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RESEARCH

Embankment Quality and Assessment of Moisture Control Implementation

tech transfer summary

Embankments are critical components of infrastructure that support pavement systems and bridge approaches.

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RESEARCH PROJECT TITLE
Embankment Quality and Assessment of Moisture Control Implementation

SPONSORS
Iowa Highway Research Board
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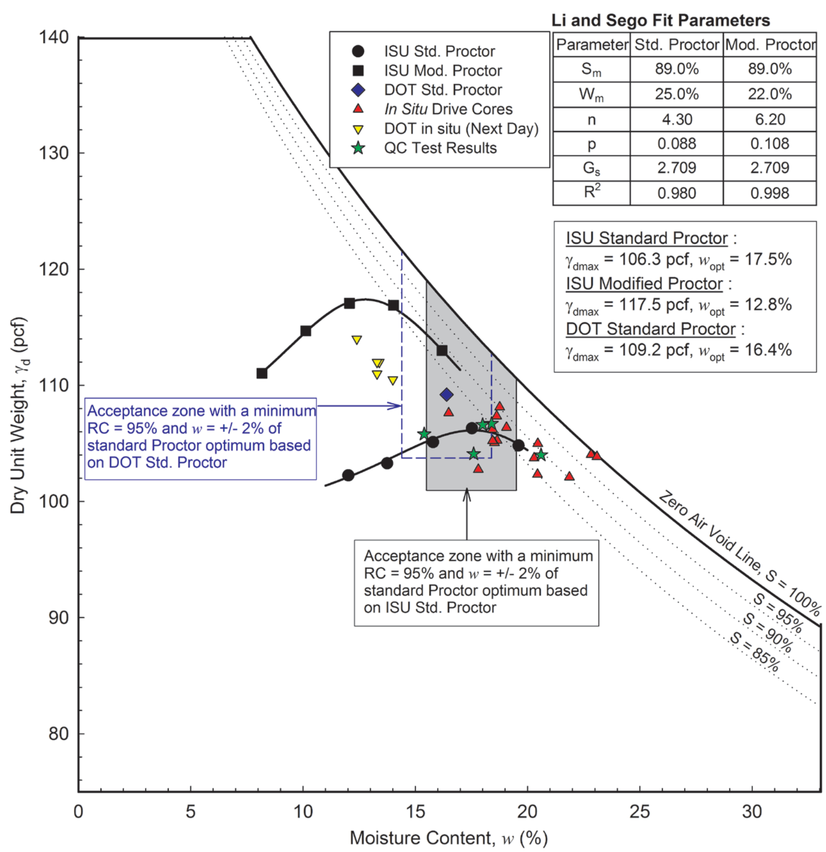
Background

Earth embankments are designed to provide the specified elevation and stability for the performance life of the overlying pavement systems and embedded drainage structures.

