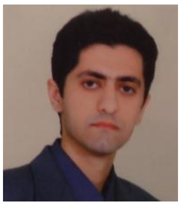

The analytical model of the BRB system for strengthening the RC building

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Abstract

In this paper, the Buckling Restrained Brace (BRB) system is utilized for strengthening the RC building. For this purpose, the structural model is constructed in the ABACUS finite element software in which the concrete has nonlinear behavior. The analytical results are then compared with different cases i.e. un-strengthened frame (un-braced building), frame with shear-wall system and building with the CFRP (Carbon Fiber Restrained Polymers) strengthener. Also, three criterions such as the energy absorption, strength and deformation are employed for judgment about the efficiency of strengthening methods. These analyses show that the maximum deformation of the BRB is more than shear-wall system. However; the energy absorption and the strength of the BRB are less than shear-wall model. On the other hand, the efficiency of the BRB system in the energy absorption and maximum displacement is more than the CFRP.

Key words: Buckling Restrained Brace (BRB), Nonlinear Frame.

1. Introduction

Strengthening and its approaches are common way for improving the structural behavior and their efficiency, which reduce the defects powered by different sources such as analytical and design errors, the lack of construction methods and codes, environmental effects during life time and etc. Based on this foundation, strengthening are procedures which affected a part or the whole structure to improve the efficiency and structural specifications (Zahraie 2006).

There are different methods for strengthening of structures and researchers try to present more effective schemes. Using the brace members in both steel and concrete frames is one of the well-known methods which have been proposed in variety of structures and different load conditions. Buckling is the main defect of the common brace members which decreases the flexibility and damping of structure .This subject causes a considerable reduction in structural stiffness under the cyclic and dynamic loads, such as earthquake. Therefore, researchers try to design a brace member which does not buckle (Clark et al. 1999). In this field, Kimura and his co-workers produce the first model of buckling restrained brace member in which the steel core is covered by a steel sheath filled (Kimura et al. 1976). The experimental study of this member shows that a pit or a hole is created because of compression deflection of steel core. This subject reduces the stability of member in cyclic loadings. In Japan, the use of these brace members has been started until 1980 decade (Watanabe et al. 1988, Hasegawa et al. 1999, Wada et al. 1989). Moreover, wide researches have been performed on these braces which lead to more effective design of structures under the seismic loadings Black et al. 2002, Tsai and Lai 2002). Another kind of anti-buckling brace system is called BRB, i.e. Buckling Restrained Braces.

In this paper, the analytical model of BRB is prepared in ABAQUS software. Then, this model is applied for strengthening of a concrete frame and results are compared with some other cases such as CFRP (Carbon Fiber Reinforced polymers), shear wall system and etc.

2.The BRB system

One of the latest anti-buckling models is BRB in which the energy damping is considerable. In this system the brace member is covered by a concrete sheath which prevents the member from the buckling risk and causes the same behaviors in both tension and compression. Therefore more flexibility followed by more energy damping are created compared with the normal braced frames as stated in the FEMA 454, December 2006. The BRB system has combined from five parts; as shown in Fig. 1; i.e. covered steel core, un-covered steel core, connection zone, isolator materials and covered sheath (Uang and Nakashima 2003).

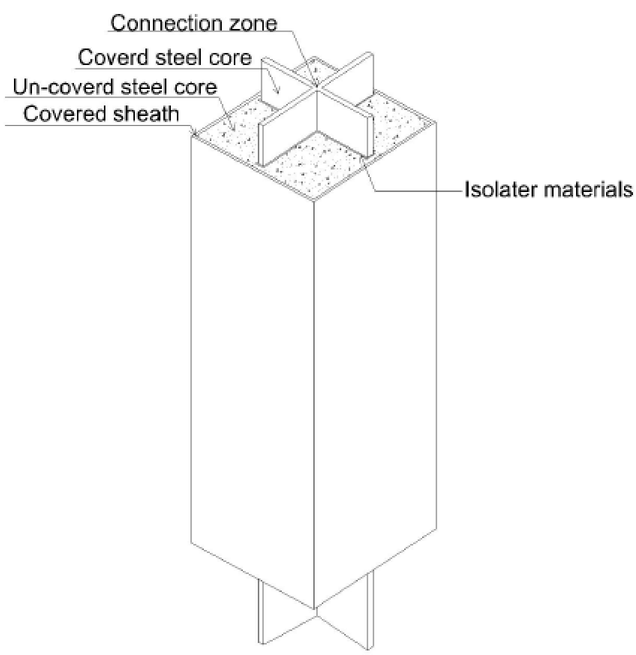

Fig 1: The schematic parts of the BRB.

