissipation,

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1 INTRODUCTION

Nowadays, energy dissipation devices are commonly used in structures. High rate of energy absorption during earthquakes is the benefit of using such devices, which results in damage reduction of structural elements, specifically columns Earthquakes causes economic losses as well as losses of lives due to collapse of structures. During a severe earthquake event, the main structural elements like beams and columns are seriously affected. So, a structural engineer has great concern in designing earthquake resisting system to dissipative energy effectively from the structure.

The primary function of an energy dissipation element is to reduce the damage in main structural components. Bracings are widely used to stabilize the structure against the lateral loads generated due to wind, earthquakes etc. Main drawback of conventional bracing is the degradation of brace strength under compression due to buckling of the brace. BRB is an effective solution for this problem. Buckling restrained braced frame system is one such earthquake resisting system which is much more efficient than conventional concentric braces.

2 THEORETICAL BACKGROUND

2.1 Buckling Restrained Braces

Buckling-Restrained Braces (BRBs) are a relatively recent development in the field of lateral load resisting structures. The concept of BRB was first conceptualized by Wakabayashi a Japanese engineer.

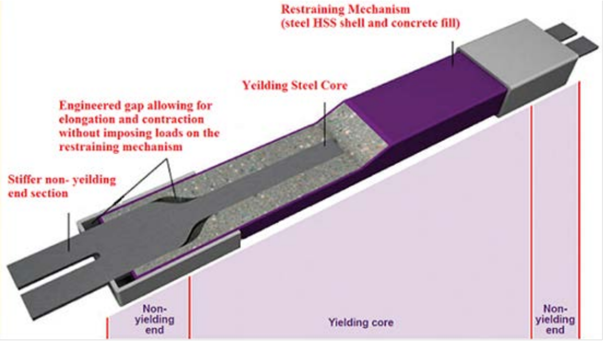

Fig 1 Typical BRB

The basic principle in the construction of BRB is to prevent buckling of a central steel core by encasing it over its length in a steel tube filled with or without concrete or mortar. BRB shows a symmetry in the response during the action of lateral loads and BRB is designed in such a way that the buckling during the compression cycle is avoided. BRB have a stable

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force-deformation curve during tension and compression cycle while concentric brace performs well during tension cycle and experiences buckling during the compression cycle.

3 STRUCTURAL MODELLING AND ANALYSIS

3.1 Modelling of Brace

The computational model of the BRB was developed using the software ANSYS workbench version 16.1. model of all steel BRB includes the core plate and a tube as the restrainer with sufficient air gap[9]. Geometric shape of section used is shown in figure 2 and table 3 contains the details of BRB

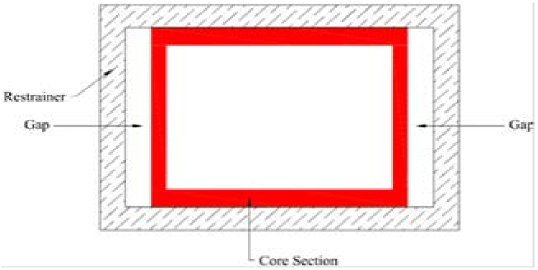

Fig 2. Typical cross section of BRB

Table 3 Details of BRB

Restrainer Dimensions (mm)	140x100x10
Length (mm)	2000
Core Plate Section	2UPN80
Core Area (mm^2)	2368
Gap (mm)	10
Yield stress F_y	370 Mpa
Poisson's ratio	0.3
Young's modulus	200 Gpa

Backbone is the maximum value at each displacement increment simply extracted by connecting the envelope of the hysteresis curves. Figure 3 shows the backbone curve. Backbone curve extracted from hysteresis loop is introduced to SAP 2000

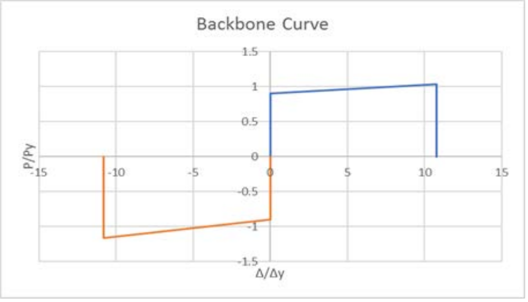

Fig 3 Backbone Curve of BRB

3.2 Modelling of Building

A four storied RC building is modelled in SAP 2000. Details of the building is shown in table. The building has five bays in X direction and five bays in Y direction with the plan dimension 25 m × 20 m. The typical plan details of regular building is shown in figures 4 and 7 type of models are considered with different configuration mainly single diagonal, V brace and inverted V brace. The ground excitations of Kobe, Loma and Northridge are considered for the non-linear time history analysis.

