EMBANKMENT QUALITY: PHASE III

Iowa DOT Project TR-401
CTRE Project 97-08

Sponsored by
the Iowa Department of Transportation
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ABSTRACT

This report describes test results from a full-scale embankment pilot study conducted in Iowa. The intent of the pilot project was to field test and refine the proposed soil classification system and construction specifications developed in Phase II of this research and to evaluate the feasibility of implementing a contractor quality control (QC) and Iowa DOT quality assurance (QA) program for earthwork grading in the future.

One of the primary questions for Phase III is “Was embankment quality improved?” The project involved a “quality conscious” contractor, well-qualified and experienced Iowa Department of Transportation field personnel, a good QC consultant technician, and some of our best soils in the state. If the answer to the above question is “yes” for this project, it would unquestionably be “yes” for other projects as well. The answer is yes, the quality was improved, even for this project, as evidenced by dynamic cone penetrometer test data and the amount of disking required to reduce the moisture content to within acceptable control limits (approximately 29% of soils by volume required disking). Perhaps as important is that we know what quality we have.

Increased QC/QA field testing, however, increases construction costs, as expected. The quality management-earthwork program resulted in an additional $0.03 per cubic meter, or 1.6%, of the total construction costs. Disking added about $0.04 per cubic meter, or 1.7%, to the total project costs. In our opinion this is a nominal cost increase to improve quality. It is envisioned that future contractor innovations have the potential for negating this increase.

The Phase III results show that the new soil classification system and the proposed field test methods worked well during the Iowa Department of Transportation soils design phase and during the construction phase. Recommendations are provided for future implementation of the results of this study by city, county, and state agencies.

INTRODUCTION

Phase I Summary

Phase I was initiated as a result of internal Iowa Department of Transportation (Iowa DOT) studies that raised concerns about the quality of embankments currently being constructed. Some large embankments had recently developed slope stability problems resulting in slides that encroached on private property and damaged drainage structures. In addition, pavement roughness was observed shortly after roads were opened to traffic, especially for flexible pavements at transitions from cut to fill and on grade and pave projects. This raised the question as to whether the current Iowa DOT embankment construction specifications were adequate. The primary objective of Phase I was to evaluate the quality of embankments being constructed under the current specifications. Overall, an evaluation of the results of Phase I indicated that we were not consistently obtaining a quality embankment constructed under the current Iowa DOT specifications.

A summary of the field and laboratory construction testing and observations is as follows:

- *Field personnel (Iowa DOT and contractors)* appeared to be generally conscientious and trying to do a good job but were (1) misidentifying soils in the field, (2) lacking the necessary soil identification skills, and (3) relying heavily on the soils design plan sheets for soil classification, which often resulted in soil misplacement.

- *Current Iowa DOT specifications*—The current method of identifying unsuitable, suitable, and select soils may not be adequate. One-point proctor does not appear adequate for identifying all soils or for field verification of compaction. Also, a “sheepsfoot walkout” is not, for all soils, a reliable indicator of degree of compaction, compaction moisture content, or adequate stability.

- *Construction observations and testing of cohesive soils*—The sheepsfoot walkout specification produced embankments where soils are placed wet of optimum and near 100% saturation, which can potentially result in embankments with (1) low shear strength/stability, (2) high pore pressure development, and (3) potential for slope failures and rough pavements. In addition, disking and lift leveling specifications were not always enforced and overly thick lifts were being placed on overcompacted and undercompacted soils.

- *Construction observations and testing of cohesionless soils*—Compaction was attempted with sheepsfoot rollers where vibratory compaction was necessary and degree of compaction was monitored using the standard proctor testing, which is an inappropriate method and can grossly overestimate degree of compaction.

Based on the foregoing, recommendations were made for Phase II to evaluate alternative specifications and develop efficient, practical, and economical field methods for compaction control and soils identification.

Phase II Summary

Continuing where Phase I left off, Phase II research was initiated with field investigations and small pilot compaction studies to develop improved field soil classification methods and proper construction practices. Due to difference in soil engineering properties and compaction methods, soils were divided into two categories for research: (1) cohesionless soils and (2) cohesive soils.

Cohesionless Soils

The following were the general conclusions as to the construction of highway embankments with cohesionless/granular materials:

- The current Iowa DOT specifications for highway embankment construction as it pertains to cohesionless materials are inadequate.
- Current practice does not recognize the difference in behavior among cohesionless materials and between cohesionless and cohesive materials.
- The standard proctor test is an inadequate test for cohesionless materials. The bulking characteristics and maximum dry density should be determined by the Iowa modified relative density test. Furthermore, maximum placement moisture content must be identified at soil saturation.
- Vibratory compaction is required for adequate compaction of cohesionless materials.
- Confinement is required for adequate compaction of cohesionless materials.
- Compacted lift thickness of up to 12 inches may be acceptable for clean cohesionless materials.
- Increasing passes of a roller does not necessarily increase density and may decrease density.
- Moisture control is essential for cohesionless materials with an appreciable amount (>15%) of fines (passing the No. 200 sieve).
- The dynamic cone penetrometer (DCP) is an adequate in-situ testing tool for cohesionless materials in order to evaluate field in-place density.

Cohesive Soils

The major conclusions derived from Phase II research pertaining to cohesive soils were as follows:

- The current Iowa DOT specification for sheepsfoot roller walkout is not, for all soils, a reliable indicator of degree of compaction, adequate stability, or compaction moisture content.
- During fill placement, much of the fill material is typically very wet and compacted at high levels of saturation, which causes instability. Moreover, highly plastic materials are

more likely to have high levels of saturation after compaction and consequently low shear strengths by comparison with lower plasticity clays. Field moisture control for highly plastic clays is an effective means of controlling deleterious soil properties.

- Earthwork construction processes including lift thickness and roller passes were not consistent at several embankment projects. Compacted lift thickness was measured to vary from 7 to 22 inches, and roller passes averaged about four to five passes.

- Reduction of clod size and aeration of wet soils by disking, which are currently a part of the Iowa DOT specifications, are rarely enforced in the field. Thus, a renewed emphasis should be placed on educating earthwork contractors and Iowa DOT field personnel about the necessity for disking.

- The DCP was found be a valuable field tool for quality control. From penetrations up to 39 inches, plots of soil strength and lift thickness were generated. Furthermore, by testing for soil stability, shortcomings from density tests (density gradients) were avoided. It is evident from the field data that stability and shear resistance as measured by the DCP are increased by compaction and reduced by high moisture contents. The DCP, however, does not appear to correlate well to moisture/density measurements.

- Through experiments involving different rolling patterns and equipment it was found that a rubber-tired loaded scraper (90 psi tire pressure) effectively compacts loose lifts of heavy fat clay up to 14 inches. With the correct tire pressure and because of the large contact area, rubber-tired rollers are effective at achieving high surface density, achieving density in underlying layers, and locating weak spots below the surface. However, in spite of the fact that the rubber-tired rolling results appear favorable, the method will have to be assessed for efficiency in the future.

- Based only on appearance and feel, predicting the physical performance and judging the suitability of cohesive soils for embankment construction are difficult. The proposed Iowa Empirical Performance Classification (EPC) chart better takes into account complex engineering properties such as swell potential, frost susceptibility, and group index weighting. Also, the EPC will facilitate design and field identification of soil because it only requires testing of Atterberg limits and percent passing the No. 200 sieve, which can be done relatively quickly in the field.

- By considering changes in soil properties from moisture content and determining desired soil properties and constructability, the proposed Iowa Moisture Construction Chart (MCC) was developed. Objectives of the MCC chart are to increase soil uniformity and overall embankment performance for cohesive soils through specifying soil specific minimum and maximum moisture contents. Acceptable moisture content ranges are based on soil classification per the EPC chart.

- Cone penetration test (CPT) shear strength measurements showed that the combined overly thick lifts observed during construction and wet highly saturated soil resulted in extremely variable embankment shear strength with depth. Differential settlement would be anticipated based on these results.

Recommendations

Short term:

1. Adopt proposed soils design and construction specifications
    - Iowa EPC chart A (granular soils)
    - Iowa EPC chart B (fine and coarse-grained plastic soils)

2. Adopt soil specific moisture control requirements
    - Iowa MCC A and B
    - Iowa modified relative density

3. Adopt DCP index and test strip construction specifications
    - Minimum 50 × 500 foot area, 30 inches deep
    - Approximately five to eight test strips per project
    - Guidelines for minimum DCP index requirements:

    a. Granular soils
        - Select ≤ 35 mm/blow
        - Suitable ≤ 45 mm/blow

    b. Fine and coarse-grained plastic soils
        - Select ≤ 75 mm/blow
        - Suitable ≤ 85 mm/blow
        - Unsuitable ≤ 95 mm/blow

4. Develop and initiate a soil certification program for Iowa DOT personnel
    - Soil classification (liquid limit, plasticity index, and grain size analysis)
    - Lab testing (standard proctor compaction and Iowa modified relative density)
    - Field testing (DCP index and moisture testing)

5. Design and let a pilot project based on proposed soils design and construction specifications

Long term:

1. Develop training programs and workshops for field personnel
    - Identification of soils and classification
    - Soil compaction basics
    - Certification programs through the Iowa DOT for design engineers, field personnel, and contractors

2. Establish a quality control/quality acceptance program
    - Ensure embankment materials are properly identified and placed
    - Ensure embankment soils are properly moisture conditioned and compacted

3. Consider the flowchart shown in Figure 1 for a quality control (QC)/quality assurance (QA) program in the future

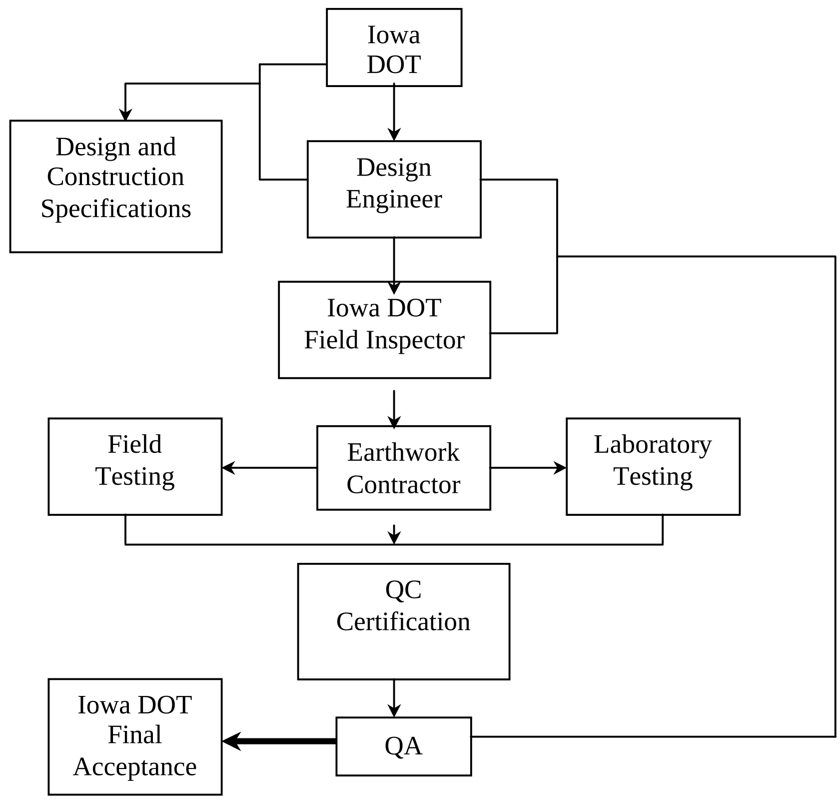

Figure 1. Proposed Iowa DOT Flowchart for QC/QA Program

Phase III Introduction

Based on recommendations from Phase II, Embankment Quality Phase III research was initiated. Phase III work consisted of developing a quality management-earthwork (QM-E) program and pilot testing the program on a full-scale project. The pilot project was used to design, field test, and refine the proposed soil classification system and construction specifications and to evaluate the feasibility of implementing a contractor QC and Iowa DOT QA program for earthwork grading in the future.

The primary tasks for Phase III research consisted of the following:

1. Develop a contractor QC and Iowa DOT QA embankment construction and testing program for feasibility testing on a pilot project.

2. Assist the Iowa DOT Office of Soils Design in redesigning the pilot project based on a newly proposed soil classification system.

3. Develop QC/QA procedures, training materials, and training program (grading technician level I) for proposed laboratory and field testing procedures. The materials are intended for use as part of a certification program for contracting agencies and contractor personnel.

4. Train contractor QC and Iowa DOT QA personnel involved in the pilot project field testing and acceptance procedures.

5. Assist in field lab setup at the pilot project site.

6. Act as a consultant to QC/QA personnel during construction and independently evaluate embankment quality being attained during construction and evaluate the adequacy of the proposed specifications and test procedures.

7. Based on the results of the pilot project, provide final recommendations for design and construction specification changes for Iowa DOT consideration and implementation.

8. Evaluate project results for practical application on county and city projects and develop tentative guidelines.

Development of a Quality Management-Earthwork Specification

The challenge of developing a QM-E specification is twofold. First, the specification must result in improved embankment quality, but must also balance increased quality with increased cost and number of working days. Second, the recent trend in Iowa's state budget restrictions magnifies the importance of not significantly increasing construction costs or over extending Iowa DOT field personnel with a QC program that is overly aggressive.

QM-E specifications were drafted early in the Phase III research period following the recommendations of Phase II. Following the initial draft, the document was revised several times over a period of about 12 months. Several discussions with the technical steering committee had a significant and positive impact on the final recommendations. The steering committee consisted of earthwork contractors, city and county representatives, senior construction technician supervisors from Iowa DOT resident construction offices, representatives of the Iowa DOT Office of Construction and Office of Soils Design, and Iowa State University (ISU) researchers. Additional input and suggestions were obtained following presentations at the Associated General Contractors (AGC) of Iowa 79th Annual State Convention and the Transportation Research Board (TRB) Earthwork Committee meetings. The special provisions for QM-E are provided in Appendix A.

Pilot Project Selection

Phase III research was initiated by selecting a suitable full-scale pilot project to evaluate the proposed design process and QM-E specifications. Early in the project selection process, criteria were established by the research team, which focused primarily on soil types. The QM-E program includes soil-specific compaction, moisture, and stability requirements. Thus, it was preferable to conduct the QM-E pilot study on a project that contained a wide range of soil types, including select to unsuitable cohesive soils (silts and clays) and granular cohesionless (fine to coarse sands) materials. Research conducted during Phases I and II showed that unsuitable fat clayey soils (i.e., A-7-6 soils) and alluvial silty clays and silty sands (i.e., A-2-4 and A-4) were some of the most problematic soils. Therefore, a project with a wide range of soil types would be helpful in development of the QM-E program. Ultimately, however, the steering committee selected an available project located in Bremer County on U.S. Highway 218 north of Waverly, Iowa, to south of Plainfield, Iowa (NHSX-218-8(39)-3H-09), where the soil conditions were relatively uniform. Soils consisted primarily of glacially derived suitable and select cohesive soils. Based on work conducted during Phases I and II, these soils, for the most part, provide good workability and rate fair to good as subgrade materials. Unfortunately, this site did not provide the opportunity to evaluate a wider range of soil types, but it did provide the project with a suitable design and construction schedule for testing. Further, an adjacent project provided the opportunity for the ISU researchers to conduct limited field tests on fine-grained sandy soils.

Soils Design

Once the pilot project was chosen, soils had to be reclassified from existing Iowa DOT specifications to the soil performance classification system developed under Phase II. This work was conducted in the Iowa DOT Office of Soils Design with assistance from the research team and required approximately two days. The design process consisted of (1) reclassifying the soils for the “Q” sheets using liquid limit (LL), plasticity index (PI), and fines content (passing No. 200 sieve) data, (2) redefining the boundaries between select, suitable, and unsuitable on the plan sheets using a CAD computer program, and (3) recalculating soil quantities, which are generated automatically by the computer software. As anticipated, the current and new classifications were similar, requiring only minor adjustments to the plan sheets. The most frequent difference between the current method and the new soil classification method was in classification of topsoil. Topsoil was often classified as select under the new method based solely on LL, PI, and fines content. Topsoil should generally be classified as unsuitable because of its relatively high carbon content (typically ≥ 3.0%). Topsoil was identified from on the soil data sheets from carbon content and soil color and classified as unsuitable on the revised “Q” sheets. Upon completing the revisions, soils information on the plan sheets included both the current Iowa DOT classification (American Association of State Highway and Transportation Officials [AASHTO] and U.S. Department of Agriculture) and the new classifications; however, the new classifications were to be followed during construction. The new system does not require any additional laboratory testing to be conducted.

Project Letting

After selection of the pilot project and plan revisions, the project went out for bid. A pre-bid meeting was held for prospective bidders to address the research team. Minutes of the pre-bid meeting and an addendum to the QM-E special provisions are included in Appendix B.

Cost/Benefit Analysis

As cost of the QM-E program is an important aspect of this research, bid prices are evaluated and discussed later in this report.

QC/QA Technician Training and Certification Program

Approximately two weeks prior to beginning construction on the pilot project, a five-day technician training program was conducted for Iowa DOT and contractor personnel. The purpose of the training program was to improve basic soils knowledge, laboratory testing skills, and field testing skills. A reference and training manual was developed by the researchers for the course titled *Grading Technician Level I—Technical Training and Certification Program.* ISU personnel taught the certification program at Des Moines Area Community College (DMACC) facilities in Boone, Iowa. The purpose of the training program was to improve basic soils knowledge and laboratory testing and field testing skills. All participants passed the certification exam at the end of the training period. A brief description of the grading technician certification program is provided in Appendix C. The complete reference and training manual is published separately from this report.

Pilot Project Field and Laboratory Testing

In-situ field testing conducted in accordance with the QM-E specifications generally consisted of soil moisture content, density/compaction, stability/strength, uniformity, and lift thickness determinations. Laboratory testing included determination of soil Atterberg limits (liquid limit, plastic limits, and plasticity index), “maximum” dry density and “optimum” moisture content at standard proctor compaction energy, and determination of percent fines (passing No. 200 sieve). A field lab was established at the construction site and was equipped by the Iowa DOT with the needed equipment for testing. A list of the needed QM-E field lab equipment and prices is provided in Appendix D. The contractor hired a technician from a local consulting firm to conduct the field and laboratory activities and provided the laboratory testing trailers. The technician was required to pass the certification tests and examination.

KEY FEATURES OF THE QUALITY MANAGEMENT-EARTHWORK PROGRAM

The following is a brief summary of the QM-E special provisions (SP-95509M) document developed for the pilot project. The original special provisions document is provided in Appendix A. It is envisioned that SP-95509M will evolve into an Iowa DOT developmental specification in the future.

Field Personnel

The contractor provides field personnel to maintain activities of the QC program (current employees or hired technicians), and the Iowa DOT provides field personnel to maintain activities of the QA program. All QC/QA technicians must successfully complete the "Certified Grading Technician Level I" training course and examinations. In order to become certified the technician must successfully demonstrate laboratory testing procedures and pass a written exam.

Field Laboratory

The contractor provides a field trailer (or trailers) equipped with a sink with potable water for the field lab. The field trailer should be able to support various testing equipment (e.g., standard proctor compactor and relative density apparatus). For the pilot project the Iowa DOT furnished the testing equipment for the field lab. However, in the future it is envisioned that the contractor will provide both the field trailer and equipment. The field lab would be a one-time purchase. A detailed list of necessary laboratory equipment and estimated cost is provided later in this report.

Test Procedures

Test procedures referenced in the QM-E document include applicable Iowa DOT Office of Materials instructional memorandums (IMs), Iowa DOT Materials Laboratory test methods, standards of AASHTO and the American Society for Testing and Materials (ASTM), and newly developed IMs as a result of this research. The new IMs are described in Attachments A through E of the QM-E special provisions document provided in Appendix A:

A. Soil Performance Classification for Embankment Design and Construction

B. Field Determination of the Percent Material Passing the No. 200 Sieve

C. Soil Moisture Content Limits for Embankment Construction Purposes

D. Standard Dynamic Cone Penetrometer in Shallow Pavement and Soil Applications

E. Iowa Modified Relative Density Test for Determination of Bulking Moisture Contents of Cohesionless Soils

Construction Equipment

For embankments constructed in accordance with the QM-E special provisions, *any type of compaction equipment* may be used that would produce the desired end result as demonstrated by test sections and quality control tests, which include moisture content, density, stability and uniformity. Test sections are areas where new equipment or methods such as thick lifts, using hauling equipment in the rolling pattern, or a varied number of roller passes may be attempted. If the equipment and alternative methods produce a fill that meets the minimum end-result test criteria, it is approved. If the fill does not meet the end-result test criteria (moisture, density, stability, and uniformity), it must be reworked until the minimum criteria are met. An exception to this specification is that if rubber-tired or steel-drum-type rollers are used for compaction, a light disking is to be used to roughen the finished surface of each lift to provide interlock between successive lifts. Interlocking is essential to reduce the potential for development of weak soil shear planes in the embankment.

It is envisioned that using an end-result specification for earthwork construction in lieu of the current method–type specification (e.g., sheepsfoot walkout and eight roller passes) will encourage and provide incentive for contractor innovation in the future.

Test Sections

Test sections are compacted fill areas within the embankment designated for field testing to establish proper rolling patterns and lift thickness. Construction of a test section is initiated by a change in soil type or a change in soil compaction methods or equipment. Information documented at each test strip includes (1) soil type, (2) maximum compacted lift thickness, and (3) compaction equipment and rolling pattern. A test strip is not approved until the moisture content, density, stability, and uniformity are within the required limits. Once a test trip is approved, the remainder of embankment fill using that soil type is compacted using the same methods. Quality is verified by random QC/QA tests. The appropriate control limits for moisture, density, stability, and uniformity are determined from laboratory analysis and are primarily a function of soil type.

A test section is initiated by first obtaining a representative sample of soil prior to construction of the test section. The soil is then classified using Attachment A of Appendix A, including tests to determine standard proctor or relative density. Minimum dimensions of test sections were established as follows: length 75 m, width 15 m, and depth of one lift. Four random locations within each test area are tested for thickness of compacted lift, moisture content of compacted lift, density (per lift as a function of roller passes), mean DCP index (per lift as a function of roller passes), and mean change in DCP index (per lift as a function of roller passes). Roller passes and lift thickness, for example, are adjusted until the minimum test criteria are meet. Once the equipment and compaction procedures are established the technician records them on a data sheet and monitors subsequent fill placement by observing the construction process and performing periodic QC tests. The Iowa DOT also monitors the construction process and performs periodic QA tests.

Test Requirements

Moisture content, density, stability, and uniformity are the key evaluation criteria used during construction. The control limits (upper and lower) for moisture content of compacted embankment materials are determined from “Soil Moisture Content Limits for Embankment Construction” (Attachment C of Appendix A). The specified range for acceptable moisture content limits is based on laboratory compaction tests. For cohesive soils the specified moisture limits ranged from 0.9 to 1.2 times standard proctor “optimum” moisture content. For cohesionless soils the "bulking" moisture content (typically 2%–7%) is to be avoided as determined from the Iowa modified relative density test, and the upper limit is set at 80% relative density. Previous work conducted during Phases I and II of the research shows that moisture contents within the specified limits facilitate compaction.

In-situ density/compaction requirements change as a function of soil type and placement depth in the embankment. Cohesive soils 0.9 m beneath final subgrade elevation require a minimum of 93% standard proctor density. Cohesive soils within 0.9 m of final subgrade elevation require a minimum of 95% standard proctor density. Cohesionless soils for all elevations require a minimum relative density of 80%. However, all embankment fill adjacent to and within 60 m of a bridge abutment is to be compacted to upper zone quality control standards. The compaction of subgrade in cut sections is compacted to quality control standards for upper zone embankments as well. The four-point moving average density of embankment fill material shall meet the compaction criteria.

The required stability/strength is measured by the DCP and is specified as shown in Table 1. DCP tests are useful because they allow measurements up to 39 inches (1m) deep. Further, the test requires a simple and relatively inexpensive instrument. Tests are conducted by driving a 0.8-inch (20 mm) 60-degree cone into the ground with a 17.6-pound (8 kg) hammer falling 22.6 inches (575 mm). Results are converted into mm/blow. The four-point moving average of the mean DCP index is not to exceed the following values listed in Table 1. Figure 2 in Attachment F of Appendix A shows an example of a mean DCP index control chart. In addition to stability/strength, the results of a DCP test provides for measurement of compaction uniformity. If the penetration per blow is consistent through the entire depth of the test, the soil is considered uniformly compacted. However, if the penetration per blow varies significantly with depth, such as occurs in the case of an "Oreo cookie" effect (alternating lifts of soft and dense soils due to excessive lift thickness), the uniformity value will be high, indicating nonuniformity. Table 2 lists the specified uniformity acceptance criteria. The four-point moving average of the mean change in DCP index shall not exceed the values listed in Table 2.

Table 1. Requirements for Mean DCP Index Indicating Stability

Soil Performance Classification (Attachment A of Appendix A)		Maximum Mean DCP Index (mm/blow)
Cohesive	Select	75
	Suitable	85
	Unsuitable	95
Intergrade	Suitable	45
Cohesionless	Select	35

Table 2. Requirements for Mean Change in DCP Index Indicating Uniformity

Soil Performance Classification (Attachment A of Appendix A)		Maximum Mean Change in DCP Index (mm/blow)
Cohesive	Select	35
	Suitable	40
	Unsuitable	40
Intergrade	Suitable	45
Cohesionless	Select	35

Controlling Moisture Content

Phases I and II of the research showed that the stability of cohesive soils is significantly affected by changes in moisture content. In light of this finding, an effort was made to build in criteria and an incentive for the contractor to better control moisture content. If the deposited soil material contains moisture in excess of the specified moisture limits, disking to remove excessive moisture is required to uniformly dry the material to within the specified moisture limits prior to compaction of the layer. The contractor is paid for disking to reduce excessive moisture. Further, disking is not considered a controlling operation for the purpose of charging working days as per Article 1108.02, paragraph F, of the standard specifications. Conversely, should the deposited material be dry to the extent that it is not within the specified moisture limits, the material is moistened uniformly to the required limits before it is compacted.

Contractor QC personnel have the responsibility to test and ensure that the moisture content of the compacted embankment material is within the range for the particular performance classification of the soil being placed. Again, the control limits for moisture content are based on "Soil Moisture Content Limits for Embankment Construction" (Attachment C of Appendix A). For reporting purposes moisture content is calculated to the nearest 0.1% based on dry weight of soil. Initially, all individual tests for moisture content during embankment construction were to be within the specified moisture control limits; however, that was later adjusted to a four-point moving average to be more realistic and practical for field construction.

Compacted Lift Thickness Measurement

As discussed above, the limit for compacted lift thickness is established during test section construction. Compacted lift thickness is measured and recorded concurrently with all density and DCP index tests. The four-point moving average of lift thickness is not to exceed the value established in the test section. DCP index tests have been found to work well for determination of lift thickness.

Test Frequency During Embankment Construction

Compacted lift thickness, moisture content, and density are measured for the uppermost lift of embankment being placed. DCP index tests (stability and uniformity) are taken at the same location to a depth of 1 m. The minimum test frequency during embankment construction is listed in Table 3. Note however, for the initial 1,000 m^3 of embankment construction following a test section, four tests shall be taken to establish a four-point moving average.

Table 3. Minimum QM-E Test Frequency

Test	Minimum Test Frequency
Compacted lift thickness Moisture content of compacted fill Density Dynamic cone penetrometer (DCP)	Concurrently every 1,000 m^3 (compacted)
Determination of soil performance classification and moisture control limits	One every 25,000 m^3 or if there is a change in material as determined by the engineer

Field Records

The contractor QC personnel are responsible for documenting all observations, records and inspection, changes in soil classification, soil moisture content, fill placement procedures, and test results on a daily basis. The results of the observations and records of inspection are noted as they occur in a permanent field record. Copies of the field DCP index tests, field moisture tests, field density tests, compacted lift thickness measurements, running average calculation sheets, soil performance classifications, field test strip construction procedures, and soil classifications are provided to the engineer on a daily basis. The original testing records (raw field and lab data sheets) and control charts are provided to the engineer in a neat and orderly manner within five days after completion of the project.

Control Charts

The contractor QC personnel are responsible for field DCP index, field moisture, field density tests, and compacted lift thickness measurements and maintaining standardized control charts for each grading area. The charts are posted at a location agreed upon by the contractor QC and the Iowa DOT QA personnel. Test results obtained by the contractor QC person are recorded on the control charts the same day the tests are conducted. The results for the described field data are recorded on the standardized control charts for all randomly selected subgrade cut and fill locations tested. Both the individual test point and the moving average of four data points are plotted on each chart.

Corrective Action

The contractor QC personnel are to notify the Iowa DOT QA personnel when a four-point moving test average of moisture, density, mean DCP index (stability), or mean change in DCP index (uniformity) falls outside the specified control limits. All randomly selected tests are part of the project files and are included in the moving average calculations.

If a four-point moving average from the field moisture and density, mean DCP index, or mean change in DCP index test falls outside of the specified control limits, the contractor takes corrective action(s) on the subsequent fill placed. The contractor and engineer discuss corrective action(s) to bring the fill material for the subsequent fill within the control limits. The contractor performs the corrective action and provides documentation. If the corrective acti on improves the failed field test such that the new moving average, after a re-test, is within the control limit, the contractor may continue subgrade cut or fill material placement.

If the new moving average point is still outside of the control limit after the re-test, the subgrade fill material in the recently tested area shall be considered unacceptable. If the embankment material is considered unacceptable, the contractor performs additional corrective action(s) to improve the fill material until the new moving average, after a re-test, falls within the control limits.

If the contractor’s initial control data are later proven incorrect (resulting in a corrected four-point moving average of field moisture and density, mean DCP index, and mean change in DCP index falling outside of the control limits), the subgrade fill material represented by the incorrect test data shall be considered unacceptable. The contractor shall employ the methods described above for unacceptable material.

Iowa DOT Quality Assurance

Iowa DOT quality assurance tests are conducted on a split sample at the exact location as the contractor’s quality control test. In the event comparison test results are outside the above allowable differences, the engineer will investigate the reason immediately. The engineer’s investigation may include testing of other locations, review of observations of the contractor’s testing procedures and equipment, and a comparison of test results obtained by the contractor, with those obtained by the contract authority.

Moisture Content

Moisture content is calculated and reported to the nearest 0.1%. Differences between the contractor’s and engineer’s moisture content test results will be considered acceptable if moisture content is within 1.0% based on dry weight of soil.

Density

Differences between the contractor's and engineer's in-place density tests will be considered acceptable if the dry density is within ±80 kg/m^3.

Optimum Density and Optimum Moisture

Differences between the contractor's and engineer's proctor test results will be considered acceptable if the optimum dry density is within ±80 kg/m^3 and the optimum moisture is within ±1.5% based on dry weight.

Referee Testing

If a difference in procedures for sampling and testing and/or test results exists between the contractor and the engineer that they cannot resolve, the Iowa DOT Central Materials Laboratory in Ames or another mutually agreed upon independent testing laboratory will be asked to provide referee testing. The engineer and contractor will abide by the results of the referee testing. The party found in error will pay service charges incurred for referee testing by an independent laboratory.

Acceptance

The engineer will base final acceptance of tests and materials on the results of the contractor's quality control testing as verified by the engineer's quality assurance tests.

Method of Measurement

All excavation in preparation for and construction of QM-E embankment are included in Class 10 excavation prices in accordance with Article 2102.13 of the standard specifications. The construction of embankment will not be measured separately for payment *except* as follows:

Disking to Reduce Excessive Moisture

The engineer will count the number of days each disking unit is used to reduce excess moisture from deposited uncompacted material, or for disking ordered by the engineer for reasons other than reducing moisture.

If the disking unit is used more than one hour but less than four hours during the day, the disking unit shall be paid as a half-day. If used for a major part of a day, or greater than four hours, the unit shall be paid for a full day.

Water for Embankment Construction

Water required to moisten materials placed in embankment will be measured in kiloliters by gauging the contents of the transporting vehicle or by metering the supply. Authorized water for finishing the roadbed will not be measured for payment if a period in excess of two calendar days has elapsed between final compaction of a dump area and final finishing of the same area.

Test Sections

For establishing the compactive effort and lift thickness to be used in construction of QM-E embankment, the contractor shall construct a test section for each classification of soil encountered. The engineer will count the number of test sections constructed.

The placement of the volume of embankment material in test sections shall be included in quantities of Class 10 excavation, roadway, and borrow.

Quality Control Program

The item will be the lump sum for the QC program.

Basis of Payment

Disking to Reduce Excessive Moisture

The contractor will be paid the contract unit price for the number of days per unit that disking is required for material to be within moisture control limits of Attachment C and was performed by the contractor, or for any disking ordered by the engineer and performed by the contractor.

Water for Embankment Construction

Water required for material to be within moisture control limits of Attachment C and added by the contractor shall be paid for at the contract unit price per kiloliter for water.

Test Sections

The contractor will be paid for each test section ordered by the engineer. The unit price shall include all labor, equipment time, and sampling and testing needed to meet requirements for test sections. Placement of embankment material in test sections shall also be paid as Class 10 excavation, roadway, and borrow.

Quality Control Program

The availability for pre-construction training and the furnishing of a full-time certified grading technician I or above during construction shall be included in the item for the QC program. This shall include all labor, sampling and testing, process control inspection, and necessary adjustments for construction of test sections and embankments to meet the requirements of this special provision.

QM-E Field Laboratory

For the QM-E field lab furnished, the contractor will be paid the contract unit price for field lab QM-E. This payment shall be full compensation for furnishing, moving, and maintaining the QM-E field lab, including a shed or trailer to house additional testing equipment, and for furnishing the utilities and sanitary facilities.

Revisions to the QM-E Special Provisions

During construction, the QM-E special provisions were modified by two no-cost contract modifications. These changes were incorporated into the above discussion and are provided in Appendix B for reference. Upon completion of the pilot project, a steering committee meeting was conducted to discuss additional changes needed to improve the special provisions. The minutes from this post-construction review meeting are provided in Appendix E. For future QM-E projects it is recommended that these changes be incorporated into a revised set of QM-E special provisions.

Cost of the QM-E Program

During development of the QM-E program, considerable emphasis was placed on developing a testing program that would not significantly increase overall costs for earthwork construction in the state of Iowa. However, it was generally accepted by the technical steering committee that "increased quality results in increased cost." Additional costs for implementation of the proposed QM-E program were anticipated from increased disking and compaction time, field technician salaries, and equipment for the laboratory and field testing. Conversely, by shifting specifications from method-type specifications to end-result specifications, it was viewed that contractor would be provided the opportunity to be more innovative in the field, which could eventually offset increased cost from the QM-E program. A pre-bid informational meeting was held to answer any contractor questions. The pre-bid meeting notes and a one-page handout provided at the meeting are included in Appendix B. An addendum followed the pre-bid meeting and is also included.

Table 4 lists the lowest five bid prices for the pilot project. Cost is divided into the (1) QM-E testing program, which includes the salary for technicians, (2) furnishing of the field lab, (3) construction of test sections, and (4) cost for disking per day. The average of the top five bidders for the QM-E program is about 2% of the total project cost. On a per-cubic-meter basis this adds about $0.04. The field lab averaged about $6,400, which was expected. The unit cost for test sections and the price for disking varied significantly, ranging from $500 to $3,000 and $600 to $3,000, respectively. This wider range may be due to contractor uncertainty in the new construction specifications. Overall, the increased cost was less than expected.

Figure 2 shows the average price of select and Class 10 soil on a per-cubic-meter basis for the period 1996–2001 (from "Summary of Awarded Contract Prices for English and Metric Items," Iowa DOT Office of Contracts, 1996–2001). During that time period, the average cost trends upward. The pilot project cost per cubic meter is also provided as the solid circle and square points in Figure 2. The actual cost per cubic meter for select ($2.25) and Class 10 ($1.69) on the pilot project was less than the 2001 averages ($2.46 and $2.31, respectively). This could be attributed to the relatively "good" soils on-site. For perspective, a range of values for the top five bid prices for the pilot project is also shown. The range of values from all five bidders encompasses the range expected.

In addition to QM-E program costs described above, it should be pointed out that approximately $26,000 was required to furnish the equipment for the field lab. The equipment, which was furnished by the Iowa DOT, was used in the technician training program at DMACC as well as for the field pilot project. An itemized list of equipment expenses is provided in Appendix D. In the future this equipment could be used on more pilot projects.

Table 4. Top Five Bid Prices for QM-E Pilot Field Testing Program

Bidder	Total Bid	% Over Low Bid	QM-E Quality Control Testing Program: Total Cost	QM-E Quality Control Testing Program: Cost/m³ of Class 10 and Select	QM-E Quality Control Testing Program: Cost as % of Total Project Cost	Cost for Field Lab	Unit Price for Test Sections	Unit Price for Disking
1 (low)	$2,768,658	—	$45,000	$0.03	1.6	$5,000	$500	$960
2	$2,779,313	0.4	$40,000	$0.03	1.4	$6,000	$1,000	$600
3	$3,159,188	14.1	$60,000	$0.04	1.9	$6,000	$3,000	$3,000
4	$3,181,949	14.9	$100,000	$0.07	3.1	$10,000	$1,500	$750
5	$3,841,489	38.7	$70,000	$0.03	1.8	$5,000	$3,000	$900
Average	—	—	$63,000	$0.04	2.0	$6,400	$1,800	$1,242
Std. dev.	—	—	$23,874	$0.02	0.7	$2,074	$1150	$993

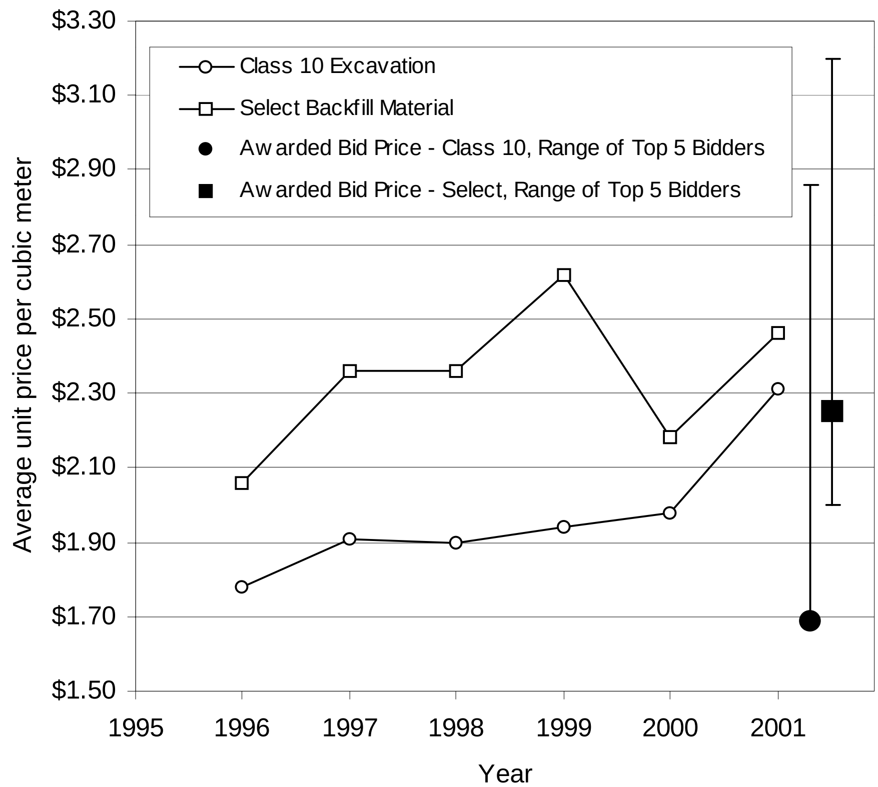

Figure 2. Average Cost per Cubic Meter for Class 10 and Select Materials Relative to the QM-E Pilot Project

GRADING TECHNICIAN CERTIFICATION PROGRAM

The training program consisted of a weeklong (five days) lecture and laboratory session conducted in the materials lab at DMACC in Boone, Iowa. The *Technician Workbook,* developed specifically for this certification class, was mailed out to participants about two weeks prior to class. The participants were asked to familiarize themselves with the logistics of the course prior to coming to class.

Materials, Course, and Examination

The following sections were taken from the workbook:

Educational Materials

This *Technician Workbook* is the primary student resource and contains the essential material you need to study prior to the training program and to prepare for the examinations.

Section A of the workbook is intended to introduce you to soil engineering terminology, soil types, soil formation and origin of Iowa soils, soil classification and engineering properties of soil. It is also intended to be a future reference source as you become more familiar with Iowa soils and their properties. You will need to read this material and complete the self-study questions at the end of each subdivision PRIOR TO COMING to the training program.

There will be a quiz over Section A on the first day. Quiz questions will be taken from the self-study questions. The purpose of this quiz is to help the training instructors assess your knowledge of soils and to determine what background lectures to focus on. The “Written and Performance” examinations will contain 5 to 10 questions from Section A.

Section B contains the soil testing methods and procedures that are the focus of this training program. At the end of each subdivision are a set of study questions and a test method checklist. These will be completed during the training program. You will be required to spend some time after class studying for the next day’s activities. The “Written and Performance” examinations will focus on materials in Section B.

Training Course

Your success on the examinations will ultimately depend on your willingness to invest an adequate amount of time studying before and during the training course. It is recommended that you allow six to eight hours before the course reviewing background information and answering self-study questions.

Figure 3 provides an overview of the certification program and process.

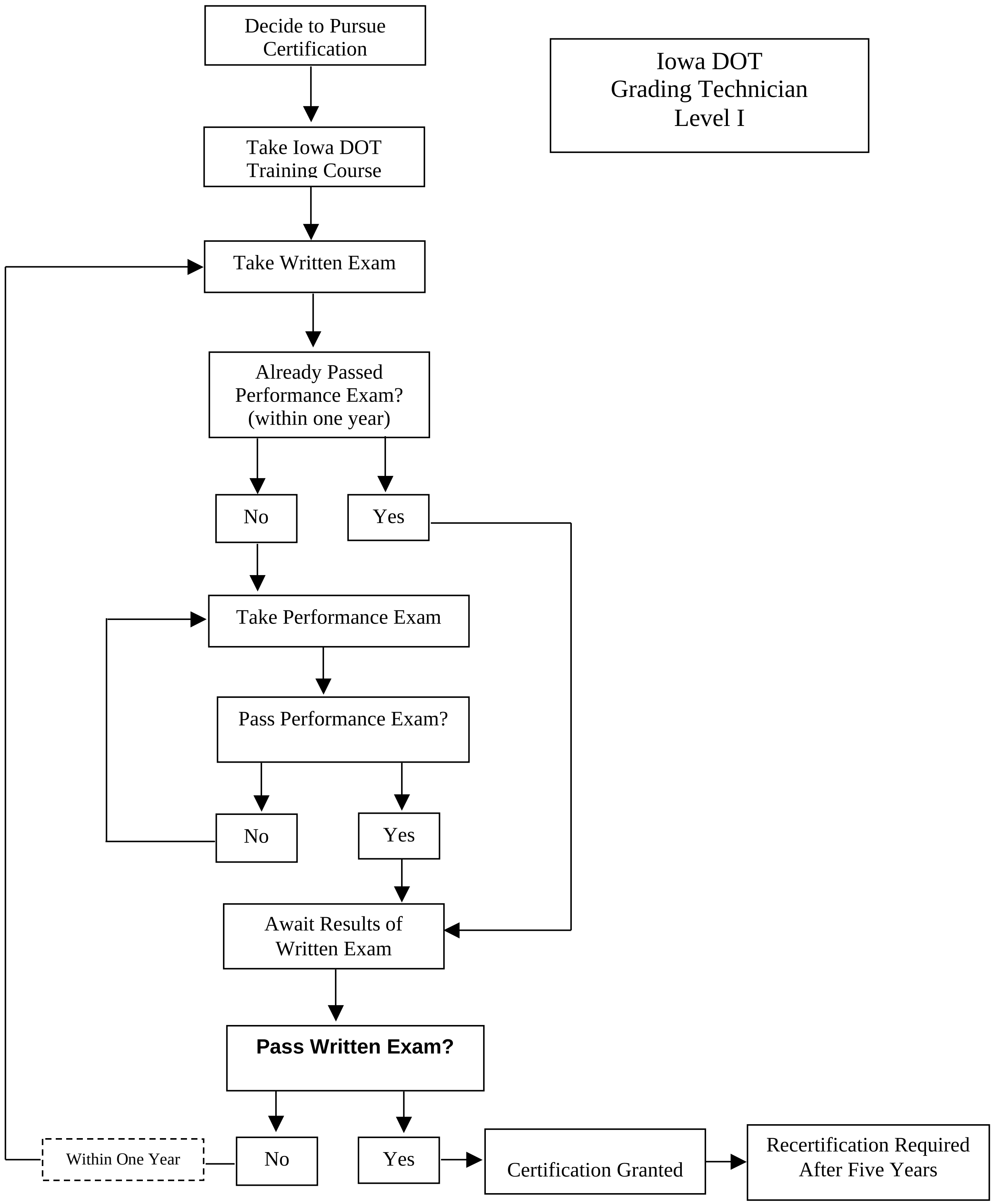

Figure 3. Proposed Certification Program and Process

Written Examination

The one-hour written examination covers the material in Sections A and B, but focuses on the eight Iowa DOT Tests included in Section B. Questions are derived directly from the text as well as special applications that you may encounter on a construction project.

The examination consists of 55 multiple choice and true/false questions.

All questions require detailed knowledge of the tests and basic reading comprehension and math skills. While the level of difficulty for each question will vary, they are not meant to trick or confuse you.

No questions will be answered during the examination.

To pass the examination, *both* of the following criteria must be met:

1. At least 60% of the questions in each of the eight Iowa DOT tests must be answered correctly (e.g., five correct out of eight equals 63%).

2. At least 70% of all questions on the examination must be answered correctly (e.g., 39 correct out of 55 equals 71%).

The written examination is closed book, which means that no technical materials or notes are allowed in the room during the examination. Calculations may be required for some questions; therefore, you may bring a battery-powered pocket calculator to the examination. You may not share a calculator with another examinee during the examination.

Performance Examination

In addition to the written examination, you are required to successfully perform each of the eight test methods. You may be required to verbally describe the procedures for testing if performance testing of the method is not feasible. You will be judged on your ability to correctly perform all required procedures for each of the tests based on the criteria shown on the performance examination checklists (included in this workbook at the end of each subdivision in Section B). Omission of one or more of the prescribed procedures will constitute failure of that test. You will be allowed two trials of the examination for each test during the course. Failure on any one of the prescribed tests after two trials will constitute failure of that part of the performance examination. Grading of the performance examination is on a pass/fail basis only.

During the performance examination, you will be required to perform each test in the direct presence of a qualified examiner. You may not refer to notes or any other written material. Talking is not prohibited, but it is not necessary. The examiner is not allowed to respond to any questions or otherwise assist you in performing each method. Therefore, you should refrain from asking for or accepting coaching or advice while the examination is in progress.

