Seismic Behavior of Reinforced Concrete Frame with Eccentric Steel Bracings

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Abstract: *The seismic performance of non ductile reinforced concrete (RC) buildings with eccentric steel bracing of inverted Y type is investigated. 10, 15 and 20 storey buildings are analyzed by using pushover analysis. The analysis is carried out by using software SAP2000v17. The effect of distribution of steel bracing over the height of RC frame was studied. The study also concentrates on effect of link length of eccentric bracing on seismic performance of RC frame. The performance of RC frame with inverted eccentric bracing is evaluated in terms of energy absorption capacity, stiffness of frame and ductility. The behavior of eccentric braced frame (EBF) is compared with conventional RC frame and inverted V bracing.*

Keywords: *Eccentric bracing, Pushover analysis, RC frame, Shear link*

I. INTRODUCTION

In the recent past earthquake several RC buildings which are designed for only gravity loads and Buildings with non-ductile detailing are suffered moderate to severe damages. The non-ductile behavior of RC frames is due to inadequate transverse reinforcement in beams, columns and joints. Therefore, it is necessary to provide special mechanism or mechanisms that improve lateral stability of the structure. One of the main strengthening approaches is installing new structural element, such as steel braces to upgrade the seismic performance of structures by using concentric and eccentric steel bracing techniques. Although it is common to employ steel braces in steel frames and use shear walls in RC structures; in recent years, there have been several studies on use of steel braces in RC buildings.

EBF is a framing system in which the forces induced in the braces are transferred either to a column or to another brace through shear and bending in small segment of beam called link [1]. Link acts as a fuse which dissipates seismic energy by deforming itself. Some of usually using eccentric braces on steel frames is shown in fig.1. In RC frames, the concrete beams are incapable of performing as a ductile link for the steel bracing system that is inserted in the frame bays. A vertical steel shear link may be introduced by the inverted Y-bracing pattern

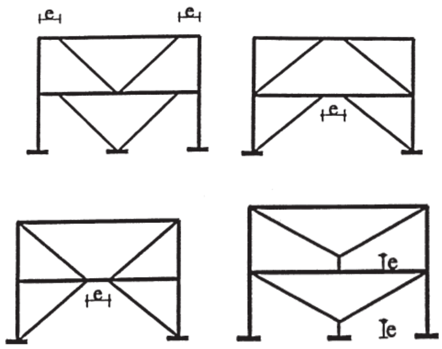
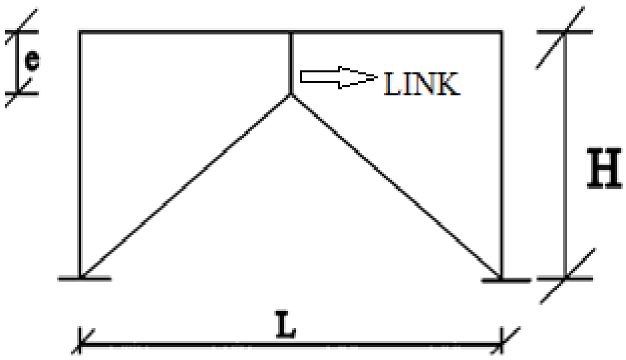
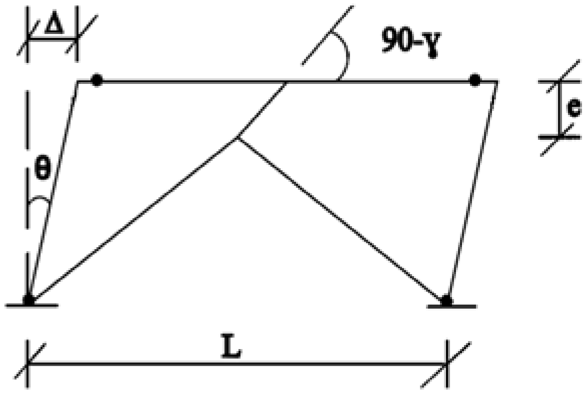


Fig. 1 Different types of eccentric brace

In the present investigation inverted Y type of bracing with shear link is used on RC frame. The link assumed to acts as cantilever. Connection between link and beam is considered as fixed and the connection between brace members and link is treated as pinned one [2]. The deformation of the steel bracing system in EBF results mainly from the link yielding while the deformation of the RC frame is developed mainly by the formation of the plastic hinges in the frame members. The inelastic hinging system shown in Fig.2 (b) represents one possible failure mechanism.