Table 4 Details of the building

Beam size	0.35m x 0.5m
Column size	0.45m x 0.9m
Slab thickness	0.120m
Unit weight of concrete	25.0 KN/m^3
floor finish	1.5 KN/m^2
live load	3.5 KN/m^2

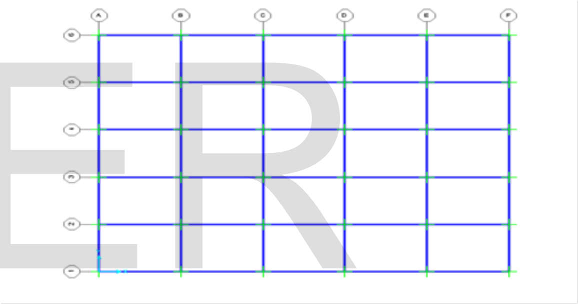

Fig 4 Plan of the building

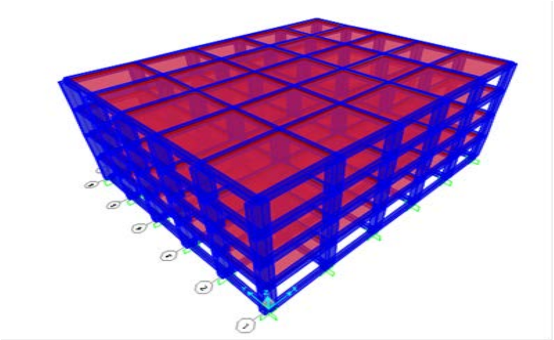

Fig 5 Model 1A of Regular Building

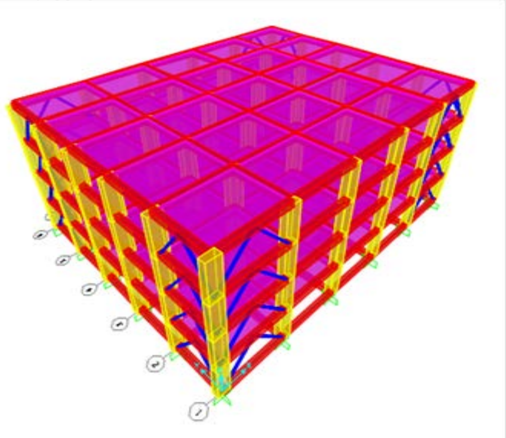

Fig 6 Model 1B of Building with BRB (inverted V) at corner location

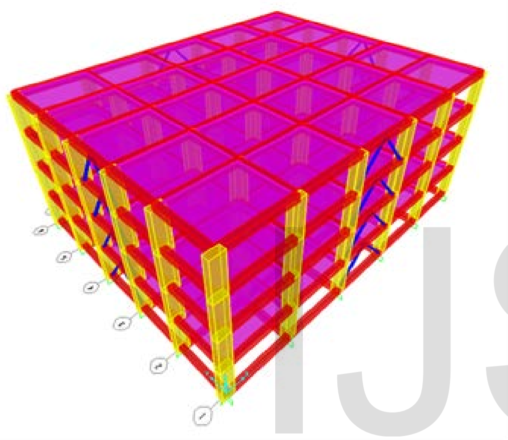

Fig 7 Model 1C of Building with BRB (inverted V) at middle bay

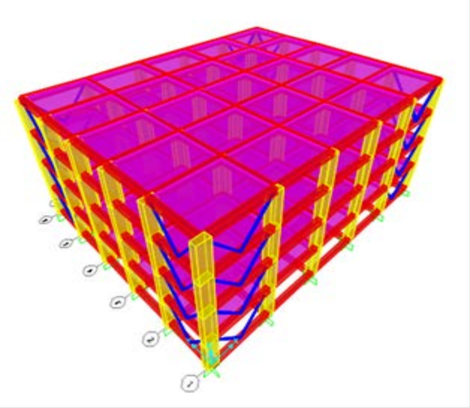

Fig 8 Model 1E of Building with BRB (V) at middle bay

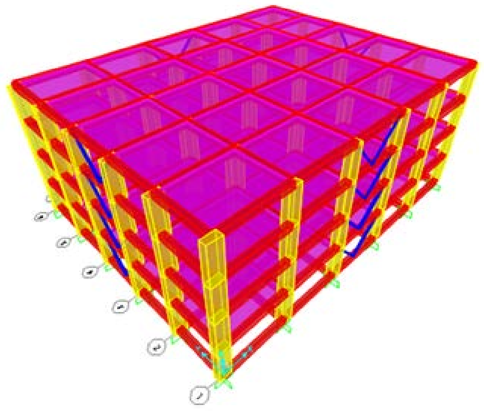

Fig 9 Model 1E of Building with BRB (V) at middle bay

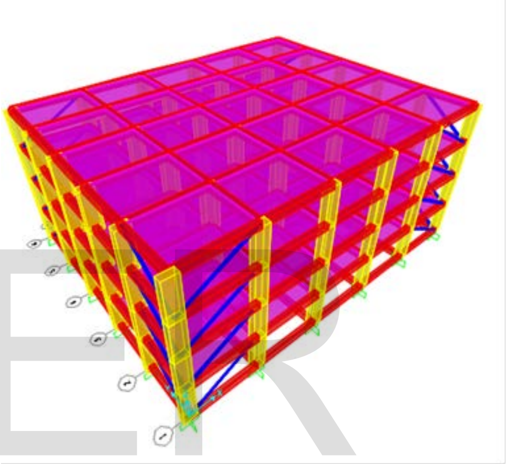

