Experimental Study on Composite Structural Walls with Steel Hysteretic Dampers

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Summary

This paper reports on a research project aimed at investigating a dual system composed of moment-resisting open frames and a new type of composite walls. The features of the proposed walls are; 1) damage deduction of the wall panels and 2) large energy dissipation capacity. The former is introduced by providing the horizontal clearance between a foundation and wall panels except for the location of the edge columns. This device avoids the sever damage which is seen at the end of conventional walls. The latter is introduced by the steel coupling girders which are spanned narrowly between two wall panels. Mechanical behavior of the new type of wall system is investigated through a series of cyclic loading tests of two three-story specimens. The experimental results show that wall specimens designed appropriately behave in a ductile manner and have very large energy absorption capacity available even in small story drifts.

Keywords: composite structure; wall-frame structure; overturning collapse mechanism; coupling girder; cyclic lateral loading test; hysteretic damper; fatigue fracture.

1. Introduction

A kinematically admissible complete mechanism of our proposed wall system is shown in Figure 1. This structural wall shown in the figure is named as energy dissipation structural wall (EDSW). The characteristics and merits of the EDSWs are itemized as followings:
(1) Plastic deformations or damages of the EDSW during a major earthquake could be limited in four plastic hinges in edge columns and coupling girders, the rest of the EDSW including concrete wall panels in the first story can be designed to stay in elastic regions. Hence, the analytical model for the wall applicable to both of static and dynamic analysis can be simple and reliable.
(2) Initial yielding of the coupling girders occurs at an early stage of lateral loading in small interstory drift level. If the coupling girders are designed to be able to dissipate large amounts of energy input without collapsing under extreme loading condition during major earthquakes, coupling girders can take a role of hysteretic dampers during earthquakes. Such a design can be easily achieved by using H-shaped steels as the coupling girders.
(3) A deformation pattern of EDSW subjected to lateral load is similar to that of a frame; hence the EDSWs do not bring a complicated three-dimensional effect into wall frame structures.

(4) A tension force induced in the bottom edge column in tension side at the ultimate state can be determined from gravity load, capacities of the beams framing into the wall system and capacities of coupling steel girders. Hence, the tension force in the edge columns can be controlled independently of a tension capacity of the edge column.

2. Test and analysis

Experimental study and analytical study have been carried out on two specimens of subassemblies representing lower three stories portion of our proposed wall system. The specimens are shown in Figure 2. In the experimental procedure, the lateral force was applied at the top beam of the specimen cyclically under constant axial load. The relations between lateral force and drift angle of

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the specimen are obtained as Figure 3. In the figures, solid line shows test results and dotted line shows analytical results. It is noteworthy that the inelastic behavior is observed in relatively small drift angle of 0.0025rad. and the large energy absorbing capacities are presented until the strength deteriorating manners are observed at the larger drift angle of 0.01rad. The reasons of the strength deteriorations are owing to the failure of the connections between the coupling girders and the concrete wall panels, or the fatigue fracture of the coupling girders mainly. In the large deformation, the concrete wall panels have only few fine diagonal cracks and are considered as acting in elastic manner. The layered models of the section of the test specimens based on the non-liner stress-strain models of steel and concrete are used to simulate the load versus deformation relations obtained by the tests. The analytical results show good agreement with the test results until the local failure occur in the large deformation. This means that if the building with this structural wall response within the small drift angle of 0.001rad. under earthquake excitations, the behavior of the structural wall stays in stable energy dissipating manner and is predicted by the simple analysis.

3. Conclusions

From the experimental and analytical study of structural wall proposed by authors which is named as energy dissipation structural wall (EDSW), the efficient seismic resting behavior of the EDSW was obtained and predicted by the practical analytical model.