(a)



(b)

Fig. 2 Eccentric braced frame (EBF) and behavior of EBF

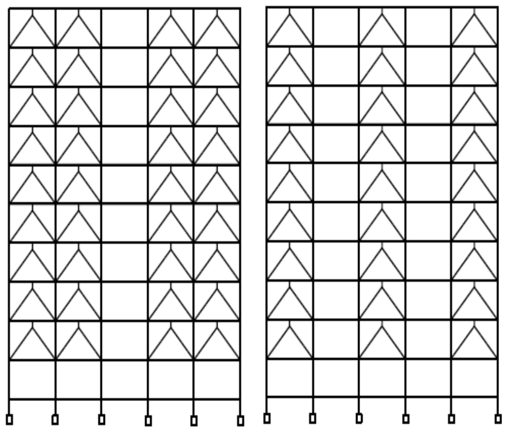


Fig. 3 Different bracing configurations

Some of researchers studied the behavior of inverted y type of EBF. Ghobarah .A and Abou Elfath. H, (2001) studied The seismic performance of a three storey RC (RC) building rehabilitated using eccentric steel bracing. Time history analysis is conducted and concluded the ratios between the initial stiffness of the rehabilitated cases to that of the existing building are 4.6, 2.8 and 3.0, respectively [2]. Ghodrati Amiri G and Gholamrezatabar. A,(2008) studied The seismic performance of a three-story RC (RC) building rehabilitated using eccentric steel bracing. Using time history data (tabas, naghan, elcentro) concludes that the capacity of energy dissipation of shear links up to 90 percent [3]. Mais M. Al-Dwaik and Nazzal S. Armouti, (2008) conducted study on 5 storey RC building with eccentric steel bracing and behavior is compared with bare frame and column jacketed buildings. They concluded the ductility for EBF increases to185% and column jacketing increases 39% Stiffness of EBF increases to 140% and column jacketing increases 49% as compared to bare frame [4]. WANG Da-peng et al.,(2012) studied behavior of EBF experimentally concluded that ductility factor And energy absorption capacity is more for W600 specimen as compared toW400 specimen for peak ground acceleration 0.40g . Lateral stiffness reduction is maximum for W600 specimen [5]

II. Objectives and Methodology

Objectives of this study is conducting pushover analysis on EBF and comparing its performance with bare frame and braced frame of inverted V type. The effect of distribution of braces over height of storey and the effect of change in link length on EBF also studied. 10, 15 and 20 storey 3D buildings are used for study with two different link lengths 0.6m and 0.75m and two different type of bracing configuration of bracing systems are used in this investigation as shown below.

Buildings consisting 5 bays in each direction(X and Y direction) with 5m bay width and 3.5m bay height are considered for analysis. Modeling is done by using SAP2000 software Pushover analysis is conducted on EBF with shear link. The buildings considered in this study are assumed to be located in Indian seismic zone 4 with medium soil conditions. The design peak ground acceleration (PGA) of this zone is specified as 0.24*g*. The material properties are assumed to be 25N/mm^2 for concrete and 415 N/mm^2 for strength of steel with young's modulus 200000 N/mm^2. The sizes of building components, brace members and link section are listed below.

Table. 1 Component Sizes of EBF

Components	Sizes
Column	800x800 mm
Beam	300x500 mm
Link	W200X46
Brace	HS114X8

Table. 2 Properties of Link and Brace Sections

Properties of link section W200x46(I Section)		Properties of link section HS114x8(Tubular Section)	
Outside height	0.204m	Outside diameter	0.1143m
Top flange width	0.203m	Wall thickness	$7.950\text{x}10^{-3}$ m
Cross-section area	$5.860\text{x}10^{-3}$ m^2	Cross-section area	$2.660\text{X}10^{-3}$ m^2

III. PUSHOVER ANALYSIS

Pushover analysis can be performed as either force-controlled or displacement controlled depending on the physical nature of the load and the behavior expected from the structure. Force-controlled option is useful when the load is known (such as gravity loading) and the structure is expected to be able to support the load. Displacement controlled procedure should be used when specified drifts are sought where the magnitude of the applied load is not known in advance, or where the structure can be expected to lose strength or become unstable.

