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Scabbled Contaminated Concrete: Waste Form Or Fix?

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Overview

- Introduction & Background
- MSc Research
  - Aims and Objectives
  - Reactivity
  - Strength
- PhD Research
  - Characterisation
  - Recycling or re-use
  - Alkali Activation

Contaminated Concrete

- Contamination occurs through direct contact with radionuclide containing air or water.
- Radionuclides can be physically or chemically bonded to the concrete[1];
  - soluble elements within pore water, physically bonded.
  - chemical bonding onto different phases within cement matrix or gel.
- Also products from activation of concrete and reinforcing steel exposed to neutron flux.
- Depth of contamination depends on properties of radionuclide. ^{239}I shown to penetrate up to several in degraded concrete, but more particulate Pu likely to remain close to surface.
- Radionuclides expected depend on exposure history of concrete. Power production facilities would differ from fuel reprocessing facilities.

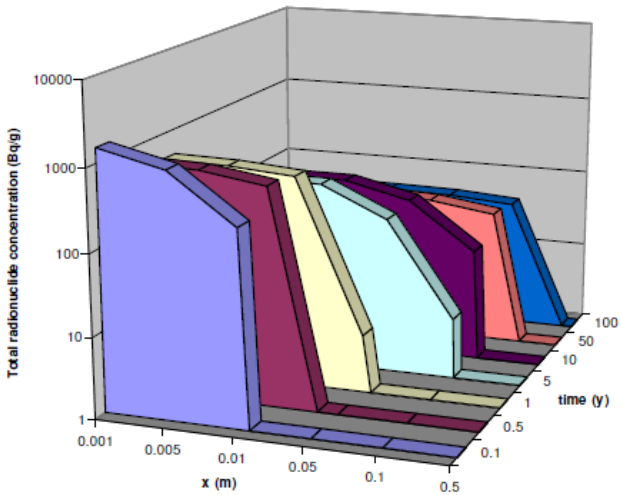


Figure 1. In-diffusion of contamination from the surface of a concrete slab (at the left side of the plot) after periods from 0.1 to 100 years. $D_e = 10^{-11}$ m^2/s, $K_d = 1$ (e.g. ^{129}I), $\varepsilon = 0.25$.

[1] BATH, A., DEISSMANN, G. & JEFFERIS, S. 2003. Radioactive Contamination of Concrete: Uptake and Release of Radionuclides. *The 9th International Conference on Radioactive Waste Management and Environmental Remediation.* Oxford: ICEM.

Scabbled Concrete

- Removal of outer contaminated layer from bulk concrete.
- Physical or mechanical removal – laser, grinding, water blasting, liquid nitrogen.
- Intact bulk concrete remains, particulate scabblings removed for treatment.
- Enables bulk concrete to be disposed of as VLLW or exempt waste.
- Arising scabblings currently treated as LLW or mostly ILW, requiring disposal.

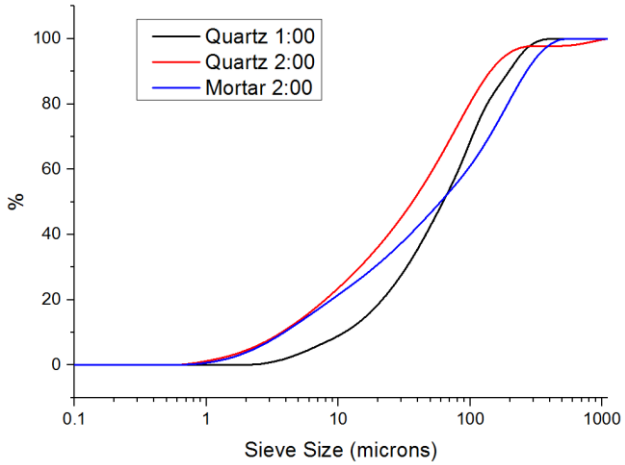
Research Basis

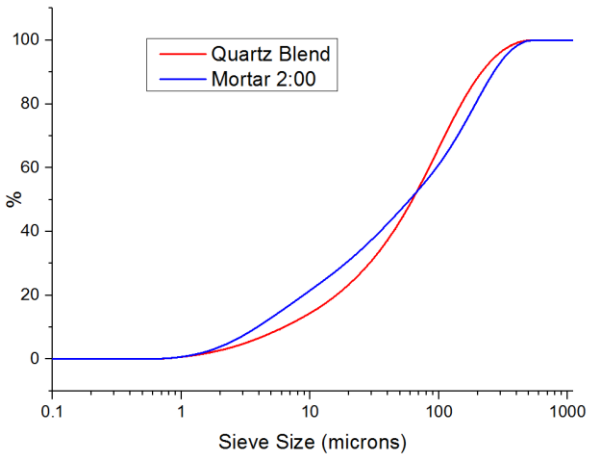
- Over 50% UK's nuclear waste is concrete and building rubble and over 2,000,000 tonnes of concrete at Sellafield site alone (ref for UK waste inventory).
- During decommissioning large volumes of contaminated scabbled concrete will arise requiring disposal. With very high disposal costs of £14,000 per m^3 of ILW[2], this will prove very costly. 2013 waste inventory shows 59,000 tonnes concrete, sand and rubble conditioned or from future arising's[3].
- As part of Waste Management Hierarchy, volume reduction of waste is vital.