Fig 10 Model 1F of Building with BRB (single diagonal) at corner location

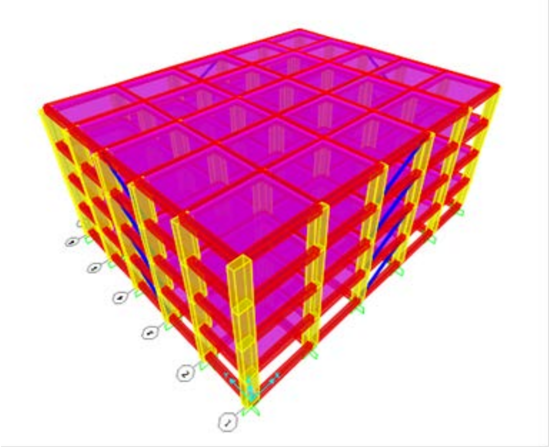

Fig 11 Model 1G of Building with BRB (single diagonal) at middle bay

4 RESULT AND DISCUSSIONS

4.1 Variation of Inter- storey Drift ratio

Inter-storey drift is the difference between the roof and floor displacements of any given storey as the building sways during the earthquake, normalized by storey height. The results obtained are tabulated in the table 5, 6 and 7

Table 5 Variation of Inter- storey Drift ratio along storey levels for Kobe Earthquake

Kobe	Model 1A	Model 1B	Model 1C	Model 1D	Model 1E	Model 1F	Model 1G
Ground	0	0	0	0	0	0	0
1	0.3066	0.016667	0.02667	0.01667	0.03	0.07667	0.1
2	0.33	0.03	0.0433	0.02667	0.05	0.08	0.10667
3	0.3333	0.026667	0.033	0.02667	0.04667	0.0633	0.09667
4	0.29	0.02	0.03333	0.02	0.033	0.04	0.07

