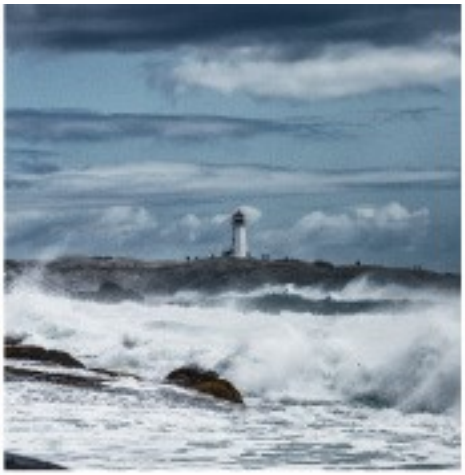
DESIGN OF CONCRETE CONTAINMENTS - FOCUS ON INTEGRITY AND TIGHTNESS

REPORT 2015:145



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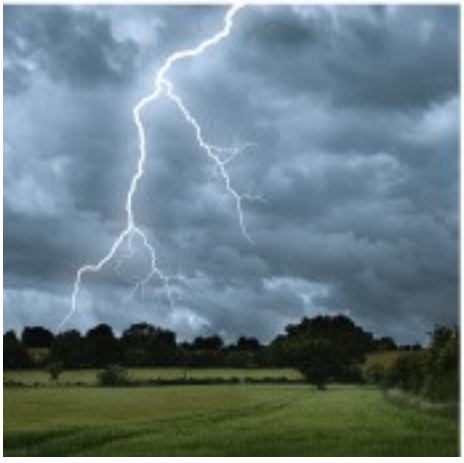

Energiforsk

Design of Concrete Containments - Focus on integrity and tightness

Documentation from seminar January 28 2015

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Foreword

This seminar was initiated to compile information on design of concrete containments from different regulatory regimes. The seminar was arranged within the Energiforsk Nuclear Concrete research program, which has the aim to initiate research and development that will contribute to a safe and cost effective long term operation of Swedish and Finnish nuclear power. The program is financed by Vattenfall, E.ON, Fortum, Skellefteå Kraft, Karlstads Energi, Strålsäkerhetsmyndigheten (SSM) and Teollisuuden Voima Oy (TVO).

Sammanfattning

Inneslutningens uppgift är att skydda kärnkraftsreaktorn mot såväl yttre som inre händelser, exempelvis jordbävning, flygplanskrasch, rörbrott m.m. Beroende på typ av reaktor (kok- eller tryckvattenreaktor), kan inneslutningens utformning skilja, vad gäller storlek, utformning och funktion. För att klara av sin uppgift krävs att inneslutningen är tät och kan innesluta trycksatt ånga med ett ångtryck av flera gånger atmosfärstrycket.

Seminariets syfte var att ge kunskap om de krav som ställs på betonginneslutningar samt olika lösningar för att uppfylla dessa krav. Seminariets fokus kommer att låg på att uppfylla krav på integritet och täthet för inneslutningar. Följande tre huvudområden behandlades:

- Myndighetskrav
- Konstruktionsnormer i olika länder
- Tillämpningar på inneslutningar

De presentationer som visades under seminariet finns att ladda ned på Betongprogram kärnkrafts hemsida.

Summary

The containment is designed to prevent the release of radioactive substances in case of a pipe break and to protect the nuclear reactor from external events, for example earthquakes, airplane impact.Depending on the type of reactor (boiling- or pressurized water), different designs are chosen regarding size, shape and function of the reactor containment. To meet those conditions, the containment must be able to withstand hot steam at high pressure and remain leak tightness.

This seminar aimed at providing knowledge about the requirements that were set for concrete containments, how the design was approached – overall and in detail – to fulfil these requirements and their differences compared to conventional civil concrete structures. The focus of the seminar was on how to fulfil the requirements on integrity and tightness of the reactor containment.

The documentation from the seminar is downloadable from the program web page.

List of content

1 Scope

The seminar was divided into the following major areas which were dealt with primarily from Finnish/Swedish points of view.

