Periodic Safety Review of Tendon Pre-stress of Concrete Containment Building for a CANDU-Type Nuclear Power Plant

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1. Introduction

Generally, as the tendon pre-stress of concrete containment buildings at nuclear power plants decreases as time passes due to the concrete creep, concrete shrinkage and the relaxation of tendon strands, the tendon pre-stress must secure the structural integrity of these buildings by maintaining its value higher than that of the designed pre-stress during the overall service life of the nuclear power plants. Moreover, if necessary, the degree of tendon pre-stress must also guarantee the structural integrity of concrete containment buildings over their lifetimes. This paper evaluated the changes in the tendon pre-stress of a concrete containment building subject to time-limited aging as an item in a periodic safety review (PSR) of Wolsong unit 1, a CANDU-type nuclear power plant to ensure that the structural integrity can be maintained until the next PSR period after the designed lifetime.

2. Methods and Results

The post-tensioning system of BBRV was applied in Wolsong unit 1. It was utilized with 85 to 105 strands, which have a diameter of 0.25 inches, depending on the location of the tendon, and is filled inside of sheath with cement grout to prevent corrosion. The post-tensioning system of Wolsong unit 1 is a bonded-type system.

2.1 Evaluation Scope

This paper set its evaluation scope on tendons installed on the base slab, vertical wall, horizontal wall, ring beam and the upper dome of the containment building for Wolsong unit 1. Comparisons of changes in the tendon pre-stress of the building were also done with changes in the tendon pre-stress of the test beam which had made in the beginning of the construction of Wolsong unit 1.

2.2 Acceptance Criteria

This evaluation of the tendon pre-stress of a containment building complied with the specifications as set by the Ministry of Education, Science and Technology (MEST) as well as those in NUREG-1800 section 4.3.2, entitled 'The acceptance criteria of Time-Limited Aging Analysis (TLAA)'. According to these sets, the evaluations must satisfy one of the following criteria [1, 2]:

a. Acceptance criterion - 1: TLAA is valid throughout the continued operation period.
b. Acceptance criterion - 2: TLAA must be predicted from the continued operation period until the end of the period.
c. Acceptance criterion - 3: The impact of aging effects on the unique function must be properly managed during the continued operation period.

In this evaluation, the acceptance criterion - 2 above was applied.

2.3 Evaluation Results

The pre-stress change curve of the test beam was derived from a regression analysis by experiments (refer to Figure 1) [3].

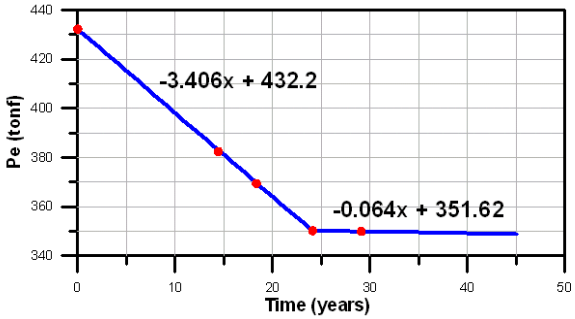

Fig. 1. Pre-stress change curve of the test beam derived from a regression analysis by experimentation.

The pre-stress change of the test beam was also obtained theoretically and the pre-stress changes of each part of the containment building were calculated as time passed (refer to Table I) [4, 5]. It is impossible for all tendons of the containment building to be tested directly except the test beam because the post-tensioning system of Wolsong unit 1 is a bonded-type system. So the theoretical evaluation was performed. The experimental and theoretical pre-stresses of the test beam were respectively compared (refer to the example in Figure 2).

Based on comparison results of the test beam, the experimentally estimated tendon pre-stress until the next PSR period was evaluated larger than the pre-stress derived theoretically. Accordingly, the tendon pre-stress installed at the containment building of the Wolsong unit 1 was convinced to be greater than the pre-stress derived theoretically.

Table I: Pre-stress changes of tendons derived theoretically at the main structural locations of the containment building.

