Assessment of the Effective Prestress Force on Bonded Tendon by a Finite Element Analysis

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1. Introduction

Bonded tendons have been used in containment buildings, which house nuclear reactors, of heavy water reactors and light water reactors of several nuclear power plants operated in Korea. The assessment of the effective prestress force on these bonded tendons is becoming an important issue in assuring their continuous operation beyond their design life time. To date, an indirect method was adapted to evaluate the prestress force on the bonded tendons for containment buildings using test beams that were manufactured at the time of construction.

In order to complement the indirect method, a system identification (SI) technique process was developed in preliminary research that mainly focused on the 1:4 scale prestressed concrete containment vessel tested by Sandia Nation Laboratory in 2000[1]. Therefore, this paper carried out a finite element (FE) analysis to evaluate the effective prestress force of a bonded tendon using the SI technique.

2. Experimental Test

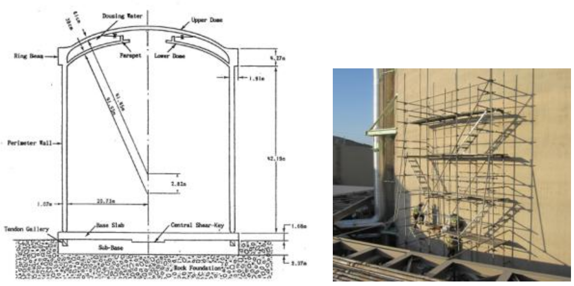
Normally, the real strain or displacement data of a containment building is necessary to analyze the prestress force of a bonded tendon using the SI technique with the FE method. For this purpose, actual testing was conducted to measure strain data of a containment building in Korea [2].

2.1 Layout of the Test Model

To obtain the strain data of a real containment building, fiber bragg grating (FBG) sensors were installed to the mid-height wall of the target containment building which utilizes a bonded type tendon in Korea. Figure 1 shows the layout of the target containment and the 25 installed FBG sensors, hoop and meridional direction, respectively. 18-temperature sensors were also installed to improve the sensitivity to the daily temperature. The measurement of the strain was recorded for approximately a 5-day period during an integrated leakage rate test.

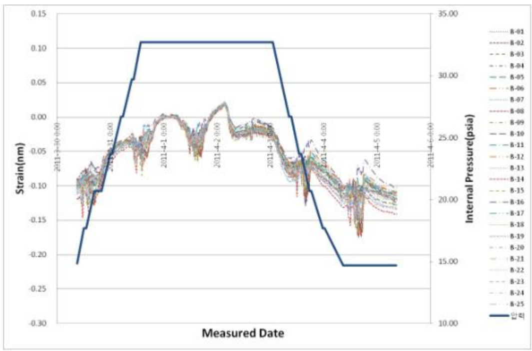
2.2 Test Results

Figure 2 shows the experimental test results for the hoop and meridional directions of the containment building. The measured values show similar trends in the two directions and ranged from 54 εμ ~ 90 εμ in the hoop direction and 17 εμ ~ 25 εμ in the meridional direction.

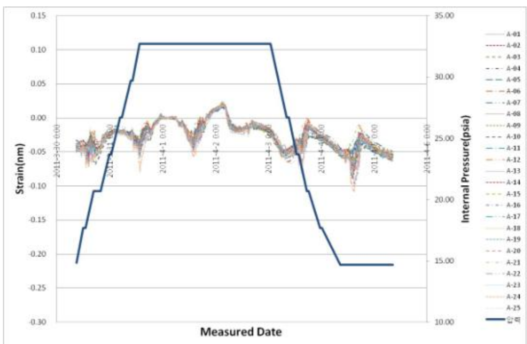


(a) Layout of the containment (b) Location of FBG sensor

Fig. 1. Layout and sensor location of the containment



(a) hoop direction

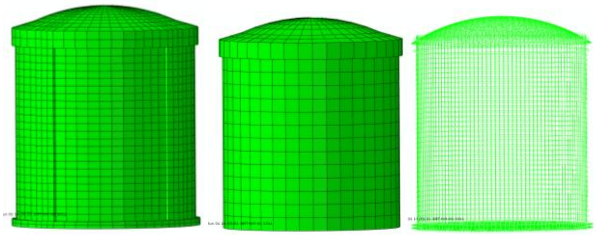


(b) meridional direction

Fig. 2. Measured strain of the containment building

3. FE Model

Figure 3 shows the FE mesh of the concrete, tendon and reinforcement for the target containment building. The mesh for the concrete wall and dome uses lower order solid elements with C3D8. The reinforcement and tendon are modeled with surface and truss elements, respectively. The truss elements are coupled with the embedded element function of the ABAQUS program. In this function, the nodes of a truss element are kinematically constrained to the nodes of the solid element in which it is located.



(a) concrete (b) reinforcement (c) tendon

Fig. 3. FE models for containment building

The material properties of the containment building are as follows [3].

Concrete
- Compressive strength: 5,000 psi
- Modulus of elasticity: 5 x 10^6 psi
- Poisson ratio: 0.15

Reinforcement
- Yield strength: 60 ksi
- Modulus of elasticity: 29 x 10^3 ksi

Tendon
- Ultimate tensile strength: 255 ksi
- Modulus of elasticity: 29 x 10^3 ksi

4. Assessment Results

Using the SI technique, an iterative analysis was performed to determine the experimentally measured strain value at the mid-height of the containment building. Because the prestress force of the tendon was unknown, the initial prestress force was inputted as 0.3 times the value of the maximum anchoring force of the tendon at the first step.

Figure 4 shows the results from the SI technique compared with the measured data and FE analysis results for the hoop and meridional directions. Tu denotes the maximum wire stress at anchoring of the containment. The anchoring force,- and design prestress force-, of the hoop and meridional directions are 0.50Tu and 0.55Tu, respectively.

The FE analysis results display good agreement with the experimental test values at 0.59Tu in the hoop direction and 0.70Tu in the meridional direction. Therefore, effective prestress force of the target containment building is still greater than the design value.

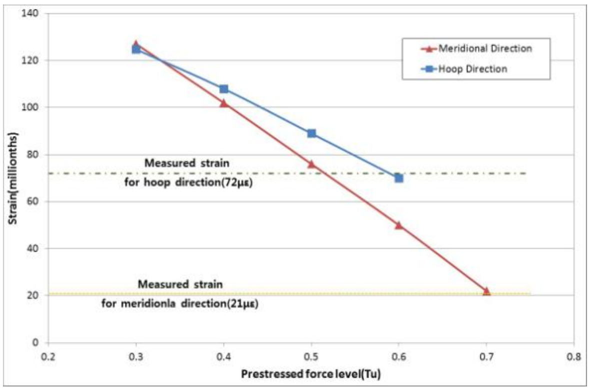


Fig. 4. FE results using SI technique

Table 1. Results of the effective prestress force

Item	Measured data (εμ)	FE analysis data(εμ)	Predicted Values	Design Values
Hoop direction	72	70	0.59Tu	0.50Tu
Meridional direction	21	22	0.70Tu	0.59Tu

5. Conclusions

The objective of this paper is to predict the effective prestress force of a bonded tendon using a FE analysis with the SI technique for a nuclear containment building. From the FE analysis results, the effective prestress force of the target containment is still greater than the design value. Finally, the results of this present study can severe as reference data, which will be needed for the development of a direct method to evaluate the prestress force of bonded tendons for nuclear containment buildings.

ACKNOWLEDGMENT

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