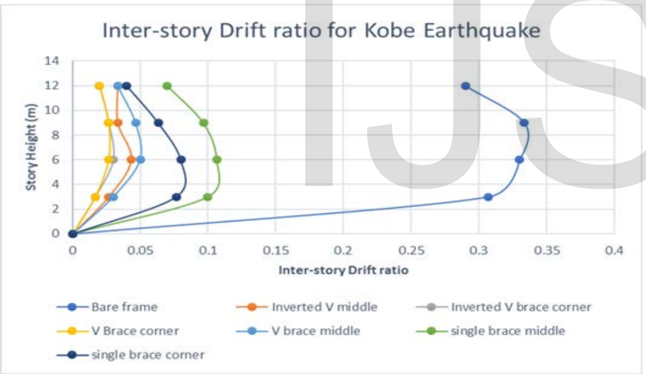

Fig 12 Variation of Inter- storey Drift ratio along storey levels for Kobe Earthquake

Table 6 Variation of Inter- storey Drift ratio along storey levels for Loma Earthquake

Loma	Model 1A	Model 1B	Model 1C	Model 1D	Model 1E	Model 1F	Model 1G
Ground	0	0	0	0	0	0	0
1	0.293	0.117	0.0467	0.04667	0.1033	0.1067	0.1067
2	0.373	0.2	0.0867	0.07	0.2067	0.19	0.2033
3	0.4	0.18	0.07	0.07	0.22	0.193	0.1933
4	0.356	0.12	0.0467	0.0467	0.1767	0.15	0.1433

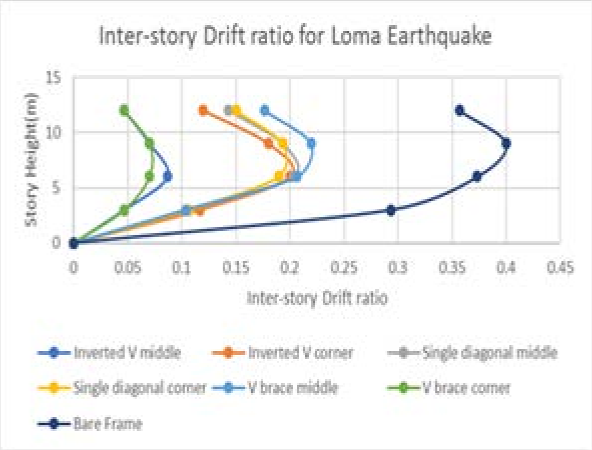

Fig 13 Variation of Inter- storey Drift ratio along storey levels for Loma Earthquake

Table 7 Variation of Inter- storey Drift ratio along storey levels for Northridge Earthquake

Northridge	Model 1A	Model 1B	Model 1C	Model 1D	Model 1E	Model 1F	Model 1G
Ground	0	0	0	0	0	0	0
1	0.48667	0.13	0.1	0.1	0.1033	0.0933	0.11
2	0.88	0.2267	0.2167	0.2533	0.21667	0.20667	0.21667
3	0.8133	0.2	0.2433	0.2	0.24667	0.23	0.26
4	0.64667	0.1267	0.22	0.1267	0.22	0.21	0.2367

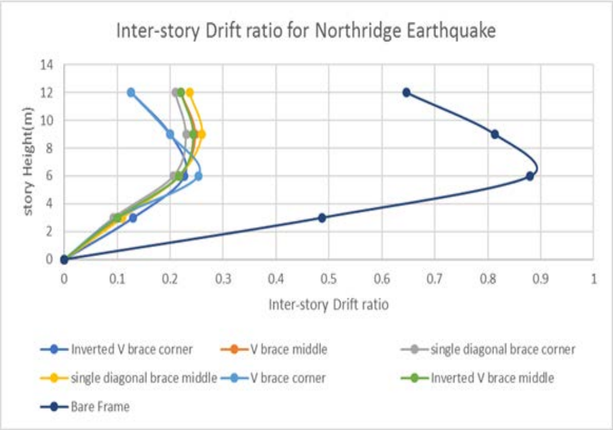

Fig 14 Variation of Inter- storey Drift ratio along storey levels for Northridge Earthquake

4.2 Variation of Storey Displacement

Storey displacement is the lateral displacement of the storey relative to the base. The results obtained are tabulated in the table 8, table 9 and table 10.

