Subgrade Stabilization Problems at ODOT

Christopher Merklin, P.E.
Geotechnical Design Coordinator
ODOT Office of Geotechnical Engineering

April 19, 2011
Past Study

ANALYSIS OF ODOT SUBGRADE STABILIZATION PRACTICES: A CASE FOR GLOBAL CHEMICAL STABILIZATION (OTEC, 10/23/07)

GENE GEIGER, P.E., ADMINISTRATOR, ODOT OFFICE OF GEOTECHNICAL ENGINEERING

PERRY RICCIARDI, P.E., DISTRICT CONSTRUCTION ENGINEER, ODOT DISTRICT THREE

BRIAN RAWLINGS, CONSTRUCTION PROJECT ENGINEER, ODOT DISTRICT THREE
## Past Study

### Table 2 – Actual Costs vs. Chemical Stabilization Costs

<table>
<thead>
<tr>
<th>Project</th>
<th>Actual Costs ($)</th>
<th>Chemical Stabilization Costs ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD - 71 - 14.38</td>
<td>1,813,279.00</td>
<td>2,472,005.25</td>
</tr>
<tr>
<td>WAY/MED - 71 - 7.04/0.00</td>
<td>1,225,870.40</td>
<td>2,469,684.36</td>
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<tr>
<td>MED - 71 - 9.56</td>
<td>1,553,111.04</td>
<td>2,495,464.40</td>
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<tr>
<td>MED - 71 - 15.78</td>
<td>11,608,916.17</td>
<td>4,074,231.04</td>
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<tr>
<td>MRW - 71 - 19.54</td>
<td>2,934,609.74</td>
<td>2,687,188.77</td>
</tr>
<tr>
<td>RIC - 71 - 6.39</td>
<td>929,152.30</td>
<td>2,681,442.50</td>
</tr>
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<td>RIC - 71 - 13.66</td>
<td>885,136.50</td>
<td>2,617,860.00</td>
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<tr>
<td>RIC - 71 - 20.22</td>
<td>3,041,143.93</td>
<td>3,199,664.00</td>
</tr>
<tr>
<td>WAY - 71 - 0.28</td>
<td>1,164,331.50</td>
<td>2,560,010.40</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>$25,155,550.58</strong></td>
<td><strong>$25,257,550.72</strong></td>
</tr>
</tbody>
</table>

Subgrade Stabilization Problems at ODOT
Past Study

A global chemical stabilization design could have produced the following benefits:

1. Improve budget accuracy
2. Facilitate scheduling by identifying all subgrade work at time of bid
3. Reduce or eliminate construction arguments, issues, and claims related to subgrade
Past Study

Benefits cont.

4. Increase productivity by providing a stable platform for the Contractor

5. Allow work on subgrade immediately after a rain, reducing weather delays

6. Provide a uniform and superior subgrade for the pavement, improving performance and durability

7. Allow for an improved subgrade CBR and reduce the overall pavement thickness
Past Study

Recommendations

- Use global chemical stabilization on major projects regardless of soil conditions. Provide superior product at no additional cost.

- Include the strength benefits of chemically stabilized subgrades into the pavement design. Savings could be up to 50% of actual stabilization costs.
Geotechnical Bulletin (GB) 1

For all Interstates and other divided highways with four or more lanes more than 1 mile in project length, the subgrade of the entire project shall be stabilized.

For all other roadways, if 30 percent or more of the subgrade area must be stabilized, consider stabilizing the entire project.
Projects

Subgrade Stabilization Problems at ODOT
Reconstruction and widening of 4.5 miles of SR 2 (CMS 2008)
Start: March 30, 2009
Scheduled finish: October 15, 2011
$85.8 million award to Anthony Allega, Inc.
420,329 yds$^2$ cement stabilized subgrade, 12 inches deep: $2.3$ million
11.5-inch PCC alternate bid pavement with slag aggregate base
LAK-2-3.32 (08-0597)

- 79% A-4a and A-6a
- Average PI = 12
- Average NL = 11
- Average N60L = 14, assuming ER = 80%

Ideal candidate for 12” cement stabilization
LAK-2-3.32 (08-0597)

Stage 1 constructed 2009
Station 392+50 to 510+00 (2.2 miles)

