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Improvement of the seismic performance of the resistant concrete moment frames against earthquake with use of the CBF and inverted EBF braces

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ABSTRACT
Use of X shape concentric braced frames (X-CBF) and inverted Y shape eccentric braced frames (inverted Y-EBF) to retrofit the reinforcement concrete moment frames(RCMF) may be applied desirable and efficiently, and removes defects of reinforcement concrete moment frame system that is applied lonely. Studies for retrofitting RCMF frames with use of X shape bracings have been done and concluded recently, but few studies for retrofitting RCMF frames by concentric braces specially inverted Y shape eccentric braces have been conducted. In this paper it will be investigated the improvement of seismic performance of the reinforcement concrete moment frames (RCMF) by using of both concentric and eccentric steel braces systems.Therefore, evaluation of RCMF frames with X shape steel braces and with inverted Y shape eccentric braces has been done by using of analytical studies. Inverted Y shape eccentric braces have vertical steel shear link. These analytical studies have been performed by SAP2000V14.2 Software and Nonlinear Static Analysis (pushover analysis).To estimate the performance of frames and the formation quality of plastic hinges, life safety acceptance criteria was selected. The results of this study showed that, the application of X shape concentric or inverted Y shape eccentric bracesin RCMF frames, is caused that plastic hinges to be formed in steel braces and vertical shear link instead of formation in columns and beam of the RCMF frame. Furthermore, existence of steel braces in RCMF frame delays both the formation process of first plastic hinge and column failure mechanism.
Keywords: *Reinforcement Concrete Moment Frame (RCMF), X shape concentric braces, Inverted Y shape eccentric braces, Vertical shear link, Plastic hinge, Performance level, Acceptance Criteria.*

INTRODUCTION

Use of steel braces has been appropriate solution to retrofit reinforcement concrete structures during recent years. Steel braces may be used in two types, consisting of X shape concentric braces that is bracing in ordinary shape. Also they may be used in the shape of inverted Y shape eccentric braces with typical vertical shear link.By the design of this vertical shear link, plastic hinge that is damage, which is expected to be formed in reinforcement concrete beam of the concrete frame, is conducted to this vertical steel shear link intelligently.To do a software work, frames with 4, 8 and 12 stories were modeled and considered, and they were exposed to pushover analysis in SAP2000 software. This program is capable of modeling concrete beams and columns, and utilizes seismic design parameters according to performance level.Life safety performance level was considered. The results prove that by joining steel braces from any type to RCMF frame, the place of plastic hinge occurrence were formed in bracing sections instead of forming in beam and columns of the concrete frame. Also steel braces delayed the process of first plastic hinge formation and damage mechanism.

As we know earthquake energy may absorb and damp by plastic hinges formation in structural members. As much as plastic hinges tolerate deformations, as much as earthquake energy is absorbed and damped [5]. So if plastic hinges are formed in ductile (deformation control) members at first, we will have more reliability to the structure that is subjected to earthquake load. Also according to the philosophy of strong column and weak beam, design of the structure must be done so that formation of the plastic hinges on columns is prevented. In other way by designing and applying steel bracings, destruction in beams is removed, and this destruction is turned to bracings, because they play fuse role in the structure. Thus the main reason for using concentric and eccentric braces in reinforcement concrete frames is to have a

frame with more ductility and to conduct formation of the plastic hinges in concentric braces and link beam in the eccentric braces.

It will be seen that one of the methods to create ductility in reinforcement concrete structures, is the confinement longitudinal bars of column by utilizing annular confining with transversal bars as stirrup bars.The ductile behavior under seismic loads especially earthquake load may absorb energy significantly from applied loading before the collapse of columndue to create deformation in column. But in reinforcement concrete structures and in their rehabilitation and retrofitting processes, it is not possible for column to be damaged easily and reconstruction of it to be done with confined bars. So one of the best methods to retrofit the reinforcement concrete structures, is to construct steel braces in concrete frames bays. Of course it should be pointed that in reinforcement concrete structures with confined columns, it is expected to be formed plastic hinges in beams yet.