Immediately following completion of each trial, the examiner will tell you whether you passed or failed that trial. If a failure has occurred, the examiner will tell you which particular part of the method was performed or described incorrectly. The examiner will not stop the trial at the point that an error is made, nor will the examiner express anything resembling approval or disapproval, either verbally or with body language. If during a trial you feel that you have made an error, you may request to suspend that trial and begin the procedure over. If a trial is suspended voluntarily, it will not be counted as a failure of the trial. You may voluntarily suspend one trial per test.

Re-Examination

Failure of the written examination by either of the criteria cited under written examination will require re-examination on the entire written examination. A re-examination may be taken at any time, but if it is not taken within one year of passing the performance examination, the entire performance examination must also be retaken.

Failure of the performance examination on five or more of the eight required tests will require re-examination on the entire performance examination. Failure on four or fewer of the eight tests will require re-examination on only those particular tests that were failed. If the re-examination is not taken within one year of passing the other portions of the performance examination and the written examination, the entire examination process must be repeated.

Course Evaluations

In an effort to improve the Iowa DOT Technician Training and Certification Program, we asked that participants fill out an evaluation form after taking the final exam. Ten participants provided comments on the facilities, instructors, and course materials and activities.

Aspects of the course were rated by the 10 participants, and the average values are presented in Table 5.

Table 5. Average Rating by Course Aspect

Course Aspect	Average Rating (1 = poor, 5 = excellent)
Facility	4.45
Material	4.70
Instructors	4.85
Course activities	4.50

The participants were also asked to answer the following question: "Are there any changes you would like to see made at the course?" Their answers follow:

- It would help to see a video of the test procedures before we had to do them in lab. It's hard to picture a procedure from just reading it in the book.
- More hands on training and better understanding of math of different formulas.
- Section A: Reduce background information required for pre-reading. Section B: Excellent as is.
- It was difficult for me to go into the lab and run tests without seeing some demonstration of techniques involved first. Some videos would have been helpful also.

- Class size seemed about right for facilities. Some tests required more usage of equipment such as microwaves and needed smaller group in the lab.

Participants also provided the following general comments:

- We had to go through a lot of material in a short amount of time, but I don't see how any of it could have been left out and still teach what we need to know. (DMACC)

- The highest hurdle I faced all week was attempting to sort and store away what was coming at me. A wagonload of new terms, procedures, and calculations were presented, and trying to understand the individual steps and place them in the context of the entire program was difficult. For instance, I'm doing an Atterberg now—why would I being doing this? What would the Atterberg tell me? How level is level in the cup? What does this groove look like when closed? While trying to process all of this I'm looking at the next procedure and trying to understand. (Iowa DOT)

- This class was very good in the following ways:

    - Excellent, knowledgeable instructors.

    - Lab work—I'm glad to see every student perform every test (performance exams).

    - Interspersing lab with lecture really helped (variety and learned primarily in the lab so we didn't need a lot of lecture).

- Some concerns:

    - A lot of down time for students waiting to use the lab. What can be done with them? Simultaneous lecture and lab with a teaching team?

    - When students come into this class with no knowledge of soil may need to do more lectures up front. We really didn't go over the chapters in Section A (1–15).

    - For certification we probably need to include testing frequency, reporting, etc. I know the students this week will have that covered in the field, but what about future students? Thanks a lot! Great class! (DMACC)

- Pace of class—just about right. A lot of material was covered. Pace was fast enough to keep everyone's attention, but not too fast. Adequate time was allowed for questions. Lab work—the "hands on" training was excellent. More microwaves would be helpful. Lecture—discussion of theory were very helpful. I would not reduce the lecture time. Maybe increase slightly. Size of Class—certifying six at a time was a good number. It would be difficult to certify more than 10 at a time. I am looking forward to field training. (Iowa DOT)

- The Iowa DOT should consider two separate courses: (1) this course as is, with lab, and (2) plan reading and contract administration of a grading project. The instructors did an excellent job of pacing lectures and explaining concepts clearly. (Iowa DOT)

- Course level of instructors was quite good for this class group. Seemed just right. Lecture and hands on pace good. Final should be “open book” as this is how all other Iowa DOT final exams are now. Could use one more day! (Iowa DOT)

- Overall it was an interesting and enjoyable course. Instructors did an excellent job. (Iowa DOT)

- More test equipment, so students aren’t waiting around. I seemed to take more in when there was only a few in the lab doing the tests. I liked that it was mostly hands on. (contractor)

- Having the material before class started was a good idea. Helped me get familiar with an unfamiliar topic. Level of teaching and pace was excellent even for someone who knew nothing about soil. Hands-on was adequate—some of the tests like LL and PI were so foreign a concept that it may just take repetition. Class size needs to be kept small in regards to the number of instructors. Testing after each procedure makes sense. (consultant)

PILOT PROJECT TESTING RESULTS AND DISCUSSION

A technician hired by the grading contractor conducted the QC testing, while the Iowa DOT conducted QA testing. ISU also conducted tests to increase the database of results, verify the special provisions, and act as an independent evaluator.

Laboratory and Field Testing

At each test location determined by the field technician, DCP and moisture and density tests were performed as stipulated in the special provisions document. For each soil type a set of four control charts was produced indicating the *quality* of compacted fill. The soil types investigated on this project are listed in Table 6. Laboratory testing consisted of Atterberg limits, fines content, and standard proctor. As discussed previously, the soils at this pilot are mostly select and suitable. Of the 29 lab samples tested, 18 were classified as select.

Figures 4–7 and Figures 8–11 show the required control charts for two different soil types, respectively, as determined by the contractor's QC personnel and Iowa DOT QA personnel. The control charts consist of compaction (Figures 4 and 8), moisture content (Figures 5 and 9), mean DCP index (stability) (Figures 6 and 10), and mean change in DCP index (uniformity) (Figures 7 and 11). For this data set it can be seen that the control parameters were mostly within specified requirements. Due to the natural variability inherent to soils, a four-point moving average was used as the control criteria. When the moving average trend line falls outside of the specified limits, "corrective action" is required.

The compaction results shown in Figure 4 indicate that several individual tests fall below the specified 93% compaction; however, the four-point moving average trend lie stays mostly between the 94%–97% compaction range. The trend line dips below 93% compaction at about tests 35–38 and tests 55–57. This finding was used in the field to alert the contactor that corrective action must be taken to increase density. At the point when the trend line falls below the specified limit, the contractor must consider adjusting the moisture content, increase compaction effort, or changing the lift thickness. In this case, the contractor was compacting with a sheepsfoot roller using an average of eight passes. Thus, additional compaction effort was not likely the cause. Furthermore, Figure 5 shows that moisture content was within the specified limits. That leaves lift thickness to consider. Figure 6 shows the mean DCP index, which shows a sharp increase in mean DCP index in the test 30 range, thus indicating low stability. Furthermore, Figure 7 shows that the uniformity, as measured from the mean change in DCP index was becoming highly variable between test 17 and test 27. In short, the DCP data suggest that lift thickness was greater than could be compacted and produced an "Oreo cookie" effect. The sharp reduction in DCP index values at about test 35 suggests that the corrective action to reduce lift thickness occurred. It is interesting that the DCP test results more clearly identify the trend of poor quality compared with the surficial density tests, which did not indicate this. It is hypothesized that the nuclear density gauge was not penetrating the full thickness of the lift during placement. Also, the nuclear density gauge takes an average density over the test depth, whereas the DCP index values are recorded approximately every one to two inches.

Figures 8–11 show excellent compaction, moisture, and DCP results for a select material. This data set suggests that different DCP control values need to be established for different soil types;

however, this needs further research. DCP "target" values likely vary similar with soils as much as 100% proctor density varies with soils. Additional QC test results are provided in Appendix F.

Table 6. QC/QA Soil Index Properties and Classifications

Sample No.	Sample Location and Material Description	Atterberg Limits		% Passing No. 200	Standard Proctor Parameters		Iowa EPC Classification
		LL (%)	PI (%)		Maximum Dry Density (kg/m^3)	Optimum Moisture Content (%)	
1	Borrow B 4–6 ft (tan)	41.9	26.5	71.4	1,850	15.0	Suitable
2	Borrow B 6–30 ft (gray/blue)	45.5	22.9	67.9	1,770	14.4	Select
3	Borrow D 2 ft (tan)	35.7	17.4	60.3	1,721	17.5	Select
4	Borrow D	37.3	18.1	57.7	1,730	17.0	Select
4*	Borrow D	37.0	19.3	56.9	1,735	17.0	Select
5	Borrow B 4–6 ft (tan)	41.9	25.5	73.7	1,834	15.2	Suitable
5*	Borrow B 4–6 ft (tan)	43.3	28.3	70.2	1,762	15.0	Suitable
8	Borrow B (tan/gray)	39.0	21.0	71.3	1,836	16.1	Suitable
10	Borrow B (tan/black with light gray)	41.5	23.8	68.4	1,793	14.8	Suitable
11	Borrow D (dark tan/black)	34.0	14.4	60.0	1,787	15.7	Suitable
14	Borrow D (tan)	31.7	15.9	58.2	1,876	13.7	Select
15	Borrow D (tan/light gray)	30.8	14.3	62.2	1,865	13.7	Select
16	Borrow D (blue/gray)	26.3	13.0	59.3	1,892	13.0	Select
17	Sta 265+00 (tan/light gray)	42.4	25.5	73.7	1,764	15.7	Suitable
19	—	22.5	6.7	37.4	2,007	10.1	Select
20	Borrow D (tan)	31.4	16.2	61.4	1,887	13.3	Select
20*	Borrow D	32.0	18.4	60.8	1,865	13.6	Select
21	—	32.3	17.0	60.4	1,862	13.2	Select
22	—	26.6	12.4	50.6	2,022	10.3	Select
23	—	25.5	11.2	49.2	1,930	12.6	Select
24	—	22.4	10.0	54.8	1,999	10.9	Select
25	Mainline Cut Sta 230+50 3–5 ft (tan/light gray)	22.0	9.8	55.6	1,994	11.0	Select
26	—	41.4	23.3	64.1	1,733	17.4	Select
27	Sta 230+00 Ditch Cut (blue/gray with sand)	26.6	11.7	42.8	1,973	11.2	Select
29	Sta 227+25 E. Ditch Cut	39.0	22.0	72.5	1,792	14.3	Select

* Indicates QA test.

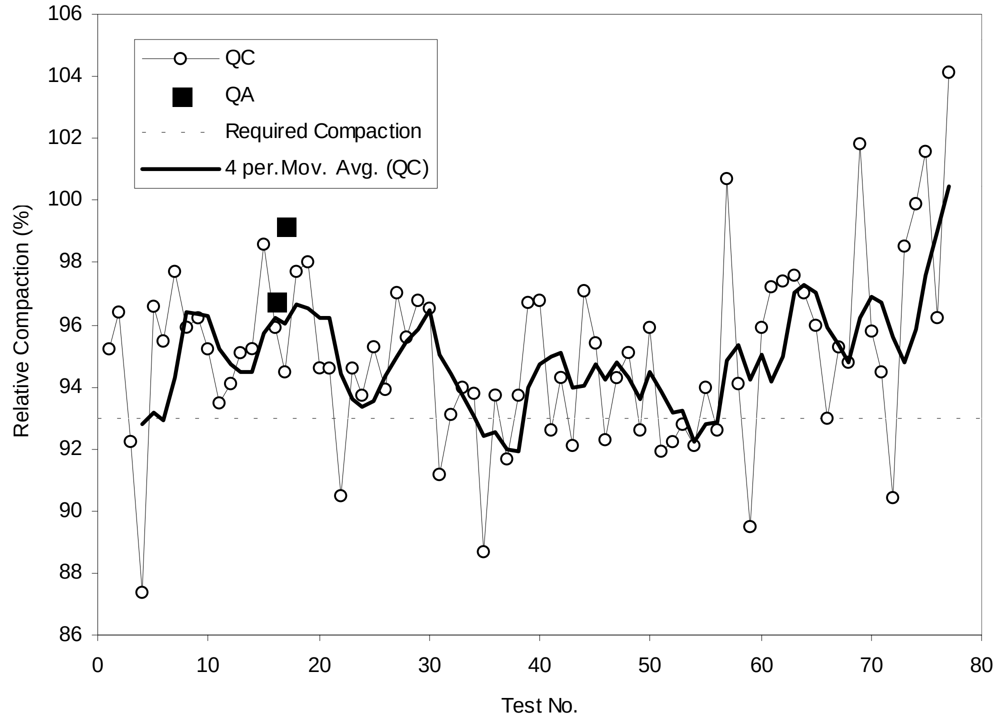

Figure 4. Relative Compaction QC/QA Results—Borrow D, TS1

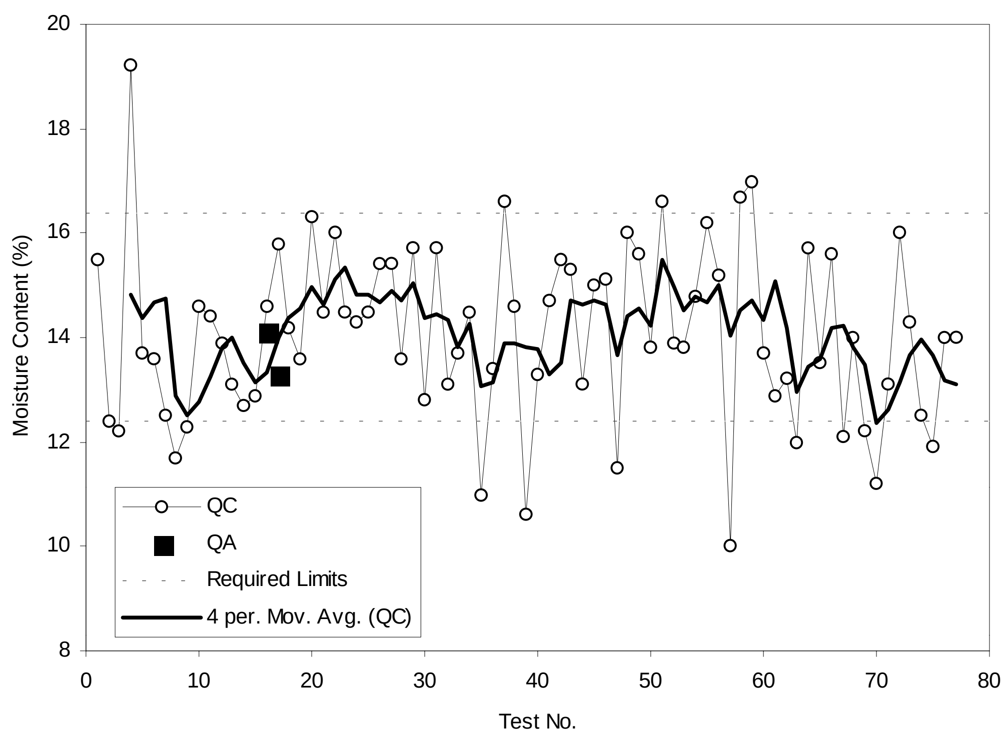

Figure 5. Moisture Content QC/QA Results—Borrow D, TS1

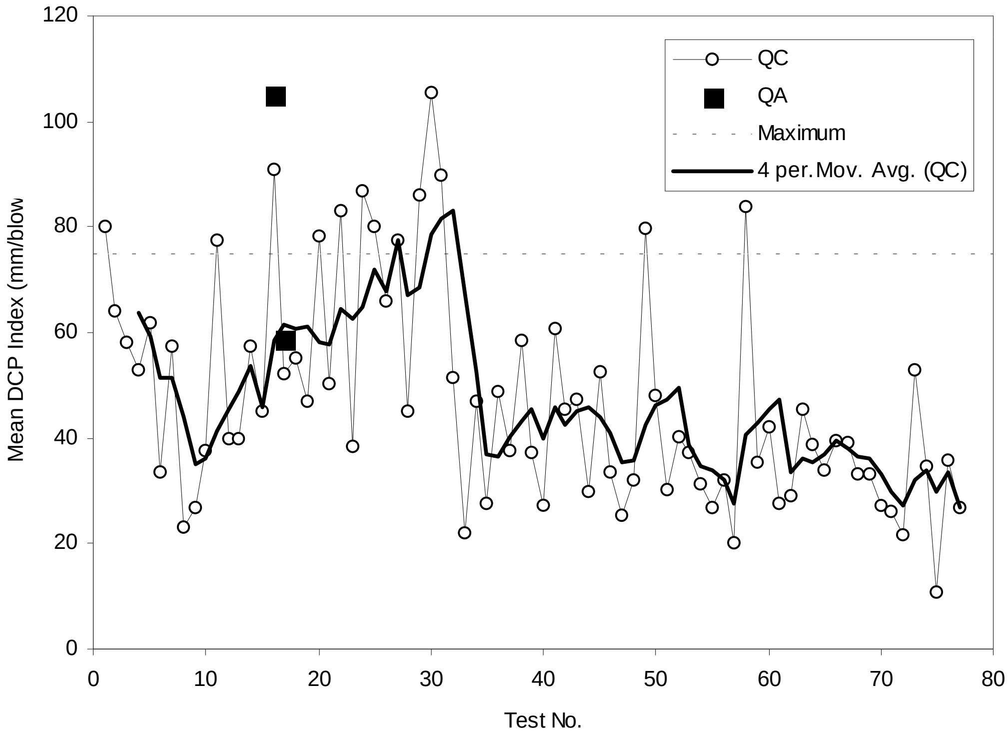

Figure 6. Mean DCP Index QC/QA Results—Borrow D, TS1

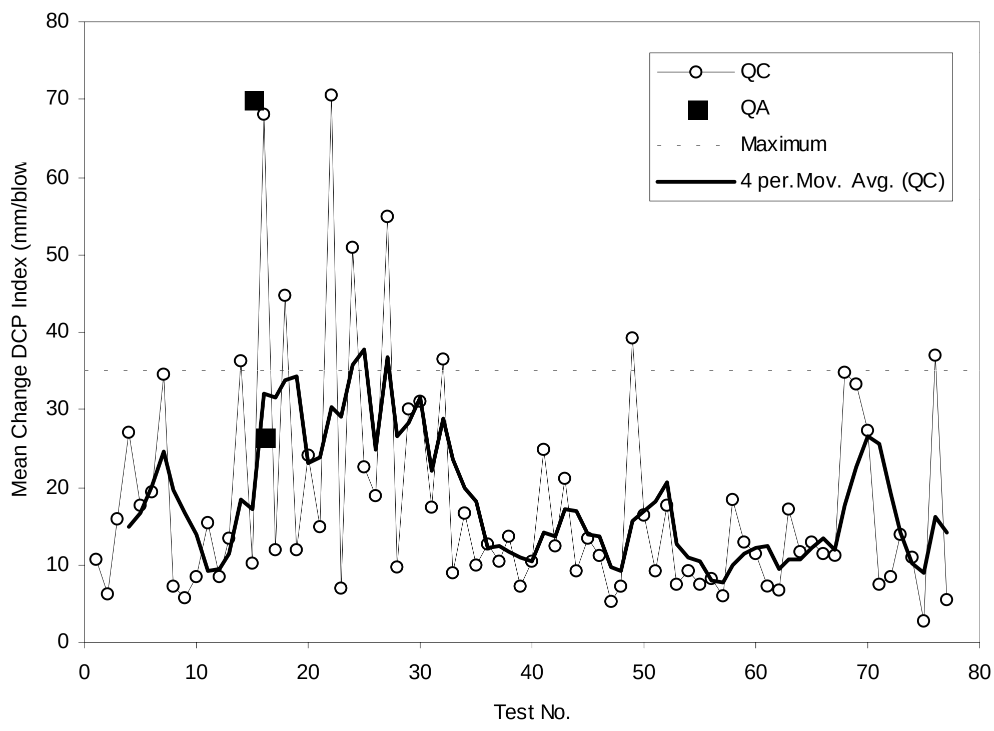

Figure 7. Mean Change DCP Index QC/QA Results—Borrow D, TS1

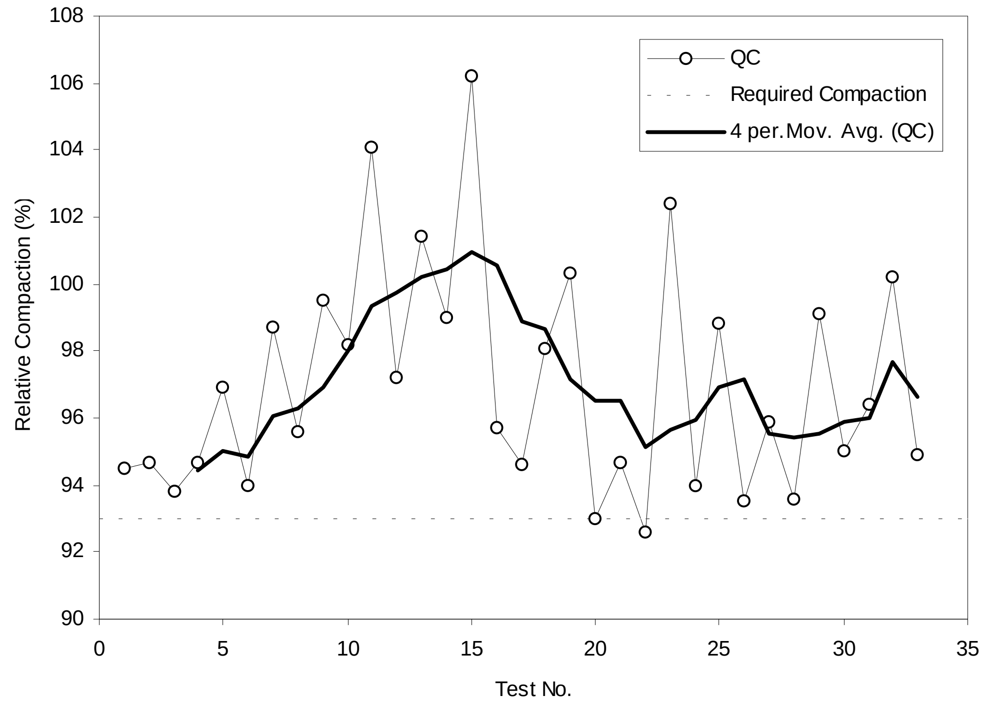

Figure 8. Relative Compaction QC Results—Borrow D, TS2

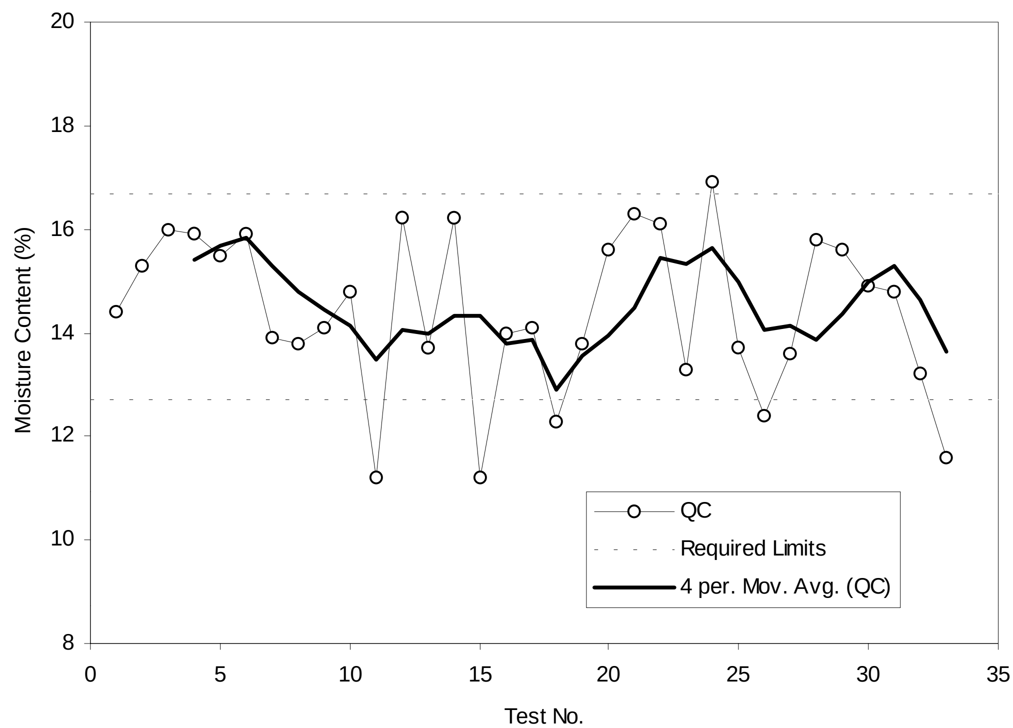

Figure 9. Moisture Content QC Results—Borrow D, TS2

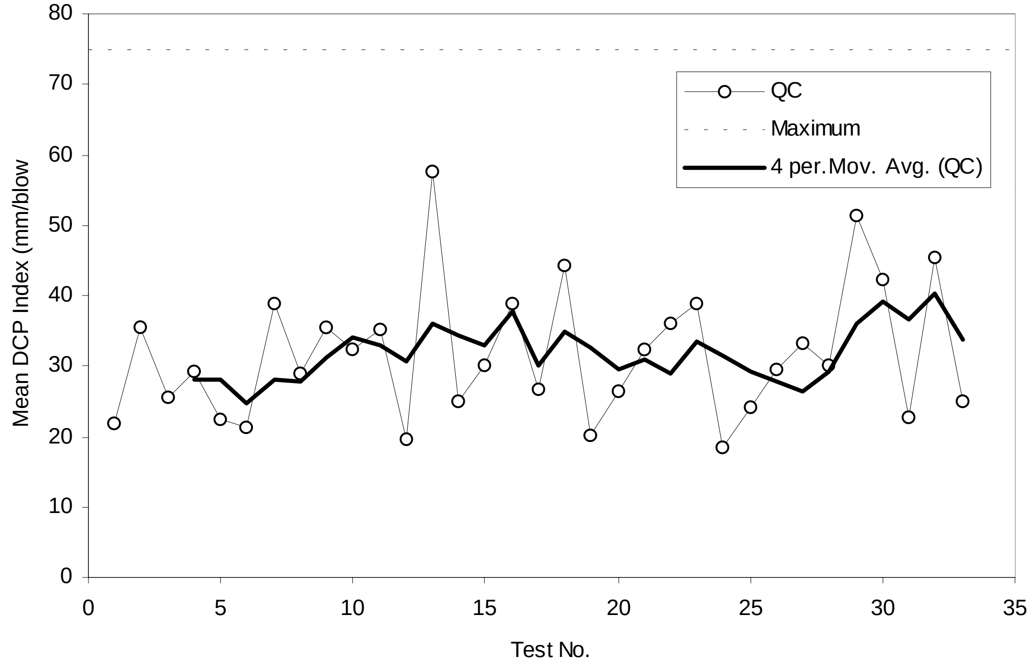

Figure 10. Mean DCP Index QC Results—Borrow D, TS2

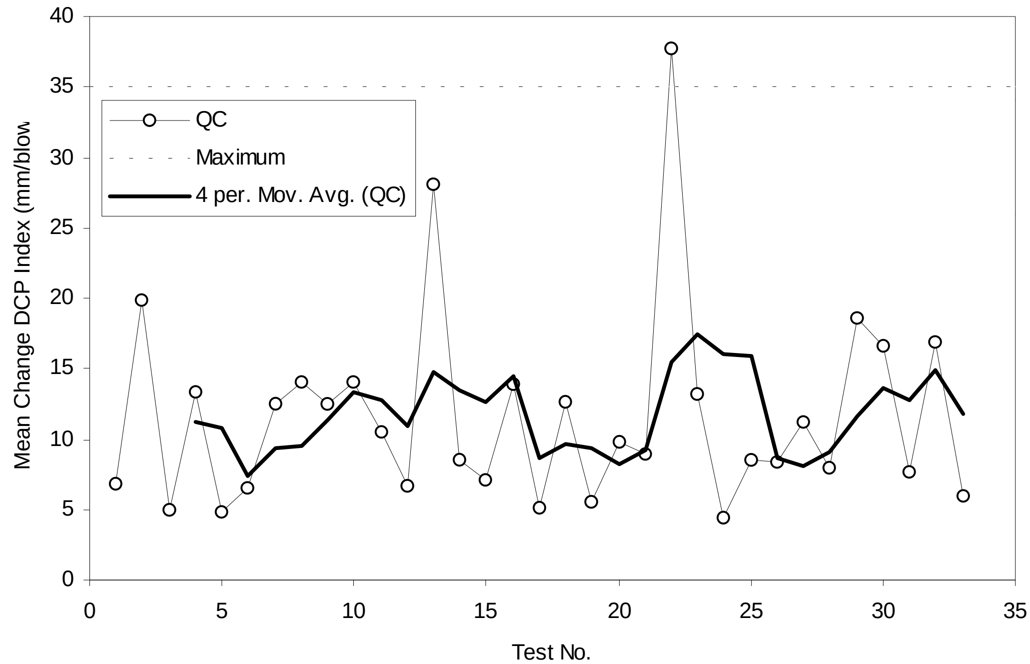

Figure 11. Mean Change DCP Index QC Results—Borrow D, TS2

Quality Assurance Testing

Three QA tests were conducted to verify QC laboratory and field results. Figure 12 indicates comparisons between lab and field QA tests and suggests that field moisture and density tests produce the highest variability, while DCP testing, standard proctor density and moisture tests, and laboratory soil index tests produce relatively uniform results. More tests are needed to fully evaluate the importance of the QA testing. On this project Iowa DOT personnel were unable to keep up with the required QA testing due to two projects being inspected along the same section of Highway 218 and due to the state time and budget restrictions. Overall, the tests needed for soil classification (LL, PI, F200) showed very good QC/QA correlation.

Disking

Disking is viewed by the authors as having a significant impact on quality of embankment fill materials (Bergeson et al. 1998; White et al. 1999). The special provisions required that disking be a bid item per day. It was anticipated that 25 disking days would be used on the project. In the end this was increased to 51 days. Approximately 370,000 m^3, or 29% of the total fill, required disking to reduce excess moisture content on this project. Based on a bid price of $950/day, disking on this project cost $48,450, or about 1.7% of the total project costs. On a per-cubic-meter basis, disking added about $0.04.

As indicated in Figure 13, disking was high in April–May and decreased to a relatively constant level during the period July–October. This trend likely follows seasonal rainfall and air temperature trends. Because the project soils at this site were for mostly select and suitable, it is anticipated that more disking would be required for a comparable project with low-quality, unsuitable soils. Disking as a bid item was generally considered to be favorable by the contractor and inspection personnel. However, at this time, the technical steering committee has discussed making disking days a set unit price instead of a variable bid price. See also Figure 14.

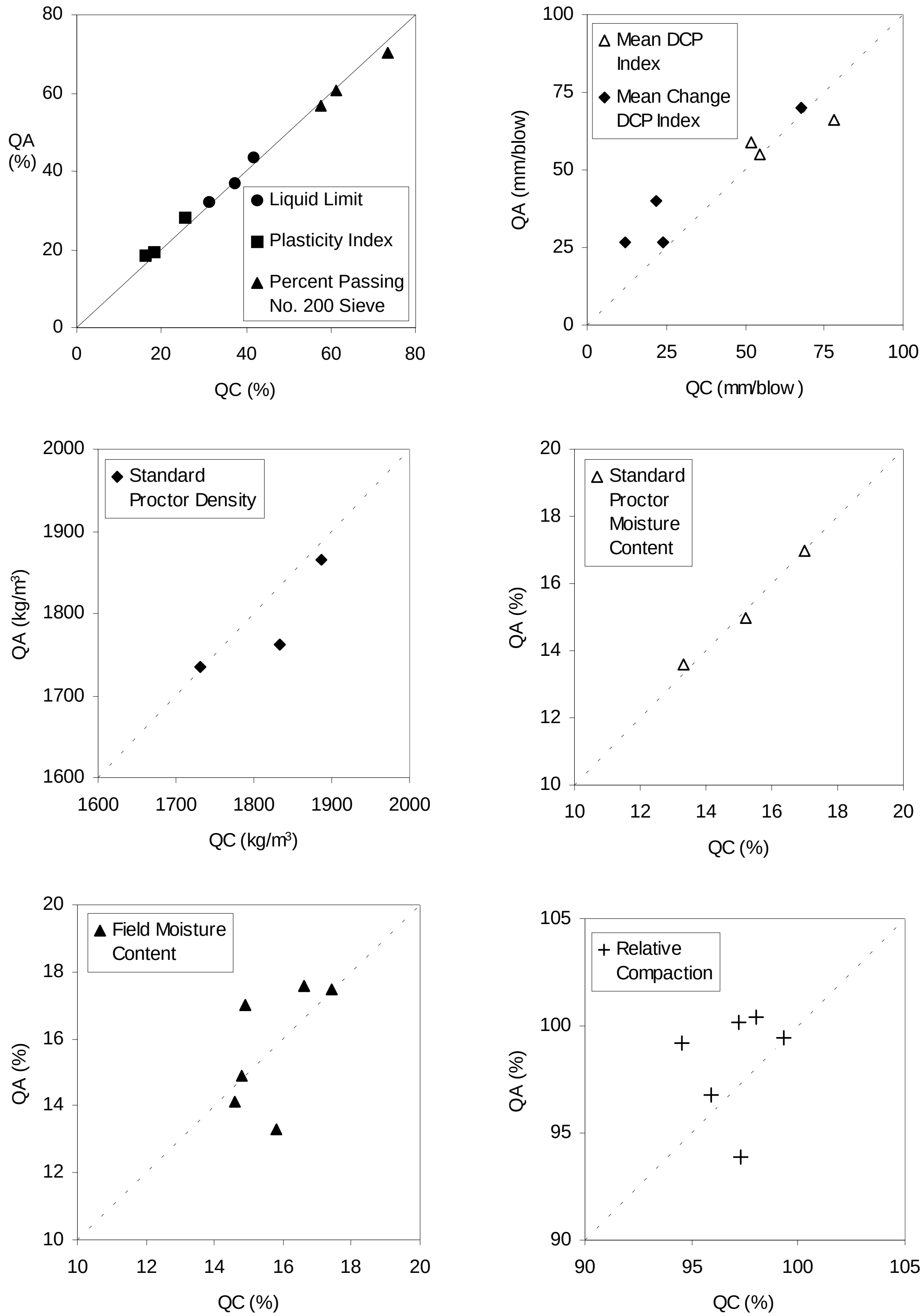

Figure 12. Comparison of QC/QA Results Indicating that Compaction and Moisture Content Determination Are the Most Variable Tests

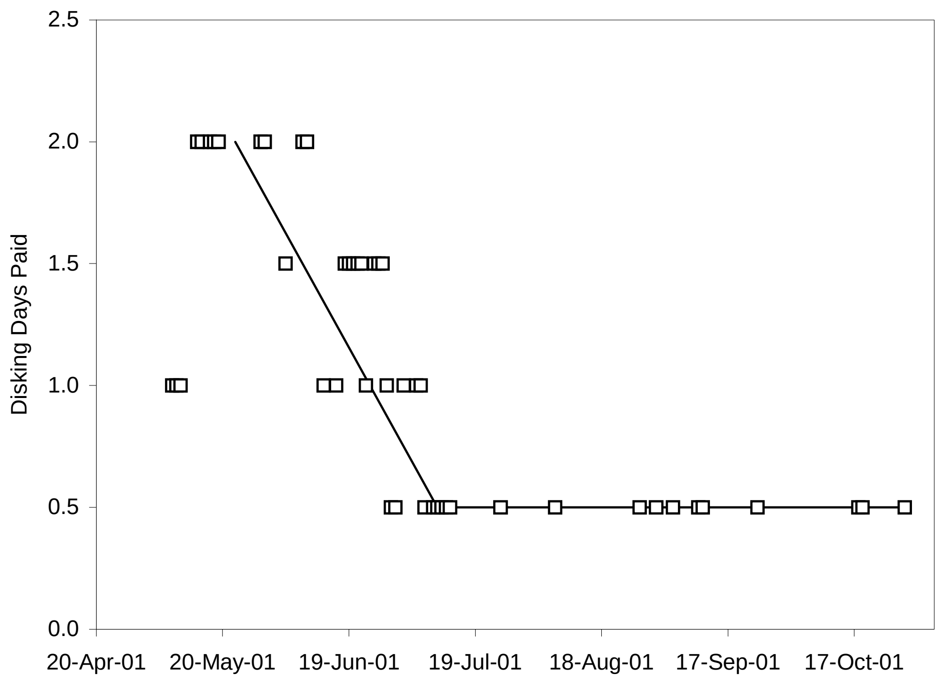

Figure 13. Number of Disking Days Charged per Day Indicating that More Disking Is Required in Early Spring

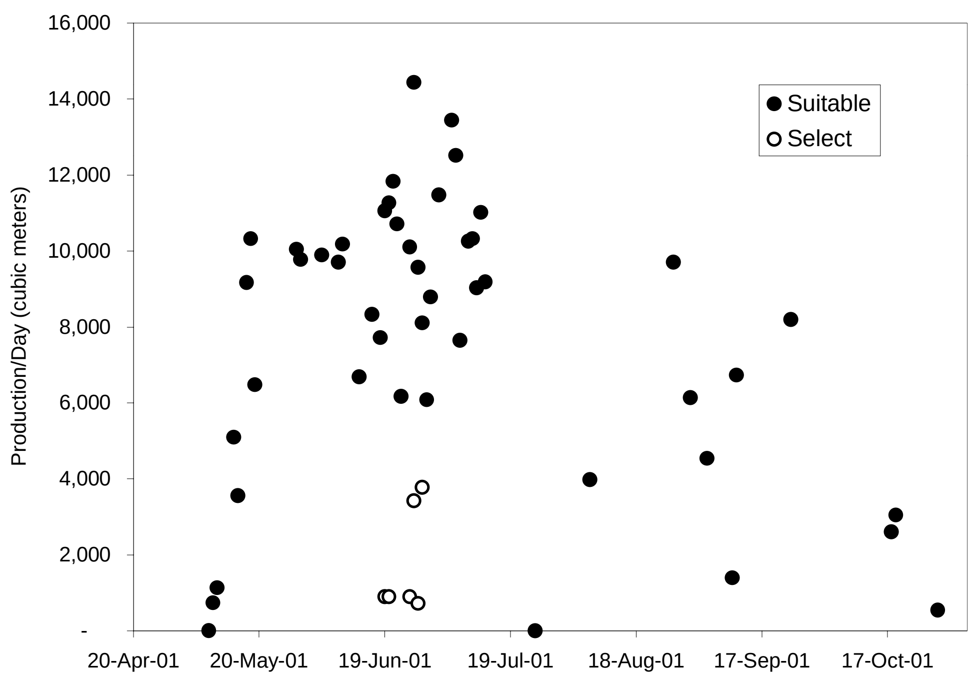

Figure 14. Production per Day During Disking Operations Indicating that Production Increases as Disking Days Charged Decreases

ISU Test Results

In addition to QC/QA data, the ISU research team conducted several field and laboratory tests to increase the database of information available. Test results are provided in Appendix G and indicate similar results to the QC data for cohesive soils (see Rupnow 2002). In addition to testing cohesive soils, special effort was made to evaluate the special provisions for cohesionless soils on an adjacent earthwork project. In brief, the following describes the effectiveness of the special provisions, field tests, lab tests, and adjustments that are needed for cohesionless soils. Results are similar to those found during previous testing of cohesionless soils (see White et al. 1999)

DCP Index Field Testing

Figure 15 shows a typical DCP index test in cohesionless select material (fine sand with about 5% passing the No. 200 sieve) conducted during this investigation. As shown, DCP index decreases with depth. At the surface, DCP index is well above the specified maximum mean DCP index of 35 mm/blow. Although the DCP index is not satisfied near the surface, it is satisfied from about 300 mm (1 foot) and deeper. This is a common trend observed in sands due to a lack of cohesion and confinement at the surface. As depth increases, confinement from overburden pressure increases and thus the DCP index decreases (see White et al. 1999). In the future, it is suggested that DCP index measurements in sand only be measured from 300 mm below existing grade and deeper. Density tests with a nuclear density gauge are also not recommended in the top 300 mm due to the state of unconfinement. Moisture testing as the material is being placed (at the surface) is still recommended, however. For future projects it is recommended that 35 mm/blow be used as the acceptance criteria for DCP testing, but continued effort is needed to fully develop a database of acceptance criteria for a wide range of cohesionless soils.

DCP index results were plotted against moisture content, dry density, and relative density to investigate possible correlations. Similar to previous attempts (White et al. 1999), no single or multiple regression correlations were determined. It is not envisioned that DCP index will be correlated to relative density in the future; therefore it is important to continue to evaluate DCP criteria for a wide range of cohesionless soils. With further development it is envisioned that DCP and moisture testing will be used in lieu of field relative density testing.

Laboratory Testing

In the field lab, several Iowa modified relative density tests were conducted to determine the "bulking range" and acceptable upper limit moisture contents for cohesionless soils. Relative density lab tests simulate standard proctor test for cohesive soils, but require a vibratory table. Moisture limits are graphically determined from a plot of moisture content versus dry density (see White et al. 1999 and Rupnow, 2002). In the future it is envisioned that this test could be supplemented and possibly replaced with an empirical relationship between fines content and maximum dry density and fines content and bulking moisture content. Further testing on a wide range of cohesionless soils is required.

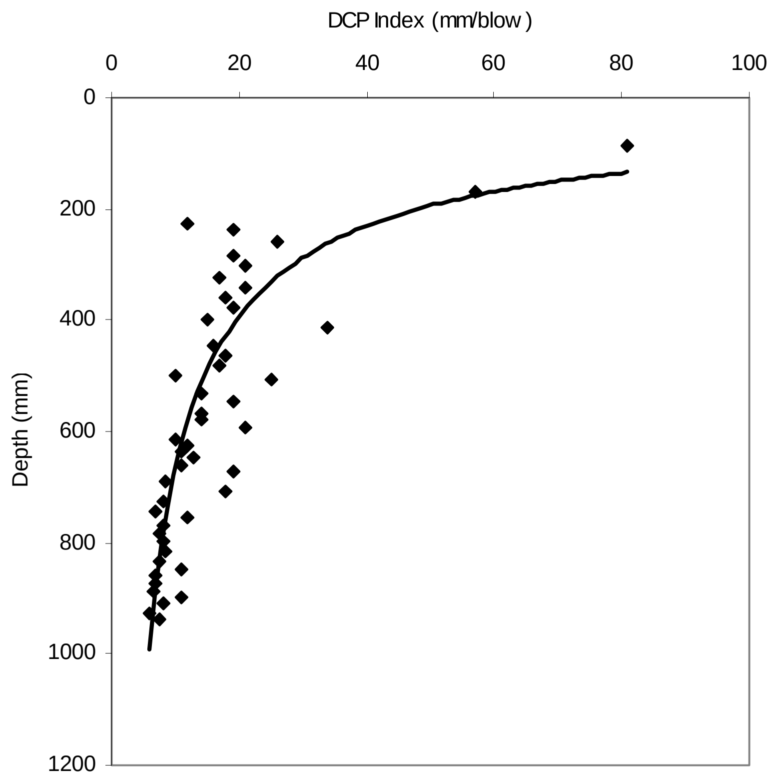

Figure 15. DCP Index Versus Depth for Cohesionless Soil Indicating Increased Strength with Depth

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on the results of this pilot project, the following conclusions are reached.

1. The new proposed soil classification system worked well during the Iowa DOT soils design phase. The only modification required was the addition of color and carbon content determination for topsoil identification. The system also worked well in the field during construction.

2. The training and certification program materials developed for the project were sufficient and required minor adjustments. The one-week (five day) training period appears adequate. The DMACC laboratory and training facilities and Iowa DOT supplied equipment are good and will become better with continued development.

3. The contractor QC and Iowa DOT QA special provisions developed jointly by Iowa DOT and ISU personnel worked well for the project and required only minor modifications during construction. The ability of Iowa DOT personnel to conduct the required QA testing was hampered by state budget reductions and project manpower shortage.

4. Proposed and provided field equipment and laboratory facilities for the project were adequate and generally very good.

5. Surficial density testing was shown not to be adequate for indicating the uniformity and stability of the embankment soils. The DCP test was able to detect nonuniformity, and development of “Oreo cookie” effects requiring corrective action. On this project “Oreo cookies” were likely a result of thick lifts, not variable compaction effort or moisture content.

6. One of the primary questions for Phase III is “Was the quality improved?” The project involved a “quality conscious” contractor, well-qualified and experienced Iowa DOT field personnel, a good QC consultant technician, and some of our best soils in the state. If the answer is “yes” for this project, the answer would unquestionably be “yes” for other projects as well. In the authors’ opinion, the answer to the above question is “yes” for this project, the quality was improved, even for this project, as evidenced by the DCP test data and the amount of disking required to reduce the moisture content to within acceptable control limits. Perhaps as important is that we know what quality we have.

7. The Class 10 and select backfill costs per cubic meter for this project were lower than previous years contract process. This is possible due to the generally good quality project soils.

8. The QM-E QC costs added $0.03 per cubic meter, or 1.6%, to the total cost of this project. Disking added about $0.04 per cubic meter, or 1.7%, to the total project costs. In our opinion this is a very nominal cost increase in order to improve quality. Future contractor innovations have the potential for negating this increase.

Recommendations

State of Iowa

Begin a three to four year phase-in of the new soils design classification system training and classification program and QM-E special provisions. During this period, the special provisions would gradually move to developmental specifications and finally to supplemental specifications. We suggest that one to two projects be designed and let per year in various construction residences around the state involving a variety of soil types. This would allow gradual training and certification of contractor, Iowa DOT, and consultant personnel around the state. With ISU assistance this would also allow further refinement of the special provisions and development of a DCP database for Iowa soils. The state may wish to consider having one or two certified grading technicians in each resident construction office to act as “roving” QA personnel rather than training and certifying individual project personnel.

County Application

We suggest that counties consider adopting these embankment construction specifications following phase-in by the state. This would help ensure that trained and experienced contractor and consultant personnel would be available to the counties for their grading projects. The counties may wish to utilize consultants for the QA testing on their projects rather than to train and certify personnel.

City Application

Cities face unique problems in reconstruction and/or construction of streets in new developments. They often do not have the options for importing select soils. As such the QM-E specifications are not viewed as practical or economical for city adaptation. We do, however, see the DCP test as being a valuable and usable tool for city construction application. Many of the problems in city streets develop from inadequate compaction of storm and sewer trenches, storm water intakes and sewer manholes. The DCP’s ability to test deep would be very applicable to city needs, following the DCP database development. Guidelines for city application could be developed.

