Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

RIC 2018 – TH28 Session: Concrete Degradation Part I: Perspectives on Alkali – Silica Reaction (ASR) Effects on the Structural Capacity of Nuclear Concrete Structures

OECD/NEA/CSNI Benchmark ASCET Phase II Summary, Conclusions and Recommendations

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Acronyms

- CNSC - Canadian Nuclear Safety Commission
- OECD - Organisation for Economic Co-operation and Development
- NEA - Nuclear Energy Agency
- CSNI - Committee on the Safety of Nuclear Installations
- CAPS - CSNI Activity Proposal Sheet
- WG IAGE - Working Group on Integrity and Ageing of Structures and Components
- ASCET - **A**ssessment of **S**tructures Subjected to **C**oncret**e** Pat**h**ologies
- EDF - Électricité de France
- IRSN - Institut de Radioprotection et de Sûreté Nucléaire, France
- NRA - Nuclear Regulation Authority, Japan
- CEBTP - Centre d'expertise du bâtiment et des travaux publics, France
- HARVEST - **HARVE**sting of concrete **S**amples as well as performing destructive and non-destructives **T**ests on concrete samples, anchorages and structures of Gentilly-2 Nuclear Generating Station

OECD/NEA/CSNI ASCET

- The CSNI CAPS ASCET is a research activity established by the CNSC and U.S. NRC in order to make general recommendations for ageing management of concrete nuclear facilities taking into account the effect of concrete pathologies on structural degradation
- The CAPS ASCET supported by Canada, France and USA was approved by the CSNI in June 2013
- The kick-off meeting was held at EPRI offices, Washington DC, on June 30, 2014
- The workshop ASCET Phase I was held at NIST, Gaithersburg, MD on June 29th to July 1st, 2015

OECD/NEA/CSNI ASCET (cont'd)

- Following the ASCET Phase I workshop the structure of ASCET program is defined
- There is a need for reliable numerical tools to predict the behaviour, as a function of time, of structures with concrete degradation mechanisms in order to assess and to quantify their ultimate and serviceability limit states
- The multiyear program ASCET was organized in three phases in order to provide these tools:
  - Phase I - Addressing general guidance regarding ageing management and research needs – Completed in 2015
  - Phase II - Blind numerical benchmark – Completed in 2017
  - Phase III - Adjustment and refinement of numerical tools using additional test data - Ongoing

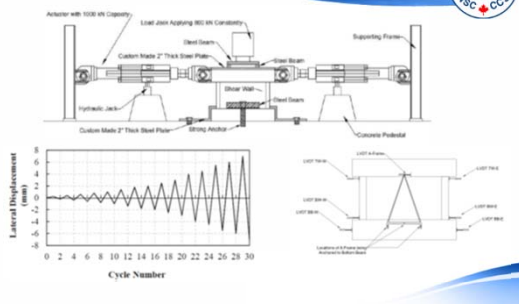
ASCET Phase II Summary

- ASCET Phase II Benchmark participants:
  - Canadian Nuclear Safety Commission
  - University of Toronto, Canada
  - IRSN, France
  - EDF, France
  - NRA, Japan
  - Nagoya University, Japan
  - Kansai University, Japan
  - Scanscot, Sweden, for the Swedish Radiation Safety Authority
  - University of Colorado at Boulder, USA
  - U.S. NRC

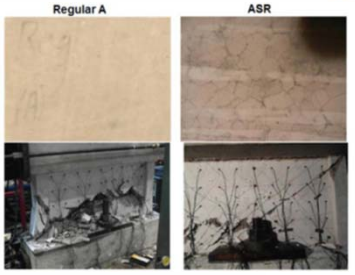
ASCET Phase II Summary (cont'd)

- The benchmark was based on the wall tests performed at the University of Toronto under a CNSC research program R523.1 (contract # 87055-12-0019) . The test results of two sets of two walls (one sound and one with ASR in each set), with two different ages, were provided for this benchmark
- The results of one set of walls (aged 240 and 260 days) were provided to participants in advance to calibrate numerical tools. For the other set of walls (aged 975 and 995 days) participants were asked to perform blind simulations
- The results of the benchmark were discussed during the ASCET Phase II workshop, held at CNSC headquarters in Ottawa, Ontario, on May 8 and 9, 2017