Stage 3 constructed 2010
Station 276+00 to 345+00 (1.3 miles)

Stage 2 to be constructed 2011
Station 345+00 to 392+50 (.9 miles)

No major pumping noticed prior to stabilization for majority of project
Subgrade Stabilization Problems at ODOT
LAK-2-3.32 (08-0597)

Contractor Designed Chemically Stabilized Subgrade

Stage 1 – 28 samples tested at 3, 6, 9%
Stage 3 – 27 samples tested at 3, 6, 9%

5% to 7% cement

Moisture conditioning expansion test

0.55% to 0.88% expansion
Average 0.72%
Standard deviation = 0.07
LAK-2-3.32 (08-0597)

Stage 1 Cement Design

Subgrade Stabilization Problems at ODOT
LAK-2-3.32 (08-0597)

Stage 3 Cement Design

Subgrade Stabilization Problems at ODOT
LAK-2-3.32 (08-0597)

Stage 3 Cement Design

Subgrade Stabilization Problems at ODOT
Chemical stabilization began June 8, 2009 in Stage 1

Textbook verification results

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Cement %</th>
<th>Strength (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/8/09</td>
<td>498+00</td>
<td>7</td>
<td>153</td>
</tr>
<tr>
<td>6/16/09</td>
<td>445+00</td>
<td>5</td>
<td>157</td>
</tr>
<tr>
<td>7/6/09</td>
<td>487+00</td>
<td>7</td>
<td>152</td>
</tr>
<tr>
<td>10/1/09</td>
<td>406+00</td>
<td>5</td>
<td>157</td>
</tr>
<tr>
<td>10/14/09</td>
<td>508+00</td>
<td>7</td>
<td>153</td>
</tr>
<tr>
<td>11/4/09</td>
<td>484+00</td>
<td>5</td>
<td>159</td>
</tr>
<tr>
<td>5/4/10</td>
<td>95+00</td>
<td>5</td>
<td>152</td>
</tr>
<tr>
<td>5/12/10</td>
<td>302+00</td>
<td>7</td>
<td>158</td>
</tr>
<tr>
<td>5/26/10</td>
<td>340+00</td>
<td>7</td>
<td>154</td>
</tr>
</tbody>
</table>
June 17, 2009 Site Visit

- Elastic deformation OK if no soft soils exist
- Plastic deformation needs to be undercut
LAK-2-3.32 (08-0597)

Subgrade Stabilization Problems at ODOT
**LAK-2-3.32 (08-0597)**

**June 29, 2010 Site Visit**

### Subgrade Stabilization Problems at ODOT

#### Areas to Correct or Investigate

<table>
<thead>
<tr>
<th>Station to Station</th>
<th>Lane Lt/Rt</th>
<th>Rut Depth</th>
<th>Cracking</th>
<th>Elastic or Plastic Movement</th>
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</thead>
<tbody>
<tr>
<td>Mainline 304+60 to 309</td>
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<td>7½” up to 3.4”</td>
<td>Yes</td>
<td>&gt; 1½”</td>
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<tr>
<td>Ramp A 310+95 to 318+20</td>
<td>Lt</td>
<td>No</td>
<td>Yes</td>
<td>&gt; 1”</td>
</tr>
<tr>
<td>320+70 to 321+50</td>
<td>Lt</td>
<td>up to 1”</td>
<td>Yes</td>
<td>&gt; 1”</td>
</tr>
<tr>
<td>318+15 to 318+35</td>
<td>Rt</td>
<td>No</td>
<td>Yes</td>
<td>&gt; 1”</td>
</tr>
<tr>
<td>SW corner of Lost Nation &amp; Clair St</td>
<td>1”</td>
<td>“Yes”</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Lost Nation 52+15 to 52+80</td>
<td>Lt, shield</td>
<td>1”</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>52+15 52+65</td>
<td>Lt</td>
<td>1”</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Signatures**

Peter Nursavage

**Inspector**

6/29/10

**Date**

ODOT Form date: 3/17/2009
June 29, 2010 Site Visit

1” rutting, cracking and elastic deformation
## LAK-2-3.32 (08-0597)

