Cement Fillers for DPCs

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SFWD

Spent Fuel & Waste Disposition

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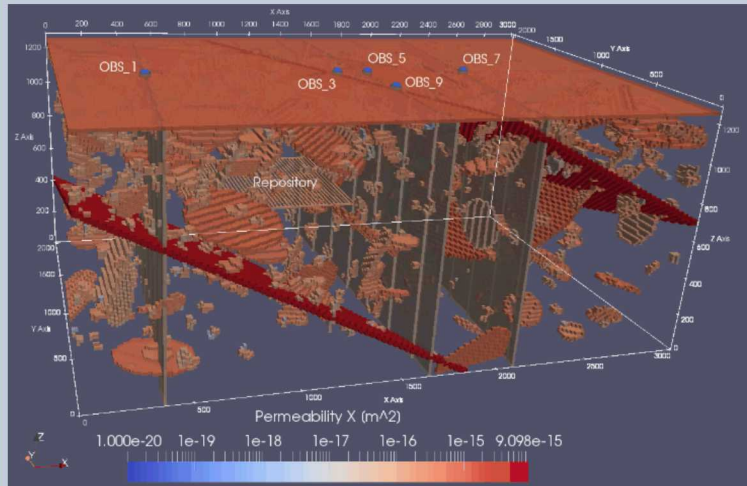


PHOSPHATE CEMENTS AS FILLERS

- Al-Phosphate (Berlinite) Cement (APC)
- Mg-K-Phosphate (MKP) Cement
- Calcium-Phosphate (Apatite) Cement (CPC)
- pH Modified Ordinary Portland Cement
- ~~Ca-Aluminate-Phosphate Cement (CAPC)~~

- Phosphate Cements:
  - Inorganic
  - Nontoxic
  - Near Neutral pH
  - Very low Solubility (at near neutral pH)
  - Chemically Bonded
  - Self-Bonding

Aluminophospate Cements

$$Al_2O_3 + 2H_3PO_4 \rightarrow 2AlPO_4 + 3H_20$$

- Inexpensive Starting Materials (Al_2O_3 and H_3PO_4)
- Low-Viscosity Mixture in Water
- Near Neutral pH Post Cure
- High Strength, Moderately Low Porosity, Moderate Thermal Conductivity
- Elevated Cure Temperature (150-200 °C)

Experimental Approach

- Vary Temperature, Time, and Water Content
- Effects of Additives: Fly Ash, Borate, Gd_2O_3
- Pressure Conditions
  - Cured in Steam at (8-10 Bar) at Constant Temperature (150-170 °C), followed by 250 °C bake
  - Cured at Ambient Pressure while Slurry Temperature is Ramped Slowly (1-2 K/hr)

RESULTS

- Steam Process Yields α–Al_2O_3 Monoliths with α–$AlPO_4$ and $AlPO_4$•H_2O as Binder Phases
  - Small (1mm or less) isolated pores
  - Requires additional curing Step at 250 °C for several days to convert $AlPO_4$•H_2O to α–$AlPO_4$

- Ambient Pressure Process Yields α–Al_2O_3 with α–$AlPO_4$ Binder Phase
  - Large (3-5 mm) isolated pores
  - Little to no $AlPO_4$•H_2O present

- Additive Effects
  - Fly Ash produces low strength poorly consolidated monoliths BUT 100% Fly Ash and H_3PO_4 produces a relatively dense monolith!
  - Gd_2O_3 appears to reduce wet monolith strength
  - Borate increases α–$AlPO_4$ content and appears to increase monolith strength

Significance and Future Work

- Aluminophosphate Cements:
  - Slurries are modestly stable (1 day) and offer good working times
  - Low-viscosity, easy to pour slurries
  - Relatively high-strength monoliths form upon heating

- Coming Soon:
  - Continued process optimization to reduce porosity
  - Define the process window for monolith production
  - Physical and chemical characterization of process optimized monoliths
  - Further explore 100% fly ash monoliths

CEMENT FILLERS FOR DPCS

ADDITIONAL SLIDES

Calcium Phosphate (Apatite) Cements

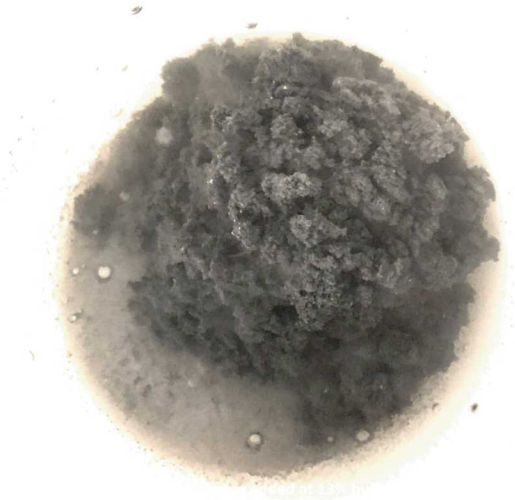
$Ca_4(PO_4)_2O + CaHPO_4 \rightarrow Ca_5(PO_4)_3OH$

- Direct Reaction of Dental Cement Precursors (TTCP and DCPA)
  - Rapid solidification of apatite, very short working times
- Modification of Dental Cement formulations (Ca complexation)
  - Increases working time but results in poorly consolidated apatite
- Precipitation from Salt Precursors
  - Results in chloride salt byproducts

Magnesium Potassium Phosphate (MKP) Cements

Variant of Commercial Bindan 3.1 Cement

- 55% Monopotassium Phosphate (KH_2PO_4)
- 23% Magnesium Oxide (MgO)
- 3.6% Tricalcium Phosphate ($Ca_3(PO4)_2$)
- 9.4% Sucrose
- 9% Boron Carbide
- Water (varied from 14 – 19 wt% of total dry powders)



Questions?

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