Table 8 Variation of Storey displacement (m) along storey levels for Kobe Earthquake

Kobe	Model 1A	Model 1B	Model 1C	Model 1D	Model 1E	Model 1F	Model 1G
Ground	0	0	0	0	0	0	0
1	0.0092	0.0005	0.0008	0.0005	0.0009	0.0023	0.003
2	0.0191	0.0014	0.0021	0.0013	0.0024	0.0047	0.0062
3	0.0291	0.0022	0.0031	0.0021	0.0038	0.0066	0.0091
4	0.0378	0.0028	0.0041	0.0027	0.0048	0.0078	0.0112

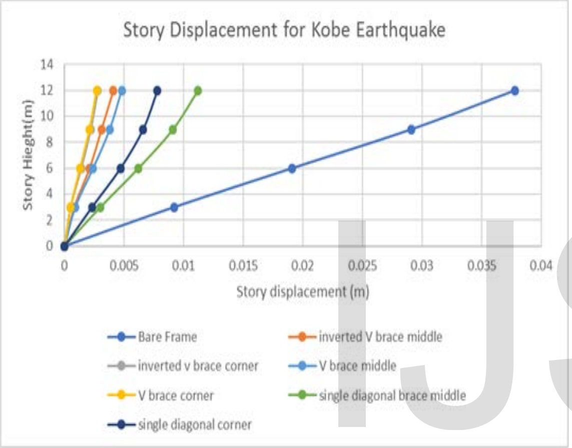

Fig 15 Variation of Storey displacement (m) along storey levels for Kobe Earthquake

Table 9 Variation of Storey displacement (m) along storey levels for Loma Earthquake

Loma	Model 1A	Model 1B	Model 1C	Model 1D	Model 1E	Model 1F	Model 1G
Ground	0	0	0	0	0	0	0
1	0.0088	0.0035	0.0014	0.0014	0.0031	0.0032	0.0032
2	0.02	0.0095	0.004	0.0035	0.0093	0.0089	0.0093
3	0.032	0.0149	0.0061	0.0056	0.0159	0.0147	0.0151
4	0.0427	0.0185	0.0075	0.007	0.0212	0.0192	0.0194

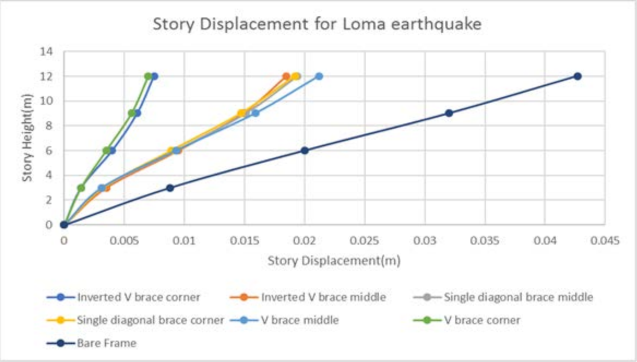

Fig 16 Variation of Storey displacement (m)along storey levels for Loma Earthquake

Table 10 Variation of Storey displacement (m)along storey levels for Northridge Earthquake

Northridge	Model 1A	Model 1B	Model 1C	Model 1D	Model 1E	Model 1F	Model 1G
Ground	0	0	0	0	0	0	0
1	0.0146	0.0039	0.0031	0.003	0.0031	0.0028	0.0033
2	0.041	0.0107	0.0096	0.0106	0.0096	0.009	0.0098
3	0.0654	0.0167	0.017	0.0166	0.017	0.0159	0.0176
4	0.0848	0.0205	0.0236	0.0204	0.0236	0.022	0.0247

