DYNAMIC RESPONSE OF BRACED STEEL STRUCTURE UNDER THE BI-DIRECTIONAL SEISMIC EXCITATION

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Abstract - *In this article response of braced steel structure subjected to bi-directional seismic excitation is studied. For the study, steel building with bare frame and different braced structures are considered. X, Diamond and inverted V steel bracings are considered in the study. Structure is subjected to bi-directional seismic excitation. The angle of incidence of earthquake is varied and corresponding response in terms of storey drift, displacement and base shear in the braced structure is observed and compared with bare frame structure. The result indicates that, braced structures reduces the dynamic response when compared to bare frame structure.*

Key Words: Steel Structure, Steel Bracings, Bi-Directional Seismic Excitation

1. INTRODUCTION

An earthquake is a natural phenomenon which produces surface waves leading to the vibration of the ground and structure resting on it. It is necessary to prevent the structure from harmful effects of the earthquake when building is subjected to earthquake which otherwise may lead to severe damage. Application of bracings is one of the technique which prevents damage to the structures during earthquake by incorporating the additional stiffness [1 and 2]. Bracings can be broadly classified as concentric and eccentric bracings. Concentric bracings means that the ends of the brace are connected to the node or joint of the frame. Eccentric bracings means that the ends of the brace are connected at a certain distance from the node of the frame. Earthquake measuring stations, record the ground motions in three orthogonal directions, two of them in the horizontal direction and third in a vertical direction. In the design of buildings, earthquake loads are considered only along principal axes of buildings. However, an earthquake can also act along any axes of the building, other than principal axes. The critical angle of incidence of an earthquake on structure causing a maximum response, may not always occur along principal axes of the building [3 and 4]. Critical incidence angle for every earthquake is unique according to its excitations conditions. There is no particular angle of incidence of earthquake for a structure causing the maximum response in all structural elements. Each member gets its maximum responses by the specific angle of incidence of an earthquake.

As per IS code IS 1893-Part1:2002, only uni-directional seismic excitations are reflected in seismic design. However, during an earthquake, the structure may be subjected to bi-directional excitations as well. Thus, if a structure designed for uni-directional seismic excitation it might not respond well to bi-directional seismic excitations especially in irregular structure [5 and 6]. To prevent the structural failure and to enhance the performance of building during earthquake, seismic forces on structural elements need to be minimized [4]. Earthquake force in structural members are counteracted by incorporating the bracings to the structure. [7, 8, 9 and 10].

Addition of bracings prolongs the formation of plastic hinges during the earthquake by providing the additional strength and stiffness to bare frame. In this paper, linear time history approach is used in ETABS to analyze the six storey building with plan irregularity. A comparative study of dynamic performance of three different steel braced structures is presented, namely Diagonal bracing, Diamond bracing, and X bracing. Performance of bare and braced steel structure is studied by considering bi-directional seismic excitations of near fault and far field earthquake.

2. METHODOLOGY

Six storey commercial steel building is considered for the study. Figure 1 show top view of building having plan irregularity. Figure 2, 3, 4 and 5 represents front elevation of bare structure, diagonal, diamond, V braced steel structure respectively. The building is considered to be located in Bangalore region. Zone factor and response reduction factor for the building is 0.16 and 5 respectively.

Fig -1: Plan of the Structure

Mass and stiffness of each storey are obtained from analytical approach and these values are verified by mathematically by considering the structural specifications and material properties. Tributary weight of the slab is generally considered as mass. Stiffness is calculated through Euler's formula (12 EI/L3). Damping ratio is assumed as an average for design and analysis of concrete structures. 2% damping ratio is considered for steel structure. Table 1 shows the dynamic parameter which includes the mass and stiffness values of individual story for bare and braced frame structure. Higher mass of the structure is observed in braced structure compared to bare frame. To compare the dynamic response of the different braced structure with bare frame, stiffness parameter of the different braced structure are made almost constant by varying the sectional properties of bracings. Then effectiveness of different bracings are compared with bars frame structure.