Pushover analysis is a upper bond seismic analysis it gives strength of building as well as it determines strength of earthquake. Remaining all analysis methods are only able to determine strength of earthquake such as time history and static equivalent methods. Inelastic analyses procedures help demonstrate how buildings really work by identifying modes of failure and the potential for progressive collapse. The use of inelastic procedures for design and evaluation is attempts to help engineers better understand how structures will behave when subjected to major earthquakes, where it is assumed that the elastic capacity of the structure will be exceeded. This resolves some of the uncertainties associated with code and elastic procedures The FEMA 356 [6] lateral load pattern is considered in this study. Energy absorption, stiffness and ductility of 10, 15 and 20storey buildings by using load verses displacement graph of pushover analysis.

Energy absorption capacity of frames is defined as area enclosed by load verses displacement graph of pushover analysis. Stiffness of the frame is given by slope of bilinear representation line of base shear verses displacement graph. Slope of line ab gives stiffness of frame. And Ductility (μ) of frames is defined as ratio of ultimate displacement (Δu) to yield displacement (Δy) as shown n equation I

$$\mu = {\Delta_u}/{\Delta_y} \qquad \text{(I)}$$

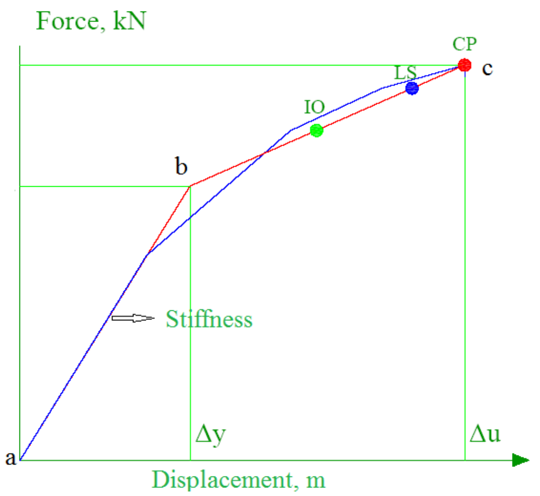


Fig. 4 Base shear verses displacement graph of pushover analysis (FEMA356)

IV. RESULT AND DISCUSSION

A. Energy Absorption

Energy absorbed by different types of frames and different configurations are shown in following figures and it indicates that energy absorbed by EBF is more as compared to bare and braced frames as EBFs absorbs less energy as they are stiffer in nature. Fig 6 shows that energy absorption capacity of EBF increases as link length increases. Fig 7 Indicates that for bare frame and braced frames the energy absorption capacity is decreases as storey height increases. For EBF it is increasing till 15 storey frame and then decreases for 20 storey frame. Except EBF of configuration 2 with link length 0.6m. Energy absorption capacity increases from 294% to 311% with increase in link length and decreases 2% to 13% with increase in bracing area.

