Bracing Applications for Improving the Earthquake Performance of Reinforced Concrete Structures

Diyar Yousif Ali

***Abstract:** Braced frames, besides other structural systems, such as shear walls or moment resisting frames, have been a valuable and effective technique to increase structures performance against seismic loads. In wind or seismic excitations, diagonal members react as truss web elements which would afford tension or compression stresses.*

This study purposes at considering the effect of bracing diagonals on values of base shear and displacement of building. Two models were created and nonlinear pushover analysis has been implemented. Results show that bracing members enhance the lateral load performance of RC frames considerably.

The purpose of this article is to study the nonlinear response of reinforced concrete Structures which contain Hollow Pipe Steel braces as the major structural elements versus earthquake loads. A five-storey reinforced concrete structure was selected in this study; two different reinforced concrete frames were considered. The first system was un-braced frame while the last one was braced frame with diagonal bracing. Analytical modelings of the bare frame and braced frame were realized by means of SAP 2000. The performances of all structures were evaluated using the nonlinear static analyses. From these analyses, the base shear and displacements were compared. Results are plotted in diagrams and discussed extensively and the results of the analyses showed that, the braced frame was seemed to capable of more lateral load carrying, had the high value for stiffness and lower roof displacement in comparison with bare frame.

***Keywords :** reinforced concrete structures, Pushover analysis, Base Shear, steel bracing.*

I. INTRODUCTION

One of the consequences for the engineers is the lateral displacement of structural buildings, and to control this lateral displacement, different mechanisms have been used in the design stages among them the braces as a lateral load resisting system have shown a considerable improvement in that area to resist lateral loads such earth quake .

Bracing members have acceptable performance in high rise reinforced concrete structures due to their high seismic load resistance. In general, they are classified into three groups: Eccentric Braced Frame (EBF), Concentric Braced Frame (CBF) and Knee Braced Frame (KBF) (Figure 1).

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Because of their relative well stiffness, concentric braced systems are more acceptable, along with their economic aspects and easy construction; these basic parameters make this type more common than eccentrically braced frames.

Although, the Moment-Resisting Frames (MRFs) have superior energy dissipating system, its members must be designed with huge uneconomical sections to meet the drift requests. The CBF is more rigid than the MRF but cannot meet the ductility requirement due to buckling of braces.

To overcome the insufficiency of the MRF and the CBF, Roeder and Popov (1978) proposed a new structural system, named EBF. It combines excellent ductility and sufficient stiffness by fixing the brace eccentrically to the beam to form a shear link. Because of the yielding of the shear link in intense earthquake, the structure gives effective preservation from buckling (Mofid and Lotfollahi, 2006).

reinforced concrete frames Bracing is generally performed for the purpose of increasing the strength or strength and ductility versus earthquake induced forces .This technique is convenient for strengthening those buildings whose connections have enough strength and can be strengthened in some openings by cross bracing (without any trouble in its serviceability).

II. A.RC STRUCTURES, PUSHOVER ANALYSIS& BASE SHEAR

A. RC Structures are much secure in seismic zones

Traditional buildings, especially in non-engineering and non-reinforced structures, suffer from many disadvantages. For example, the traditional un-engineered or non- reinforced constructions like masonry buildings has huge dead weight and they are extremely rigid buildings, inducing a big earth quake internal forces. Also their shear and tensile strength are very low.

Recent engineering has made many evolutions in improving different construction techniques that can build structures to survive during an earthquake expected to expectations and in accordance with applicable building codes.

Reinforced concrete buildings are more secure because steel bars resist tensile forces resulting from the earthquake and concrete resists compression forces. The unique ductility of steel bars to withstand tensile strength forces, as well as the concrete-like ability to resist compressional forces, makes reinforced concrete a typical material in seismic-prone areas.

Reinforced concrete buildings produce three major seismic resistance characteristics: strength, rigidity and ductility.

