Critical Studies in support of the Ageing Management of NPP Concrete Infrastructure – CONAGE

KYT2022-SAFIR2022 Interim Seminar

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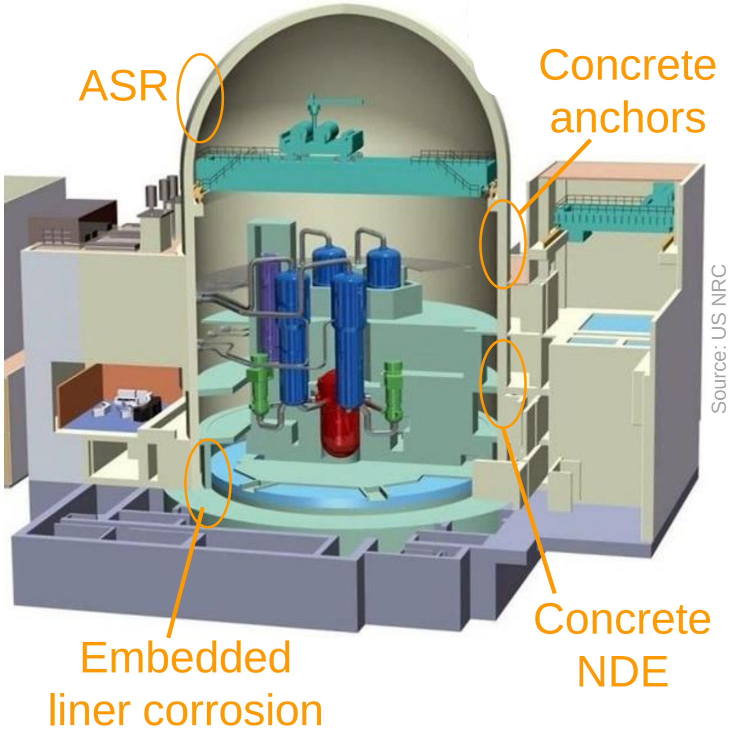
What is the challenge?

- Research on **ageing phenomena** of **concrete structures**, systems and components, important to safety for long-term operations (LTO) of NPPs
- Develop **operational practices** to support safe LTO of existing NPPs
- **Knowledge development** of **NDE methods** for NPP concrete, and **tools** for accurate assessment of remnant service
- International **cooperation**, **education** and **training**



CONAGE - Critical Studies in support of the Ageing Management of NPP Concrete Infrastructure

Raise the level of concrete infrastructure related NDE research, address key ageing mechanisms identified by both Finnish and foreign utilities and regulators, and update ageing management practices of Finnish NPP concrete infrastructures

- Duration: **4 years** (February 2019 – January 2023)
- Budget: 439.6 k€ (for first three years)
- Partners: **VTT Technical Research Centre of Finland** and **Aalto University – Department of Civil Engineering**

Work Package structure

- WP1 – Non-destructive evaluation of NPP concrete infrastructure –
  Fahim Al-Neshawy (Aalto University)

- WP2 – Assessing the risk of internal expansive reactions for NPP concrete infrastructure – Miguel Ferreira (VTT)

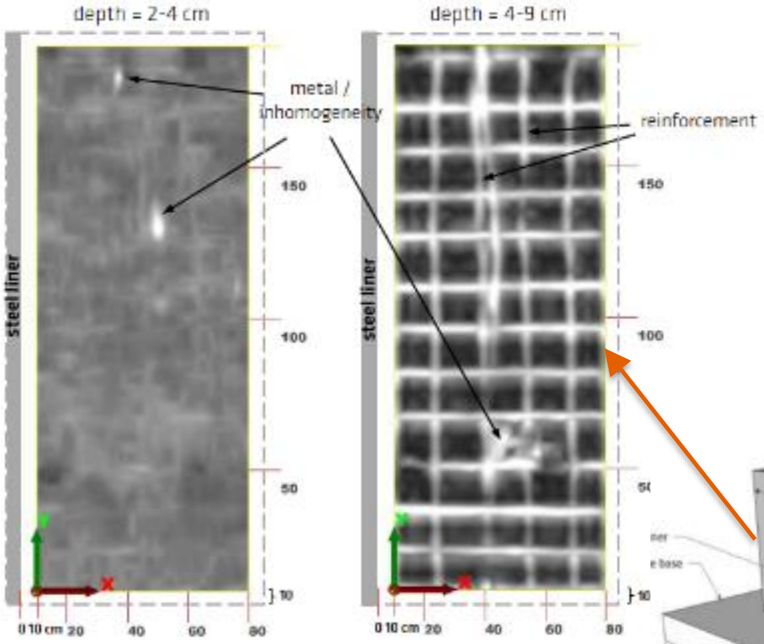
- WP3 – Assessing steel liner and anchor corrosion – Edgar Bohner (VTT)