First, the analytical model of the BRB is prepared in ABACUS software, using continuous element. This element can model the nonlinear large strain, large rotation and creep. In this analysis, just the internal core has been modeled and the effect of other parts of the BRB is considered by restraining the lateral displacement of the brace member. The cross section of steel internal core is 0.01007 m^2 i.e. 0.153×0.019 which its length, modulus of elasticity and yielding stress are 5.38 m, 2×10^{11} n/m^2 and 4185×10^5 n/m^2, respectively. Fig. 2 shows the results of nonlinear analysis which has been compared with the experimental data (Black et al. 2002).

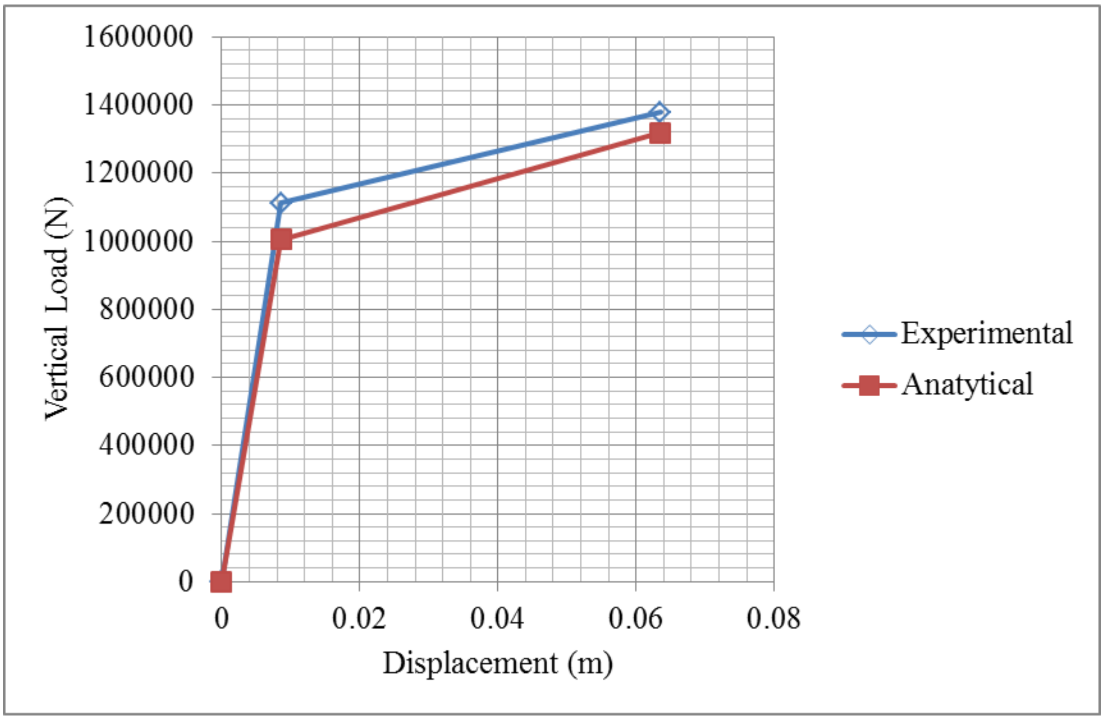

Fig 2: Comparison between the analytical and experimental results of a single BRB.

From Fig. 2, it is concluded that the analytical model of the BRB which has been prepared here is suitable for numerical analysis. Therefore, this model is utilized for strengthening of a concrete frame.

3. The Analytical Model of the Strengthened Frame

Fig. 3 shows a two story three bay frame which has been modeled in ABACUS software using continuous elements and the analytical results are compared with the experimental ones (Erdem et al. 2006). All beams and columns are 110×110 mm and 110×150 mm, respectively. The longitudinal armature of beams and columns are 4Φ8. Also, all latitudinal armatures are made from Φ4. This frame is subjected to some vertical and horizontal loads, shown in Fig. 3. It should be noted that in the experimental case (Erdem et al. 2006), the horizontal load is applied by a hydraulic jack.

To verify the analytical model the results of the un-strengthened frame obtained from the ABACUS are compared with the experimental data (Erdem et al. 2006). Fig. 4 shows the experimental and analytical results of the un-strengthened frame. It is clear that the prepared analytical model has suitable accuracy.

