SEISMIC BEHAVIOR OF RC FRAMES RETROFITTED BY ECCENTRICALLY BRACED FRAMES WITH VERTICAL LINK

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Abstract: Earthquake resistant structural design and strengthening of buildings are important subjects for many countries that is laying most of its land on earthquake zone. System and component based reinforcements can be performed through the process of retrofitting of reinforced concrete buildings. System based retrofitting type can be categorized into two groups. The first one is the traditional type that aims to fix the ductility, stiffness and the strength of the structures. The second one is the more innovative one that is oriented to reduce the effects of the seismic forces on the structures. Traditional strengthening techniques require heavy demolition and construction work. However, innovative methods that reduce the detrimental effects of earthquakes on buildings are generally expensive to implement, which makes them unsuitable for ordinary buildings. Accordingly, some researchers have focused on the methods that combine the advantages as well as eliminating the disadvantages of the both conventional and modern techniques. One of these methods is installing a link by applying an eccentrically braced system in the shape of “Y”.

In this study, a link is designed and used as a shear element in order to understand the effect of the change at the length of this link on the behavior of system by applying an eccentrically braced system in the shape of “Y” connected vertically to the beam. For this purpose, single story, single span RC frame specimens were produced. The features of the RC frames were chosen according to the conditions of the current reinforced concrete buildings. Lean RC frame specimen were retrofitted with eccentrically braced vertical links. The produced specimens were tested under the reversible loads. Finally; with the help of the results of the tests, analyzed retrofitting technique improved the energy dissipation and lateral load bearing capacities of the lean RC specimen.

Keywords: RC frame, Retrofitting, Y brace.

I. INTRODUCTION

System and component based reinforcements can be performed through the process of retrofitting of Reinforced Concrete (RC) buildings. Coating of columns and application of fibrous polymers can be classified for component based reinforcement methods. Installation of curtain wall [1], reinforcement of infill walls with fibrous polymers [2] and steel traverses are the system based techniques. Installation of Curtain Wall method is the most commonly used method in these reinforcement methods. But there are lots of disadvantages when adding curtain wall to the buildings from the time and application point of view. Putting out of use of structure while strengthening process goes on, makes significantly difficult to applicate. According to all these factors, practical, fast, dependable and economic strengthening techniques have to be developed and design methods have to be proposed accordingly in order to treat seicmic behavior of RC buildings. Usage of structural steel members for retrofitting purposes is a popular method in the literature because of providing practical approach to the subject [2,3].

It is a common result in the Literature that, RC buildings can be strengthened in many ways but especially retrofitting with cross steel elements method is an advantages method from many point of views. Especially strengthening with eccentric bracing is superior to central cross retrofitting in terms of the rigidity and the ductility improvement point of view. Strengthening of RC structures using a Y-shaped shear element of cross-system applications provide advantages in many aspects such as economy and strength. There are studies on the eccentrically braced systems in the shape of “Y” connected vertically to the beam[4-13]. However, theoretical and experimental studies conducted are not still sufficient.

In this study, to reflect the general condition of the existing building stock, strong beam- weak column design and stirrup densification made of 1/3 scale as the epicenter of the reinforced concrete frame produced by Y braced activity on the behavior of the framework of strengthening the system has been studied experimentally.

II. SYSTEM OF STRENGTHENING

In this study, method of strengthening the structural system of a RC building with eccentrically braced steel members has been chosen. Earthquake force energy is consumed at the eccentrically braced frame by the beam element in a stable manner. Therefore, the length of the link element at the eccentrically braced frames also shows the way in which energy is consumed. Short link beams consume energy by shear force whereas long link beams consume energy by momentum. In this study, RC frame will be strengthened by Y type eccentric element in which, link beam will be the shear element. As the first phase of the retrofitting design, the length and the cross section of the link beam is determined.

It is important to determine the length of the beam element which is a characteristic element of eccentrically braced frame. In this study, the length of the link element of the frame is calculated as (e)=5cm by using Equation (1) which is advised by Bauwkamp and Vetr (1998) [14].

$$e \leq 0.35(1+k)\frac{M_p}{V_p}k = \frac{M_2}{M_1} \quad (1)$$

Mp, Moment capacity of link
Vp, Shear capacity of link
e, Link length

Two 1/3 scale RC frame is constructed for this study. Design is applied according to strong beam - weak column combination at joints, stirrup densification is not applied and the hoops are not inserted into beam-column joints. C20 / 25 class concrete was used at the samples.

