Soil Mixing Design Methods and Construction Techniques for Use in High Organic Soils

GRIP 2014
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Problem Statement

- Organic soils are problematic for roadway construction; typically, the material is replaced, modified, or bridged.
- In-situ soil mixing is one method that can be used to stabilize the material but the high moisture content and low pH necessitates high binder contents.
- Design and quality control methodologies are required.
Project Overview

- Existing Soil Mixing Methods
- Case Histories with Long-Term Performance
- Various Binder Materials
- Techniques for New and Existing Roadways
- Lab / Field Tests to Evaluate Long Term Performance
- Cost Evaluation
- Guidelines for Soil Mixing
Research Approach

- Task 1 Literature Review
- Task 2 Laboratory Testing
- Task 3 Field Testing and Exploration
- Task 4 Cost Evaluation / Guidelines and Recommendations
- Task 5 Reporting
Research Approach

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Wet Soil Mixing

Moisture content < 40%
Dry Soil Mixing

Moisture content > 60%
Strength Considerations

Adapted from Filz, 2012
Design Considerations

- Bulk or mass soil treatment, or
- Treated deep column supported embankments
- Transfer platform or geo-fabrics may be needed
- Strength of treated soil dictates available quality control measures (e.g. post treatment coring not feasible in weakly treated soils)
Column Supported Embankments

\[ H = H_1 + H_2 \]

Stiffer Surface Layer(s), if present

Soft Soil Layer(s)

Surcharge, \( q \)

Select Fill & Geosynthetic Reinforcement

Columns

(Filz, 2012)
Transfer Platform Thickness
(without geo-fabric)

\[ H_{\text{crit}} = 1.15s'/d + 1.44d \]

- **Circle**: Differential surface settlement not reported, competent near-surface soils reported for the majority of cases below the trend line.
- **Diamond**: Critical height determined.
- **Square**: Differential surface settlement reported, critical height greater than reported height.

(Filz, 2012)
Transfer Platform Thickness
(without geo-fabric)

\[ H_{\text{crit}} = 1.15s' + 1.44d \]

(Filz, 2012)
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Organic Laboratory Samples
Organic Laboratory Samples
Organic Laboratory Samples
Organic Soil Properties

- Organic Content = 50-65% (ASTM D 2947-00)
- Moisture Content = 260-300% (ASTM D 2974-00)
- pH = 5.5-7 (ASTM D 4972)
- Resistivity = 5 kΩ-cm (FM 5-551)
- Chloride Content = 590 ppm (FM 5-552)
- Sulfate Content = 35 ppm (FM 5-553)
Laboratory Testing
Soil Mixing Test Matrix

- UC tests on 4x8 inch Cylinders
- 100 – 300 pcy cement content
- Dry & Wet Mixing
- Starting Soil pH Range from 6 to 9
  - Soda Ash
- Moisture Content (265 to 450%)
Unconfined Compression Testing
Volume Diagram
(concrete w/c 0.4 – 4000 psi)
Volume Diagram
(loose sand w/c 3.6 – 100psi)

- Water
- Cement
- Loose Sand

**MC = 66%**

- Water: 0.6348 ft³ (w=39.61 lb, 36%)
- Cement: 0.1634 ft³ (w=11.1 lb, 10%)
- Loose Sand: 0.3652 ft³ (w=60.4 lb, 54%)

Total Weight = 111.1 pcf
Total Volume = 1.1634 ft³
Volume Diagram
(organic soil w/c 4.5 – 20psi)

Water

Cement

Organics
(OC=47%, MC=350%)

0.7938 ft³ (w=49.5 lb, 66%)

w/c=4.5

Total Weight=74.8 pcf
Total Volume=1.1634 ft³

0.1634 ft³ (w=11.1 lb, 15%)

0.2062 ft³ (w=14.2 lb, 19%)
Historical Soil Mixing Data

Lab Test Data
Research Approach

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Case Histories

- District 1: SR 33 North of Polk City
- District 2: SR 100 in Putnam County
  The Rail and Trail Bike Path
- District 5: SR 46 in Sanford
- District 6: US-1 Jewfish Creek
- Turnpike: Milepost 284.7 in Lake County
- US331: Choctawhatchee Bay Causeway
US331: Choctawhatchee Bay Causeway

