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EFFECT OF BASE ISOLATION AND DIFFERENT BRACING SYSTEM TO IMPROVE BUILDING PERFORAMANCE UNDER EARTHQUAKE EXCITATIONS

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ABSTRACT

The performance of different types of frame with base isolator and Rectangular shape frames with different types of bracing under earthquake is investigated to know the building response. A 20 story SAC frame was selected for this study and the base isolated frame is introduced to compare with the rectangular shape frames. Modal time period and frequency are compared between base isolated frame and rectangular frame with bracing. Displacement and drift is compared with the rectangular frame bracing and base isolated frame. The results show that base isolator reduce the inertia forces introduced in the structure due to earthquake by shifting the fundamental time period of the structure. The displacement of a base isolator frame is 42% higher than the E Bracing frame for the case of EI Centro and hereby increases the flexibility of the structure.

Keywords: Base isolation; bracing system; rectangular frame; SAC frame

INTRODUCTION

Earthquake is one of the most uncertain loads in nature. It cannot be predicted when and with how much energy it will be generated. Like other loads, it cannot be calculated precisely or forecasted with reasonable accuracy. Due to the unpredictable nature of the load it has always been a challenging task for structural researchers and professionals to prepare any guideline. Therefore, the behaviour of different types of frame under earthquake should be determined. The technique of base isolation has been developed in an attempt to mitigate the effects on buildings and their contents during earthquake attacks and has been proven to be one of the more effective methods for a wide range of seismic design problems on buildings in the past two decades. Seismic isolation consists essentially of the installation of mechanisms which decouple the structures and their contents from potentially damaging earthquake-induced ground motions. This is achieved by mounting the structure on an isolation system with considerable horizontal flexibility so that during an earthquake, when the ground vibrates strongly under the structure, only moderate motions are induced within the structure itself. During earthquakes, the conventional structure without seismic isolation is subjected to substantial Story drift, which may lead to damage or even collapse of building (Hoq, S.M. 2010). Whereas the isolated structure vibrates almost like a rigid body with large deformations or displacements endured by the isolation bearings. The lateral forces of the isolated building are not only reduced in magnitude but also fairly redistributed over the floors, which further mitigates the overturning moment of the structure (Peng-Hsiang et al. 1998). The aim of this paper is to model and investigate a SAC frame with base isolation system to minimize contents related damage by controlling acceleration response and keep allowable resonance range. Maison, B. F et al. (1999) studied the effect of semi-rigid connections within the SAC program. But, in those studies all the connections were considered as partially restrained (FEMA-355c). Thus base isolated frames and bracing frames are selected which were subjected to four earthquake records from four different frequency earthquake. These are for El Centro, Northridge, Array and Kobe earthquakes. The control frame was selected to be the rectangular frame based on the SAC frame geometry. The aspect ratio and geometrical dimensions were same to obtain their earthquake response which included lateral displacement, inter-story drift. For the first part of the investigation, time period and frequency compared between base isolated frame and rectangular frame with bracing. In the second part of the study displacement and drift is compared with the rectangular frame with different types of bracing and base isolated frame to identify the effect of base isolation. Finally a 20 story of SAC frame (FEMA-355e) as a case study has been taken into consideration through simulated analysis for both, with and without base isolation systems. Fig. 1 represents the 20 story of SAC frame. Fig. 2 to fig. 4 shows the sac frame with Cross bracing, E bracing and inverted V bracing. Numerical analyses are applied in order to observe dynamic behaviour of such structures under seismic loads.

