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DISPLACEMENT ANALYSIS OF SAC FRAMES UNDER DIFFERENT BRACING SYSTEMS & ISOLATORS

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ABSTRACT

Earthquake causes the shaking of the Earth's surface, resulting from the sudden release of energy in the Earth's lithosphere that creates seismic waves. The objective of the study has been to observe the displacement behavior of a structure under different earthquake excitations and static loading. A 9 story SAC (joint venture between the Structural Engineers Association of California, the Applied Technology Council and the California Universities for Research in Earthquake Engineering) frame model is selected for this present study following LOS Angles method of FEMA-355C using the computer program SAP2000 v14. Different types of bracing systems namely: eccentric bracing and V bracing and also rubber base isolator have been incorporated into the structure accordingly. Excitations data from Fukushima and Corralit earthquake has been used as dynamic loading. A comparative study has been carried out amongst all the cases to observe different response under static and dynamic loading. Results showed that, the maximum displacement values are governed by the base isolated structure and the minimum displacement values are governed by the V braced structure for both static and dynamic loading. The maximum top displacement value of isolated structure is 1.7 inch & the minimum value is 0.003 inch for V braced structure. Again, maximum displacement value under static loading is 64.7 percent higher than that under Corralit earthquake. Finally, it can be said that, the structure has more displacement when it is subjected to static loading than being subjected to dynamic loading.

Keywords: *Displacement, SAC frame, base isolator and different bracing systems, static loading, Fukushima and Corralit earthquake.*

1. INTRODUCTION

The sac (joint venture between the structural engineers association of California, the applied technology council and the California universities for research in earthquake engineering) joint venture was formed in mid-1994 with the goal of developing reliable, practical and cost-effective guidelines and standards of practice for repairing or upgrading damaged steel moment frame buildings, the design of new steel buildings, and the identification and rehabilitation of at-risk steel buildings("sap2000 v14"). In this study, the sac frame behaviour is noticed under static and dynamic loading. For dynamic analysis, two earthquake data is selected, namely Fukushima and Corralit earthquake. The same building model with this different earthquake data is also analyzed for different frame conditions such as base isolated, chevron (v) braced, eccentric and unbraced conditions.

Fukushima earthquake data ("Revolvy",n.d.) is gathered from the earthquake occurred on 11th April, 2011 in the Hamadori region of Fukushima, Japan. The earthquake was a potent intraplate aftershock of 6.6 mw magnitude. With a shallow focus of 13 km (8.1 mi), the earthquake was centred inland about 36 km (22 mi) west of Iwaki. Corralit earthquake data is taken from the software package sap2000 v-14 which comprised the excitations of a sharp aftershock felt throughout the Santa Cruz mountains and the Pajaro river valley, in the central coast region of California on 19th September, 1923. The earthquake reached an intensity vi according to the Rossi-Forel scale.

Displacement profiles are observed and compared when the structure is subjected to static loading and earthquake excitations. Deformed shapes of the external corner column, external middle column and central column of the structure are considered. The result indicated the extent of effect of the static and dynamic loading as well as the isolation and bracing forms' effect on the structure.

Previous study on 'Effect of base isolation and different bracing system to improve building performance under earthquake excitations' for a 20 story sac frame was done by Ms. F.T. Zahura, Mr. S. A. Javed & Ms. R. Naznin from department of Civil Engineering, Ahsanullah University of Science and Technology, Dhaka, Bangladesh. This study illustrated that the displacement of a base isolator frame is higher than the e bracing (eccentric bracing) frame for the case of EI Centro earthquake. In present study, the structure under base isolation condition also have showed more displacement under Fukushima and Corralit earthquake than its e braced (eccentric braced), chevron (v) braced and unbraced conditions.

2. METHODOLOGY

The structural responses which have been found from this present study can help to identify the load which has more effect in deforming the structure and also the form in which the structure is most weak under the loading systems. The observations will contribute further in selecting the appropriate dimensions and materials for the member sections of a structure for withstanding the possible acting loads on the structure.

