Recent Advances and Field Applications
Using Alternative Cementitious Binders

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Outline

• Problems from Dust Production
• Dust, Corrosion, and Soil Stabilization
• Location of Test Area
• Local Materials
• Chemically-Bound Soil Technologies for Soil Stabilization
• Test Road Sections
• What’s Going On…
• Summary and Questions
Dust Production in Army Training Areas

- Unsurfaced roads and landing zones are major problems in arid terrain.
- Dust introduces abrasives into the vehicle systems and clogs air filters.
- Dust control agents are frequently inorganic salts (chloride-containing) that can produce additional corrosion problems.
- Conventional paving is not practical in many locations.
Pohakuloa Training Area (PTA) Test Site

- Serious dust problem at site
- Abrasive, corrosive dust
- Moderate traffic
- Soil is largely volcanic glass that is reactive in an alkali-activated geopolymer
- Cementation should be more durable than dust palliatives
Soils at PTA Test Site

- Alumino/siliceous aggregates with limited crystallinity
- Amenable to formation of chemically-bound geopolymer
- Sharp edges, and corners
- Wide range of particle sizes

SEM Micrograph of Soil

Gradation of Native Soil

Only crystalline phase present feldspar Anorthite

\[ Na_{0.05}Ca_{0.95}Al_{1.95}Si_{2.05}O_8 \]
Alkali-Activated Geopolymer: An Alternative

• Alkali-activated geopolymers are special cements formed by mixing a concentrated alkaline solution with a finely-divided reactive aluminosilicate (sometimes with Ca too)

• Alkali-activated geopolymeric cements are strong, fast-setting, inexpensive, and very versatile

• Manufactured from glassy silicates like slag, fly ash, metakaolin, and volcanic ash

• Can use waste alkalis from manufacturing operations

• No portland cement is involved!

Soil solidified with alkali-activated mixture using slag
Why Use an Alkali-Activated Alternative?

- Fast: mixture sets in hours and gets ultimate strength in days
- Easy to Obtain Materials: suitable raw materials are available almost everywhere (e.g., fly ash, slag)
- Economical: uses waste/local materials or low-fired clay soils
- Versatile: basic chemistry adapts from a wide variety of glassy aluminosilicates
- Variation of natural weathering process that occurs in volcanic ash deposits

Skvara et al., 2006
Previous Usage Worldwide

- Widely used in Australia
- Marketed by Blue Circle Cement Company and Boral Cement
- Used in over 100 projects of 10,000 to 150,000 m² (2.5 to 37 acres)
- Reported to use Na-rich kiln dust, slag, and activator such as lime
- Broad range of compositions

Boral Roadment® application
Current Geopolymer Formulation

• Alkali Rich Glassy Aluminosilicate Aggregates
  • From local PTA volcanic soil
• Slag (ASTM C989) – Approx 6 wt%
  • Source: foundry located in Southern California
• Fly Ash (Direct from Coal Plant) – Approx 6 wt%
  • Plant located on the island of Oahu
  • Chemical composition close to Class F (not F or C)
• Hydrate Lime (ASTM C977) – Approx 6 wt%
• Sodium Carbonate (Soda Ash) – Approx 6wt%
• Water: w/cm of approx 0.17
Geopolymerization Reactions

**Exchange Reaction**
- Initial: $\text{Na}_2\text{CO}_3 + \text{Ca(OH)}_2$
- Final: NaOH and CaCO$_3$

**Geopolymerization Rxn: Aggregates**
- NaOH breaks down reactive surface of aggregates
- Forms A-S-H gel phase

**Geopolymerization Rxn: Supplementary Cementing Materials**
- Alkalis down fly ash and slag
- For C-A-S-H gel phase
Batch Mixing in Laboratory

- Blend Dry Components
- Add Activator Solution
- Blend Until Balling Occurs
- Mixture Components
Consolidation Methods

• Best performance observed when mixture is roller-compacted to consolidate

• Roller Compacted Method Pros:
  • Decreased Manpower
  • Faster Placement Times
  • Method Similar to Soil Compaction
  • Does Not Require Specialized Skill Set

• Roller Compacted Method Cons:
  • Does Not Produce the Highest Quality Surface
  • Density Depends on Compacted Effort
  • Somewhat Requires Continuous Placement
Trial Batching at Univ. of Hawaii and ERDC

- University of Hawaii test sections:
- Trial batching at ERDC Concrete & Materials Branch:
Resulting Microstructure

- Alkali attacks edges and corners of coarse volcanic aggregates
- Fines can react completely
- C-A-S gel phase acts as binder similar to C-S-H in Portland cement systems
- Secondary minerals (zeolites) also contribute to cementation
Resulting Microstructure

- Hardened chemically-bound soil microstructure similar to hardened Portland cement concrete

Current Mixture:
- \(~6.4\) MPa (927 psi) at 7 days
- \(~12.4\) MPa (1800 psi) at 28 days
- Highest compressive strengths when \(>135\) pcf unit weight achieved during field compaction

Polished Cross Section of Hardened Chemically-Bound Soil
From the Lab to the Field…

- Placement of chemically-bound soil mixture in the field using roller-compacted method:

<table>
<thead>
<tr>
<th>←</th>
<th>24' Lane Width</th>
<th>→</th>
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<tbody>
<tr>
<td>8&quot; to 10&quot; RCCCBS Pavement on 2% Grade (Crown)</td>
<td></td>
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</tr>
<tr>
<td>2&quot; to 4&quot; Crushed Sub-Grade, Native Material</td>
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<tr>
<td>Bed Rock, In-situ Material, Lightly Compacted</td>
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Stats on PTA trial placement:
- Two 12ft lanes
- 6in compacted
- 8-10in placed
- 0.5mi in length

Cross section of roller-compacted placement of chemically bound soil
What’s Happened!

• Placement at the PTA test site
• Photos from the field provided by Chris Moore and Samuel Craig (US Army ERDC – CMB)
What’s Happened…

- Placement at the PTA test site
- Issues with high winds
- Iterative process to optimize placement

On-site equip. for placement

On-site batch plant

Spreading for roller-compaction
Summary and Conclusions

• Control of abrasive dust is a serious corrosion and equipment maintenance issue
• Alkali-activated geopolymerization is being investigated using glassy volcanic soils
• Reports in the literature support feasibility along with experience from Australian manufacturers
• ERDC has developed initial mixture designs and procedures for field placement
• Successful placement of test section at PTA site using chemically-bound soil stabilization technology
Future Directions

• Temporary storage pads for government facilities
  • Upcoming project in Charleston, SC to construct parking slabs for storage of MRAPs returning to US
  • Working with Intelligent Concrete to produce alternative cementitious material mixture proportions using the “less reactive soil” from local SC area
  • Include the use of nanoparticles to activate the system
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Thank You!

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