Table -1: Details of the Earthquake Records

Earth quake	Recording station	Magnitude	Peak ground acceleration (PGA) in g
Chi-Chi	Hualian, Taiwan	7.3	0.152
Kobe	Kobe university, Japan	6.9	0.284
El-Centro	El Centro Array #5	6.53	0.386

Unsymmetrical building is considered in the study to accomplish the torsional irregularity. Due to asymmetry, centre of mass and stiffness of the structure are not lying at the same point, leading to eccentricity in the structure. Height of each storey is 3.5m. Beam and columns are assemble of steel sections and slabs are reinforced concrete section (RCC). Unit weight of concrete is 25 KN/m2. Slab thickness is 120 mm and grade of concrete is M20. ISHB 255252 I section is defined for beam and column. Live load on all floors is 3 kN/m2 and on roof is 1.5 kN/m2. A 3 D model of the building is developed in ETABS.

Linear time history analysis is carried out for the study by considering three different earthquake records. As per guidelines of ASCE7-05 16.1.3 minimum three different previously recorded earthquake data should be considered for the design in dynamic analysis. Out of three earthquake records considered Chi-Chi and Kobe are far field earthquakes and El-Centro is near fault earthquake. Details of earthquake records are given in Table 1.

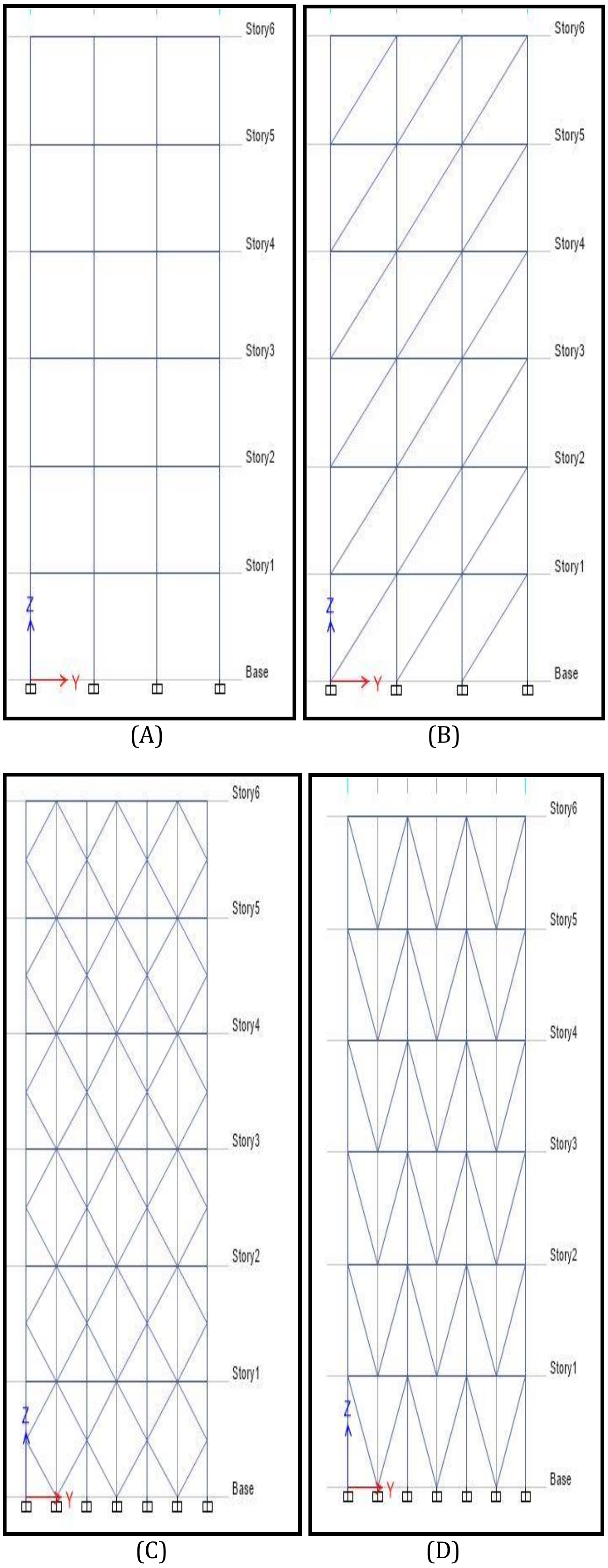

Fig -2: Elevation of Structure Showing Different Bracings, A) Bare Frame, B) Diagonal Bracing C) Diamond Bracing, D) Inverted V Bracing

