Automated Dynamic Cone Penetrometer for Characterization of Pavement Subgrades

Presented by

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INTRODUCTION

• General overview
• Use in characterization of natural subgrades
• Use in characterization of stabilized subgrades
• Available equipment
• Evaluation of Existing Pavement
• Dynamic Cone Penetrometer (DCP)
  – Introduced in 1959 by Professor George F. Sowers of Georgia Tech
  – Used in footing excavation observation
  – 15 lb weight manually lifted and dropped 20 inches
  – 1.5 inch diameter steel rod with 45° conical tip
  – Hand auger down to desired depth
  – Count blows at 1.75 inch increments
  – Blow counts can be directly correlated to N values from standard penetration test (SPT)
  – Can be used to obtain samples
GENERAL OVERVIEW

Manual DCP
GENERAL OVERVIEW

• Automated Dynamic Cone Penetrometer (ADCP)
  – Modeled after USACE single- and dual-mass cone penetrometer
  – Trailer-mounted
  – 17.6 lb (8 kg) weight dropped 2.26 feet (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
  – Results reduced to 95th percentile of all data – reduced to account for any anomalies
GENERAL OVERVIEW

• Uses
  – Able to analyze stiffness and shear strength by measuring the rate of penetration
  – Simple and quick method for obtaining data between soil borings
  – Can be useful in both the design stage and in field verification
GENERAL OVERVIEW

• Method
  1. Hammer drill used to make 1-inch hole and penetrate through existing pavement structure
  2. Insert probe
  3. Initiate data logger
  4. Perform test
  5. Remove probe
  6. Backfill with fine aggregate concrete

Approximately 5 minutes on exposed subgrade soil, with additional time to penetrate through existing pavement structure
GENERAL OVERVIEW

Trailer-Mounted ADCP System

ADCP Probe
GENERAL OVERVIEW
CHARACTERIZATION OF NATURAL SOIL SUBGRADES

• CBR Calibration
• Comparison with FWD:
  – Ohio Turnpike Third Lane Widening
• Comparison with Laboratory and Field CBR Test Results:
  – PCIA South Runway Relocation
• Comparison with SPT data:
  – CLA-70-6.75/10.55 Pavement Rehabilitation
CHARACTERIZATION OF NATURAL SOIL SUBGRADES

• CBR Calibration
  – Based on US Army Corps of Engineering

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

Where DCPI = Penetration Rate (mm/blow)
CHARACTERIZATION OF NATURAL SOIL SUBGRADES

• Ohio Turnpike Third Lane Widening
CHARACTERIZATION OF NATURAL SOIL SUBGRADES

- Ohio Turnpike Third Lane Widening
  - CBR data obtained using falling weight deflectometer (FWD) testing and ADCP testing
  - Data comparable – ADCP CBR values slightly higher than FWD CBR
FWD vs. ADCP (Ohio Turnpike)
FWD vs. ADCP (Ohio Turnpike)
FWD vs. ADCP (Ohio Turnpike)

Mainline Pavement Evaluation Master Plan
Mile Post 165 - 170
CBR - Current Testing

![Graph showing CBR vs Mile Post for Ohio Turnpike]
CHARACTERIZATION OF NATURAL SOIL SUBGRADES

- PCIA South Runway Relocation
  - Field CBR, laboratory CBR and ADCP performed at 4 locations along new taxiway alignment
## CBR Testing (PCIA South Runway)

<table>
<thead>
<tr>
<th>Bag Sample Designation</th>
<th>Boring</th>
<th>CBR Value</th>
<th>DCP-SPT Correlations</th>
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</table>
CHARACTERIZATION OF NATURAL SOIL SUBGRADES

• CLA-70-6.75/10.55 Pavement Rehabilitation
  – ADCP testing performed directly adjacent to new SPT soil borings and between previously performed SPT soil borings
  – Plan to use ADCP for field verification of chemically stabilized subgrade during construction, if recommended
  – More to come…
CHEMICALLY STABILIZED SUBGRADE EVALUATION

• Using the Automated Dynamic Cone Penetrometer (ADCP) to collect the stiffness values of chemically stabilized soil
• Using the ADCP to ensure consistency of chemical stabilization with the ability to collect large amounts of data throughout the project.
Why Chemically Stabilize Pavement Subgrade?