2.1 Numerical Modelling and Load Assigning

Numerical modelling uses some sort of numerical time-stepping procedure to obtain the models behaviour over time. Computer software package SAP2000 V-14 is used following LOS Angles method of FEMA (Federal Emergency Management Agency)-355C for creating the model and accomplishing the result of this analysis. SAP2000 V-14 is a general purpose finite element program which performs the static or dynamic, linear or nonlinear analysis of structural systems. In this study, a 9 story SAC frame model is created ("SAP2000 V14.2.0"). Behaviour of the structure is analyzed under static loading & earthquake excitations. Base isolated, eccentric braced, chevron (V) braced and unbraced conditions of the structure are introduced in the analysis. Static loading is taken from BNBC requirements in which roofing, ceilings/flooring, mechanical/electrical, partitions and exterior wall loading along with live load, wind load and seismic load are included. Static loading consisted of 10 combinations of loads including live load, dead load, wind load and earthquake load. Envelope load is also included into static loading. Envelope load represents the possible worst condition of failing of the structure under loading. It is the summation of all of the 10 load combinations. Dynamic load is given by time history analysis.

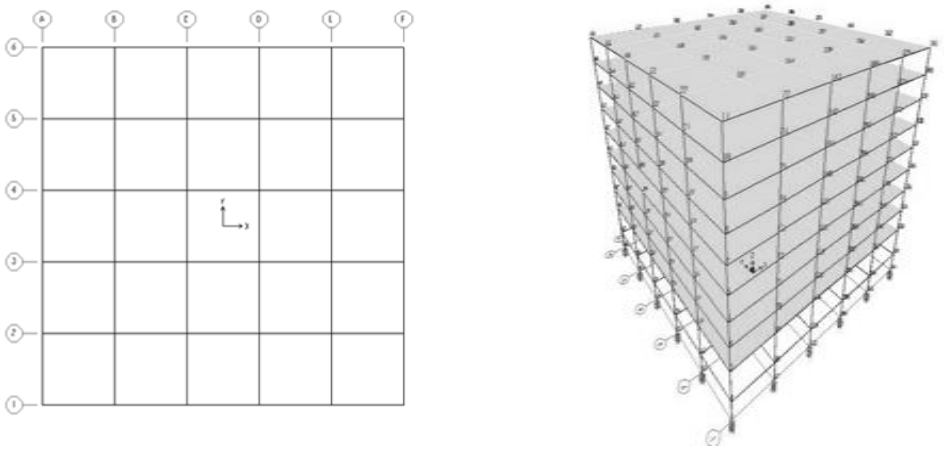
2.1.1 Analysis

Creating model, assignment of bracing and installation of base isolator have been done before the analysis. Defining function, graph plotting and defining load case data are the steps of giving dynamic load on the structure. After applying the static and dynamic loading, the model has been run under these loadings using software package SAP2000 V-14. The analysis results have showed the structural behaviour in different bracing conditions and base isolation condition under static and dynamic loadings. This analysis results are illustrated by graphs.

3. ILLUSTRATIONS

3.1 Figures

A 9 story SAC frame model has been created by software package SAP2000 V-14.The plan view and 3D view of the model is given below.



(a) (b)

Figure 1: (a) Plan View of 9 Story SAC Frame & (b) 3D View of 9 Story SAC Frame

3.2 Tables

According to LOS Angles method of FEMA-355C, A99 steel is used for beams, girders and columns. The design yield strength of the beams and girders is given by 36 ksi and of the columns is 50 ksi. Material properties of the structural members are given in the table below:

Table 1: Material properties of the structural members

Members	Materials
Beams and Girders	A99Fy36
Columns	A99Fy50

According to LOS Angles method of FEMA-355C, the following section properties are used for the structural members:

Table 2: Section properties of the members

Story/Floor	Column		Doubler Plates (in)	Girder
	Exterior	Interior		
-1/1	W14x370	W14x500	0,0	W36X160
1 /2	W14x370	W14x500	0,0	W36X160
2/3	W14x370, W14x370	W14x500,W14x455	0,0	W36X160
3/4	W14x370	W14x455	0,0	W36X135
4/5	W14x370,W14x283	W14x455, W14x370	0,0	W36X135
5/6	W14x283	W14x370	0,0	W36X135

6/7	W14x283,W14x257	W14x370, W14x283	0,0	W36X135
7/8	W14x257	W14x283	0,0	W30X99
8/9	W14x257, W14x233	W14x283, W14x257	0,0	W27X84
9/Roof	W14x233	W14X257	0,0	W24X68

3.3 Graphs, Results and Discussion

Under static loading, displacement profiles of corner column, external middle column & central column are considered.

