QUALITY ASSURANCE TESTING OF LIME-STABILIZED SUBGRADE USING THE AUTOMATIC DYNAMIC CONE PENETROMETER AND THE LIGHTWEIGHT DEFLECTOR

Presented by: Dane Redinger
Resource International, Inc.
Agenda

- OTC 39-11-01 Project Overview
- Automated Dynamic Cone Penetrometer (ADCP) and Lightweight Deflectometer (LWD) Overview
- Results of ADCP and LWD
OHIO TURNPIKE
RECONSTRUCTION PROJECT
OTC 39-11-01

Presented by: Dane Redinger, PE
Project Overview

- **OTC 39-11-01**
  - 5-mile reconstruction of the original mainline pavement from Westbound Mile Post 95 to 101

- Kokosing Construction Company was the low bidder
  - Ten-Mile Creek Excavating performed quicklime-soil subgrade stabilization

- Started Construction in April 2011

- Completed in October 2011
Project Overview

SCHEMATIC DESIGN

10" P.C. CONCRETE
13" P.C. CONCRETE
3" ASPHALT
ROLLER
COMPACTED CONCRETE
6" GRANULAR BASE
5"-7" ASPHALT
10" P.C. CONCRETE
6" GRANULAR BASE
Project Overview

- OTC 39-11-01
  - Soil subgrade stabilization consisted of 5% quicklime at 16 & 12-inch depths
  - Existing subgrade soil was oversaturated and unstable
Quicklime-Soil Subgrade Stabilization

- Soil Stabilization
  - Checked application rate (square yard method and total area method)
Quicklime-Soil Subgrade Stabilization

- **Soil Stabilization**
  - Checked application rate (square yard method and total area method)
  - Treatment depth via hand-auger & phenolphthalein
Quicklime-Soil Subgrade Stabilization

- Compaction Testing
  - One-point Proctor
    - ODOT Family of Curves
  - Offset nuclear gauge moisture content due to quicklime
  - 98% Compaction
  - 0-3% Above Optimum Moisture Content
AUTOMATED DYNAMIC CONE PENETROMETER (ADCP) AND LIGHT WEIGHT DEFLECTOMETER (LWD) FOR ROADWAYS AND PAVEMENTS

Presented by: Dane Redinger, PE
Overview of ADCP

Subgrade Soil Strength – Measured Directly

The Automated DCP system is equipped with an automatic lift/drop mechanism and Windows-based data acquisition system (DAS), providing direct and accurate shear strength results in less than five minutes without the need for extensive laboratory testing. An additional probe provides continuous moisture, temperature, and resistivity data with depth.

ADCP testing is less intrusive and requires drilling a 1-inch diameter hole, rather than procuring a core; thus, increasing the production rate to about 7 to 14 tests per hour.
Overview of ADCP

- **ADCP**
  - Modeled after USACE single- and dual-mass cone penetrometer
  - Trailer-mounted
  - 17.6 lb (8 kg) weight dropped 2.26 ft. (575 mm)
  - 5/8-inch diameter steel rod with 60° conical tip
  - Real-time data acquisition system
  - Delivers approx. 30 to 40 blows per minute
  - 1-inch hole needed in existing pavement for probe
  - Measured in mm or inches per blow
Subgrade CBR – Measured Directly

Penetration Rate (PR) values can be correlated to CBR values for use in the evaluation of the subgrade soils using the Army Corps of Engineers developed equations presented in ASTM D6951/D6951M as follows:

\[
CBR = \frac{292}{(DCPI)^{1.12}}
\]

\[
CBR = \frac{1}{(0.002871 \times DCPI)} \quad \text{for all CH soils}
\]

\[
CBR = \frac{1}{(0.017019 \times DCPI)^2} \quad \text{for CL soils with CBR < 10 from above}
\]

Where:

\(DCPI = PR \times \text{(Hammer Factor)}\) in mm/blow

Hammer Factor = 1.0 for a 17.6 lb hammer
Overview of ADCP

- Trailer-Mounted ADCP System
- ADCP Probe
Overview of ADCP

Output Log from Ohio Turnpike showing ADCP CBR and Penetration Rate with depth
Characterization of Chemically Stabilized Subgrade

- Using the ADCP to collect the stiffness values of chemically stabilized soil and to ensure consistency of chemical stabilization with the ability to collect large amounts of data throughout the project.
- ADCP can effectively show actual increase in CBR from non-stabilized soil subgrade to stabilized soil subgrade.
- ADCP can illustrate effective layer thickness of chemically stabilized soil.
- ADCP can verify that 16 inches of chemically stabilized soil has increased stiffness for 16 inches.
ODOT WAR 75-3.40 - Stage 2 Northbound

Station 267+48, 20' Rt.
Penetration Rate (in/blow)

Station 269+50, 5' Rt.
Penetration Rate (in/blow)

- Stabilized PR = 0.3 mm/blow
- Stabilized PR = 8.0 mm/blow

Penetration Rate (mm/blow)

Depth of Penetration (inches)
Improving the Construction Process

- The ADCP able to shorten curing periods for subgrades stabilized with quicklime or lime-kiln dust
- The lime-stabilized soil subgrade may allow pavement construction to proceed after only 48 hours
  - Only need to measure enough stiffness / CBR value for pavement construction
The LWD provides an accurate measure of the resilient modulus value, MR by creating a pulse similar to that of a vehicle loading.

This can be correlated to a CBR value or directly input into pavement design.

