BUILD A RELIABLE CEMENT-TREATED SUBGRADE LAYER

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Pavement Structure

- Surface Course
- Base Course
- Sub-Base Course (optional)
- Subgrade Layer (optional)
- Natural Subgrade
<table>
<thead>
<tr>
<th>Specification Section</th>
<th>Raw Materials</th>
<th>Cement Content, %</th>
<th>Compaction Moisture</th>
<th>Field Compaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>305 Subgrade Layer</td>
<td>PI ≤ 25%, Sand ≤ 79%, Silt ≤ 69%</td>
<td>150 psi</td>
<td>Optimum ± 2%</td>
<td>95% of standard or modified proctor</td>
</tr>
</tbody>
</table>
Basic Question

What if wet subgrade soil is cement-treated and also compacted at the field moisture content?

LTRC research project: 03-2GT with State Project No. 736-99-1124
Lab Testing Program

- TR 432, including both unconfined compressive strength (UCS) and durability (ASTM D1633 and D559)
- Soils, A-6 and A-7 with PI of 12 and 22, respectively
Basic Properties - Gradation

![Gradation Graph]

<table>
<thead>
<tr>
<th>Soil</th>
<th>Sand, %</th>
<th>Silt, %</th>
<th>Clay, %</th>
<th>LL, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-6</td>
<td>8</td>
<td>64.5</td>
<td>27.5</td>
<td>34</td>
</tr>
<tr>
<td>A-7</td>
<td>41.5</td>
<td>30.6</td>
<td>27.9</td>
<td>37</td>
</tr>
</tbody>
</table>
- Standard Compaction

### Table: Soil Properties

<table>
<thead>
<tr>
<th>Soil</th>
<th>Optimum Moisture Content, %</th>
<th>Maximum Dry Density, pcf</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-6</td>
<td>17.5</td>
<td>108.0</td>
</tr>
<tr>
<td>A-7</td>
<td>13.5</td>
<td>119.0</td>
</tr>
</tbody>
</table>
## Testing Factorial

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Optimum moisture, %</th>
<th>Cement, %</th>
<th>Molding moisture, %</th>
<th>Curing, days</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-6</td>
<td>17.5</td>
<td>4, 8, 12</td>
<td>8.5 - 29.5 (too wet to mold)</td>
<td>7, 28</td>
</tr>
<tr>
<td>A-7</td>
<td>13.5</td>
<td>4, 8, 12</td>
<td>7.5 – 25.5 (too wet to mold)</td>
<td>7, 14, 28</td>
</tr>
</tbody>
</table>
Sample Compaction: A-6

Graph showing the relationship between Moisture Content and Dry Unit Weight for different cement percentages: 0%, 4%, 8%, and 12%. The graph also includes a line for zero voids.

- Moisture Content, %
- Dry Unit Weight, pcf

Key:
- 0% cement: Diamond (●)
- 4% cement: Pink (◆)
- 8% cement: Red (▲)
- 12% cement: Green (★)
- Zero void: Dashed line
Sample Compaction: A-7

Dry Unit Weight, pcf vs Moisture Content, %

- 0% cement
- 4% cement
- 8% cement
- 12% cement
- Zero void
Sample Compaction: A-6

- Unconfined Compressive Strength, psi
- Molding Moisture Content, %

- 0% cement
- 4% cement, 7 day
- 4% cement, 28 day
- 8% cement, 7 day
- 8% cement, 28 day
- 12% cement, 7 day
- 12% cement, 28 day
Sample Compaction: A-7

Unconfined Compressive Strength, psi

Molding Moisture Content, %
Data Analysis

- **Major influence factors**
  - Cement content
  - Molding moisture content
  - Curing time
  - Sample dry density
Water Cement Ratio

\[ R = \frac{w}{C} \]

“w” is the molding moisture content in the percent of dry soil weight;

“C” is the cement content used in soil in the percent of dry soil weight.
## Correlations