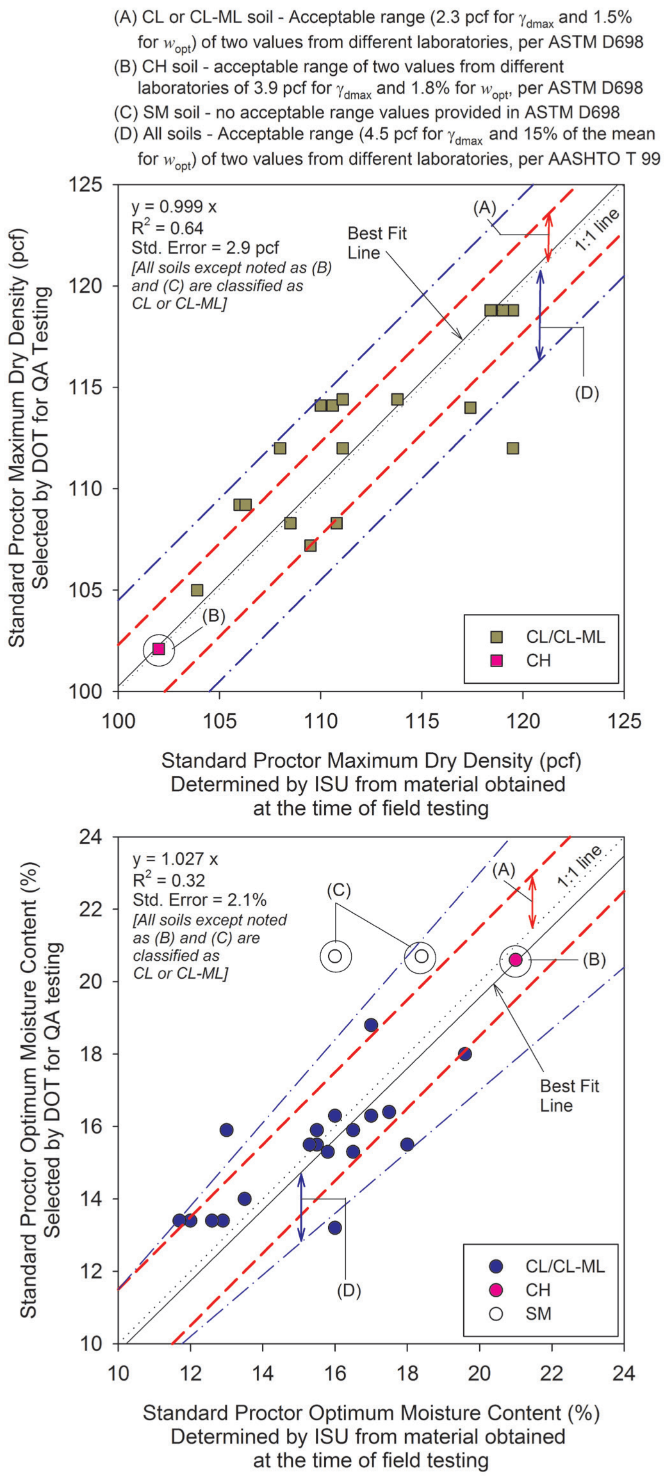
Past research shows that significant variability exists in the final compaction conditions (e.g., moisture content) for embankment fills and that variability in compaction quality is largely influenced by wet Iowa fill materials and variable lift thickness control and compaction operations.

Past experimental pilot projects have been conducted in Iowa to document compaction quality using the "walk out" roller specification versus end-result alternative requirements including moisture/density control and use of dynamic cone penetration testing as a measurement of lift thickness, uniformity, and soil strength.



Comparison of in situ moisture-density measurements with laboratory Proctor compaction test results and Iowa DOT acceptance limits for Pottawattamie County Project 6 TB2

Based on the outcomes from these past research studies, the Iowa Department of Transportation (DOT) implemented a specification for contractor moisture or moisture-density quality control (QC) in roadway embankment construction that has been in use for about 10 years in Iowa on about 190 projects.



Comparison between selected Proctor test results (optimum moisture content and maximum dry density) by Iowa DOT for QC/QA testing and measured Proctor test results by CEER from all project sites

The current study set out to study the impact of the current specifications in terms of quality compaction and to identify further areas for improvement given recent advancements in compaction measurement systems and in situ testing technologies.

Problem Statement

The motivation for this project was based on work by Iowa State University (ISU) researchers at a few recent grading projects that demonstrated embankments were being constructed outside moisture control limits, even though the contractor QC testing and quality assurance (QA) testing showed all work was being performed within the control limits. This finding initiated the need for a more detailed study with testing on several active grading projects across Iowa.

Research Description

Field testing was conducted on nine active construction sites in Iowa with materials consisting of glacial till, western Iowa loess, and alluvium sand.

Drive cylinder tests were performed to determine in situ moisture content and dry density; dynamic cone penetrometer (DCP) tests were performed to determine California bearing ratio (CBR) profiles with depth.

Field test results from ISU testing were assessed if the data were within the moisture control limits (± 2% of optimum moisture content) and above the minimum relative compaction control limit (95% of standard Proctor test). The data that were available from contractor QC testing and Iowa DOT QA testing were also assessed in comparison with the ISU test results.

