PGA
PARTNERSHIP FOR
GEOTECHNICAL ADVANCEMENT

October 2007

RESEARCH PROJECT TITLE
Compaction of Unsuitable Embankment Fill Using End-Result Construction Specifications

SPONSORS
Iowa Highway Research Board (TR-492)
Iowa Department of Transportation

PRINCIPAL INVESTIGATOR
David White
Associate Professor, Civil, Construction and Environmental Engineering
Iowa State University
515-294-1463
djwhite@iastate.edu

CO-PRINCIPAL INVESTIGATOR
Charles Jahren
Associate Professor, Civil, Construction, and Environmental Engineering
Iowa State University
515-294-3829
cjahren@iastate.edu

MORE INFORMATION
www.ctre.iastate.edu/pga

PGA
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-8103

ctre
Center for Transportation Research and Education

IOWA STATE UNIVERSITY

Compaction of Unsuitable Embankment Fill Using End-Result Construction Specifications

tech transfer summary

The Quality Management Earthwork (QM-E) construction specification is evaluated for construction of embankments in unsuitable soils

Objective

The objectives of this project were to evaluate the Quality Management Earthwork (QM-E) embankment construction specification for construction of roadway embankments in unsuitable soils and to develop necessary modifications based upon field observations and data collection.

Problem Statement

One of the existing Iowa DOT specifications for compaction of earthen embankment fill relies upon process-based quality control (number of roller passes and roller walkout). The QM-E program utilizes in situ testing results including dry unit weight, moisture content, lift thickness, and dynamic cone peneterometer (DCP) tests to control fill compaction. While previous research has indicated that this specification has benefits of improved quality, it remains largely untested in projects with predominately unsuitable soil.

Research Description

The QM-E program was implemented at a pilot project in Fairfield, IA. This project involved the construction of a portion of the Highway 34 bypass around the city of Fairfield, spanning 4.6 km. In total, 699,527 cubic meters of fill were compacted for this project using the QM-E program.

A majority of the compacted fill from this project was classified as unsuitable fill according to the Iowa DOT construction specification 2102.06. The unsuitable classification is designated for cohesive soils with more than 45% passing the No. 200 sieve, dry unit weights less than 95 lb per cubic ft., or those with an AASHTO M145-91 group index greater than 30; its use is restricted to at least five feet below the top of subgrade. This type of soil is abundant in southeastern Iowa, found in layers of weathered loess and ancient soils called paleosols. These soils are fine grained and plastic, with often greater than 80% of material passing the No. 200 sieve and plasticity indexes in excess of 30.

Construction at this project was conducted from April to December 2006. There was a combined effort in performing testing at this project by the Iowa DOT, the contractor, and Iowa State University (ISU). A majority of this testing was in the form of QC/QA testing by the contractor and the Iowa DOT. ISU also conducted cone penetrometer (CPT) testing, soil borings, and monitored an inclinometer at the Crow Creek embankment; in addition, independent sets of testing similar to the contractor and DOT QC/QA testing were performed.

The compaction of fill is controlled by dry unit weight, moisture content, lift thickness, and DCP testing. Following is a brief description of the QM-E program testing requirements for each type of test.

- The dry unit weight testing was required once for every 500 cubic meters of fill placed. The dry unit weight control limits from the pilot specification required that all fill exceed 95% maximum standard Proctor dry unit weight.

- Moisture content testing was required once for every 500 cubic meters of fill placed. The moisture control limits specified for the pilot project were ± 2% of standard Proctor optimum moisture content for all types of fill material.

- The lift thickness was measured once for every 500 cubic meters of fill placed. Control limits are established during the construction of test strips. Test strips are portions of embankment that are used to establish the required number of roller passes and lift thickness for a given soil and piece of compaction equipment to attain the desired compaction.

- The dynamic cone penetrometer(DCP) is used to measure the stability (DCP index) and uniformity (variation in DCP index) of compacted fill. The QM-E has set control limits for DCP index and variation in DCP index that vary based upon material classification.