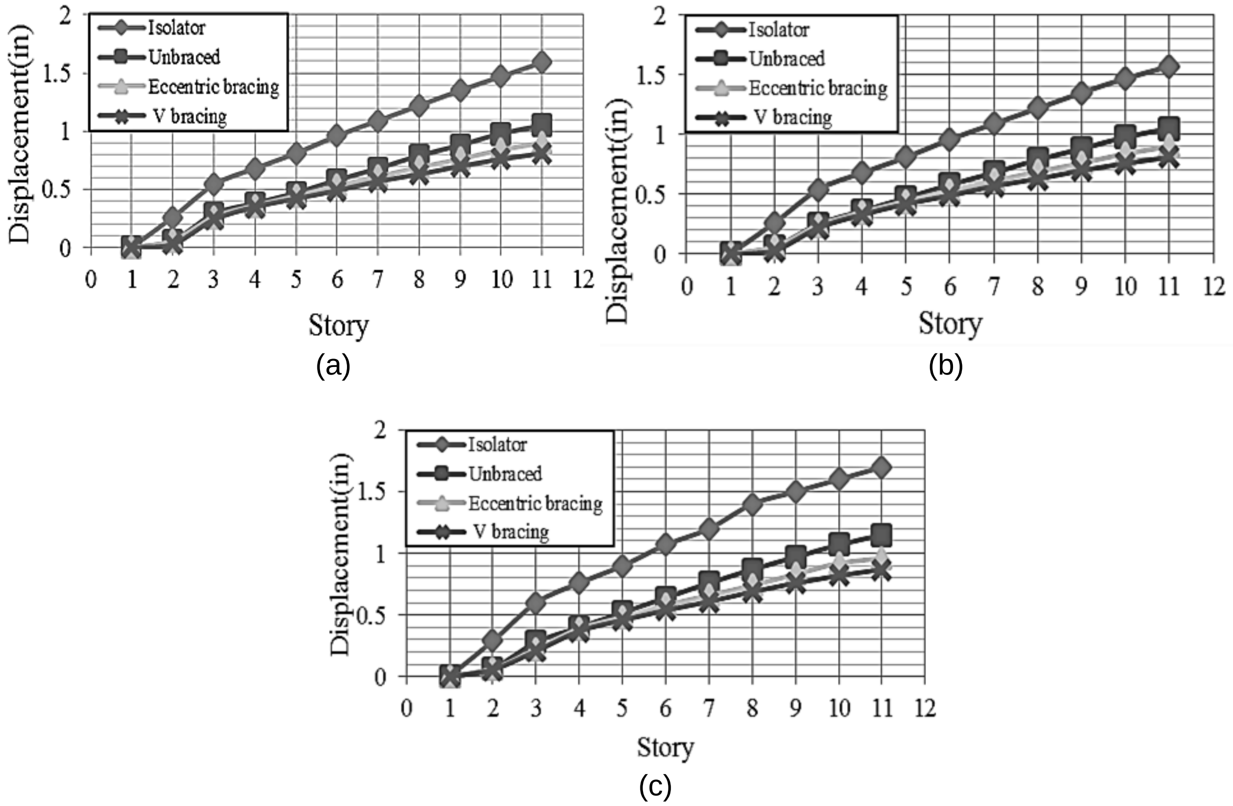
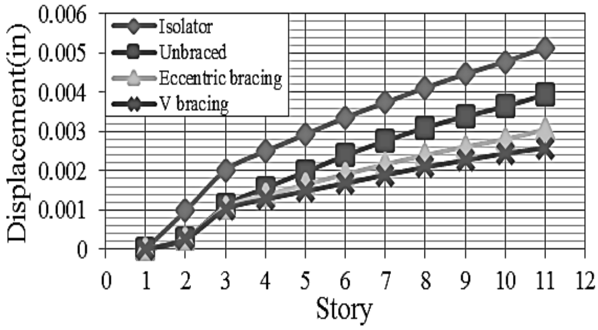


