Bridging the Gap: Using microstructural properties to predict macroscopic behavior of lime-stabilized clays

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**Background**

Clay swelling damages in pavement = $1 billion costs annually

Treatment

- Clay
- Water
- Lime (CaO)

Clay swelling problems are complex and difficult to address.

**Problem**

Clay swelling damages in pavement = $1 billion costs annually

**Materials Scientist**

- Take soil from site
- Create different mixes with lime or cement
- Measure strength at 28 days

**Civil Engineer**

- Analyze soil properties
- Study reactions over time
- Create kinetic model to predict strength

**Approach**

- Pure materials:
  - Most common clays along risk continuum
  - Pure bentonite cannot be obtained in large quantities (~20% other minerals present)
  - Lime (CaO) most basic stabilizer

- Compaction and strength
- Pore water extraction and analysis
- Solid Analysis (NMR, TGA, XRD)

**Qualitative Analyses**

- TGA data shows formation of a distinct hydration product whereas XRD shows only one hydrate formation.
- Both TGA and XRD data shows decrease in the hydrate concentration after 540 days.
- 29Si NMR data shows significant hydrate formation from 270 days whereas in XRD stratlingite concentration increases from 360 days with an exception at 540 days.

**Macrostructural Analysis (Strength data)**

- Kaolinite Strength continues to evolve beyond 1 year of curing
- Bentonite Strength development is significantly quicker and almost complete within 28 days

**Microstructural Analysis (Kaolinite)**

- Due to incongruent dissolution of kaolinite, there was preferential release of Si over Al in the beginning, forming amorphous CSH which increased strength for the first year.
- After Al became more available, crystalline stratlingite was formed scavenging Ca from the previous amorphous CSH phase, disturbing the matrix and decreasing strength.

**Working Hypothesis for Mechanisms**

- Ca consumption & Fate
- XRD & TGA Quantitative Analysis
- Ca mass balance in the system calculated from both TGA and XRD data

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