Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, November 2-3, 2006

Failure Mode and Shear Strength Test of PCCV Wall-Base Juncture

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1. Introduction

Hyundai Institute of Construction Technology Development (HICTD) has been conducting the project on the research and development of prestressed concrete containment vessel (PCCV) that would be sponsored and funded by Korea Atomic Energy Research Institute (KAERI). As a part of this research, quasi-static Structural Failure Mode Test (SFMT) will be carried out on a 1:16 scale PCCV model of existing Korea Standard Nuclear Power Plant (KSNP). Many types of global and local analyses on a 1:16 PCCV test model were performed to establish a test methodology in our research program.

The PCCVs are required to withstand various extreme accidental and external loads, such as internal pressure and thermal loading, seismic events, external explosions and aircraft impacts. Among these loads, this study is aimed at observing its failure mechanisms and obtaining shear strength from behavior of specimen, especially in case of seismic events, i.e. subjected to lateral forces during earthquake. Horizontal quasi-static structural failure mode test (SFMT) will be accomplished to inspect PCCV wall-base juncture behavior in the event of seismic events, i.e. obtain elastic and inelastic responses, failure modes and ultimate strength of specimen. Obviously, this study will provide some insights into the mechanisms leading to the structural failure.

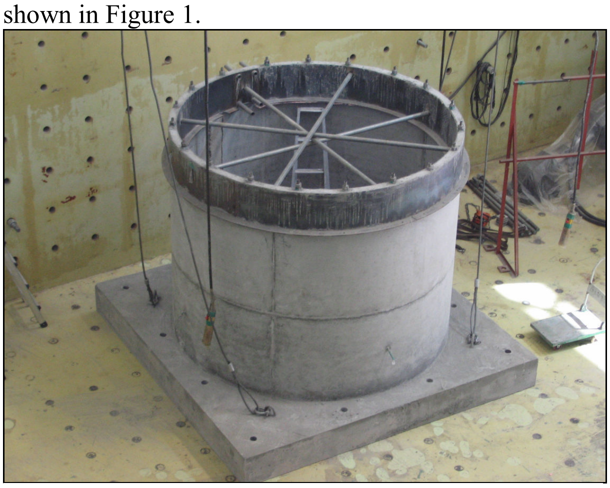
2. Structural Failure Mode Test

In this section the design, construction and instrumentation of PCCV test model, procedures and objectives of SFMT are described.

2.1 PCCV Test Model

The PCCV test model is a uniform 1:16 scale model of actual PCCVs used in Korea (KSNP). This simple test model includes only a prestressed concrete cylinder wall and basemat with rebars and vertical post-tensioned unbonded tendons. There are no dome, buttress, hoop tendons, and various kinds of openings in this model. Both the rebar ratios and the wall thickness are the same as those of general cylinder walls for reinforcement. The reinforcement consists of one layer of vertical rebar and one layer of hoop rebar. The test model has been prestressed with 19 vertical steel tendons that are anchored at the basemat. The level of prestressing force in each of the vertical tendons is approximately a tenth of 1:16 scaled that. Also, there is no internal pressure to which the test model is subjected. The cylindrical portion of the model is long from basemat up to the center of mass of PCCV test model with hemispherical dome, to fulfill the test effectively in case of seismic events.

Test model construction was made at the Structural Testing Laboratory in HICTD. Cylinder wall of the test model was fabricated into two segments for the convenience of concrete placement, because the thickness of the cylinder wall is 7.5cm thin. The configuration and structure outline of the test model is shown in Figure 1.



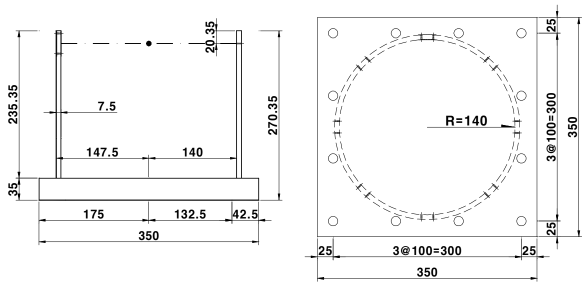


Figure 1. Configuration and structure outline of PCCV test model (unit : cm).

2.2 Instrumentation

HICTD instrumented the model with nearly 40 transducers, i.e. 4 LVDTs, 2 optical sensors, 34 straingages, to measure strain, displacement and forces in the model through testing. To monitor plastic strain, the plastic stain-gauges were installed at the test model. These transducers will be monitored by a data acquisition system while providing real time display of any sensor channel.