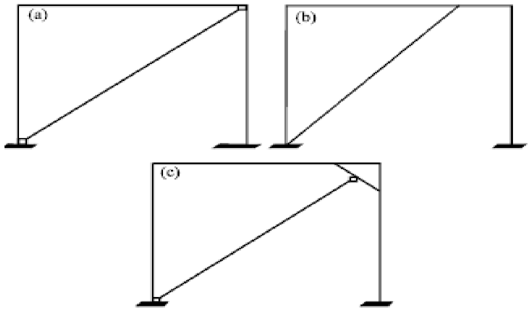

Fig.1.(a-c): Commonly used steel braced frame systems, (a) CBF, (b) EBF and (c) KBF

B. Pushover Analysis

In earthquake resistant design, structures are generally designed for a lower level of seismic forces and permitted to undergo nonlinear response due to severe ground motion. Therefore it is important to understand the performance of these structures during failure.

Pushover analysis may be categorized as analysis of the displacement controlled pushover when lateral displacement is forced on the frame. Similarly, when horizontal forces are impelled, the analysis is described as force controlled pushover analysis. The target force or target displacement is planned to represent the maximum displacement or maximum force or the likely to be experienced by the structure through the design earthquake. The performance of frames that exceed the maximum strength can only be found by analysis of the displacement-monitoring pushover. Thus, in the current paper, analysis of the displacement-monitoring pushover procedure is utilized to analyze RC structural frames with diagonal members and without diagonal members.

The version of the Sap2000 Analysis Software package was used for this purpose. Figure 2 illustrates the method of determining the yield and final state of the base shear versus the roof displacement relationship curve.

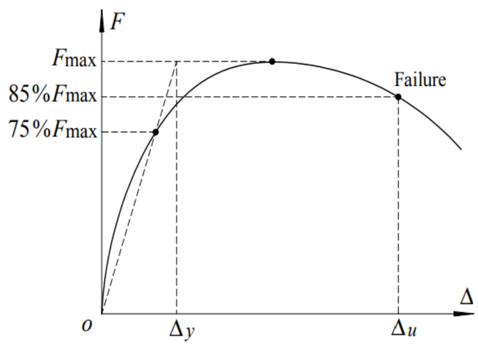

Fig. 2. Definitions of Yield and Ultimate State.

C. Base Shear

Base shear is an estimation of the ultimate predicted horizontal force that will happen because of the motion of seismic ground at the foundation of a structure. In this paper the base shear for two different frames will be calculated and results will be compared by graphical representation, then the clear difference between bare and braced buildings will be evaluated.

III. CASE STUDY

The study has done on two different models of a five (5) story reinforced concrete structure is modeled. The building has three bays in X direction; having beam size (0.4m x 0.4m), column size (0.5m x 0.5m) for the first and second floors and (0.4m x 0.4m) for the rest floors, in the current study, the outer diameter of brace members is (200mm) and The diagonal brace members were selected as circular hollow section. The height of stories is 3.5 m in all the floors as shown in figure 3. The unit weight of concrete is taken as 21 KN/m3; the live load on floors is taken as 4 KN/m2. In seismic weight computations, 30 % of the floor live loads are considered. The modulus of elasticity and steel bar yield stress were 200 GPa and 420 MPa, respectively. The modulus of elasticity and yield stress of the bracing steel frames were 200 GPa and 350 MPa, respectively. The elevation of the braced frame studied is illustrated in Figure 4. And the Specifications of the studied frame are given in Table 1. The columns go continuously over the entire storey height and fixed at their bottom ends. All structural models were subjected to the nonlinear static pushover analysis. The impact of the diagonal members on the seismic performance of the strengthened building was evaluated.