### June 29, 2010 Site Visit

#### TP-1 @ 306+70

### CA-EW-3 Log of Test Pit Investigation

<table>
<thead>
<tr>
<th>Depth from</th>
<th>Depth to</th>
<th>Hand Penetrometer</th>
<th>Layer Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.0'</td>
<td></td>
<td>Material type: cement stabilized soil</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Layer thickness (ft): about 12'' - up to 14''</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Soil / rock conditions:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Avg = 4.5 +</td>
<td>Comments:</td>
</tr>
<tr>
<td>1.0</td>
<td>4.0</td>
<td></td>
<td>Material type: Gray + brown silty clay A-66 or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U1 = 2.0</td>
<td>Layer thickness (ft): 3'</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U2 = 2.5</td>
<td>A-7-6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U3 = 4.0</td>
<td>Soil / rock conditions: moist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Avg = 2.8</td>
<td>Comments: Elastic clay perhaps</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Glacial till used for emb. fill</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U1 =</td>
<td>Material type:</td>
</tr>
</tbody>
</table>

Subgrade Stabilization Problems at ODOT
June 29, 2010 Site Visit

Subgrade Stabilization Problems at ODOT

LAK-2-3.32 (08-0597)

TP-2 @ 307+70

### CA-EW-3 Log of Test Pit Investigation

<table>
<thead>
<tr>
<th>Depth from</th>
<th>Depth to</th>
<th>Hard Penetrometer ton/ft²</th>
<th>Layer Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>19&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 ft</td>
<td>13 1/4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>307+70</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Proof Rolling Results

<table>
<thead>
<tr>
<th>Station to Station</th>
<th>Lane</th>
<th>Rut Depth</th>
<th>Cracking</th>
<th>Elastic or Plastic Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>304</td>
<td>309</td>
<td>1¼&quot;</td>
<td>Yes</td>
<td>&gt; 1&quot;</td>
</tr>
</tbody>
</table>

Test Pit Location: TP 2
Offset 35 ft Left of Right Subgrade Elevation

Material type:
- **U1 =** cement stabilized soil
- **U2 =** Dark gray clay, organic
- **U3 =** Gray-brown silty clay A恬

Comments:
- On one side wall of trench, there was also a larger packet of organic soil and bit asphalt pieces.
- HP reading may be overestimating strength, got 175pci on some pieces of crushed soil.
LAK-2-3.32 (08-0597)
Through Stage 1 and Stage 3 construction, cement stabilized subgrade area requiring undercut:

- 4.66% of the 12” stabilized area
- 5.04% of the 16” stabilized area

Most common repair has been 2-foot undercut replaced with Type B Granular
LAK-2-3.32 (08-0597)

Subgrade change order history to date

- 11/20/2009: $200,000 (undercut)
- 5/14/2010: $113,800 (undercut)
- 7/20/2010: $89,681 (increase to 16”)
- 8/30/2010: $345,990 (undercut)

Total to date: $749,471
LAK-2-3.32 (08-0597)

- Cracks and heaved pavement appear in concrete pavement in Stage 1, late winter (early 2010)
- After March 31, 2010 site meeting, Contractor documents cracks at 9 locations totaling 1603 lineal feet
- As of December 1, 2010 Contractor has documented cracks at 33 locations totaling 3295 lineal feet
LAK-2-3.32 (08-0597)

Subgrade Stabilization Problems at ODOT
LAK-2-3.32 (08-0597)

Subgrade Stabilization Problems at ODOT
LAK-2-3.32 (08-0597)

Subgrade Stabilization Problems at ODOT
Contractor initiates a study and concludes that heaved and cracked pavement is caused by subgrade swelling due to reaction between cement and sulfate in the soil.
Subgrade Stabilization Problems at ODOT
### Level of risk associated with lime stabilization in sulfate-bearing clays (Little and Graves, 1995)

<table>
<thead>
<tr>
<th>Risk Involved</th>
<th>Soluble Sulfate Concentrations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Parts Per Million</td>
</tr>
<tr>
<td>Low Risk</td>
<td>&lt; 3,000 ppm</td>
</tr>
<tr>
<td>Moderate risk</td>
<td>Between 3,000 ppm and 5,000 ppm</td>
</tr>
<tr>
<td>Moderate to high risk</td>
<td>Between 5,000 ppm and 8,000 ppm</td>
</tr>
<tr>
<td>High to unacceptable risk</td>
<td>&gt; 8,000 ppm</td>
</tr>
<tr>
<td>Unacceptable risk</td>
<td>&gt; 10,000 ppm</td>
</tr>
</tbody>
</table>
# LAK-2-3.32 (08-0597)