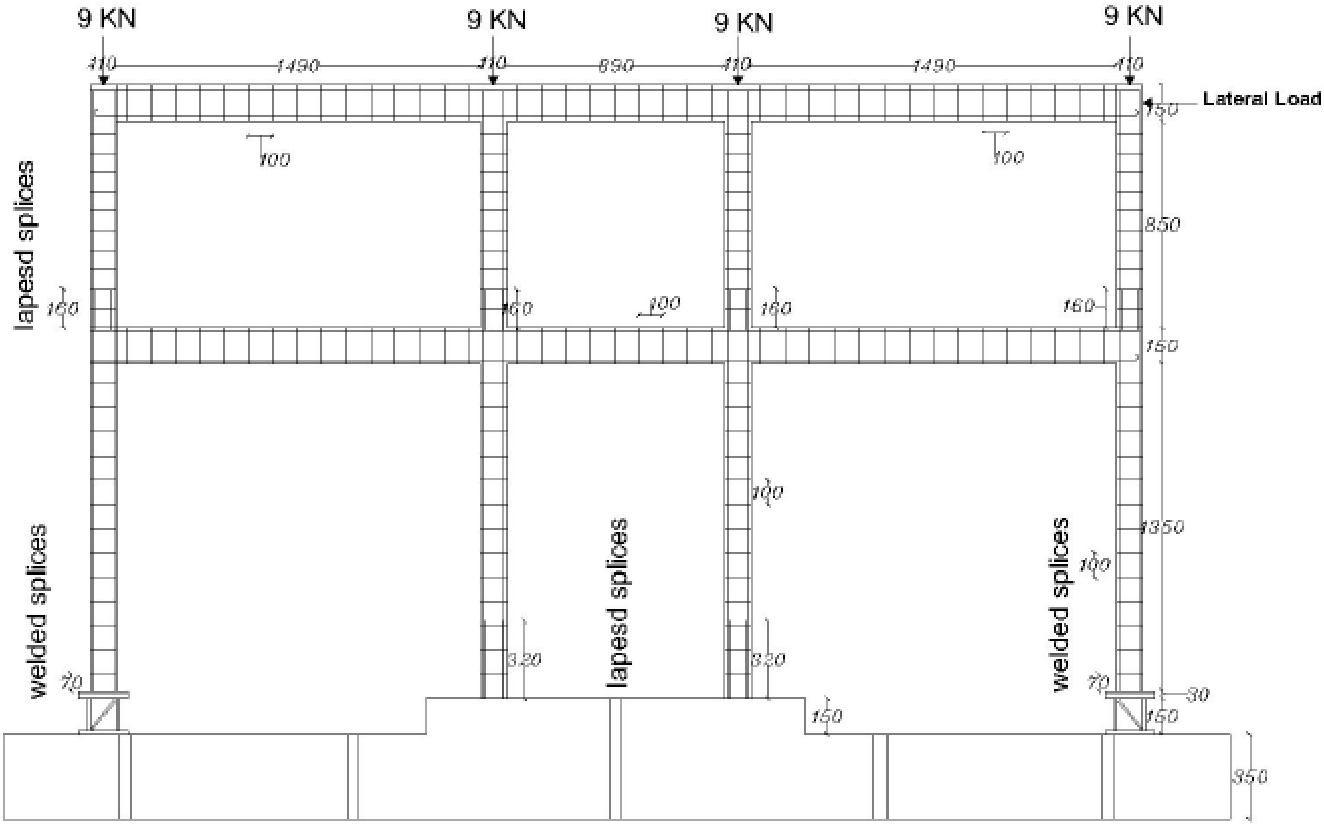

Fig 3: The analyzed concrete frame (Dimensions in millimeters).