Work Package 1 –
Non-destructive evaluation of NPP concrete infrastructure

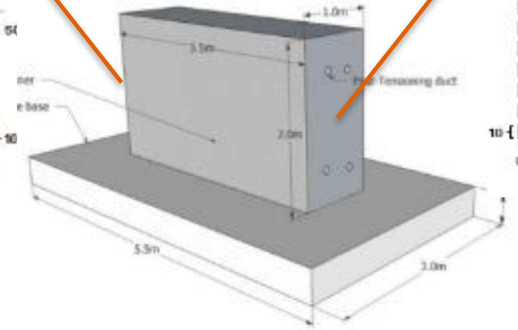
→ NDE of general defects in mock-up wall

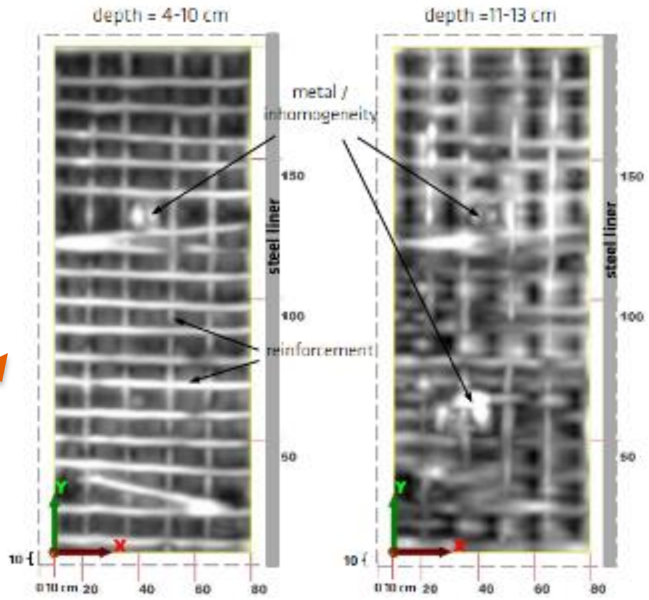
→ Enhanced analysis through combined NDE

NDE of general defects in mock-up wall – Ground penetrating radar (GPR)