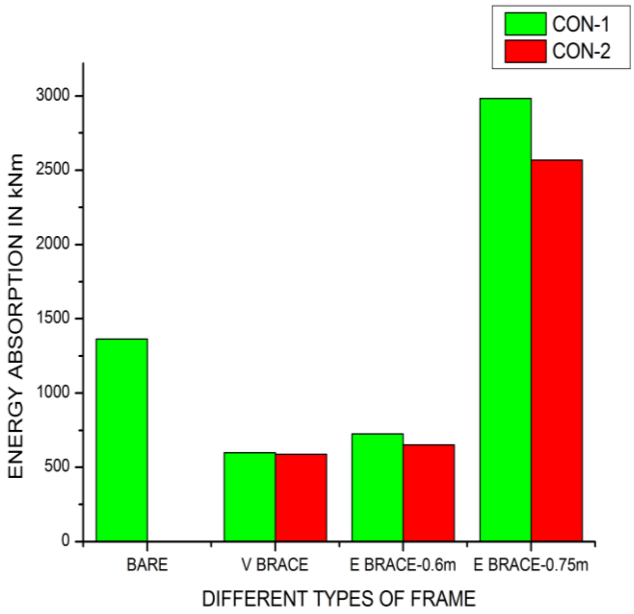


Fig. 5 Effect of configuration of bracing on energy absorption

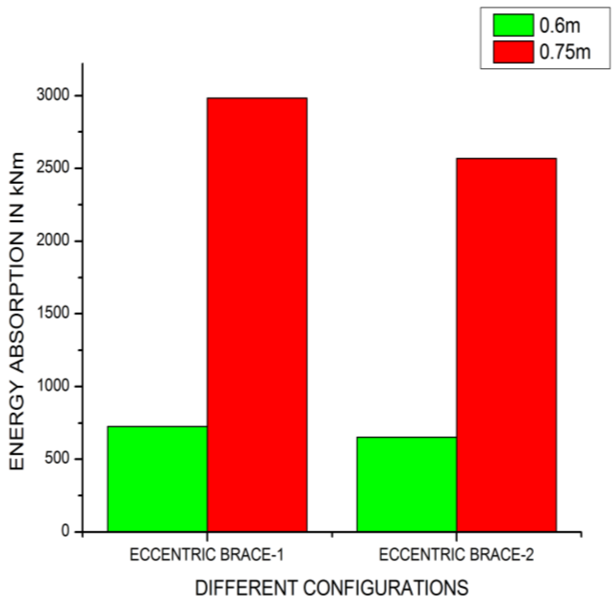


Fig. 6 Effect of link length on energy absorption

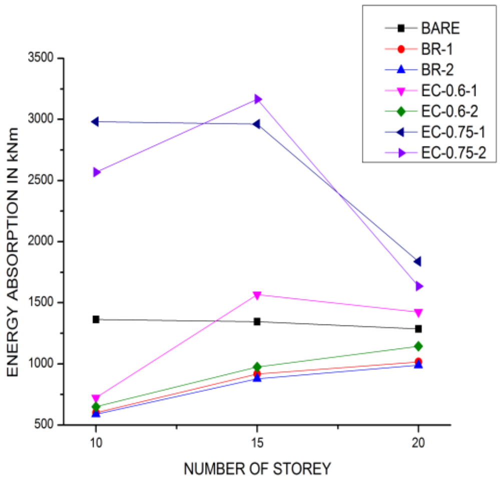


Fig. 7 Effect of number of storey on energy absorption

B. Stiffness

Fig 8 and Fig 9 shows variation of stiffness of frames verses configurations of bracing and link lengths as bracing area increases the stiffness of frame increases maximum stiffness is seen for braced frames and minimum for bare frame. Increased stiffness makes building to resist more lateral loads at the same time it reduces ductility of building and reduces energy absorption capacity of building as a result braced frames are more susceptible for damage.

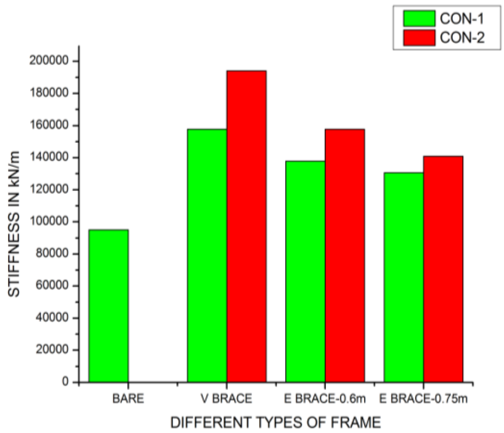


Fig. 8 Effect of configuration of bracing on stiffness

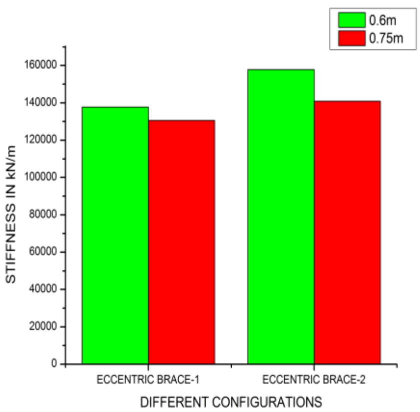


Fig. 9 Effect of link length on stiffness

Fig 10 shows the variation of stiffness with respect to storey height indicates that stiffness reduces as number of storey increases. Stiffness of structures increases with increase in brace area from 7.89% to 22.97%. Stiffness of structure decreases from 5.49% to 11.96% as link length increases.