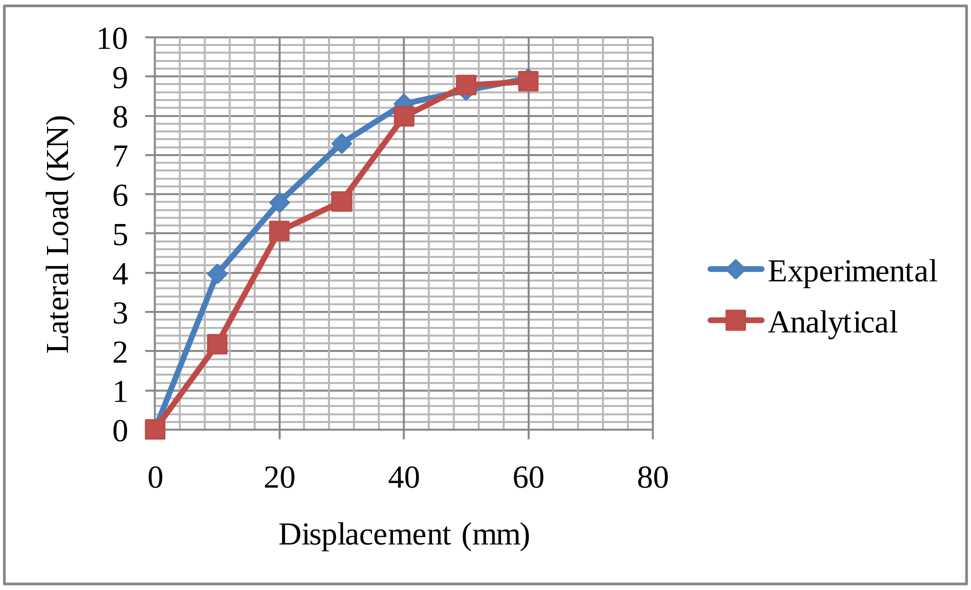

Fig 4: The horizontal displacement of top of the frame versus lateral load.

At the next stage, the frame is strengthened by the BRB system and reanalyzed. Fig. 5 shows the horizontal displacement of the top of the frame obtained from the strengthened and un-strengthened models. On the other hands, the results of the BRB system have been compared with the shear-wall (Prota et al. 2004) and the CFRP (Limam et al. 2005) strengthening mechanisms, shown in Fig. 5.

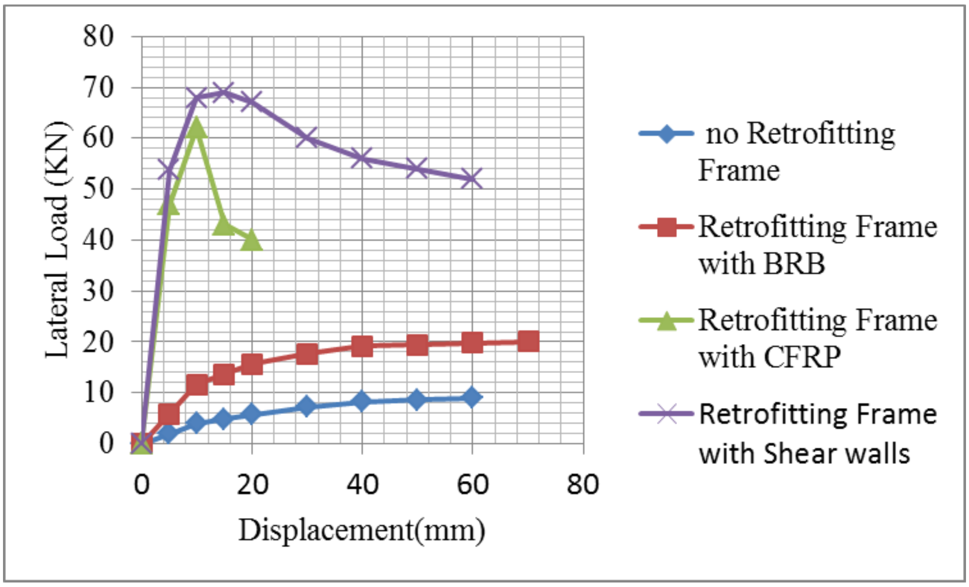

Fig 5: The horizontal displacement of top the frame obtained from different retrofitting method.

From Fig. 5, it is possible to compare models from different points of view. For this purpose, strength is defined as the maximum force carried by the frame. The corresponding displacement is named as the maximum displacement. Moreover, measuring the area created by the curve of the lateral load versus horizontal displacement is called the energy absorption. Based on the codes definition, this area is limited by the point which has eighty percent of the maximum strength. The results for the strength, the maximum displacement and the energy absorption of different model have been inserted in Table 1. Findings show that the BRB model produces a considerable energy absorption compared with no retrofitting frame and also the CFRP frames.

Model	Strength (KN)	Energy Absorption	Maximum Displacement (mm)
No Retrofitting Frame	8.9	385	60
Retrofitting Frame with BRB	20.1	1136	70
Retrofitting Frame with CFRP	63.8	540	10.7
Retrofitting frame with Shear wall	69.3	2441	16

Table 1. The strength, energy absorption and maximum displacement of the frame with different retrofitting systems

4. Conclusions

This paper deals with some specifications of a strengthening method called BRB i.e. Buckling Restrained Brace. First, the analytical model of the BRB was prepared in the ABACUS software and results were verified by the experimental studies. Then some other strengthening methods such as the shear-wall and the CFRP were compared with the BRB system in a concrete frame. Results show that the frame deformation in the BRB system i.e. maximum displacement is higher than both shear-wall and CFRP systems. However the energy absorption and strength of the BRB are less than shear-wall mechanism.

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