- Low in-situ CBR / $M_R$ value – need to increase stiffness
- Increase life cycle of pavement structure
- Reduce shrink-swell potential
- Increase compressive, tensile and flexural strength
- Create a uniform support for rigid pavement
- Create a platform for construction of pavement structure
Low in-situ CBR / $M_R$ value – need to increase stiffness

- Pavement engineer relies on chemically stabilized soil to provide an increase in the soil subgrade CBR / $M_R$ value
- Unconfined compressive strength (UCS) testing of chemically stabilized soil provides real strength results
  - Not feasible to obtain UCS samples at increased increments (every 20-50 ft of roadway construction)
  - ODOT SS 1120 only requires three samples every 15,000 SY of chemically stabilized soil
INCREASED CBR / $M_R$

• Automated Dynamic Cone Penetrometer (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
INCREASED CBR / $M_R$

- ADCP can collect large volume of data in little amount of time (~5 minutes per location)
- Nondestructive testing of chemically stabilized soil
• Performed ADCP testing on both lime and cement stabilized soils
• Observed average penetration rate (PR) to be 3.8 mm/blow on ODOT chemically stabilized soil projects
  – Found stabilized soil did not maintain its maximum stiffness for the full treatment depth (Effective thickness ≠ treatment depth)
• Determined acceptable PR for chemically stabilized soil is 8 mm/blow
Rii performed laboratory testing to determine minimum Portland cement content to meet requirements of ODOT SS 1120.

After testing A-2-4, A-2-7, A-4a, A-6a, A-6b soil types, 6% Portland cement was selected for Stage 2 Northbound.

Rii performed ADCP testing before and 6 days after soil-cement stabilization at various locations.
ODOT 090171 WAR IR-75-3.40
Stage 2 Northbound
• CBR measurements using ADCP for in-situ subgrade soil vs 6% soil-cement stabilization at 14-inch treatment depth after 6 days of curing.
Results

- Rii observed the average effective depth to be 14 inches based on an acceptable penetration rate of 8mm/blow.
- The average PR was 12.41 mm/blow for natural soil subgrade soil.
- The average PR was 6.87 mm/blow for cement-stabilized subgrade soil.
Results

– Rii confirmed a significant increase in CBR and stiffness (decrease in PR) from nonstabilized soil subgrade to cement stabilized soil subgrade.

– Rii observed that the designated stabilized subgrade thickness (14 inches) was achieved.
Goals

– Rii to continue gathering PR and CBR data before and after soil-cement stabilization
– Rii is working on developing a correlation between PR/CBR and unconfined compressive strength values
• If necessary, soil subgrade will be chemically stabilized with Portland cement
• Rii will obtain PR and CBR values before and after soil-cement stabilization
• Lime stabilized subgrades exhibit improved strength qualities immediately after mixing
• Pavement construction may be able to proceed once the soil subgrade reaches a certain stiffness or CBR value
• Lime stabilized subgrades do not start forming long-term pozzolanic bonds till after 28 days
IMPROVING CONSTRUCTION PROGRESS

• The ADCP might be able to shorten curing periods for subgrades stabilized with quicklime or lime-kiln dust
• The lime-stabilized soil subgrade might allow pavement construction to proceed after only 48 hours
  – Only need to measure enough stiffness / CBR value for pavement construction
Upgrades allow the ADCP measure in-situ soil moisture content, resistivity and temperature.

ADCP can obtain PR / CBR values, moisture content, resistivity, and temperature of existing or recently constructed pavement subgrades.
EXISTING PAVEMENT EVALUATION

• The ADCP can easily perform pavement subgrade evaluations 2, 5, 10, 15, etc. years after construction of pavement
• Allows for better evaluation of existing and recently constructed pavements
• The ADCP can obtain PR / CBR values of lime stabilized subgrades well beyond 28 days to ensure proper strength gain and effective layer thickness
MORE DATA TO COME…

- Rii will continue to collect soil stabilized subgrade data for:
  - ODOT 090171 WAR IR-75-3.40
  - ODOT CLA IR-70-6.75
  - PCIA Runway Phase 2
  - ODOT 080211 CUY IR-77-1.89

- Goal – to establish a relationship between ADCP CBR values and unconfined compressive strength
Thank you!

Questions?