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Cyclic test for shear capacity of cylindrical wall

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ABSTRACT

In Korea where high-frequency earthquakes with magnitude 5.8 has occurred, it is necessary to reevaluate seismic performance of nuclear power plant structures and installed equipment. Especially, containment building is important building because of covering radioactivity. Various tests were conducted for verify the shear capacity of concrete wall and most tests were about I-shaped or H-shaped wall. However, containment buildings were cylindrical shape. In cylindrical shaped wall, some part of area resist to shear force with in-plane-direction and the others resist with out-of-plane direction.

EPRI[2)] and ACI-ASME[1)] code suggest shear capacity of cylindrical wall. However, the test program was conducted in 1960s and most test specimens were not similar with nuclear power plant containment building. In order to verify the shear capacity of cylindrical concrete wall, cyclic test was conducted for reinforced concrete walls with cylindrical shape. The test variables were loading rate, vertical and horizontal prestressing force. The experimental and analytical result were analyzed to propose the shear strength of cylindrical concrete wall and effective shear resistance area of prestressing wall.

1. INTRODUCTION

In recent years, earthquakes magnitudes 5.8 (2017) 5.4(2016) have occurred in the southeastern region of South Korea, where nuclear power plant are located. Thus, concerns about the safety of NPP have increased. Especially, since the containment building is the most important building to maintain NPP, an accurate safety evaluation is required. Containment building of NPP is the final safeguard against radioactive leakage in case of an emergency accident such as an earthquake or an airplane crash. In the event of an emergency accident, containment building withstands rapidly increasing pressure inside the building. Thus Pre-stressed reinforcement concrete is commonly

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used to resist membrane tensile stresses caused by internal pressure.

For reinforced concrete wall, the flexural strength evaluation can be accurately calculated compared to the shear strength. Many studies have performed shear strength tests on concrete walls, and most of them were conducted with an I-shaped simple wall. However, the curved walls resists shear resistance with in-plane resistance section to the out-of-plane resistance section is also not clear. Uchida et al (1979) was tested the reinforced cylindrical concrete vessels (RCCVs) with internal pressure using water tank to verify the shear strength and ductility of them. Ogaki et al. (1981) was test the pre-stressed cylindrical concrete vessels (PCCVs) with aspect ratio 2.0 under the torsional and horizontal loading. The test result indicated that the tangential shear strength of PCCV may be evaluated approximately by the shear strength evaluation expressions based on truss analogy or a concrete failure envelope. Katoh et al. (1987) was studied seismic performance of cylindrical walls using a shaking table test, and Wu et al. (2019) was tested two RCCVs to verify the shear-friction strength and reinforcement effect for shear-friction. Further, structural component test, the results of which serves as evidence for the design or evaluation code, has historically been performed under low rate loading. However, the strain rate under earthquakes is significantly higher than that. Such high rate loading change the strength of structure through that stain rate is not as high as that of impact loading.

2. TEST PLAN

In NPP containment buildings, because of the high seismic resistance capacity, the shear reinforcement ratio for the design is about 1% and flexural reinforcement ratio for the design is about 2%. Thus, the majority of the specimens tested in the present study were designed with the actual reinforcement ratio of NPP containment buildings. Further, in the case of NPP containment buildings, post-tensioning force is applied. The post-tensioning force helps to prevent radioactive leaks and improve shear strength. The post-tensioning bar ratio is 1.0% and 0.6% for horizontal and vertical direction, respectively.

Two same reinforced concrete specimen were prepared for the test. Fig. 1 shows the construction of specimen. The dimensions of specimens were 1400mm (external diameter), 1300mm (height), and 90mm (thickness). The aspect ratio of specimen was designed to be the same ratio of the M/V ratio of the actual containment building under the seismic load at the specimen base.

Fig. 1 Specimen construction

The major test parameter was loading rate. To simulate static and dynamic loading rate effects, loading rate of 1 and 100mm/s were applied. The loading rate of 100mm/s was calculated based on the maximum velocity of walls estimated from a time history analysis of an NPP building under PGA 0.3g earthquake.

3. TEST RESULT

Fig.2 shows the load-displacement of test results. The failure mode of Both specimens were diagonal shear failure. The maximum strengths of static results were 1769 kN and 1491 kN at positive and negative direction, respectively. On the other hand, the maximum strengths of dynamic test result were 1935kN and 1799kN at positive and negative direction, respectively.

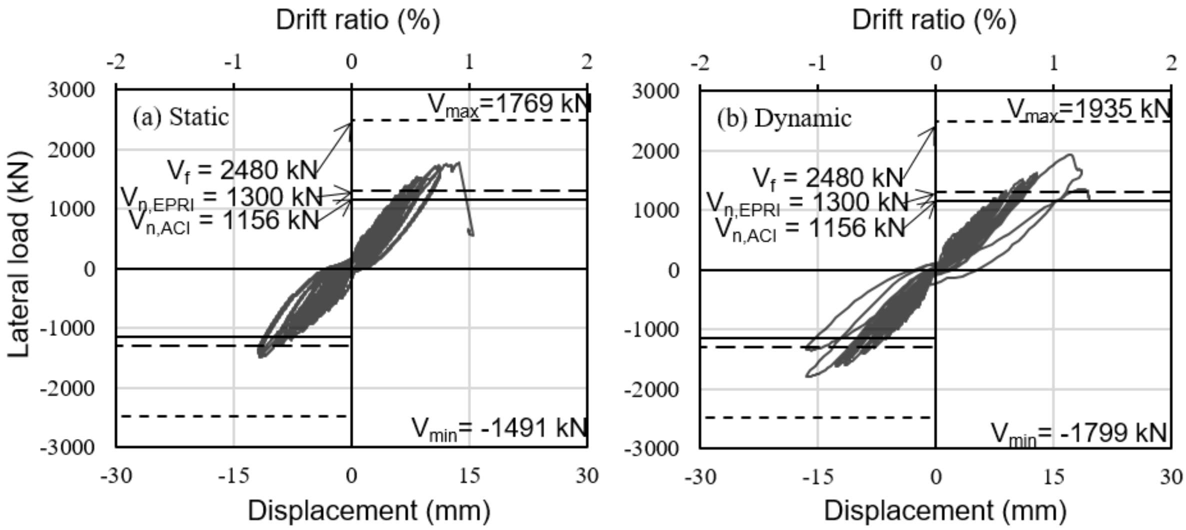

Fig 2. Load-displacement relationship

4. CONCLUSION

In the test results, the effect of loading rate on the shear strength can be investigated. In the case of dynamic specimen with high loading rate, the maximum strengths were 9.4% and 20.6% greater than static specimen. This results was similar as the in-plane wall test results (Baek, 2020). Thus, the major finding of the present study indicates high-loading rate can increased the shear capacity of reinforced concrete wall.

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