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Selection of materials in respect to the content of long-lived radioisotopes and alkali-silica reaction

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Motivation

- Concrete elements may become radioactive through exposure to neutron radiation from the nuclear reactor - **long-lived radioisotopes**.
- The design of concrete for radiation shielding structures is principally based on the selection of materials of adequate elemental composition.
- However, the research has not yet considered the risk of an alkali-silica reaction (ASR), although it is already known that this type of concrete deterioration occurs in structures related to NPP.

1. ASR in NPPs around the world

- In NPPs, the probability of ARS can not be ruled out – Multiple NPPs have already been diagnosed with ASR:
  - **Tihange 2 NPP, Belgium** – ASR in the ring beam of the containment structure
  - **Ikata 1 NPP, Japan** – expansion observed in the turbine generator foundation
  - **Seabrook NPP, USA** – ASR-induced micro-cracking has led to larger macro-cracking (bulk expansion) and the displacement of some concrete walls; detected in many concrete structures
  - **Gentilly 2 NPP, Canada** – ASR detected in the containment structure

a) Tihange 1 NPP (GreenPeace, Briefing-Lifetime-extension-of-ageing-nuclear-power-plants), b) Ikata NPP (Wikipaedia), c) Seabrook (doi.org/10.1016/j.nucengdes.2014.06.012), d) Gentilly NPP (www.hydroelectricite.ca)

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ASR research in support of Ageing Management programs for NPPs – ACES project

2nd JCSE Concrete Committee Webinar – Aging Management of Concrete Structures in Nuclear Power Plants

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Goal of research

The goal of the research is a formulation of a new criterion for the selection of materials for NPP structures.

A reduction of the content of long-lived radioisotopes in constituents of alkali-silica resistant concrete will have an impact on:

- Reducing the volume of waste and
- Facilitation of the necessary disposal procedures during plant decommissioning

Materials

- **7 fine aggregates**: siliceous and limestone sand
- **9 coarse aggregates**: various origin
- **4 cements**: 3 - various Na_2O_{eq} content and 1 - white cement (low content of iron)

Rock origin		Aggregate	Designation	Density, g/cm^3
igneous rock	plutonic rock	granite	G1	2.63
			G2	2.64
	volcanic rock	melaphyre	M1	2.70
sedimentary rock	clastic	greywacke	GW1	2.70
	organogenetic	flint	F1	2.65
		limestone	L1	2.71
	evaporite	baryte	B1	4.20
metamorphic rock		quartzite	Q1	2.62
			Q2	2.60

Constituent	C1	C2	C3	C4
	CEM I 42.5R	CEM I 52.5R	CEM I 42.5R	CEM I 52.5R
SiO2	19.03	19.42	19.43	24.40
Fe2O3	3.22	2.94	3.18	0.30
CaO	63.64	64.1	61.81	68.40
Na2Oeq	0.56	0.88	1.12	0.23

