2012 Road School

Dynamic Cone Penetrometer (DCP)

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Outline

- Current Earth Work Specifications
- INDOT Quality Control (QC) issues
- Uniform Compaction & Design Issues
- Use of Dynamic Cone Penetrometer for Earthwork (Reoccurring Spec’s.)
- DCP use in 2011 Construction Season
- Other State’s Spec’s
- Conclusions
- Notes
- Questions
Current Earthwork Specifications

**Requirements:**

**Compaction:** 95% of Max Density within of -3 to +1 of Optimum Moisture Content

**Lab Testing:** Std. Proctor Test (T-99) for Dry Density vs water content curve.

Modified Proctor (T-180) for Railroad Approach backfill

**Field Testing:** Nuclear Gauge, Sand Cone, Moisture Test by Stove top & Microwave, and 1-Point Proctor Test

**Moisture Density Curve:** Y:\Div.material& Test\Moisture Density Curve
INDOT Quality Control Issues

• INDOT provides QC for compaction

• Takes several days for lab testing (Standard Proctor, etc.)
INDOT QC Issues (Con’t.)

Std. Proctor Curve

Dry Density (kN/m$^3$) vs. Water Content (%)

$\gamma_{d \text{ max}}$, $W_{opt}$, $S = 0.9$, $S = 1$
INDOT QC Issues (Con’t.)

- Variation of Soils during placement: Required additional one-point Proctor tests (AASHTO T-272)
- Safety issues: The use of Nuclear Gauge
- Time consuming: Sand Cone.
- Low production: contractors waiting for INDOT testing & approval
### Soil Variability -- example

<table>
<thead>
<tr>
<th>Grain Size Distribution</th>
<th>Sta. 33+00</th>
<th>Sta. 34+00</th>
<th>Sta. 35+00</th>
</tr>
</thead>
<tbody>
<tr>
<td>#10</td>
<td>96</td>
<td>97</td>
<td>95</td>
</tr>
<tr>
<td>#40</td>
<td>85</td>
<td>89</td>
<td>85</td>
</tr>
<tr>
<td>#200</td>
<td>52</td>
<td>56</td>
<td>52.5</td>
</tr>
<tr>
<td>Liquid Limit</td>
<td>27</td>
<td>34</td>
<td>29</td>
</tr>
<tr>
<td>Plastic Limit</td>
<td>17</td>
<td>19</td>
<td>18</td>
</tr>
<tr>
<td>ASTM</td>
<td>CL</td>
<td>CL</td>
<td>CL</td>
</tr>
<tr>
<td>Proctor Density (lb/ft³)</td>
<td>111.4</td>
<td>109.9</td>
<td>117.3</td>
</tr>
<tr>
<td>Optimum Moisture (%)</td>
<td>15.7</td>
<td>16.8</td>
<td>13.0</td>
</tr>
</tbody>
</table>

**Note:**

No uniform compaction if the target number is not recognized.
Use of Dynamic Cone Penetrometer for Earthwork (Recurring Spec’s.)

Lab Testing Requirements for borrow:

Sample from the representative soils from project limit or borrow pit:

Sieve Analysis..........................AASHTO T-88, T-89, ASTM D-1140
Atterberg Limits.................................................................AASHTO T-90
Density and Moisture..........................................................AASHTO T-99
Loss on Ignition.................................................................AASHTO T-267
Ca/Mg Carbonate............................................................ITM-507
# DCP use in 2011 Construction Season