Key Findings

- The QM-E program was implemented successfully at this project with minimal construction delays.
- The current control limits and testing requirements contained in the QM-E special provision appear to be adequate for unsuitable soil. Throughout the project, the compaction tests exceeded the set control limits only a handful of times. Additional research and implementation of the QM-E at other projects may reveal that these control limits can be further refined.
- While a majority of the testing that was conducted at this project by the Iowa DOT, contractor, and ISU agreed well, the areas with the largest discrepancies were material classification and moisture-density relationships. This is concerning because many of the control limits for the compaction control testing are established based upon the determined soil properties. To address these concerns, the one-point proctor method should no longer be allowed for the determination of moisture-density relationships of soils; furthermore, additional testing should be required if at any time the running average of relative compaction begins to exceed 105%.
- The comparison between the performance of natural cut material and compacted fill material using CPT testing revealed that the compacted fill has strength at least equivalent, if not greater, than the original cut material.

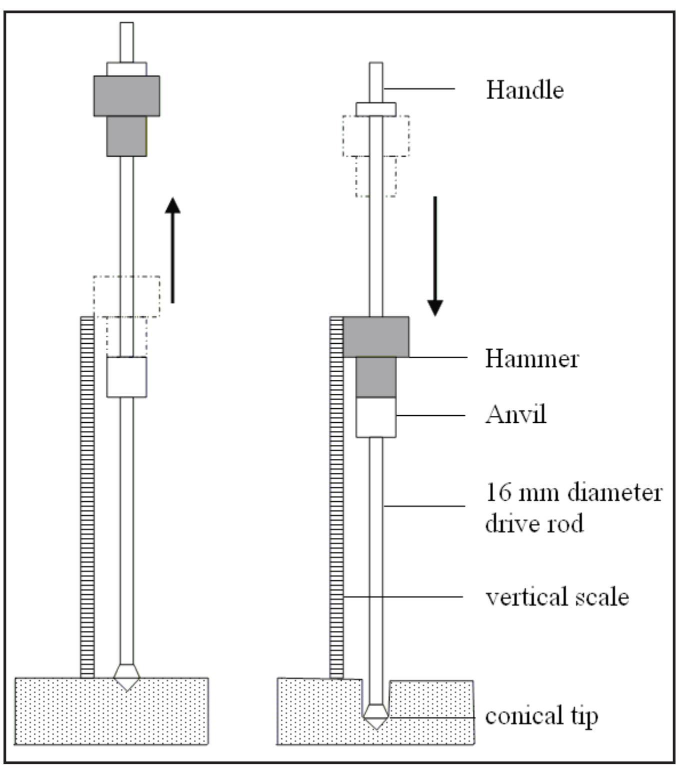
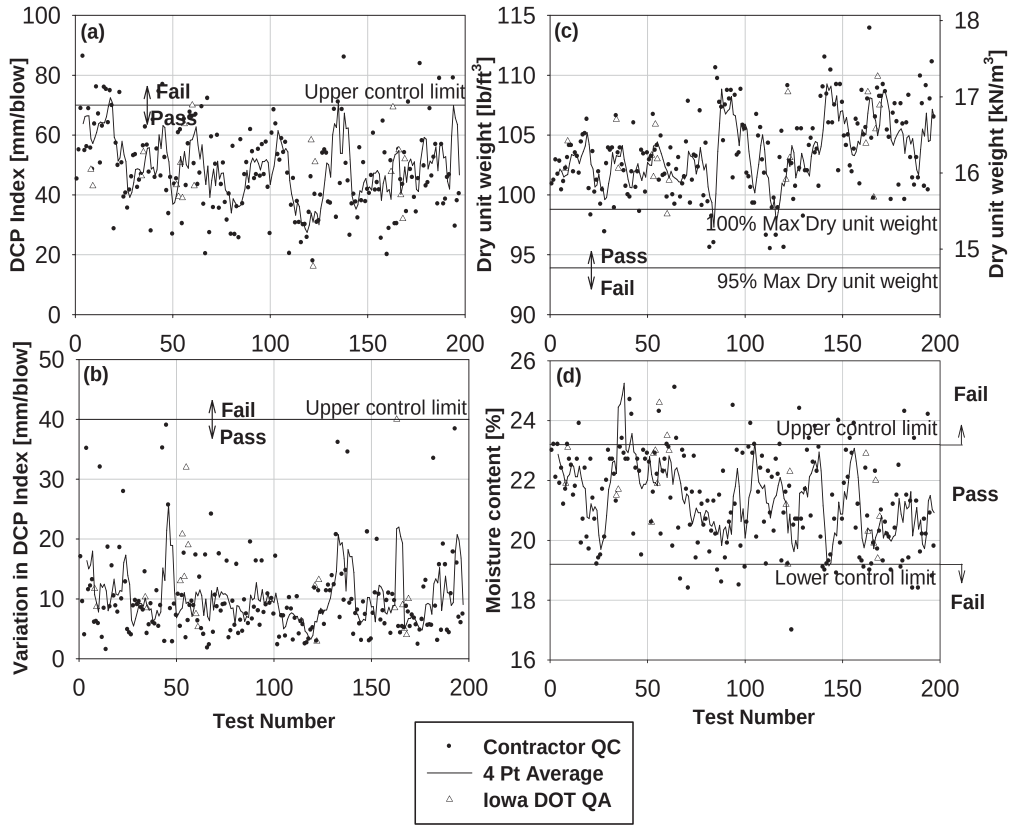
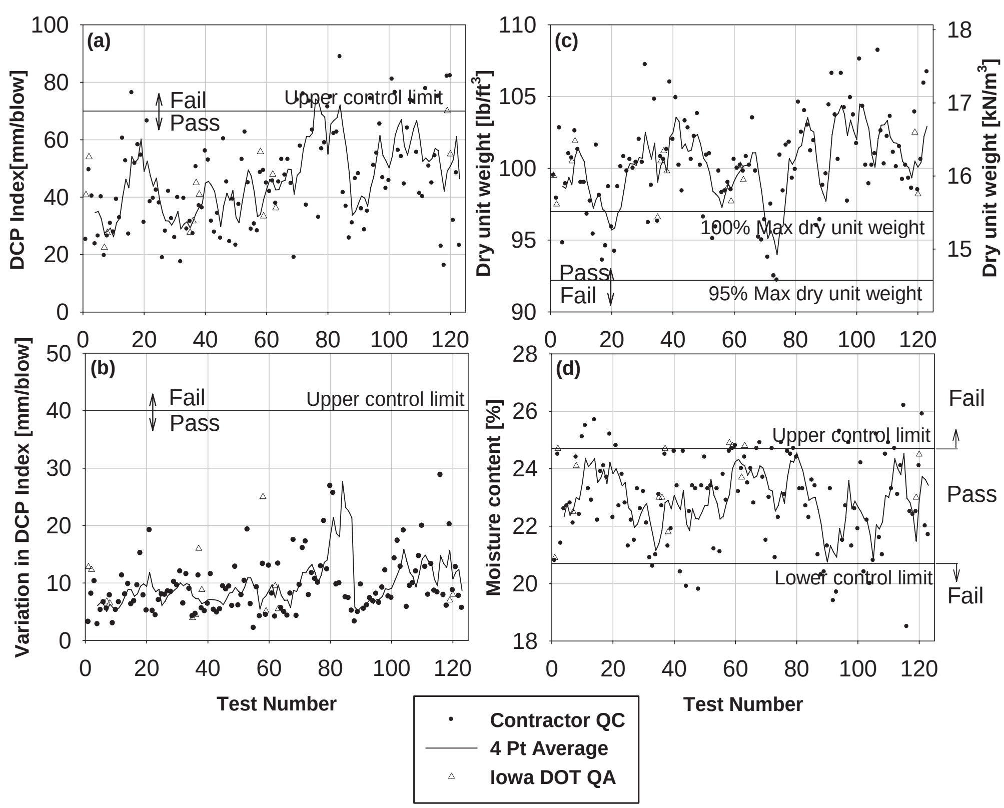


Diagram of dynamic cone pentrometer (DCP)