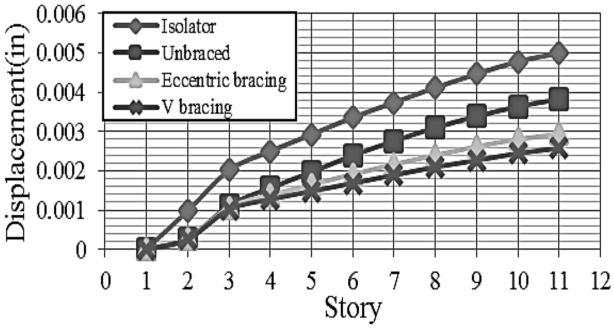
Figure 2: Displacement Profiles under static loading at (a) corner column (b) external middle column (c) central column.

All of the displacement profiles follow a same ascending pattern. For corner, external middle and central column, the structure has highest displacement when it is in base isolation condition than its unbraced, eccentric braced and chevron (V) braced condition. Chevron (V) braced condition gives the lowest displacements to the structure at all of these columns. At central column, the structure has the maximum displacements in base isolation condition in figure 3(c). In figure 3(a) and 3(b), the displacements are almost same at corner column and external middle column respectively.

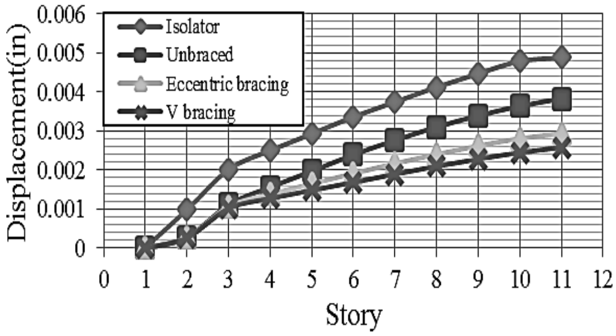
Displacement profiles of corner column, external middle column & central column are observed under Fukushima earthquake.



(a)



(b)

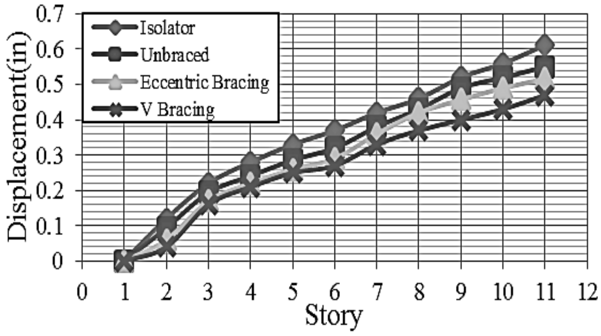


(c)

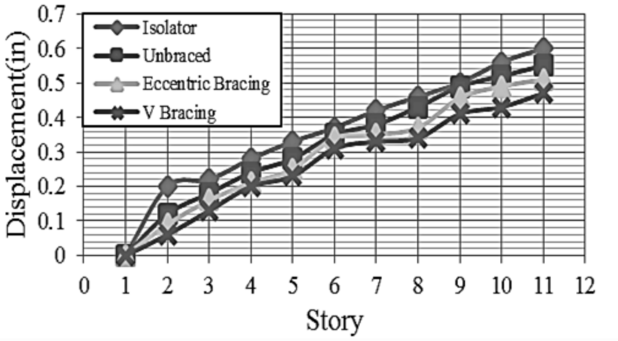
Figure 3: Displacement Profiles under Fukushima earthquake at (a) corner column (b) external middle column (c) central column.

All of the displacement profiles are in a rising pattern. When the structure is in base isolation condition, it carrys the largest displacements at corner, external middle and central column than its unbraced, eccentric braced and chevron (V) braced condition. At all of these three columns, Chevron (V) braced condition gives the minimum displacements to the structure under Fukushima earthquake too. At corner column, the structure has the maximum displacements in base isolation condition in figure 4(a). In figure 4(b) and 4(c), the displacements are less than the corner column at external middle column and central column respectively.