Modeling of the samples

Three lateral resistant systems consisting of concrete moment frame alone, concrete moment frame with X shape braces and concrete moment frame with inverted Y shape braces were considered. Above models were taken from the other researchers models in concrete framed structures field with short and medium height. The vertical shear link in 4, 8 and 12 - stories frames were designed in this manner that yield subject to shear [4]. Above frames were used for framed structures with short and medium heights by the other researchers [2], [3]. All of the frames had three bays that was braced their central bay. Stories height was 3 meters and all of the bays had 5 meters length. In table1 concrete and consumed steel strength specifications is observed. Also design basic shear was determined for maximum ground acceleration which it's size was 0.35g.

table1: concrete and consumed steel strength specifications

	Specified concrete compressive strength (MPa)	Nominal Steel yield strength of reinforcement (MPa)	Modulus Elasticity (MPa)
concrete	22	-	2×10^4
Longitudinal bars steel	-	400	2×10^5
transversal bars steel (confined bars)	-	300	2×10^5
Bracings steel	-	240	2×10^5

$$S_a = 0.35g = 0.35 \times 9.81 = 3.4335 \ m/s^2$$

In above systems their loading was assumed consisting of total dead load plus 20 percent of live load. Concrete frames were designed with use of ACI code provisions as intermediate ductility and steel bracing systems were designed according to AISC-LRFD code. Concrete moment frame alone, concrete moment frame with X shape brace and concrete moment frame with inverted Y shape (EBF) brace figures have been shown in Fig.1-1. Concrete moment frame geometry with two types X shape brace and inverted Y shape bracehave been shown in Fig. 1-2 [1].

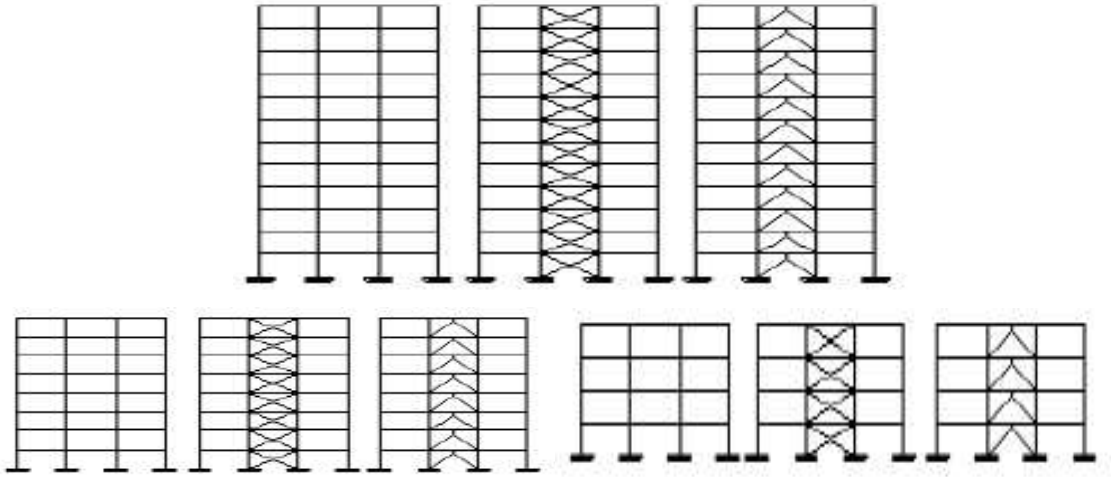


Fig 1-1: Concrete moment frame alone, Concrete moment frame with X shape brace and Concrete moment frame with inverted Y shape brace figures in three height 4, 8 and 12 stories[1]

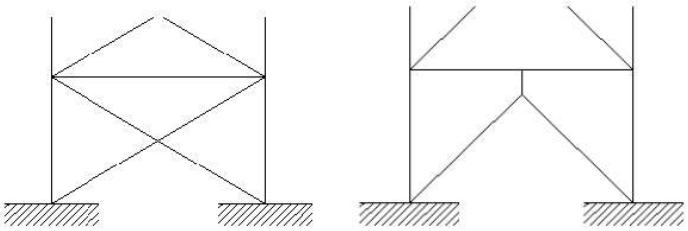


Fig.1-2: Concrete moment frame geometry with two types X shape centric brace and inverted Y shape eccentric brace

Analysis method

We use from pushover analysis to evaluate performance of frames against earthquake and the formation quality of plastic hinges.In other to verify modeled frames, we compared the analysis and its results with Maheri experimental models[6]. Base shear curves in terms oftarget delta displacement were compared to two types experimental and numerical states and were done by pushover analysis, has been shown in Fig. 2 [1].

