Comparing the Nonlinear Behaviors of Steel and Concrete Link Beams in Coupled Shear Walls System by Finite Element Analysis

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ABSTRACT

Regarding the role of link beams in the seismic behavior of coupled shear walls, in this study, at first a pre-designed concrete link beam of a coupled shear walls system, tested previously under cyclic loading, has been analyzed by Finite Element Modeling (FEM). Then it has been substituted by a steel link beam, and the analyses have been repeated to find out the differences between the hysteretic behavior of the concrete link beam with that of the steel link beam, designed with the same loading. In the verified FEM 8-node elastoplastic solid elements have been used. For the concrete link beams the material has been of ‘concrete damage plasticity’ type, and for the steel link beams the multi-linear elastoplastic material model has been used. The steel reinforcement bars in concrete elements have been modeled as ‘truss’ element. The steel link beams have been considered once without stiffeners and once with them to see how they improve its behavior. The embedded length of the steel link beams in the concrete walls has been considered long enough to be able to assume that no sliding occurs between the steel beam and its surrounding concrete. Numerical results show that in case of steel link beams the hysteretic loops does not show any pinching effect, and therefore these link beams are better in seismic energy absorption. The amount of energy absorption can be more than 3 times in comparison with the concrete link beams. Using stiffeners in the steel link beams does not have much effect on their hysteretic behavior, and add their energy absorption capacity only around 10 percent.

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1. INTRODUCTION

Link beams play a great role in the seismic behavior of coupled shear walls. They are the main sources of energy dissipation in the coupled walls system, and their pre-mature failure can drastically change the stiffness and strength of the system. As the coupled walls system have been made conventionally of reinforced concrete (R/C) the material of the link beams has been also R/C. However, in recent years using other materials as the main material of the link beams or for upgrading their seismic behavior have been taken into consideration by some researchers, and a few experimental studies have also been conducted. Experimental and numerical studies on the use of external steel plates for strengthening of reinforced concrete coupling beams (Su and Zhu 2005), is a sample of these studies. Also Park and Yun (2006) have conducted a study on the seismic behavior of steel coupling beams in a hybrid coupled shear wall system and have proposed some design guidelines for this purpose.

In this study, at first a pre-designed concrete link beam of a coupled shear walls system, tested previously under cyclic loading, has been analyzed by Finite Element Modeling (FEM). Then it has been substituted by a steel link beam, and the analyses have been repeated, to find out the differences between the hysteretic behavior of the concrete link beam with that of the steel link beam, designed with the same loading. Details are explained in the next sections of the paper.

2. VERIFICATION OF FINITE ELEMENT MODELING (FEM)

Regarding that using steel and concrete parts together as structural elements, either in contact or in combination, faces to some uncertainty, before using the finite element program for the steel link beam in the coupled wall system, verification of modeling is necessary. For this purpose two experimental cases were considered in this study, a deep reinforced concrete coupling beam under monolithic loading (Zhao et al. 2004) and a steel coupling beam in a hybrid coupled shear wall systems under cyclic loading (Park and Yun 2006).

2.1 Deep R/C Coupling Beam

Figure 1 shows the deep coupling beam under test subjected to a monolithic loading, and Figure 2 shows the specifications of the used steel and concrete materials.
Figurer 2- The stress – strain specifications of steel (a) and concrete materials in compression (b) and tension (c) used in the study by Zhao and his colleagues (2004)

Figure 3- The developed FEM of the deep beam sample for its numerical analysis

Figure 4- Force – displacement curves obtained by the test and the numerical analysis
For making the FEM of the deep beam sample the concrete body was modeled by 8-node solid elements of ‘concrete damage plasticity’ material type, and the steel bars were modeled by 3-node ‘truss’ elements. An L form rigid part was also considered in the numerical model to make it possible to apply the load by using just a point load at its free end as shown in Figure 3. The force – displacement curves obtained from the test and the numerical analysis are shown in Figure 4, which shows a good agreement between the FEM and the test result.

2.2 Steel Coupling Beam in a Hybrid Coupled Shear Wall Systems

The second test results used for verification of the FEM relate to a steel coupling beam in a hybrid coupled shear wall system under cyclic loading (Park and Yun 2006). The sample beam and the corresponding test set-up is shown in Figure 5, and the specifications of the steel and concrete material used for the sample wall are given in Figure 6.

![Figure 5 - Steel coupling beam in a hybrid coupled shear wall system under cyclic loading studied by Park and Yun (2006)](image)

![Figure 6 - The stress – strain specifications of steel (left) and concrete (right) materials used in the study by Park and Yun (2006)](image)
For making the FEM of the sample wall, similar to the previous case, the concrete body was modeled by 8-node solid elements of 'concrete damage plasticity' material type, and the steel bars were modeled by 3-node ‘truss’ elements. For the steel link beam the multi-linear elastoplastic material model was used. The developed finite element model of reinforcements and the concrete wall and the steel coupling beam are shown in Figure 7.

![Figure 7](image)

Figure 7- The developed FEM of the hybrid coupled wall system with steel coupling beam

The hysteretic curves obtained form the test and the numerical analysis are shown in Figure 8, which again shows a good agreement between the FEM and the test result.

![Figure 8](image)

Figure 8- Hysteretic curves obtained by the test (left) and the numerical analysis (right)
3. ANALYSIS OF THE STEEL LINK BEAM

After verifying the FEM, the coupled shear walls system studied by Su and Zhu (2005) was considered and at first its energy dissipation behavior, obtained from the test, was simulated by FEM. Then its R/C link beam was substituted by a steel link beam, designed to have the same capacity (Sadeghi 2010), to study its nonlinear behavior in comparison with the original R/C link beam. This coupled shear wall system and corresponding test set-up, and also its geometric and reinforcement details are shown in Figure 9.

The steel link beam was considered once without stiffeners and once with them to see how they affect its behavior. The parts of the wall with steel link beams, considered for numerical analysis, and their corresponding FEM are shown in Figure 10.

The embedded length of the steel link beams in the concrete walls was considered long enough to make it possible to assume that no sliding occurs between the steel beam and its surrounding concrete.

It can be seen in Figure 11 that the steel link beam, either without or with stiffeners, have much higher energy dissipation capacity in comparison with the R/C link beam, basically since no pinching happens in the case of steel link beam. To have a better comparison of the energy dissipation behavior of R/C and steel link beams their cumulative energy dissipation during the loading are shown in Figure 12.

It can be seen in Figure 12 that in case of using steel link beam the amount of energy absorption can be more than 3 times in comparison with the case of concrete link beam. It is also observed that using stiffeners in the steel link beam does not have much effect on their hysteretic behavior, and add the energy absorption capacity only around 10 percent.
4. CONCLUSIONS

Using steel link beams are architecturally desired since their height is less than their equivalent R/C link beams. In addition to this architectural advantage, based on the numerical results it can be said that in case of steel link beams the hysteretic loops does not show any pinching effect, and therefore these link beams behave much better in seismic energy absorption. The amount of energy absorption can be more than 3 times in comparison with the concrete link beams. Finally, it can be said that using stiffeners in the steel link beams does not have much effect on their hysteretic behavior, and can increase their energy absorption capacity only around 10 percent.
REFERENCES