ACKNOWLEDGMENTS

The authors gratefully acknowledge and thank Iowa DOT technical advisors John Vu (Phase I) and Dave Heer (Phases II and III) for their cooperation, timely assistance, and advice. We also thank the steering committee Bob Stanley, Bob Jimerson, Tom Jacobson, Jerry Danforth, Charles Marker, Jeff Krist, John Moyna, Jesse Steger, Larry Thompson, and Chris Reilly for their advice and council. The Iowa Department of Transportation and the Iowa Highway Research Board sponsored this study under contract TR-401.

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APPENDIX A: IOWA DOT SPECIAL PROVISIONS FOR QUALITY MANAGEMENT-EARTHWORK

(New)

Iowa Department of Transportation

METRIC

SPECIAL PROVISIONS

FOR

QUALITY MANAGEMENT – EARTHWORK (QM-E)

Bremer County
NHSX-218-8(39)--3H-09

February 27, 2001

THE METRIC STANDARD SPECIFICATIONS, SERIES OF 1995, ARE AMENDED BY THE FOLLOWING ADDITIONS AND MODIFICATIONS. THIS IS A SPECIAL PROVISION AND IT SHALL PREVAIL OVER PROVISIONS OF THE STANDARD SPECIFICATIONS.

INDEX
These Special Provisions are comprised of the following Sections:

95509M.01 DESCRIPTION.

A. GENERAL

QM-E embankment construction shall consist of the preparation of the site and placement and compaction of excavated materials to the required moisture content, density, stability, elevation, and cross section as shown in the Contract Documents and in accordance with the requirements of this Special Provision.

95509M.02 MATERIAL.

A. SOIL CLASSIFICATION

Soils shown on the plans have been classified and determined as select, suitable, and unsuitable by the method described in Attachment A to this Special Provision, 'Soil Performance Classification for Embankment Design and Construction'.

The definition of soils as select, suitable, and unsuitable in Attachment A shall prevail over those of Article 2102.06, Paragraph A, (1), (2), (3) of the Standard Specifications.

Note is made that necessary adjustments were made during design to some of the classifications obtained by strict utilization of the classification method. For example, certain soils described in field borings as "black silty clay" classified as select soil. Those adjustmen ts that have been made shall prevail over the soil classification method of Attachment A. Similar adjustments may also be necessary during construction.

Project soils shall be field sampled and classified during construction as described in this Special Provision and as required by the Engineer.

B. PLACEMENT OF SOIL

Select soils for subgrade treatments, suitable soils for embankments, and unsuitable soils shall be determined by the method of Attachment A.

Soils classified as Unsuitable shall be placed within embankments as directed in Attachment A and shown in Standard Road Plan RL-1B for Type A, B, or C disposal.

95509M.03 CONSTRUCTION

A. QUALITY CONTROL PROGRAM

The Contractor shall provide and maintain a Quality Control Program, defined as all activities of training, sampling, testing, process control inspection, and necessary adjustments for construction of embankments to meet the requirements of this Special Provision.

As part of the Quality Control Program, the Contractor shall provide a technicia n who will be trained to perform the required testing on all embankment and subgrade soils placed on this project. The technician shall be dedicated full-time to testing and Quality Control, and shall be present on the project when embankment is being placed. As a minimum, the technician shall have a high school education and preferably some experience in earthwork construction.

The Contract Authority will provide training for the technician to become a 'Certified Grading Technician I'. After the contract has been signed and prior to starting embankment work on this project, the technician shall be available for one week of full-time training in soil classification and testing at Des Moines Area Community College (DMACC) in Boone and one week of full-time training at the project site. The technician must successfully complete the training course and examinations. The Contracting Authority will provide training for one or two technicians.

In an emergency, the Contractor will be allowed to operate a maximum of two days without a Certified Grading Technician on the project site. Embankment placement and compaction during this period shall be as per Article 2107.09 of the Standard Specifications, Compaction with Moisture Control, for all embankment construction. After two days, if the Contractor cannot provide a trained Quality Control technician, the Contract Authority will perform the Quality Control Program, with reimbursement by the Contractor, until a Quality Control Technician can be provided.

B. QM-E FIELD LABORATORY

1. Facilities Furnished by Contractor

The plans require one Field Laboratory as per Section 2520 of the Standard Specifications and one separate QM-E Field Laboratory. The QM-E Field Laboratory shall meet the requirements of Section 2520 of the Standard Specifications with the following additions:

a. The sink with potable water supply to sink faucet shall be a deep wash sink.

b. A portable shed with minimum dimensions of 3.1 m by 3.1 m and 2.44 m of headroom shall be provided on a 0.15 m concrete floor on grade. This facility shall be adjacent to and considered as part of the QM-E Field Laboratory. It shall be able to support a base and equipment for Proctor compaction (285 kg), a Rapid Soil Processor (185 kg), and Relative Density testing equipment (255 kg).

As an alternative, the Contractor may provide a utility tool trailer capable of housing and supporting this equipment and providing adequate working room for testing. A trailer is subject to approval of the Engineer.

The shed or tool trailer shall be weather tight and include adequate lights and heavy-duty 110 volt and 230 volt electrical outlets. The door shall be wide enough to allow passage of a Rapid Soil Processor frame, which is 0.813 m by 0.915 m.

2. Facilities Furnished by Contract Authority

The following QM-E Field Laboratory testing equipment will be supplied by the Contract Authority:

a) Rapid Soil Processor, Model H-4215, purchased from Humboldt Mfg. Co.
b) Two Atterberg Limit test sets
c) Small soil grinder
d) Two sets of 0.425 mm and 0.075 mm sieves
e) Sieve shaker
f) Standard Proctor set
g) Automatic Proctor compaction unit
h) Relative density set with 0.0142 m^3 mold set
i) Dynamic Cone Penetrometer (DCP) test set with 500 disposable cone tips
j) Laboratory grade microwave oven
k) Portable 2-burner propane stove
l) Rubber balloon density test set
m) Nuclear moisture/density gauge
n) Electronic balance (capacity 12,000 g to +/- 0.1 g)
o) Two metal sawhorses and one 1.22 m by 2.44 m sheet of 19mm thick plywood
p) 0.5 m box electric fan
q) Computer and laser printer for data logging, analysis, reports, and e-mail. Minimum requirements: Pentium 100 MHZ, Windows 95, Microsoft Excel, Microsoft Word, 56K modem, Internet access

C. TEST PROCEDURES

All test procedures and equipment shall conform to applicable Iowa DOT Office of Materials Instructional Memorandums (I.M.'s), IDOT Materials Laboratory Test Methods, or to equivalent standards of the American Association of State Highway Transportation Officials (AASHTO) or the American Society for Testing and Materials (ASTM).

Equivalent standards shall be subject to review by the Engineer and mutually agreed upon by the Engineer and Contractor.

Acceptable test methods for determining moisture content are:

Oven drying	AASHTO T-265
Pan drying	AASHTO T-265 modified to use an open burner
Microwave	ASTM D 4643
Nuclear gauge	Iowa DOT Materials I.M. 334

AASHTO T-265 oven drying method shall be considered the reference method for calibration.

D. CONSTRUCTION EQUIPMENT

1. Equipment for Compaction

On embankments constructed on this project, any type of compaction equipment may be used which will produce the desired results as demonstrated by test sections and compaction quality control tests.

2. Equipment for Applying Water

The distributor shall be equipped to distribute water evenly over the intended area.

3. Equipment for Disking

The equipment used for disking shall be capable of aerating the entire placed lift.

E. TEST SECTIONS

1. General

Construction of a test section for each soil performance classification encountered in excavation will be used to determine:

a. Soil classification and required moisture control limits
b. Maximum compacted lift thickness
c. Acceptable equipment and minimum compactive effort for embankment construction.

Test sections shall be incorporated into the embankment.

Initial test sections shall be ordered by the Engineer upon first excavation of material to be used for embankment fill. Additional test sections shall be ordered by the Engineer for each excavated source material which varies as to change the expected soil classification.

All embankments shall be constructed using the same compaction equipment, minimum number of equipment passes, and compacted lift thickness indicated by test sections for each soil classification unless the Engineer approves modifications.

Density tests and Dynamic Cone Penetrometer (DCP) stability tests of the compacted test section shall be used to determine acceptable compaction.

2. Required Laboratory Soil Testing Before Construction of Test Sections

A representative sample of soil shall be taken prior to construction of the test section. The soil shall be classified as per Attachments A and C of this Special Provision, including tests to determine Standard Proctor or Relative Density.

3. Dimensions of Test Section

Minimum dimensions of the test section shall be:

Length	75 m
Width	15 m
Depth	0.9 m

4. Testing Frequency During Test Section Construction

Every 15 m by 15 m square area of each compacted lift within a test section shall be tested for:

a) Thickness of compacted lift
b) Moisture content of compacted lift
c) Density (per lift as a function of roller passes)
d) Mean DCP Index (per lift as a function of roller passes)
e) Mean Change in DCP Index (per lift as a function of roller passes)

A Test Section Data Sheet is available in Attachment G.

5. Moisture Content of Compacted Soil

It shall be the responsibility of the Contractor to test and insure that the moisture content of the material is within the range for the particular performance classification of the soil being placed. The control limits for the moisture content of compacted embankment material shall be based on 'Soil Moisture Content Limits for Embankment Construction' (Attachment C).

Moisture content shall be calculated and reported to the nearest 0.1% based on dry weight of soil.

All moisture contents measured in test sections must be within the specified moisture control limits.

6. Density Requirements

All density tests in test sections shall meet the following criteria:

a. Cohesive Soils (Attachment C definition)
Below a surface 0.9 m beneath final subgrade elevation:
Minimum of 93% of Standard Proctor Density

Within 0.9 m of final subgrade elevation:
Minimum of 95% of Standard Proctor Density

b. Cohesionless Soils (Attachment C definition)
For all elevations:
Minimum Relative Density of 80%
(as per ASTM D 4253 and D 4254)

7. Stability Requirements

Stability shall be measured per lift by Dynamic Cone Penetrometer (DCP) as described in Attachment D of these Special Provisions, "Method of Test, Standard Cone Penetrometer in Shallow Pavement and Soil Applications".

a. Mean DCP Index

The Mean DCP Index value for each test shall not be greater than that shown below:

Soil Performance Classification (Attachment A)		Maximum Mean DCP Index (mm/blow)
Cohesive	Select	75
	Suitable	85
	Unsuitable	95
Intergrade	Suitable	45
Cohesionless	Select	35

b. Mean Change in DCP Index

The Mean Change in DCP index between consecutive readings in a single test shall not be greater than that shown below:

Soil Performance Classification (Attachment A)		Maximum Mean Change in DCP Index (mm/blow)
Cohesive	Select	35
	Suitable	40
	Unsuitable	40
Intergrade	Suitable	45
Cohesionless	Select	35

8. Compactive Effort and Lift Thickness

Acceptable compacted lift thickness, compaction equipment, and number of passes shall be those for which the full depth of the test section can be uniformly compacted as shown by meeting density and stability requirements given above.

If rubber tired or steel drum type rollers are used for compaction, the finished surface of each lift shall be roughened by a light disking or other approved means to provide interlock between lifts.

Compacted lift thickness shall be measured and recorded concurrently with Strength/Stability, Moisture Control, Density, and Stability tests. An example of the lift thickness record chart is shown on Fig. 5 of Attachment F.

9. Acceptance Criteria

Test sections which meet the requirements of this section as well as other requirements of Article 95509M.03, Paragraph F, shall be accepted by the Engineer.

The following information documented from each test section shall determine acceptable procedure for construction of subsequent embankments for each soil classification:

a) Equipment type and weight
b) Minimum number of equipment passes
c) Maximum thickness of compacted lifts

F. EMBANKMENT CONSTRUCTION

1. Preparation of Site

Where the height of proposed embankment at the centerline is 1.5 m or less, all sod, after thorough disking, shall be removed from the area and placed on the area to be occupied by the outer portion of the embankment as provided in Article 95509M.03, Paragraph F (2).

Whenever an embankment is placed on or against an existing slope, which is generally steeper than 3 horizontal to 1 vertical and is more than 3 m high, the slope shall be cut into steps as the construction of the new embankment progresses. These steps shall assure that all sod or other potential sliding surfaces are removed. Each step or series of steps shall be cut to approximate horizontal planes, which have vertical slope cut dimensions of not less than 1 m.

2. Depositing Embankment Material

Except for granular blankets, embankments shall be deposited in horizontal layers at uniform thickness. The outer portion of an embankment shall be kept lower than its center, and wherever construction is to be suspended for a period during which rain is likely to occur, the surface shall be smoothed to produce a surface sufficiently smooth and compact to shed water. Soils containing quantities of roots, sod, or other vegetable matter shall be deposited outside of the shoulder line and within the outer 1 m of the embankment. Tree stumps and other large woody objects shall not be deposited in embankments. Embankments shall not be constructed on frozen ground, and frozen material shall not be used in construction of embankments.

During compaction operations the following shall apply:

a. Hauling Equipment and Dump Areas.

When the width at the attained height is 10 m or more, the Contractor shall divide the area upon which the layer is to be placed into separate and distinct dump areas having widths not less than 5 m. If hauling equipment is operated within a dump area, the area shall be covered with at least one passage of a tandem axle disk or two passages with a single axle disk, prior to compaction.

Hauling equipment shall be kept off dump areas of embankment 11 m or more in width during compaction operations. Within 11 m of a bridge or other limiting structure or where the width of the embankment is less than 11 m at the attained height, empty hauling units may travel on the dump area during compaction operations as necessary to pass loaded hauling units. If the design width of embankment is less than 10 m at the attained height, hauling units will be allowed to travel through areas where compaction operations are in progress. When any hauling equipment is allowed to pass through compaction operations, water, disking, and compacting equipment shall not be required to deviate from their intended paths.

After depositing and disking, if required, the material shall be smoothed to a uniform depth by means of a suitable motor patrol, bulldozer, or self-propelled roller with a blade attachment. In addition to the initial smoothing operation, this smoothing and leveling of the lift shall continue during compaction, as necessary, to provide a surface area free from ruts and other objectionable irregularities.

3. Moisture Control of Deposited Material

It shall be the responsibility of the Contractor to test and insure that the moisture content of the material is within the specified range for the particular performance classification of the soil being placed. The control limits for the field moisture content of embankment material shall be based on 'Soil Moisture Content Limits for Embankment Construction,' Attachment C.

If the deposited soil material contains moisture in excess of the specified moisture limits, disking to remove excessive moisture shall be done to uniformly dry the material to within the specified moisture limits prior to compaction of the layer. The Contractor shall be paid for "Disking to Reduce Excessive Moisture' for labor and equipment to accomplish the disking.

Should the deposited material be dry to the extent that it is not within the specified moisture limits, the material shall be moistened uniformly to the required limits before it is compacted. Authorization may be given for the use of water in the final finishing of the roadbed.

Aeration and compaction operations shall proceed in an orderly fashion without unreasonable and unnecessary delay. Compensation will not be allowed for delays occasioned by the ordering of work to dry or moisten the soil.

Disking shall not be considered a controlling operation for the purpose of charging working days as per Article 1108.02, Paragraph F, of the Standard Specifications.

4. Compaction

After the surface of the layer has been smoothed and before material for the next layer is deposited upon it, the layer shall be compacted using the equipment and rolling pattern as indicated by the test section. Compaction shall require a minimum of one rolling per lift. In addition, compaction shall continue until the required density and stability are achieved.

If rubber tired or steel drum type rollers are used for compaction, the finished surface shall be roughened by a light disking or other approved means to provide interlock between lifts.

5. Compacted Lift Thickness Measurement

The limit for compacted lift thickness shall be established during test section construction. Compacted lift thickness shall be measured and recorded concurrently with all density and DCP Index tests. An example of the lift thickness record chart is shown on Fig. 5 of Attachment F.

The 4-point moving average of lift thickness shall not exceed the value established in the test section.

6. Moisture Content of Compacted Lifts

It shall be the responsibility of the Contractor to test and insure that the moisture content of the compacted embankment material is within the range for the particular performance classification of the soil being placed. The control limits for moisture content shall be based on 'Soil Moisture Content Limits for Embankment Construction' (Attachment C).

Moisture content shall be calculated and reported to the nearest 0.1% based on dry weight of soil.

All individual tests for moisture content during embankment construction must be within the specified moisture control limits.

7. Compaction Zones

The quality control criterion for density is based on vertical location of embankment being placed. Embankment fill beneath a surface 0.9 m below the final subgrade elevation shall be compacted to lower zone quality control standards. Embankment fills within 0.9 m of the final subgrade elevation shall be compacted to upper zone quality standards. However, all embankment fill adjacent to and within 60 m of a bridge abutment shall be compacted to upper zone quality control standards.

Pipe culvert trenches shall be compacted in accordance with the zone the trench is located in.

The compaction of subgrade in cut sections shall be compacted to quality control standards for upper zone embankments.

8. Density Control Limits

a. Cohesive Soils (Attachment C definition)

Lower Zone
The 4-point moving average of density of embankment fill material placed in the lower zone shall be a minimum of 93% of the maximum dry density as determined by Iowa DOT Materials Laboratory Test Method 103 (Standard Proctor Density). Any individual test shall have a minimum of 90% of the maximum dry density.

Upper Zone
The 4-point moving average of density of embankment fill material placed in the upper zone shall be a minimum of 95% of the maximum dry density as determined by Iowa DOT Materials Laboratory Test Method 103 (Standard Proctor Density). Any individual test shall have a minimum of 93% of the maximum dry density for any individual test.

b. Non-Cohesive Soils (Attachment C definition)

Lower and Upper Zone

The 4-point moving average density of embankment fill material shall be a minimum Relative Density of 80% as determined by ASTM D 4253 and D 4254.

An example of a field compaction control chart is shown on Fig. 1 of Attachment F.

9. DCP Index Control Limits

The stability of embankment placed in the upper and lower zones shall be measured for a 0.9 m depth of DCP test as described in Attachment D.

a. Mean DCP Index

The 4-point moving average of the Mean DCP Index shall not exceed the following values:

Soil Performance Classification (Attachment A)		Maximum Mean DCP Index (mm/blow)
	Select	75
Cohesive	Suitable	85
	Unsuitable	95
Intergrade	Suitable	45
Cohesionless	Select	35

Fig. 2 in Attachment F shows an example of a Mean DCP index control chart.

b. Mean Change in DCP Index between Consecutive Readings

The 4-point moving average of the Mean Change in DCP index shall not exceed the following values:

Soil Performance Classification (Atachment A)		Maximum Mean Change in DCP Index (mm/blow)
	Select	35
Cohesive	Suitable	40
	Unsuitable	40
Intergrade	Suitable	45
Cohesionless	Select	35

Fig. 3 in Attachment G shows an example control chart of the mean change in DCP index between consecutive readings.

G. TEST FREQUENCY DURING EMBANKMENT CONSTRUCTION

Compacted Lift Thickness, Moisture Content of Compacted Fill, and Density shall be measured for the uppermost lift of embankment being placed. DCP Index tests shall be taken at the same location to a depth of 0.9 m.

Test	Minimum Test Frequency
Compacted Lift Thickness	Concurrently every 1000 m^3 (compacted)
Moisture Content of Compacted Fill	Concurrently every 1000 m^3 (compacted)
Density	Concurrently every 1000 m^3 (compacted)
DCP (Dynamic Cone Penetrometer)	Concurrently every 1000 m^3 (compacted)
Determination of soil performance classification and moisture control limits	One every 25,000 m^3 or if there is a change in material as determined by the Engineer

However, for the initial 1000 m^3 of embankment construction following a test section, four tests shall be taken to establish a 4-point moving average.

H. FIELD RECORDS

The Contractor shall be responsible for documenting all observations, records and inspection, changes in soil classification, soil moisture, fill placement procedures, and test results on a daily basis. The results of the observations and records of inspection shall be noted as they occur in a permanent field record. Copies of the field DCP index tests, field moisture tests, field density test, compacted lift thickness measurements, running average calculation sheets, soil performance classification, field test strip construction procedures, and soil classification shall be provided to the Engineer on a daily basis. The original testing records (raw field and lab data sheets) and control charts shall be provided to the Engineer in a neat and orderly manner within five days after completion of the project.

I. CONTROL CHARTS

Standardized control charts shall be maintained for each grading area by the Contractor for field DCP index, field moisture, field density tests, and compacted lift thickness measurements. The charts shall be posted at a location agreed upon by the Contractor and the Engineer. Test results obtained by the Contractor shall be recorded on the control charts the same day the tests are conducted. The results for the described field data shall be recorded on the standardized control charts for all randomly selected subgrade cut and fill locations tested.

Both the individual test point and the moving average of four data points shall be plotted on each chart. The Contractor's test data shall be shown as black (filled) circles and the moving average in unfilled circles. Additional tests or retests, which have been randomly selected, shall be plotted in gray. Other means of chart plotting may be used when approved by the Engineer. Legends used on the control charts shall be consistent throughout the project.

Refer to Attachment F for format and examples of Control Charts.

J. CORRECTIVE ACTION

The Contractor shall notify the Engineer when a single Moisture Content test or a 4-point moving test average of Density, Mean DCP Index, or Mean Change in DCP Index falls outside the specified control limits.

All randomly selected tests shall be part of the project files and shall be included in the moving average calculations.

1. Moisture Content

If a single moisture content of compacted fill falls outside of the control limits, the material in the area represented by the test shall be considered unacceptable. The Contractor shall perform corrective action(s) to bring the material within the specified moisture control limits as shown by a re-test.

2. Field Density, Mean DCP Index, Mean Change in DCP Index

If a 4-point moving average from the Field Density, Mean DCP Index, or Mean Change in DCP Index test falls outside of the specified control limits, the Contractor shall take corrective action(s) on the subsequent fill placed. The Contractor and Engineer shall discuss corrective action(s) to bring the fill material for the subsequent fill above the control limits. The Contractor shall perform the corrective action and provide documentation.

If the corrective action improves the failed field test such that the new moving average, after a re-test, is within the control limit, the Contractor may continue subgrade cut or fill material placement.

If the new moving average point is still outside of the control limit after the re-test, the subgrade fill material in the recently tested area shall be considered unacceptable. If the embankment material is considered unacceptable, the Contractor shall perform additional corrective action(s) to improve the fill material until the new moving average, after a re-test, falls within the control limits.

C. Incorrect Data

If the Contractor's initial control data is later proven incorrect, which results in a corrected single Moisture Content or a corrected 4-point moving average of Field Density, Mean DCP Index, Mean Change in DCP Index falling outside of the control limits, the subgrade fill material represented by the incorrect test data shall be considered unacceptable. The Contractor shall employ the methods described above for unacceptable material.

K. IOWA DOT QUALITY ASSURANCE

1. Required Testing and Personnel Requirements

The Engineer will conduct assurance tests on split samples taken by the Contractor for soil performance classification, soil moisture content limits determination, and laboratory compaction testing. These samples may be from sample locations chosen by the Engineer from anywhere in the process. The frequency of testing for the split samples will be equal to or greater than 10 percent of the tests taken by the Contractor. The referenced assurance test results will be provided to the Contractor within one working day after the Contractor's quality control test results have been reported.

The frequency of assurance testing for the field density, field DCP index, field moisture tests and compacted lift thickness measurements will be equal to or greater than 10 percent of the tests required for the Contractor's quality control. The results of referenced testing and measurement will be provided to the Contractor on the day of testing.

A Certified Grading Technician shall perform all field-testing and data analysis. The Certified Grading Technician shall retain split samples from those obtained by the Contractor for the soil performance classification and subsequent test section construction. The Engineer may select any or all of the Contractor-retained split samples for assurance testing.

The Engineer will periodically witness field-testing being performed by the Contractor. If the Engineer observes that the quality control field tests are not being performed in accordance with the applicable test procedures, the Engineer may stop production until corrective action is taken. The Engineer will notify the Contractor of observed deficiencies, promptly, both verbally and in writing. The Engineer will document all witnessed testing.

2. Testing Precision

The Contract Authority's assurance tests shall be conducted on a split sample at the exact location as the Contractor’s quality control test.

In the event comparison test results are outside the above allowable differences, the Engineer will investigate the reason immediately. The Engineer's investigation may include testing of other locations, review of observations of Contractors testing procedures and equipment, and a comparison of test results obtained by the Contractor, with those obtained by the Contract Authority.

a. Moisture Content

Moisture content shall be calculated and reported to the nearest 0.1%. Differences between the Contractor's and the Engineer's moisture content test results will be considered acceptable if moisture content is within 1.0% based on dry weight of soil.

b. Density

Differences between the Contractor's and the Engineer's in-place density tests will be considered acceptable if the dry density is within 80 kg per m^3.

c. Optimum Density and Optimum Moisture

Differences between the Contractor's and the Engineer's Proctor test results will be considered acceptable if the optimum dry density is within 80 kg per m^3 and the optimum moisture is within 1.5% based on dry weight.

d. DCP Index

There is no accepted reference value for the DCP index test. Therefore, bias cannot be determined.

3. Referee Testing

If a difference in procedures for sampling and testing and/or test results exists between the Contractor and the Engineer which they cannot resolve, the Iowa DOT's Central Materials Laboratory in Ames or another mutually agreed upon independent testing laboratory will be asked to provide referee testing. The Engineer and the Contractor will abide by the results of the referee testing. The party found in error will pay service charges incurred for referee testing by an independent laboratory.

L. ACCEPTANCE

The Engineer will base final acceptance of tests and materials on the results of the Contractor's quality control testing as verified by the Engineer's quality assurance.

95509M.04 METHOD OF MEASUREMENT

All excavation in preparation for and construction of QM-E embankment shall be included in Class 10 Excavation in accordance with Article 2102.13 of the Standard Specifications. The construction of embankment will not be measured separately for payment except as follows:

A. Disking To Reduce Excessive Moisture

The Engineer will count the number of days each disking unit is used to reduce excess moisture from deposited uncompacted material, or for disking ordered by the Engineer for reasons other than reducing moisture.

If the disking unit is used more than one hour but less than four hours during the day the disking unit shall be paid as a half-day. If used for a major part of a day, or greater than four hours, the unit shall be paid for a full day.

B. Water for Embankment Construction

Water required to moisten materials placed in embankment will be measured in kiloliters by gauging the contents of the transporting vehicle or by metering the supply. Authorized water for finishing the roadbed will not be measured for payment if a period in excess of 2 calendar days has elapsed between final compaction of a dump area and final finishing of the same area.

C. Test Sections

For establishing the compactive effort and lift thickness to be used in construction of QM-E embankment, the Contractor shall construct a test section for each classification of soil encountered. The Engineer will count the number of test sections constructed.

The placement of the volume of embankment material in test sections shall be included in quantities of Class 10 Excavation, Roadway and Borrow.

D. Quality Control Program

The item will be the lump sum for the Quality Control Program.

E. QM-E FIELD LABORATORY

The Engineer will count the QM-E Field Laboratory.

95509M.05 BASIS OF PAYMENT

Except as listed herein, the work of building QM-E embankments will not be paid for directly, but will be considered as associated work pertaining to the various classes of excavation and included in contract prices therefore.

A. Disking to Reduce Excessive Moisture

The Contractor will be paid the contract unit price for the number of days per unit that disking is required for material to be within moisture control limits of Attachment C and was performed by the Contractor, or for any disking ordered by the Engineer and performed by the Contractor.

B. Water for Embankment Construction

Water required for material to be within moisture control limits of Attachment C and added by the Contractor shall be paid for at the contract unit price per kiloliter for water.

C. Test Section

The Contractor will be paid for each Test Section ordered by the Engineer. The unit price shall include all labor, equipment time, and sampling and testing needed to meet requirements for Test Sections.

Placement of embankment material in test sections shall also be paid as Class 10 Excavation, Roadway and Borrow.

D. Quality Control Program

The availability for pre-construction training and the furnishing of a full-time Certified Grading Technician I, or above, during construction shall be included in the item for Quality Control Program. This shall include all labor, sampling and testing, process control inspection, and necessary adjustments for construction of test sections and embankments to meet the requirements of this Special Provision.

E. QM-E Field Laboratory

For the QM-E Field Laboratory furnished, the Contractor will be paid the contract unit price for Field Laboratory (QM-E). This payment shall be full compensation for furnishing, moving, and maintaining the QM-E Field Laboratory, including a shed or trailer to house additional testing equipment, and for furnishing the utilities and sanitary facilities.

ATTACHMENT A

SOIL PERFORMANCE CLASSIFICATION FOR EMBANKMENT DESIGN AND CONSTRUCTION

NOTE

This standard classifies soil into suitability classes (Select, Suitable, or Unsuitable), which determine location of placement of soil in embankments during design and construction. Properties obtained from two test methods are needed for classification:

- Percent Material Passing the 425 µm or 75 µm Sieve (Attachment B)
- Atterberg Limits of Soils (AASHTO Test Methods T 89 and T 90)

SCOPE

The method covers the system for classifying cohesive, intergrade, and cohesionless soils for embankment design and construction based on determination of the fraction finer than the 425-µm and/or 75-µm sieves, liquid limit, and plasticity index.
This soil performance classification system identifies three major soil performance groups: (1) Select, (2) Suitable, and (3) Unsuitable. The Unsuitable soils are further characterized for disposal by one of the three methods in Standard Road Plan RL-18. Based on the results of the prescribed laboratory tests, a soil is classified according to the basic soil performance group. For cohesive soils, Fig. 1 and Table 1 are used to assign the appropriate soil performance classification.

PRELIMINARY CLASSIFICATION PROCEDURE

Before a soil can be classified, the percent passing the 75 µm sieve material and the plasticity characteristics of the minus 425 µm sieve material must be determined.

A. Classify the soil as 'Cohesive' if 36% or more by dry weight of the test specimen passes the 75 µm sieve and then follow the “Procedure for Classification of Cohesive Soils”.

B. Classify the soil as 'Intergrade' if 16 to 35% by dry weight of the test specimen passes the 75 µm sieve and then follow the “Procedure for Classification of Intergrade Soils”.

   However, if the liquid limit is greater than 40 and the plasticity index is greater than 10, reclassify the soil as 'Cohesive' and follow “Procedure for Classification of Cohesive Soils”.

C. Classify the soil as 'Cohesionless' if less than 16% by dry weight of the test specimen passes the 75 µm sieve and then follow the “Procedure for Classification of Cohesionless Soils”.

PROCEDURE FOR CLASSIFICATION OF COHESIVE SOILS

A. **High Plasticity Inorganic Clays** - The soil is a high plasticity inorganic clay if on Fig. 1, the position of the plasticity index versus liquid limit plot falls on or above the “A” line and the liquid limit is greater than 50.

   1. Classify the soil as Suitable if the percent by dry weight of the test specimen passing the 75 µm sieve is less than the interpolated Fineness Designation Number (FDN) of the point as plotted on Fig. 1.

2. Classify the soil as Unsuitable if the percent by dry weight of the test specimen passes the 75 µm sieve is more than the interpolated FDN of the point as plotted on Fig. 1. Use the Type "B" disposal method according to Standard Road Plan RL-1B.

B. **Medium Plasticity Inorganic Clays** - The soil is a medium plasticity inorganic clay if the position of the Plasticity Index versus Liquid Limit plot falls on or above the "A" line on Fig. 1, and the liquid limit falls on or below 50, and the PI $\geq$ (28 – 0.38LL) when the liquid limit is from 28 to 38.

1. Classify the soil as Select if the percent by dry weight of the test specimen passing the 75 µm sieve is less than the interpolated FDN of the point as plotted on Fig. 1.

2. Classify the soil as Suitable if the percent by dry weight of the test specimen passes the 75 µm sieve is more than the interpolated FDN of the point as plotted on Fig. 1.

C. **Low/Medium Plasticity Clays** - The soil is a low to medium plasticity clay if the position of the Plasticity Index versus Liquid Limit plot falls on or above the "A" line on Fig 1, and the plasticity index falls on or above 10, and PI $<$ (28 – 0.38LL) when the liquid limit is from 28 to 38.

1. Classify the soil as Select if the percent by dry weight of the test specimen passing the 75 µm sieve is less than 60%.

2. Classify the soil as Suitable if the percent by dry weight of the test specimen passing the 75 µm sieve is from 60% to 70%.

3. Classify the soil as Unsuitable if the percent by dry weight of the test specimen passes the 75 µm sieve is more than 70%. Use the Type "C" disposal method according to Standard Road Plan RL-1B.

D. **Low Plasticity Clays** - The soil is a low plasticity clay if the position of the Plasticity Index versus Liquid Limit plot falls on or above the "A" line on Fig.1, and the plasticity index falls below 10.

1. Classify the soil as Select if the percent by dry weight of the test specimen passing the 75 µm sieve is less than or equal to 45% and the percent by dry weight of the test specimen passing the 425 µm sieve is less than or equal to 70%.

2. Classify the soil as Suitable if the percent by dry weight of the test specimen passing the 75 µm sieve is from 46% to 70%.

3. Classify the soil as Unsuitable if the percent by dry weight of the test specimen passes the 75 µm sieve is more than 70%. Use the Type "C" disposal method according to Standard Road Plan RL-1B.

E. **Inorganic Silts of Medium Compressibility** - The soil is an inorganic silt of medium compressibility if the position of the Plasticity Index versus Liquid Limit plot falls below the "A" line on Fig. 1, and the liquid limit is less than or equal to 50. Classify the soil as Unsuitable. Use the Type "B" disposal method according to Standard Road Plan RL-1B.

F. **Highly compressible inorganic silts and high plasticity clays** - The soil is a highly compressible inorganic silt and high plasticity clay if the position of the Plasticity Index versus Liquid Limit plot falls below the "A" line on Fig. 1, and the liquid limit is greater than 50.

1. Classify the soil as Unsuitable if the percent carbon by dry weight of the test specimen is equal to or more than 3.0%. Use as Slope Dressing only.

2. Classify the soil as Unsuitable if the percent carbon by dry weight of the test specimen is less than 3.0%. Use the Type A disposal method according to Standard Road Plan RL-1B.

PROCEDURE FOR CLASSIFICATION OF INTERGRADE SOILS

A. Classify the soil as Suitable if the percent passing the 75 µm sieve is 16 to 35%.

PROCEDURE FOR CLASSIFICATION OF COHESIONLESS SOILS

A. Classify the soil as Select if the percent by dry weight of the test specimen passing the 75 µm sieve is less than or equal to 15%.

Note 1: All soils other than "highly compressible inorganic silt and high plasticity clays" containing 3.0% or more carbon are placed according to the Type C disposal method indicated on Standard Road Plan RL-1B.

Note 2: Unless otherwise specified, Shale is placed according to Type A disposal method indicated on Standard Road Plan RL-1B.

EXAMPLES OF SOIL PERFORMANCE CLASSIFICATION

The following examples show how the required soil information (liquid limit, plasticity index, and percent passing the 425 µm and 75 µm sieves can be reported. The appropriate descriptive information is included with each soil performance classification.

NO.	LL	PI	Percent passing 425 µm sieve	Percent passing 200 µm sieve	Preliminary Classification	Descriptive Regions for Cohesive Soils from Fig. 1	Final Soil Performance Classification
1	0	NP	—	10	Cohesionless	—	Select
2	21	14	—	13	Cohesionless	—	Select
3	15	13	—	17	Intergrade	—	Suitable
4	28	4	—	39	Cohesive	Inorganic Silts of Medium Compressibility	Unsuitable (Type B disposal)
5	22	9	68	44	Cohesive	Low Plasticity Clays	Select
6	19	7	—	63	Cohesive	Low Plasticity Clays	Suitable
7	33	11	—	62	Cohesive	Low/Medium Plasticity Clays	Suitable
8	35	21	—	61	Cohesive	Medium Plasticity Inorganic Clays	Select
9	49	27	—	95	Cohesive	Medium Plasticity Inorganic Clays	Suitable
10	65	41	—	71	Cohesive	High Plasticity Inorganic Clays	Suitable
11	76	37	—	91	Cohesive	Highly compressible inorganic silts and high plasticity clays	Unsuitable (Type B disposal)
12	97	71	—	95	Cohesive	High Plasticity Inorganic Clays	Unsuitable (Type A disposal)

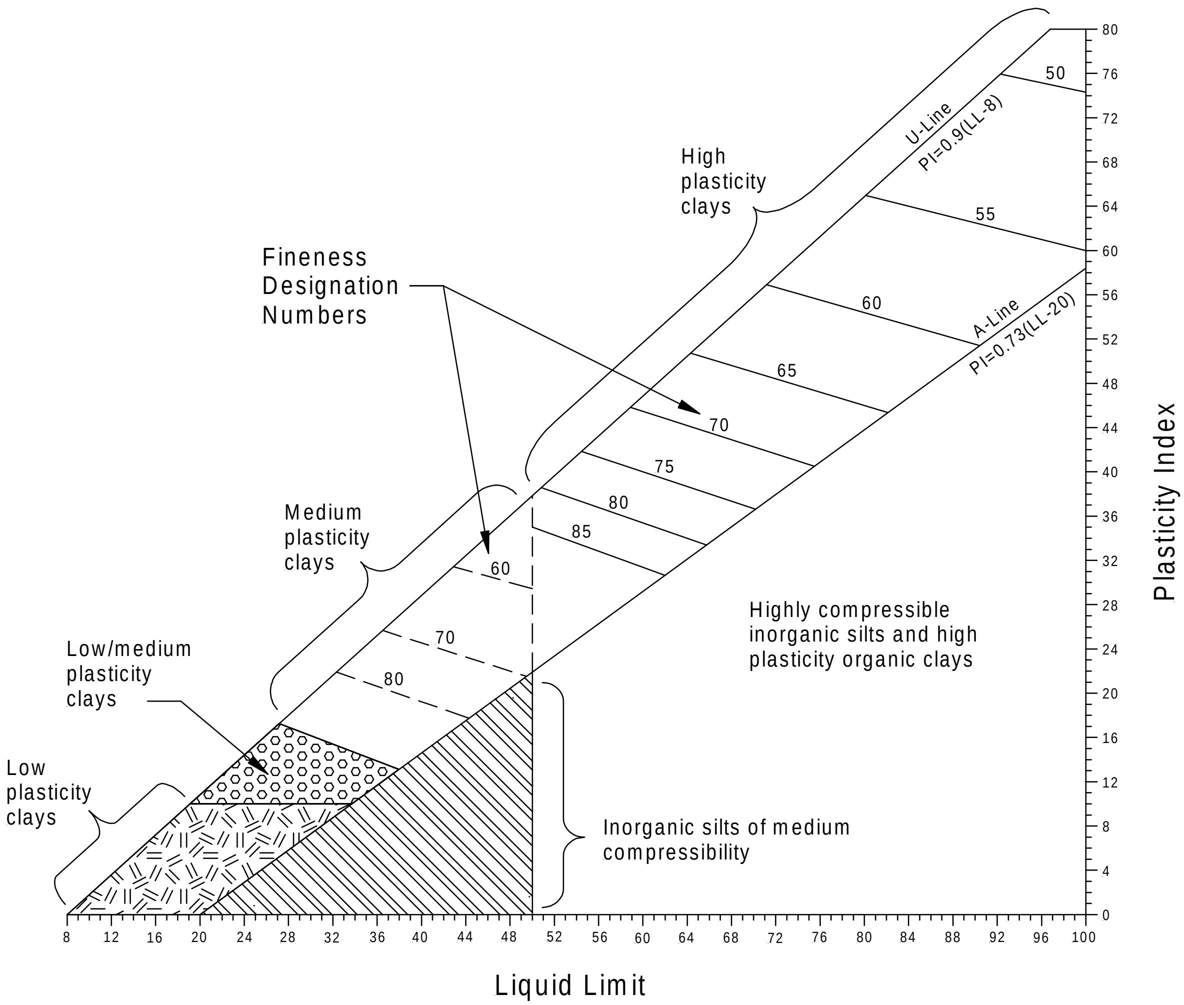


Figure 1. Soil performance classification for cohesive soils

Table 1. Final classification for cohesive soils

Preliminary Soil Group	Final Classification and Criteria			Unsuitable Disposal Requirements
	Select	Suitable	Unsuitable	
Low plasticity clays	$F_{75\,\mu m} \leq 45$ and $F_{40} \leq 70$	$46 \leq F_{75\,\mu m} \leq 70$	$F_{75\,\mu m} > 70$	Type C
Low/Medium plasticity clays	$F_{75\,\mu m} < 60$	$60 \leq F_{75\,\mu m} \leq 70$	$F_{75\,\mu m} > 70$	Type C
Medium plasticity clays	$F_{75\,\mu m} \leq$ FDN	$F_{75\,\mu m} >$ FDN	——	——
High plasticity clays	——	$F_{75\,\mu m} \leq$ FDN	$F_{75\,\mu m} >$ FDN	Type B
Inorganic silts of medium compressibility	——	——	All soils in this region	Type B
Highly compressible silts and high plasticity organic clays	——	——	All soil in this region	Type A -or- Slope dressing only if carbon content ≥ 3.0%

NOTE: $F_{75\,\mu m}$ = Percent passing 75 µm sieve; $F_{425\,\mu m}$ = percent passing 425 µm sieve; FDN = Fineness Designation Numbers from Fig. 1.

ATTACHMENT B
FIELD DETERMINATION OF THE PERCENT MATERIAL PASSING THE 75 µm SIEVE

SCOPE

This is a standard for the quantitative field determination of the percent of material passing the 75 µm sieve for cohesive and cohesionless soils.

PROCEDURE

A. Test Sample – The total test sample required for sieve washing and hygroscopic moisture determination consists of about 150 g of well-pulverized air-dry soil.

B. Procedure – After the sample has been air-dried and pulverized, transfer approximately 100 g of soil onto the 75 µm sieve. Record the exact amount of air-dry soil transferred to the sieve. Next wash the soil through the sieve with tap water until the wash water is clear. After washing transfer the material retained on the 75 µm sieve to a suitable container, dry in an oven or microwave and record the dry mass of soil retained on the 75 µm sieve.

C. Hygroscopic Moisture – When the soil sample is weighed for washing over the 75 µm sieve, weigh out an auxiliary portion of from 40 to 50 g in a small crucible, dry the sample to a constant mass in an oven or microwave, and weigh again. Record the mass before and after drying.

CALCULATIONS

The percent passing the 75 µm sieve is calculated as follows:

$$\%\ \text{Passing } 75\ \mu\text{m sieve} = \{(M_{TOTAL\text{-}DRY} - M_{RETAINED\text{-}DRY}) \div M_{TOTAL\text{-}DRY}\} \times 100\%$$

Where:

$M_{TOTAL\text{-}DRY}$ = $M_{TOTAL} \div [1 + (M\%)/(100)]$

M_{TOTAL} = Air-dry mass of sample transferred to 75 µm sieve before washing
$M\%$ = Hygroscopic moisture content, in percent
= [(mass of water in soil sample) ÷ (dry mass of soil sample)] 100

$M_{RETAINED\text{-}DRY}$ = Oven-dry mass of soil retained on 75 µm sieve after washing

ATTACHMENT C
SOIL MOISTURE CONTENT LIMITS FOR EMBANKMENT CONSTRUCTION PURPOSES

NOTE

This is a standard for determination of soil moisture control limits during construction of highway embankments.

SCOPE

The method determines acceptable moisture content limits based on the soil's performance classification (Attachment A) and on its Relative Density and/or Standard Proctor maximum density and "optimum" moisture content. Based on the results of the prescribed laboratory tests, moisture content limits are established for cohesive and cohesionless soils.

PRELIMINARY CLASSIFICATION PROCEDURE

Before soil moisture content limits can be determined, generally the percent passing the 75 µm sieve material, relative density, and/or standard Proctor moisture-density relationship must be determined.

A.

Classify the soil as Cohesive if 36% or more by dry weight of the test specimen passes the 75 µm sieve and follow Procedure for Determination of Moisture Limits for Cohesive Soils.

B.

Classify the soil as Cohesionless if 15% or less by dry weight of the test specimen passes the 75 µm sieve and follow Procedure for Determination of Moisture Limits for Cohesionless Soils.

C.

Temporarily[1] class the soil as Intergrad*e* if 16% to 35% by dry weight of the test specimen passes the 75 µm sieve and follow Procedure for Determination of Moisture Limits for Intergrade Soils. ([1]Soil will be reclassified as either cohesive or cohesionless.)

<u>PROCEDURE FOR DETERMINATION OF MOISTURE LIMITS FOR COHESIVE SOILS</u>

A three-point standard Proctor moisture-density relationship is used to establish the acceptable moisture content limits.

A. Select and Suitable - The acceptable moisture content limits for select or suitable cohesive soils (Attachment A) are fixed at –1% to +3% of optimum.

B. Unsuitable - The acceptable moisture content range for unsuitable cohesive soils (Attachment A) varies depending on optimum moisture content as shown on Fig. 1. For optimum moisture contents 20% or more the acceptable moisture content limit is fixed at –2% to +4% of optimum. Below optimum moisture content of 20% the acceptable moisture content limits vary according to the following:

[1] $M\%_{\text{upper limit}} = 1.2\ (M\%_{\text{optimum}})$

[2] $M\%_{\text{lower limit}} = 0.9\ (M\%_{\text{optimum}})$

Note 1: Notwithstanding Eq. 1 and 2, soil moisture content limits are not to be restricted to limits narrower than –1% to +3% (i.e. all cohesive soils shall have moisture limits ranging from –1% to +3% at a minimum).

PROCEDURE FOR DETERMINATION OF MOISTURE LIMITS FOR COHESIONLESS SOILS

All cohesionless soils require the identification of the bulking moisture contents (to be avoided during placement) and an upper limit to prevent placement of overly wet material.

To determine the bulking moisture content limits, follow the procedure for the Iowa Modified Relative Density Test (Attachment E). The bulking moisture content limits are graphically determined as those for which 80% relative density cannot be achieved.

The upper bound moisture limit is based on the maximum dry density (RD_{max}) from the relative density test and is calculated based on the following:

[3] $$M\%_{upper\ limit} = [(800 / RD_{max}) - 0.3] 100$$

where RD_{max} is in kg per m3.