<table>
<thead>
<tr>
<th>Independent Factors</th>
<th>Dependent Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement Content:</td>
<td>Water cement ratio</td>
</tr>
<tr>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td></td>
<td>dry side of compaction curve</td>
</tr>
<tr>
<td></td>
<td>Wet side of compaction curve</td>
</tr>
<tr>
<td>Molding Moisture Content:</td>
<td>Water cement ratio</td>
</tr>
<tr>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td></td>
<td>Dry density</td>
</tr>
<tr>
<td></td>
<td>Strength</td>
</tr>
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<td></td>
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<td></td>
<td>Strength</td>
</tr>
</tbody>
</table>
Correlation: A-6

The graph shows the correlation between the UCS (psi) and the water-cement ratio for 7 days and 28 days curing. The data points for 7 days curing are indicated by diamonds, and the data points for 28 days curing are indicated by squares. The UCS values range from 0 to 450 psi, and the water-cement ratio values range from 0.00 to 7.00.
Correlation: A-7

UCS, psi vs. Water-Cement Ratio

- 7 days curing
- 14 days curing
- 28 days curing
Simple Correlation

<table>
<thead>
<tr>
<th>Target value of UCS (7 day curing)</th>
<th>Water-Cement Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 psi</td>
<td>5.0</td>
</tr>
<tr>
<td>100 psi</td>
<td>3.0</td>
</tr>
<tr>
<td>150 psi</td>
<td>2.0</td>
</tr>
<tr>
<td>200 psi</td>
<td>1.75</td>
</tr>
</tbody>
</table>

Only GOOD on the wet side of a compaction curve
Laboratory

**Step 1:** Select representative subgrade soil sample from the roadway to be stabilized.

**Step 2:** Determine its Plastic Index (PI) and optimum moisture content, $w_{wo}$. If $\text{PI} < 25$, follow the procedure described here.

**Step 3:** Select the target value in the term of unconfined compressive strength (UCS) for the treated subgrade layer.
**Step 4:** Determine the corresponding Water-Cement Ratio, $R_{wc}$ using the correlation above; interpolate if needed.

**Step 5:** Calculate the cement content in percent at the optimum moisture content of the soil as follows:

$$C_{wo} = \frac{W_{wo}}{R_{wc}}$$
Step 6: Mold the specimens of the cement-soil mixture with the cement content $C_{wo}$ determined at the optimum moisture content, $w_{wo}$ according to the LA DOTD’s standard procedure and cure them for 7 days to check the target value of UCS.

or

Step 5(optional): Use TR 432 to determine the cement content for the target value of UCS and skip Step 6.
Field Construction

**Step 7:** Adjust the cement content \( C_{wf} = C_{wo} + \Delta C_{wf} \) used according to the field moisture content at construction, \( C_{wf} \), as follows.

\[
\Delta C_{wf} = \frac{W_{wf} - W_{wo}}{R_{wc}}
\]

Where the variables in the formula are as defined before.

**Note:** if \( w_{wf} < w_{wo} \), water is required to be added in the field.
Step 8: Compact the wet cement-stabilized subgrade to reach a 100% of dry density at the corresponding field moisture content, determined by lab test.

Step 9 (optional for emergency): In cases where the field soil is different from the one tested in the laboratory, the cement content can be determined directly as follows.

\[ C_{wf} = \frac{W_{wf}}{R_{wc}} \]
Help Needed

- Field test data is needed to validate the correlation and procedure developed from the lab test.

- Variation of correlations with soil types.

- Information needed:
  Soil type, gradation, PI, water-cement ratio used in the field, UCS of samples mixed and molded in the field and/or laboratory.
Contact Information

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Durability of Cement Stabilized Soils

- Samples failing PCA soil-cement loss criterion
- Samples passing PCA soil-cement loss criterion
- Boundary curve, +0.05
- Boundary curve: w/c=0.0018*UCS
Questions?