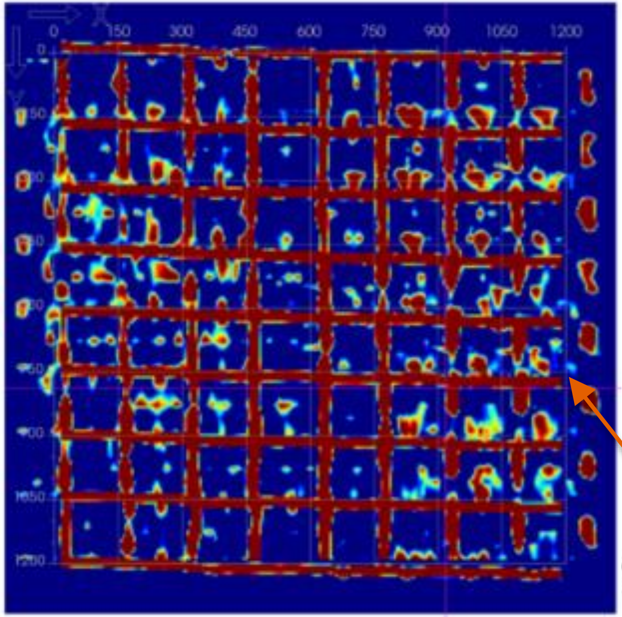
Western mockup wall



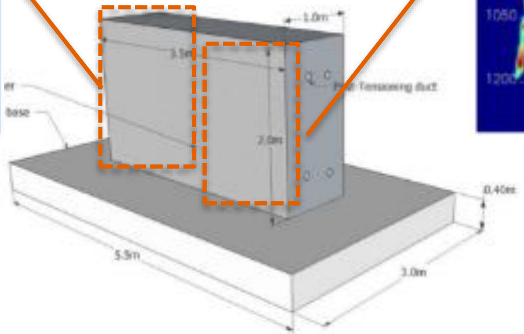


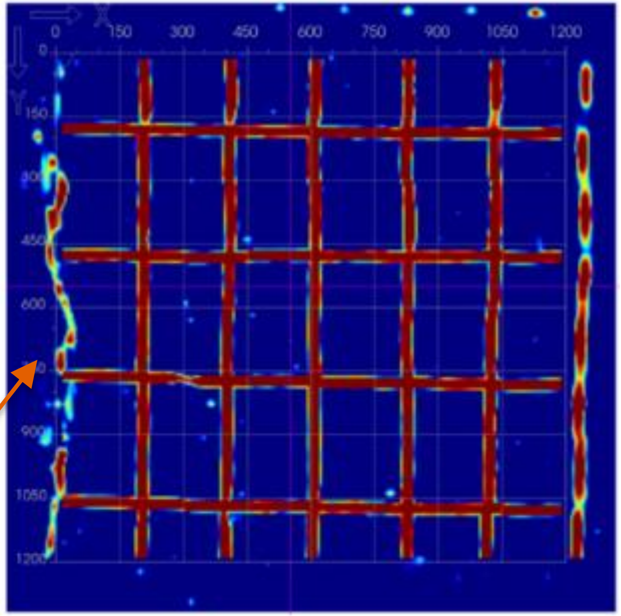
Eastern mockup wall

NDE of general defects in mock-up wall – Ground penetrating radar (GPR)



Southern mockup wall – left side

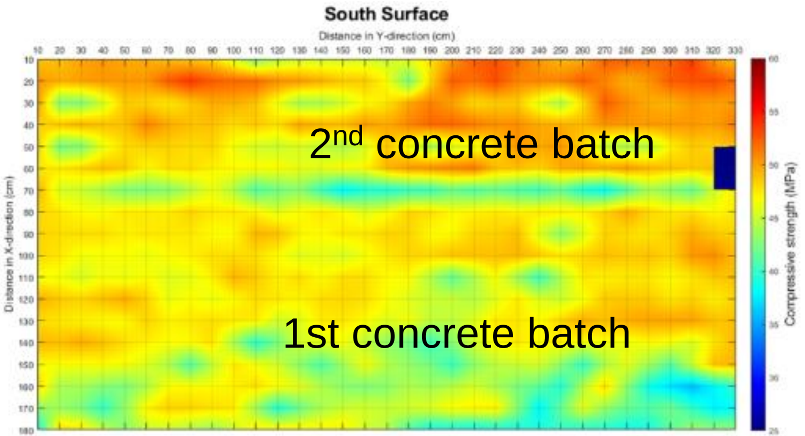


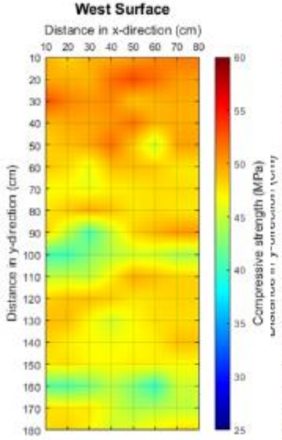


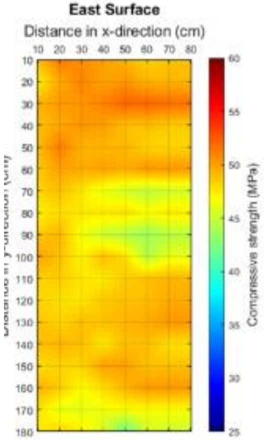
Southern mockup wall – right side

Enhanced analysis through combined NDE testing

- Combined NDT techniques:
  - Rebound hammer (R-value and Q-value)
  - Ultrasonic pulse velocity (UPV)
  - Coring samples for calibration of compressive strength with SonReb method
- Rebound hammer
  - 9 points in 100cm², calculated median
- UPV
  - Best fit straight line of 4 measurements







Combined R-value rebound hammer with UPV – Estimated compressive strength→

Work Package 2 –
Assessing the risk of internal expansive reactions for NPP concrete infrastructure

→ Assessment of the risks for DEF/ASR in NPP

→ Akali aggregate reaction (ASR) testing for NPP concrete

Assessment of the risks for DEF/ASR in NPP

Table 3. Structures and module specific data for OL1.