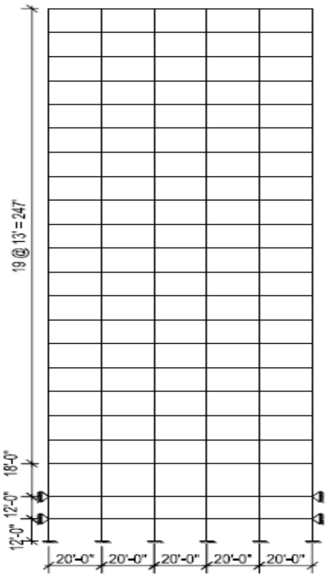


Fig. 1: Twenty Story SAC Frame

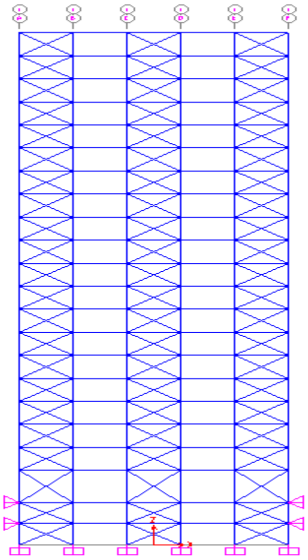


Fig. 2: SAC frame with cross bracing

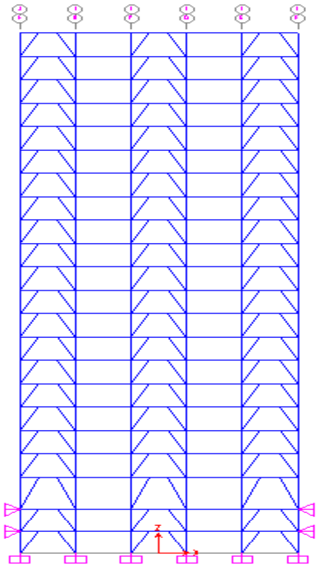


Fig. 3: SAC frame with E bracing

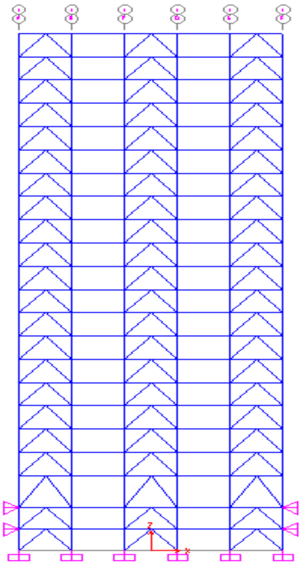


Fig. 4: SAC frame with inverted V bracing

METHODOLOGY

A 20 story 5-bay frame is used to observe the effect of earthquake on medium high-rise building. All the member sizes are W14 X 283. All the frames are analyzed under four different earthquake excitation data. These earthquakes reflect a wide variation in frequency content. Later a base isolator has been proposed to see the effect of behavior of the frame. The base isolator has been constructed by placing the rubber isolator between the building and the foundation of the rectangular frame. This isolated frame has the same height and width ratios as the rectangular shape. All member sizes, joint loads and uniformly distributed loading were kept the same for both the shapes. For each earthquake results of rectangular, braced frames are compared with base isolator frame. Comparison is accomplished with the help of Time history analysis and modal history analysis by using SAP2000 software. All the connections are considered to be rigid. Total dead load and 25 percentage of live load are considered for calculating member mass. Results include top displacements and inter story drifts. All the results are plotted to compare the performance of individual shape under earthquake excitations. The time steps and the step size for different earthquakes are listed in the Table 1. Corresponding time period and frequencies for first ten modes are also determined.

Table 1: Time steps and step size

Earthquake	Number of output time steps	Output time step size
EICentro	2674	0.02
Array	3939	0.01
Northridge	2990	0.005
Kobe	3000	0.02

RESULTS AND DISCUSSIONS

Comparison between the time period and frequency of the moment resisting frame with the other bracing frames are obtained from the SAP2000 software. Time periods and frequencies are tabulated in Table 2 and Table 3.