[2] DEPARTMENT OF ENERGY & CLIMATE CHANGE 2011. Waste Transfer Pricing Methodology for the Disposal of Higher Activity Waste from Nuclear Power Stations. London: Department of Energy and Climate Change.
[3] PÖYRY ENERGY LIMITED & AMEC PLC 2014. The 2013 UK Radioactive Waste Inventory. Moor Row, Cumbria.

MSc Research

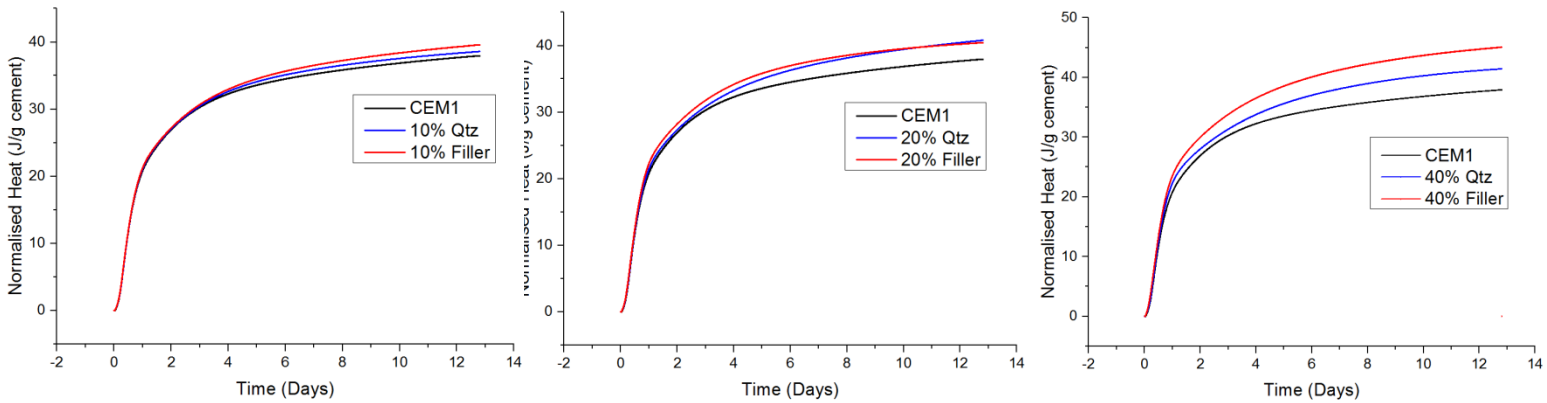
- 'INVESTIGATING THE IMPACT OF RECYCLED CONCRETE FINES ON THE ENGINEERING PERFORMANCE OF CEMENTITIOUS INFILL'
- Precursor to PhD work, primarily investigating the properties and performance of ground mortar as CRM in new material.
- 50MPa mortar cast, cured under ideal conditions for 28 days.
- Ground for 2 minutes, with quartz also ground to matching PSD in order to provide reference material.





MSC Research - Reactivity

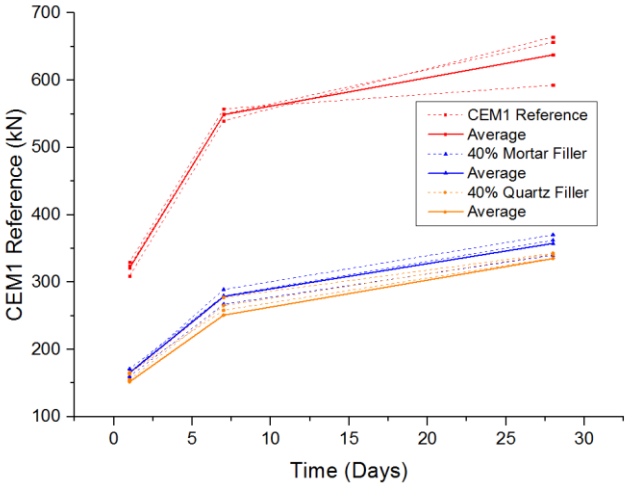
- Macro and Micro scale testing carried out to ascertain extent of any latent reactivity within ground mortar, above that of filler effect.
- Calorimetry and chemical shrinkage work carried out on 3 replacement mixes – 10, 20, 40% replacement.

