Bonded Tendons in Nuclear Reactor Containments -
Testing of five 30-year-old Prestressed Concrete Beams

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1. INTRODUCTION

The Swedish nuclear reactors are enclosed by a concrete containment prestressed both horizontally and vertically. The corrosion protection of the tendons can be arranged in several different ways, either by cement grouting (bonded tendons) or e.g. by grease injection (unbonded tendons).

The main objective of this PhD-project is to evaluate the status of the containments with bonded tendons. This regards both the prestress losses and the risk of corrosion on tendons and stressing anchorages. The prestress losses will be estimated by using various models regarding the creep and shrinkage of concrete and the relaxation in the prestressing steel and also by testing of several prestressed concrete beams.

Among the test objects are five beams which, for the past 30 years, have been stored inside of the reactor containment building in the nuclear power plant Olkiluoto in Finland. This paper presents the results from the testing of the prestress losses in these beams. The lengths of the beams are 3 m with a cross-section area of 0.25 m^2. Two different post-tensioning systems are used, for two of the beams VSL type 19 Φ13 has been used and for the other three BBRV type 72 Φ6 has been used. The initial tensioning forces in the beams are 2.44 MN and 2.52 MN respectively. The tendons are placed in the centre of the cross-sections.

2. RESEARCH SIGNIFICANCE

The reactor containment is the most important safety barrier in a nuclear power plant. In the event of a serious accident in the reactor, the prestress in the containment wall will ensure the leak tightness of the concrete thus preventing any radioactive discharge to the environment. To be able to monitor the status of the prestressing system, e.g. evaluating models for predicting prestress losses, is therefore of the utmost importance.

3. METHOD

In order to determine the remaining tendon force in the beams the so-called crack re-opening method was used. The beams were subjected to a single point-load at midspan and the load increased until flexural cracks appeared at the bottom. The initial crack was marked and the beam unloaded. The beam was loaded again until the crack re-opened. In order to determine this so-called decompression load, one LVDT-gauge was mounted across the crack. The beam was loaded and unloaded three times in order to increase the accuracy of the measurements. By intersecting the two slopes in the load-displacement diagram, the decompression load was determined, see figure 1. Since the stress in the bottom of the beam is zero at the decompression load, the effective prestress force can be calculated using Naviers formula.

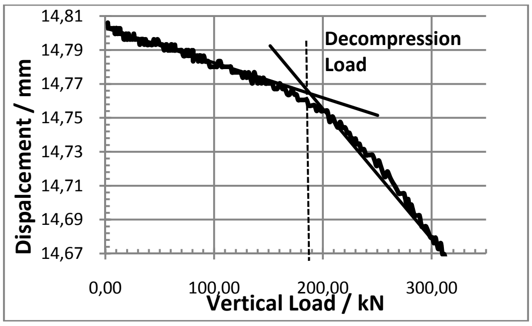

Figure 1 - Decompression load.

4. RESULTS

The prestress losses in the beams were 37%, 38%, 38%, 49% and 60%. The big scatter in the results can be explained by the fact that during the testing of the two beams with the highest losses, splitting cracks occurred and propagated at both ends and did not close after unloading. There was also extensive cracking in the zones surrounding the anchor-plates. This indicates that the anchors have moved inwards during the testing. This leads to a shortening of the tendon thus increasing the prestress losses. For the beam with 60% prestress losses the time between casting and tensioning was 63 days, while for the others, it was more than 135 days. This affects the prestress losses significantly, since the drying of the concrete and therefore also the shrinkage has proceeded during a shorter period of time before tensioning. The shorter period of drying also increases the drying-creep of the concrete.

5. CONCLUSIONS

The prestress losses in the beams are relatively high compared to results from testing of old bridge beams in the literature, which probably is due to that the beams have been stored indoors at approximately 25°C. This increases both the shrinkage and creep of the concrete.

6. FINANCIAL SUPPORT

The project is jointly financed by ELFORSK, the Swedish Electrical Utilities R&D Company, and TVO, a company owned by several industrial and power companies which is in charge of the nuclear power production in Finland.

7. PROJECT DATA

This project is conducted as a PhD-project with duration of five years, started in January 2007.