Table 2: Time periods of different types of bracing

Time Period (sec)					
Mode	Moment Resisting Frame	Base Isolator Frame	Cross Bracing Frame	E Bracing Frame	Inverted V Bracing Frame
1	2.612	2.824	1.774	1.843	1.753
2	0.860	0.929	0.499	0.576	0.501
3	0.481	0.592	0.318	0.314	0.318
4	0.338	0.517	0.227	0.293	0.233
5	0.301	0.364	0.217	0.221	0.215
6	0.268	0.297	0.177	0.191	0.171
7	0.241	0.272	0.134	0.168	0.143
8	0.203	0.219	0.112	0.145	0.111
9	0.183	0.198	0.096	0.115	0.102
10	0.169	0.182	0.093	0.110	0.094

Table 2 shows the maximum time period 2.824 sec is obtained for base isolated frame and minimum 1.753 sec for inverted V bracing frame. Using of base isolator increases time period and decreases frequency. Table 2 shows that moment resisting frame has 2.612 sec time period and after introducing base isolator time period increases and frequency decreases. Among all types of frames inverted V frame shows minimum time period.

Table 3: Frequency of different types of bracing

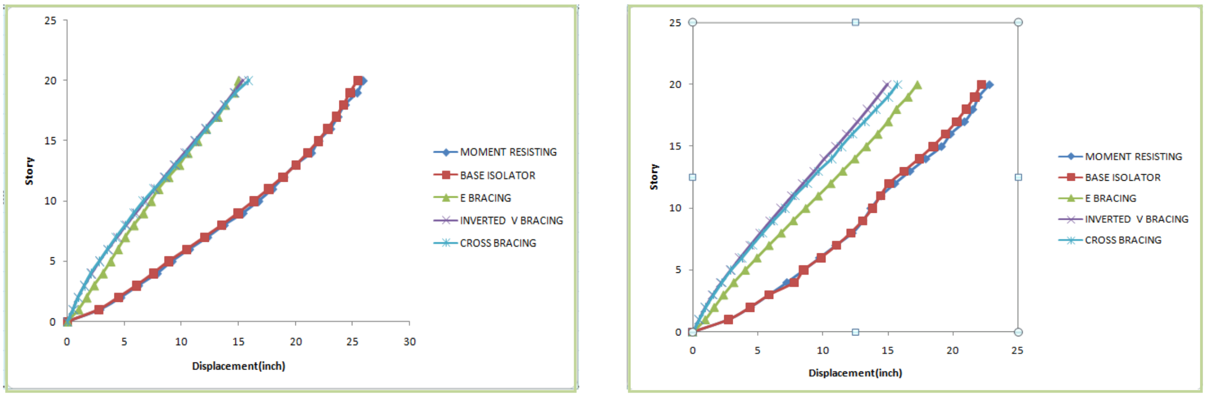
Frequency (cyc/sec)					
Mode	Moment Resisting Frame	Base Isolator Frame	Cross Bracing Frame	E Bracing Frame	Inverted V Bracing Frame
1	0.382	0.354	0.563	0.542	0.570
2	1.162	1.075	2.001	1.735	1.992
3	2.076	1.688	3.143	3.181	3.136
4	2.959	1.931	4.406	3.408	4.285
5	3.321	2.747	4.593	4.510	4.629
6	3.864	3.368	5.633	5.230	5.829
7	4.150	3.669	7.435	5.923	6.966
8	4.914	4.554	8.920	6.883	8.930
9	5.466	5.037	10.340	8.647	9.764
10	5.912	5.493	10.679	9.042	10.562

Table 3 shows that minimum frequency 0.354 cyc/sec is obtained for base isolated frame and maximum 0.57 cyc/sec for inverted V bracing frame. Using of base isolator frequency decreases. Table 3 shows that moment resisting frame has 0.382 cyc/sec frequency and after introducing using base isolator frequency reduces.

Graphical presentation of displacement profile for all frames with different earthquakes considering El Centro, Northridge, Kobe, Array earthquakes are shown in Fig. 5 and Fig. 6. Table 4 shows displacement for 10% earthquake. Displacement for Elcentro and Array earthquakes increases to 25.45 inches and 22.18 inches which was 25.91 inches and 22.86 inches for simple moment resisting frame. By increasing displacement base isolator decreases time period.