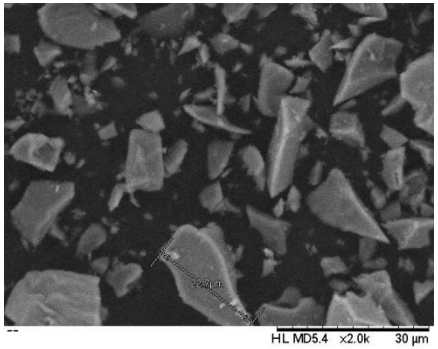


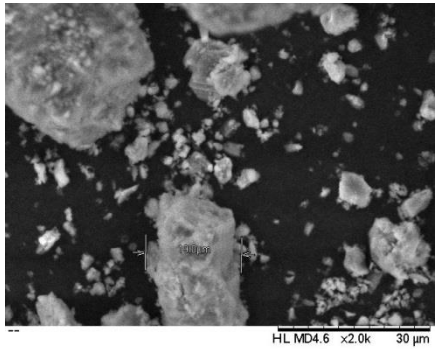
- Increased reactivity observed within calorimetry work, above and beyond that of filler effect.
- No additional reactivity demonstrated by chemical shrinkage work however.

MSC Research - Strength

- Strength testing carried out to BS EN 12390 – 2 on 100mm mortar cubes. Carried out on 40% replacement mixes, based on a 50MPa reference mix.
- Noticeable strength increase when mortar used as CRM compared to quartz.
- Larger standard deviation in mortar however, leading to very similar characteristic strengths.
- Increase in average strength, at both 7 and 28 days shows possible increased hydration contributing to strength.
- Increased strength could also be related to particle shape.
- Quartz (left) more angular but smoother surfaces, with mortar having increased roughness, possibly with greater cohesion to cement matrix







PhD Research

- 'SCABBLED CONTAMINATED CONCRETE: WASTE FORM OR FIX?'
- Volume reduction of scabbled waste through re-use or recycling within encapsulation grout.
  - Tight specifications for ILW encapsulation grouts[4];
    - Setting time must be within a 4 to 24 hour window such that 4h<setting time<24h.
    - Cumulative heat of hydration must be less than 250 Joules per gram within the first 24 hours after casting.
    - Bleed water must be less than 1% by weight.
    - Flow must be above the pessimum level within the Colflow test.
    - 3:1 Blast Furnace Slag (BFS) to Ordinary Portland Cement (OPC) ratio. Target W/C of 0.35
  - Maximum replacement percentage advised such that specifications still met
- Volume reduction of waste through minimising requirement of virgin material for immobilisation of scabbled waste.
  - Activation of material to activate any latent reactivity – alkali-activation or hydrothermal.

[4] COLLIER, N. C. & MILESTONE, N. B. 2010. The Encapsulation of Mg(OH)2 Sludge in Composite Cement. Cement and Concrete Research, 40, 452-459.

PhD Research - Characterisation

Initial aim: Get hold of scabbled material. Number of different methods could affect material. If possible, attain samples of different scabbling methods.

Analyse, physically and chemically;

- particle size (Malvern Mastersizer) will affect
- particle shape (SEM imaging and Blaine specific surface area)
- presence of anhydrous material (XRD and TGA)
- degree of carbonation (Phenolphthalein)

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PhD Research – Re-use

Primary Aim, building on MSc work, to use scabbled material as replacement in encapsulation grout.

- CRM suitability. Replacement of cement or slag within grout. Effects on reactivity, workability, final pH and other specifications.
- Use as pure filler. At what percentage replacement will specifications still be met and integrity of encapsulation remain.

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Aims & Objectives

Initial aim: Get hold of scabbled material.

Analyse, physically and chemically;

- particle size - Malvern Mastersizer
- Particle shape – SEM imaging and Blaine specific surface area
- presence of anhydrous material - XRD
- degree of carbonation – Phenolphthalein

Synthesise material for use in further research.

Preferred option, building on MSc work, to use scabbled material as replacement in encapsulation grout.

Stringent specifications with regards to fluidity and engineering properties

- CRM suitability. Replacement of cement or slag within grout. Effects on reactivity, workability, final pH and other specifications.
- Use as pure filler. At what percentage replacement will specifications still be met and integrity of encapsulation remain.

Aims & Objectives

Can alkali-activation be used as a method to reduce the amount of cement required to achieve suitable properties within encapsulation.

- Following characterisation of scabbled material, examine possible mechanisms for alkali-activation in low cement grouts.
- High slag cements and clinkerless cements have been created, examine the possibility of using these in order to achieve high packing density of waste material

Thermal/hydrothermal activation

Use as raw material in new clinker for production of encapsulation materials.