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# Capacity Evaluation of Shear Wall with Concrete Voids Using Numerical Simulation

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## 1. Introduction

After the Fukushima nuclear power plant accident in 2011 and the shutdown of the Wolseong nuclear power plant due to the Gyeongju earthquake in 2016, anxiety about the safety of nuclear power plants has become a big social issue. Shear wall structures with high resistance to lateral loads such as earthquakes are widely used in nuclear power plant structures. The shear wall structure of the nuclear power plant structure is designed to perform elastic behavior under the design seismic load, and the cross-section and reinforcement ratio are much larger than those of general structures. Because of this, there are many difficulties in analyzing the extreme state of the wall of a nuclear power plant structure. In particular, concrete voids were recently discovered in the containment buildings of some nuclear power plants in Korea, and repair work had been carried out for several years. If concrete voids are concentrated in vulnerable areas, there is a possibility of causing a decrease in the shear performance of the wall.

To predict the performance of a typical shear wall composed of reinforced concrete, the formula presented by Barda et al. [1] can be used, and in the case of a cylinder-shaped structure such as a containment building, the formula presented by Ogaki et al. [2] can be used. However, additional research is still needed on the case where the effective shear area is reduced due to the occurrence of concrete voids.

Therefore, in this study, we conduct a study to predict the degradation of shear wall performance considering concrete voids. In the shear wall experiment, it is quite difficult to artificially create realistic concrete voids in the wall. In addition, it is necessary to identify the vulnerable part of the wall and to conduct a parametric study according to the size or location of the void first, so a preliminary study is conducted using a numerical method. A numerical model is developed by selecting the shear wall test [3] previously performed by the Korea Atomic Energy Research Institute (KAERI) as a reference test. Numerical analysis is performed using LS-DYNA, a commercial finite element software, and concrete voids are expressed by removing some elements in the middle of the wall. Parameter analysis is performed using the area and thickness of the void as variables, and the shear performance degradation according to the shape of the void was quantitatively derived.

## 2. Methods and Results

### *2.1 Reinforced Concrete Shear Wall Test*

Fig. 1 shows the shear wall test specimen and setup, and Fig. 2 represents the reinforcement diagram used to fabricate the shear wall specimen. The shear wall was manufactured on a reduced scale with the auxiliary building of the Korean nuclear power plant as the target structure. The result of the uniaxial cyclic load test with axial load is selected as the target test.

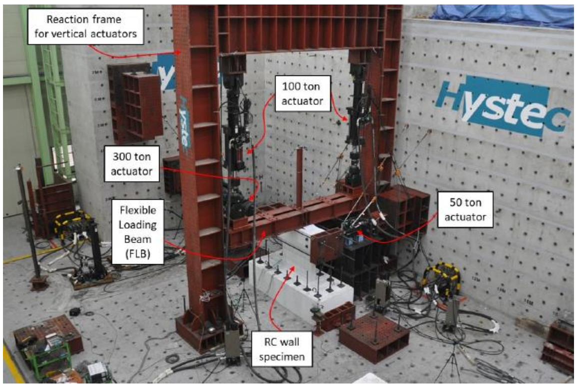



Fig. 1. Shear wall test specimen and experimental setup

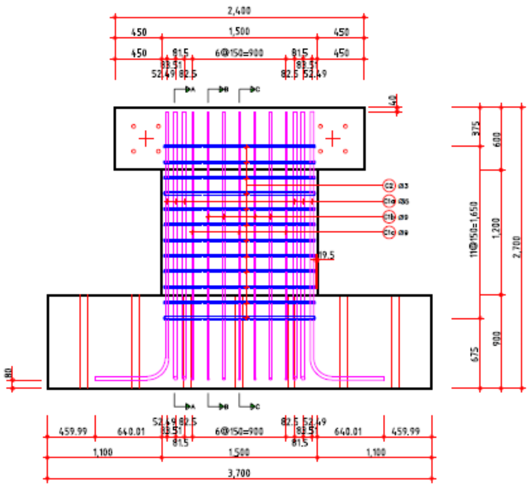
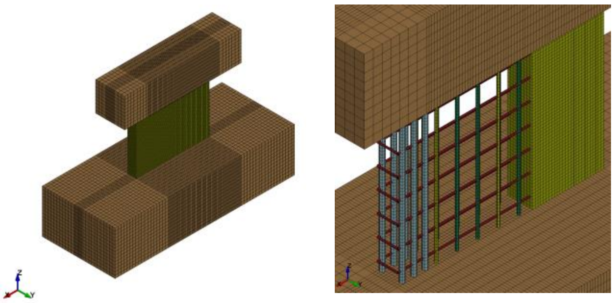