<table>
<thead>
<tr>
<th>Location</th>
<th>TEX-145 E</th>
<th>AASHTO T290B</th>
</tr>
</thead>
<tbody>
<tr>
<td>439+50, 2.5-4.5’ top</td>
<td>12,480 ppm</td>
<td>2,570 ppm</td>
</tr>
<tr>
<td>439+50, 2.5-4.5’mid</td>
<td>13,600 ppm</td>
<td>1,620 ppm</td>
</tr>
<tr>
<td>486+05, 1-2.5’</td>
<td>Not tested</td>
<td>1,190 ppm</td>
</tr>
<tr>
<td>486+05, 2.5-3.0’</td>
<td>Not tested</td>
<td>1,220 ppm</td>
</tr>
<tr>
<td>486+05, 3-4.5’</td>
<td>Not tested</td>
<td>3,180 ppm</td>
</tr>
<tr>
<td>495+72, 2-4’comp</td>
<td>11,120 ppm</td>
<td>1,790 ppm</td>
</tr>
<tr>
<td>495+72, 4-6’ top</td>
<td>12,000 ppm</td>
<td>4,640 ppm</td>
</tr>
<tr>
<td>495+72, 4-6’ bottom</td>
<td>Not tested</td>
<td>879 ppm</td>
</tr>
</tbody>
</table>

## Contractor Sulfate Test Results

Subgrade Stabilization Problems at ODOT
LAK-2-3.32 (08-0597)

Stage 2 fill placement to begin April 1, 2011

Do we continue to cement stabilize the subgrade?

ODOT initiated a study of the soil sulfate content for Stage 2
Subgrade Stabilization Problems at ODOT
Subgrade Stabilization Problems at ODOT
LAK-2-3.32 (08-0597)

LAK-2-3.32, SPN 2008-0597, Phase 2
Sulfate Concentration, TEX-145 test method

Subgrade Stabilization Problems at ODOT
LAK-2-3.32 (08-0597)

- ODOT decides to suspend cement stabilization of subgrade for balance of project.

- Proof roll and stabilize by excavation and replacement with Type C granular material.
LAK-2-7.76 (10-0215)

Subgrade Stabilization Problems at ODOT
LAK-2-7.76 (10-0215)

Reconstruction and widening of 5.73 miles of SR 2 (CMS 2008)
- Start: July 14, 2010
- Scheduled finish: October 15, 2012
- $60.7 million award to Shelly Company

- 473,344 yds$^2$ cement stabilized subgrade, 12 inches deep: $2.2$ million

- 13.25-inch asphalt pavement with limestone aggregate base
LAK-2-7.76 (10-0215)

- 82% A-4a and A-6a
- Average PI = 12
- Average NL = 11
- Average N60L = 14, assuming ER = 80%

Ideal candidate for 12” cement stabilization
LAK-2-7.76 (10-0215)

- Phase A (2010): Shoulder reconstruction entire length
- Phase B (2010-2011): Median pavement and barrier entire length
- Phase C (2011-2012): Outside pavement entire length
- Some sloppy subgrade before, generally OK
Contractor designed chemical stabilization:
- A-1-b soil, 6% cement – 280 psi
- A-4a soil, 6% cement – 217 psi
- A-6b soil, 6% cement – 173 psi
- A-7-6 soil, 6% cement – 130 psi

Verification testing was not available.
LAK-2-7.76 (10-0215)

Used same proof roll interpretation as the LAK-2-3.32 project:
- Accept elastic deformation only
- Undercut plastic deformation

Project estimates that 50% of the cement stabilized subgrade performed has deflected
**LAK-2-7.76 (10-0215)**

- Increased to 16” stabilized depth east of SR 615

- After 130,000 yd$^2$ of stabilization (27% of total), area requiring undercut:
  - 3.23% of 12” CSS
  - 5.93% of 16” CSS
  - $165,000 in change order undercuts
March 22, 2011 – Heaving of asphalt pavement noticed in 500-foot section starting at station 640+00