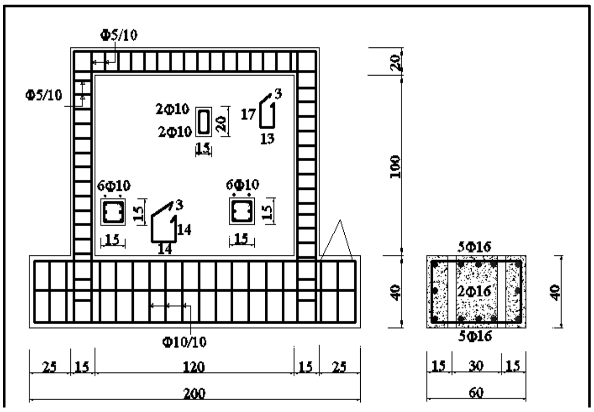

Fig.1. Bare RC Frame Specimen

One of the frames produced is left as plain. The other one was reinforced with eccentrically braced Y system with vertical link beam. Views of plain and retrofitted designs of RC frame systems are shown in Figure 2. Length of the link element at retrofitted RC frame system is designed as 5 cm. The steel material is St 37 steel.

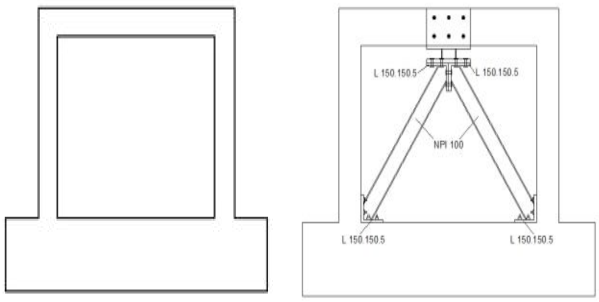

Fig.2. Bare and retrofitted RC Frames

Installation apparatus consist of reaction wall, rigid floor, load cells, hydraulic cylinder and manual override hydraulic jacks. Horizontal load is applied with hydraulic jacks and load cell to the hinged specimen (Fig.3).

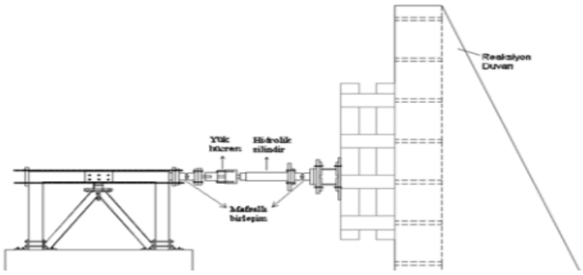

Fig.3. Test assembly

III. RESULTS AND DISCUSSION

3.1. Lean specimen

Produced frame samples were tested after 28 days of concrete strength under repeated reversible loads. 5 kN of load increments were carried out during the experiments. The first cracks at the sample occurred at the lower end of column at 10 kN thrust load. The thrust load bearing capacity of 50 kN is reached and 47 kN is at reverse loading. Lean pre-test sample frame view is given in Fig.4.

Fig.4.The appearance of the pre-test plain sample

It is seen that, column bottom and upper ends became hinged during experiments. Because of the stirrup densification is not applied, frame has reached its load carrying capacity and buckling occurred at the lower end of the column reinforcement (Fig.5.).
The capacity curve obtained for plain frame sample is provided in Fig.6.

Fig.5. Views of the plain specimen after the test and the damage occurred at the test

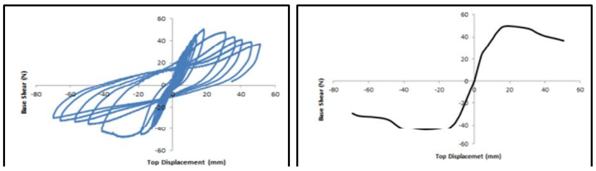

Fig.6. Horizontal load - displacement cyclical envelope curve for plain sample

3.2. System that is retrofitted with Y eccentric braces

Test sample is formed by the addition of Y vertical link system. It is formed by adding vertical link beams to the plain sample produced in the same features. In this sample, the cross section of the link beam and cross profiles are IPE 100, merger tools are M16 bolts and steel St 37 steel. Steel profiles are retrofitted by the aid of RC frame columns and beams directly with bolts and epoxy injection. Link beam connection is formed with the help of cross connection bolts while L150.150.5 using steel profiles. (Fig.7.).

Fig.7. View of the Retrofitted sample before the test

The first cracks have occurred in the upper end of the column loading 40 tons of thrust to the sample. For the load bearing capacity, 90 kN thrust and 88 kN tension values have been reached. Occurred damages during testing in the Y traversing retrofitted RC frame sample is given in Fig.8.. Cracks formed remained at a more capillary level according to the plain sample. However, due to their larger load transfer values, stripping have been observed at the column anchors at the bottom end of cross-connections.