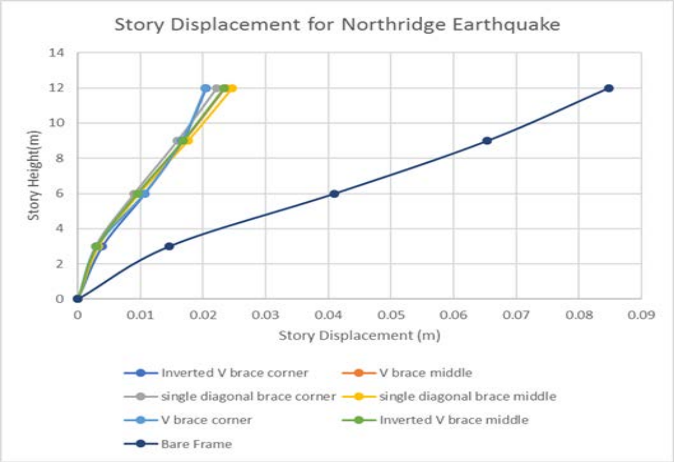

Fig 17 Variation of Storey displacement (m)along storey levels for Northridge Earthquake

Variation of storey displacement along storey levels for three set of earthquakes mainly Kobe, Loma and Northridge shows similar pattern of behaviour. Building with BRB has lower displacement value when compared to the building without BRB. For all the three earthquakes, BRB bracing provided in the corner location shows more effective than the middle bay. This pattern of behaviour is same for inverted V brace, V brace and single diagonal brace.

4.3 Variation of Base Shear

Base shear is defined as the maximum expected lateral force that will occur due to seismic ground motion at the base of the structure. The results for base shear obtained for earthquake is tabulated in the table 11

Table 11 Variation of Base Shear for Different Cases

BASE SHEAR (kN)			
Model Type	Kobe	Loma	North Ridge
1A	10189.85	32263.189	35332.994
1B	1442.07	5395.8	9550
1C	1709.031	6257.29	6890.2
1D	1438.27	5247.5	6886.9
1E	2127.78	6830.13	9533.35
1F	4385.08	7026	6199.31
1G	4673.71	7801.02	7704

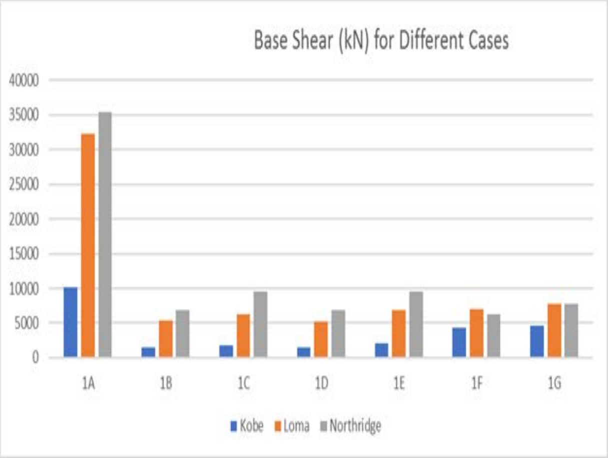

Fig 18 Variation of Base Shear for Different Cases

5 CONCLUSION

From the present study, the following conclusions are observed:

- Inter- story drift ratio of the building with BRB shows lesser value compared to the bare frame. This may be due to the symmetric behavior of the brace
- The story displacement of the building with BRB is considerably decreased which shows the effectiveness of BRB in resisting the seismic force
- V brace shows lower value for Inter -story drift and story displacement when compared with other type of brace configuration for the given set of earthquake data.
- While comparing the location of bracing, corner location shows better result compared to middle bracing.
- Base shear of building with BRB is lesser compared to the building without bracing. This shows some amount of energy is dissipated through the action brace
- V brace at the corner location shows lesser base shear value when compared to other type of configuration for two set of earthquakes (Kobe and Loma). For Northridge earthquake, base shear value is lesser for single diagonal bracing provided at the corner location

6 RECOMMENDATIONS AND SCOPE FOR FUTURE WORK

- The study considered building with symmetric in plan. Building with un-symmetric plan can also be studied.
- The study can be extended to 3D steel structures
- Only low-rise building is considered in this study. So, it can be done with tall buildings and the effects can be evaluated.
- Only three set of earthquake datas are considered in this study. It shows a contradiction in the value of base shear and thus it cannot be generalized. Therefore, more set of earthquake datas should be considered for the future study.

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