Table 4: Displacement for 10% earthquake

	Displacement (inch)				
Earthquake	Moment resisting frame	Base isolator frame	Cross Bracing Frame	E Bracing Frame	Inverted V bracing frame
El Centro	25.91	25.45	15.9	15.00	15.36
Array	22.86	22.18	15.72	17.24	14.93



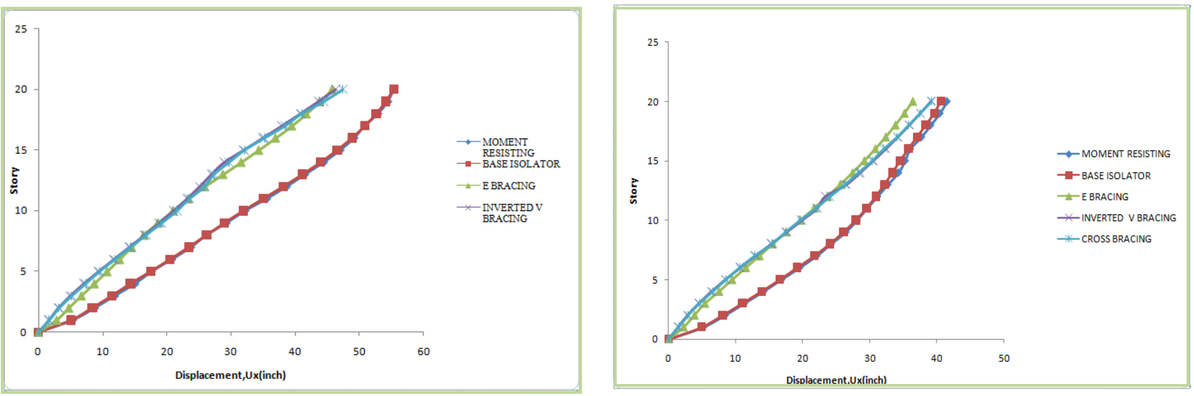
a) EI Centro b) Array

Fig. 5: Displacement profile for 10 % earthquake EI Centro and Array

Table 5 shows maximum displacement for 2% earthquake. Displacement for Northridge earthquakes increases to 55.36 inches which was 55.34 inches for simple moment resisting frame. But displacement for Kobe earthquakes decreases to 40.56 inches which was 41.47 inches for simple moment resisting frame.

Table 5: Displacement for 2% earthquake

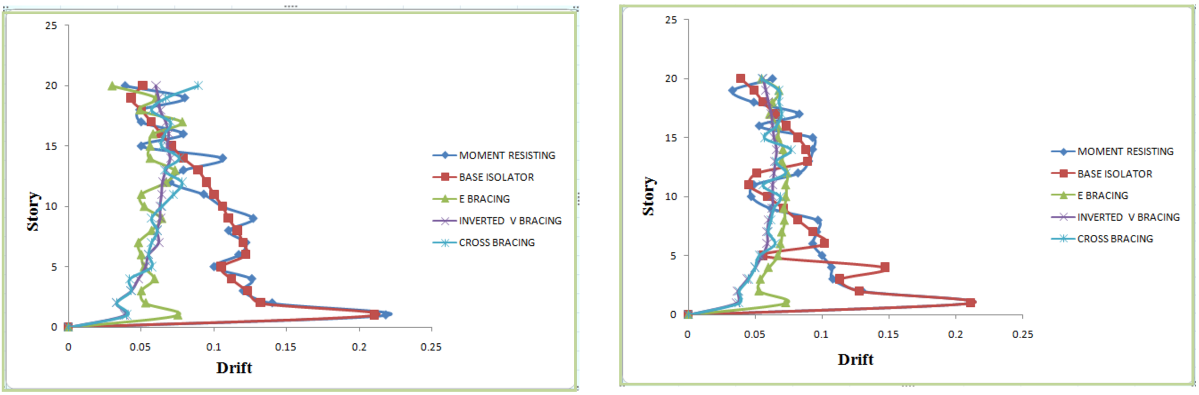
	Displacement(inch)				
Earthquake	Moment resisting frame	Base isolator frame	E bracing frame	Inverted V bracing frame	Cross bracing frame
Northridge	55.34	55.36	45.8	46.26	47.41
Kobe	41.47	40.56	36.39	39.08	39.22