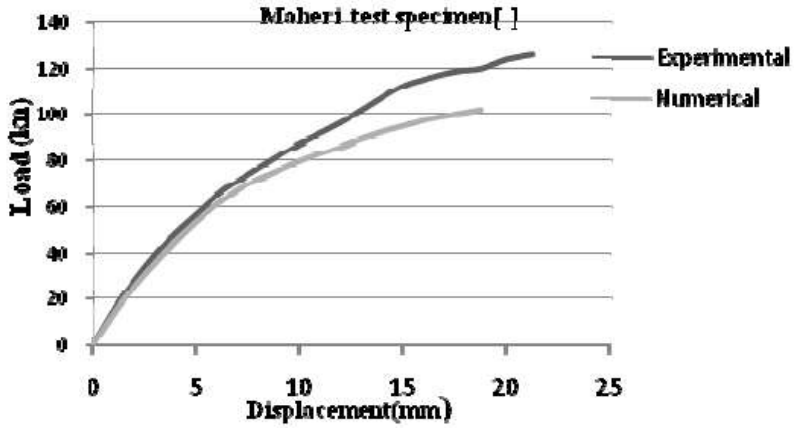


Fig2. The comparison between numerical and Maheri experimental results [1], [3]

Pushover analysis (nonlinear static analysis)[7]

A resistant structure to earthquake must resist against specified force and it should be capable to have specified displacement. Above force and displacement values are determined by selecting building performance level. A resistant structure to earthquake does this displacement by deformation-controlled(ductile) actions. Therefore,performance level is supplied by controlling the amounts of sustained force and performed displacement. In this paper the seismic rehabilitation of structure is done by retrofitting of it. It must pay attention to this point that rehabilitation aim is communication between hazard level and performance level.

Before performing an nonlinear analysis, we must know what earthquake is applied to structure and what performance is considered to be taken from the structure. As a matter of fact the aim of the rehabilitation is communication between analysis input that is hazard level and analysis output that is performance level.

Pushover analysis method is the same nonlinear static analysis. In this analysis the amount of force has not very importance but the amount of displacement is very important in it. In this analysis control point may be roof mass center. This point is displaced to the size of target displacement. After doing this displacement, the actions are read. The target displacement (δ_t)is the amount of displacement that the structure ought to do at Pushover analysis and in considerable hazard level until to stay in desirable performance. In above analysis we require to use from load pattern or appropriate distribution of lateral loading. As a matter of fact a pattern is appropriate that is close to the results of time history. In nonlinear analysis procedures, at first the structure is subjected to gravity load, when force and deformations due to gravity load were formed in structural sections, then the structure is subjected to lateral loading.

Performance levels in structural components that utilize in structural retrofitting and rehabilitation codes are immediate occupancy (IO), life safety (LS) and collapse prevention (CP) levels.

In immediate occupancy level, it is expected the strength of structural components doesn't change significantly due to earthquake occurrence. Building meeting this target building performance level are

expected to sustain minimal or no damage to their structural elements and only minor damage to their nonstructural components. In life safety level it is expected to create damage in structure, but the rate of damages is not so that to create life injury. Building meeting this level, may experience extensive damage to structural and nonstructural components. In collapse prevention performance level it is expected to create widespread damage in structure due to earthquake, but the structure is not collapsed and life injury reaches to minimal. It must remind that SAP software has been painted the plastic hinges in every performance level, in other description due to the color that hinge plastic receives the performance level of it becomes distinguished. For example the color of hinges that take place in life safety performance level are pink and blue and the color of hinges that are not in this performance level consist of turquoise, green, yellow, orange and red respectively. In the structural components rehabilitation according to 360Issue that is for the seismic rehabilitation of existing buildings, plastic hinge was defined and assigned to members in SAP software. If plastic hinges performance level is out of desirable performance level, structural components must be stiffened until their performance level remains according to desirable performance level.

RESULTS

In nonlinear analysis the first plastic hinge formation is very important. In figure 3 the force ratio associated with the first plastic hinge formation in concrete moment frames that is retrofitted with CBF and EBF braces to the same force inmoment resistant frame alone, has been shown and compared.