- Introduction by Energiforsk
- Regulatory requirements in Finland and Sweden
- Design requirements and acceptance criteria in USA, France and (tentatively) Sweden
- Applications: Design of Olkiluoto 3 and codes for future plants)

2 Summary of presentations

2.1 INTRODUCTION BY ENERGIFORSK

Dr **Monika Adsten** presented the ongoing research activities sponsored by Energiforsk (Post-tensioned tendons: Instrumentation of tendon at Forsmark 2 and US long term experiences on tendons as well as PhD works on containment climatic conditions and on embedded anchors). Energiforsk will launch a new research programme for 2016-2018. The programme might include tests at the closed NPPs of Barsebäck.

2.2 REGULATORY REQUIREMENTS IN FINLAND AND SWEDEN

The presentations were made by Mr **Lars Skånberg** from the Swedish Radiation Safety Authority (Strålskyddsmyndigheten=SSM) and by Mr **Pekka Välikangas** from the Finnish Radiation and Nuclear Safety Authority (Strålsäkerhetscentralen=STUK)
As the present situations are different in Finland and Sweden regarding construction of new NPPs, it is natural that the presentation by Mr Välikangas primarily referred to new NPPS while the presentation by Mr Skånberg mainly referred to issues regarding design life extension of existing plants. In both countries the present regulatory requirements are based upon general Eurocodes, ASME lll Div.1-2 and various recommendations from EU, IAEA and WENRA. Documents from WENRA deal with lessons learnt from the Fukushima accident.

2.3 DESIGN REQUIREMENTS AND ACCEPTANCE CRITERIA IN USA, FRANCE AND (TENTATIVELY) SWEDEN

Dr **Jorma Arros** from ABS Consulting in USA presented US practices regarding containment design including Beyond Design Basis Events (=BDBE) as well as Beyond Design Basis Accidents (=BDBA). The established code ASME lll Div.2 is still in rule with new supporting codes:
-ASCE 4-98 (4-09) and ASCE 43-05 for seismic design
-NEI 07-13, revision 8 for aircraft impact
-ASME/ANS RA-S-2009 for external events PRA
Dr Arros presented various examples with non-linear analyses for BDBE regarding containment overpressure and for BDBA regarding aircraft impact. The analyses for aircraft impact have been supported with laboratory impact tests (including tests at the Finnish research institute VTT). The BDBA results correspond well with the expected structural behavior. Example: The cylindrical wall of a PWR containment proved to withstand notably large radial displacements prior to failure.
Mr **Etienne Gallitre** from EDF, France presented the latest edition of the AFCEN code RCC-CW (replacing previous ETC-C) regarding civil works for EPRs. AFCEN is primarily intended to deal with French NPPs but includes organizations from various countries. The revisions from previous editions include regards to experiences from the Fukushima accident and the latest French NPP Flamanville 3. Although the code is valid for EPRs the design criteria are not EPR specific and

thus might apply for other reactor types as well. AFCEN´s code is based upon Eurocodes with regard taken to other international guide-lines.
Mr **Jan-Anders Larsson** from Scanscot Technology devoted his presentation primarily to the Swedish "Design Guide for Nuclear Structures" (=DNB). Formally, SSM has issued DNB as an R§D report. DNB is based upon Eurocodes and the present regulatory requirements stated by SSM. DNB is not a fully covering code. It should be used together with international codes and standards for NPPs (ASME lll Div 2, ASCE 4-98 e t c) and is currently used in Sweden for upgrading works of present containments.

2.4 APPLICATIONS: DESIGN OF OLKILUOTO 3 AND FUTURE CODES

Dr **Burkhard Wienand** from AREVA presented the design for the Finnish Olkiluoto 3 EPR Reactor Containment. The design has been made according to the regulatory guides previously presented by Mr Välikangas, i. e. the Eurocodes have been used in combination with ASME lll Div. 2.The construction works for Olkiluoto 3 are more or less completed. Conventional testing has been supplemented with various "Mock-Up" tests like concreting of dense re-bar zones, grouting of post-tensioning tendons and tendon friction tests. The tendons are grouted with exception of 4 NoS of vertical non-grouted vertical tendons which might be used for future tests.
Dr **Patrik Andersson** from Scanscot has been involved in an international benchmark project SPE (=Standard Problem Exercise) regarding the performance of containments under severe accident situation. He presented the "SPE Test Model Sandia 1/4" which was used for pressure tests. The monitoring during the test included: Global displacement, Strains in re-bars, liner and tendons, Tendon anchorage force, Material tests e t c. The results showed good correspondence between theoretical and measured data.
Mr **Sten Forsström** from SWECO expressed personal views regarding future codes. As working in a large European consulting company he expressed wishes on harmonization of codes in Europe based upon the existing Eurocodes. If ASME codes and or other non-European codes would be referred to, it would be preferred that the regulating authorities explicitly include all their requirements in 1 code. Especially, he expressed a "Vision for 2025" that Finland and Sweden would have more or less identical codes for NPPs.