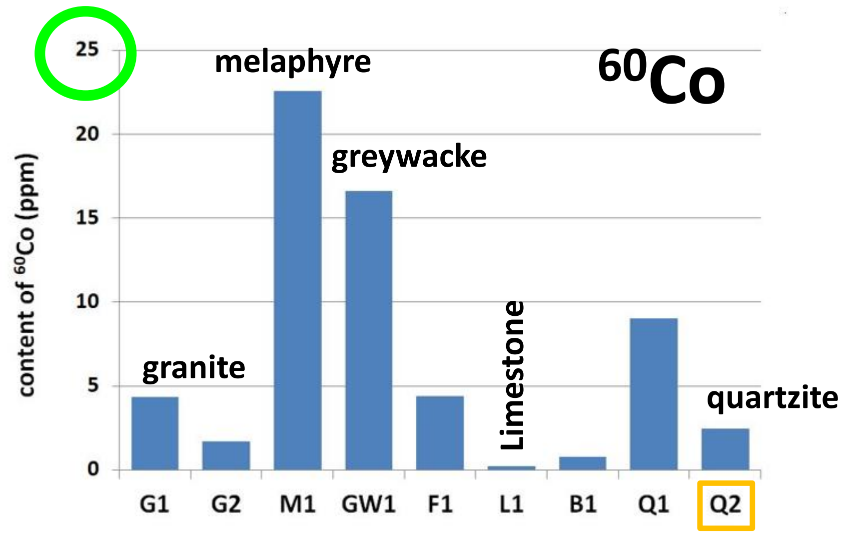
Methods

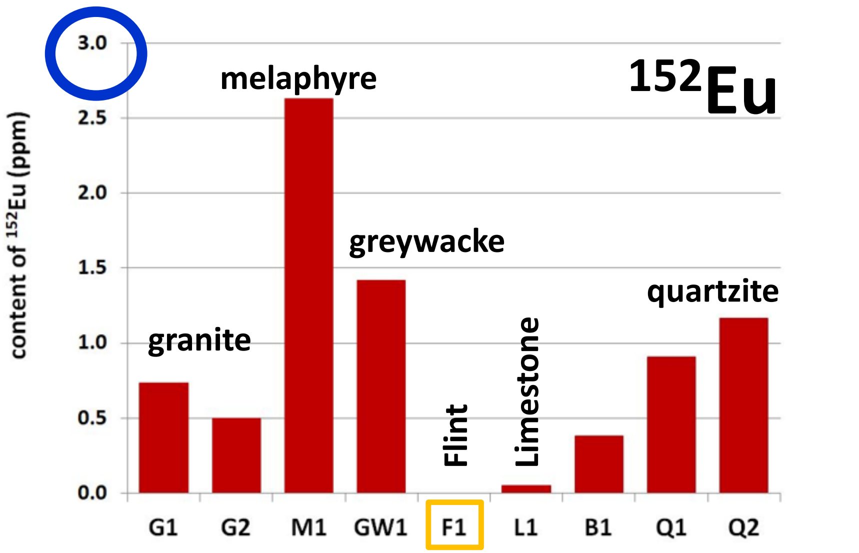
- Neutron activation analysis (NAA) → **long-lived radioisotopes ^{60}Co and ^{152}Eu**

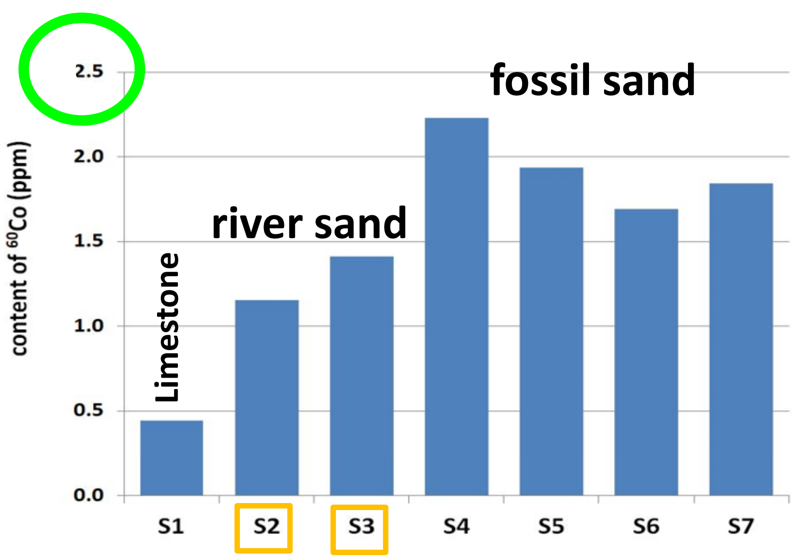
- Thin section petrography
- Accelerated mortar bar test (AMBT) in a 1 M NaOH solution at a temperature of 80°C
- Concrete prism test (CPT) in a highly humid environment (RH > 95%) at a temperature of 38°C
- SEM-EDS

