Dry Soil Mixing - Current US Practices

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Mass Stabilization
2015 – Lahti, Finland
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Presentation Outline

- History of Dry Mixing
  - USA Experience
- Dry Mixing Design/Applications
- Equipment and Tooling
- Case Histories
- QC
What is the experience in the USA with dry mixing?

- IHNC test program by Underpinning and Foundations in 2003 for the COE – New Orleans district
- Other uses by UAF/Skanska on the I-4 project in Salt Lake City in 2004-2005
- Mixing done in upstate NY and Nebraska by Hayward Baker and UAF for COE and NBDOT - 2006
US History with Deep Mixing continues to grow through various uses…

- 2003 – Large scale dry mixing project performed for US1 in Florida
- 2006 following Katrina mixing in COE – NOLA district continued to grow, some 7 jobs completed
- Regularly used in the Oil and Gas industry as well as still evaluated for use and compared to Wet mixing methods for COE Projects
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What limitations in regards to soil strength should we consider before using Dry Mixing

- Shear strength of soil has to be low enough to allow mixing
- Binder requirement has to be in line with output
- Moisture content has to be high enough to allow complete hydration
- Compute $I_C \geq 0$ and $I_L > 1$
Binder Types and Dosage

- Lime
- Cement
- Lime-cement blends
- Slag-cement blends
- Typical dosage is 10% by weight of soil
  - 50 to 200 kg/m³
- Lab testing with site soil and binder
Mixing energy or Blade Rotation Number (BRN) a function of the tool type and installation speed

BRN (Blade Rotation Number) = \( \Sigma [(\text{no. blades} \times \text{rotation speed} \times \text{penetration rate}) + (\text{no. blades} \times \text{rotation speed} \times \text{withdraw rate})] \) per 1 meter length of column

Example:
Number of blades = 4-8
Retrieval rate = 10-30mm/rev
Rotation speed = 100-200 rpm

- Organic soils, peat = BRN > 400
- Organic clay, Sandy clays = BRN > 300
- Clay, Silty clay = BRN > 200

\[
BRN = \frac{6}{0.025} = 240
\]
Embankment built on soft soil/peat can be designed using block/column treatment.
Application: Sheet Pile Stabilization – Working over Water
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Dry Soil Mixing installation techniques include Columns and Blocks to meet design needs

Mass Mixing to form blocks

Column Mixing to form panels or single columns
Dry Deep mixing methods are utilized in wetter softer soils or where REM is a problem.

- Dry binder materials are pneumatically injected into the soil during the dry mixing process.
- Bottom up method of soil mixing.
- There must be adequate soil moisture for the binders to fully hydrate often limiting design strengths.
Mass Soil Mixing Movie
Dry Mixed Columns
Mass Mixing Tool
Binder Handling

**Keller – Shuttle Type S1010**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Weight</td>
<td>20 tons</td>
</tr>
<tr>
<td>Volume Storage Vessel</td>
<td>10 m³</td>
</tr>
<tr>
<td>Operating Pressure Max.</td>
<td>10 bar</td>
</tr>
</tbody>
</table>

**Technical Data Sheet**

- **Empty weight**: 1,500 kg
- **Total weight**: 2,500 kg with binding agent 1,000 kg/m³
- **Total weight**: 2,500 kg with binding agent 1,700 kg/m³
- **Climb angle for empty machine**: 30°
- **Climb angle for fully machine**: 20°

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*Keller – Shuttle Type S1010*

Status: Dec.07
Originator: Wolter/Kimmig
Subject to technical modifications
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Levee Stability enhancements made possible using Soil Mixing

17th Street Canal New Orleans

800 mm diameter soil mixed columns installed from a barge
Dry mass mixing is working in block cell arrangement working from platform for a Tank
Los Vientos

- Los Vientos I and II
  - 180 Wind turbines
  - 402 MW total capacity
  - Both Built in 2012
- Rio Grande Valley
  - Willacy County, TX
- Dry Mass Soil Mixing (DMSM)
  - 26 foundation locations
Foundation Design
Mass Stabilization Design

Unconfined Compressive Strength (psi)

Specimen Age (days)

A1-100
A1-125
A1-150
A2-100
A2-125
A2-150
A34-200
A34-225
A34-250
Mass Stabilization Construction

- 26 foundation sites
- Construction process
  - Strip topsoil
  - Pre-excavate 8.5 ft
  - Perform DMSM
    - Outside excavation
    - Within excavation
  - Grading
  - Form and pour foundation
Foundation Construction
QAQC and Verification Testing
QAQC and Verification Testing

![Graph showing compressive strength over sample age](image)

**Axes:**
- **Y-axis:** Compressive Strength (psi)
- **X-axis:** Sample Age (days)

**Legend:**
- Min
- Max
- Mean

**Graph Details:**
- Min, Max, and Mean lines are plotted against sample age and compressive strength.
- Compressive strength increases with sample age.
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How do you measure the quality of the Dry Mixed material...CORE it

Core the columns and check continuity...destructive testing
Field control methods

- Column CPT (Column Penetration Test)
- PORT (Pull Out Resistant Test)

Resistance (kN)
Depth (m)
Mass Mixing Grid Control

- Shows the real-time depth & position of the mixing tool along the length of the cell

- Grid sub-cells are drawn in red, yellow, or green to indicate when the target binder content or mixing time has been reached within each sub-cell

- Rig software also tracks the rig heading vs. cell center line & the tool distance from the center line to aid in proper positioning along the cell

- Binder and mixing time are proportionally assigned to sub-cells based on the position of the center of the tool

- For example, if the tool center is at the corner between 4 sub-cells each cell would receive 25% of the binder added
Mass Dry Mixing Report

- Profile grid shows binder distribution grid by depth and cell length
- Tool depth is tracked using elevation from rig GPS system
- System tracks binder content & time for each sub-cell within the design cell area
Mass Dry Mixing Report

- Time plot report
  - Tool Depth vs. Time
  - Binder Weight vs. Time
  - Binder Flow & Air Pressure vs. Time
  - Left & Right Tool RPM vs. Time
- Avg. Treatment Depth
- Avg. Air Pressure
- Avg. Binder Content
Mass Dry Mixing Report

- Grid report showing cell divided into several sub cells
- Grid dimensions (rows & columns) are specified in rig software
- Grid is adjustable based on cell type for projects with multiple cell sizes
QA/QC – Expose it if you can

Temporary excavation pit Clay – UK (2005)

Exposed DDM columns for permanent slope stability in Uppsala – Sweden (2005)

DDM columns supporting a temporary excavation for the railway link between Gothenburg and Malmö – Sweden (2003)
This is the Last Slide
Thank You!! Questions?

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