3 Conclusions for Finnish/Swedish conditions

New NPPs in Finland are designed according to the latest international know how including considerations for lessons learnt from "9-11" and from the Fukushima accident. The important overall task is to ensure that abundant cooling water volumes are available at BDBE and at BDBA.
For old NPPs still in operation (and possibly with extended operation time) it would not be possible to apply the latest safety requirements. These NPPs have been designed according to old codes and it is mostly a delicate matter to apply different codes simultaneously. In Sweden the tentative handbook DNB is used for upgrading of various parts of the existing NPPs.
Future research: For the time being, much effort is made regarding the efficient long term forces in post-tensioned containment tendons, especially for NPPS which are planned for extended design life compared with the design criteria at the original design. So far, both analyses and research work show that the long term pre-stressing forces are within acceptable limits. A qualified guess would be that this issue soon would be classified as "Solved". Instead the tendons should be investigated with regard to corrosion protection. Energiforsk is currently investigating the possibility to use the 2 closed reactors at Barsebäck (Sweden) for research issues. Parts of the tendons might be uncovered from the surrounding concrete and the cement grout around the tendons might be examined. At the part it would be possible to test the bond of single steel strands and of entire multi-strand tendons. The reactors of Barsebäck might also be used for inspection of the corrosion protection of the embedded steel liner.
As Dr Adsten informed at the inauguration of the seminar, Energiforsk is currently supporting a PhD work regarding anchor plates. The Barsebäck NPPs might be used also for the purpose of full scale tests of embedded items. Such research would result in spin off effects for the Swedish Construction Industry in general.

4 Final words

Currently, the planning in Sweden for new NPPs is more or less postponed. In spite of this fact, Energiforsk succeeded in getting 52 participants to the seminar, including both grey-haired veterans and young engineers with most part of their professional life in the future. I want to conclude by expressing thanks from the participants to Energiforsk for the outcome of this event!

5 Appendix A: Seminar program

PROGRAM

09.00 ***Registration and coffee***

09.30 **Welcome and introduction**

Monika Adsten, Energiforsk

09.40 **Regulatory Requirements**
Moderator: Kostas Xanthopoulos, The Swedish Radiation Safety Authority

- Finnish regulatory requirements on concrete containments
  Pekka Välikangas, STUK, Finland
- The Swedish Radiation Safety Authority work on new regulatory requirements
  Lars Skånberg, The Swedish Radiation Safety Authority, Sweden

10.50 ***Coffee***

11.00 **Design requirements and acceptance criteria at service, ultimate limit states, and severe accidents**

Moderator: Anders Bergkvist, Forsmark

- U.S. practices for concrete containment design and evaluation for design basis and beyond design basis loads
  Jorma Arros, ABS Consulting (U.S.)

11.40 ***Lunch***

12.40 **Design requirements and acceptance criteria at service, ultimate limit states, and severe accidents**

Moderator: Anders Bergkvist, Forsmark

- AREVA EPR-reaktor: ETC-C: EPR Technical code for civil Works
  Etienne Gallitre, EDF, France
- Swedish Design Guide for Nuclear Civil Structures, DNB
  Jan-Anders Larsson, Scanscot, Sweden

13.50 **Coffee**

14.10 Applications
Moderator: Johanna Spåls, Ringhals

- **The Design of the OL3 Reactor Containment**
  Burkhard Wienand, Areva, Germany
- **Design of Swedish Reactor Containments**
  Sten Forsström, Sweco, Sweden
- **Standard problem exercise (SPE) on performance of containment vessel under severe accident condition**
  Patrick Anderson, Scanscot, Sweden

Discussion

Moderator: Sten Forsström, Sweco, Sweden

16.30 Ending of seminar

Design of Concrete Containments- Focus on integrity and tightness

This seminar was arranged to compile international experience on how to fulfil the requirements on integrity and tightness of nuclear reactor containments. The program contained regulatory requirements, design requirements, acceptance criteria and applications.