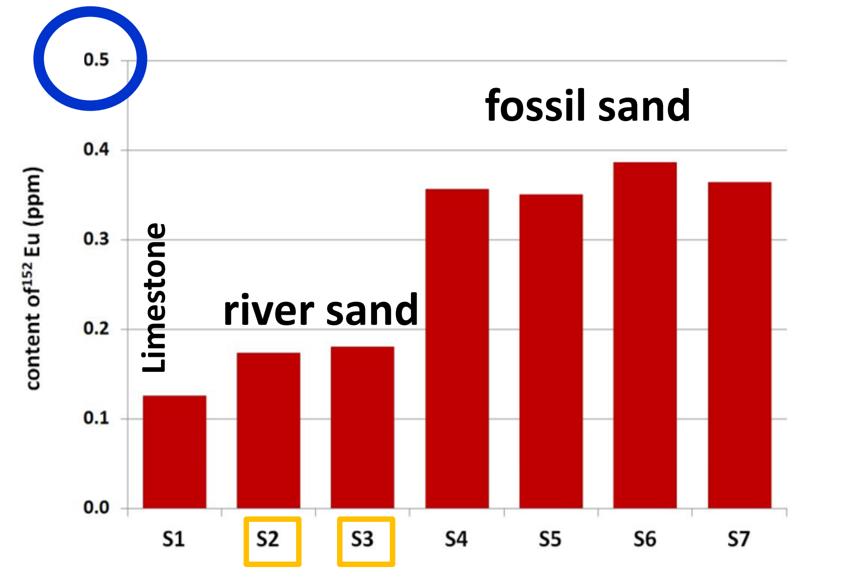
} **alkali-silica reaction**

Results – NAA, aggregate

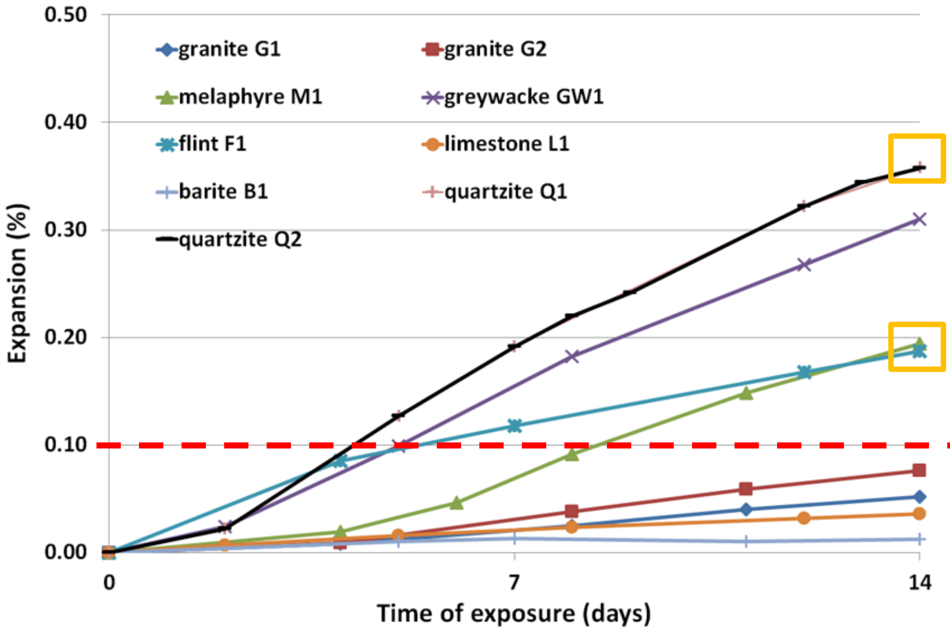


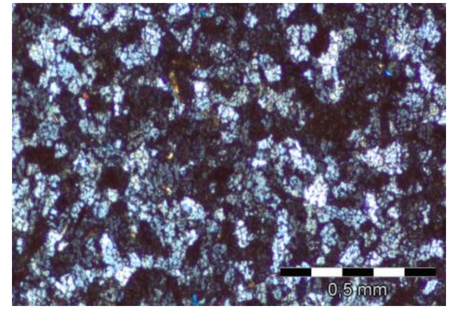




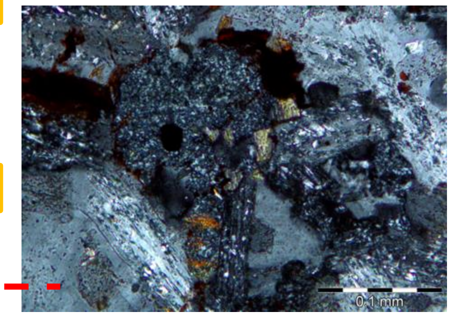


Results - ASR

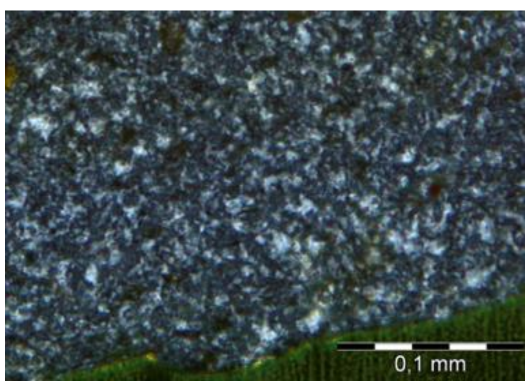




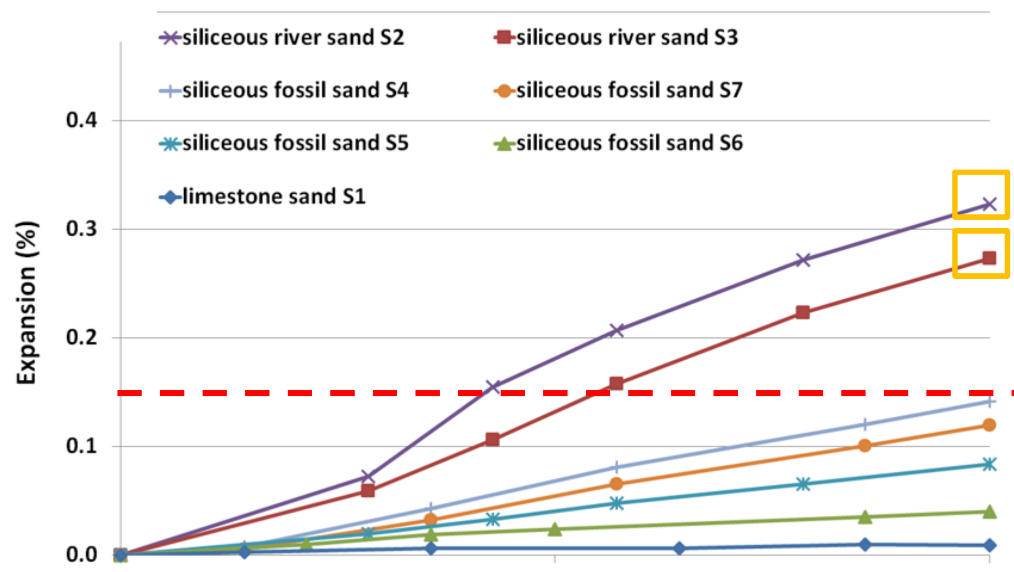
Quartzite Q2



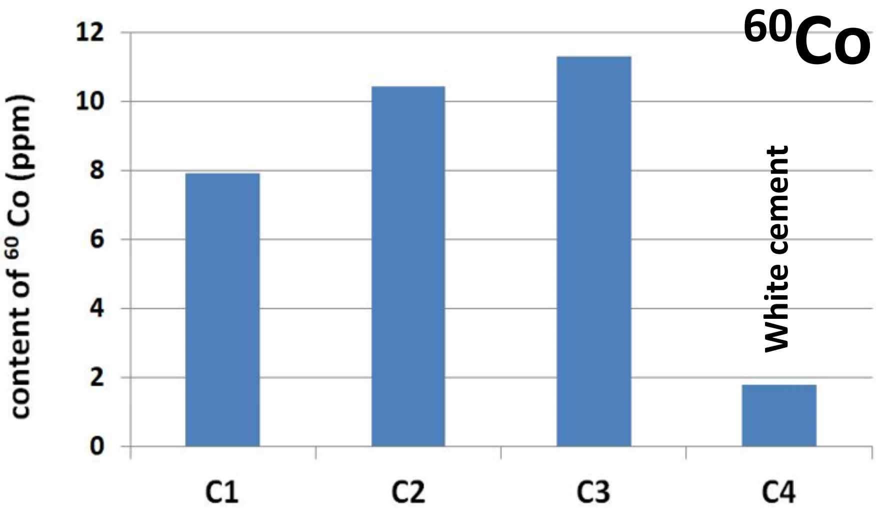
Melaphyre M1

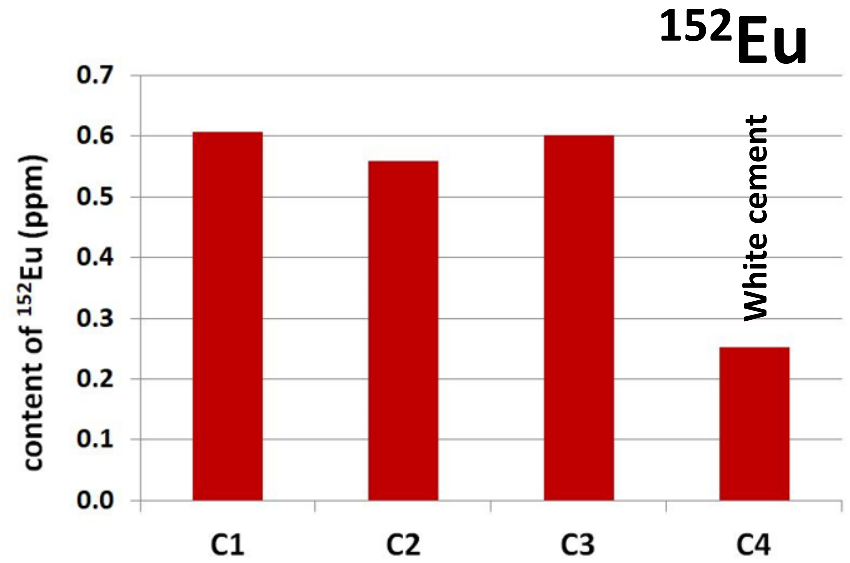


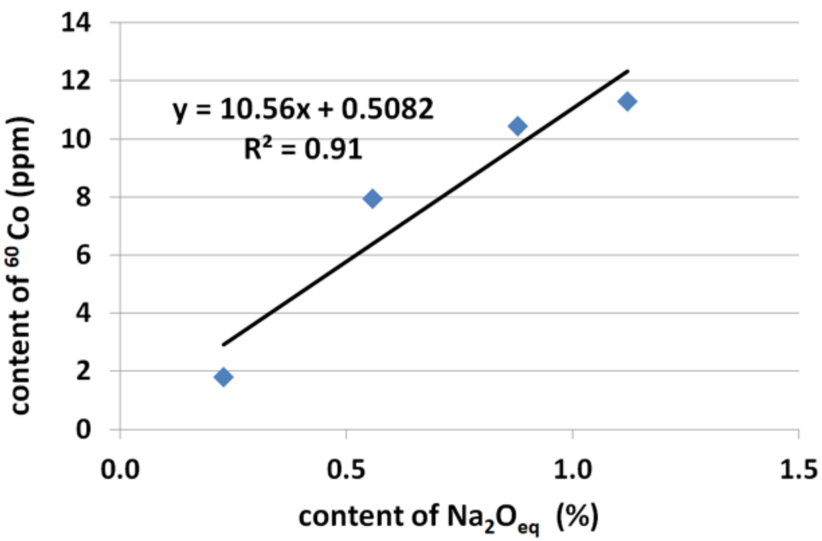
Siliceous river sand S2

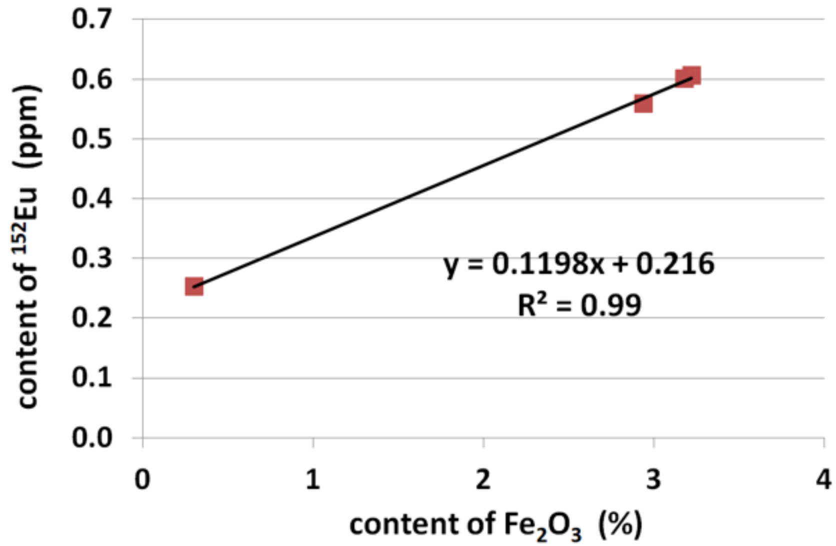


Results - NAA, cement









Conclusions