Year / Location	1992 (tonf)	2002 (tonf)	2012 (tonf)	2022 (tonf)
Test Beam	340.40 (77.36)*	339.68 (77.20)	339.33 (77.12)	339.13 (77.08)
Base Slab	349.50 (86.30)	346.11 (85.46)	344.13 (84.97)	342.81 (84.64)
Vertical Wall	435.70 (86.28)	431.49 (85.44)	429.04 (84.96)	427.39 (84.63)
Horizontal All	355.58 (86.31)	352.16 (85.48)	350.16 (84.99)	348.82 (84.67)
Ring Beam	378.53 (86.03)	374.89 (85.20)	372.77 (84.72)	371.34 (84.40)
Upper Dome	366.70 (85.68)	363.12 (84.84)	361.03 (84.35)	359.63 (84.03)

* ( ): Efficacy rate (%)

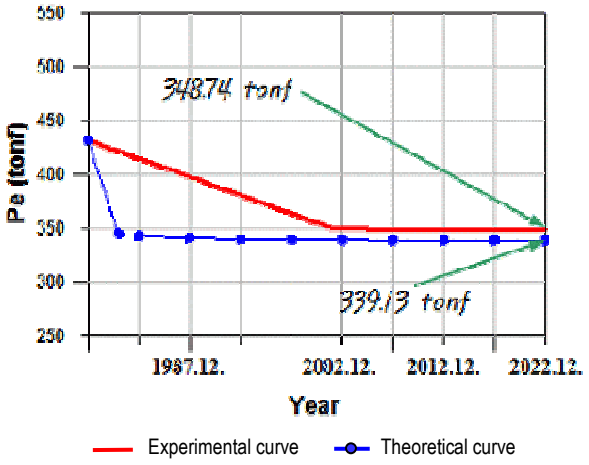

Fig. 2. Comparison of experimental and theoretical curves of changes in the pre-stress of the test beam.

As indicated in Table I, this paper compared the pre-stress derived theoretically until the subsequent PSR for each part of the containment building (the base slab, vertical wall, horizontal wall, ring beam and the upper dome) with designed pre-stress. An example of the comparison result for the base slab is shown in Figure 3.

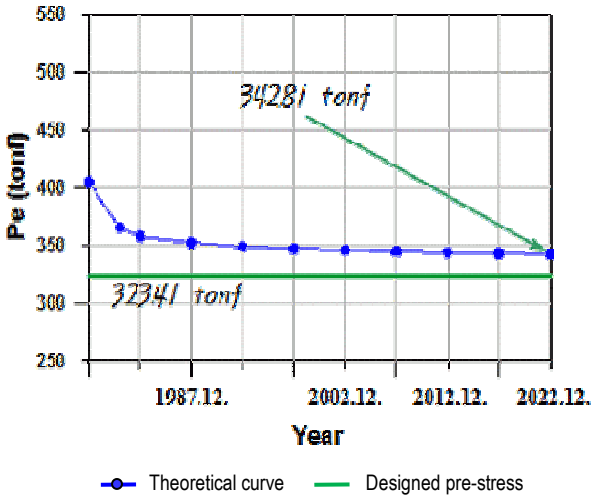

Fig. 3. Example of a comparison of the changes in the pre-stress of the base slab.

As indicated in Figure 3, the theoretically derived pre-stress was found to be greater than the designed pre-stress calculated until the next PSR period. In addition, parts other than the base slab showed the same result [6].

Therefore, it was confirmed that the tendon pre-stress of the containment building for Wolsong unit 1 would maintain a higher value than the theoretically derived pre-stress until the next PSR period.

Additionally, this value was greater than that of the designed pre-stress and was hence to ensure structural integrity.

3. Conclusions

This paper conducted a TLAA evaluation of the tendon pre-stress of the concrete containment building according to the methodology presented by the specifications of MEST and NUREG-1800 for the PSR of Wolsong unit 1. The evaluation method and key results were given below.

- ○ A TLAA evaluation of the tendon pre-stress was conducted on the base slab, vertical wall, horizontal wall, ring beam and on the upper dome of the containment building of Wolsong unit 1.
- ○ The estimated tendon pre-stress using measured data was found to be greater than the pre-stress derived theoretically.
- ○ For each part of the containment building, the pre-stress derived theoretically was found to be greater than the designed pre-stress.

Therefore, the TLAA of the tendon pre-stress of the containment building of Wolsong unit 1 (a CANDU-type nuclear power plant) was properly carried out according to the specifications of MEST and NUREG-1800. The evaluation results also satisfied the acceptance criteria; therefore, the structural integrity of the tendons of the concrete containment building will be secured until next PSR period.

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