Wall Test Setup, Boundary Conditions, Loading Cycles and Location of Displacement Gauges



Condition of the Walls Before and After the Tests



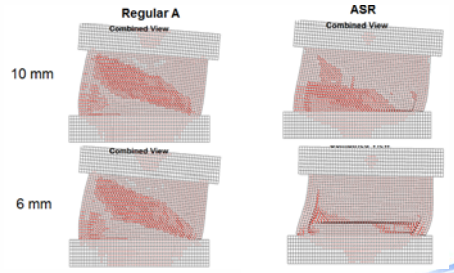
Surface of the regular shear wall (left) and ASR shear wall (right) before testing (Habibi, F., et al, 2015)

Regular shear wall (left) and ASR shear wall (right) after testing (at failure) (Habibi, F., et al, 2015)

ASCET Phase II Simulation Results

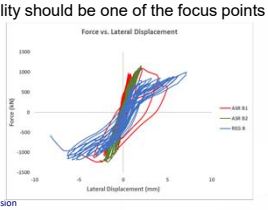
- All participants successfully predicted the ultimate capacity of the walls, calculating that ASR walls would have higher capacity than the regular walls, which was in accordance with the test results
- The predictions regarding wall displacements were less successful. The measured displacements were up to three times higher than calculated displacements
- The predictions of the wall hysteretic loops and failure modes were also not successful
- The loss of ductility of ASR walls was not captured

Sensitivity of Failure Modes to the Aggregate Size (U.S. NRC analysis)



ASCET Phase II Wall Ductility

- The loss of ductility, over time, of ASR walls was discussed during the workshop as a very important point, especially for seismic loading. The hysteresis loops became narrower and the energy consumption was divided by a factor of four compared to a regular, sound wall
- The loss of ductility should be one of the focus points of future studies



ASCET Phase II Conclusions

- The analysis results of the ASCET Phase II were mainly focused on the ultimate wall capacity. The planned next phase of the ASCET benchmark should focus on evaluation of: displacements, deformations, the failure modes, the crack pattern, crack width and crack distribution
- The wall displacement measurements were not sufficiently documented. A single measurement of the displacement of the upper beam is not enough to calibrate numerical models
- Based on numerical simulations, the wall boundary conditions have a more important impact on wall displacements than the constitutive laws

OECD/NEA/CSNI ASCET Phase II Recommendations

- A new phase, ASCET Phase III Benchmark, is in place, and the next workshop will be held at OECD/NEA in Paris on April 16 and 17, 2018
- To perform a successful benchmark, additional test data is needed from the University of Toronto on the measured displacements from all relevant gauges, the crack pattern, and the crack width and length
- The IRSN tests performed in 2001 at CEBTP, Paris, with similarly designed regular walls, should be analyzed to understand the failure mechanism
- OECD/NEA/CSNI recommend correlating the results of non-destructive and destructive tests. The results of non-destructive tests performed on the walls by the University of Sherbrooke could be used

OECD/NEA/CSNI ASCET Phase II Recommendations (cont'd)

- The accelerated ASR degradation of reduced-size specimens cured in laboratory conditions does not necessarily reflect actual degradation shown in the real structure. There is a need for testing and assessment of degraded specimens from real structures
- During the NEA/CSNI/WG IAGE Concrete Subgroup meeting at OECD on April 25 and 26, 2017 it was proposed to harvest ASR affected concrete samples from Gentilly-2 Nuclear Generating Station, in Quebec, Canada. The plant has been shut down since 2012
- A proposal for a separate CSNI Joint Research Program HARVEST is currently under discussion and will be submitted to the CSNI by the CNSC in February 2018. The program will include a proposal for concrete sample harvesting as well as for non-destructive and destructive testing

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