<table>
<thead>
<tr>
<th>Classification</th>
<th>Lab</th>
<th>Field</th>
<th>Total Count</th>
<th>Total &gt; 10%</th>
<th>Total &gt; 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1, A-2, A-3 (0 – 12 in.)</td>
<td>8 or 9</td>
<td>13.97</td>
<td>1795</td>
<td>95.1%</td>
<td>84.8%</td>
</tr>
<tr>
<td>A-4 (0 – 12 in.)</td>
<td>8 or 9</td>
<td>14.84</td>
<td>1832</td>
<td>96.1%</td>
<td>91.0%</td>
</tr>
<tr>
<td>A-6, A-7 (0 – 6 in.)</td>
<td>4</td>
<td>6.91</td>
<td>649</td>
<td>88.8%</td>
<td>88.8%</td>
</tr>
</tbody>
</table>
Recommendations:
1. A-2, A-3, b-borrow or soils with sandy behavior (PI < 8)

\[(N_{\text{DCP}}) \text{ req/ 0~12”} = 4.0 \text{ in (Cu) + 2.6}\]

\[Cu = \text{coefficient of uniformity}\]

\[(N_{\text{DCP}}) \text{ req/0~12”} = \text{minimum required blow count for 0 - 12 inch}\]
2. Silty and Clay Soils (PI > 8)

\[(N_{DCP}) \text{ req/ 0 ∼ 6”} = 17 \exp [-0.07(\text{PI})(\% \text{ passing #40})/100]\]

\[(N_{DCP}) \text{ req/ 0 ∼ 6”} = \text{minimum required blow count for 0 – 6 inch}\]

*PI – Plasticity Index*
### DCP Specifications of Other States

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Blow Counts Minnesota DOT</th>
<th>Blow Counts Iowa DOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silty/clay Subgrade</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Select Granular Aggregate</td>
<td>21</td>
<td>----</td>
</tr>
<tr>
<td>Select Granular Subgrade</td>
<td>----</td>
<td>4</td>
</tr>
<tr>
<td>Class 3 Special Gradation Granular Base Materials</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>
DCP - Dynamic Cone Penetrometer

1- 17.6 lb Drop hammer
2- 22.6 in Drop Height
3- 60° angle
Disposable DCP cone slides on end of attachment
If using a non-disposable cone, penetrate the cone to the top of the cone apex. Penetrate to this point.
6” Mark on rod

Record the number of hammer drops it takes to reach 6 in.
Acceptance testing shall be performed with a Dynamic Cone Penetrometer (DCP) in accordance with ASTM D-6951. The chemically modified soil lift shall meet the following requirements for compaction:

1. A minimum DCP blow count of 17 for the top 6 in. of a 14 in. lift
2. A minimum DCP blow count of 16 for the bottom 8 in. of a 14 in. lift
3. A minimum DCP blow count of 20 for an 8 in. lift
4. A minimum of 1 passing test for each 1,500 ft of chemically modified soil for each two-lane pavement

*Suggestion: Terminate DCP test at 25 blow counts even if DCP does not penetrate to a specified depth of 6 or 8 in. in Cement-modified soils.
For lime modified soils make another mark at 14 inches.

Record the drops from 6 in. to 14 in.
Conclusions:

1. The DCP is portable, easy to operate, and requires no electronics. It takes only a couple of minutes to learn how to use the DCP.

2. It is an effective tool to identify weak layers when penetration rates are plotted vs. depth.

3. DCPs can take deeper measurements.

4. DCP readings are not affected by minor shrinkage cracks in soils.

5. CBR and resilient modulus values can be reliably predicted using DCP test results. Hence, the stiffness of the materials can be represented by blow counts or DCP penetration rates.
6. Improve inspector safety
7. Directly related to Design
8. Very sensitive to water content
9. Increase compaction uniformity
10. Increase productivity due to less time per test
11. DCP is a good indicator of strength and moisture conditions.
12. Reduce the reliance of the Nuclear Gauge
13. Improve documentation and reporting.
Conclusions, Con't.

- DCP is suitable for:
  - Cohesive Soils
  - Granular Soils w/Aggregate Passing ¾ in., b-borrow and structural backfill sizes 1 in., ½ in., No. 4 and No. 30
  - Chemically Modified Soils
Notes:

- If the DCP is bouncing and does not appear to be penetrating it could be on a rock. If that is the case remove the DCP and start another test nearby.

- In most cases disposable cones are recommended. The disposable cones cause less wear and tear on the equipment when it is being removed from the ground.
Questions?