Transactions of the Korean Nuclear Society Spring Meeting
Gwangju, Korea, May 30-31, 2013

Ultimate internal pressure capacity assessment of SC structure

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1. Introduction

The SC(Steel-Concrete) structure has been applied to several types of structures, because the construction period and costs are less than in other structure types. An SC structure applied to a containment building can be quite effective. However, an SC structure cannot be applied to a containment building, because its internal pressure resistance performance has not been verified. The containment building, which undergoes ultimate internal pressure, resists the internal pressure through a pre-stress tendon. It is hard to apply a tendon to an SC structure because of its structural characteristics. Therefore, the internal pressure resistance performance of the SC structure itself should be ensured to apply it to a structure with internal pressure resistance.

In this study, the suitability of an SC structure as a substitution for the tendon of a pressure resistant structure was evaluated. A containment structure model was used in this study, because it was representative structures that resistance of ultimate internal pressure be required.

2. Finite Element Analysis

The 1/4 scale containment structure was used in this study to comparatively analyze the internal pressure on the affected tendon and steel plate. Two cases are modeled. The first cases are a tendon structure model, and the second is an SC structure model. The commercial software ABAQUS/CAE [1] was used for the three-dimensional nonlinear inelastic analysis of the 1/4 scale model. The major specifications of the 1/4 scale model are listed in Table 1.

Table Ⅰ: Major specifications of the containment building scale model

Category		Dimension (mm)
containment building scale model	total height	16,400
	inner wall diameter	10,750
	wall thickness	325
	dome thickness	275
	Foundation slab diameter	14,400
	Foundation slab thickness	3,500

2.1 Tendon Model

For the slab, wall, and dome of a 1/4 scale model was made C3D8R provided within the ABAQUS library. The C3D8R is a linear hexahedral solid element with 8 nodes. 28,676 elements were used. To consider the nonlinear inelastic property of the concrete material model, the Concrete Damaged Plasticity model provided by ABAQUS was employed.

The tendons and rebars were modeled using T3D2 provided within the ABAQUS library. T3D2 is a truss element with 2 nodal points. 138,200 elements were used. To consider the inelasticity for the tendon and rebar material model, the material model was established using the material options, Elastic and Plastic, provided within ABAQUS.

The material properties of the 1/4 scale model are listed in Table 2.

Table Ⅱ: material property of the containment building scale model (MPa)

	Young's Modulus	Yield Stress
Concrete	26,790	48.84
Tendon	200,000	1,347.15
Rebar	183,000	487.99
Liner Plate	183,000	450.00

The shape of the 1/4 scale model is as shown in Fig. 1 and has 171,900 elements.

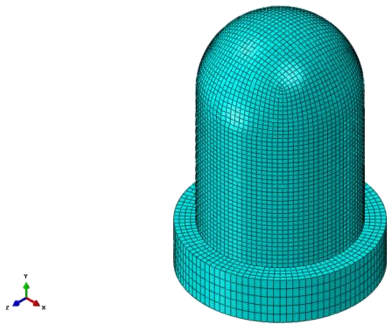


Fig. 1. Shape of the 1/4 scale model

2.2 SC Structure Model

The concrete of the foundation slab, wall, and dome of the SC structure containment building was modeled in the same manner as that of the 1/4 scale model.

The steel plate was modeled using the S4R element provided within the ABAQUS library. It is a rectangular shell element with 4 nodal points and each node has 6 degrees of freedom.

The force of the tendon was calculated by multiplying the yield strengths of the containment building scale model tendon to the total volume of the tendon. The SC steel plate thickness was determined by the calculated force and the SC steel plate yield strength. Equation 1 was used to calculate the steel plate thickness which was 7mm for both the inner and outer steel plates.

$$V_{sc} \times F_{Sy} = V_{TENDON} \times F_{Ty} \qquad (1)$$

Here, V_{SC} : $Steel\ plate\ volume$
F_{Sy} : $Yield\ strenght\ of\ steel\ plate (= 450MPa)$
V_{TENDON} : $Tendon\ volume (=2.82\times 10^{9}mm^{3})$
F_{Ty} : $Yield\ strenght\ of\ tendon (= 457MPa)$

To compare the ultimate internal pressure performance according to the steel plate thickness, steel plates of 6mm, 7mm, and 8mm thicknesses were modeled. The model has 9,898 elements.

To take into account the adhesion between the concrete and steel plate, the surface to surface contact was set using the *Contact tied option. As this option shares nodes in proximity even if they are not the same in the contact surface, modeling is possible without being affected by the nodal points of each element. The concrete and steel plate were assumed to be completely attached.

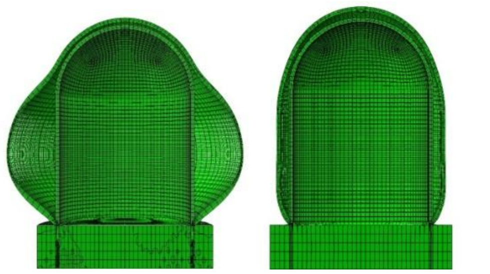
2.3 Load Conditions

The initial internal pressure load is 0.13MPa, and this was increased using the *Riks method option. The *Riks method has the advantage of automatically adjusting the load increments during a nonlinear inelastic analysis and enhancing the solution convergence. The *STATIC, RIKS option adopts the arc-length method to solve the nonlinear equilibrium equations. Therefore, the ultimate load point and the falling curve afterwards (in other words, the behavior after fracture) can be identified. Therefore, the *STATIC, RIKS option was selected to obtain the ultimate strength of the structure.

3. Analysis Result

3.1 Deformation Shape

Figures 2 show the final cross section deformation of the tendon model and SC structure model. In the tendon model case, deformation of the dome top is less than the SC structure model due to the effect of the tendon pre-stress. However, it can be observed in the final deformation shapes that more deformation of wall occurred for the tendon model in comparison to the SC structure model.



(a) Tendon model (b) SC structure model
Fig. 2. Final deformation cross section shapes(x100)

3.2 Internal Pressure-Displacement

Figure 4 compares the internal pressure-displacements of the tendon model with the SC structure model. The measured point was 6,200 mm height from the top of the foundation slab.

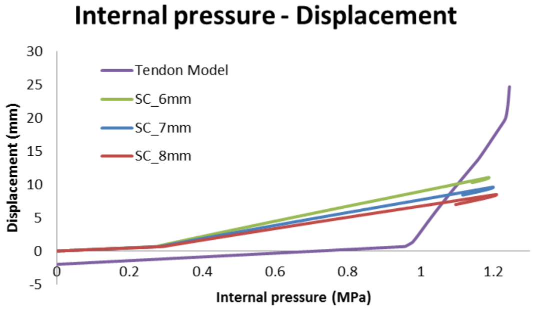


Fig. 4. Internal pressure-displacement analysis result

It can be observed that initial deformation of the SC structure model is greater than that of tendon model because of the pre-stress load on the tendon. However, the displacements after 1.07MPa and 1.03MPa for SC structure model steel plate thicknesses of 6mm and 8mm, respectively, were less than that found for the tendon model.

4. Conclusions

In this study, a nonlinear analysis was performed to evaluate and compare the behaviors of tendon model and SC structure model. By comparing the internal pressure-displacement according to the structure type, the stability of SC structure model was assessed.

Acknowledgement

This work was supported by Nuclear Research & Development Program of the National Research Foundation of Korea (NRF) grant, funded by the Korean government, Ministry of Science, Ict & future Planning (MSIP).

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[1] ABAQUS/CAE user's manual version 6.11, vol V. SIMULIA