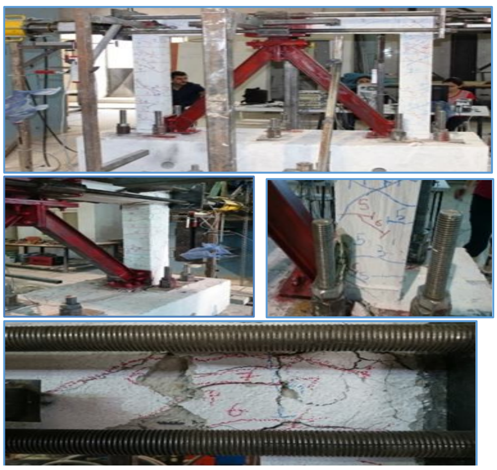

Fig.8. View of the damage occurred after the experiment at retrofitted sample

Obtained capacity curve is given in Fig.9. for retrofitted sample.

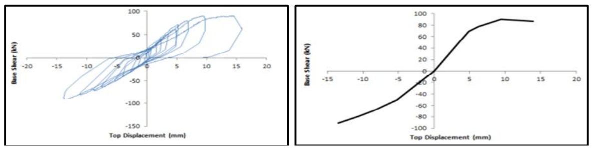

Fig.9. Obtained horizontal load- strain for retrofitted sample.

Horizontal load (kN)-displacement (mm) curve is shown in Fig.10. for reversible repeated tests carried out at simple and reinforced for comparison. The load bearing capacity of the system reinforced with Y traversing shown an increase of 1.8 times of lean RC frame frame capacity at thrust, pulling capacity is increased 1.91 times that of lean RC frame. Energy dissipation capacity of the sample is calculated as □□/ h = 0:02 level from the area under the curve. Energy consumption levels of lean sample for the thrust load is 436 kNmm, for tensile loading is 408 kNmm obtained whereas for retrofitted samples, thrust loading as 1002 kNmm to 1088 kNmm for tensile loading. Therefore, energy consumption capacity has increased 2.67 times for tensile loading and 2.30 times for thrust loading.

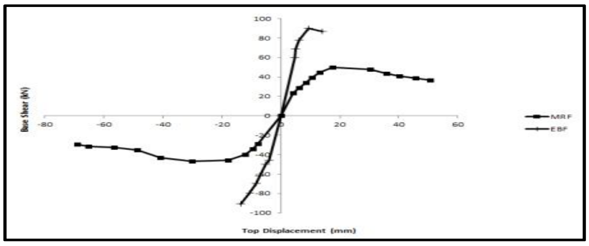

Fig.10.Capacity Curves of Bare RC Frame and Retrofitting Frame

CONCLUSIONS

In this study, it is focused on a strengthening method that combines the advantages of innovative retrofit methods, economic, practical and safe. This method is applied on eccentrically braced frames with vertical link technique which is designed as a Y type shear element of the link beam and vertically connected to the RC frame. 1/3 scale, single-storey, single-span, 2 RC frame samples were produced. The experiments were carried out for the strengthened and lean frames under reversible repeated loads. Following these experiments, horizontal load-bearing capacity curves of lean and reinforced frames were obtained. Thus, it is intended to contribute to the literature regarding the subject and to increase the empirical research on the subject.

Considering damages occurred during the experiments; first cracks seen at the lean RC frame sample at 10 kN thrust load on the lower end of the column, whereas first cracks were observed at the reinforced frame sample at 40 kN thrust load on the upper end of the column. It is also observed that, cracks formed at the strengthened frame remained in a more capillary level. However, due to larger load transfers, stripping at the bottom end of the column anchors where the cross-connections made have been observed.

When findings of the tests of reversible thrust load on RC frame under cyclic loading carried out from experimental studies in the lean and Y traversing reinforced models are evaluated, the load bearing capacity of the reinforced system is 1.8 times the thrust based on lean RC frame, increased 1.91-times in the drawing. The energy consumptioncapacity showed 2.67-times for tensile loading and an increase of 2.30for thrust loading.

It can be noticed that, not only load bearing capacity, but also energy consumption of reinforced frames are increased according to the lean frame. However, considering the problems of stripping anchor encountered during the experiment, it can be claimed that, if the RC elements taped to steel elements at the connection zone; from the horizontal load capacity and energy consumption point of view, is likely to further increase capacity and ductility.

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