

CONTAINMENT MONITORING OL3

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OL3 CONTAINMENT STRUCTURE, GENERAL INFORMATION

OL3 EPR primary containment is a prestressed concrete containment with steel liner:

- Height: approximately 70 m (incl. base slab)
- Inner diameter: 46.8 m
- Concrete class C50/60
- Liner thickness: 6 mm
- Prestressing system: Freyssinet C 54T15
- Designed operation life time 60 years
- Design pressure 4.3 bar overpressure







Preparatory work for tensioning of gamma tendons OL3

TVO

Grouted tendon (mock-up result)

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Strains in the concrete structure are measured by embedded acoustic strain gauges of TELEMAC model C110

Three one-dimensional gauges (one for radial, tangential and vertical direction) have been installed in one frame set to represent a three dimensional strain state

> Totally ~ 350 strain gauges have been embedded into the concrete



The temperatures in the concrete structure are measured by embedded temperature sensor TELEMAC model PT100, which function is based on the determination of the resistance of a platinum resistor

➤The temperature sensors have been installed at the position of each one of the strain gauges sets

Totally ~120 temperature gauges embedded into the concrete



The global displacements of the containment structure are measured by direct pendulums (TELEMAC).

> The pendulums have been installed in 3 different axes

> It consist of a wire suspended from the upper reading point and a reading station fixed to the structure at the lower point

➢ Horizontal displacements are measured from 3 levels (+10, +23, +38): the result is difference between the measurement level and reading level (ca. 2 m above the top surface of the base slab)

➢ Vertical displacement are measured from the uppermost pendulums at level +38 m: the result is the difference between +38 and top surface at the base slab at -4.3 m



The tendon forces are measured by CV8 load cells:

> 4 pure vertical tendons are measured

➤ The local compressive strains, induced by tensile force in the tendons, are measured by eight vibrating-wire sensors placed longitudinally along the mean circumference of the cylinder

The main function is to measure the total loss of tendon force over the life time



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The strains at containment liner surface are measured by fibre optic sensors, DiTeSt:

> 7 continuous horizontal sensors and 3 vertical sensors covering also dome part

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➤ results: the average strain at liner surface over a length of each 0.4 m step of the optical fibre



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OL3 CONTAINMENT MONITORING, OTHER MEASUREMENTS

>Humidity measurements:

- EE06 embedded sensors, currently not in use
- Cylindrical concrete specimens
- Test specimens for measuring of strength and E-modulus



- > Crack monitoring:
 - o Specific areas are inspected during the tests under pressure
 - Existing cracks are monitored by strain gauges and transducers during the tests
- > Displacements at dome area during the pressure test: laser measurements
- Local strains in liner: strain gauges

Local deformations in liner: specific areas are monitored regularly (laser scanning), especially during the tests

RELEVANT DATES RELATED TO OL3 CONTAINMENT MONITORING

Prestressing in July-October 2010 in 10 different monitored phases.

- Concrete age at the time of prestressing of cylinder part ~ 540 days, dome part ~ 90 days
- Containment Tests CTT, including ILRT, ISIT, February 2014
 - ISIT test under pressure of 1.15 xDP = 6.0 bar abs.
 - Increasing and releasing of pressure, both in 5 monitored steps
 - CTT was completed successfully with good results
- Periodical tightness tests (3 times in every 15 years) will be done under LOCA pressure of 4.9 bar abs. Structure monitoring will be done similarly like during ISIT
- Monitoring of the long term behavior has been started at early construction phase and will be continued up to the end of the life time. Comparable concrete strains and tendon forces (zero-measurements) are available since the date of end of presressing, October 2010



USE OF MONITORING RESULTS

The monitoring results have been/will be compared with the calculated theoretical values (design calculations provided by AREVA and also TVO's analyses made by Scanscot Technology).

➢ By monitoring the delayed strains and total loss of tendon forces, it can be e.g. verified that the losses due to relaxation, creep and srinkage stay below the calculated values, i.e the designed stress level will be kept. This is supported by the results obtained so far.

➤There has been quite good coincidence between the theoretical values and the measurement results obtained during prestessing phase and ISIT. A few strange values have been investigated separately.

➤ In following pages some examples from the results are shown

EXAMPLE FROM THE RESULTS: CONCRETE STRAINS DURING PRESSURE TEST

Measured concrete strains at level +10 (cylindrical wall at 14.3 m above the base slab) at each pressurization/depressurization step: average strains for all 6 measured locations (3 axis, inner+outer surface) / for comparison, predicted value at max. pressure in the middle of the red area



Figures from AREVA's report "Evaluation of ISI Results"

EXAMPLE FROM THE RESULTS: CONTAINMENT DISPLACEMENTS AT TEST PRESSURE

Containment cylindrical wall: pre-calculated relative radial displacements / for comparison, measured values (points) from pendulum measurements



CONCLUSION

Covering monitoring system has been installed in Olkiluoto 3 primary containment for monitoring the structural behaviour of the concrete structure and steel liner during construction phase, pressure test and entire life time.

> The monitoring gives a lot of valuable information from the behavior of the containment structure. For example, by monitoring of the delayed strains, it can be verified that the losses due to relaxation, creep and srinkage stay below the design values. This is supported by the results obtained so far. Consequently, the monitoring will be continued over the life time.

➤Generally, there has been so far a good coincidence between the theoretical values and the measurement results. A few strange values have been/are investigated separately.



THANK YOU