Dynamic cone pentrometer in use



Control charts for unsuitable soil D



Control charts for unsuitable soil E

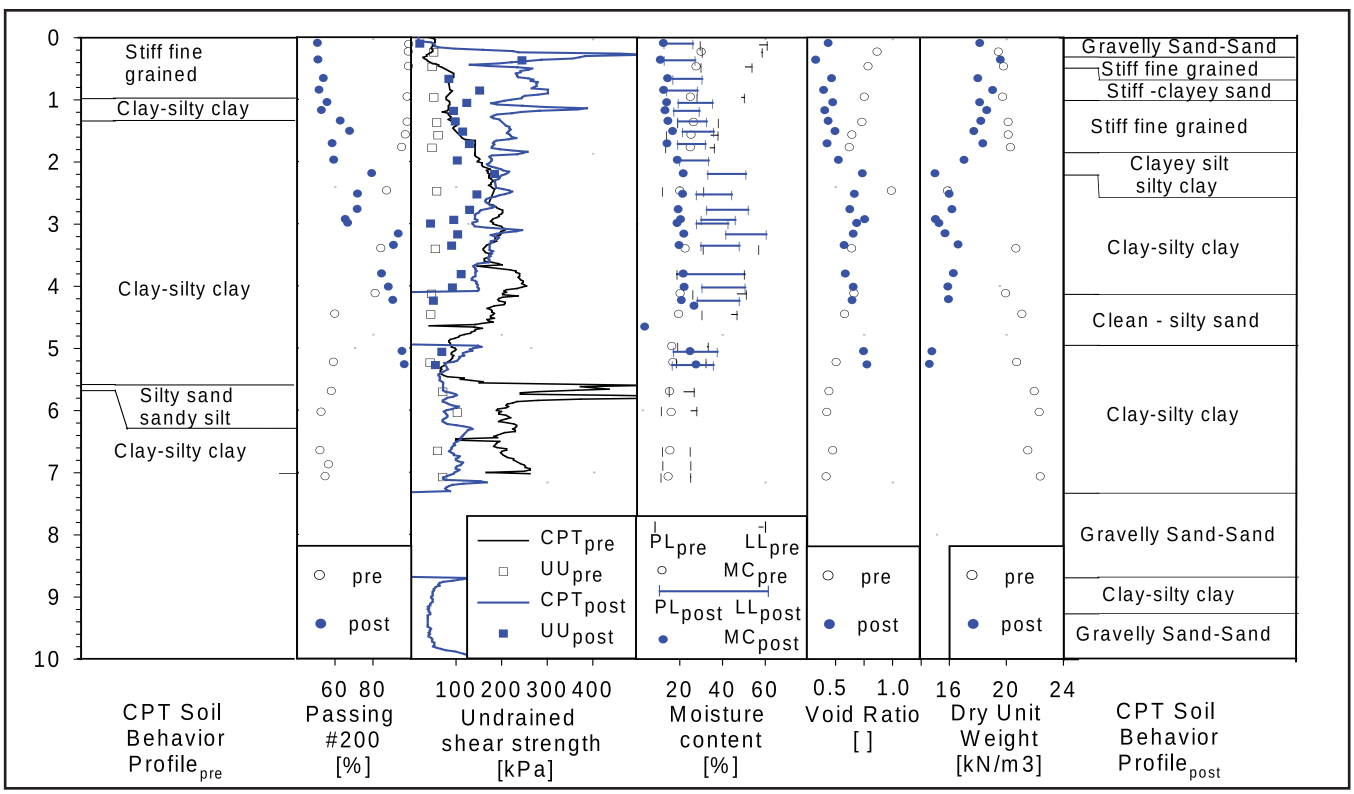
Placement of unsuitable fill

Compaction and testing of unsuitable fill

Implementation Benefits

- Thorough documentation of the quality of fill compaction from multiple in situ tests
- Net improvement in overall quality in comparison to process based compaction control methods
- End result-based specification encourages contractor innovation

Soil boring and CPT testing of finished embankment



Comparison of soil performance and classification properties from CPTU and soil boring investigation at the Crow Creek embankment