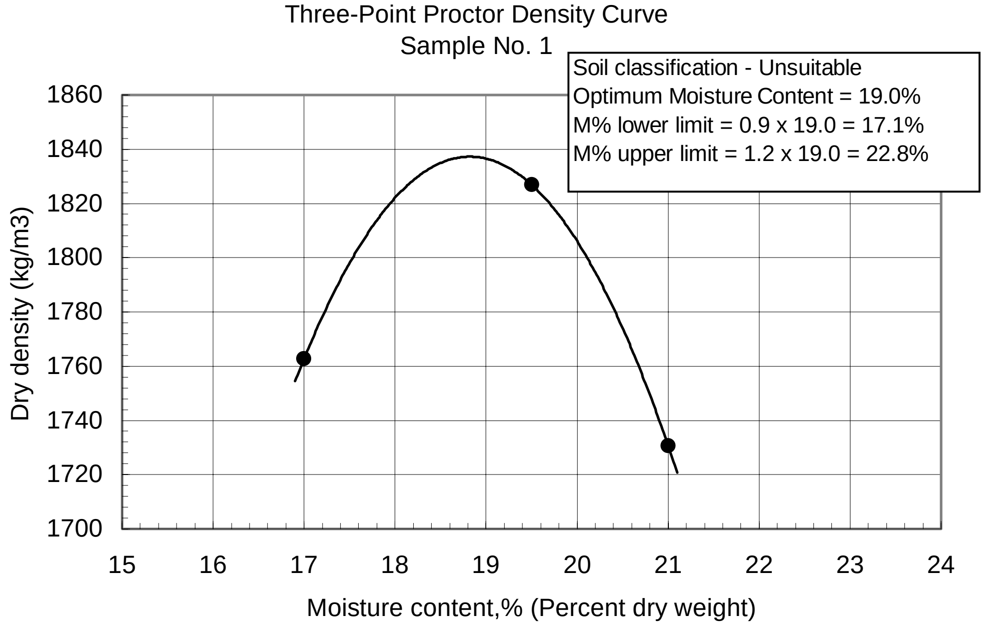
PROCEDURE FOR DETERMINATION OF MOISTURE LIMITS FOR INTERGRADE SOILS

Perform both the relative density test and standard Proctor compaction test and determine which test results in the higher maximum dry density. Reclassify the soil as Cohesive if the standard Proctor maximum dry density controls and follow “Procedure for Determination of Moisture Limits for Cohesive Soils”. Reclassify the soil as Cohesionless if the relative density test controls and follow “Procedure for Determination of Moisture Limits for Cohesionless Soils”.

EXAMPLES OF SOIL MOISTURE CONTENT LIMITS

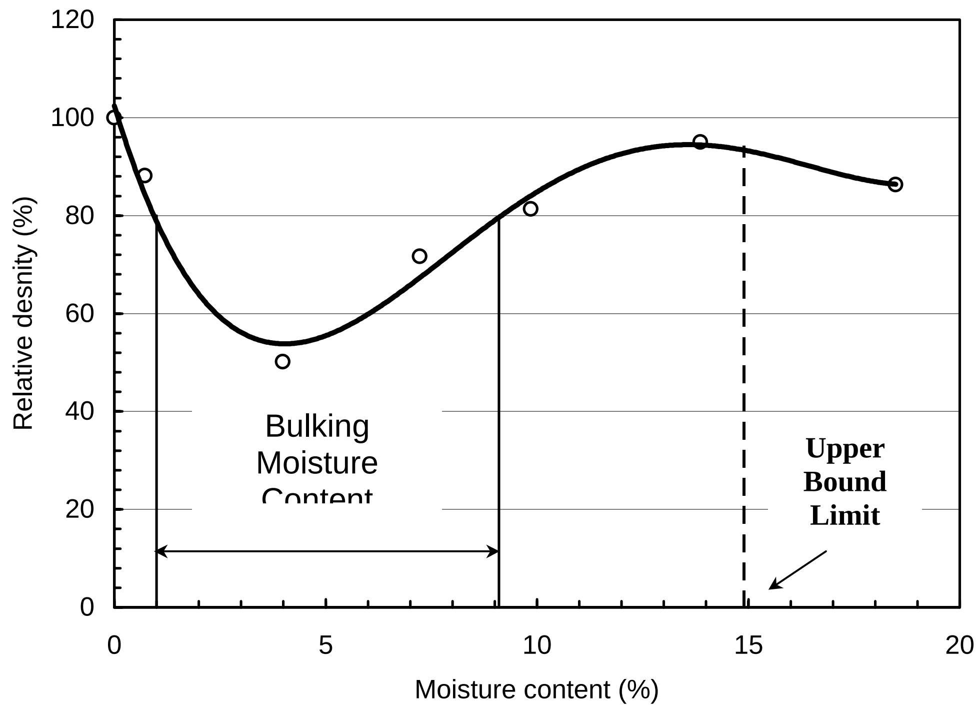
The following examples show how the required relative density and standard Proctor results can be reported. The appropriate moisture information and calculations are included.

EXAMPLES - COHESIVE SOILS



NO.	Soil Performance Classification (Test Method A)	Optimum moisture content, %	Calculated lower limit (dry side)	Calculated upper limit (wet limit)	Final Construction Moisture Content Limits
1	Unsuitable	19.0	0.9 x 19.0 = 17.1	1.2 x 19.0 = 22.8	19.0% (-1.9% to +3.8%)
2	Unsuitable	23.5	23.5 - 2.0 = 21.5	23.5 + 4.0 = 27.5	23.5% (-2% to +4%)
3	Select	16.0	16.0 - 1.0 = 15.0	16.0 + 3.0 =18.0	16.0% (-1% to +3%)
4	Suitable	18.5	18.5 - 1.0 = 17.5	18.5 + 3.0 =21.5	18.5% (-1% to +3%)
5	Unsuitable	14.0	0.9 x 14.0 = 12.6	1.2 x 14.0 = 16.8	14.0% (-1.4% to +3%)[1]
6	Unsuitable	28.0	28.0 -2.0 = 26.0	28.0 + 4.0 = 32.0	28.0% (-2% to +4%)
[1] By default the upper moisture limit is set at +3% (16.8 - 14.0 = 2.8%; cannot be less than +3%)					

EXAMPLES - COHESIONLESS SOILS



NO.	Soil Performance Classification (Test Method A)	Max. dry density, RD_{max} (kg/m^3)	Bulking moisture content, % (to be avoided)	Calculated upper moisture limit, $M\%_{upper\ limit}$	Final Construction Moisture Content Limits
1	Intergrade - suitable	1778	1.5 to 8.5	15.0	0 to 1.5% and 8.5% to 15.0%
2	Select	2128	3.0 to 4.5	7.6	0 to 3.0% and 4.5% to 7.6%
3	Select	1951	2.0 to 8.0	11.0	0 to 2.0% and 8.0% to 11.0%
4	Select	1874	2.5 to 8.0	12.7	0 to 2.5% and 8.0% to 12.7%

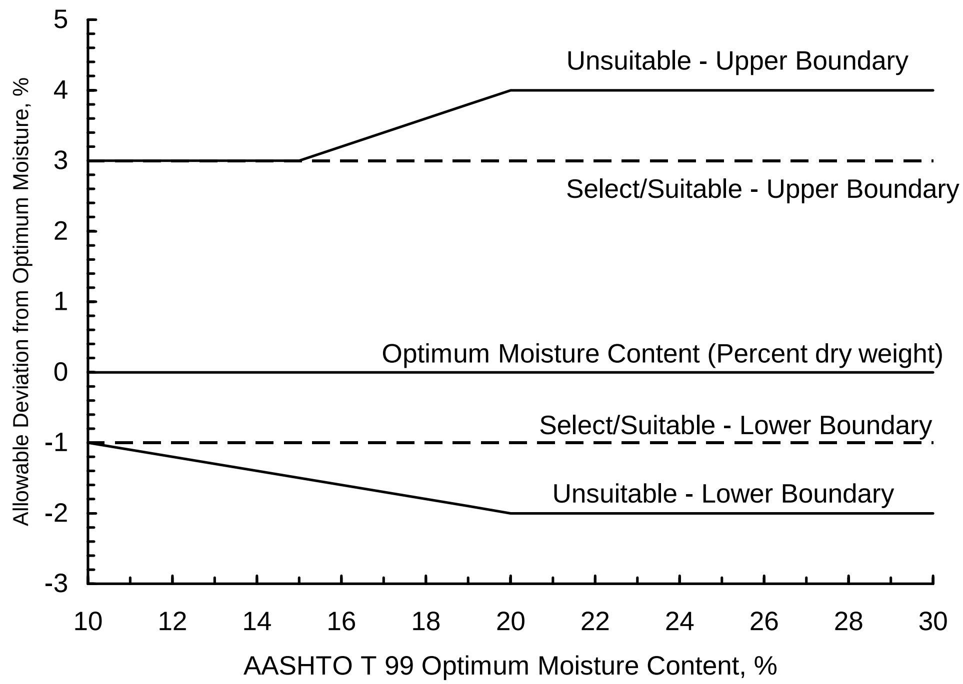


Figure 1. Iowa Moisture Content Construction (MCC) chart for cohesive soils

ATTACHMENT D
STANDARD DYNAMIC CONE PENETROMETER IN SHALLOW PAVEMENT AND SOIL APPLICATIONS

NOTE

This standard is based on a draft ASTM Standard for the Dynamic Cone Penetrometer (DCP) using the specific equipment shown on Fig. 1. Other test methods exist that use other types of DCPs. Other correlations exist which are specific to those devices.

SCOPE

The method covers the measurement of the penetration rate of the DCP through paving materials and subgrade soils.

PROCEDURE

A. Significance and Use

1. This test method is used to assess the in situ strength of unbound paving materials and subgrade soils. The penetration rate of the DCP can be used to estimate in-situ California Bearing Ratio (CBR) and shear strength of strata and identify strata thickness.

2. The DCP is held vertically and therefore is typically used in horizontal construction applications, such as pavement and floor slabs.

3. The DCP is typically used to assess material properties to a depth of 1.0 m below the surface. The penetration depth can be increased using drive rod extensions. However, if drive rod extensions are used, care should be taken when using correlations to estimate other parameters since these correlations are only appropriate for specific DCP configurations. The mass and inertia of the device will change and skin friction along drive rod extensions will occur.

4. The DCP can be used to estimate the strength characteristics of fine and coarse-grained soils, granular construction materials, and weak stabilized or modified materials. The DCP cannot be used in highly stabilized or cemented materials containing a large percentage of aggregates greater than 50 mm.

5. The DCP can be used to estimate the strength of in-situ materials underlying a bound or highly stabilized layer by first drilling or coring an access hole.

B. Apparatus

1. The DCP specific to this standard is shown schematically in Fig. 1. It consists of the following components: a 15.8 mm diameter steel drive rod with a replaceable or disposable cone tip, an 8 kg weight or hammer which is dropped a fixed height of 575 mm, a coupler assembly, and a handle. The cone tip has an included angle of 60 degrees and a diameter at the base of the cone of 20 mm. The drive rod or a separate vertical scale is graduated using increments of 5.0 mm. The apparatus is typically constructed of stainless steel, with the exception of the cone tip, which may be constructed from hardened tool steel or a similar material resistant to wear.

Note 1: A disposable DCP cone tip may be used, provided its dimensions are as specified above. The disposable cone tip is held in place with an o-ring, which allows the cone tip to be easily detached when the drive rod is pulled upward after completion of the test.

Note 2: A 4.6 kg hammer may be used in place of the 8 kg hammer provided that the standard drop height is maintained. The 4.6 kg hammer is used in weaker materials where the 8 kg hammer would produce penetration due to its static load.

Note 3: An automated version of the DCP may be used provided all requirements of this standard with respect to the apparatus and procedure is met.

2. The following tolerances are recommended:

    a. Hammer Weight – measurement of 8.0 kg; tolerance is ± 0.010 kg.
    b. Hammer Weight – measurement of 4.6 kg; tolerance is ± 0.010 kg.
    c. Drop of Hammer – measurement of 575 mm; tolerance is ± 1.0 mm.
    d. Cone Tip Angle – measurement of 60 degrees included angle; tolerance is ± 1 degree.
    e. Cone Tip Base Diameter – measurement of 20 mm; tolerance is ± 0.25 mm.

3. In addition to the DCP, the following equipment is needed:

    a. Tool set for assembling/disassembling the DCP.
    b. Lubricating oil.
    c. Thread locking compound.
    d. Data recording form (Table 1).

    Depending on the circumstances, the following equipment may also be needed or is recommended:

    e. A vertical scale longer than the longest drive rod or rod extension graduated using increments of 5.0-mm if the drive rod(s) are not graduated.
    f. Reference jig for used with a graduated drive rod.
    g. A rotary hammer drill capable of drilling a minimum diameter hole of 40 mm or a coring apparatus with a minimum core barrel diameter of 25 mm.
    h. Wet/dry shop vacuum or suitable alternative to remove loose material and fluid if an access hole is made prior testing.
    i. Field power supply to power items in c and d above.
    j. Disposable cone tips.
    k. Extraction jack

C. Test Procedure

1. Equipment Check – Prior to beginning a test, the DCP device is inspected for fatigue-damaged parts, in particular the coupler and handle, and excessive wear of the drive rod and cone tip. All joints must be securely tightened including the coupler assembly and the cone tip to drive rod.

2. Basic Operation – The Operator holds the device by the handle in a vertical or plumb position and lifts and releases the hammer from the standard drop height. The Recorder measures and records the total penetration for a given number of drops or the penetration per drop.

3. Initial Reading

    a. Testing a Surface Layer – The DCP is held vertically and the cone tip is seated such that the widest part of the cone is flush with the surface of the material to be tested. An initial reading is obtained from the graduated drive rod or a separate vertical scale. The distance is measured to the nearest 1 mm by interpolating between graduations.

b. Testing Below a Bound Layer – When testing materials underlying a bound layer, a rotary hammer drill or coring apparatus is used to provide an access hole to the layer to be tested. Wet coring requires that the DCP test be performed as soon as possible, and not longer than 10 minutes following completion of the coring operation. The coring fluid must not be allowed to soak into or penetrate the material to be tested. A wet/dry shop vacuum or suitable alternative is used after completion of drilling or coring to remove loose material and fluid from the access hole prior to testing.

4. Testing Sequence

a. Dropping the Hammer – The DCP device is held in a vertical or plumb position. The operator raises the hammer until light contact is made with the handle. The hammer shall not impact the handle when being raised. The hammer is then allowed to free-fall and impacts the coupler assembly. The number of drops and corresponding penetration is recorded as described in section C.5.

b. Depth of Penetration – The depth of penetration will vary from application to application. For typical highway applications, a penetration less than the length of the standard drive rod will generally be adequate.

c. Refusal – The presence of large aggregates or rock strata will either stop further penetration or deflect the drive rod. If, after 10 drops, the device has not advanced more than 5 mm or has noticeably deflected from the vertical position, the testing shall be stopped and the device moved to anther test location. The new test location should be located a minimum of 300 mm from the prior location to minimized testing error caused by disturbance of the material.

d. Extraction – Following completion of the test, the device should be extracted using the extraction jack. In the absence of the extraction jack, the used of disposable cone tips greatly lessens the possibility of damage to the device caused by driving the hammer upward against the handle.

5. Data Recording - A form as shown in Table 1 is suggested for data recording. The Recorder enters the header information prior to the test. The actual test data are recorded in columns 1 and 2 (Number of Drops Between and Scale Reading). Reading Number 1 (column 2) corresponds to the initial DCP reading at the surface of the layer to be tested (as per C.3.a). When testing a subsurface layer through a drilled or cored access hole, Reading Number 1 corresponds to the reference reading at the top of the layer to be tested (as per C.3.b).

The number of drops between readings may be varied depending on the resistance of the material. The cone tip should be advanced a minimum of 10 mm between readings.

The penetration to the nearest 1 mm corresponding to a specific number of drops is recorded. A reading is taken immediately when the material properties change substantially.

6. Calculation and Report – The penetration between readings and penetration per drop in Table 1 are computed after testing. The penetration per drop is calculated for each reading beginning with reading number 2. The penetration per drop may then be plotted against the scale reading or total depth. The penetration per drop is then used to estimate in-situ CBR or shear strength using the appropriate correlation from the references listed. It is beyond the scope of this standard test method to describe the various correlations referenced. Selection of the appropriate correlation is a matter of professional judgment.

Note 4: The estimates of CBR and shear strength are based on a specific hammer weight, drop height, and cone tip configuration. The DCP configuration is noted on the data sheet in order to select the correct correlation.

Note 5: If a distinct layering exists within the material tested, a change of slope will be observed for each layer. The exact interface is difficult to define because, in general, a transition zone exists between layers. The layer thickness can be defined by the intersection of the lines representing the average slope of adjacent layers. Once the layer thickness has been defined, the average penetration rate per layer is calculated.

D. Precision and Bias

1. Precision – Test data on precision are not presented due to the nature of this test method. The variability of soil and the destructive nature of the test make it very difficult to provide for repetitive duplication of tests at a particular location to obtain a meaningful statistical evaluation.

2. Statement of Bias – There is no accepted reference value for this test method. Therefore, bias cannot be determined.

Table 1. DCP Data Sheet

Project____ **Date**____________________

Test Location and Elevation________________________ **Personnel**_______________

Weather Conditions_________________________ **Hammer Weight**__________

Material Classification________________ **Moisture Content** _____________

Depth of Seated Cone below Surface____

Notes____

No. of Blows (1)	Accumulative Penetration, mm (2)	Penetration per Blow Set, mm (3)	Penetration per Blow, mm (4)	Hammer Blow Factor (5)	DCP Index (6)	CBR, % (7)	Depth, inches (8)

(1) No. of hammer blows between test readings
(2) Accumulative cone penetration after each set of hammer blows (minimum penetration between test readings should be 25 mm)
(3) Difference in accumulative penetration (2) at start and end of hammer blow set
(4) (3) divided by (1)
(5) Enter 1 for 8 kg hammer; 2 for 4.6 kg hammer
(6) (4) x (5)
(7) From CBR versus DCP correlation using a chosen formula; for example CBR = $(292) / (DCP)^{1.12}$
(8) Previous entry in (2) divided by 25.4 rounded off to 0.1 in.

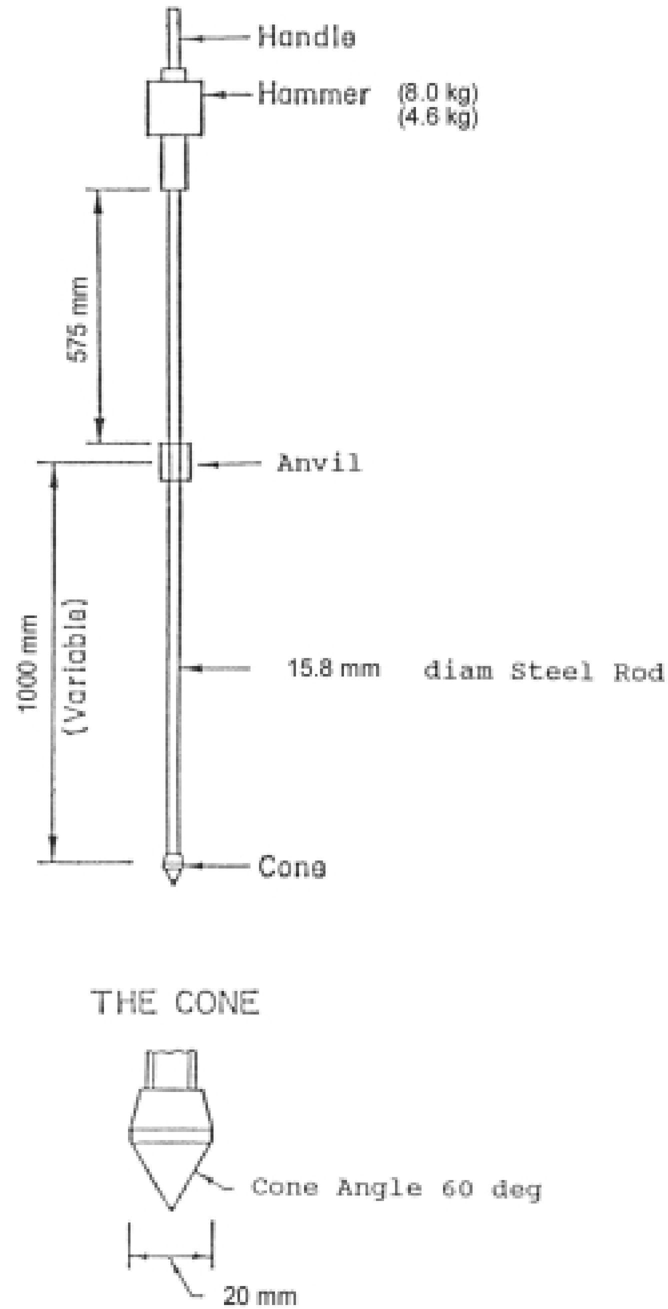


Figure 1. Schematic of DCP Device

ATTACHMENT E
Iowa modified relative density test for determination of bulking moisture contents of cohesionless soils

NOTE

This is a standard for the Iowa Modified Relative Density Test for determination of the bulking moisture content for cohesionless/granular and intergrade soils during design and construction of highway embankments.

SCOPE

The test method covers the system for defining the bulking moisture content of cohesionless/granular and intergrade soils. Maximum relative density as specified by ASTM Test Designations D 4253 and D 4254 are based on soils that are (1) compacted in the dry state or (2) compact in the presence of excessive moisture so that the material is saturated. The assertion that a soil with $F_{75\ \mu m} < 15\%$ will attain its maximum density in the dry condition or in a saturated condition is true and not under scrutiny. However, soils in the field will rarely be in the dry condition, and will most often exist at some moisture content between bulking and saturation. Soils with moisture contents in the bulking range are difficult to compact regardless of the amount of compaction energy applied to the soil.

Until this time, there has been no test to measure the influence of increasing moisture contents on cohesionless/granular materials with $F_{75\ \mu m} < 15\%$ and intergrade soils with $15\% < F_{75\ \mu m} < 36\%$. This was the basis for the development and design of the Iowa Modified Relative Density test. Just as every soil test is designed to define a certain characteristic of that soil, the Iowa Modified Relative Density test is designed to define the bulking moisture content of cohesionless/granular and intergrade soils. The Iowa Modified Relative Density Test provides a compaction characteristic curve, Fig. 1, for each soil tested similar to a standard Proctor moisture-density relationship. Thus, percent relative density is plotted as a function of moisture content.

Procedure

Cohesionless/granular and some intergrade soils exhibit a characteristic compaction curve through moisture contents ranging from about 0% to 25%. This range of moisture content is tested in the laboratory using the relative density test equipment and according to test designations ASTM D 4253 and D 4254 with the following modifications:

1. The test is to be performed at five different moisture contents, starting with oven-dry material and progressing through increasing moisture content steps of approximately 4-5%.

2. The Iowa Modified Relative Density test must provide for drainage of the wetted material. Thus, the standard 12.5 mm surcharge base plate used to hold the surcharge mass in position must allow for one-dimensional drainage (similar to field activities) of water as the material is vibrated. A modified surcharge base plate, used when the materials is wet, will have the same dimensions as the standard plate but will have seventeen 1.0 to 1.5 mm diameter holes drilled through the plate. In addition, a rubber gasket around the perimeter of the modified surcharge base plate will be needed. During the test a filter paper, the same diameter as the steel load plate, will be placed between the soil samples and the modified surcharge base plate to prevent material from escaping or clogging the holes in the plate, Fig. 2.

The Iowa Modified Relative Density Test is designed to increase the $F_{75\,\mu m}$ upper limit of 15% stipulated by current ASTM Test Designations D 4253 and D 4254 to 36%. The reasoning behind this is that some intergrade soils with $F_{75\,\mu m} > 15\%$ exhibit properties that make them more effectively compacted by vibratory means.

After the described tests are performed the plot of relative density versus moisture content is used to graphically determine the bulking moisture content. The bulking moisture content is defined as the moisture content range for which 80% relative density can not be achieved.

EXAMPLE OF BULKING MOISTURE CONTENT DETERMINATION

The following example shows how the plot of relative density versus moisture content is used to identify the bulking moisture content. See ASTM Test Designations D 4253 and D 4254 for example relative density calculations.

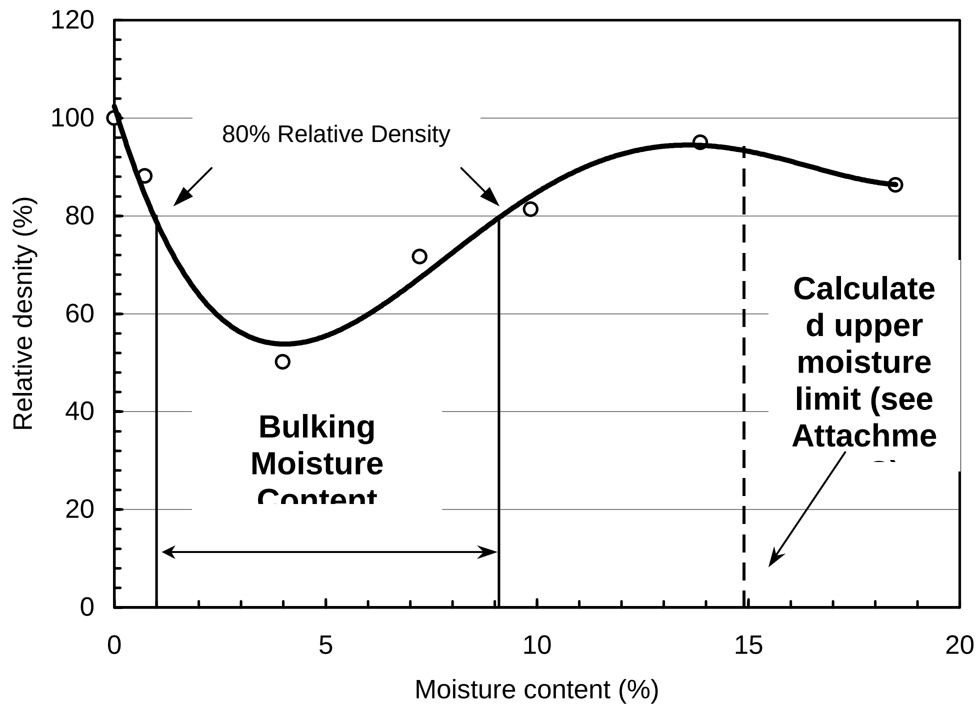
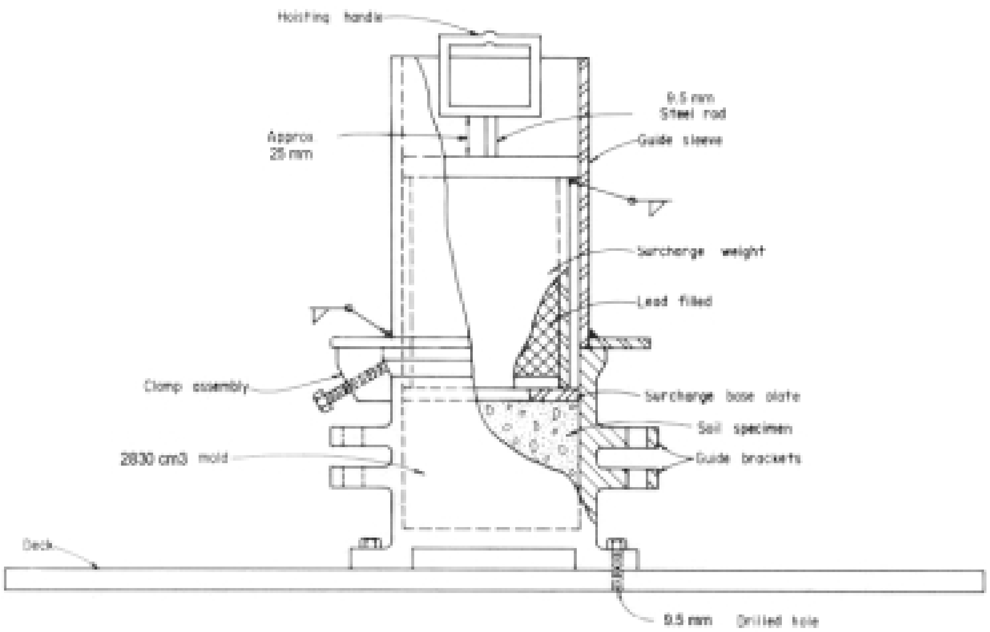
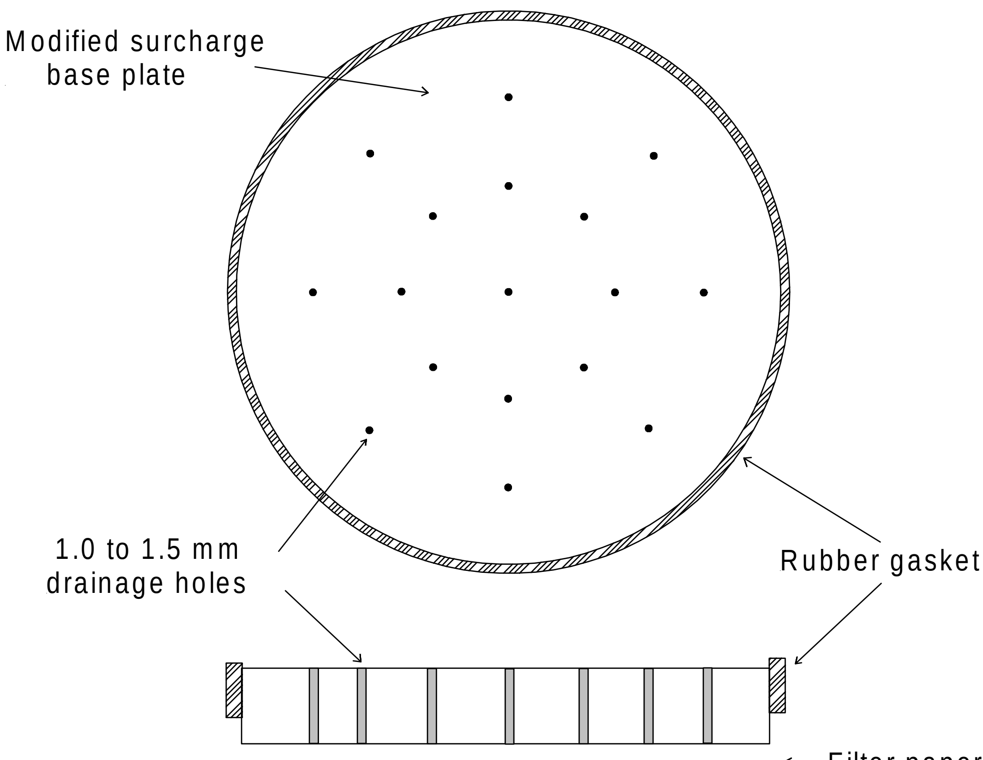


Figure 1. Plot of relative density versus moisture content. Bulking moisture content is graphically determined as the moisture content range for which 80% relative density cannot be achieved.



(a)



(b)

Figure 1. (a) Schematic drawing of typical mold assembly and (b) modified surcharge base plate

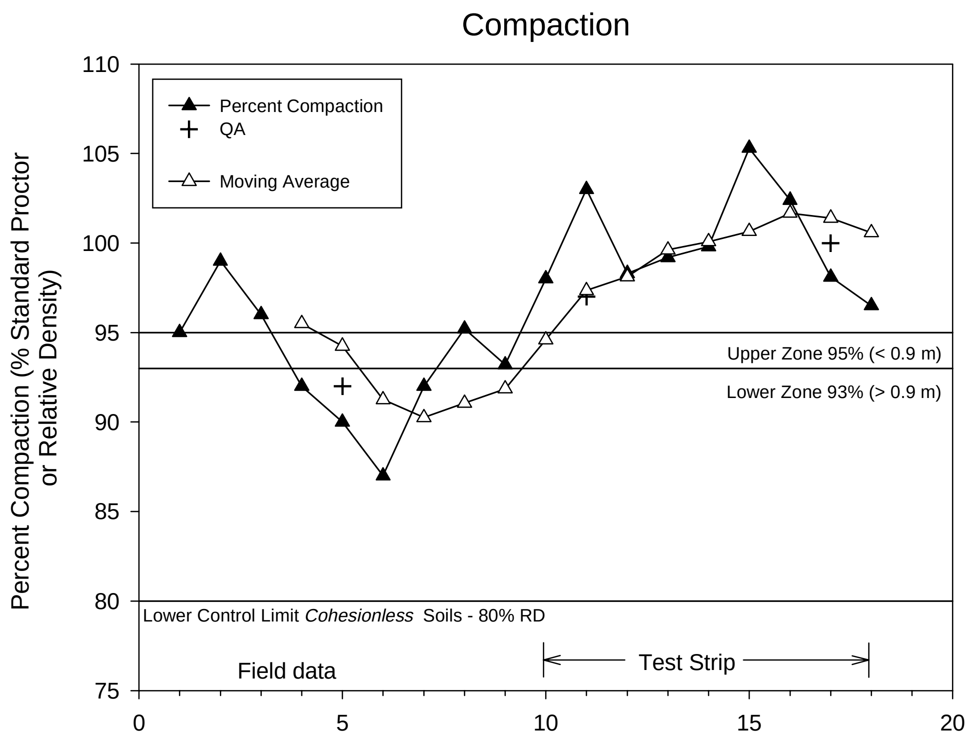


Figure 1. Field compaction control chart

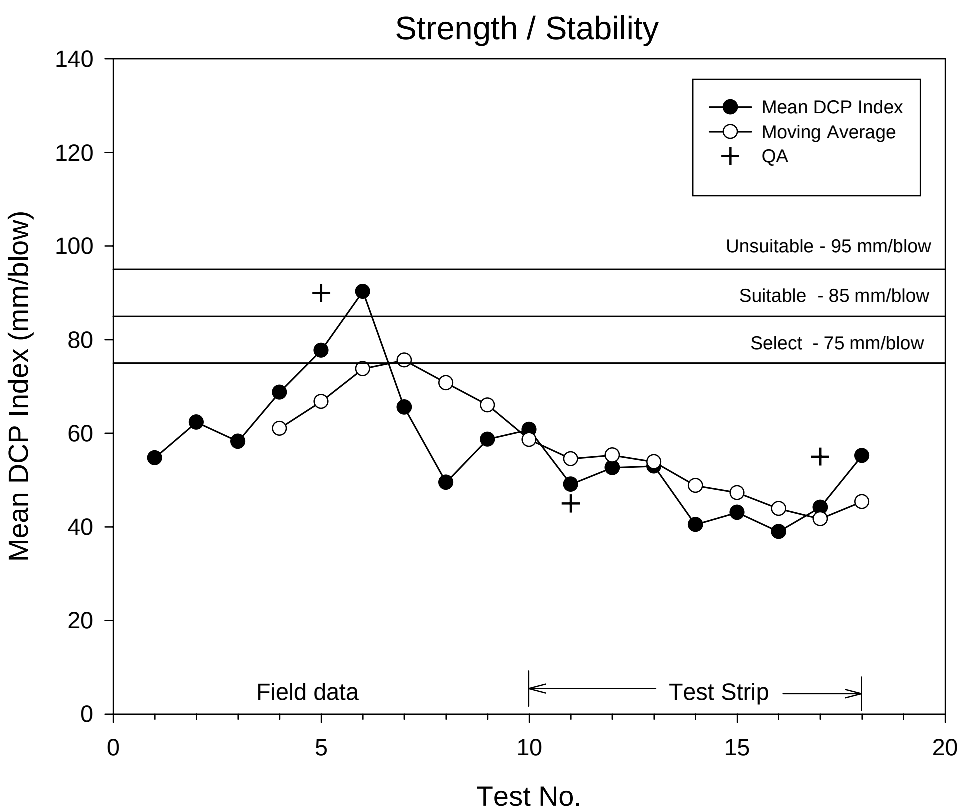


Figure 2. Mean DCP Index control chart

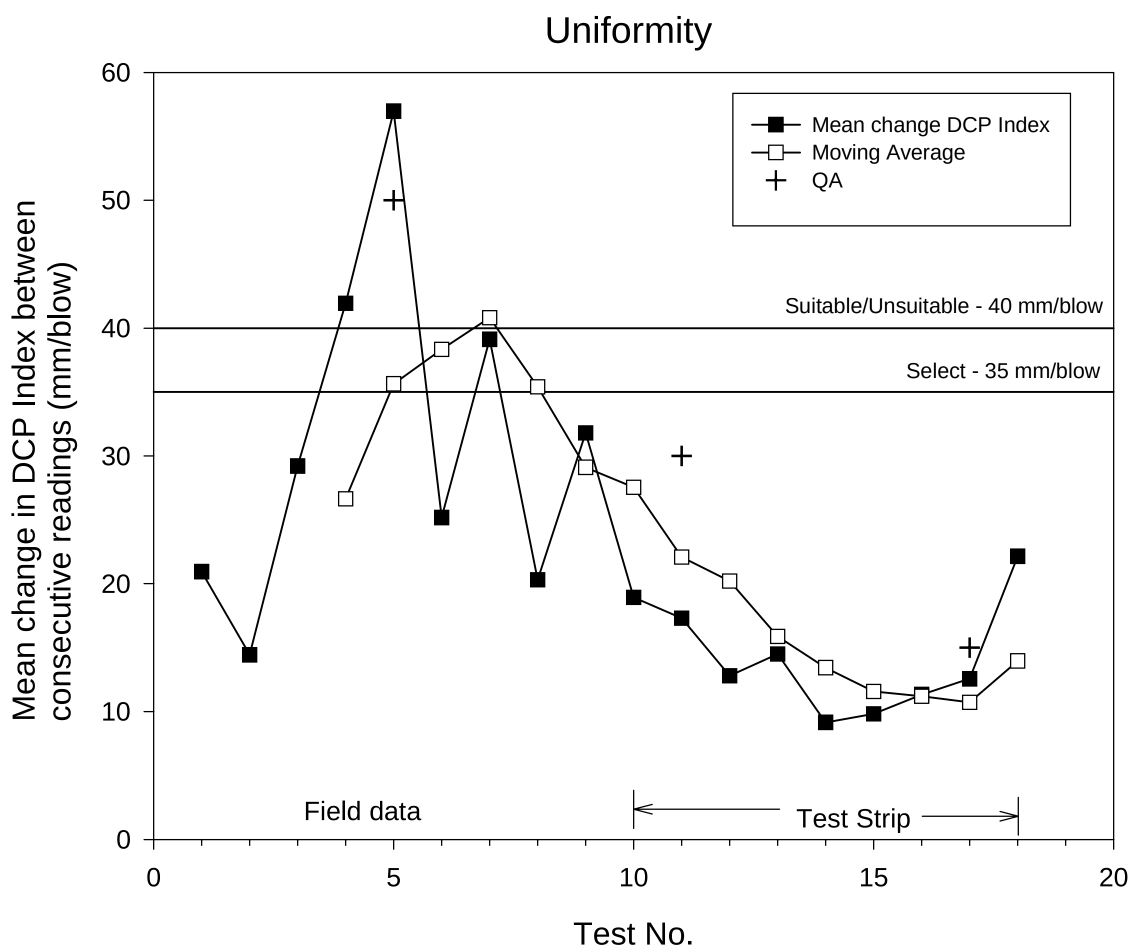


Figure 3. Mean change in DCP Index between consecutive readings control chart

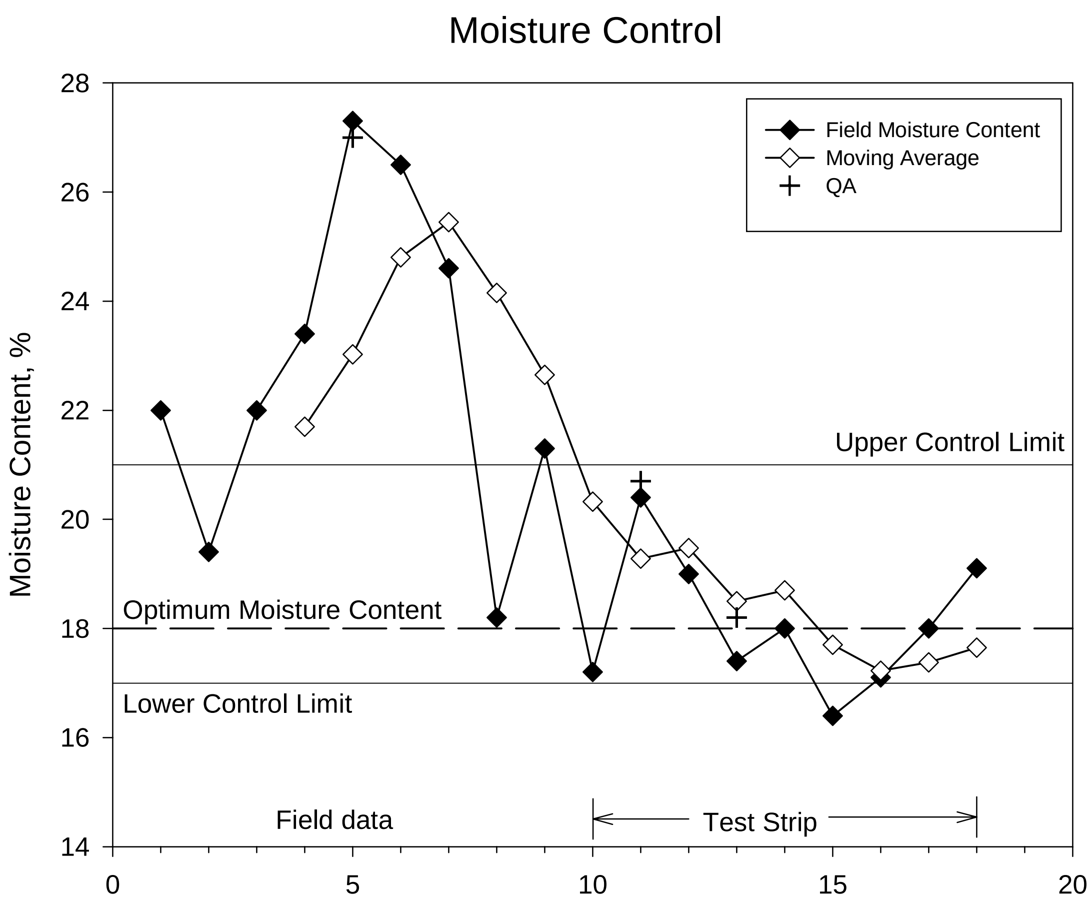


Figure 4. Moisture control chart

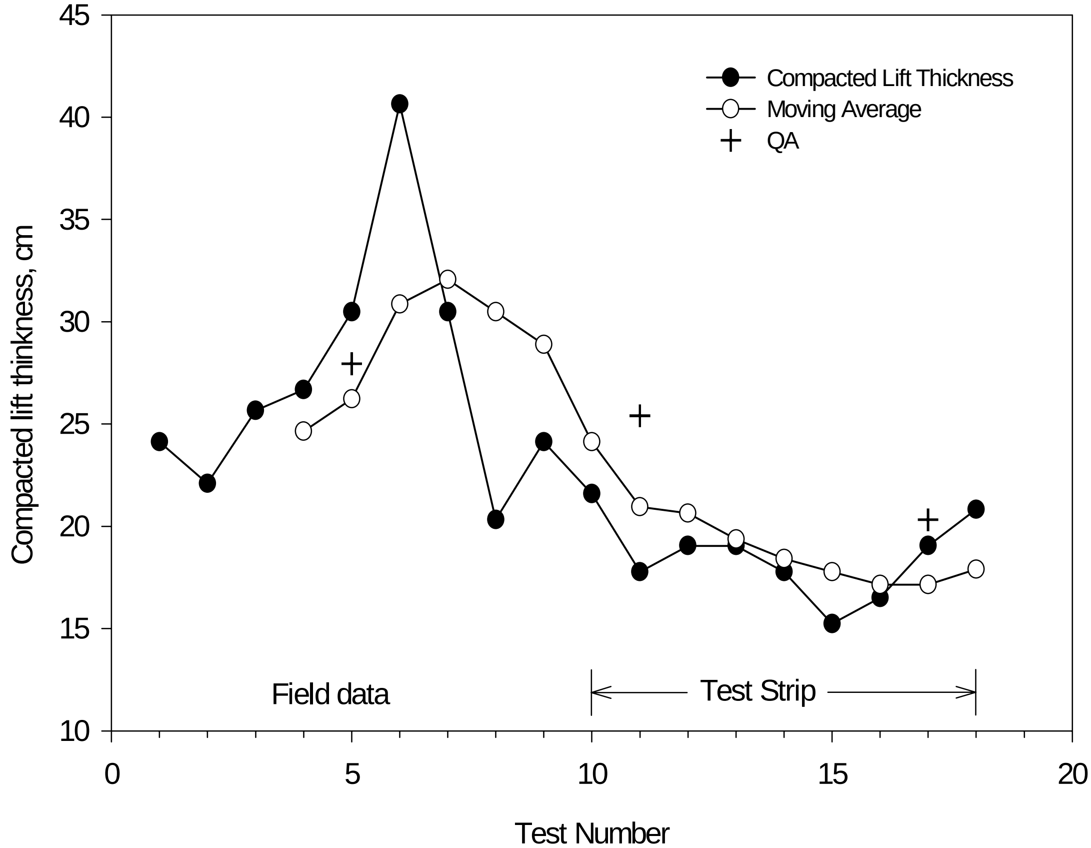


Figure 5. Lift thickness

Test Section Data Sheet

Project____ **Date**______________________

Test Location and Elevation_____________________ **Personnel**_________________

Weather Conditions_____________________________ **Test Section No.**____________

Material Classification ___________________________ Initial Moisture Content_______

Moisture Conditioning/Drying Notes____

Equipment Notes____

Lift Number (1)	Number of Roller Passes (2)	Number of Disc Passes (3)	Compacted Lift Thickness (4)	Dry Density (5)	Moisture Content (%) (6)	Mean DCP Index (mm/blow) (7)	Mean change in DCP Index (mm/blow) (8)

Mean DCP Index and Mean Change in DCP Index Data Sheet

Project______________________________________ **Date**______________________

Test Location and Elevation____________________ **Personnel**_________________

Weather Conditions___________________________ **Hammer Weight**____________

Material Classification____

Moisture Content ______________________________**Notes**___________________________

Number of Readings (1)	DCP Index (mm/blow) (2)	Change in DCP Index between Consecutive Readings (3)	Depth, (mm) (4)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
SUM =			

(5) Mean DCP Index = ______

(6) Mean change in DCP Index = ______

(1) Number each DCP Index increment consecutively starting at 1.
(2) DCP Index mm/blow
(3) Non-negative difference between consecutive DCP Index readings (i.e. Number 1 – Number 2)
(4) Depth recording during DCP Index testing
(5) Mean DCP Index = [sum of column (2)] / [Number of readings column (1)]
(6) Mean change in DCP Index = [sum of column (3)] / [Number of readings column (1) – 1]

Compaction Test Data Sheet

Project____**Date**___________________

Project No.____________________________________**Soil Type(s)**_____________

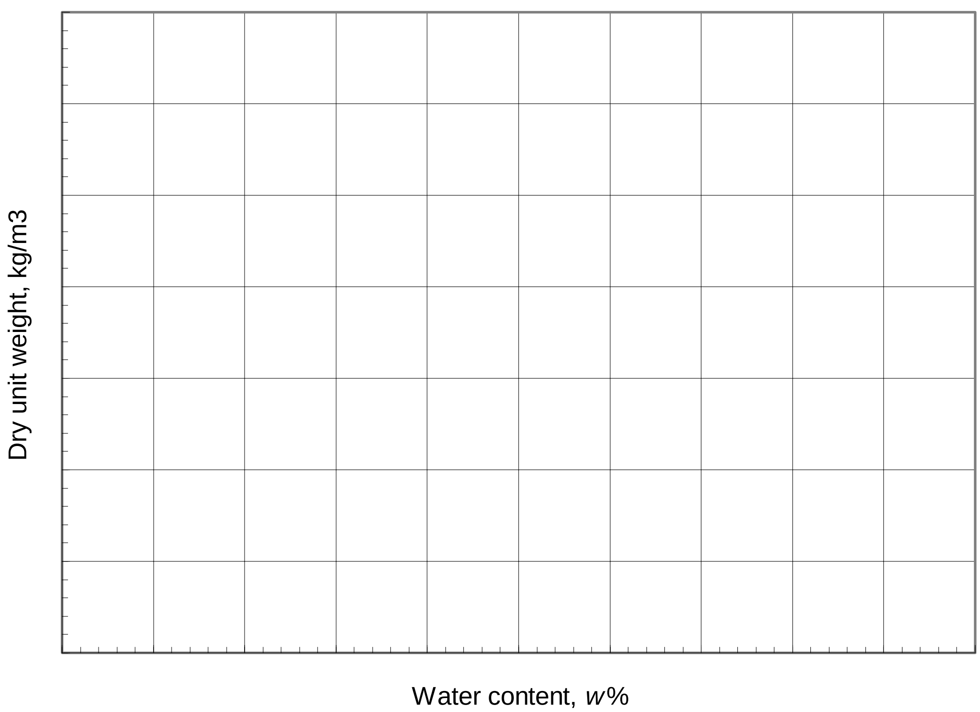
Location_______________________________________**Test No.**________________

Water Content Determination

Sample No.	**1**	**2**	**3**	**4**	**5**
Tare No.					
Mass of wet soil + tare (1)					
Mass of dry soil + tare (2)					
Mass of tare (3)					
Mass of dry soil (4) = (2) - (3)					
Mass of moisture (5) = (1) – (2)					
Water content, *w*% (6) = [(5) / (4)] x 100					

Unit Weight

Water content, *w*% (6) = [(5) / (4)] x 100					
Mass of soil + mold, g (7)					
Mass of mold, g (8)					
Mass of soil, g (9) = (7) – (8)					
Wet unit weight, kg/m^3 (10) = (9) x 1.059					
Dry unit weight, kg/m^3 (11) = (10) / { 1+ [(6)/100] }					



Optimum Moisture content

= _______________%

Maximum dry unit weight

= ____________kg/m3

MCC chart moisture range

= ______% - ______%

Soil Performance Classification

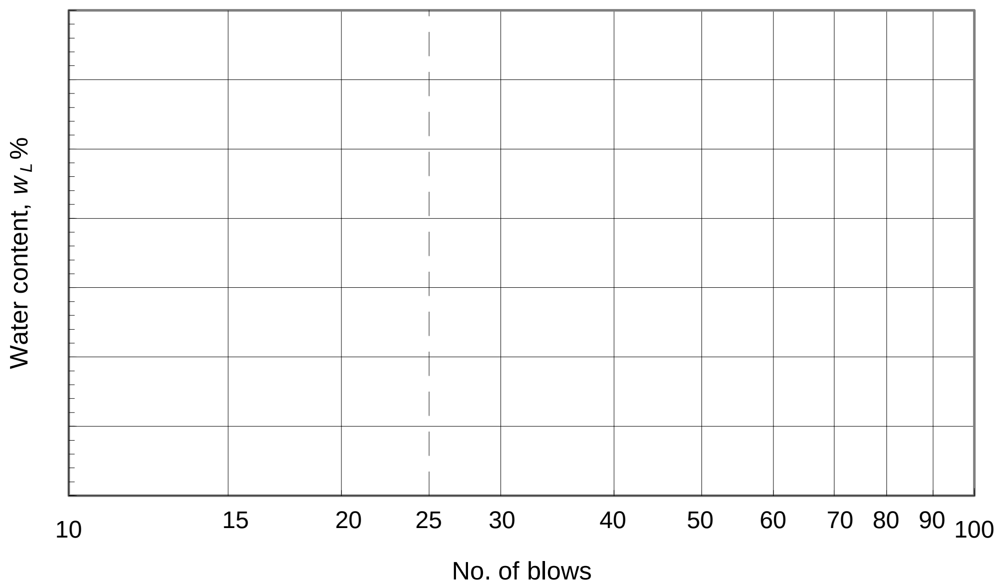
Project____**Date**____________________

Project No._______________________________________**Soil Type(s)**_____________

Location____**Test No.**________________

Liquid Limit Determination

Tare No.					
Mass of wet soil + tare (1)					
Mass of dry soil + tare (2)					
Mass of tare (3)					
Mass of dry soil (4) = (2) - (3)					
Mass of moisture (5) = (1) – (2)					
Water content w_L% = [(5) / (4)] x 100					
No. of blows					



Liquid limit = __________

Plastic limit = __________

Plasticity index = ______

F_{200} = ______________

☐ Select

☐ Suitable

☐ Unsuitable

Plastic Limit Determination

Tare No.					
Mass of wet soil + tare (1)					
Mass of dry soil + tare (2)					
Mass of tare (3)					
Mass of dry soil (4) = (2) - (3)					
Mass of moisture (5) = (1) – (2)					
Water content, w_P% = [(5) / (4)] x 100					

APPENDIX B: MODIFICATIONS TO QM-E SPECIAL PROVISIONS CONTRACT

Addendum

Iowa Department of Transportation
Office of Contracts

Date of Letting: April 3, 2001
Date of Addendum: March 28, 2001

B.O.	Proposal ID	Proposal Work Type	County	Project Number	Addendum
302	09-2188-039	Grading	Bremer	NHSX-218-8(39)--3H-09	03apr302.a01

Notice: Only the bid proposal holders receive this addendum and responsibility for notifying any potential subcontractors or suppliers remains with the proposal holder.