2.3 Procedures and Objectives

Quasi-static testing of the model, as shown in Figure 2, is strength test fixing specimen on a strong floor and applying alternating cycles of a series of horizontal static monotonic load of increasing magnitude to the specimen top. This test is for the purpose of grasping the mechanical properties and strength of the structure when subjected simultaneously to bending moment and shear force.

In the predictions of local wall-base juncture behavior, the SFMT will provide additional insight as to how the structural failure is likely to be developed. Maybe, there will be a shear or combined shear/flexural failure at the wall-base juncture.

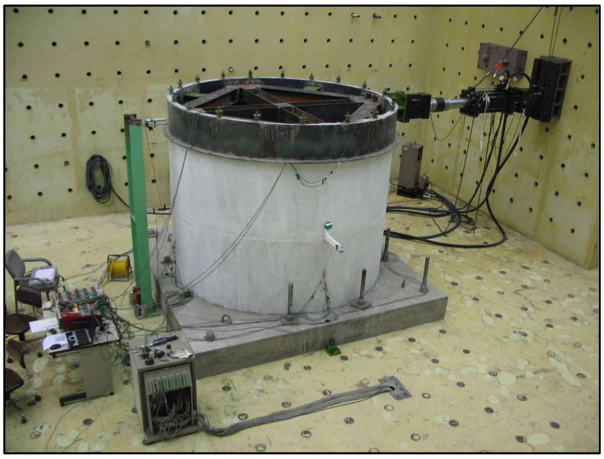


Figure 2. Setup view before SFMT of PCCV test model

3. SFMT Results

3.1 Load-Displacement Relations

Envelope of the load-displacement relations of the specimen is given in Figure 3. Average shear stress τ_{av} (=Q/A, Q : acting shear force, A : total cross-sectional area of cylindrical wall)is taken on the ordinates and rotational angle R (= δ_H / ℓ , δ_H : horizontal displacement at top of cylindrical wall, ℓ : length of cylindrical wall)on the abscissae.

3.2 Failure Process

With the triggering event of a massive wall rupture, response mechanism may have caused shear demand to exceed capacity. Creating large rotations in the vicinity of the base of the wall would crush the outer concrete of the flexural section and thereby reduce the capacity. There is a failure view after SFMT of PCCV test model as shown in Figure 4. Obviously, there is a through-wall failure around the circumference of the wall at about a quarter elevation of overall wall height from the basemat. And this fact is the nearly same as Ogaki et al.'s test results.

3.3 Shear Strength

Shear strength will be examined employing an evaluation method based on truss analogies and another method applying failure envelope of concrete. Hereafter, there will be an assessment on shear strength of specimen through the analysis of test results.

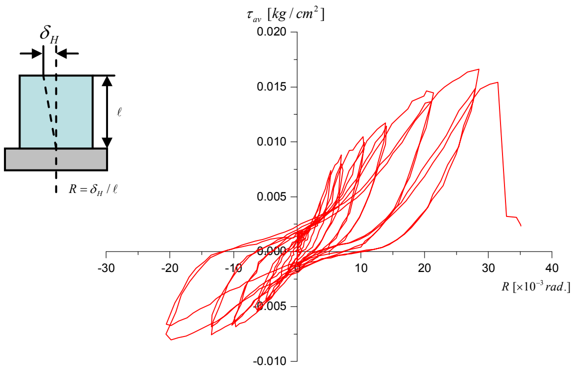


Figure 3. Load-Displacement Relation of PCCV test model

Figure 4. Failure view after SFMT of PCCV test model

4. Conclusion

This paper presented results of analysis of PCCV loading with seismic cases until total break of the structure.

Failure mode such as first concrete cracking, rebar yielding, and loss of bond between concrete and steel members and through thickness cracking of cylinder wall was showed in this SFMT.

This would further help in improved understanding of PCCV wall-base juncture behavior near the ultimate and the structural collapse states, in case of seismic accidents. Hereafter, there will be comparisons of the posttest analysis with test results. The details of the experimental results will be published shortly from HICTD.

REFERENCES

[1] Y. Ogaki, M. Kobayashi, T. Takeda, T. Yamaguchi, S. Yoshizaki, and S. Sugano, Shear Strength Tests of Prestressed Concrete Containment Vessels, SMiRT 6, 1981, Paris.