3. RESULTS AND DISCUSSION

Maximum storey drift observed in the different braced Figure 7 represents maximum storey drift occurred in the braced structure along the Y direction of the structure. Bare frame structure is subjected to the static earthquake load and three different previously recorded earthquake data. Results of the bare frame structure are compared with the different bracings. All the bracings have effectively reduced the storey drift of the structure along Y direction. Maximum drift was observed in the bare frame structure for El-Centro earthquake which is far field earthquake. Bracings are effective in reducing the drift for both near and far field earthquake.

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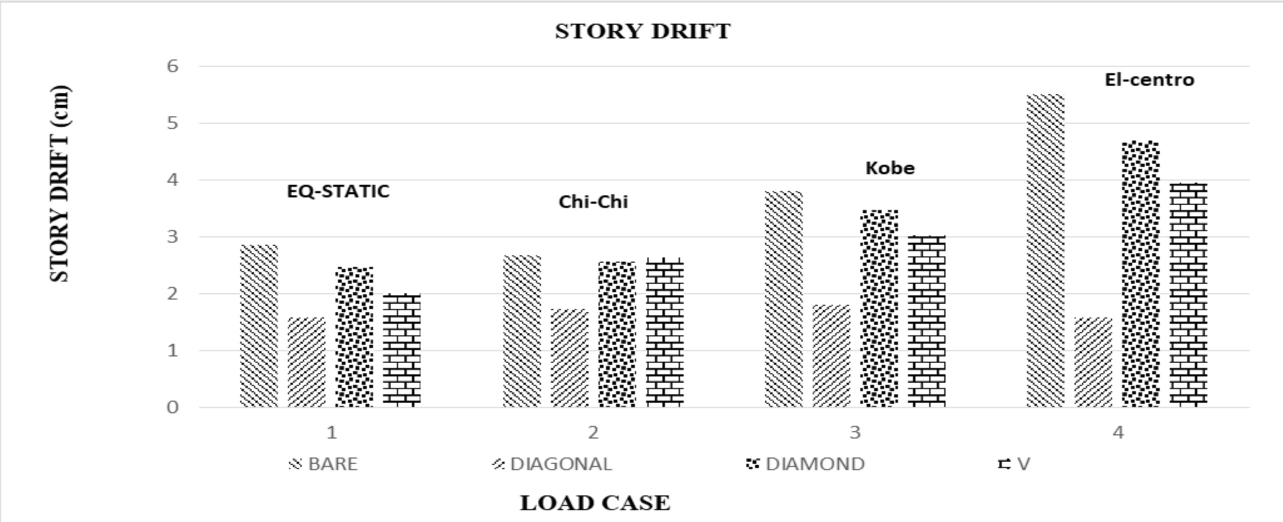