Make the following changes to Page 2 of the PROPOSAL DETAILS:

> Add Site Number 03, Contract Period/Site Description LATE START DATE, 04/01/02, TO CONSTRUCT PROJECT FROM STA. 295+00 TO 299+00 & CLEANUP, 20 Working Days, $1200.00 Liquidated Damages,

Add the following note to the PROPOSAL NOTES:

*** WORKING DAY INFORMATION ***
THE WORKING DAYS FOR SITE “02” AND SITE “03” WILL BE ADMINISTERED INDEPENDENTLY FROM THE WORKING DAYS FOR THE “CONTRACT” SITE.

Make the following changes to the PROPOSAL SCHEDULE OF PRICES:

> Change Line No. 0130 2107--200300 TEST SECTIONS (QM-E) from 15.000 EACH to 30.000 EACH.

If the quantity is not changed on the proposal form, the bid amount will be extended using the unit price times the correct quantity as shown here.

Make the following changes to SP-95509M, SPECIAL PROVISIONS FOR QUALITY MANAGEMENT - EARTHWORK (QM-E):

Article 95509M.03 (A), QUALITY CONTROL PROGRAM

> CHANGE the last sentence of the third paragraph to:
> The Contracting Authority will provide training for up to four of the Contractor’s technicians.

ADD sentence:
Training at DMACC will be from April 16-20, 2001

CHANGE the last paragraph to:
In an emergency, the Contractor will be allowed to operate a maximum of two days during the contract without a Certified Grading Technician I on the project site. Embankment placement and compaction during this period shall be as per Article 2107.09 of the Standard Specifications, Compaction with Moisture Control. During the two days, the Contract Authority shall determine moisture limits and perform tests for moisture content. Moisture limits shall be those specified in Attachment C of these Special Provisions. Test frequency for moisture content shall be every 1000 m3 of compacted volume. After two days, if the Contractor cannot provide a trained Certified Grading Technician I, the Contract Authority will perform the Quality Control Program, with reimbursement by the Contractor, until a Certified Grading Technician I can be provided. Reimbursement by the Contractor to the Contract Authority shall be at a rate of $500.00 per day.

Article 95509M.03 (B), QM-E FIELD LABORATORY
Section (2), Facilities Furnished by Contract Authority

DELETE: Item m) Nuclear moisture/density gauge

Article 95509M.03 (C), TEST PROCEDURES

For the Pan Drying method, change
CHANGE: "AASHTO T-265 modified to use an open burner"
TO: "ASTM D 4959"

ADD sentence at end of Article:
Minimum sample size for moisture content is 450 g.

Article 95099M.03 (F) EMBANKMENT CONSTRUCTION
ADD at end of Section (1), Preparation of Site:

If the foundation of proposed embankment or cut grade line below subgrade treatment is unsuitable or unstable soil, the Engineer may require the Contractor to remove that soil as below grade excavation and backfill to the foundation ground line or cut grade line. Placement of selected or special backfill material, or granular blanket may be required by the Engineer. Unsuitable or unstable soil may be stabilized in place by fly ash or cement as directed by the Engineer.

Unsuitable or unstable soils shall be removed and placed as directed by the Engineer, and in the case of unsuitable soils, in accordance with Standard Road Plan RL-1B.

The Contractor shall conduct operations in such a way that the Engineer is given opportunity to take cross sectional measurements required before the backfill is placed.

Selected backfill material shall be obtained from locations shown in the contract documents or as directed by the Engineer.

When selected or special backfill material is placed in areas where unstable soils have been excavated and the thickness of backfill placed is 0.6 m or more, the condition of underlying soil may limit the amount of compaction to be done in the bottom 0.3 m of embankment or subgrade treatment. In exceptionally wet or unstable areas, the Contractor may be permitted to end dump the first 0.3 m of backfill material and doze it into position with only partial compaction, as directed by the Engineer. For this first 0.3 m, the requirements of Article 95509M.03 (E), TEST SECTIONS will not apply. For this first 0.3 m, the requirements of Article 95509M.03 (F), EMBANKMENT CONSTRUCTION will not apply except for Section (6), Moisture Content of Compacted Lifts. Material above the bottom 0.3 m in such areas shall be compacted as provided in these Special Provisions.

Excavation ordered by the Engineer will be paid for at double the contract price of Class 10 excavation to a maximum depth of 1 m. If the extra depth of Class 10 excavation exceeds 1 m, payment will be made as extra work as provided in Article 1109.03, Paragraph B of the Standard Specification. Excavation involved in rebuilding embankments will be paid for at the contract price for the class of excavation involved.

Where a granular blanket is directed by the Engineer, material meeting the requirements of Section 4133 of the Standard Specifications shall be spread as directed by the Engineer without the use of compaction equipment. The blanket may be constructed in several lifts, but foreign material shall not be incorporated from hauling equipment or other sources. Payment will be made as extra work as provided in Article 1109.03, Paragraph B of the Standard Specification.

When unsuitable or unstable soil is stabilized in place by fly ash or cement, the material source, application rate, and method of incorporation shall be approved by the Engineer. Payment will be made as extra work as provided in Article 1109.03, Paragraph B of the Standard Specification.

Article 95509M.03 (F), EMBANKMENT CONSTRUCTION
Section (3), Moisture Control of Deposited Material

Within the last sentence:
CHANGE: "Article 1108.02, Paragraph F"
TO: "Article 1108.02, Paragraph D"

Article 95509M.03 (K), IOWA DOT QUALITY ASSURANCE
Section (2)(a), Moisture Content

REPLACE: Existing Section (2)(a)

WITH the following:
Differences between the Contractor's and the Contract Authority's field moisture content tests will be acceptable if moisture content is within 1.5% based on dry weight of soil. The sample for the Contract Authority's assurance test shall be taken from a split sample at the exact location as the Contractor’s quality control test.

ADD NEW Section (2)(e), Relative Density

Differences between the Contractor's and the Contract Authority's maximum dry density by ASTM D 4253 or minimum dry density by ASTM 4254 will be considered acceptable if the difference between the two values is less than 10% of their average value.

Bremer County NHSX-218-8(39)--3H-09
Pre-Bid Minutes for
Quality Management - Earthwork (QM-E)

An overview of the Quality Management - Earthwork (QM-E) specification was given that discussed the history of its development and the things the Iowa DOT would like to achieve with it. It was initiated due to failures with embankments and failures under AC pavements. Iowa State University was retained to examine the methods to obtain a good fill. They found that some soils were too wet and some lifts were too thick (over the 8" loose fill specification). ISU found that field soils were being misidentified so they wanted to develop a procedure to sample and classify soils in the field. ISU wanted the testing to be quick, stating that there needs to be a balance between testing and production. Following are items discussed during the meeting.

• Does the specification apply to the whole fill?
Yes, it applies to the entire fill from the bottom up.
• What is to be done with the muck and peat in the cuts? If it can not be put on the foreslopes is it waste? How are natural ground cuts that are never going to be in a usable condition going to be handled?
If those areas are indicated on the plan than it is the responsibility of the contractor. Otherwise it would be covered by 1109.16A Differing Site Conditions.
• Is disking of natural ground included in the specifications?
No, however some contractors thought bad sections in the natural ground would be a good spot for a test section.
• The Special Provisions took bridging out of the Standard Specifications. Those specifications will be added back in by addendum.
• The contract period was set up to optimize the time allotted to the grading contractor and the paving contractor to allow the project to be opened to traffic by the end of 2002. A contractor felt the DOT was starting this off on the wrong foot doing this new specification on an accelerated project. It was mentioned that the Bremer 218 projects in the April letting were better than the grading projects being let in the June lettings (June 12th, 26th and 29th).
• A contractor asked why a nuclear g age could not be used to take an average density of the lift rather than the Dynamic Cone Penetrometer (DCP).
The DCP can go three feet down and the nuke gage can not go as deep. This will help prevent the Oreo cookie effect, hard on the outsides but soft in the middle.
• In the specifications it says the contractor can go two days without a Quality Control Technician. Who does moisture control in their absence?
The DOT would perform the moisture control tests.
• The specifications say that after two days the DOT will provide a Quality Control Technician. How much will this cost the contractor?
This is addressed in the addendum.
• The Contractor is only allowed training for two Certified Grading Technicians, can this be increased?

The addendum changed the number to four, this allotment is for the Contractor's/Consultant personnel.

- Can a Speedy Moisture meter be used to test moisture?

No, it is not an approved test method because of the small sample size and it requires site calibration curves for clays and sands.

- Page C.02 in the plans indicates that no more than 70,000 square meters of exposed erodible soil is allowed. A contractor wanted to know if this could be changed?

For this project, limits on area of exposed erodible soil will be by usual practice per the PPP: "No more than 70,000 square meters of exposed erodible area is allowed in any one grading spread without permission of the project engineer."

Included with these minutes is a list of those attending the Pre-Bid/Informational Meeting and also a handout that was given at the meeting.

Contract Modification

Iowa Department of Transportation

6/5/01 8:52 AM

FieldManager 3.1e

Contract: 09-2188-039, GRADING

Cont. Mod. Number	Revision Number	Cont. Mod. Date	Net Change	Awarded Contract Amount
1	1	6/5/01	$0.00	$2,768,658.43

Route

Contract Location

Short Description

Changes to Quality Management-Earthwork (QM-E)

Description of Changes

The following changes are made to Special Provision 95509M for Quality Management-Earthwork (QM-E).
On page 7 of 50, Section 95509M.03, E. Test Sections, 3. Dimensions of Test Section, delete Depth 0.9 m and replace it with Depth one lift.
On page 7 of 50, Section 95509M.03, E. Test Sections, 5. Moisture Content of Compacted Soil, delete the third paragraph and replace with the following: The average of all moisture contents in the test sections must be within the specified moisture control limits.

Contract Modification

Iowa Department of Transportation

7/16/01 9:42 AM

FieldManager 3.1e

Contract: 09-2188-039, GRADING

Cont. Mod. Number	Revision Number	Cont. Mod. Date	Net Change	Awarded Contract Amount
4		7/5/01	$0.00	$2,768,658.43

Route

Contract Location

Short Description

Changes to Special Provision 95099M for Quality Management-Earthwork (QM-E).

Description of Changes

On page 6 of 50, Section 95509M.03, E. TEST SECTIONS, 1. General:
Add the following sentence at the end of the third paragraph:
"Test sections shall be ordered by the Engineer following a new soil performance classification, or every 25,000 m3 of each classified material, as required in Section 95509M.03, G. TEST FREQUENCY DURING EMBANKMENT CONSTRUCTION."

On page 7 of 50, Section 95509M.03, E. TEST SECTIONS, 3. Testing Frequency During Test Section Construction:
Delete the first sentence and replace with:
"Four random locations within each test section shall be tested for:"

On page 7 of 50, Section 95509M.03, E. TEST SECTIONS, 3. Testing Frequency During Test Section Construction,
d) Mean DCP Index:
Delete "per lift" and replace with "depth of 0.9m")

On page 7 of 50, Section 95509M.03, E. TEST SECTIONS, 3. Testing Frequency During Test Section Construction,
e) Mean Change in DCP Index:
Delete "per lift" and replace with "depth of 0.9m")

On page 9 of 50, Section 95509M.03, E. TEST SECTIONS, 9. Acceptance Criteria:
Add the following sentence:
"Equipment type and weight, minimum number of equipment passes, and maximum thickness of compacted lifts shall be documented by the Contractor for each test section and provided to the Engineer by the following working day."

On page 11 of 50, Section 95509M.03, F. EMBANKMENT CONSTRUCTION, 6. Moisture Content of Compacted Lifts:
Delete the last sentence and replace with:
"The 4-point moving average of moisture content must be within the specified moisture control limits."

On page 12 of 50, Section 95509M.03, F. EMBANKMENT CONSTRUCTION, 7. Compaction Zones:
Add a new sentence after the last sentence:
"Cut sections in natural soil below subgrade treatment depth which meet quality control standards for upper zone embankments may left in place. Cut sections below subgrade treatment depth not meeting upper zone requirements shall be excavated and recompacted to meet the requirements. If cut sections below subgrade treatment are excavated and recompacted, payment shall be made at the contract price for Class 10 Excavation."

On page 13 of 50, Section 95509M.03, G. TEST FREQUENCY DURING EMBANKMENT CONSTRUCTION:
Add after the first sentence:
"For cohesionless soils, moisture content and density shall be measured after removing loose material from the uppermost lift being placed. DCP Index tests shall be taken at the same location to a depth of 0.9 m."

On page 14 of 50, Section 95509M.03, G. TEST FREQUENCY DURING EMBANKMENT CONSTRUCTION:
Delete the last sentence and replace with:
"The four locations within a test section shall be used to establish a 4-point moving average for subsequent fill. "

On page 14 of 50, Section 95509M.03, J. CORRECTIVE ACTION:
Delete the first sentence and replace with:
"The Contractor shall notify the Engineer when a 4-point moving average of Moisture Content, Density, Mean DCP Index, or Mean Change in DCP Index falls outside the specified control limits."

On page 15 of 50, Section 95509M.03, J. CORRECTIVE ACTION, A. Moisture Content:
Delete the paragraph and replace with:
"If a 4-point moving average of moisture content of compacted fill falls outside of the control limits the material in the area

Contract Modification

Iowa Department of Transportation

7/16/01 10:17 AM
FieldManager 3.1e

Contract: 09-2188-039, GRADING

Cont. Mod. Number	Revision Number	Cont. Mod. Date	Net Change	Awarded Contract Amount
5		7/16/01	$56,000.00	$2,768,658.43

Route

Contract Location

Short Description

Provide Payment for Dust Control, Increase Disking Days.

Description of Changes

Payment for dust control will be made to the contractor for earthmoving equipment working along US 218 while the roadway is opened to traffic.

The number of Disking Days on the contract is increased. More days are needed than estimated to dry the embankment material to allowable moisture ranges.

Increases / Decreases

Project: 09-2188-039, 010403 421 CAL SALES TAX ESTIMATE WAIT

Category: 0001, ROADWAY ITENS

Item Description	Item Code	Prop.Ln.	Item Type	Unit	Quantity Chg.	Unit Price	Dollar Value
DISK TO REDUCE EXCESSIVE MOISTURE (QM-E)	2107--200100	0110	ORIGINAL	DAY	50.000	960.00000	$48,000.00

Reason: Contract Unt Price

Subtotal for Category 0001: $48,000.00

Subtotal for Project 09-2188-039: $48,000.00

New Items

Project: 09-2188-039, 010403 421 CAL SALES TAX ESTIMATE

Category: 0001, ROADWAY ITENS

Item Description	Item Code	Prop.Ln.	ItemType	Unit	Proposed Qty.	Unit Price	Dollar Value
EWO-WATER-DUST CONTROL	6100--110710	0825	SUPPLEMENT/	KL	2,000.000	4.00000	$8,000.00

Reason: As Per Specification 1107.07.

Subtotal for Category 0001: $8,000.00

Subtotal for Project 09-2188-039: $8,000.00

Contract Modification

Iowa Department of Transportation

12/7/01 3:26 PM

FieldManager 3.1e

Contract: 09-2188-039, GRADING

Cont. Mod. Number	Revision Number	Cont. Mod. Date	Net Change	Awarded Contract Amount
8		12/7/01	$300.00	$2,768,658.43

Route

Contract Location

Short Description

PAYMENT TO TRANSPORT QME TRAILER.

Description of Changes

PROVIDES PAYMENT TO COMPENSATE CONTRACTOR TO MOVE QME TRAILER AND EQUIPMENT TO AMES.

New Items

Project: 09-2188-039, 010403 421 CAL SALES TAX ESTIMATE

Category: 0001, ROADWAY ITENS

Item Description	Item Code	Prop.Ln.	ItemType	Unit	Proposed Qty.	Unit Price	Dollar Value
(LUMP SUM ITEM) TRANSPORT QME TRAILER.	2599--999916	0835	SUPPLEMENT/	LS	1.000	300.00000	$300.00

Reason: AGREED PRICE BETWEEN RCE AND CONTRACTOR.

Subtotal for Category 0001: $300.00

Subtotal for Project 09-2188-039: $300.00

APPENDIX C: IOWA DOT GRADING TECHNICIAN CERTIFICATION AND TRAINING PROGRAM

GRADING TECHNICIAN CERTIFICATION PROGRAM

GENERAL

The purpose of the Grading Technician Certification Program (GTCP) is to ensure quality sampling and testing of soils for embankment construction by certification of industry and contracting authority personnel.

Through a cooperative program of training, study and examination, technicians will be able to better ensure satisfactory soil identification, classification and testing during construction.

The technician cannot delegate the sampling or testing responsibility to a non-certified person.

ADMINISTRATION

The GTCP will be carried out in accordance with general policy guidelines established or approved by the Director of the Division of Project Development. A Board of Certification composed of the following members will advise the Director:

Engineer – Office of Construction
Representative of the DOT District Construction Engineers**
Representative of the Association of General Contractors (AGC of Iowa)
Representative of the County Engineers
Representative of the City Engineers

The Technical Training and Certification Program (TTCP) Coordinator of the Office of Materials will be the Program Director. A GTCP Coordinator will be appointed by the Program Director to assist in the administration of the program and to handle such planning, administrative and coordinating functions as may be needed.

Appeals on actions taken in this program shall be submitted to the TTCP Coordinator. Unresolved appeals will be submitted to the Certification Board.

** Appointed by the TTCP Coordinator.

REQUIREMENTS

Certification as a Level I Technician can be obtained by successfully passing the written and demonstration examinations.

Certified Technicians may represent any company or agency for which they have been formally authorized as representatives.

Registered Professional Engineers and civil engineering graduates from accredited institutions will be exempt from the training requirement. In order to obtain certification for any technical level, these persons must pass all applicable tests for the level of certification they wish to obtain. Certificates issued in accordance with these requirements will be subject to the same regulations concerning expiration, etc. that apply to certificates obtained by examinations.

OUT-OF-STATE APPLICANTS

Requests for certification from persons for Level I Grading Technicians from another state will be issued when the following criteria is met:

> The applicant shall pass an examination, or examinations, administered by the Iowa DOT to obtain the certification level desired.

Out-of-State applications should be submitted to the Iowa DOT Office of Materials in Ames to schedule test dates. Copies of all certifications must accompany the application.

CERTIFICATION INFORMATION

Certification information will be available in the Iowa Technical Training Booklet. The booklet contains information on the Technical Training Program and a description of all classes offered. Class schedules for all technical training classes statewide and applications will be included. The booklets are available from any of the Iowa DOT District Construction Offices.

The fees for the schools and examinations are indicated in the booklet.

INSTRUCTIONAL SCHOOLS AND EXAMINATIONS

The DOT Office of Materials will conduct schools and provide the study materials. Contractors are encouraged to conduct their own pre-training programs. All new applicants must attend an Iowa DOT school and pass the applicable exams to become certified. The Office of Materials will conduct all examinations.

The locations and dates of examinations will be found in the Technical Training and Certification Registration Booklet.

CERTIFICATION

Upon successfully completing the requirements for certification, the Program Director will issue a certificate and a pocket certification card. This certification is not transferable.

PERFORMANCE REQUIREMENTS

A WRITTEN NOTICE MAY BE ISSUED TO THE CERTIFIED TECHNICIAN FOR ANY INADEQUACIES IN PERFORMING HIS/HER DUTIES. Upon receipt of two such notices, the certified technician may be given a three-month suspension. After three written notices, the certified technician is subject to decertification. An example of this notice is shown in Appendix A.

DECERTIFICATION

The certificate will become invalid for reasons such as:

1. Failure of the certificate holder to renew the certificate prior to regular expiration described below.
2. False or fraudulent information is used to secure or renew the certificate.
3. False or fraudulent actions or documentation by the certificate holder.

RENEWAL OF CERTIFICATION

Certifications will remain valid for five (5) years (a three-month grace period will be allowed). If the individual has not renewed their certification within the 90-day grace period they are automatically decertified. The individual may obtain certification by taking the examinations for the level of certification they are requesting. If the individual does not take the examinations within one year from the date of decertification, they must retake all applicable schools and pass the examinations. **The responsibility for applying for recertification shall rest with the certified individual.**

It shall be the responsibility of the individual to inform the Office of Materials of any address change.

Retesting will be required every five years regardless of work experience or performance. Failure of any level shall require the applicant to retake the applicable certification program and pass the tests.

FUNCTIONS AND RESPONSIBILITIES

The sampling and testing of soils at each project shall be performed by a Certified Technician. The technician shall sample and test in accordance with specified frequencies and promptly submit designated reports.

The Resident Construction Engineer will be responsible for monitoring embankment construction quality control and the sampling and testing of soils by the Certified Technician.

The Resident Center Construction Office will have the authority and responsibility to question and, where necessary, require any changes in quality control procedures to ensure the construction of a quality embankment which consistently complies with specification requirements.

Embankment Quality Phase III
Grading Technician Level I Certification Program
April 16-20, 2001

Session	Time	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	Notes
Morning Session	8:00	Introductions Program Overview	Hands on Sieve Analysis (Technicians)	**Performance Exam No. 4** **(Soil Performance Classification - Test Data Supplied)**	**Performance Exam No. 6** **(Relative Density)**	Soil Moisture Limits (Lecture and Definitions) (Test Procedures and Calculations)	
	8:30	Weeks Activities					
	9:00	Quiz - Section A	**Performance Exam No. 2** **(Sieve Analysis, F_{200})**	Standard Proctor Density (Lecture and Definitions)		**Performance Exam No. 8** **(Moisture Limits - Test Data Supplied)**	
	9:30	Quiz Review		(Test Procedure) (Calculations)			
	10:00	Break (10:00-10:15) Section A Review	Break (10:00-10:15) Atterberg Limits	Break (10:00-10:15) Hands on Proctor Density Testing	Break (10:00-10:15) Modified Relative Density	Break (10:00-10:15) Dynamic Cone Penetrometer	
	10:30	Iowa Soils Hands on Soils	(Lecture and Definitions) (Test Procedures and Calculations)	(Technicians)	(Lecture and Definitions) (Test Procedure)	(Lecture and Definitions) (Calculations)	
	11:00	(Gravel, Sands, Silts, and Clays) Field Soils Identification	Hands on Atterberg Limits Testing (Technicians)		(Calculations)	Hands on DCP Testing	
	11:30	(Tills: Fat, Medium, Lean) (Alluvium: Loess)			Hands on Modified Relative Density (Technicians)	(Technicians)	
Afternoon Session	12:00	Lunch (12:00-1:00pm)	Lunch (12:00-1:00pm)	Lunch (12:00-1:00pm)	Lunch (12:00-1:00pm)	Lunch (12:00-1:00pm)	
	12:30						
	1:00	Soil Moisture (Definitions and calculations)	Atterberg Limits Review	**Performance Exam No. 5** **(Proctor Density)**	Hands on Modified Relative Density (Technicians)	**Performance Exam No. 9** **(DCP)**	
	1:30	Moisture Test Procedures	**Performance Exam No. 3** **(Atterberg Limits)**				
	2:00	Hands on Moisture Testing (Technicians)					
	2:30					Test Strip Construction and Testing	
	3:00	Break (3:00-3:15)	Break (3:00-3:15)	Break (3:00-3:15)	Break (3:00-3:15)	Break (3:00-3:15)	
	3:30	**Performance Exam No.1** **(Moisture Tests)**	Soil Performance Classification (Lecture and Definitions)	Relative Density (Lecture and Definitions)	**Performance Exam No. 7** **(Modified Relative Density)**	CERTIFICATION EXAM	
	4:00	Sieve Analysis (F_{200})	(Examples) (Technician Example)	(Test Procedure) (Calculations)			
	4:30	Grain-Size Test Procedures and Calculations					

**Actual project plans, cross sections, soil data sheets, and special provisions will be periodically reviewed as time permits.

Grading Technician Certification – Level I

Performance Checklist

Test Method No. 1: Determination of the percent material passing the No. 40 or No. 200 sieves

Following is a summary of the key steps involved in the quantitative determination of the percent of material passing the No. 40 (425-µm) or No. 200 (75-µm) sieves for soil. This checklist is derived from the actual test method used in the performance examination.

CHECKLIST

☐ 1. After the sample has been air-dried and pulverized, transfer approximately 100 g of soil onto the sieve.

☐ 2. Record the exact amount of air-dry soil transferred to the sieve.

☐ 3. Wash the soil through the sieve with tap water until the wash water is clear.

☐ 4. After washing transfer the material retained on the sieve to a suitable container, dry in an oven or microwave and record the dry mass of soil retained on the sieve.

☐ 5. To determine the moisture content (M%) of the air-dry soil, weigh out an auxiliary portion of from 40 to 50 g in a small crucible, dry the sample to a constant mass in an oven or microwave, and weigh again. Record the tare mass, the mass before and after drying and then calculate the moisture content (M%) of the air-dry soil.

☐ 6. Calculate the percent passing the sieve as follows:

☐ $$\%\,\text{Passing} = \left(\frac{M_{\text{TOTAL DRY}} - M_{\text{RETAINED DRY}}}{M_{\text{TOTAL DRY}}}\right)100$$

☐ $$M_{\text{TOTAL DRY}} = \frac{M_{\text{TOTAL}}}{1 + \left(\frac{M\%}{100}\right)}$$

☐ $M_{\text{RETAINED-DRY}}$ = Oven-dry mass of soil retained on sieve after washing
M_{TOTAL} = Air-dry mass of sample transferred to sieve before washing

☐ $$M\% = \frac{A - B}{B - C}100 = \text{percent moisture}$$

A = mass of wet soil plus tare
B = mass of oven-dry soil plus tare
C = mass of tare

____________________ Candidate

____________________ Examiner

Grading Technician Certification – Level I

Performance Checklist

Test Method No. 2: Determining the Atterberg Limits of Soils

Following is a summary of the key steps involved in the quantitative determination of liquid limit, plastic limit and plasticity index for soils. This checklist is derived from the actual test method used in the performance examination.

CHECKLIST – LIQUID LIMIT

☐ 1. Place about 250 g of the air-dry soil passing the No. 40 (425-µm) sieve in a mixing dish. Add sufficient tap water to the material in the dish to bring it to a plastic state. Thoroughly mix this material by repeatedly stirring, kneading and chopping with the mixing spatula.

☐ 2. Determine the tare weight of three moisture cans.

☐ 3. Place a portion of the paste from the porcelain dish into the brass cup of the liquid limit device. Squeeze and spread the material with the knife to form a smooth, level surface parallel with the device base, and at the same time trim away excess material so that the depth is equal to approximately 8 mm which is the height of the grooving tool. Care should be exercised to prevent the entrapment of air bubbles within the mass.

☐ 4. By a firm stroke of the grooving tool divide the mixture in the cup along the diameter through the centerline of the cam follower so that a clean sharp groove of the proper dimension will be formed.

☐ 5. Lift and drop the cup until the two sides of the sample come in contact at the bottom of the grove along a distance of 13 mm. If the number of blows, N, is from 25 to 35 collect a moisture sample from the soil in the cup in moisture can.

☐ 6. Adjust the water content in the mixing dish and mix well. Repeat this process to get blow count, N, between 15 and 20, 20 and 25 and 25 to 35 for a groove closure of 13 mm. Collect a moisture sample from the cup for each successful test.

☐ 7. Plot a semi log graph of moisture content (arithmetic scale) versus number of blows, N (log scale). Draw a best-fit straight line through the points. The liquid limit is graphically determined as the moisture content corresponding to 25 blows.

CHECKLIST – PLASTIC LIMIT

☐ 1. Place about 100 g of the air-dry soil passing the No. 40 (425-µm) sieve in a mixing dish. Mix the material thoroughly by hand kneading and adjust the moisture content so that it can be easily shaped into a ball (about 25 mm diameter) without sticking to the fingers when squeezed.

☐ 2. Separate a small amount of the material from the plastic limit ball. Form this portion of the material into an ellipsoidal-shaped mass and roll the material between the smooth glass plate on the tabletop and the heel of the palm of the hand using sufficient pressure to roll it into a tread of uniform diameter throughout its length. If the diameter of the thread cannot be reduced to 3.18 mm (1/8 in) without breaking apart, the material is too dry and more water must be added to all of the material and thoroughly mixed before trying to roll the sample again.

☐ 3. When it is possible to successfully roll the material down to 3.18 mm in diameter without breaking apart, reform this portion of the material into a uniformly mixed ellipsoidal shaped mass and again roll the sample down to a 3.18 mm diameter thread.

☐ 4. Repeat steps 2 and 3 until the thread crumbles into several pieces when it reaches a diameter of 3.18 mm. The rolling surface must be kept clean and dry at all times.

☐ 5. Gather the portion of crumbled material together and place them into a moisture container and place a lid on the container. Repeat this procedure with similar portions of material from the original ball until at least 20 grams of crumbled material are in the moisture container.

☐ 6. Calculate the plastic limit as the moisture content at which the thread of soil crumbles when rolled to 3.18 mm diameter.

<u>CHECKLIST – PLASTIC LIMIT</u>

☐ 1. Calculate the plasticity index, PI as: PI = LL – PL

________________________________ Candidate

________________________________ Examiner

Grading Technician Certification – Level I

Performance Quiz

Test Method No. 3: Soil performance classification

Directions: Fill in the correct information for the blank spaces in the table below.

NO.	LL	PI	Percent passing No. 40 sieve	Percent passing No. 200 sieve	Preliminary Classification	Descriptive Regions for Cohesive Soils from Fig. 1	Final Soil Performance Classification
1	0	NP	—	10	Cohesionless	—	Select
2	21	14	—	13	Cohesionless	—	Select
3	15	13	—	17	Intergrade	—	Suitable
4	28	4	—	39	Cohesive	Inorganic Silts of Medium Compressibility	Unsuitable (Type B disposal)
5	22	9	68	44	Cohesive	Low Plasticity Clays	Select
6	19	7	—	63	Cohesive	Low Plasticity Clays	Suitable
7	33	11	—	62	Cohesive	Low/Medium Plasticity Clays	Suitable
8	35	21	—	61	Cohesive	Medium Plasticity Inorganic Clays	Select
9	49	27	—	95	Cohesive	Medium Plasticity Inorganic Clays	Suitable
10	65	41	—	71	Cohesive	High Plasticity Inorganic Clays	Suitable
11	76	37	—	91	Cohesive	Highly compressible inorganic silts and high plasticity clays	Unsuitable (Type B disposal)
12	97	71	—	95	Cohesive	High Plasticity Inorganic Clays	Unsuitable (Type A disposal)

Candidate ______________________

Examiner ______________________

Grading Technician Certification – Level I

Performance Checklist

Test Method No. 4: Standard Proctor compaction test

Following is a summary of the key steps involved in the multiple point test procedure for determining the standard Proctor relation between moisture content and dry density of soils. This checklist is derived from the actual test method used in the performance examination. Note: this checklist represents only a portion on the actual test method.

CHECKLIST

☐ 1. Thoroughly pulverize and mix the selected representative sample of 2250 g until no soil lumps remain larger than No. 4 sieve size.

☐ 2. Measure and record the mass of the Proctor mold (*not the collar*), M_1, in grams.

☐ 3. Form a specimen by compacting the prepared soil sample in the compaction mold (*with collar attached*) in three approximately equal layers to give a total compacted depth in excess of the mold height by 2.5 mm (0.1 in) to 10 mm (0.4 in). Compact each layer with 25 uniformly distributed blows from the rammer dropping from a height of 305 mm (12 in) above the elevation of the soil. *Do not allow soil to accumulate on the bottom of the rammer*.

☐ 4. Following compaction, remove the extension collar and carefully trim the excess material even with the top of the mold with the straightedge. Patch small holes developed in the surface by compacting small-sized material with a rubber mallet. Again use a straightedge to trim the surface.

☐ 5. Weigh and record the mass of the mold and its compacted contents, M_2, in grams.

☐ 6. Extrude the material from the mold, and slice vertically through the center of the specimen. Place into a weighed tare at least a 500 g moisture sample and put into an oven to dry to a constant weight.

☐ 7. Calculate the moisture content and dry density in kg/m^3 of the soil as compacted as follows:

[1] $$M\% = \frac{A - B}{B - C}100 = \text{percent moisture}$$

[2] $$\gamma = \frac{\text{mass of moist soil}}{\text{volume of mold}} = \frac{M_2 - M_1}{0.9439} = \text{wet density in kg / m}^3$$

[3] $$\gamma_d = \frac{\gamma}{1 + \frac{M\%}{100}} = \text{dry density}$$

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Candidate

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Examiner

Grading Technician Certification – Level I

Performance Checklist

Test Method No. 5: Relative Density Compaction Test

Following is a summary of the key steps involved in the quantitative determination of the minimum and maximum dry density of cohesionless soils and the procedure for determining percent relative density. This checklist is derived from the actual test method used in the performance examination.

CHECKLIST

- ☐ 1. Fill the mold approximately 13 mm to 25 mm above the top of the mold. Then screed off the excess soil (one to two passes) level with the top of the mold by carefully trimming the soil surface with a straightedge.
- ☐ 2. Record the mass mold, M_M, plus the mass of the soil, M_S, as $M_T = (M_M + M_S)$.
- ☐ 3. Calculate the minimum dry density, ρ_{dmin}, in accordance with Eq. 1 shown below.
- ☐ 4. After the sample mass has been recorded the sides of the mold may be ***struck a few times using a rubber hammer*** to settle the soil so that the surcharge base plate can be easily placed into position.
- ☐ 5. Place the surcharge base plate on the surface of the soil and ***twist it slightly several times*** so that it is firmly and uniformly in contact. The base plate should be positioned so that it is level with the top of the compaction mold. Attach the surcharge weight and guide sleeve.
- ☐ 6. Vibrate the soil sample under the surcharge weight for ***8 minutes*** at 60 Hz.
- ☐ 7. After the vibration period, remove the surcharge weight, and guide sleeve from the mold. Check that the surcharge base plate is firmly and uniformly in contact with the surface of the soil.
- ☐ 8. Record dial indicator gage readings on opposite sides of the surcharge base plate by placing the indicator gage holder in each of the base plate brackets. Remove the surcharge base plate and record the thickness of the plate, T_P.
- ☐ 9. Calculate the minimum dry density, ρ_{dmin}, in kg/m^3 as follows:

  [1] $$\rho_{d\,min} = \frac{M_s}{V_M}$$ M_S = mass of oven dry specimen; V_M = Volume of mold

- ☐ 10. Calculate the maximum dry density, ρ_{dmax}, in lb/ft^3 (or kg/m^3) as follows:

  [2] $$\rho_{d\,max} = \frac{M_s}{V}$$ M_s = mass of oven dry specimen; V = volume of densified specimen

- ☐ 11. Calculate the relative density, D_d, expressed as a percentage, of the difference between the maximum dry density, ρ_{dmax}, and any given field density, ρ_d, as follows:

  [3] $$D_d = \frac{\rho_{d\,max}(\rho_d - \rho_{d\,min})}{\rho_d(\rho_{d\,max} - \rho_{d\,min})} \times 100$$

________________________ Candidate

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Grading Technician Certification – Level I

Performance Quiz

Test Method No. 7: Moisture content limits

Directions: Fill in the correct information for the blank spaces in the tables below.

[COHESIVE]

NO.	Soil Performance Classification	Optimum moisture content, %	Calculated lower limit (dry limit)	Calculated upper limit (wet limit)	Final Construction Moisture Content Limits
1	Unsuitable	19.0			
2	Unsuitable	23.5			
3	Select	16.0			
4	Suitable	18.5			
5	Unsuitable	14.0			
6	Unsuitable	28.0			

[COHESIONLESS] Recall: $M\%_{\text{upper limit}} = \left(\frac{800}{RD_{max}} - 0.3\right)100$ where RD_{max} is in kg per m^3.

NO.	Soil Performance Classification (Test Method No. 1)	Max. dry density, RD_{max} (kg/m^3)	Bulking moisture content, % (to be avoided)	Calculated upper moisture limit, $M\%_{\text{upper limit}}$	Final Construction Moisture Content Limits
1	Intergrade - suitable	1778	1.5 to 8.5		
2	Select	2128	3.0 to 4.5		
3	Select	1951	2.0 to 8.0		
4	Select	1874	2.5 to 8.0		

Candidate

Examiner

Grading Technician Certification – Level I

Performance Checklist

Test Method No. 9: Determination of water content for soil

Following is a summary of the key steps involved in the quantitative determination of water (moisture) content of soil by the microwave method. This checklist is derived from the actual test method used in the performance examination.

CHECKLIST

☐ 1. Determine the mass (0.01 g precision) of the empty moisture container (C) and record the can number.

☐ 2. Place about 100 grams of the representative moist soil sample into the moisture container.

☐ 3. Determine the combined mass (0.01 g precisions) of the wet soil and the moisture container (A).

☐ 4. Place the wet soil and moisture container in the microwave oven and turn the microwave on for 3 minutes.

☐ 5. After the set time has elapsed, remove the moisture container with soil from the microwave and allow cooling for a few minutes. Determine and record the mass (0.01 g precision).

☐ 6. Return the moisture container and soil to the microwave and reheat for 1 minute. Repeat steps 5 and 6 until two consecutive mass readings differ by less than 0.1%.

☐ 7. Calculate the moisture content as follows:

$$M\% = \frac{A - B}{B - C} 100 = \text{percent moisture}$$

A = mass of wet soil plus moisture container
B = mass of oven-dry soil plus moisture container
C = mass of moisture container

☐ 8. Report M% to 0.1% precision.

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Candidate

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Examiner

Grading Technician I – Written Exam Answer Sheet

Name______________________________________ Date__________________

For each question, mark the letter on this answer sheet that corresponds to the ***single best*** answer. Hand in both this answer sheet and the exam when completed.
Do not use the back of this sheet for work.

1)	a	b	c	29)	a	b	c
2)	a	b	c	30)	a	b	c
3)	a	b	c	31)	a	b	c
4)	a	b	c	32)	a	b	c
5)	a	b	c	33)	a	b	c
6)	a	b	c	34)	a	b	c
7)	a	b	c	35)	a	b	c
8)	a	b	c	36)	a	b	c
9)	a	b	c	37)	a	b	c
10)	a	b	c	38)	a	b	c
11)	a	b	c	39)	a	b	c
12)	a	b	c	40)	a	b	c
13)	a	b	c	41)	a	b	c
14)	a	b	c	42)	a	b	c
15)	a	b	c	43)	a	b	c
16)	a	b	c	44)	a	b	c
17)	a	b	c	45)	a	b	c
18)	a	b	c	46)	a	b	c
19)	a	b	c	47)	a	b	c
20)	a	b	c	48)	a	b	c
21)	a	b	c	49)	a	b	c
22)	a	b	c	50)	a	b	c
23)	a	b	c	51)	a	b	c
24)	a	b	c	52)	a	b	c
25)	a	b	c	53)	a	b	c
26)	a	b	c	54)	a	b	c
27)	a	b	c	55)	a	b	c
28)	a	b	c				

Grading Technician I
Written Exam

For each question below, mark the letter on the answer sheet that corresponds to the single ***best*** answer. Make your calculations in the spaces adjacent to the questions or on the backs of the exam pages.

Hand in both your answer sheet and this exam when completed.

1) Water has a significant influence on the soil engineering properties of a clay soil.
   a) True
   b) False

2) The soils most susceptible to "severe" frost heave potential are:
   a) clays and silts
   b) silts, coarse sands, and fine gravels
   c) silts, silty sands, very fine sands

3) The soil types in the material passing the #200 sieve may be either:
   a) clays and silts
   b) silts, coarse sands, and fine gravels
   c) silts, silty sands, and very fine sands

4) The three phases present in a soil are:
   a) cations, anions, and water
   b) air, water, and soil solids
   c) water, soil solids, and ions

5) For moisture control of an unsuitable cohesive soil with an optimum = 23%, the limits are
   a) 22 – 26%
   b) 21 – 27%
   c) 20.7 – 27.6%

6) Compaction is the process of driving ___________ out of a soil.
   a) air
   b) soil solids
   c) water

7) Clay particles are ____________ in shape.
   a) round
   b) blocky
   c) flat

8) *Granular* soils are formed by ____________weathering of rock and *Clays* are formed by ______weathering of rock or granular soils.
   a) chemical and physical
   b) physical and chemical
   c) physical and physical

9) Loess is a wind deposited soil consisting mostly of silts with some very fine sand and clay particles.
   a) True
   b) False

10) The primary surficial soil types currently present in Iowa have been transported by:
   a) glaciers and wind
   b) lakes and rivers
   c) earth movers

11) Most soils are dried to a constant mass after 30 seconds in a microwave.

a) True
b) False

12) For drying soil in an oven the temperature must be maintained at _________ °C.

a) 100°C
b) 110°C
c) 220°C

13) Calculate the moisture content from the data shown below.