Table1 Dimensions of structural members for the case study structure

Storey	Columns	Beams
	Dimensions (cm)	Dimensions(cm)
1	50 x 50	40 x 40
2	50 x 50	40 x 40
3	40 x 40	40 x 40
4	40 x 40	40 x 40
5	40 x 40	40 x 40

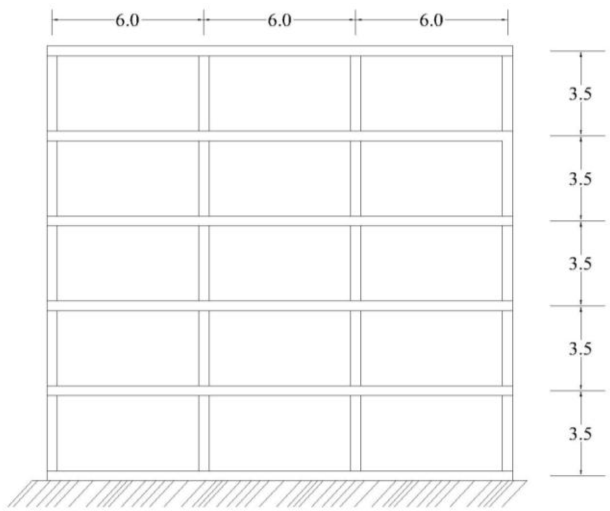

Fig. 3. Elevation view of 5 storey case study building.

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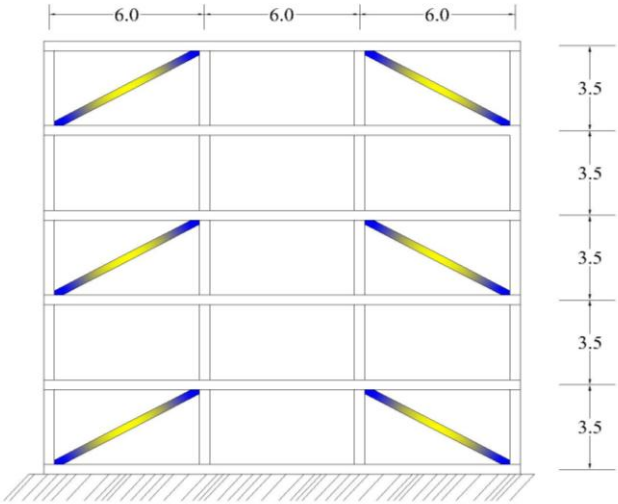

Fig. 4. braced frame of 5 storey case study building.

IV. RESULTS AND DISCUSSION

The Storey Shear is decreased as height of the building increased and reduced at top floor in all the building models subjected to seismic loads considered. The story shear is ultimate at the base which is the base shear.

Figure 5 shows the pushover curve for two dimensional 3-bay frame without bracing and Figure 6 shows the pushover curve of the frame with bracing system, It can be observed in fig.5&6 that the effect of bracing increase the base shears carrying capacity and decreases the roof displacement of the frame building.

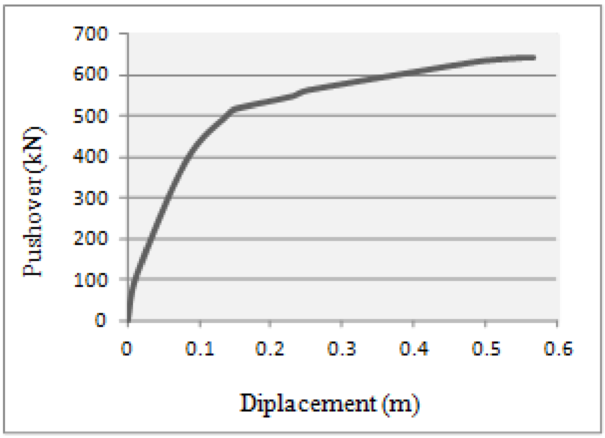

Fig.5. Bare frame Pushover capacity curve.