Initially believed to be frost heave

Adjacent to flooded ditchline

Clayey organic soils, tree stumps in the median

Described as mogals

Good after paving, rougher now throughout
LAK-2-7.76 (10-0215)

Subgrade Stabilization Problems at ODOT
LAK-2-7.76 (10-0215)

Subgrade Stabilization Problems at ODOT
ATB-90-14.25 (09-0460)

- Reconstruction and widening of 5.25 miles of IR90 (CMS 2008)
  - Start: February 11, 2010
  - Scheduled finish: October 31, 2011
  - $31.9 million award to Shelly & Sands, Inc.

- 260,588 yds$^2$ cement stabilized subgrade, 14 inches deep: $1.6 million

- 13-inch asphalt (warranty pavement) limestone aggregate base

Subgrade Stabilization Problems at ODOT
ATB-90-14.25 (09-0460)

- 82% A-4a and A-6a
- Average PI = 11
- Average NL = 11
- Average N60L = 14, assuming ER = 80%
- 2X minimum number of borings

Ideal candidate for 12” cement stabilization; 14” used
ATB-90-14.25 (09-0460)

Phase 1 (2010): Rebuild EB outside shoulder for MOT

Phase 2 (2010): Rebuild EB outside shoulder for MOT (Contra flow)

Phase 3 (2010): Construct WB inside permanent pavement and MOT shoulder

Phase 4 (2010): Construct WB outside permanent pavement
ATB-90-14.25 (09-0460)

Phase 5 (2011): Construct all of EB permanent pavement
ATB-90-14.25 (09-0460)

Subgrade Stabilization Problems at ODOT
ATB-90-14.25 (09-0460)

 Contractor Designed Chemically Stabilized Subgrade

 WB lanes – 3 samples tested at 3, 6, 9%
 A-1-b: 423 psi at 6%
 A-4a: 243 psi at 6%
 A-6a: 260 psi at 6%
 Used 4.75%

 Moisture conditioning expansion test
 -0.1% to 0.2% expansion
ATB-90-14.25 (09-0460)

Verification Test Results (150 psi target)
- Sta 149+55 – 143 psi
- Sta 215+79 – 80 psi
- Sta 220+69 – 250 psi
- Sta 327+50 – 105 psi
- Sta 138+00 – 103 psi
- Sta 116+00 – 240 psi

Subgrade Stabilization Problems at ODOT
ATB-90-14.25 (09-0460)

- WB passing lane cement stabilization performed (Phase 3)
- Encountered two very small soft spots
- Temporary median pavement for MOT (Phase 3) – some blow-outs due to wet subgrade
ATB-90-14.25 (09-0460)

- WB driving lane (Phase 4)

- Encountered wet soft subgrade coinciding with temporary pavement blow-outs

- Non perform cement and undercut worst areas
ATB-90-14.25 (09-0460)

- Worst areas had high clay content (0.7% of samples classified as A-7-6)
- Increased cement to 16”” and 6% where deep rutting was observed (tried 10% in some areas)
- Many areas failed proof roll
  - Repaired with 2’ UC replaced with fabric/grid, 1’ No. 4 stone, grid, 1’ 304
- Set up $700,000 change order
ATB-90-14.25 (09-0460)

- Undercuts encountered high plastic clays and water filled underdrains

- Project concerned similar conditions will be encountered in the EB lanes and change order totals will exceed $1 million
ATB-90-14.25 (09-0460)

PE and contractor noticed wavyness in pavement end of January 2011

- Very smooth when first placed
- Intermediate course may have been profiled; will profile again and compare
Chemical stabilization is not infallible but still effective. Expect 5%± failure and put in the plans. Is improvement from 4” rutting to 1” rutting a success? Test rolling? Undercuts are rarely proof rolled. Is soil sulfate content more severe than we realize?
Summary

Did we accomplish these?

1. Improve budget accuracy
2. Facilitate scheduling by identifying all subgrade work at time of bid
3. Reduce or eliminate construction arguments, issues, and claims related to subgrade
4. Increase productivity by providing a stable platform for the Contractor
Questions?

Subgrade Stabilization Problems at ODOT