Mass of moisture container, g (2)	Mass of moisture container plus wet soil, g (3)	Mass of moisture container plus dry soil, g (4)	Moisture Content, % (5)
15.95	122.23	113.56	

a) 14.0%
b) 13.0%
c) 8.9%

14) Calculate the percent passing the No. 40 sieve based on the following information:

$M_{TOTAL\ DRY}$ = 93.7g, $M_{RETAINED\ DRY}$ = 63.2 g

a) 67.4%
b) 148.3%
c) 32.6%

15) Calculate the percent passing the No. 200 sieve based on the following information:

M_{TOTAL} = 109.2g, $M_{RETAINED\ DRY}$ = 33.2g, M% = 3.7%

a) 68.5%
b) 30.4%
c) 69.6%

16) The water content at which a soil changes from a semisolid to a plastic state is termed the:

a) plastic limit
b) moisture limit
c) liquid limit

17) The numerical difference between the liquid limit and the plastic limit is the plasticity index.

a) True
b) False

18) When placing the soil paste into the brass cup of the liquid limit device, the material should be trimmed away so that the depth is equal to the height of the grooving tool.

a) True
b) False

19) When conducting a liquid limit test, count the number of blows for the grove in the soil to close through a distance of ______________ mm.

a) 10 mm
b) 25 mm
c) 13 mm

20) The liquid limit test is repeated at three different moisture contents so that blow counts, N, fall in the ranges of 15 to 20, 20 to 30, and___________ .

a) 30-35

b) 30-40
c) 35-40

21) The plastic limit is the moisture content at which a thread of soil will crumble when it reaches a diameter of ____ _______ in.
a) 1/4 in
b) 1/16 in
c) 1/8 in

22) Heavy clay soils require much pressure to deform the thread, particularly as they approach the plastic limit.
a) True
b) False

23) Calculate the plasticity index (PI) from the following: LL = 59, PL = 23.
a) 23
b) 36
c) 82

24) The soil performance classification system identifies three major soil suitability classes, which include:
a) good, bad, ugly
b) select, marginal, class 10
c) select, suitable, unsuitable

25) Preliminary classification for soil with F_{200} = 38% is:
a) select
b) cohesive
c) cohesionless

26) The final classification for soil with F_{200} = 12% is:
a) Select
b) Suitable
c) Unsuitable

27) If a soil has the properties of LL = 40 and PI =13, the plot of LL and PI falls below the "A" line [PI=0.73(LL-20)].
a) True
b) False

28) Percent passing the No. 40 sieve must be determined for a select soil if the position of the plasticity index and liquid limit plot above the "A" line and the plasticity index is less than 10.
a) True
b) False

29) Unsuitable soils from the High Plasticity Inorganic Clay region are to be disposed of according to method Type "A" from Standard Road Plan RL-1B.
a) True
b) False

30) Low/Medium Plasticity Clays are classified suitable if the percent passing the No. 200 sieve is:
a) < 60
b) 60-70
c) >70

31) Soils with LL ≤ 50 that plot below the "A" line are within the descriptive region____________ and must be disposed of according to _________ disposal method.

a) Highly compressible inorganic silts: Type A
b) Inorganic silts of medium compressibility: Type B
c) Inorganic silts of medium compressibility: Type A

32) Soils with LL = 56, PI = 18, F_{200} = 90%, and carbon content = 3.8% have a final classification of:
   a) select
   b) suitable
   c) unsuitable

33) For the standard Proctor compaction test, before adding water the soil must be passed through the No. ________ sieve.
   a) No. 4
   b) No. 200
   c) No. 40

34) For the standard Proctor compaction test, pour the moist soil into the mold in three equal layers with each layer being compacted by the standard Proctor hammer 25 times.
   a) True
   b) False

35) During standard Proctor compaction the hammer should drop a minimum of 12 inches above the elevation of the soil.
   a) True
   b) False

36) Calculate dry density from the following information: M% = 23.2, γ = 2272 kg/m^3 , γ_d = ____________ kg/m^3 .
   a) 1844 kg/m^3
   b) 18.4 kg/m^3
   c) 93.9 kg/m^3

37) For the Relative Density Test, prior to compacting the soil sample, it must NOT be oven dried.
   a) True
   b) False

38) For the Relative Density Test, to determine the minimum dry density, ρ_{dmin}, the soil must be placed ___________ _______________ in the compaction mold.
   a) as compact as possible
   b) as loosely as possible
   c) as anticipated in the field

39) In general terms, the DCP is used to assess the _________________ and __________________ of soils and pavement base materials.
   a) in situ strength, strata thickness
   b) moisture content, and DCP Index
   c) lift thickness, density

40) The DCP can be used in weak stabilized and highly stabilized soils.
   a) True
   b) False

41) The penetration rate of the DCP (mm/blow) can be used to estimate the in-situ _____________________ Ratio.
   a) Iowa Bearing Ratio

b) Mars Landing Ratio
c) California Bearing Ratio

42) The DCP consists of a steel drive rod with a ___________° cone tip and _________________ kg slide hammer, which is dropped ______________ mm.

a) 30°, 8 kg, 875 mm
b) 60°, 8 kg, 1000 mm
c) 60°, 8 kg, 575 mm

43) During operation the DCP must always be held in a vertical or plumb position.

a) True
b) False

44) Once the cone tip is seated an initial reading is measured and recorded to the nearest ______________ mm.

a) 1 mm
b) 2.54 mm
c) 100 mm

45) A quick test to determine whether silt or clay is the predominant particle size can be conducted by

a) rubbing the soil in your eye
b) grinding it between your teeth
c) throwing it at your assistant

46) The bulking moisture content limits are graphically determined as the moisture contents below which 50% relative density cannot be achieved.

a) True
b) False

47) The upper moisture content limit for a *cohesionless* soil with RD_{max} = 1850 kg/m^3 is:

Recall: $M\%_{\text{upper limit}} = \left(\dfrac{800}{RD_{max}} - 0.3\right)100$ Where RD_{max} is in kg per m^3.

a) 20.1%
b) 13.2%
c) 42.9%

48) The bulking moisture content is to be avoided during placement of *cohesionless* soils.

a) True
b) False

49) The moisture limits for a suitable *cohesive* soil with optimum moisture content of 24% are _________________ to ___________________.

a) 22 to 28%
b) 23 to 27%
c) 22.2 to 27.8%

50) All *cohesive* soils shall have moisture limits that deviate from optimum moisture content by –1% to +3% at a minimum and –2% to +4% at a maximum.

a) True
b) False

51) The Iowa Modified Relative Density Test limits the percent passing the No. 200 sieve to less than___________ .

a) 15%
b) 100%
c) 36%

52) According to the Iowa Modified Relative Density Test, the bulking moisture content is defined as the moisture content for which ______________________________ cannot be achieved.

a) 95% standard Proctor
b) 80% Relative Density
c) 90% Vibratory Compaction

53) Relative density is performed in lieu of standard Proctor compaction because cohesionless and some intergrade soils are effectively compacted by ______ means.

a) vibratory
b) static
c) pneumatic

54) Changes in water content can cause some types of clays to exhibit shrink/swell behavior.

a) True
b) False

55) Surficial soil distributions in Iowa, by percentage, are

Glacial till______,Loess____ , and Alluvium_______________.

a) 13, 35, 42 %
b) 29, 38, 20 %
c) 53, 14, 27 %

APPENDIX D: QM-E FIELD LAB EQUIPMENT AND EXPENSES

QM-E Field Lab Expenses

Description	Quantity	Total Cost
Rapid Soil Processor	1	$6,240
Soil Grinder	1	$643
Liquid Limit Test Set	2	$576
Grooving Tool	2	$54
Dynamic Shaker	1	$1238
USA Sieve 12” No. 40	2	$120
Cover, 12”	2	$38
Bottom Pan, 12”	2	$76
Mechanical Compactor	1	$5,185
Sample Ejector	1	$432
Straightedge, 12”	1	$16
Vibrating Table 230V 60 Hz	1	$4387
Relative Density Mold Set 0.1	1	$710
Vibration Indicator Gauge Set	1	$6
Relative Density Gauge Set	1	$240
Gas Hot Plate, 2 burner	1	$73
Voluvessel w/gauge, 1/13 cu ft	1	$384
Balance 12000g	1	$1995
Ohaus Balance to 0.01 g	1	$610
Lab pans		$264
Lab Oven	1	$860
Microwave	1	$186
Set of 8 sieves	1	$370
Ohaus balance, 8100 g	1	$548
Ohuas balance, 410 g	1	$597
Total laboratory expenses		= $ 25,848

APPENDIX E: MINUTES OF POST-CONSTRUCTION REVIEW MEETING

<u>DRAFT</u> MINUTES OF:
Post-construction review meeting for
U.S. 218 Bremer Co. grading project NHSX-218-8(39)--3H-09;
Phase III Pilot Project for
Iowa Highway Research Board Project TR-401, 'Embankment Quality';
Meeting held at the DOT Waterloo RCE office, Friday December 14th, from 1:00 to 3:00.

Minutes of the December 14 meeting are being sent to those listed below. Persons present at the meeting are marked with initials. Refer to these initials for speakers noted in the minutes. Please forward corrections or additions to me. Comments/speakers were reconstructed from my notes/memory and may be incorrect, or some discussion may have been missed. I will send out revised minutes as needed.

A copy of these minutes as MSWord file 'Dec14' is attached at the bottom of this LotusNote, in case of format problems with this document via e-mail.
Please call me with any comments or questions.

David Heer
Office of Construction
Iowa DOT
800 Lincoln Way
Ames, Iowa 50010
Phone (515) 239-1280
Fax (515) 239-1845

Note: A previous 'tour' meeting for the Phase III Pilot Project was held on August 23, 2001 at the job site. The semi-trailer lab and EarthTech field lab were visited, the DCP hammer was demonstrated on till and sand, and grade work was observed. No minutes were released.

Iowa State University
Chuck Jahren (CJ), Dave White (DW), Ken Bergeson (KB), Tyson Rupnow, Zach Thomas
Iowa DOT
Jerry Danforth (JD), David Heer (DH), Bob Jimerson, Bob Stanley (RS), Tom Jacobson, Dave Roeber
Iowa DOT - Waterloo RCE Office
Steve Armstrong, Ed Bailey (EB), Mark Homan (MH), Ron Loecher (RL), Dave Peters (DP), Larry Wheeler (LW)
EarthTech
Chad Brown (CB), Theresa Lund (TL)
Cass County
Charles Marker (CM)
City of Council Bluffs
Jeff Krist
Contractors
John Moyna (JM), Dave Kahrs (DK), Larry Thompson (LT), Jesse Steger (JS)
AGC rep
Charlie Davis

The meeting was opened at 1:00 with introductions.

DH: A brief overview of research of Embankment Quality Research since 1997 will be useful:
Phase I was investigation and evaluation of present DOT practices.
Phase II was development/recommendation of improved test methods and earthwork practices.
Phase III was a trial of Phase II recommendations on a grading pilot project from design through construction.

Feedback from this meeting is part of evaluation for Phase III. The outline of SP-95509M, "Special Provisions for Quality Management - Earthwork (QM-E)" is a rough meeting guide, but anyone can bring up items in order of importance.

DW: How did testing work on this project?

DK: Testing was okay, but pass/fail acceptance specs need a better explanation of locations and re-tests if needed.

CB: DCP data did not control acceptance in 99.9% of tests; nuclear density was used more for control. What does DCP data show beyond density data? What if DCP tests fail but moisture and density are OK? How would the contractor adjust his operations to improve compaction?

DW: The DCP was not expected to control compaction on this pilot project. The DCP Index cutoffs were estimated from previous trials and were set conservatively. Future projects would use lower (stricter) DCP values, after calibration with more data and adjustment for different soils. The DCP is hoped to replace the nuclear gauge because of general safety/license concerns, and because DCP is a direct measure of stability. The DCP also picks up problems with lift thickness.

DW: Did testing delay work on this project?

DK: Not on this job since the soils were good, but testing could easily slow down another project with poor soils.
For silty or wet soils, the limit of 750,000 square feet (17 acres) in the Standard Specifications would have to be changed to let multiple spreads be opened up and worked while a wet spread was drying.

JM: Working days and berm dates control many grading projects. Drying soils to pass moisture slows down production.

DW: What was the Waterloo inspectors' point of view of the project?

LW: Our inspection staff was also assigned to an adjacent grading project (Kueter's to the north). We were busy with both projects and with other inspection duties, and did not get to monitor work as much as desired. We had daily contact but relied more on test results by EarthTech.

EB: We had to chase QA (Quality Assurance) for 'catch-up' because of time reasons. On future projects QA should be allocated through the project timeline, with lots of QA during start-up, but the frequency reduced later in the project.

RS: Before we get into evaluation of detailed test requirements, we should talk about the larger question: What improvement does QME give over the present soil classification and construction specifications? At some point the DOT needs to decide if the new system will be adopted.

JD: QME need not be applied to all jobs, maybe only on selected jobs depending on soils and other conditions.

JM: Either system works well when done right.

LW: QME worked on this project because the inspectors had confidence in the testing procedures by EarthTech and had the cooperation of the contractor Moyna.

JS: From experience, when moisture is right, embankment quality follows. Another big factor is drainage of wet areas during design, or of areas unforeseen and found during construction.

DW: In general, what causes poor embankment quality?

JM: Disking increases quality, since it but slows down production there is always a time factor. Time pressure to complete work reduces quality.

JS: Moisture control by disking is important. From the previous Phase I and II reports, enforcing disking to reduce 12" clods, as required under DOT specs, was a big factor to improve quality.

JM: Direct payment of disking creates an incentive to dry soil, and it helps cash flow during nonproductive days/weeks spent disking.

DW (to the group): What makes a good embankment?

DH: Here is a partial list from our discussion: moisture control, drainage, the right soil in the right place. What other factors are there?

EB: Also important are: Lift thickness, proper compaction, observed behavior of soils under equipment, classification and identification of soils.

CM: What were the costs to the contractor, such as training and technicians? These get passed onto project costs.

JM: Moyna underestimated the testing costs to the subcontractor EarthTech. We paid an additional $25,000 (above the Quality Control Program lump sum bid of $45,000) because equipment was moved to other jobs. The project took longer because of slower production, but daily testing was still needed.

TL: Technicians were trained to do soils classification in the field, but classification should be more of a determination as for design.

EB: Technician training is an extra cost, but quality is improved by it.

JM: Embankment quality is improved under QME because the contractor is more conscientious under testing.

DK: On this project, equipment was supplied by the DOT. There will be additional cost on future jobs if the testing lab will be supplied by the contractor.

DH: The cost for the Proctor compactor, soil processor, and vibratory table, plus some smaller lab equipment, was about $22,000.

DK: Costs would be lower if the nuclear gauge was used alone without the DCP.

LT: What was the time cost to Moyna? How many days were added to production time?

JM: About 10 extra days were added to the project because of extra disking. A lot of disking was done at the start, but the weather turned dry which helped. Payment for disking helped with cash flow through the wet period. The class 10 cost was $1.69 per cubic meter; average cost is about $2.00. Some of the cost went into the Disking item.

JM: Soil classification and stability were not a problem on this job, but moisture control was important.

DK: Moisture control for sands was a problem, as far as the upper moisture limit by the formula in the Special Provision. 12% was the calculated upper limit of moisture fro the sand, but 15% was needed to make density. The specs should allow placement at wetter than 12%.

CM: What soils should be stayed away from for this system?

RS: Would it help for soils that are worse?

JM: The glacial till and sand on this project were good soils.

DW: ISU would have preferred much poorer soils for the pilot project; these were too good.

CM: Marginal soils, such as wet and silty soils ones, are more critical.

JS: For example, Jones County soils would be difficult.

EB: Disking of wet soils was definitely more aggressive on this project.

DK: After the first test section trials, Moyna used 8" lifts with sheepsfoot roller 8 passes on clays, the same as for present specs. On sands, Moyna used 12" lifts and 3 roller passes with a vibratory padfoot.

CJ: The intent of the 'end result' spec with test sections was to get away from a prescribed method spec. Roller and passes can be different with test sections, which allows some innovation by the contractor.

LT: How many working days did this project have?

JM: 120 working days. A better product results if greater working days are allowed on grading jobs.

DP: Working days were not charged if only disking was done, or re-disking was done after rain.

DW: What needs to be done to have the new system adopted?

LT: It should be tried on marginal soils and by different contractors. Moyna was interested in making the project work, but other contractors may look more at the bottom line of cost. We are looking at an extra cost of about $0.25 per cubic meter, similar to that for jobs with moisture control.

DW: Aside from the need for moisture control, research has shown that as soils get marginal, this magnifies the need for accurate soil classification and control of lift thickness.

CM: To get additional experience, some additional pilot work should be done in 2002. With lead time for design and specifications, we may lose a construction season. Counties can also be candidates for projects this year. Training frequency and costs will be important to counties. State specifications are often used by counties.

DW: Should the test frequency be adjusted for future work?

DP: Every 1000 cubic meters was okay.

JD: How long was the training for this project?

DW: One week at DMACC in Boone, with a second week of additional field assistance on the job.

KB: ISU would like feedback on the training.

TL: The initial one week was the right length. The second week was needed to fully understand the spec. Most of the difficulty was understanding the initial test section and production requirements.

??: A future spec, if made standard, should be stand-alone and not require additional training on site.

LW: Training should be considered along with other DOT schools.

EB: A field 'apprenticeship' is needed after training to become familiar with the system.

LW: For further work, a single project without an adjacent job would be better because of the difficulty of inspecting two projects. However, on this project DOT inspectors were comfortable with the QC program by EarthTech and Moyna.

EB: Will the nuclear gauge be retained for use?

??: At present only one nuclear gauge is within each DOT district, used mostly for bridge deck overlays.

RS: Was the 'Speedy' moisture meter allowed on this project?

DH: It would have been, but DOT Environmental Services recommended against its use by the DOT because of safety and environmental problems with storing, shipping, and using the carbide reagent which becomes flammable when wet.

DW: There are other test methods on the market, such as the TDR (?) test probe which is inserted in soil for a direct reading of moisture.

MH: One week is the maximum time for office training. Complete soil classification and moisture limits took time, 1/2 to 1 day. Test techniques were difficult to retain if not done regularly. Once a month would not be enough.

JD: Maybe QA could be done by a few persons trained at the Materials District office, and not by project inspectors. This is how it is done for other materials. We have to consider what is needed for training and certification.

DP: More time for assurance is desired, but it is difficult for project staff. Maybe the central DOT lab could do QA tests, similar to how soil samples are sometimes sent in on other projects. This would free up inspectors for other duties.

EB: The time issue was helped by DOT inspectors being comfortable with Moyna's work. That could change with a different grade foremen or with another contractor.

DH: Most topics in the outline of Special Provision have been covered. One thing not yet talked about was field records. Were the field records and daily charts okay or too much?

CB: They were difficult to keep up with, especially in the beginning when an average of 4 tests was required for every 1000 cubic meters. It took the whole project to catch up from that. The charts were not needed as much because we had daily contact with the DOT inspectors.

JM: Is there an incentive payment for QME which could be used, similar to incentive for core lengths in concrete paving?

DH: The problem would be what to measure for incentive.

CM: If soil meets certain minimum properties, the quality should be there. Minimum thresholds would be enough. Incentive past a certain point may not give a return.

JM: On a recent job in Wisconsin, Moyna was required to have a staggered wheel compaction pattern, followed by proof rolling. This was direct from the Wisconsin spec book, and gave good quality.

JS: An important thing to consider is the condition of the grade after the grading contractor leaves and the paving contractor moves in. The grade may pond water over the winter and not be in good condition before paving. Re-disking and re-compaction should be required before paving.

RS: The newer grading 'Typicals' have a 2% crown, which sheds water better than the older 1% crown. The 2% crown is trimmed to 1% just before paving.

DH: The new spec for Modified Subbase under AC pavement has a provision for disking and re-compaction of the top 6" before placement of Modified Subbase, followed by proof rolling with a legal axle of 20,00 pounds. Areas which rut more than 2" are corrected before paving. It would be a good idea to extend disking and re-compaction to all grades before paving.

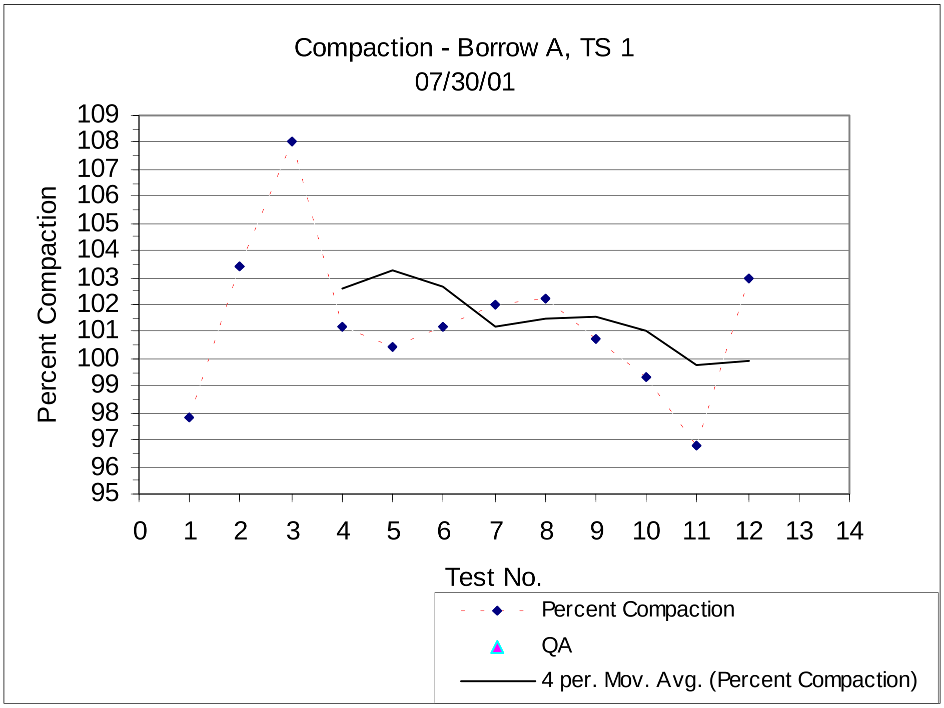
JM: Is fly ash being considered for stabilization of subgrades? What are the results of the test areas on U.S. 30 east of Cedar Rapids?

DH: The U.S. 30 section will be watched for performance. No policy on fly ash use is decided. It is being used more to dry up wet areas before starting fills.

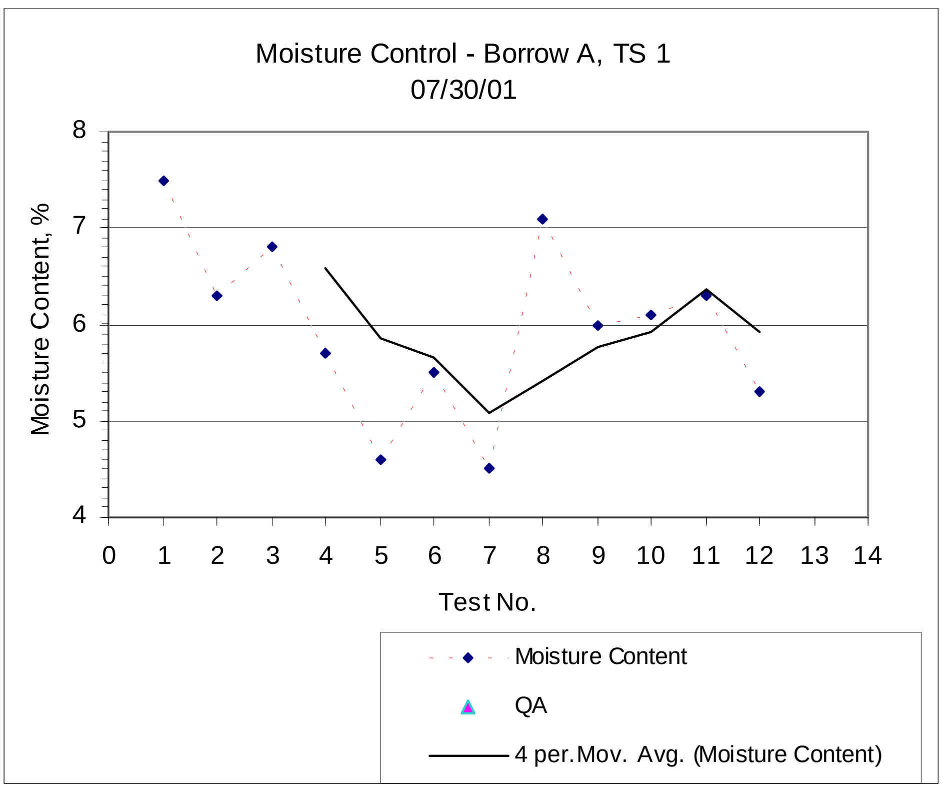
LT: Hydrated lime has been used to stabilize grade under AC paving with good results.

DH (to all): Thank you for your time and input.
(Meeting adjourned about 3:00)

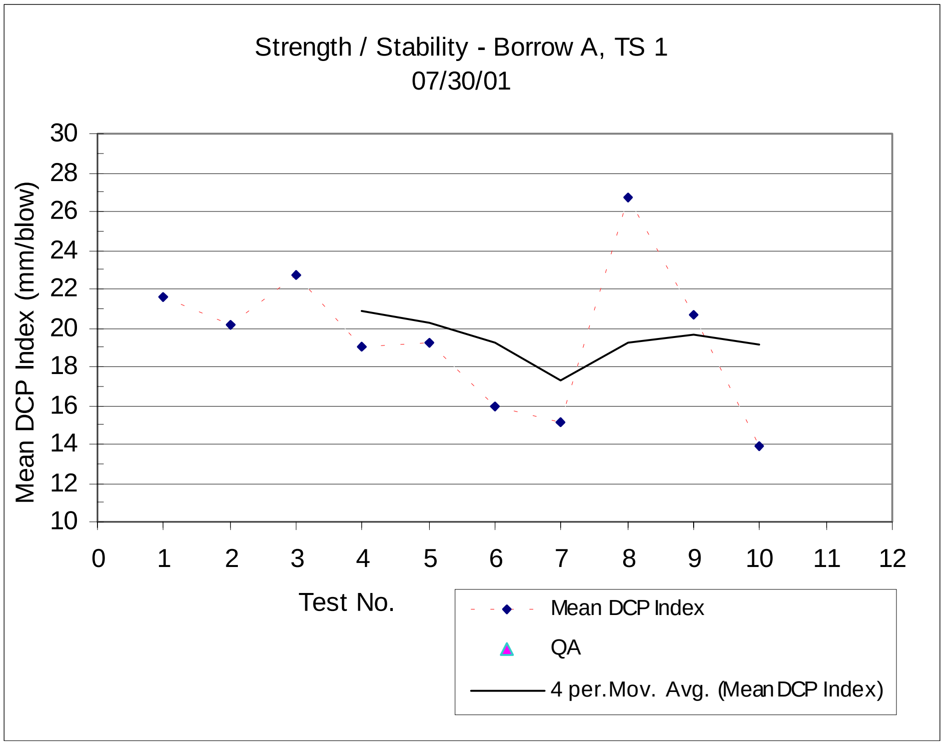
APPENDIX F: QC FIELD TEST RESULTS

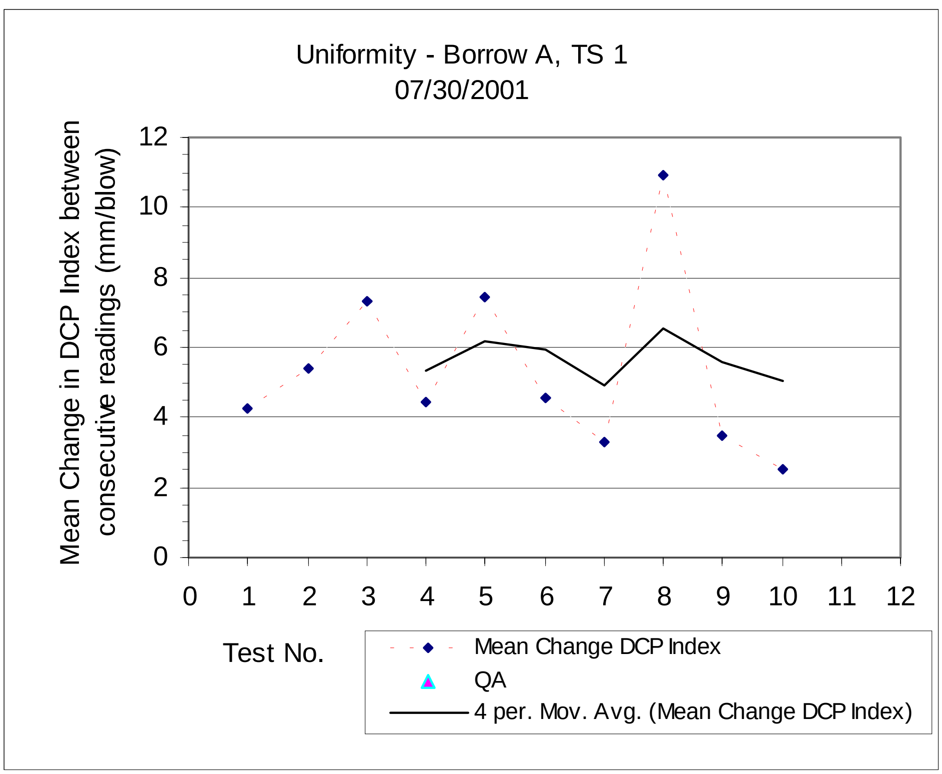


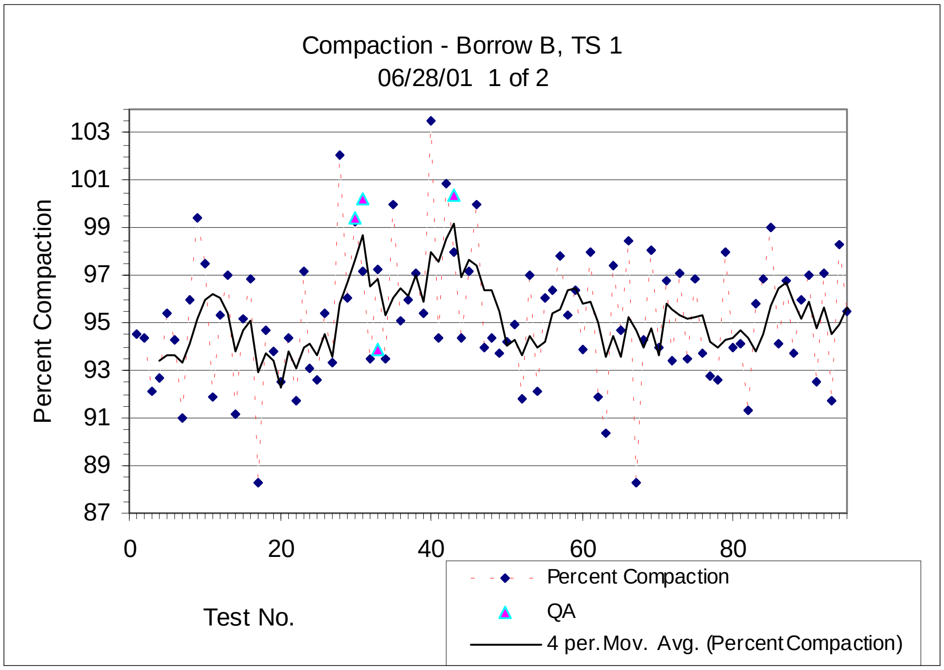
Compaction - Borrow A, TS 1
07/30/01
Percent Compaction
109
108
107
106
105
104
103
102
101
100
99
98
97
96
95
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Test No.
Percent Compaction
QA
4 per. Mov. Avg. (Percent Compaction)

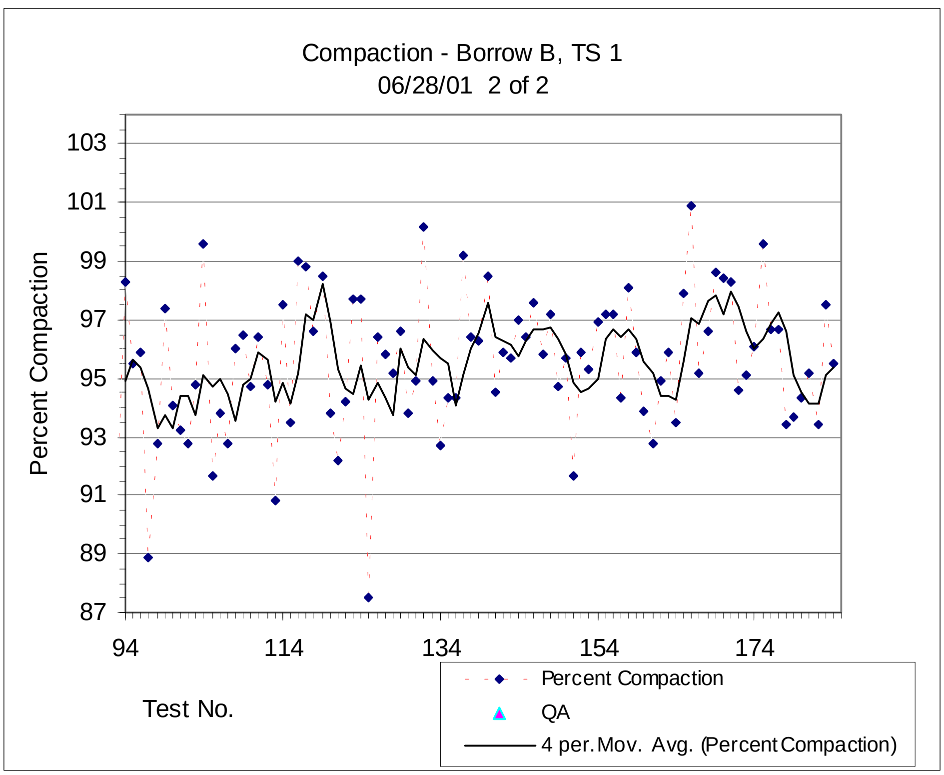


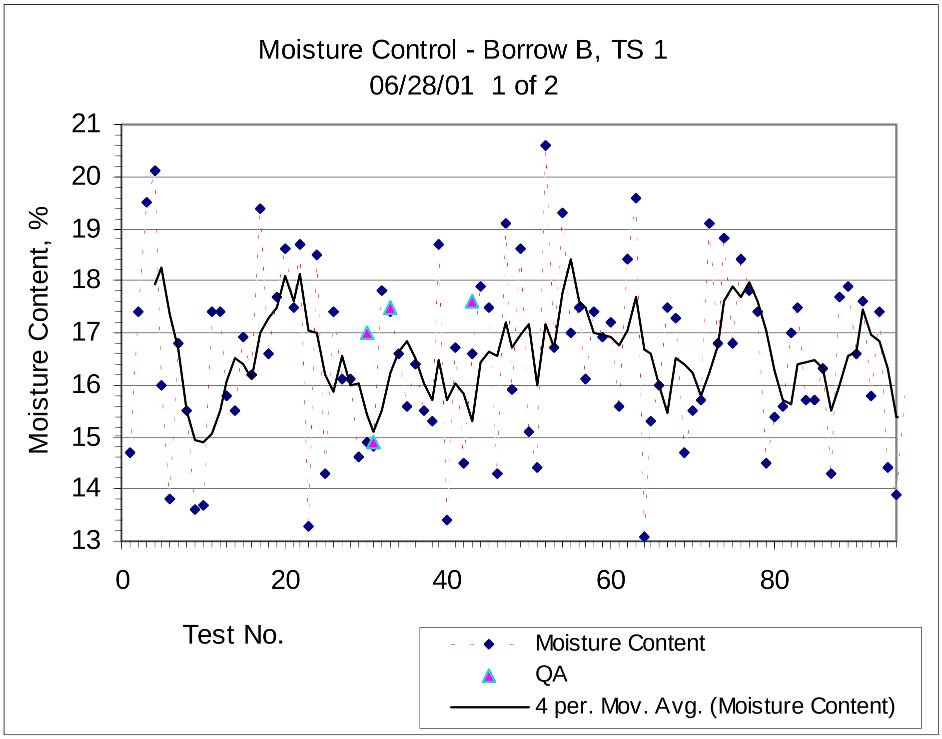
Moisture Control - Borrow A, TS 1
07/30/01
Moisture Content, %
8
7
6
5
4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Test No.
Moisture Content
QA
4 per.Mov. Avg. (Moisture Content)

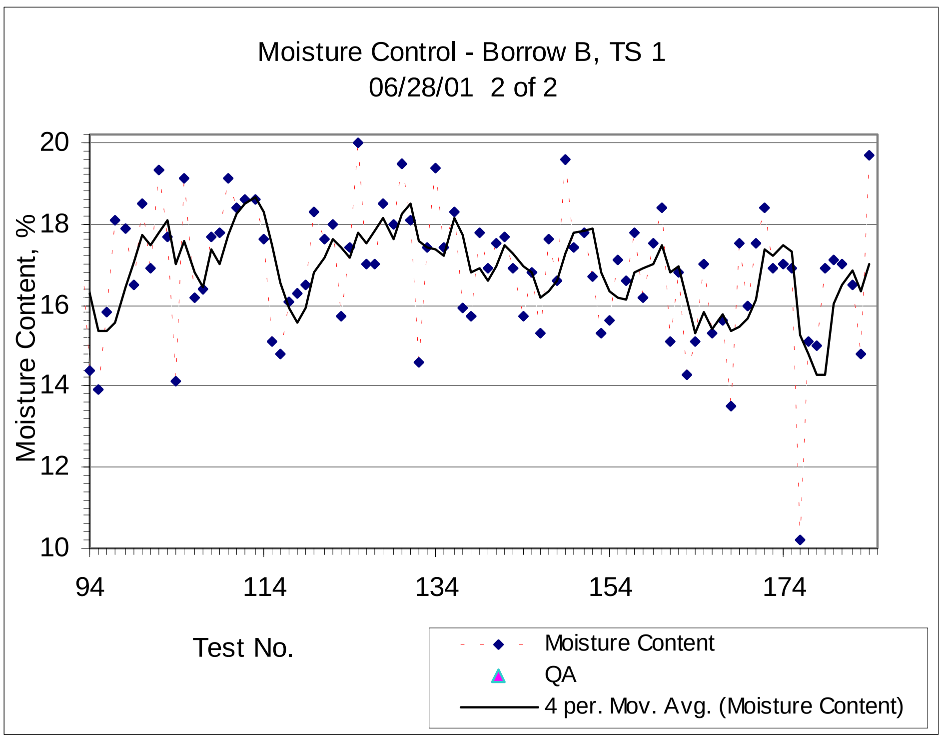

Strength / Stability - Borrow A, TS 1
07/30/01
Mean DCP Index (mm/blow)
30
28
26
24
22
20
18
16
14
12
10
0 1 2 3 4 5 6 7 8 9 10 11 12
Test No.
Mean DCP Index
QA
4 per.Mov. Avg. (Mean DCP Index)

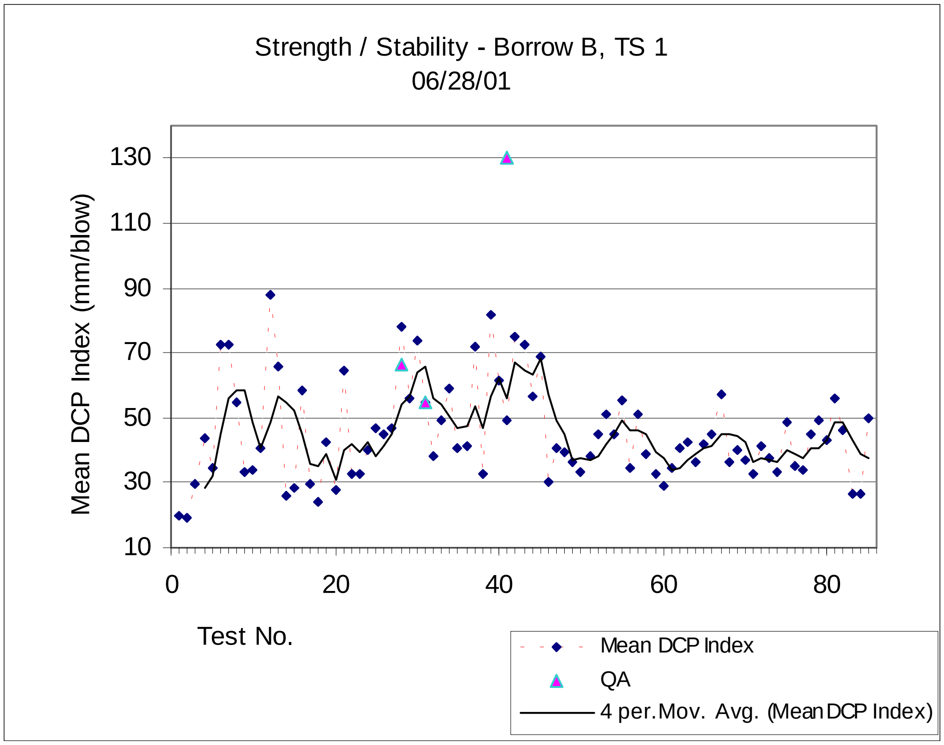

Uniformity - Borrow A, TS 1
07/30/2001
Mean Change in DCP Index between consecutive readings (mm/blow)
12
10
8
6
4
2
0
0 1 2 3 4 5 6 7 8 9 10 11 12
Test No.
Mean Change DCP Index
QA
4 per. Mov. Avg. (Mean Change DCP Index)


Compaction - Borrow B, TS 1
06/28/01 1 of 2
Percent Compaction
103
101
99
97
95
93
91
89
87
0
20
40
60
80
Test No.
Percent Compaction
QA
4 per. Mov. Avg. (Percent Compaction)

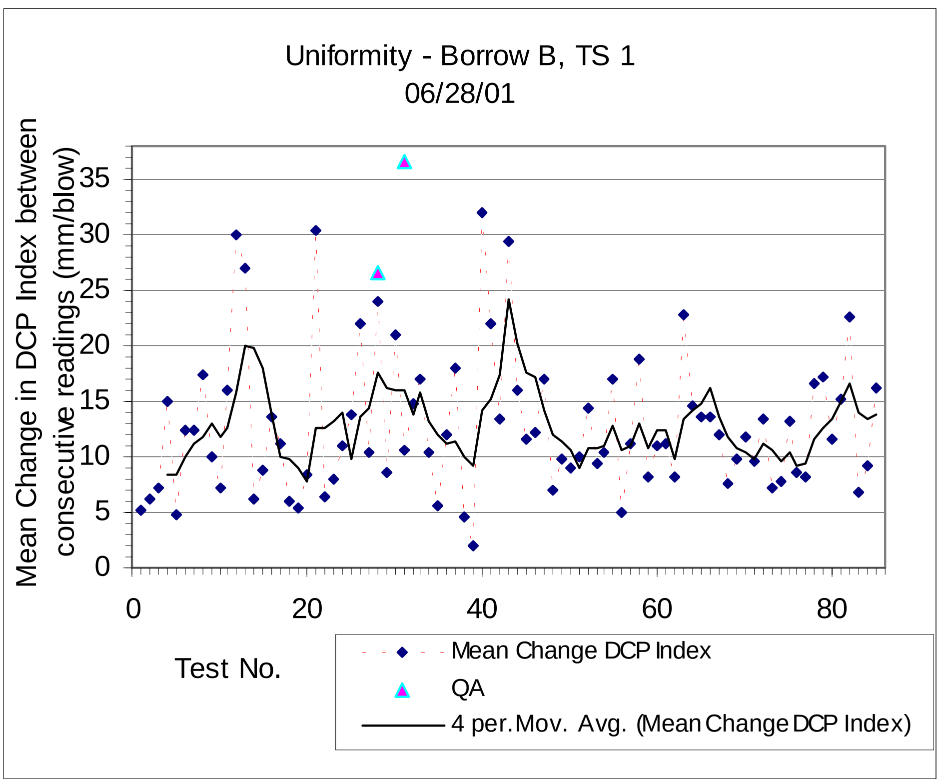

Compaction - Borrow B, TS 1
06/28/01 2 of 2
Percent Compaction
103
101
99
97
95
93
91
89
87
94
114
134
154
174
Test No.
Percent Compaction
QA
4 per. Mov. Avg. (Percent Compaction)


Moisture Control - Borrow B, TS 1
06/28/01 1 of 2
Moisture Content, %
21
20
19
18
17
16
15
14
13
0
20
40
60
80
Test No.
Moisture Content
QA
4 per. Mov. Avg. (Moisture Content)

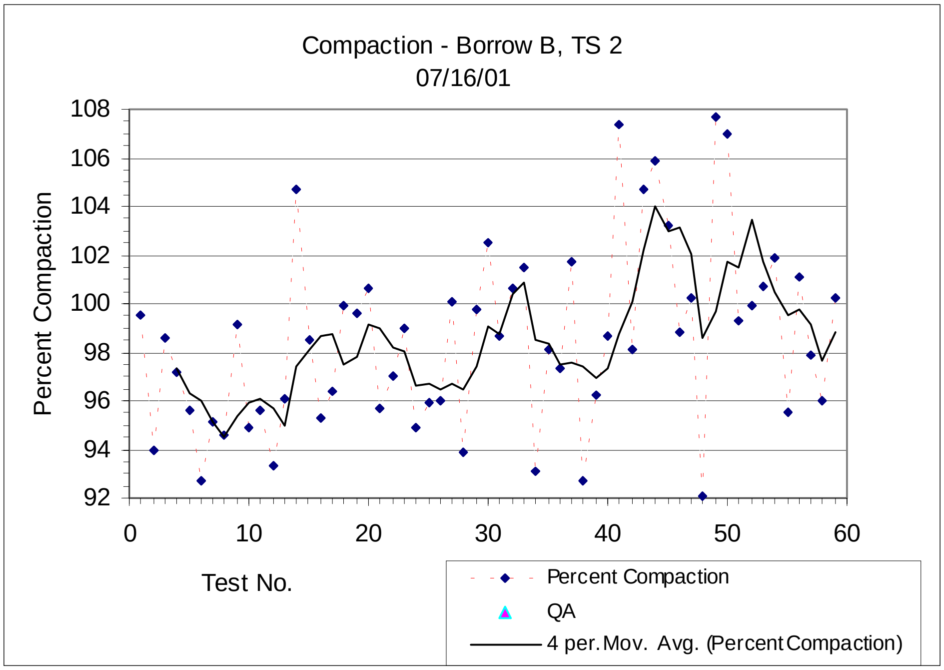

Moisture Control - Borrow B, TS 1
06/28/01 2 of 2
Moisture Content, %
20
18
16
14
12
10
94
114
134
154
174
Test No.
Moisture Content
QA
4 per. Mov. Avg. (Moisture Content)