a) Northridge b) Kobe

Fig. 6: Displacement profile for 2 % earthquake Northridge and Kobe

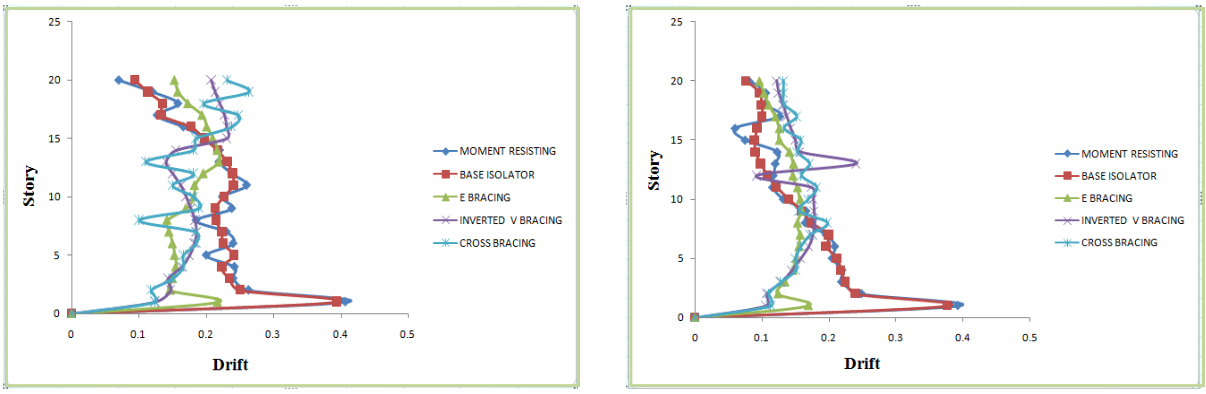
Fig. 7 and Fig. 8 shows the inter story drift profile for rigid rectangular frame with different types of framing and base isolator for four types of earthquake.



a) EI Centro b) Array

Fig. 7: Drift for 10 % earthquake EI Centro and Array

For Northridge and Kobe earthquake, base isolated frame experience less drift than the rigid frame. Base isolated frame subjected to EI Centro and Array earthquake gives greater drift values than the rigid rectangular frame. For EI Centro and Array earthquakes moment resisting frame drifts are 0.03076 and 0.04615 which increases to 0.08923 and 0.09384 for base isolated frame. For Northridge and Kobe earthquake moment resisting frame drifts are 0.07769 and 0.10076 which increases to 0.11692 and 0.17384 for base isolated frame. Semi- rigid connections make a structure flexible and for that reason, in those levels the structure experience more drifts than the rigid frame.



a) Northridge b) Kobe

Fig. 8: Drift for 2 % earthquake Northridge and Kobe

CONCLUSIONS

For all the considered earthquakes, base isolator frame experience less inter story drift than the other frames in portion of the higher story. In contrast, few stories like story 1 and 2 of a 20-story base isolator frame experience a more drift than the other frames. The time period of base isolator for all modes is much higher than the all other frames. The time period ranged from 2.824 sec to 0.182 sec for base isolator and 1.774 sec to 0.093 sec for cross bracing frame. Whereas the frequency of base isolator is much lower than the other frames. The frequency ranged from 0.354 cyc/sec to 5.4993 cyc/sec for base isolator and 0.563 cyc/sec to 10.679 cyc/sec for cross bracing frame. Therefore, it can be said that Time period increase in the base isolated structure but as frame frequency reduces the frame does show some flexibility on the stories. Time period can also be changed within safe limit of resonance. Base isolator does not make a building earthquake proof but it can make the structure more flexible to control its frequency from dangerous resonance range. It can reduce amplitude. The segmental building concept can be considered as an extension of the base isolation technique with a distributed flexibility in the superstructure. Base isolator also protects nonstructural elements and equipment by reducing the entire structures acceleration during an earthquake, as opposed to reinforcement alone.

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