Finally, field test results from this project were compared with data from previous embankment research projects to assess if there was a statistically significant improvement in terms of the percentage of data within the control limits of the current specifications.

Key Findings

- For cohesive materials, QC data showed that 1% to 45% of moisture measurements were outside of the specification and 2% to 75 % of density measurements were outside of the specification. QA data at two project sites showed that 63% to 69% of moisture measurements were outside of the specification. ISU testing results showed all test measurements within the moisture and density specification limits at one project site. At the remaining project sites, 12% to 62% of ISU moisture measurements were outside of the specification; and, 4% to 40% of ISU density measurements were outside of the specification.
- For cohesionless materials, the contractor QC results at one site showed that 2% of the moisture measurements were outside of the control limits. Iowa DOT QA data

at the same site showed that 20% of the moisture measurements (11% dry of the lower control limit and 9% wet of the upper control limit) were outside of the specification control limits. ISU testing at the same site showed that 66% of the moisture content measurements were outside of the specification control limits (2% dry, 64% wet).

- Two other project sites with cohesionless materials showed 85% to 100% of the moisture measurements outside of the control limits, of which a majority of the measurements (81% to 100%) were dry of the lower control limit. One of the sites showed that all density measurements were > 95% relative compaction (RC), while the other showed 14% of density measurements were < 95% RC.
- DCP results showed that the compacted fills have relatively low and variable CBR values, about 0.6 to 8.2% for 8 in. depth and 0.5 to 8.6% for 12 in. depth.
- During in situ construction observations, discing did not effectively aerate wet fill material.
- Comparisons between the measured values by ISU and selected values by the Iowa DOT for QA showed a standard error of 2.9 lb/ft^3 for maximum dry density and 2.1% for optimum moisture content. The difference in optimum moisture content was as high as 4% and maximum dry density was as high as 6.5 lb/ft^3.
- For maximum dry density, AASHTO T 99 allows 4.5 lb/ft^3 variation between two test results from different laboratories, while ASTM D698 allows 2.3 lb/ft^3 to 3.9 lb/ft^3, depending on the soil type. Results indicated that only 1 of 19 test results fell outside the allowable limits per AASHTO T 99, while 7 of 19 fell outside the allowable limits per ASTM D698.
- For optimum moisture content, AASHTO T 99 allows variation of 15% from the mean of the two test results, while ASTM D698 allows a variation of 1.5% to 1.8%, depending on the soil type. Only 3 of 26 test results fell outside the allowable limits per AASHTO T 99, while 7 of 26 fell outside the allowable limits per ASTM D698.
- Statistical analysis indicated statistically significant differences between the moisture content measurements relative to optimum (Δw) and RC measurements obtained from this project and the previous embankment research projects. The results indicated that data obtained from the current Iowa Highway Research Board (IHRB) TR-677 project had a higher percentage of data that were within the control limits for Δw and above the control limit for RC compared to all previous project phases. This suggests improvement over the previous project results.

Based on the field testing and observations documented through this project, although results show a statistically significant improvement over previous projects, QC/QA results are not consistently meeting the specification.

CEER in situ drive cylinder test at Linn County Project 4

Implementation Readiness and Recommendations

Recommendations are detailed in the last chapter of the report along with a one-page graphic presentation (which is also on the last page of this tech transfer summary) for three proposed options for improvements to the current specifications. Briefly, the three options are as follows:

- Option 1: Enhance the current Iowa DOT moisture and moisture-density specifications in terms of differentiating the material types, developing a spatial random sampling method, and improving process control through control charts
- Option 2: Develop alternative QC/QA specifications using dynamic cone penetrometer or modulus based testing
- Option 3: Incorporate calibrated intelligent compaction (IC) measurements into QC/QA specifications by developing statistically valid field calibrations and mapping of final layers to determine areas of non-compliance

Implementation Benefits

Because the quality of embankment construction directly influences performance of the support infrastructure, improvements to embankment compaction quality will reduce cost of future maintenance and reconstruction.