- Provide a more representative picture of a pavement’s ability to handle traffic loads than laboratory density measurements
- Direct verification of the soil values used during pavement design
- Quicker results - no construction delay
- No additional lab work so inspector stays on-site
Characterization of Chemically Treated Subgrades

- The LWD is currently being used to evaluate the chemically treated subgrade soils within the footprint of the mainline reconstruction.
- No formalized reports yet; however results indicate that MR and CBR values exceed the design assumptions.

Ohio Turnpike Mainline Reconstruction – MP 95 to 101
QUICKLIME-SOIL SUBGRADE STABILIZATION RESULTS

Presented by: Dane Redinger, PE
Quicklime-Soil Subgrade Stabilization Results

- Traditional Quality Tools:
  - Depth Verification
  - Compaction Testing
  - Application Rate
  - Proof Rolling
Quicklime-Soil Subgrade Stabilization Results

Questions:

- How do traditional quality tools results compare with the design values?
- If compaction, treatment depth, application rate and proof rolling passes, are we getting the design values?
- If compaction, treatment depth, application rate and proof rolling fails, are we getting the design values?
- Can we characterize QUANTITATIVELY the chemically stabilized soil subgrade?
Quicklime-Soil Subgrade Stabilization Results

- **ADCP & LWD Testing:**
  - Performed 2 days after final compaction of the quicklime-soil subgrade stabilization
  - Performed ADCP & LWD testing at 500-ft intervals
  - Performed ADCP & LWD on untreated soil subgrade in shoulder adjacent to stabilized subgrade test locations
Quicklime-Soil Subgrade Stabilization Results

- ADCP Acceptance Requirements
  - Target Maximum Penetration Rate (PR) of 8.0 mm/blow in the top 16 inches (or 12 inches for 12-inch treatment depth) at 48 hours after final compaction
    - If passes – contractor can proceed with pavement construction
    - If fails – proof roll 3 days later
Quicklime-Soil Subgrade Stabilization Results

- **LWD Testing**
  - No acceptance criteria
  - Testing performed at same locations as ADCP testing
Quicklime-Soil Subgrade Stabilization Results

- **ADCP Acceptance Testing Results**
  - Displays PR with depth during testing
  - Outputs .txt files
  - ADCP results and plot for each test location
    - Generated in the office
**Quicklime-Soil Subgrade Stabilization Results**

Top 6-8 inches of stabilized soil meets the criteria. Bottom of stabilized soil fails to meet the PR of 8.0 mm/blow.

However, observe the uniform increase in CBR.
Quicklime-Soil Subgrade Stabilization Results

- **ADCP Acceptance Testing Results**

  - On average, stabilized soil subgrade only met PR of 8.0 mm/blow in the top 8 inches at 2 days.
  - At depths of 8 to 16 (12) inches, PR increased to PR ~9.0 to 11.0 mm/blow.
Quicklime-Soil Subgrade Stabilization Results

- **LWD Testing**
  - Confirmed composite CBR values in excess of the design CBR

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<th>Station No.</th>
<th>Stress (ksi)</th>
<th>M_R (ksi)</th>
<th>Avg. M_R (ksi)</th>
<th>Avg. CBR (1.5)</th>
<th>Avg. CBR (1.2)</th>
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*LWD data for same location as ACPD log shown previously*
Quicklime-Soil Subgrade Stabilization Results

- Field Verification Sampling
  - Unconfined Compressive Strength Samples
  - Followed ODOT SS1120
  - Samples tested at 3 and 8 days
    - 3-day Results ~95 psi
    - 8-day Results ~ 200 psi
Quicklime-Soil Subgrade Stabilization Results

Data Analysis

- Split the stabilized layer into two layers
  - PR used as separator
  - Remainder of layer

- Multi-Layer Elastic Analysis
  - Use LWD & ADCP Data
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<th>Date Tested</th>
<th>Layer Description</th>
<th>Layer No.</th>
<th>Layer Thickness (in)</th>
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<th>$M_p$ (ksi)</th>
<th>$M_s$ (psi)</th>
<th>Layer Thickness (in)</th>
<th>CBR</th>
<th>$M_p$ (ksi)</th>
<th>$M_s$ (psi)</th>
<th>Effective Subgrade* (DCP Data)</th>
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<th>Effective Subgrade* (LWD Data)</th>
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<th>% Difference, $M_s$</th>
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Effective Subgrade* = Combined layers of Stabilized and Natural Subgrade, semi-inf. Thickness.
SI denotes Semi-infinite layer.
Quicklime-Soil Subgrade Stabilization Results

12 inch design
Quicklime-Soil Subgrade Stabilization Results

16 inch design
Stabilized Layer Profile - ADCP
Top Stabilized Layer Thickness by ADCP

Top Layer Thickness
Bottom Stabilized Layer Thickness by ADCP

Bottom Layer (Offset)
Stabilized Layer CBR - (ADCP)
Effective Stabilized Layer (ADCP)

Effectiv Stabilized Layer CBR

Design CBR 4.0

CBR from lab UCS data
Effective Subgrade CBR

GB1 Design
CBR=4
Quicklime-Soil Subgrade Stabilization Results
Summary

Quicklime-Soil Subgrade Stabilization

- Stabilization contractor had difficulty achieving uniform mixing of quicklime-soil subgrade with consistent moistures
  - 98% compaction become difficult with inconsistent moisture
- Difficulty maintaining stabilized subgrade in a moist condition
- Observed an increase in effective thickness as the lime-stabilized soil continued to cure beyond 2 days
Summary

- **Quicklime-Soil Subgrade Stabilization**
  - ADCP & LWD collectively displayed evidence of a *quantitative* increase in soil subgrade CBR and MR due to chemical stabilization
  - Will continue to collect data on further chemically treated soil subgrades
Questions and Answers

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