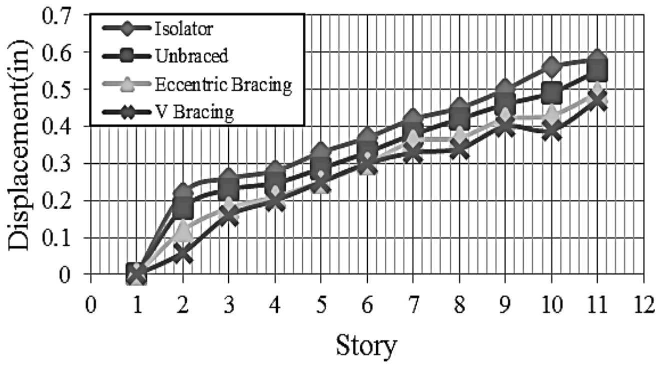
At corner column, external middle column & central column, displacement profiles are noticed under Corralit earthquake.



(a)



(b)



(c)

Figure 4: Displacement Profiles under Corralit earthquake at (a) corner column (b) external middle column (c) central column.

The displacement profiles are in a developing form. The structure has showed the maximum displacements under the earthquake excitation in base isolation condition than its unbraced, eccentric braced and chevron (V) braced condition at corner, external middle and central column. Like under static loading and Fukushima earthquake, chevron (V) braced condition gives the minimum displacements to the structure under Corralit earthquake at these three columns. At corner column, the structure has the maximum displacements in base isolation condition in figure 5(a). In figure 5(b) and 5(c), the displacements are less than the corner column at external middle column and central column respectively.

Under both Fukushima and Corralit earthquake, the structure has behaved similarly. Displacement profiles have showed a rising shape for both of these dynamic loadings. Base isolation condition has carried the maximum displacement and Chevron(V) condition has showed the minimum displacement in the structure at corner, external middle and central column for dynamic loadings. Among the three types of columns, the corner column has suffered from the highest displacements under both earthquake excitations. Exterior middle column has carried slightly higher displacements than central column. Under these earthquakes, the unbraced and eccentric braced conditions of the structure have taken higher displacements respectively after base isolation condition.

After comparing the values of displacement profiles obtained under Fukushima and Corralit earthquake, it has been found that the displacement profiles have carried higher values when the structure has been under Corralit earthquake than under Fukushima earthquake at the corner column in base isolation condition. So, further comparison of the effect on structure has been made between Corralit earthquake and static loading.

Static loading agrees at some point with dynamic loadings. For both static and dynamic loadings, displacement profiles are following an increasing shape. Base isolation condition has underwent the largest displacements and the Chevron (V) braced condition has given the lowermost displacements to the structure under static and dynamic loadings. Unbraced and eccentric braced conditions of the structure have had higher displacements respectively after base isolation condition under static loading too. But the central column displacements are highest among the three types of columns under static loading while under dynamic loadings it is the corner column which has the highest displacements. The maximum top displacement value of 1.7 inch is found when the isolated structure has been under static loading. The value is found to be 0.003 inch for V braced structure under Fukushima earthquake. As the base isolation condition of the structure carrys maximum displacement values under both static and dynamic loadings, so, displacement values of the isolated structure is taken for further comparison between static and dynamic loading.

Comparison between static and dynamic loading on displacement:

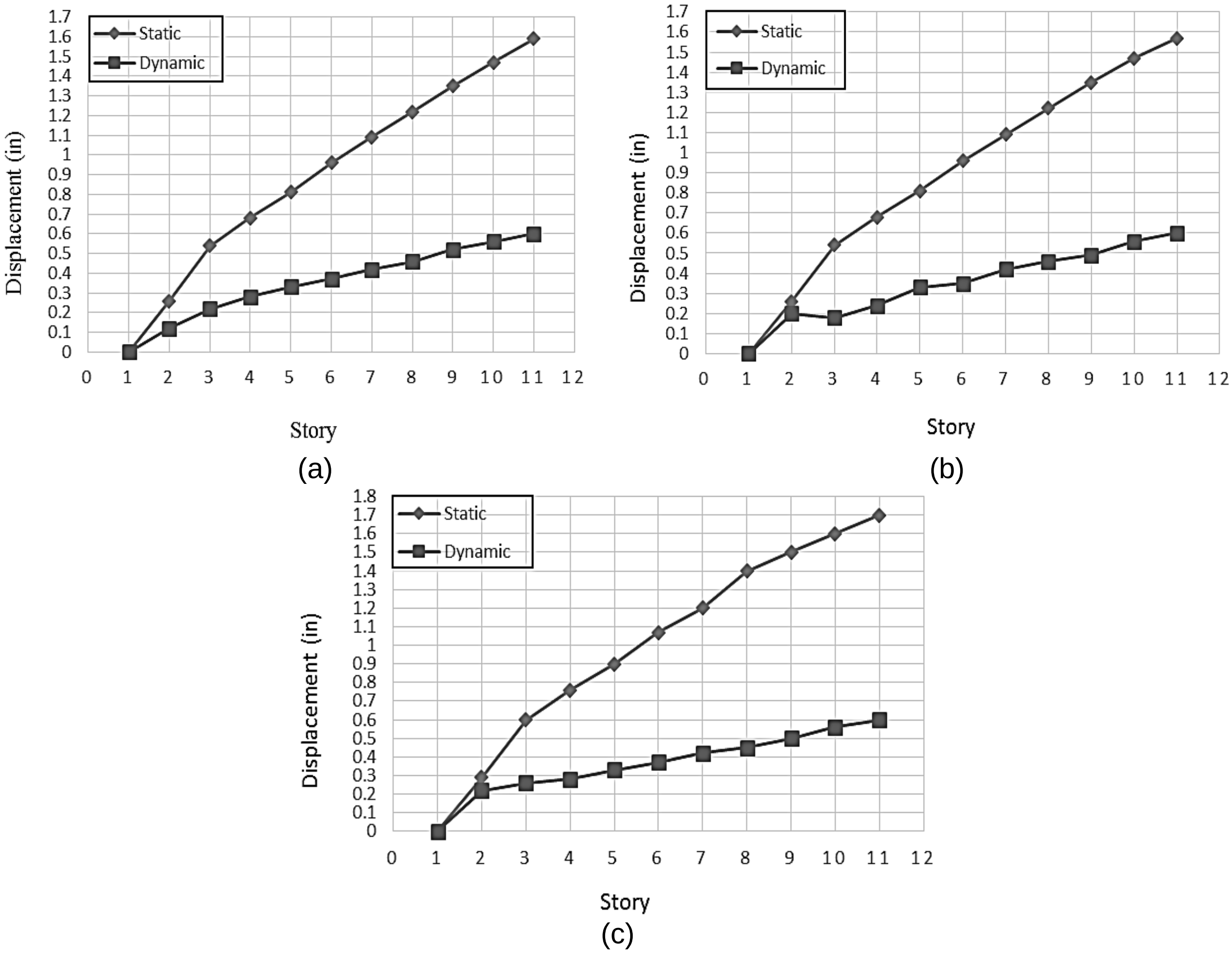


Figure 5: Comparison of displacement Profile under static and dynamic loading at (a) corner column (b) external middle column (c) central column.

After comparing among the displacement profiles of corner column, external middle column and central column in figure 6(a), (b) and (c), it is observed that static loading has more effect on these columns than dynamic loading. The maximum central column displacement is found to be 1.7 inch under static loading and maximum corner column displacement is 0.6 inch under Corralit earthquake. So, maximum displacement value under static loading is 64.7 percent higher than that under Corralit earthquake.

4. CONCLUSIONS

- After comparing the displacement profiles under static and dynamic loading, it is noticed that the structure goes through higher displacement when it is subjected to static loading than dynamic loading.
- The structure undergoes more displacement at its central column under static loading and under dynamic loading, corner column carries the higher displacement.
- Introducing base isolator into the structure provides higher displacements than Unbraced,

Eccentric braced and Chevron (V) braced structural conditions.

- Chevron (V) braced condition provides less valued displacement into the structure under loading.

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