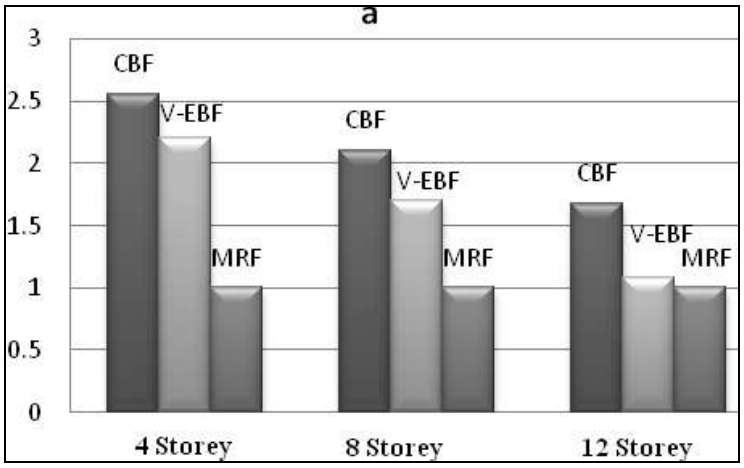
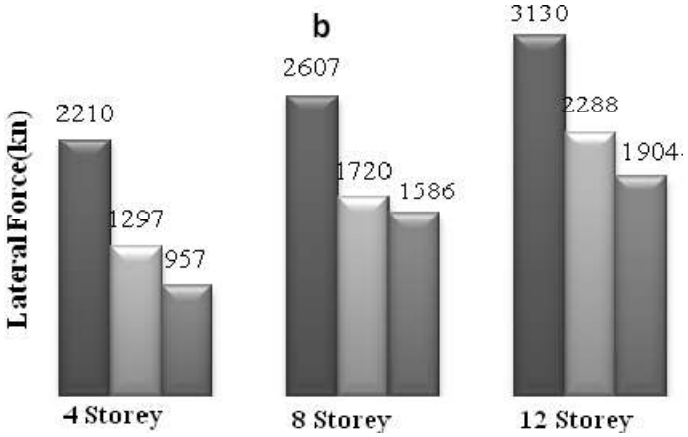


Fig.3 Comparison of the force associated with the first plastic hinge formation in concrete moment frames that retrofitted by CBF and EBF braces withthe same force in moment resistant framealone

Just as it is regarded steel braces of any type may increase the force corresponding to the first plastic hinge formation considerably. Alsowith this retrofit type it is prevented from plastic hinge formation in columns and beam and structure damage has been initiated by plastic hinge formation in braces[1]. The force related to the first plastic hinge that has been formed in column shown in Fig.4 that is its damage reason.



The other important aspect is the place of plastic hinge that is formed at a special performance level. At this research design based on performance is used for evaluating frames performance. Life safety performance level (LS) is considered for calculating target displacement and evaluate plastic hinges status. A number of plastic hinges that pass from life safety performance level and their places in frame shown in table 2.

table 2. the number and the place of plastic hinges occurrence place

	Story Numbers	Beams	Columns	Brace Members	Link Beam
MRF	4	6	3	-	-
	8	16	4	-	-
	12	30	-	-	-
CBF	4	-	-	3	-
	8	-	1	5	-
	12	-	1	5	-
Y-EBF	4	-	-	-	3
	8	-	-	-	6
	12	-	-	-	11

According to above table it is observed that in the resistant concrete moment frames (MRF), all of plastic hinges are formed in the beam and columns of the frame.In the concrete moment framesretrofitted with concentric X shape brace, itis observed that all of the plastic hinges are formed in steel bracing members of the frame. In the concrete moment frames retrofitted with eccentric inverted Y shape brace,it is observed that all of the plastic hinges are formed in shear link of the frame, that it is the most important advantage of the eccentric braces in concrete moment frames. Since in the concrete moment frames retrofitted with concentric X shape bracing, whole plastic hinges are formed in steel bracing members of frame, so in this system braced members tolerate the compressive force and the plastic hinges formation may cause buckling of the braces. But in the concrete moment frames that retrofitted by inverted Y shape eccentric braces, all of the plastic hinges are formed in shear links of frame, and axial forces is not applied to this shear link. This link may tolerate very much deformation and it damps and absorbs energy very well [1].

Conclusions

1. Steel braces increase the force corresponding to the first plastic hinge that is formed in the concrete frame.
2. Steel braces delay the failure of columns in concrete moment frames.
3. By applying eccentric steel bracings with vertical shear link, plastic hinges is formed in the link beam and because of this fact that the link beam may be constructeddiscrete of the main beam at that level, it can be replaced comfortably.
4. Based on this study, it can be seen by performing steel braces of any type, the number of formed plastic hinges decrease and plastic hinges are formed in the desirable places intelligently (in X shape brace members and in link beam).

APPRECIATION

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