Fig. 2. Reinforcement diagram for shear wall

### *2.2 Numerical Model of Shear Wall*

Fig. 3 shows the numerical model of the shear wall and rebar. Concrete was modeled using solid elements, and reinforcing bars were modeled using beam elements.

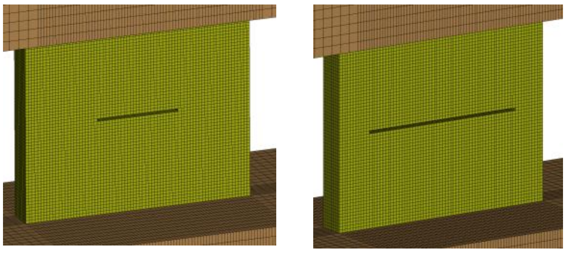
The compressive strength of concrete is 45.2 MPa, and the yield strength of reinforcing steel is about 500 MPa. The horizontal load is applied with displacement control using the "prescribed_boundary_motion" keyword.



(a) (b)

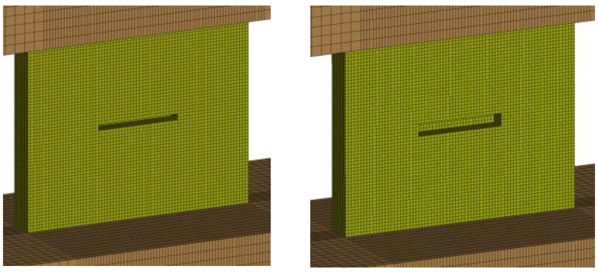
Fig. 3. Numerical models of (a) shear wall and (b) rebar in concrete wall

Figs. 4 and 5 show the numerical model with shear area reduction and with varying void thickness, respectively. The effects of the area and thickness of concrete voids on the shear performance of walls are investigated.



(a) (b)

Fig. 4. Concrete voids in shear wall model for (a) 20%, (b) 40% of shear area.



(a) (b)

Fig. 5. Concrete voids in shear wall with thickness of (a) 4 cm, (b) 8 cm.

### *2.3 Shear Wall Capacity Considering Concrete Voids*

Through numerical analysis results, the effect of concrete voids on the performance of shear walls was derived. Table I summarizes the effect of concrete void area, and Table II summarizes the effect of concrete void thickness. It is confirmed that the wall shear strength decreases by about half of the reduction rate of the shear area as the shear area decreases. If the void thickness is increased, the overall shear performance is reduced, but it is confirmed that there is no clear tendency.

Table I: Shear strength reduction with different shear areas considering the concrete void

| Shear area | Shear strength (kN) | Reduction ratio (%) |
|---|---|---|
| 100% | 2398 | 0.0 |
| 95% | 2341 | -2.4 |
| 85% | 2247 | -6.3 |
| 70% | 1998 | -16.7 |

Table II: Shear strength reduction with different concrete void thickness

| Thickness (cm) | Shear strength (kN) | Reduction ratio (%) |
|---|---|---|
| 4 cm | 2162 | -9.8 |
| 6 cm | 2069 | -13.7 |
| 8 cm | 2098 | -12.5 |
| 10 cm | 2048 | -14.6 |

## 3. Conclusions

Through numerical analysis results, the effect of concrete voids on the performance of shear walls was derived. Table I summarizes the effect of concrete void area, and Table II summarizes the effect of concrete void thickness. It is confirmed that the wall shear strength decreases by about half of the reduction rate of the shear area as the shear area decreases. If the void thickness is increased, the overall shear performance is reduced, but it is confirmed that there is no clear tendency.

## ACKNOWLEDGEMENT

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