References for Last Page

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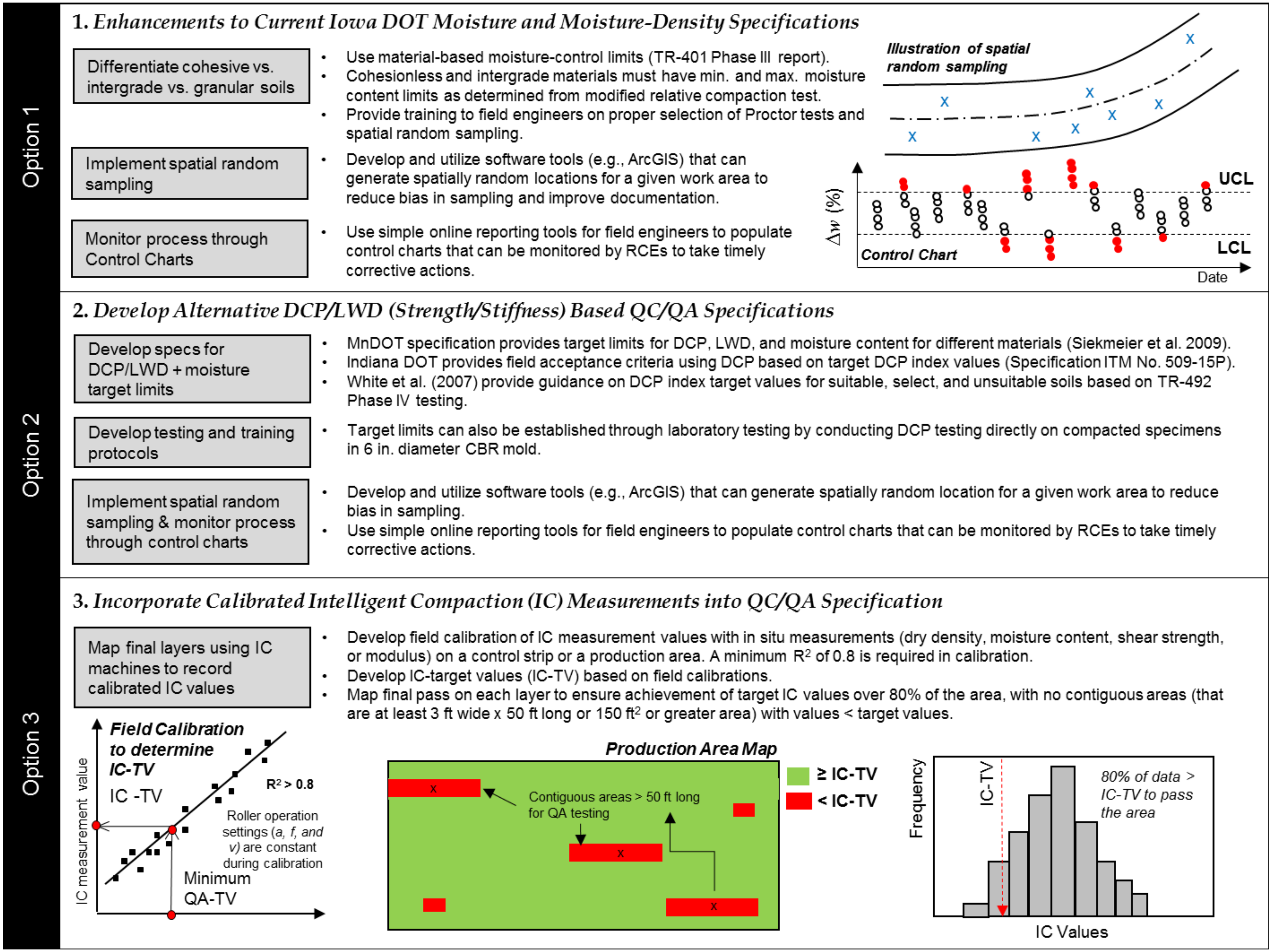

Recommended specification options for future QC/QA