- The concentration of ^{60}Co and ^{152}Eu activated by neutron radiation in natural fine aggregate was lower than in natural coarse aggregate.
- The influence of the sand origin on the ^{60}Co and ^{152}Eu content was clearly visible in the analyzed natural fine aggregate.
- The content of ^{152}Eu was proportional to the content of Fe_2O_3 in Portland cement.
- The content of ^{60}Co was proportional to the content of alkalis in Portland cement.
- Despite low contents of ^{60}Co and ^{152}Eu aggregates revealed susceptibility to ASR.

- Due to the high potential of ASR, it is not recommended to use quartzite as coarse aggregate as well as siliceous river sand as fine aggregate for shielding concrete, despite the low content ^{60}Co and ^{152}Eu.
- It is suggested to use cement with the lowest alkali content, both due to the possibility of alkali-silica reaction of the aggregate in concrete as well as a lower content of ^{60}Co.

Publications

1. Jóźwiak-Niedźwiedzka D., Gmeling K., Antolik A., Dziedzic K., Glinicki M.A., Estimation of long lived isotopes in alkali-silica resistant concrete designed for nuclear installations, Materials, Vol.14, No.16, pp.4595-1-15, 2021, doi: 10.3390/ma14164595,
2. Jóźwiak-Niedźwiedzka D., Gméling K., Harsányi I., Dziedzic K., Glinicki M.A., Assessment of long-lived residual radioisotopes in cement induced by neutron radiation, MATBUD'2020 Scientific-Technical Conference: E-mobility, Sustainable Materials and Technologies, 19-21.10.2020, Kraków, Poland, Vol.322, pp.01019-1-7, doi:10.1051/matecconf/202032201019,
3. Jóźwiak-Niedźwiedzka D., Antolik A., Dziedzic K., Gméling K., Bogusz K., Laboratory investigations on fine aggregates used for concrete pavements due to the risk of ASR, Road Materials and Pavement Design, pp.1-13, 2020, doi: 10.1080/14680629.2020.1796767.

Thank you for your attention

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