Fig -3: Storey Drift along X-Direction

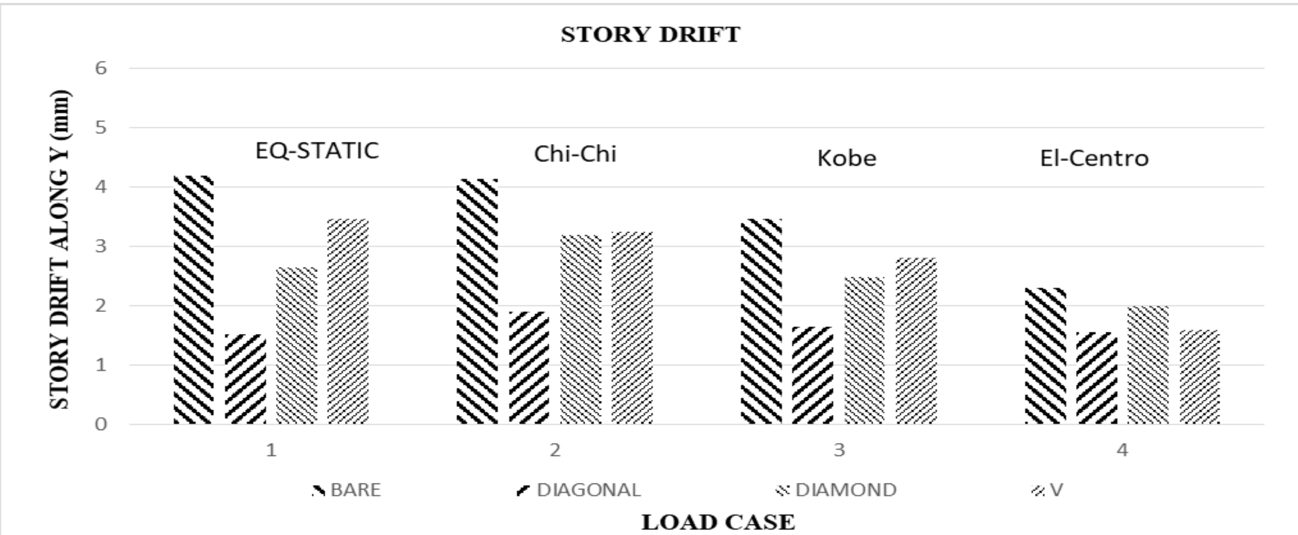

Fig -4: Storey Drift along Y-Direction

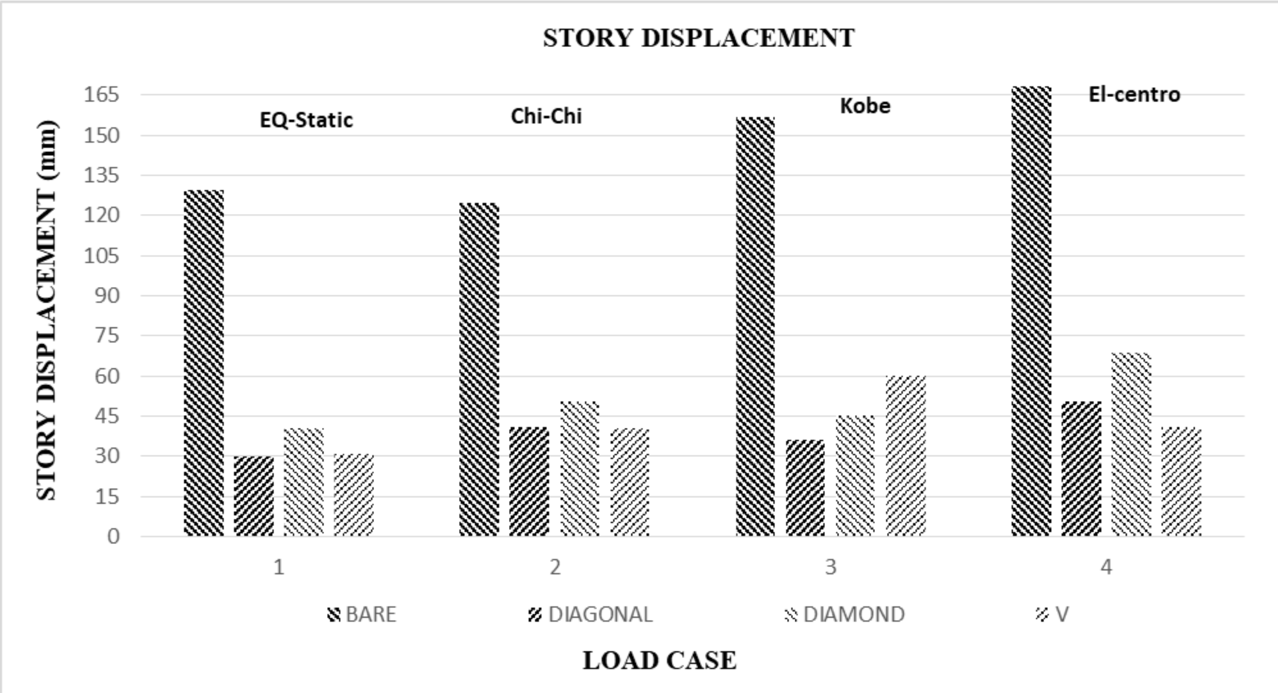

Fig -5: Storey Displacement along X-Direction

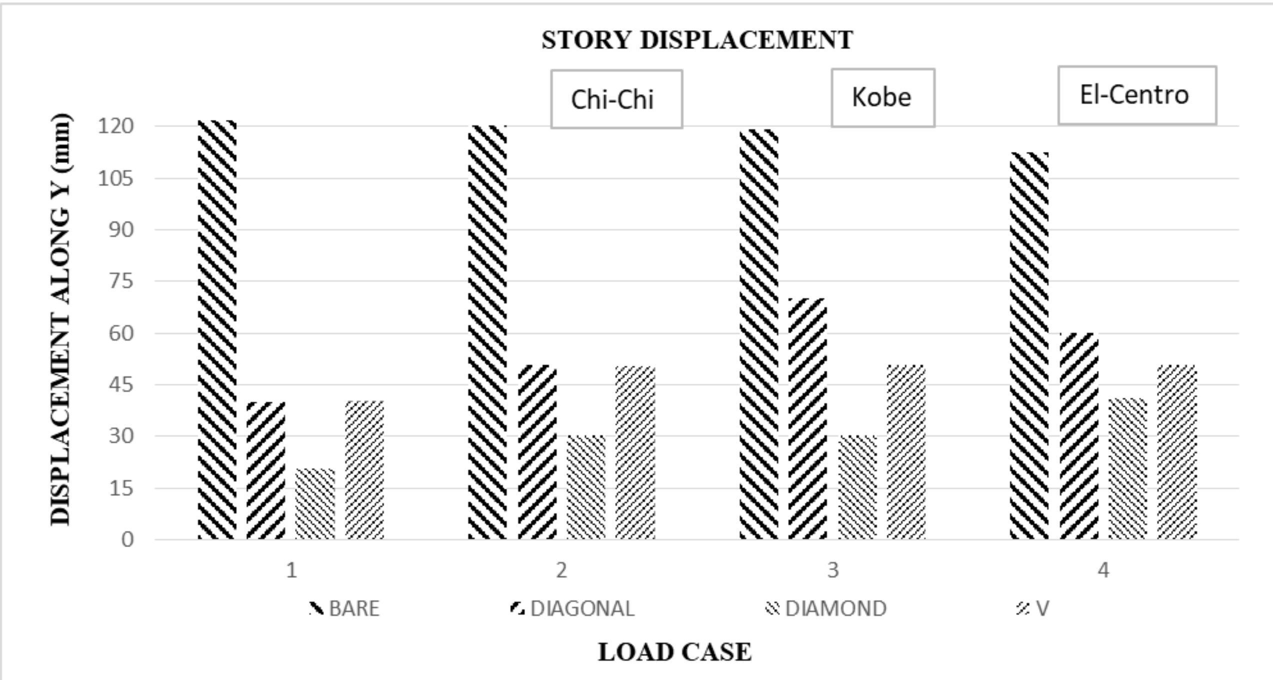

Fig -6: Storey Displacement along Y-Direction

4. CONCLUSION

Effect of angle of incidence of the earthquake on dynamic response of bare and steel braced structure is studied. Structure is subjected to three previously recorded earthquake data and angle of incidence of earthquake is varied from 0^{o} to 180^{o} by 10^{o} increments. Storey drift and displacement in bare and braced steel structure is observed for every 10^{o} increment. All three bracings has effectively reduced the response in the structure for every earthquake incidence angle. Diagonal bracing is more effective compared to other bracings. It is found that maximum torsional rotation in structure was not along earthquake of orthogonal direction. If building is designed by considering earthquake along orthogonal direction, it might not respond well if earthquake incidence is in other direction. Even, for some angle of incidence of the earthquake, particular bracing is most effective. Combination of the bracings in the structure works well compared to one identical bracings for entire structure.

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