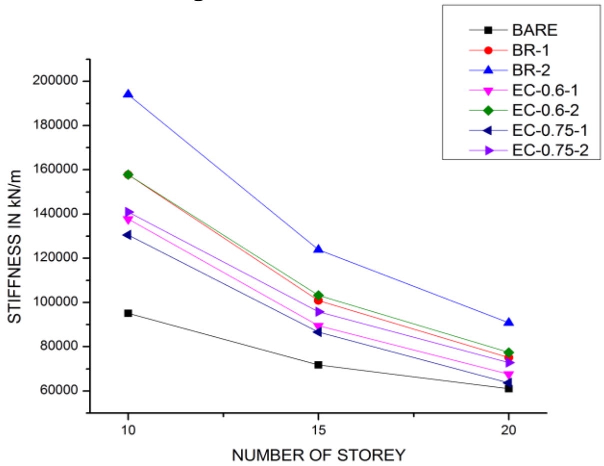


Fig. 10 Effect of number of storey on stiffness

C. Ductility

Fig 11 and Fig 12 shows variation of ductility with respect to bracing configuration and link length. As braced area increases the ductility decreases and as link length increases ductility increases. Fig13 shows variation of ductility for increased number of storey it indicates that ductility increases to 15 storey and then decreases to 20 storey. Except braced and EBF with link length 0.6m. Ductility of structure decreases from 11.09% to 38.29% for configuration 2 as compared to configuration 1 and increases with increase in link length from 29.11% to 32.14%.

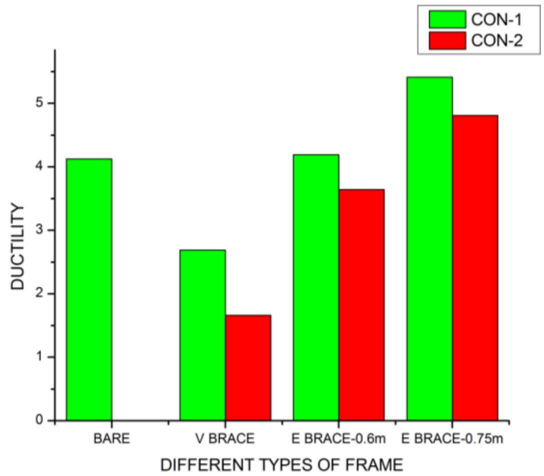


Fig. 11 Effect of configuration of bracing on ductility

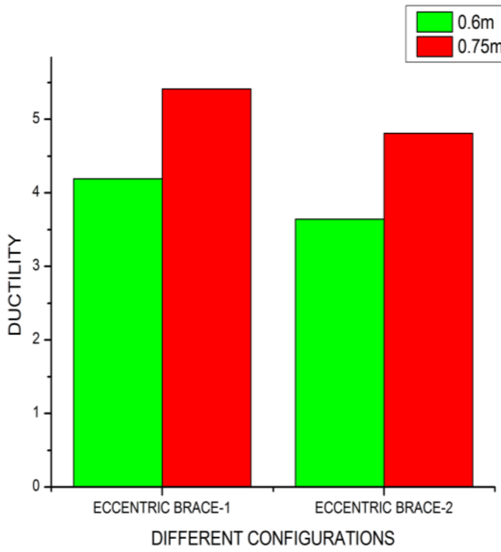


Fig. 12 Effect of link length on ductility

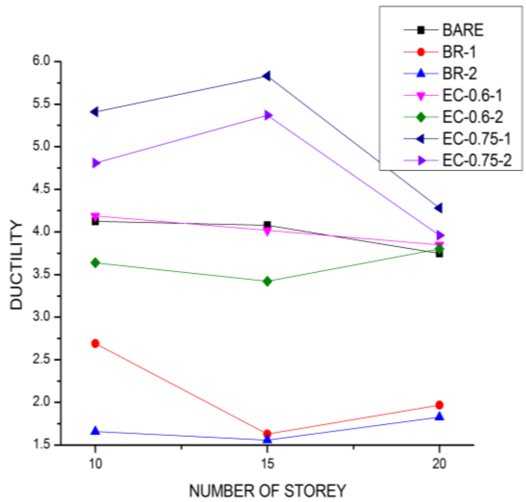


Fig.13 Effect of number of storey on ductility

V. CONCLUSIONS

1. Energy absorption capacity is major requirement for every structure as EBF absorbs more energy as compared to bare and braced frames
2. Stiffness of building helps in resisting lateral force but more stiffness reduces energy absorption capacity as compared to bare and braced frame EBF provides moderate stiffness to building
3. Ductility is prime requirement for every building built in seismic zone ductility for EBF is more as compared to bare frame, braced frame indicating well performance.
4. Increased area of bracing makes building stiffer and reduces ductility and energy absorption capacity of building and increased link length is vice-versa.
5. EBF reduces all the seismic hazards efficiently hence EBFs are well suitable for seismic regions till 15 storey

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