Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

Hysteretic Evaluation of Seismic Performance of Normal- and Fiber-Reinforced Concrete Shear Walls

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1. Introduction

The use of fibers in concrete or cement composites can enhance the performance of structural elements. Fibers have been used for a cement mixture to increase the toughness and tensile strength, and to improve the cracking and deformation characteristics. The addition of fibers into concrete can improve the ductility and increase the seismic resistance of concrete structures.

The application of fibers to earthquake-resistant concrete structures has a major research topic. A recent study shows that an excellent seismic performance can be obtained in shear-critical members constructed with high-performance fiber-reinforced cement composites [1].

To increase the seismic performance of safety-related concrete structures in nuclear power plants, fibers can be used. This study investigated the effect of fibers on the hysteretic behavior of a reinforced concrete (RC) shear wall by cyclic tests.

2. Seismic Behavior of Shear Walls

The seismic behavior of concrete shear walls is typically different from the height-to-width ratio. For high-rise shear walls with a height-to-width ratio of greater than 2.0, the failure is mainly governed by flexure force. In contrast, for low-rise shear walls with a height-to-width ratio of less than 1.0, a failure is mainly governed by the shear force. For medium-rise walls with a height-to-width ratio between 1.0 and 2.0, the failure is governed by both flexure and shear forces.

Past experimental studies on the seismic behavior of RC shear walls have revealed that low-rise and medium-rise shear walls have less ductility and lower energy dissipation owing to the angle between the orientations of rebars and the principal direction of applied tensile stresses on shear walls [2]. Recent test results show that both the ductility and energy dissipation capacity are greater when steel bars are in the principal direction of the applied tensile stresses.

3. Experimental Program

3.1 Test Setup

Fig. 1 shows the test setup for the cyclic tests. Lateral displacements were applied through a 3,000 kN hydraulic actuator connected to the loading beam of a specimen at one end and a strong reaction wall at the other end.

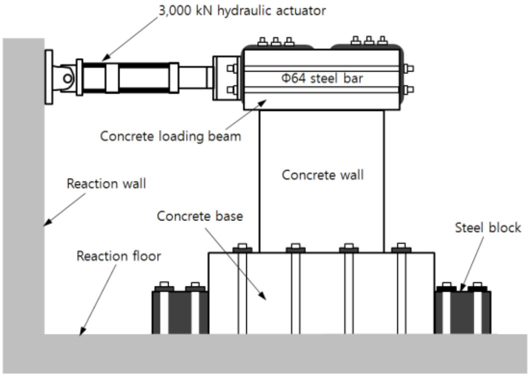


Fig. 1. Wall cyclic test setup

3.2 Specimen

The specimen consists of a loading beam, wall, and base. Fig. 2 shows the dimensions and reinforcement details of the wall specimens. The height-to-width ratio of the wall is 1.15. Three RC materials were used: 1) normal RC with a compressive strength of 42 MPa (NRC), 2) steel fiber RC containing a 1.0% volume hooked steel fiber with a diameter of 0.5 mm, length of 30 mm, and tensile strength of 1,200 MPa (SFRC), and 3) polyamide fiber RC containing a 1.0% volume polyamide fiber with a diameter of 2.31 mm, length of 30.28 mm, and tensile strength of 650 MPa (PFRC).

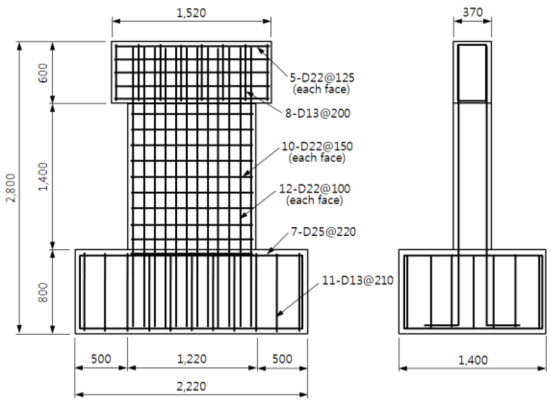


Fig. 2. Reinforcement details of wall specimens

3.3 Displacement History

The wall specimens were subjected to a lateral displacement cycle as shown in Fig. 3. The range of the drift was up to 3.0%.

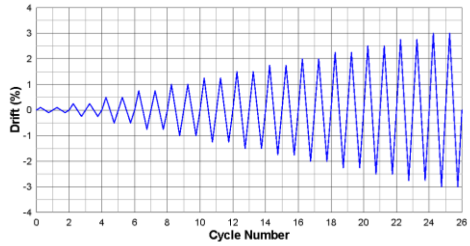


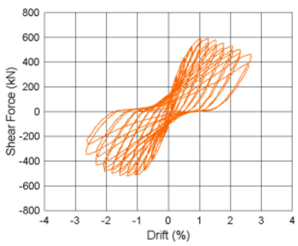
Fig. 3. Lateral displacement history for cyclic test

4. Experimental Results and Discussions

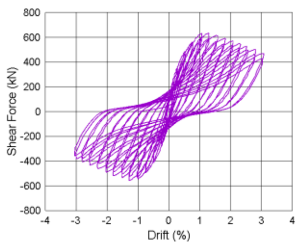
The key experimental results for the three test specimens, including the maximum shear force, draft capacity, and energy dissipation, are given in Table I. The shear force versus drift response of all specimens is shown in Fig. 4.

Table I: Summary of Experimental Results

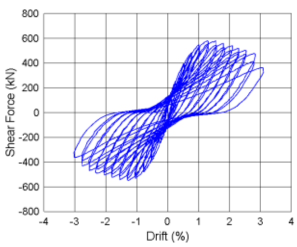
Specimen	Maximum shear force (kN)	Draft capacity (%)	Energy dissipation (kN·mm)
NRC	591.8	2.5	145,421
SFRC	634.0	3.0	236,895
PFRC	581.3	3.0	199,164



(a) NRC



(b) SFRC



(c) PFRC

Fig. 4. Shear force versus drift response

The SFRC specimen, which was constructed with steel fibers at a 1.0% volume fraction, has the largest shear force, draft capacity, and energy dissipation. The maximum shear force was approximately 7% larger than that in the NRC specimen. The displacement capacity reached a 3.0% draft. The energy dissipation was approximately 63% larger than that in the NRC specimen.

The PFRC specimen, which was constructed with polyamide fibers at a 1.0% volume fraction, has a larger draft capacity and energy dissipation than those in the NRC specimen. The displacement capacity reached a 3.0% draft, and the energy dissipation was approximately 37% larger than that in the NRC specimen. However, the maximum shear force was similar to that of the NRC specimen.

Fig. 5 shows damage patterns at a 2.5% draft. Although the height-to-width ratio of the test wall is 1.15 (i.e. medium-rise walls), the failure in the SFRC specimen was governed by the shear force (Fig. 5(b)).

(a) NRC

(b) SFRC

(c) PFRC

Fig. 5. Cracking pattern at a 2.5% drift

5. Conclusions

The effect of fibers on the seismic performance of RC shear walls was evaluated experimentally. Fibers can be used to enhance the seismic resistance of conventional RC structures. Steel fiber will increase the shear capacity and ductility of RC structures significantly. It is necessary to determine the appropriate volume fraction of fibers for safety-related RC structures in nuclear power plants.

Acknowledgement

This work has been achieved with the financial support of the research project granted by Korea Institute of Energy Technology Evaluation and Planning (2010161010004K). All support is gratefully acknowledged.

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