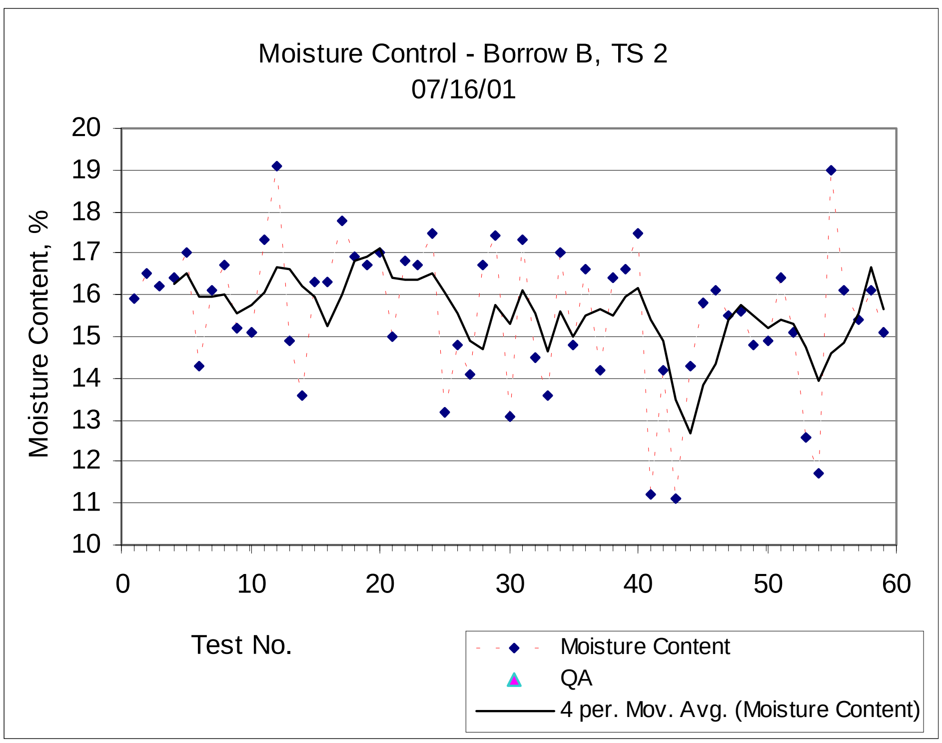


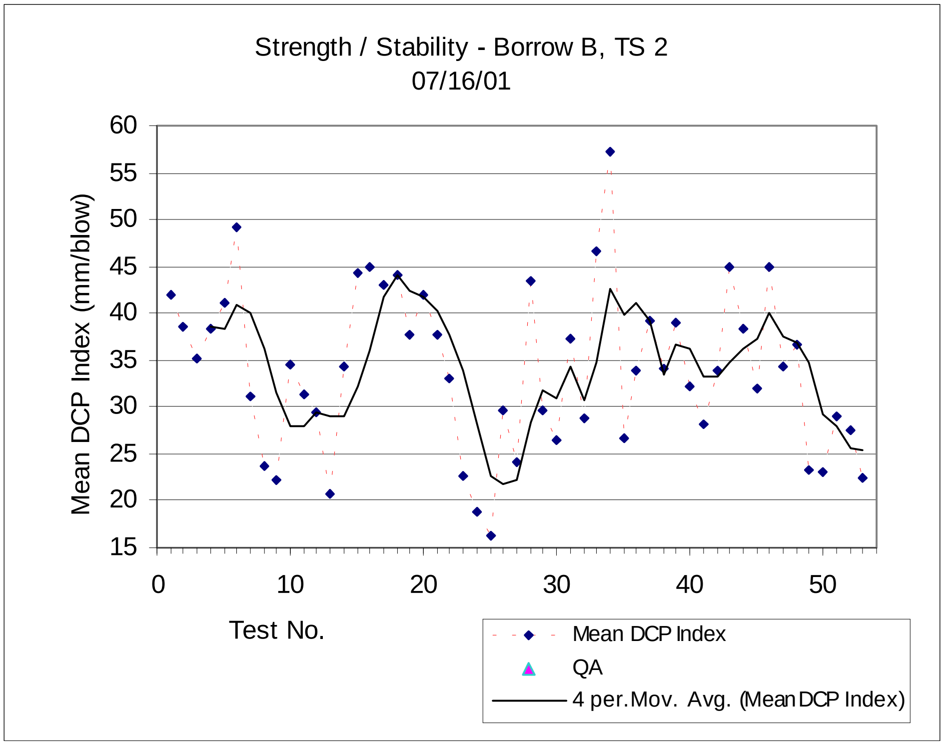
Strength / Stability - Borrow B, TS 1
06/28/01
Mean DCP Index (mm/blow)
130
110
90
70
50
30
10
0
20
40
60
80
Test No.
Mean DCP Index
QA
4 per.Mov. Avg. (Mean DCP Index)

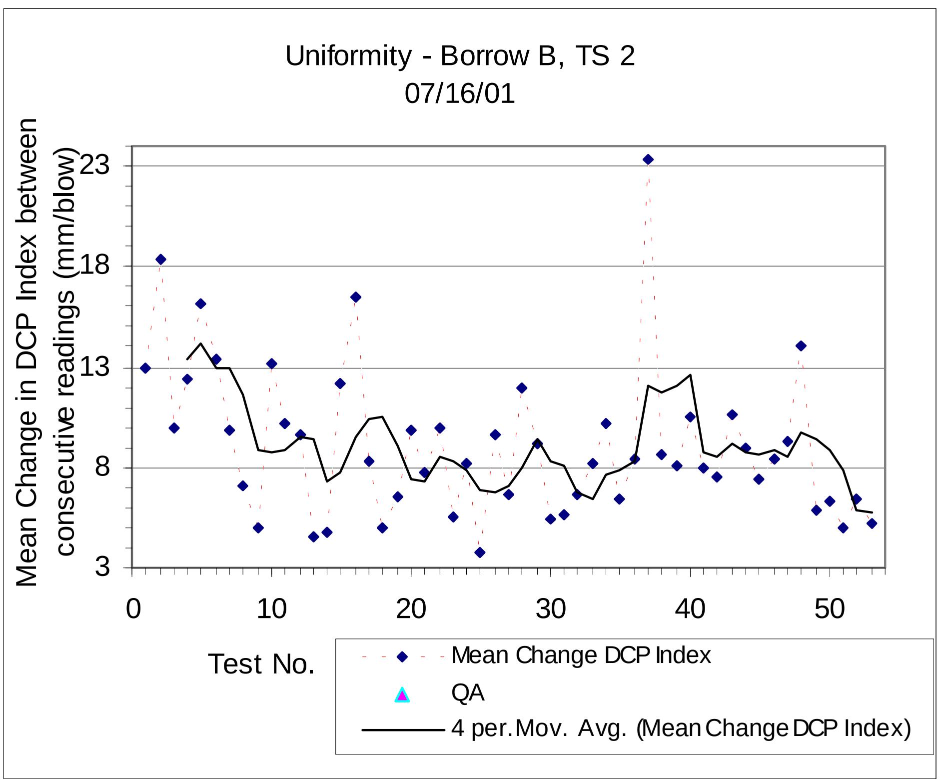


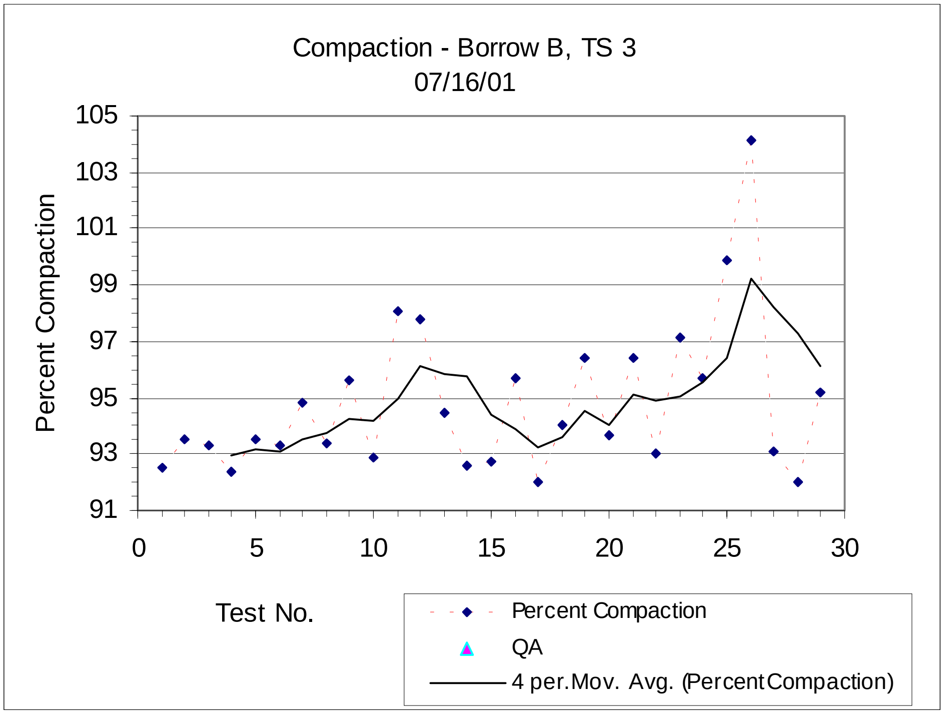
Uniformity - Borrow B, TS 1
06/28/01
Mean Change in DCP Index between consecutive readings (mm/blow)
35
30
25
20
15
10
5
0
0
20
40
60
80
Test No.
Mean Change DCP Index
QA
4 per.Mov. Avg. (Mean Change DCP Index)

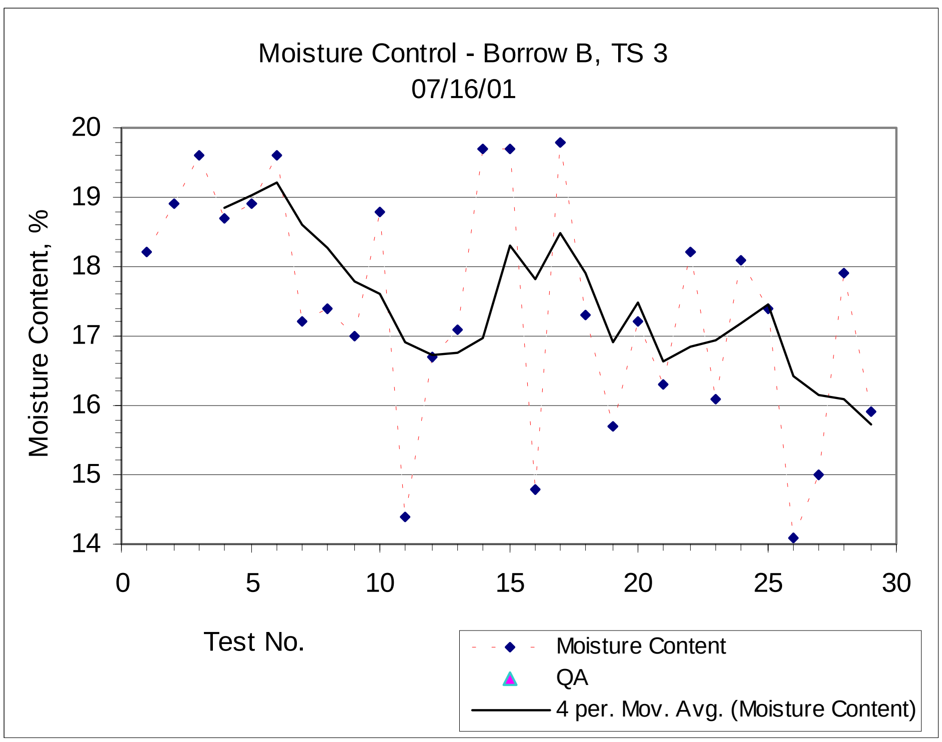

Compaction - Borrow B, TS 2
07/16/01
Percent Compaction
108
106
104
102
100
98
96
94
92
0
10
20
30
40
50
60
Test No.
Percent Compaction
QA
4 per. Mov. Avg. (Percent Compaction)

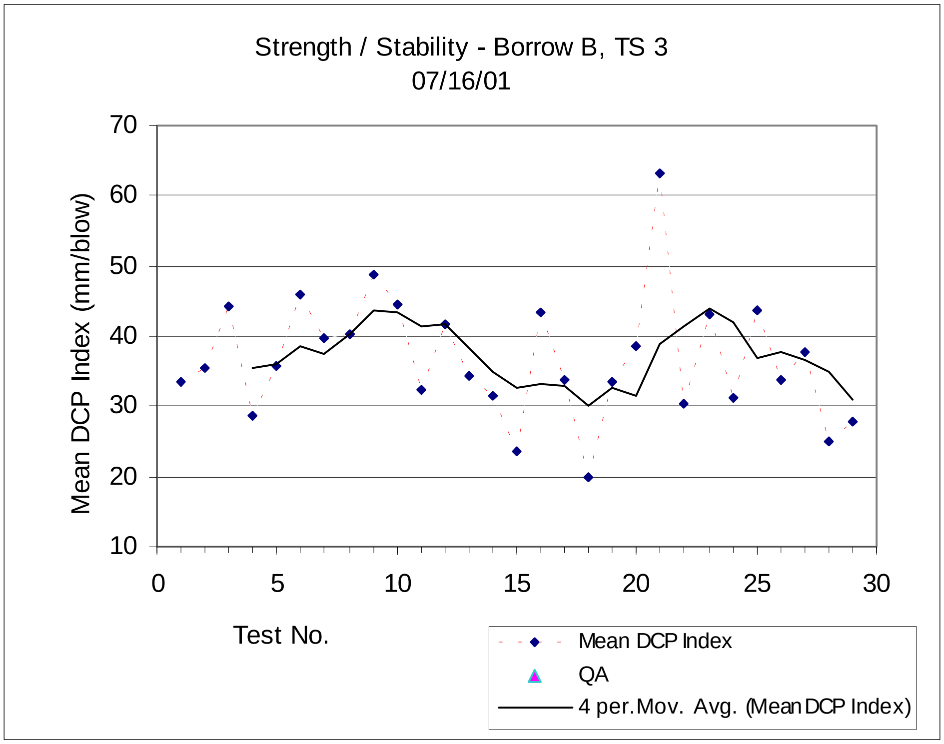

Moisture Control - Borrow B, TS 2
07/16/01
Moisture Content, %
20
19
18
17
16
15
14
13
12
11
10
0
10
20
30
40
50
60
Test No.
Moisture Content
QA
4 per. Mov. Avg. (Moisture Content)

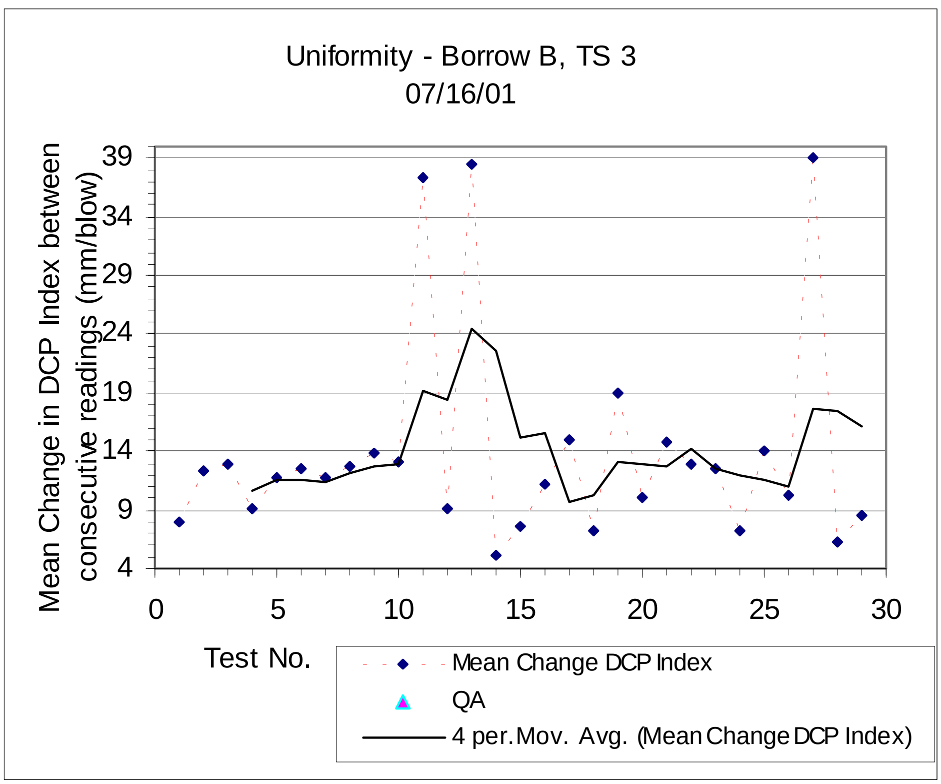

Strength / Stability - Borrow B, TS 2
07/16/01
Mean DCP Index (mm/blow)
60
55
50
45
40
35
30
25
20
15
0
10
20
30
40
50
Test No.
Mean DCP Index
QA
4 per. Mov. Avg. (Mean DCP Index)

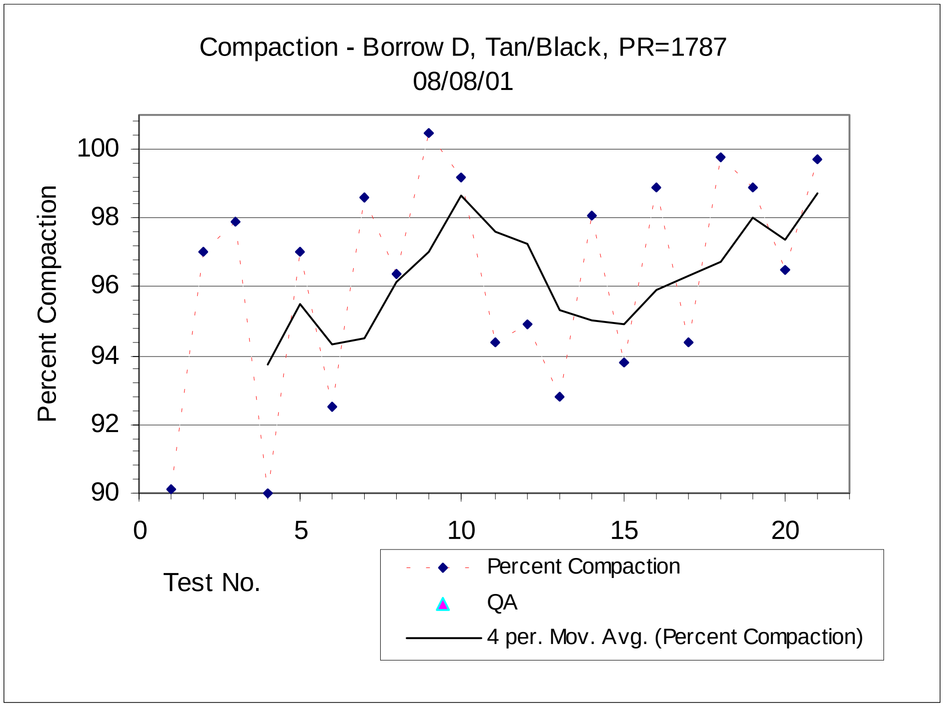

Uniformity - Borrow B, TS 2
07/16/01
Mean Change in DCP Index between consecutive readings (mm/blow)
23
18
13
8
3
0
10
20
30
40
50
Test No.
Mean Change DCP Index
QA
4 per. Mov. Avg. (Mean Change DCP Index)

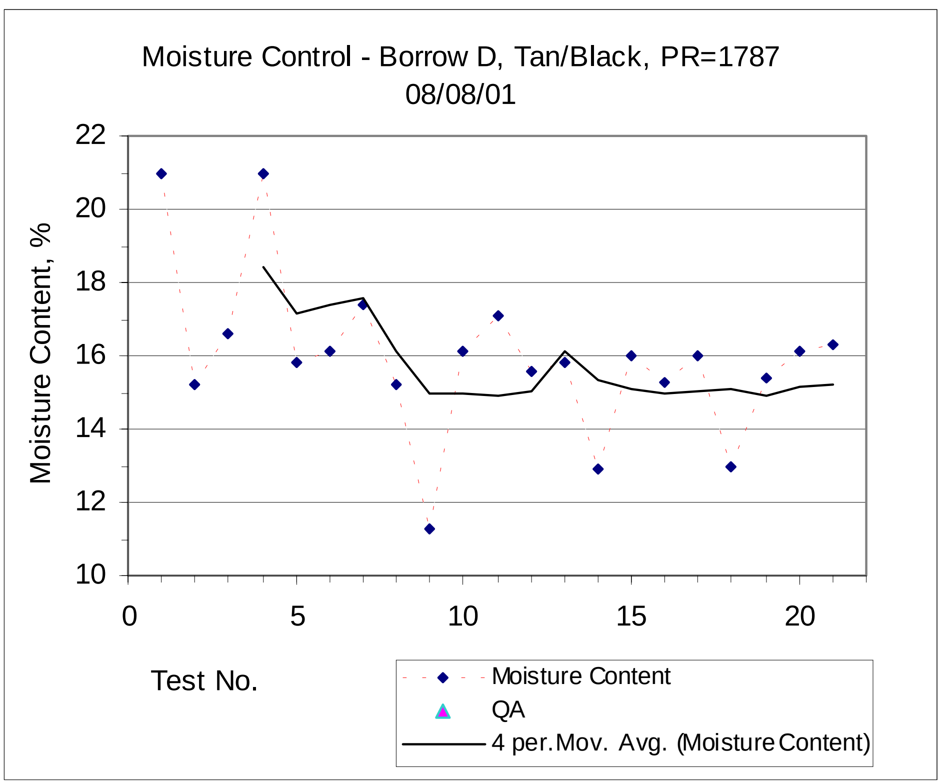

Compaction - Borrow B, TS 3
07/16/01
Percent Compaction
105
103
101
99
97
95
93
91
0
5
10
15
20
25
30
Test No.
Percent Compaction
QA
4 per.Mov. Avg. (Percent Compaction)

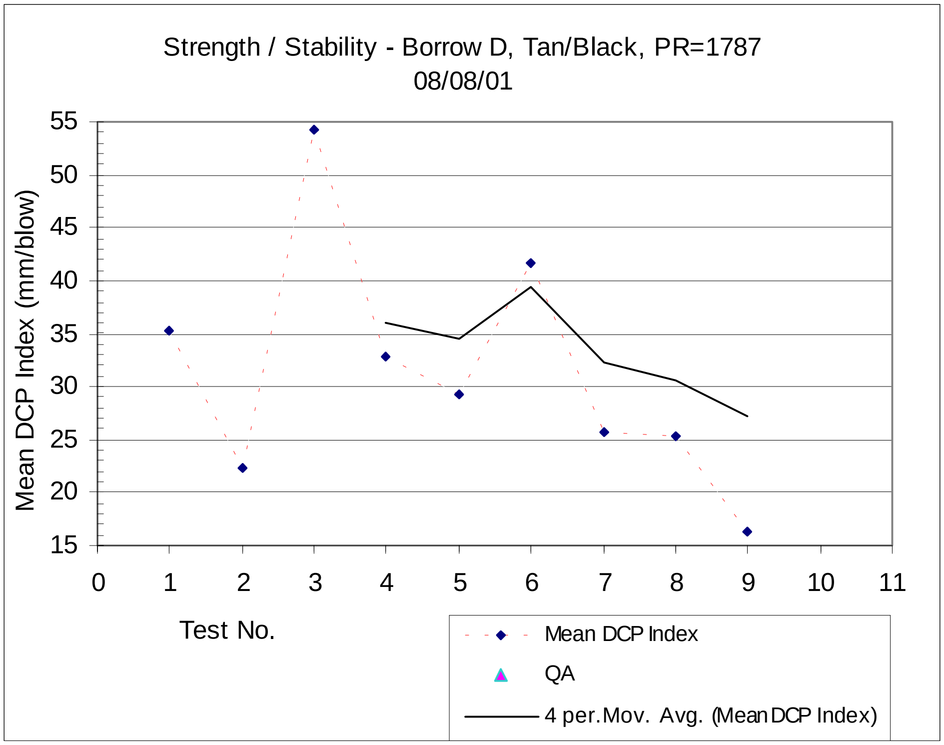

Moisture Control - Borrow B, TS 3
07/16/01
Moisture Content, %
20
19
18
17
16
15
14
0
5
10
15
20
25
30
Test No.
Moisture Content
QA
4 per. Mov. Avg. (Moisture Content)

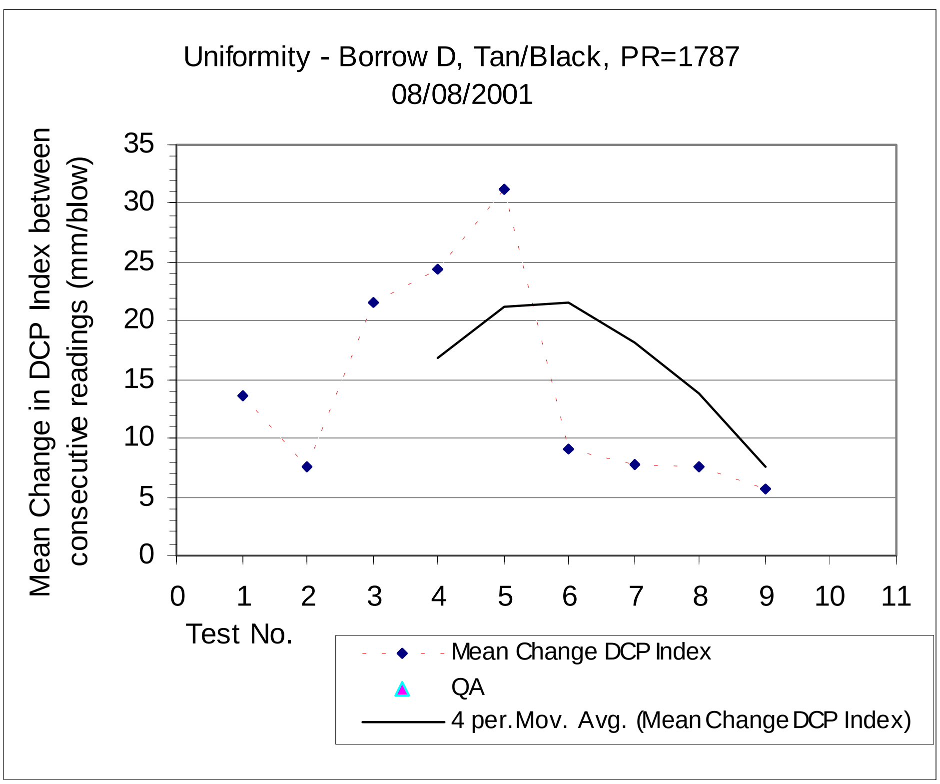

Strength / Stability - Borrow B, TS 3
07/16/01
Mean DCP Index (mm/blow)
70
60
50
40
30
20
10
0
5
10
15
20
25
30
Test No.
Mean DCP Index
QA
4 per. Mov. Avg. (Mean DCP Index)

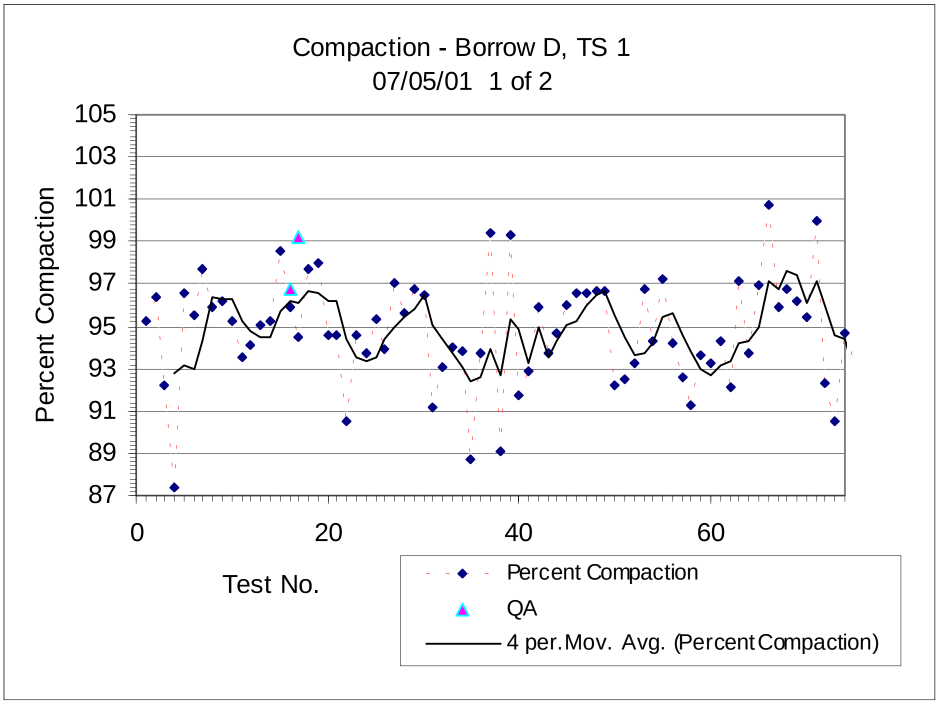

Uniformity - Borrow B, TS 3
07/16/01
Mean Change in DCP Index between consecutive readings (mm/blow)
39
34
29
24
19
14
9
4
0
5
10
15
20
25
30
Test No.
Mean Change DCP Index
QA
4 per. Mov. Avg. (Mean Change DCP Index)

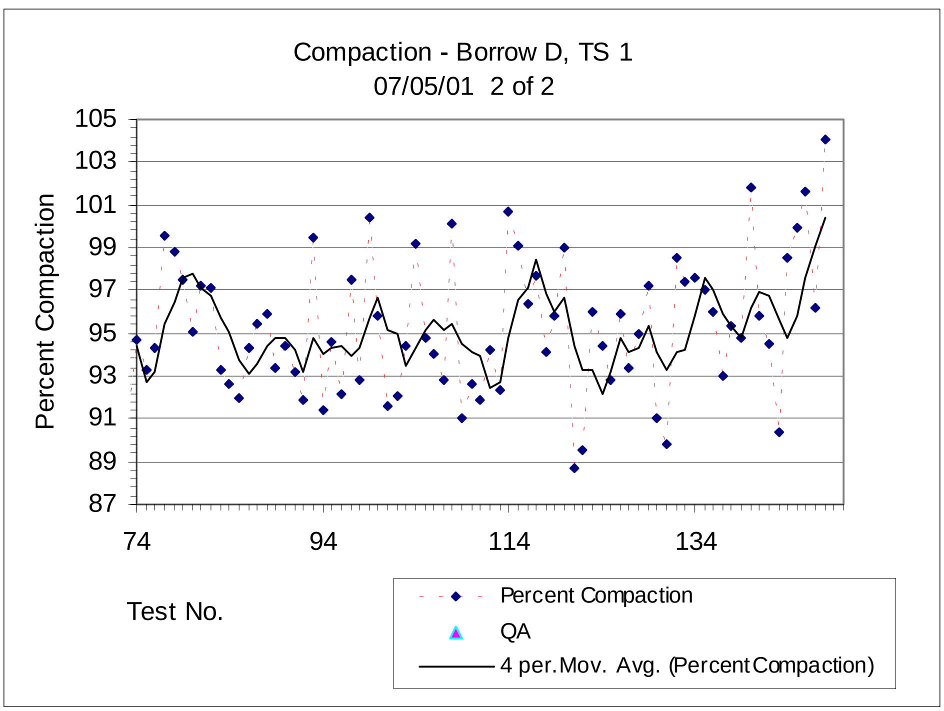

Compaction - Borrow D, Tan/Black, PR=1787
08/08/01
Percent Compaction
90
92
94
96
98
100
0
5
10
15
20
Test No.
Percent Compaction
QA
4 per. Mov. Avg. (Percent Compaction)

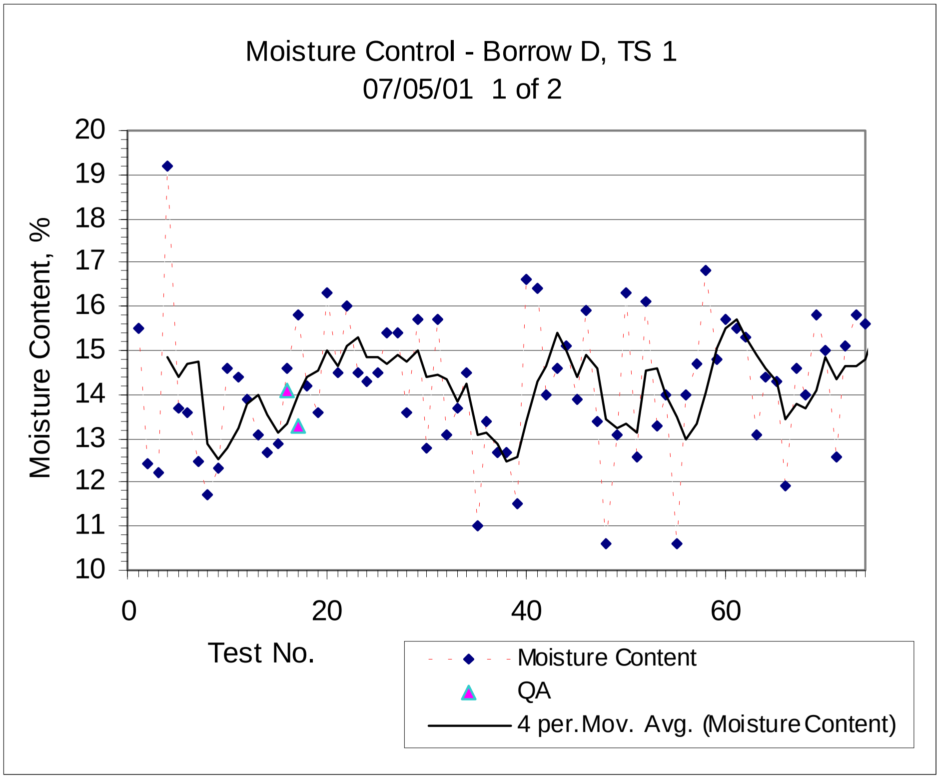

Moisture Control - Borrow D, Tan/Black, PR=1787
08/08/01
Moisture Content, %
10
12
14
16
18
20
22
0
5
10
15
20
Test No.
Moisture Content
QA
4 per. Mov. Avg. (Moisture Content)

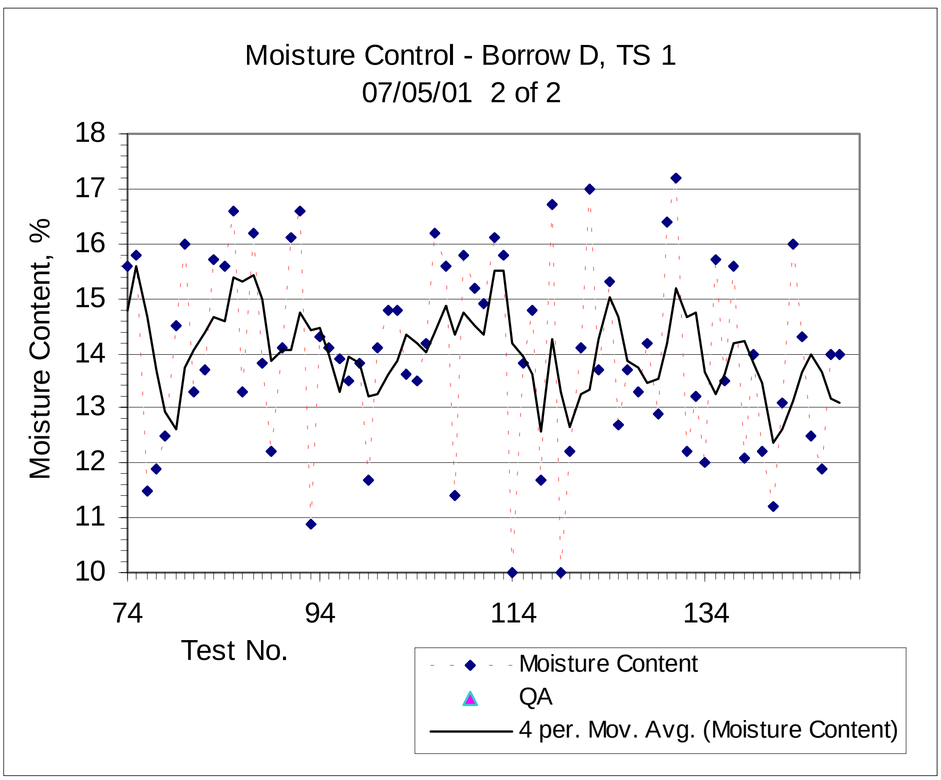

Strength / Stability - Borrow D, Tan/Black, PR=1787
08/08/01
Mean DCP Index (mm/blow)
55
50
45
40
35
30
25
20
15
0 1 2 3 4 5 6 7 8 9 10 11
Test No.
Mean DCP Index
QA
4 per. Mov. Avg. (Mean DCP Index)

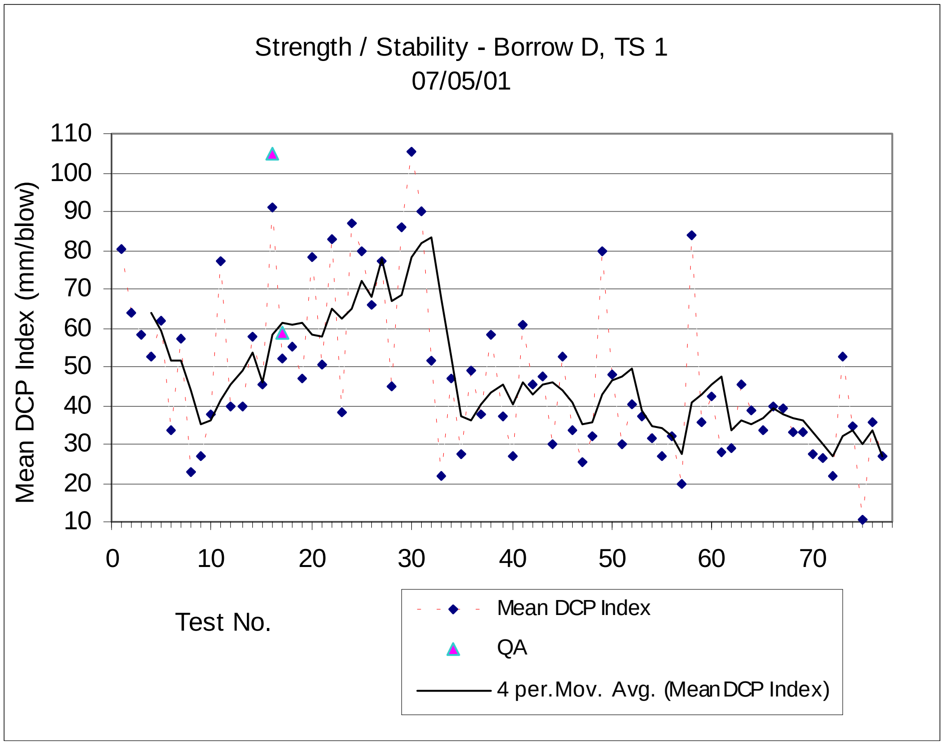

Uniformity - Borrow D, Tan/Black, PR=1787
08/08/2001
Mean Change in DCP Index between consecutive readings (mm/blow)
35
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11
Test No.
Mean Change DCP Index
QA
4 per. Mov. Avg. (Mean Change DCP Index)

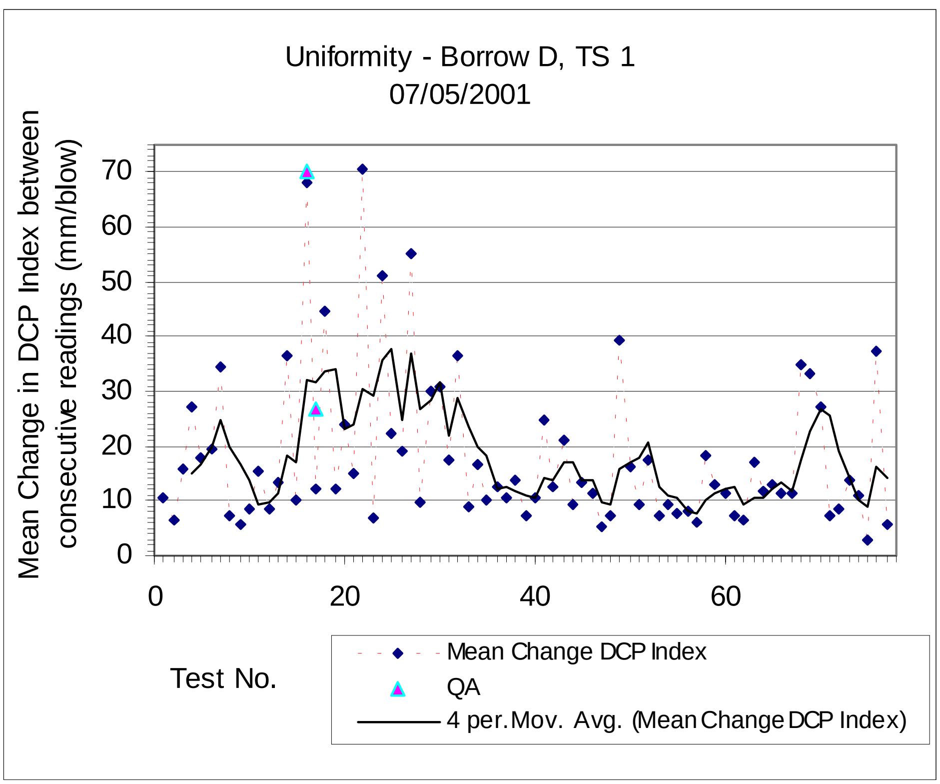

Compaction - Borrow D, TS 1
07/05/01 1 of 2
Percent Compaction
105
103
101
99
97
95
93
91
89
87
0
20
40
60
Test No.
Percent Compaction
QA
4 per. Mov. Avg. (Percent Compaction)

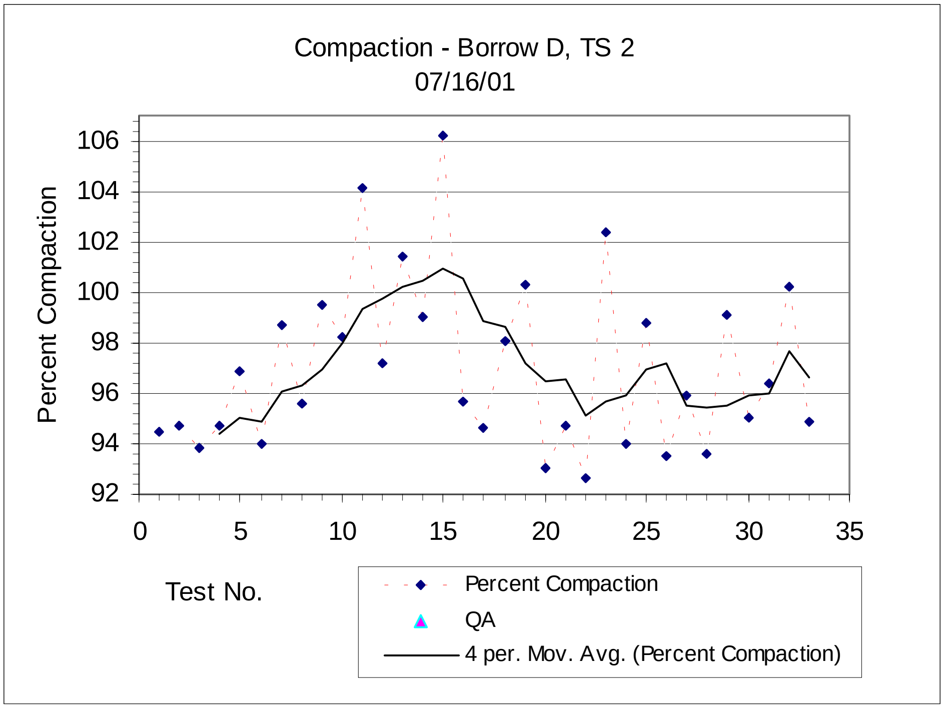

Compaction - Borrow D, TS 1
07/05/01 2 of 2
Percent Compaction
105
103
101
99
97
95
93
91
89
87
74
94
114
134
Test No.
Percent Compaction
QA
4 per. Mov. Avg. (Percent Compaction)

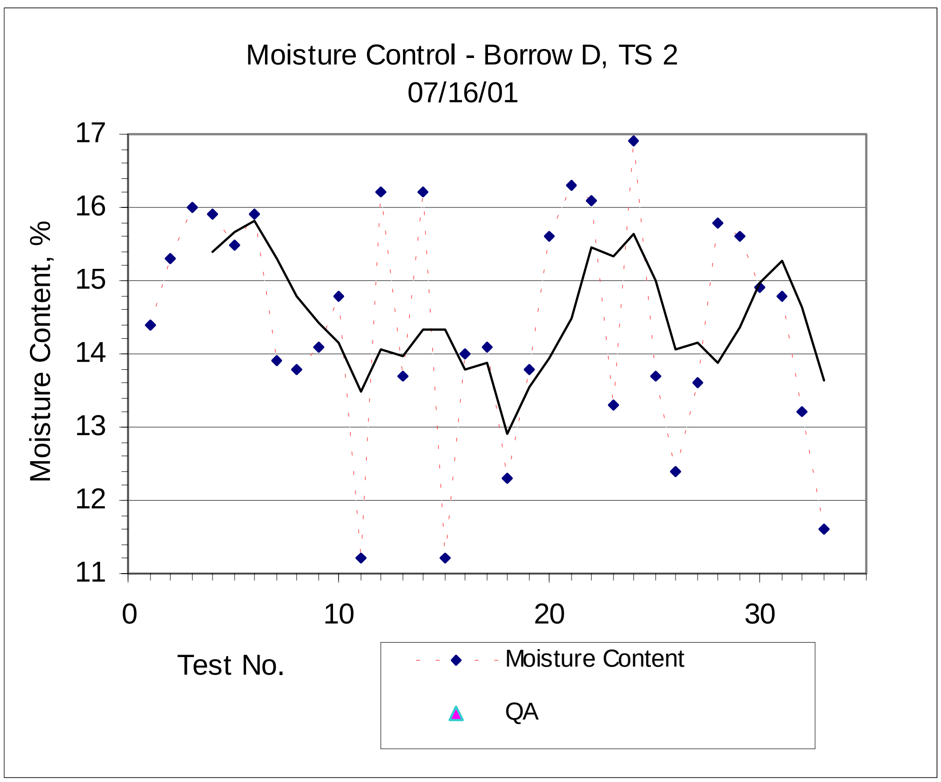

Moisture Control - Borrow D, TS 1
07/05/01 1 of 2
Moisture Content, %
Test No.
Moisture Content
QA
4 per. Mov. Avg. (Moisture Content)

