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Experimental investigation for the Secondary Failure Behavior of Partial Wall-Base Juncture Model in 1/4 PCCV

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1. Introduction

Hyundai Institute of Construction Technology Development (HICTD) has been conducting the project on the research and development of pre-stressed concrete containment vessel (PCCV) that would be sponsored and funded by Korea Atomic Energy Research Institute (KAERI). As a part of this research, an experimental investigation is carried out to examine the secondary failure behavior of PCCV that is expected to occur at the wall-base juncture. The ultimate condition of nuclear power plant containment vessel will be happened under the internal pressure. The internal pressure induces biaxial tensile stress in the containment wall.

This research purposes to experimental investigation on the secondary failure. The huge size of PCCV causes to scale down to 1/4 and designed in the partial level. To describe the wall-base juncture, point of inflection which is free flexural point must be the experimental loading point.

2. 3D-Shell Analysis

The first failure mode will occur at the middle of containment wall approximately over 3.5 designed pressures. As the internal pressure increasing, the deformation grows larger and finally develops to the secondary failure mode.

Based on the 3D-Shell F.E.M analysis, find out the point of inflection (Figure 1. (a)) and loading system built up (Figure 1. (b)).

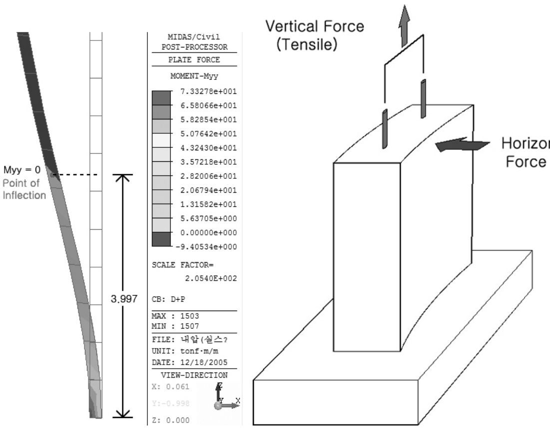


Figure 1. (a) Point of Inflection (b) Loading System

Increasing the internal pressure, the inflection point moves to upward. As the result of 3D-shell analysis, the equation (1) is derived from tensile-flexural pre-stressed concrete element, based on the 3D-Shell F.E.M analysis stress level.

$$H = 0.25V + 579\,(\mathrm{KN}) \qquad (1)$$

3. Specimen Design

The failure condition is defined when the stress of tendon reach to the yield stress. To ascertain a failure feature we loaded up to limitation of actuator or specimen. As the result of 3D-shell analysis, vertical tensile force and horizontal force are respectively 16,212KN and 4,618KN at every unit length(m) and inflection point is 5.5m from foundation upper side.

Herein, equipment capacity and construction of the stable loading system restrict the dimension of specimen as figure 2. Thickness ratio of wall/base is defined as following the KNSP. In the case of transverse rebar, the 0.8% to the concrete area is used but we assumed the effect of rebar detail is negligible.

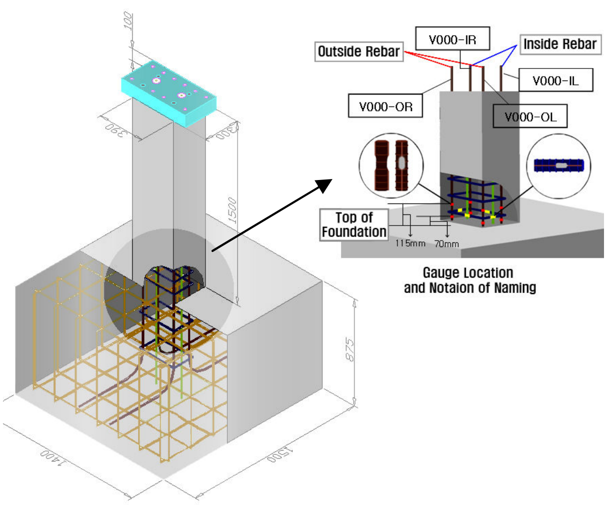


Figure 2. Wall-Base juncture partial element specimen

4. Yielding Force

There is no standard investigating method for partial element on the PCCV. Biaxial loading condition is very complex system to calculate. To calculate simply, we divide complex stress condition into vertical and horizontal components. The equation (2) and (3) respectively mean the stress due to the horizontal component and vertical component. And equation (4) is the stress on the tensile surface.