Structure/Module	Age [y]	T [°C]	RH [%]	w/c [-]	f_{ck} [MPa]	CEM	TWS >m
Containment							
Foundation on rock, bottom surface	45	10	90	0.59	35	I	> 0.5
Foundation on rock, sides and upper surface outside the steel liner	45	10	90	0.59	35	I	> 0.5
Foundation on rock, upper surface inside the steel liner	45	20	65	0.49	40	I	< 0.5
In-situ cast bottom parts, outside the steel liner	45	10	90	0.49	40	I	< 0.5
In-situ cast bottom parts inside the steel liner a… …enser pool liner							
…u cast bottom parts inside the steel liner i… …room							
…stressed outer cylinder cast with sliding for… …l liner							
…stressed outer cylinder cast with sliding for… …el liner against the pool liner							
…estressed outer cylinder cast with sliding for… …ner in the wet room							
…restressed outer cylinder cast with sliding for… …teel liner in the upper dry room							
…nner cylinder wall cast with sliding form and th… of the conveying channel in the lower dry room							
Inner cylinder wall cast with sliding form, again… wall							
Inner cylinder wall cast with sliding form and th… of the conveying channel in the wet room							
Biological shelter							
Intermediate floor (slab between dry and wet w…							
Roof, under the steel liner							
Roof and non-prestressed pool structures agai… liner							
Roof and non-prestressed pool structures, out…							
Prestressed pool structures, against the pool li…							
Prestressed pool structures, outer side	45	20	65	0.52	40	I	< 0.5
Cooling water intake plant							
Fine grating area, structures above splash zone	44	10	95	0.50	35	I	< 0.5
Fine grating are, water level and under	44	10	100	0.50	35	I	< 0.5
Basket filter area, structures above splash zone	44	10	95	0.50	35	I	< 0.5
Basket filter area, water level and under	44	10	100	0.50	35	I	< 0.5
Sea water pump area, structures above splash zone	44	10	95	0.50	35	I	< 0.5
Sea water pump area, water level and under	44	10	100	0.50	35	I	< 0.5
Intake chamber to condenser							
Structures under water level	44	10	100	0.50	35	I	< 0.5

Table 11. Classification of the potential for occurrence of AAR of NPP's reinforced concrete structures if the aggregate is found to be reactive.

	Factors affecting RH	CS < 0.2m	0.2m <CS< 0.5m	CS > 0.5m
		RH < 70%	70% < RH < 80%	RH > 80%
Source of Alkalis*	Level	Low	Medium	High
CEM III	Low	LOW	LOW	MEDIUM
CEM I/II + SW CEM III + SW	Medium	LOW	MEDIUM	HIGH
CEM I, CEM II, CEM I/II + SW	High	MEDIUM	HIGH	(VERY) HIGH

SW – seawater

* – General indicator of cement types, but for confirmation exact binder composition should be known.

ASR testing for NPP concrete

TVO coarse aggregate (AAR-4.1)

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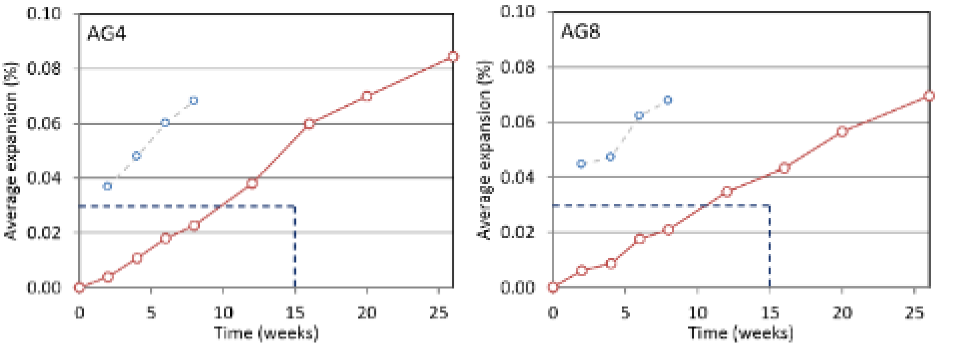
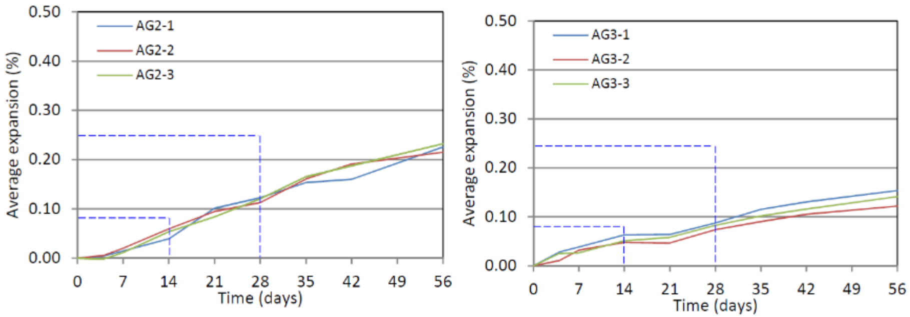