- ~16,000ft bay water crossing
- ~8000ft is filled causeway (late 1930’s)
- Very loose fill and natural soils have settled and continue to cause maintenance problems
- Soils: sand, silt, clay and organic material
- Combination of deep and shallow soil mixing used to stabilize causeway portions
Test Program

- Bench scale tests
- Full scale demonstration elements
- Surcharge test section (19ft embankment)
- Instrumentation
  - Pore pressure transducers
  - Vibrating wire extensometers
  - Settlement plates
Design and QA/QC

- Req’d strength 75 – 150psi
- Depth of treatment
  - 0 – 10ft full coverage (transfer platform)
  - 10 – 45ft isolated deep columns
- Bench scale set cement content at ~10-17pcf
- Field demonstration set mixing effort by number of blade revolutions ~350-500
- Settlement control verified by surcharge test
Surcharge Test Section

- **Top of Surcharge**
- **Existing Ground**
- **Shallow Element** (10 ft thick typical)
- **Deep Element** (35 ft long typical)

**Multi-Point Extensometers**
- Upper Head (0 ft)
- 2nd Head (10 ft)
- 3rd Head (45 ft)
- Anchor Point (60 ft)

Upper Unit: 10 feet gage length with 2 inch stroke
Second Unit: 35 feet gage length with 2 inch stroke
Third Unit: 15 feet gage length with 2 inch stroke
Installation of Elements
Automated Measurement Systems

**Site:** SR83  
**Pile:** NSAC041

**Drilling Phase**
- **Start:** 4/15/2014 7:49:49 AM  
- **End:** 4/15/2014 6:23:05 AM
- **Pause time:** 3 hrs 17 min  
- **Duration:** 10 hrs 17 min  
- **Design Depth:** 10 ft.  
- **Depth Reached:** 44.07 ft.
- **Total Volume (L):** 363.46 ft³  
- **Total Volume (R):** 363.61 ft³

**Fluids Used**
- **Tool Diameter:** 69 in.  
- **Number of Blades:** 8  
- **Mast Tilt (X):** 0.20°  
- **Mast Tilt (Y):** -0.17°
- **Specific weight of cement:** 196.65 lbs/ft³  
- **Ratio Water / Cement:** 1.00

**Withdrawal Phase**
- **Start:** 4/15/2014 8:23:28 AM  
- **End:** 4/15/2014 8:30:37 AM
- **Total Volume (L):** 26.42 ft³  
- **Total Volume (R):** 26.11 ft³

**Zone**
- **Depth**
  - 1: From 0.0 to 15.0 ft.  
  - 2: From 15.0 to 44.0 ft.
- **N. Retreat:**
  - Zone 1: 1  
  - Zone 2: 1  
- **Cement Factor**
  - Zone 1: 12.0 lbs/ft³  
  - Zone 2: 17.6 lbs/ft³

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**BRN Drilling**
- (N)

**Cement Factor 1.00 LO**
- (lb/ft³)

**PullDown Pressure**
- (psi)

**Rotary Press. 1 (LH)**
- (psi)

**Mixture Press. 1 (LH)**
- (psi)

**Mixture Flow 1 (LH)**
- (Gal/min)
Slight pauses cause increased cement and mixing effort.
Required Strength
## Inclinometer Evaluation

<table>
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<th>Rod ID</th>
<th>Top of Settlement Rod Lateral Offset (ft)</th>
<th>Vertical error (in)</th>
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<tr>
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<td>Survey</td>
<td>Inclinometer</td>
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Tracking Quality

- On-board computer systems may malfunction and could be “manipulated”
- Should verify via manual readings
  - Daily cement usage
  - Location of elements
  - Watching depth of rig
- Coring and UC tests are good where possible
- Weaker soil mix designs may not be able to retrieve cores (need alternate method)
Interim Conclusions

- While cement content and w/c ratio are key components to strength, organic soils will still require more cement.
- Long term settlement surveys show no discernible movements (some distress between treated and untreated regions of Jewfish Creek site).
Interim Conclusions

- Post treatment performance evaluation should be considered during design
  - strong enough to core or use alternate method
  - will geo-fabric hamper sampling
- Automated field QC should be supplemented with manual QA logs
Questions?