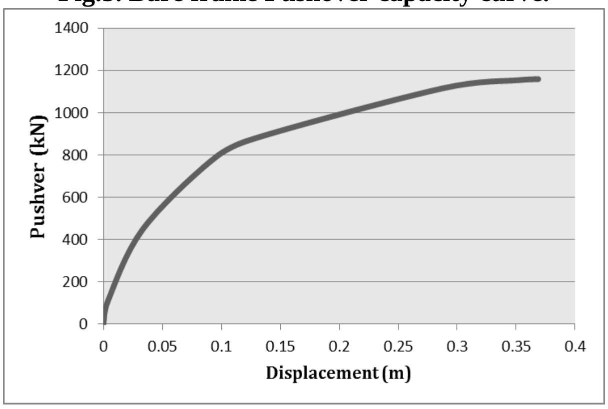

Fig. 6. Braced frame Pushover capacity curve

A storey displacement was considered the points at which the maximum storey displacement occurred. The displacement of building models increases with the increasing of building height. The displacement is very high at roof and very low at the base. Figure 7 and Figure 8 shows the distribution of displacement of the buildings with and without of diagonal bracing. According to the results of the plots indicated that the buildings with diagonal bracing had considerably lower roof displacement compare to the without bracing building

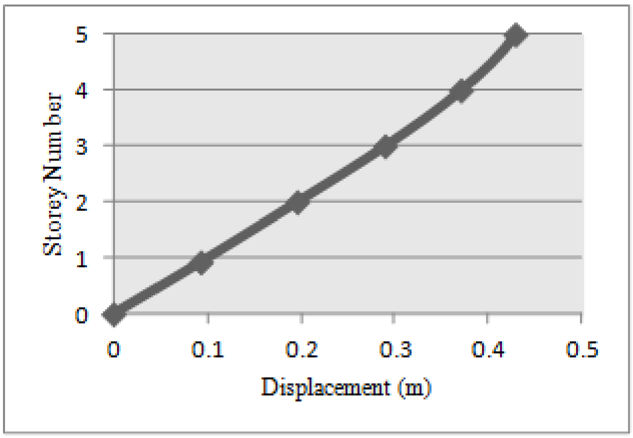

Fig. 7. Bare frame height and displacement curve.

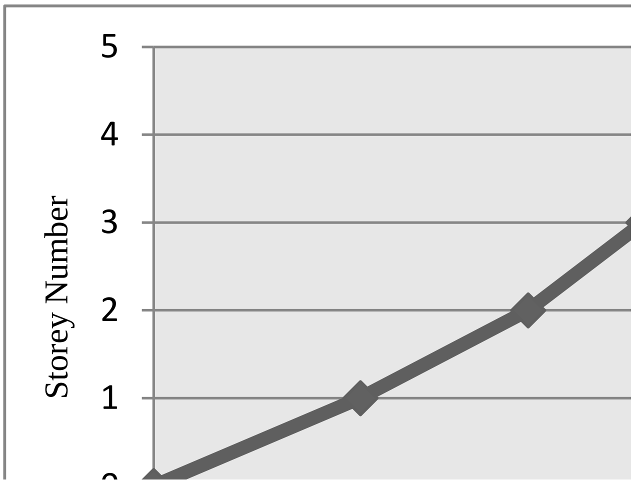

Fig. 8. Braced frame height and displacement curve.

V. CONCLUSION

This study was performed because of the very high importance of retrofitting concrete structures via bracing systems. Displacement analyses were performed for investigating the stiffness of each of these systems and pushover analysis was performed for investigating the ductility of these frames. Outcomes of these analyses show the effectiveness of bracing of concrete frames both as an effective shear resisting system at design level and as a retrofitting measure against horizontal earthquake loading.

Furthermore, the results of this study lead the conclusions that:

• The seismic response of un-braced frame is weak. Accordingly, they are required to be retrofitted with the capabilities provided by systems that have sufficient stiffness and ductility

• Based from the result obtained for a 5–storey frame, the ductility is highest for a frame without brace. While in the Braced Frame, stiffness is highest among other properties.

• The strength capacity of reinforced concrete structures can be increased to a required level using concentric bracing. Thus, the bracing systems can be conservatively designed for the desired strength development.

• To increase the ultimate capacity of reinforced concrete structure, Concentric bracing system can be used; significant increases can be obtained by utilizing concentric bracing. Furthermore; to reduce the roof displacement of the reinforced concrete frame to an acceptable limit, Concentric bracing system can be applied.

• Steel bracing reduces the ductility of the reinforced concrete frame.

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