TVO coarse aggregate (AAR-4.1)



FORTUM fine aggregate (AAR-2.2)

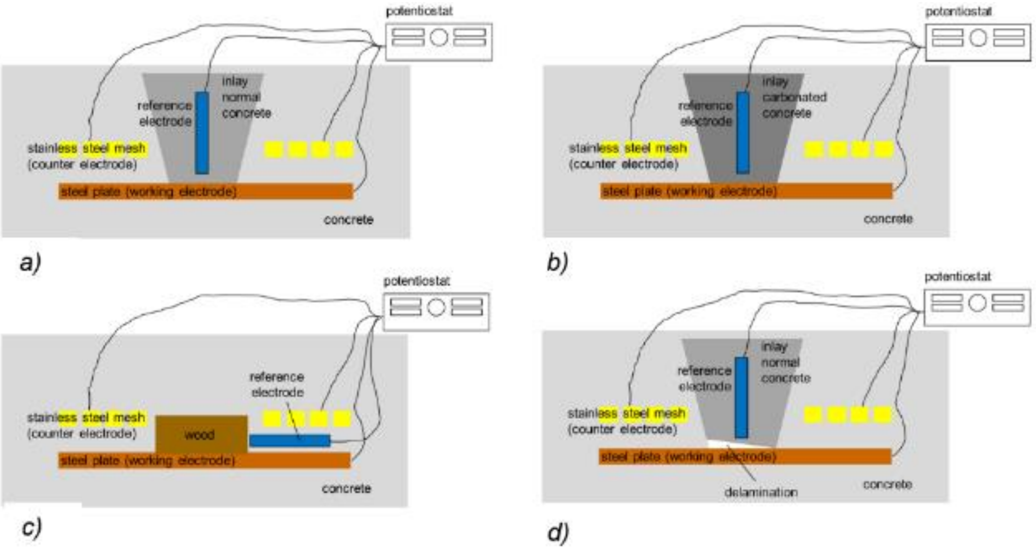
Work Package 3 – Assessing steel liner and anchor corrosion

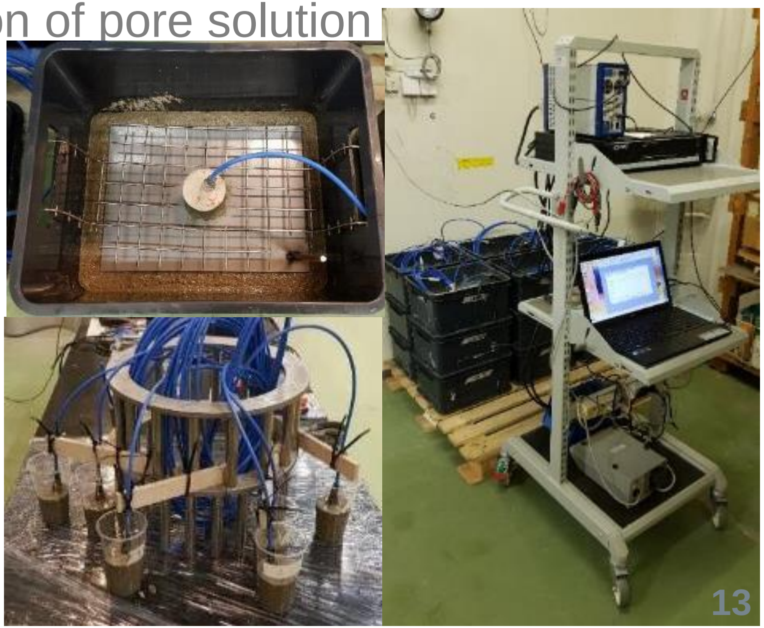
→ Steel liner corrosion experiments

→ Anchor bolt corrosion experiments

Steel liner corrosion experiments

- Possible causes of embedded steel liner corrosion: pH of the concrete, foreign debris (e.g. wood, etc.), voids and/or delamination gaps and presence of Cl^-
- Likely corrosion mechanisms include: the loss of passivity, or a delamination gap between concrete/steel, enabling accumulation of pore solution





Anchor bolt corrosion experiments

- Study the corrosion characteristics of three types of anchors: undercut, expansion, and bonded anchors (ordinary, galvanised, stainless steel anchors)
- Sample subject to accelerated deterioration using carbonation (4-5 vol% CO_2, 60% RH, T = 22 °C), and cyclic wetting/drying (1day/6days) with 20% NaCl

Pre-testing wedge anchors

Pre-testing epoxy anchors

VTT

beyond the obvious

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