$$\sigma_{H,t} = \pm\frac{M}{I} y_t = 1.469\times10^{-5} H \quad (2)$$

$$\sigma_{V,t} = \sigma_{V,b} = \frac{V}{A} = 5.342\times10^{-7} V \quad (3)$$

$$\sigma_t = 4.207\times10^{-6} V + 8.501\times10^{-3} \quad (4)$$

The yield force estimation carries on the normal pre-stressed concrete theory. Then the yield moment, stress can be calculated as follow to the original wall-base juncture model. Substitute this result to equation (4) and adopting similitude ratio, then the failure load of experimental specimen.(equation (5))

$$M_n = A_p \cdot f_{ps}(d_p - \frac{a}{2}) = 2784\times1760\times(600 - \frac{92.37}{2})$$

$$= 2.713\times10^9 \; N - m$$

$$\sigma_t = \frac{M}{I} y_t = \frac{2.713\times10^9}{2.246\times10^{11}}\times600 = 7.248 \; (MPa)$$

$$V_{1/4} = 107.7 \text{ (KN)}, \quad H_{1/4} = 63.1 \text{ (KN)} \quad (5)$$

5. Experimental Investigation

In order to perform the experimental investigation, grasp the relationship between vertical and horizontal displacement. Equation (6) is derived from 3D-Shell analysis with Abaqus.

$$\Delta V = 0.2618 \Delta H \quad (6)$$

Table 1. Loading pattern

	ΔV	ΔH
Displ.(mm)	0.3	1.146
Duration (Sec)	120	120
Velocity (mm/sec)	0.0025	0.00955

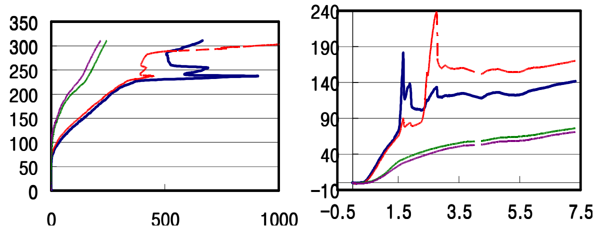
(a) Elastic Behavior Region I

	ΔV	ΔH
Displ.(mm)	0.615	2.35
Duration (Sec)	120	120
Velocity (mm/sec)	0.0051	0.0196

(b) Elastic Behavior Region II

	ΔV	ΔH
Displ.(mm)	0.615	2.35
Duration (Sec)	120	120
Velocity (mm/sec)	0.0051	0.0196

From upper equation (6) loading pattern has been schedule as table 1. Figure 5 shows the result of strain and vertical displacement with regard to the vertical load. Herein, critical points on the biaxial load condition are formed near the top of foundation. As shown in the Figure 6, main cracks are observed in wall-base boundary and 40cm height from boundary. 40cm height is twice of the inside rebar depth.



(1) Force-strain (2) Stress vertical Displacement

Figure 5. Strain, Displ. according to Vertical load

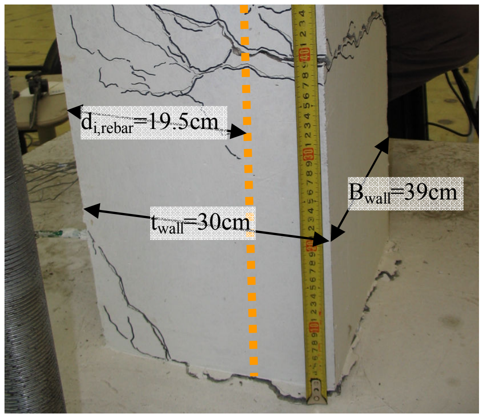


Figure 6. Failure feature

6. Conclusion

This paper will present results of analysis of PCCV wall-base juncture partial element model describe of secondary failure behavior under the ultimate internal pressure condition.

Yielding force of the specimen is simply calculated on the assumption that each stress component can be linearly superposed on each other. In the result of 3D-shell analysis, under the plastic behavior range each force component can be transformed to displacement relation.

In this study, from wall-base boundary to inside rebar depth is the secondary failure region of PCCV.

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