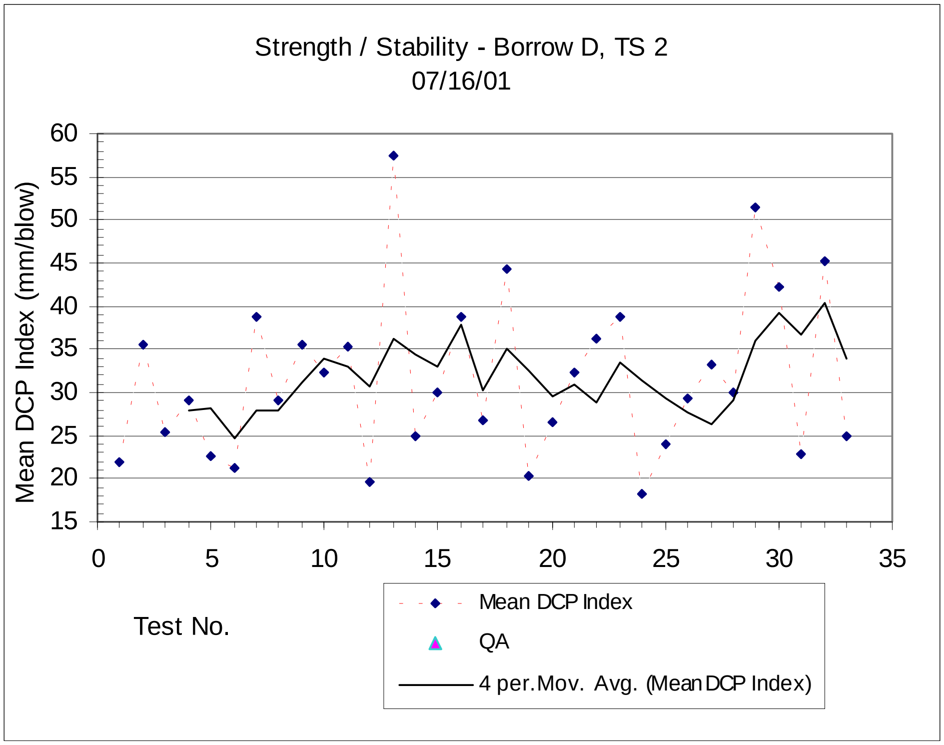

Moisture Control - Borrow D, TS 1
07/05/01 2 of 2
Moisture Content, %
Test No.
Moisture Content
QA
4 per. Mov. Avg. (Moisture Content)

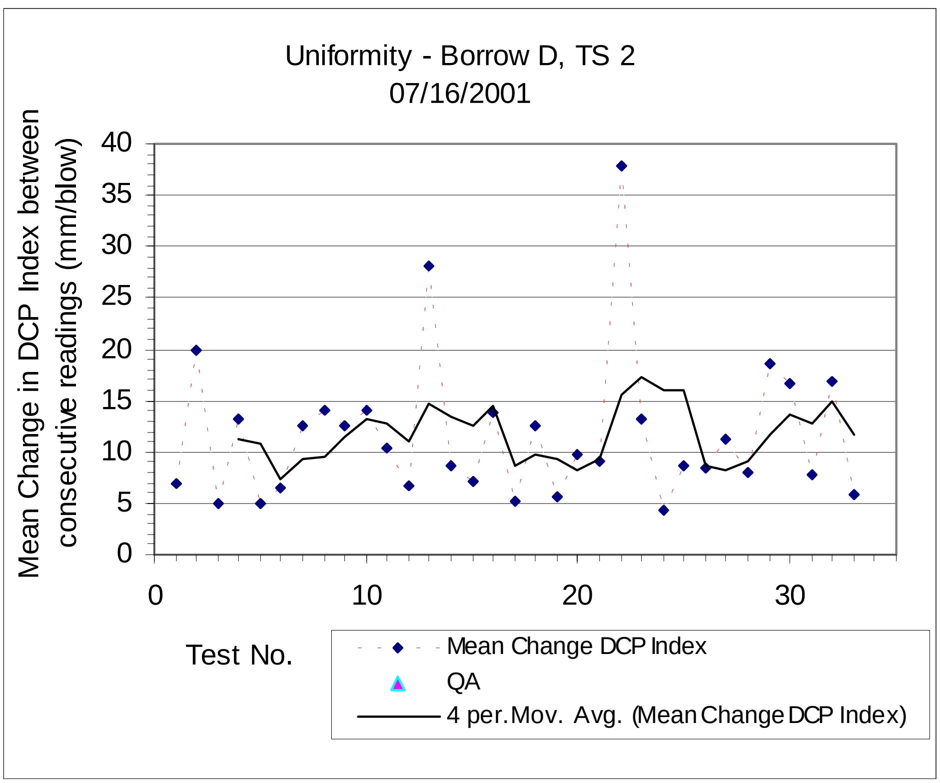

Strength / Stability - Borrow D, TS 1
07/05/01
Mean DCP Index (mm/blow)
110
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
Test No.
Mean DCP Index
QA
4 per. Mov. Avg. (Mean DCP Index)

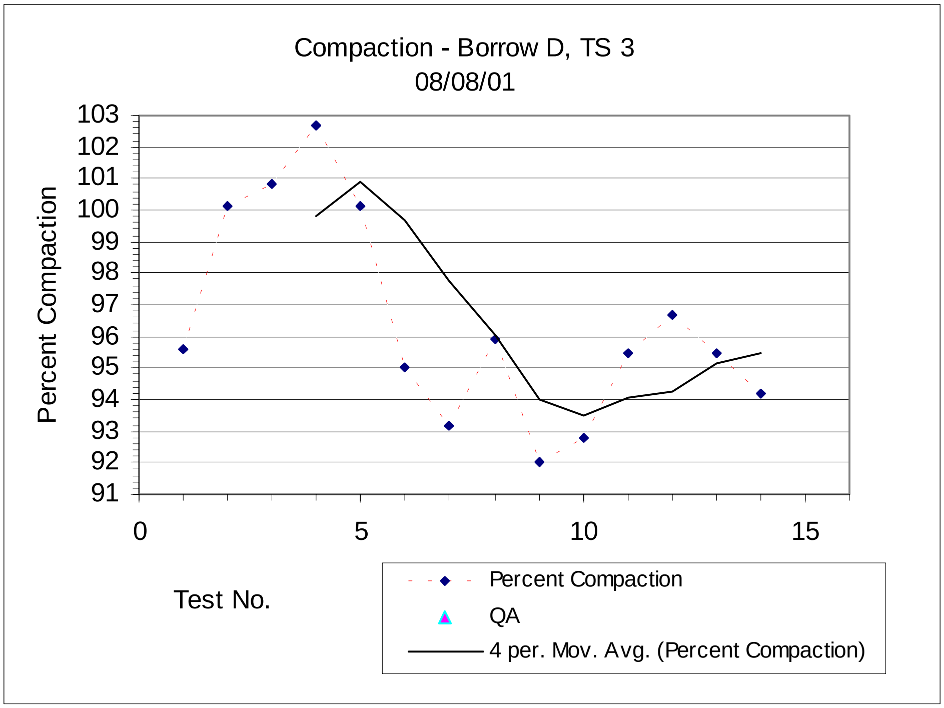

Uniformity - Borrow D, TS 1
07/05/2001
Mean Change in DCP Index between consecutive readings (mm/blow)
70
60
50
40
30
20
10
0
0
20
40
60
Test No.
Mean Change DCP Index
QA
4 per. Mov. Avg. (Mean Change DCP Index)

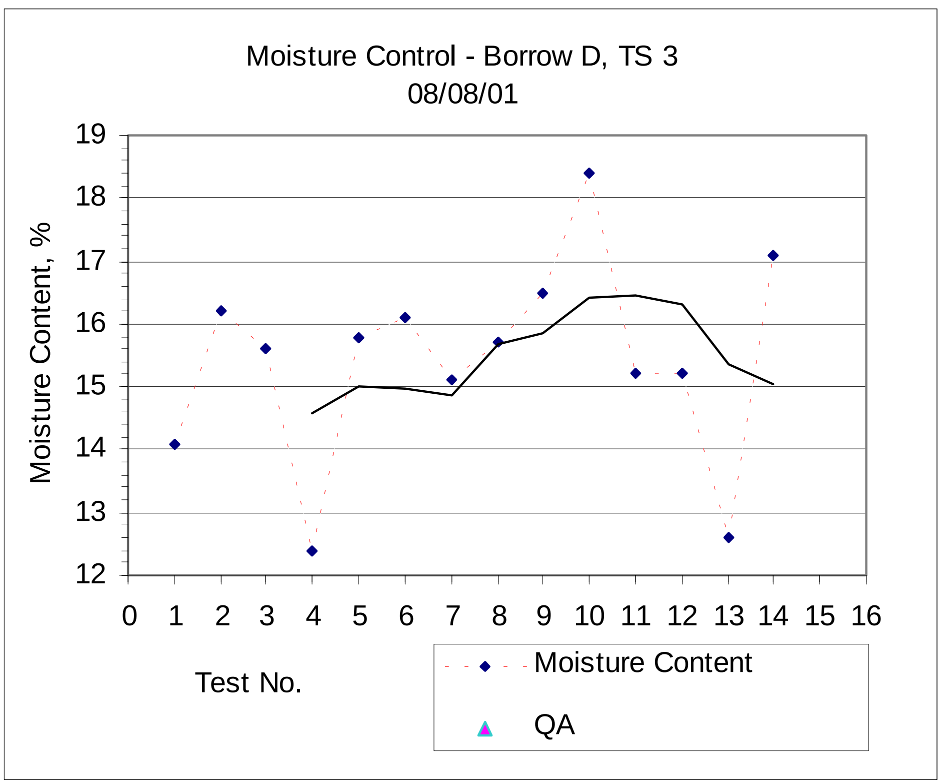

Compaction - Borrow D, TS 2
07/16/01
Percent Compaction
106
104
102
100
98
96
94
92
0
5
10
15
20
25
30
35
Test No.
Percent Compaction
QA
4 per. Mov. Avg. (Percent Compaction)

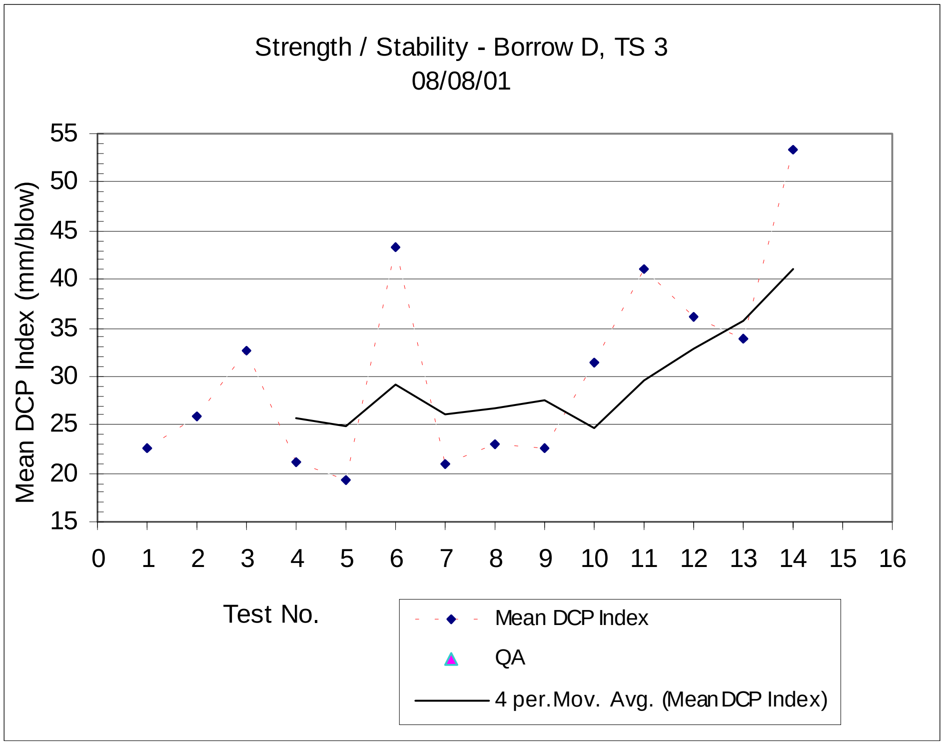

Moisture Control - Borrow D, TS 2
07/16/01
Moisture Content, %
17
16
15
14
13
12
11
0
10
20
30
Test No.
Moisture Content
QA

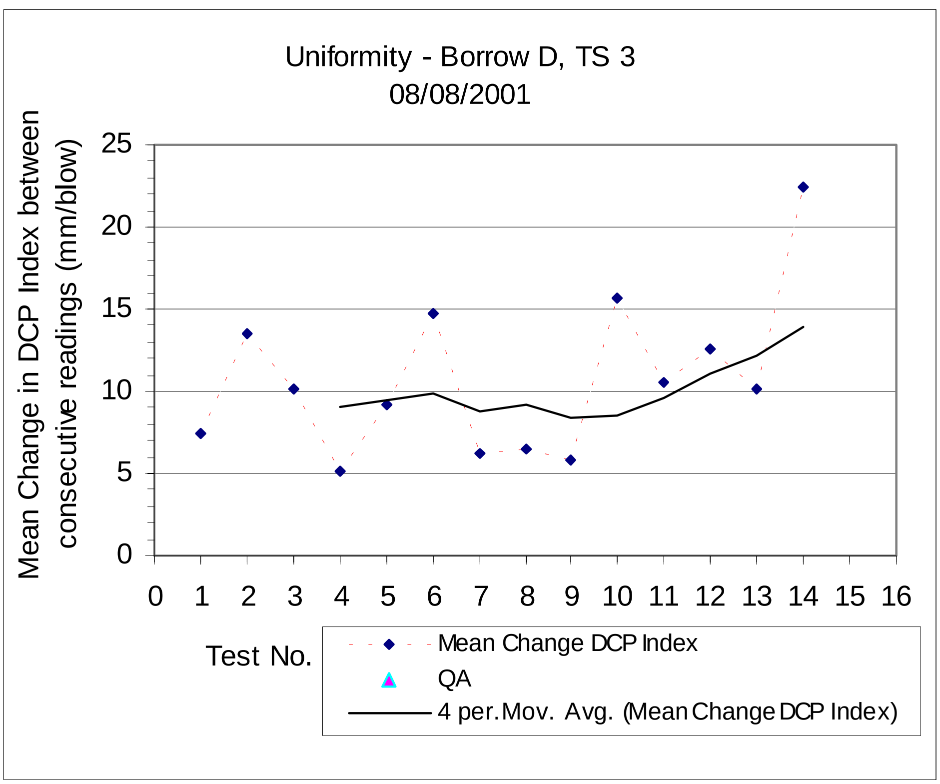

Strength / Stability - Borrow D, TS 2
07/16/01
Mean DCP Index (mm/blow)
Test No.
Mean DCP Index
QA
4 per.Mov. Avg. (Mean DCP Index)

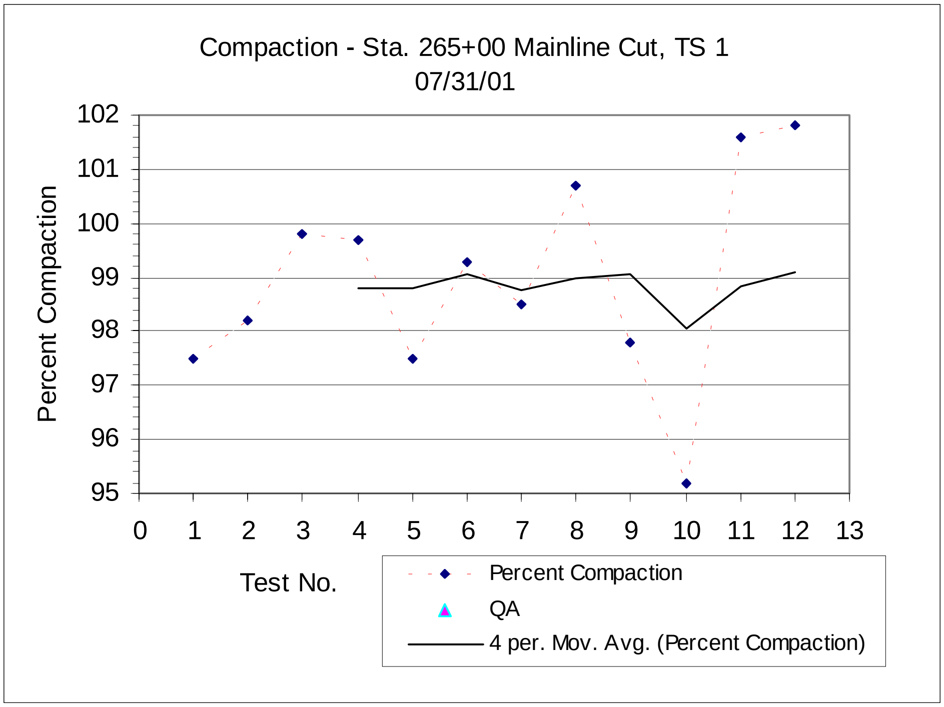

Uniformity - Borrow D, TS 2
07/16/2001
Mean Change in DCP Index between consecutive readings (mm/blow)
Test No.
Mean Change DCP Index
QA
4 per.Mov. Avg. (Mean Change DCP Index)

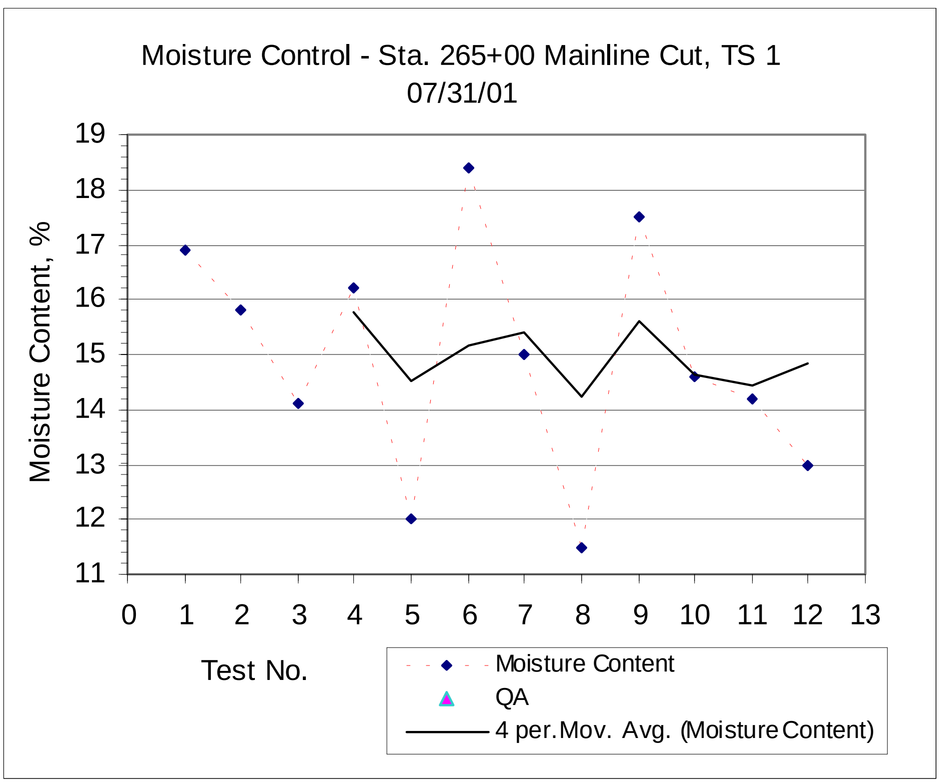

Compaction - Borrow D, TS 3
08/08/01
Percent Compaction
103
102
101
100
99
98
97
96
95
94
93
92
91
0
5
10
15
Test No.
Percent Compaction
QA
4 per. Mov. Avg. (Percent Compaction)

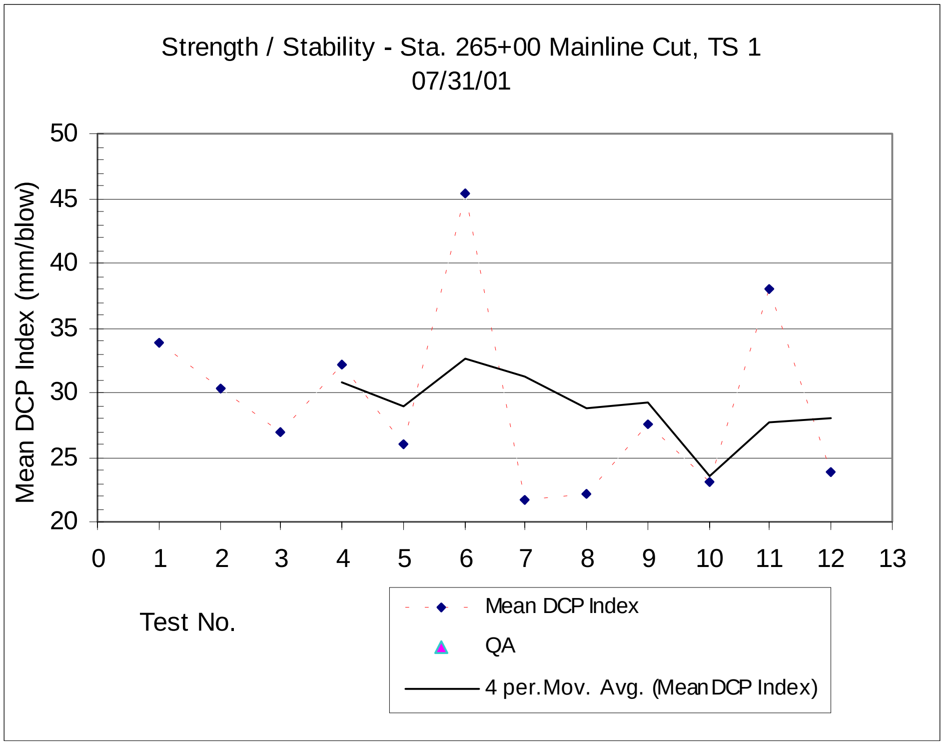

Moisture Control - Borrow D, TS 3
08/08/01
Moisture Content, %
19
18
17
16
15
14
13
12
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Test No.
Moisture Content
QA

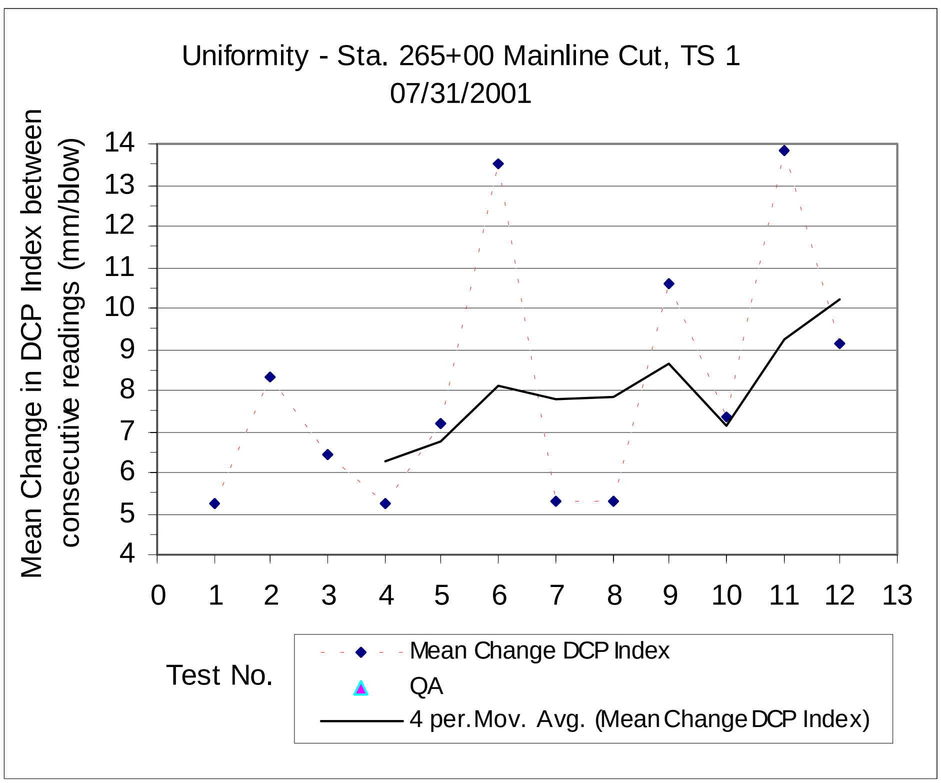

Strength / Stability - Borrow D, TS 3
08/08/01
Mean DCP Index (mm/blow)
55
50
45
40
35
30
25
20
15
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Test No.
Mean DCP Index
QA
4 per. Mov. Avg. (Mean DCP Index)


Uniformity - Borrow D, TS 3
08/08/2001
Mean Change in DCP Index between consecutive readings (mm/blow)
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Test No.
Mean Change DCP Index
QA
4 per. Mov. Avg. (Mean Change DCP Index)


Compaction - Sta. 265+00 Mainline Cut, TS 1
07/31/01
Percent Compaction
102
101
100
99
98
97
96
95
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Test No.
Percent Compaction
QA
4 per. Mov. Avg. (Percent Compaction)

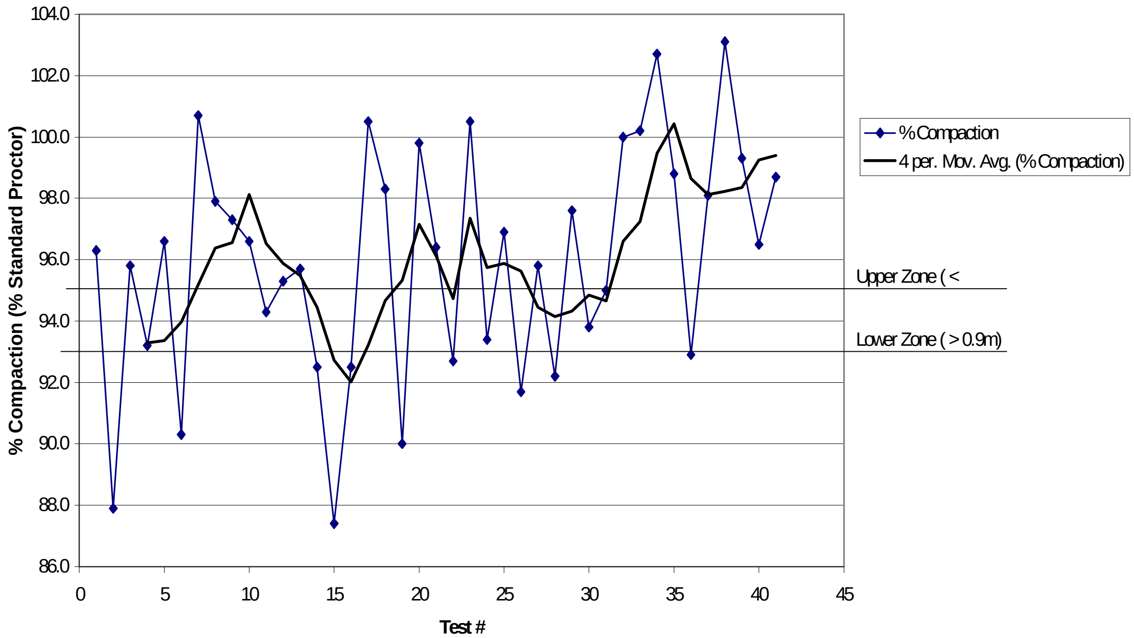

Moisture Control - Sta. 265+00 Mainline Cut, TS 1
07/31/01
Moisture Content, %
19
18
17
16
15
14
13
12
11
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Test No.
Moisture Content
QA
4 per.Mov. Avg. (Moisture Content)


Strength / Stability - Sta. 265+00 Mainline Cut, TS 1
07/31/01
Mean DCP Index (mm/blow)
Test No.
Mean DCP Index
QA
4 per. Mov. Avg. (Mean DCP Index)

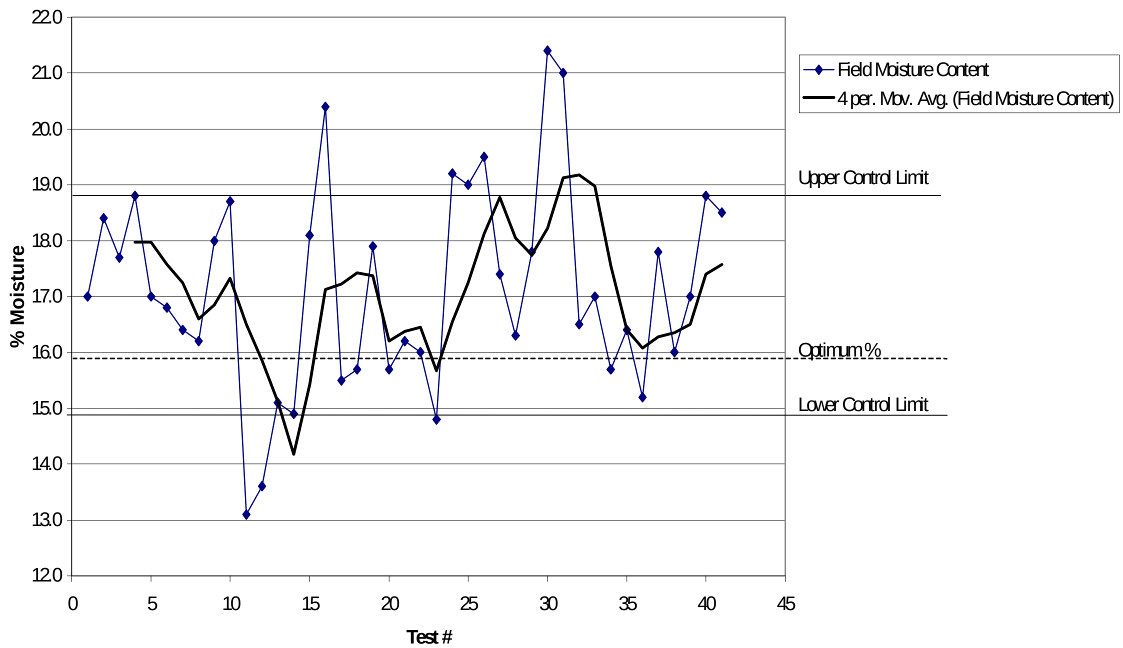

Uniformity - Sta. 265+00 Mainline Cut, TS 1
07/31/2001
Mean Change in DCP Index between consecutive readings (mm/blow)
Test No.
Mean Change DCP Index
QA
4 per. Mov. Avg. (Mean Change DCP Index)

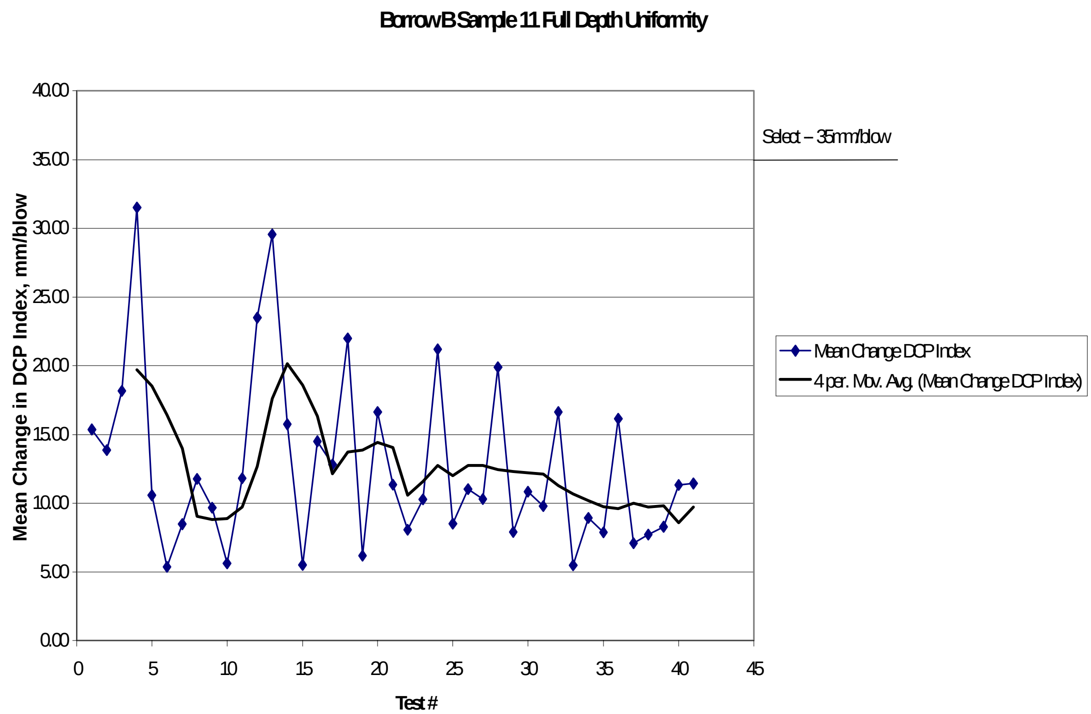
APPENDIX G: ISU FIELD TEST RESULTS

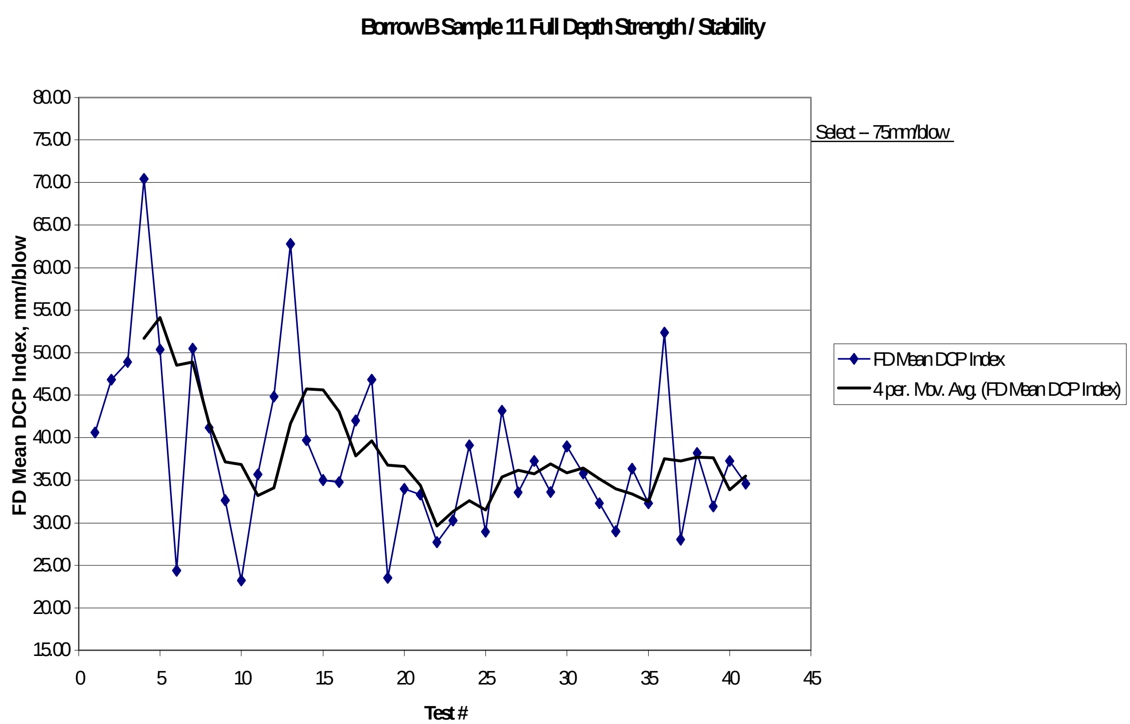
Borrow B Sample 11 Compaction



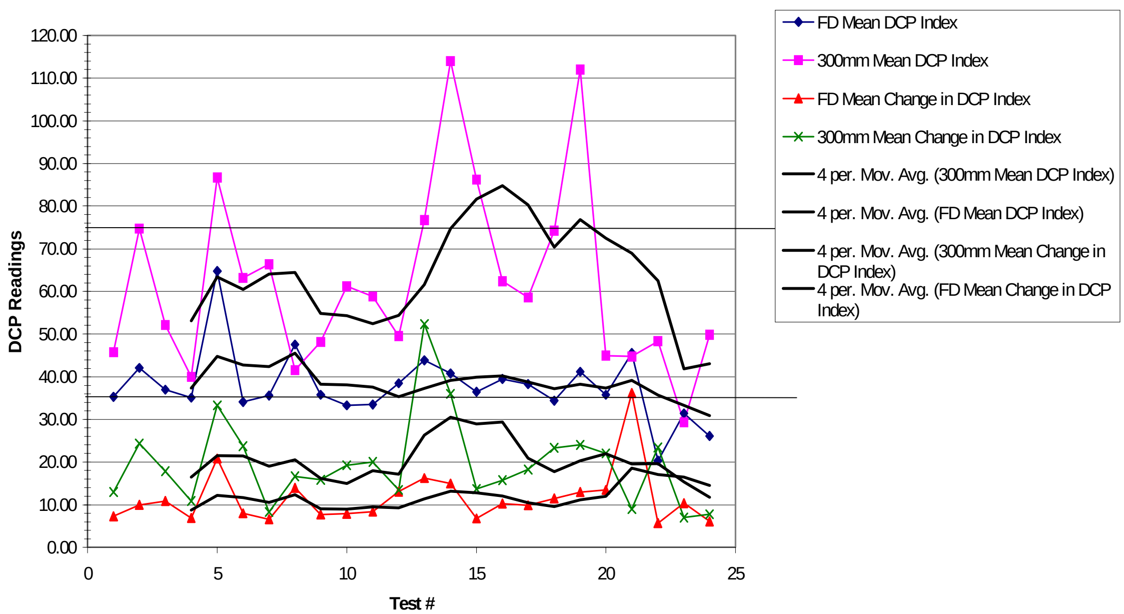
Borrow B Sample 11 Moisture Control



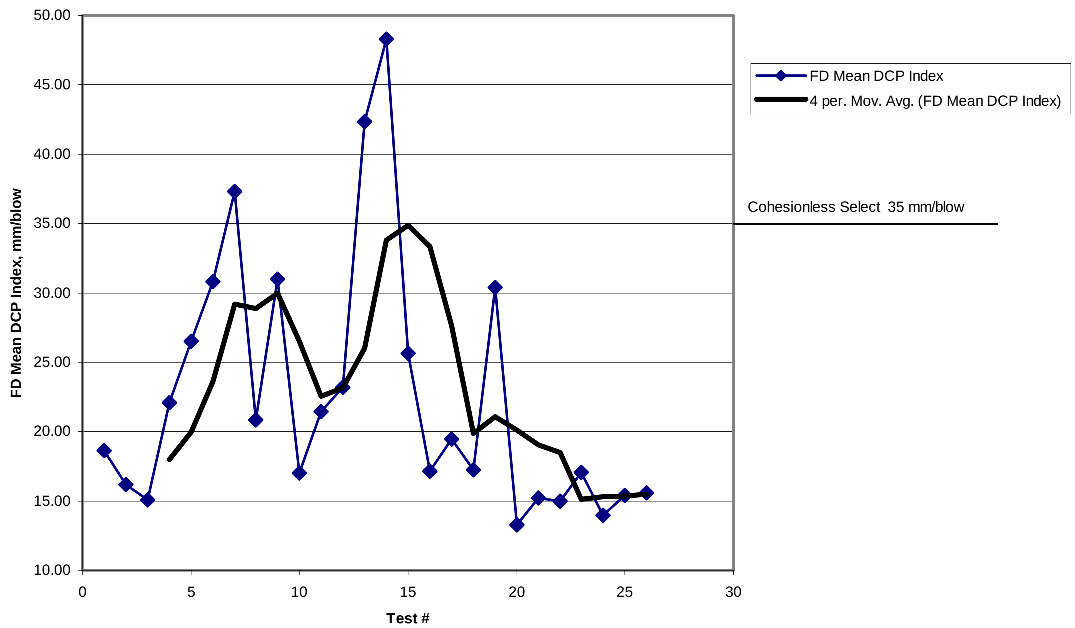

Borrow B Sample 11 Full Depth Uniformity
Mean Change in DCP Index, mm/blow
Test #
Select – 35mm/blow
Mean Change DCP Index
4 per. Mov. Avg. (Mean Change DCP Index)


Borrow B Sample 11 Full Depth Strength / Stability
FD Mean DCP Index, mm/blow
Test #
Select – 75mm/blow
FD Mean DCP Index
4 per. Mov. Avg. (FD Mean DCP Index)

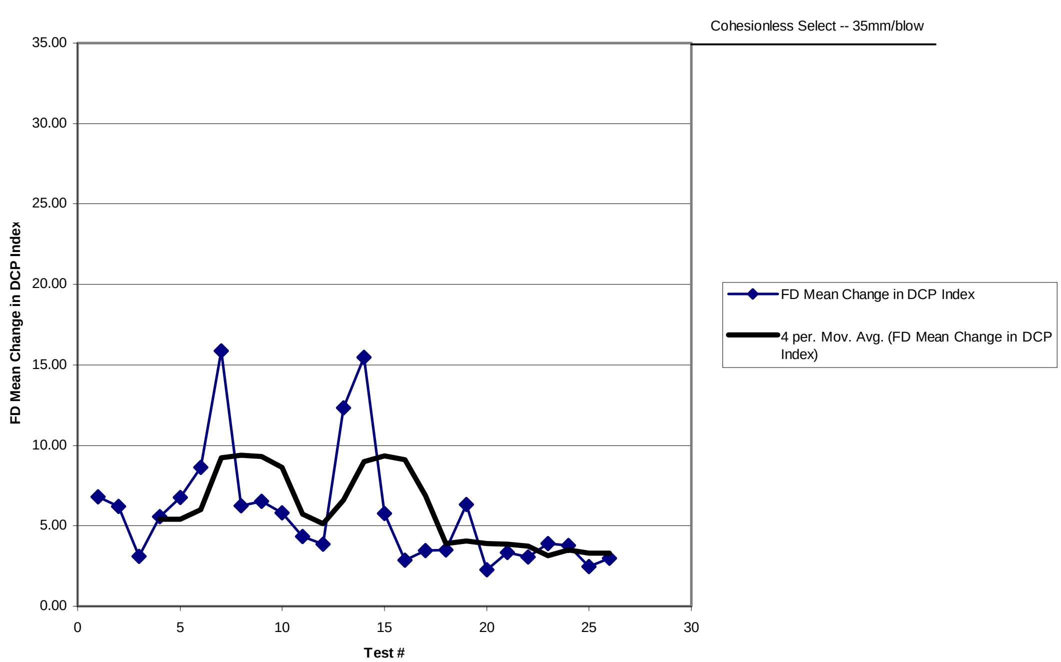
Borrow B Sample 17 comparison between all DCP tests



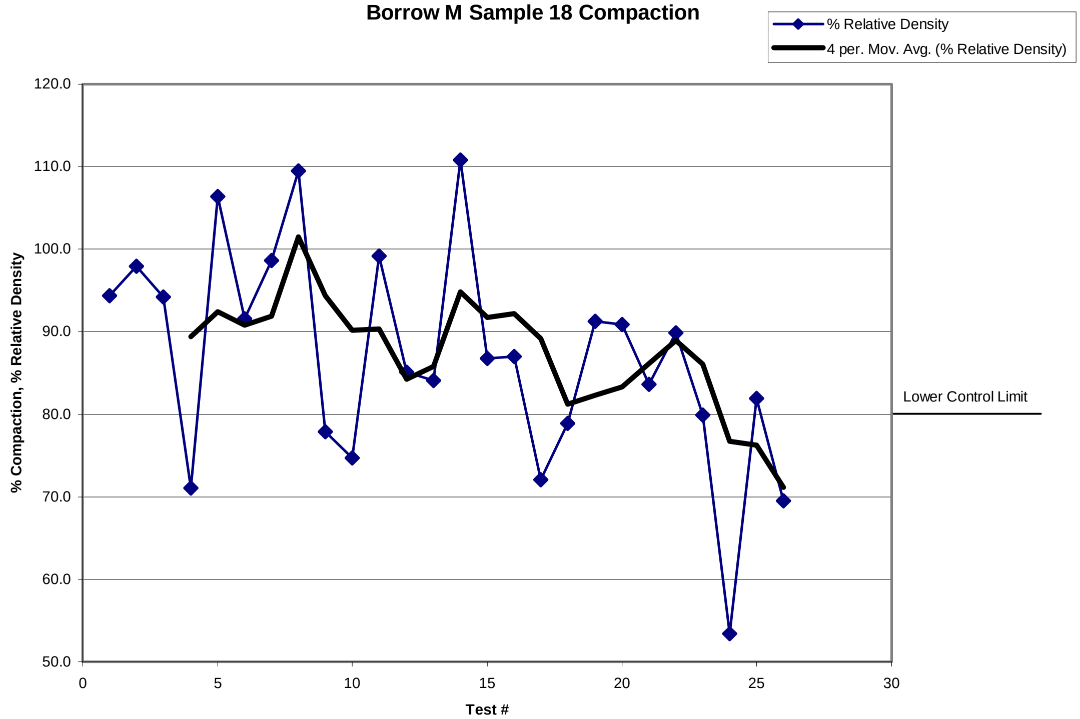
Borrow M Sample 18 Full Depth Strength / Stability



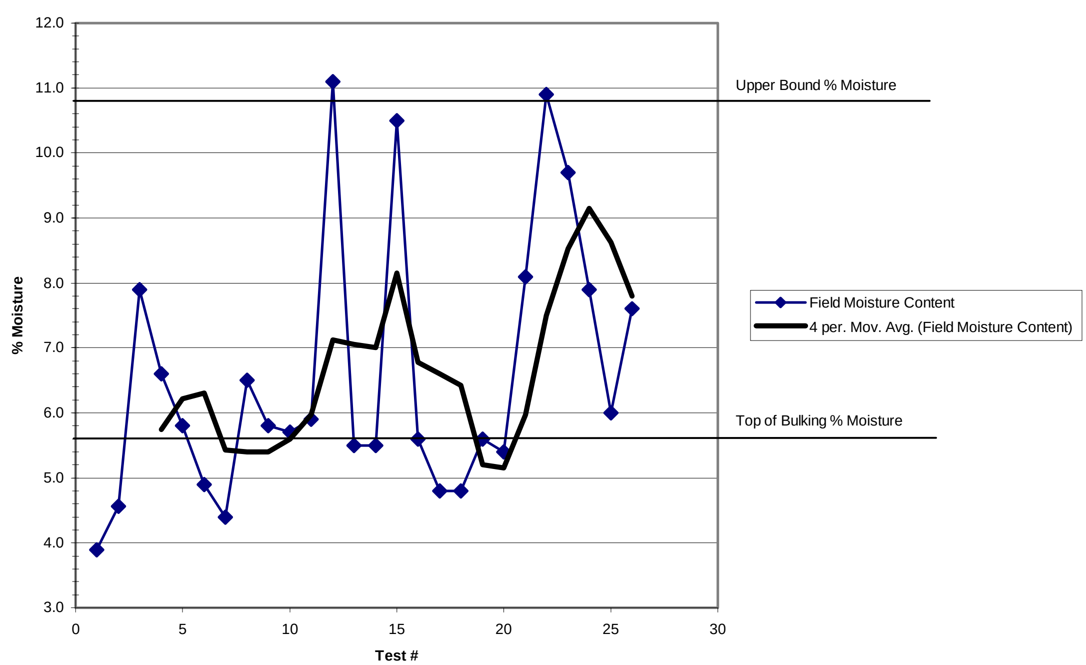
Borrow M Sample 18 Full Depth Uniformity



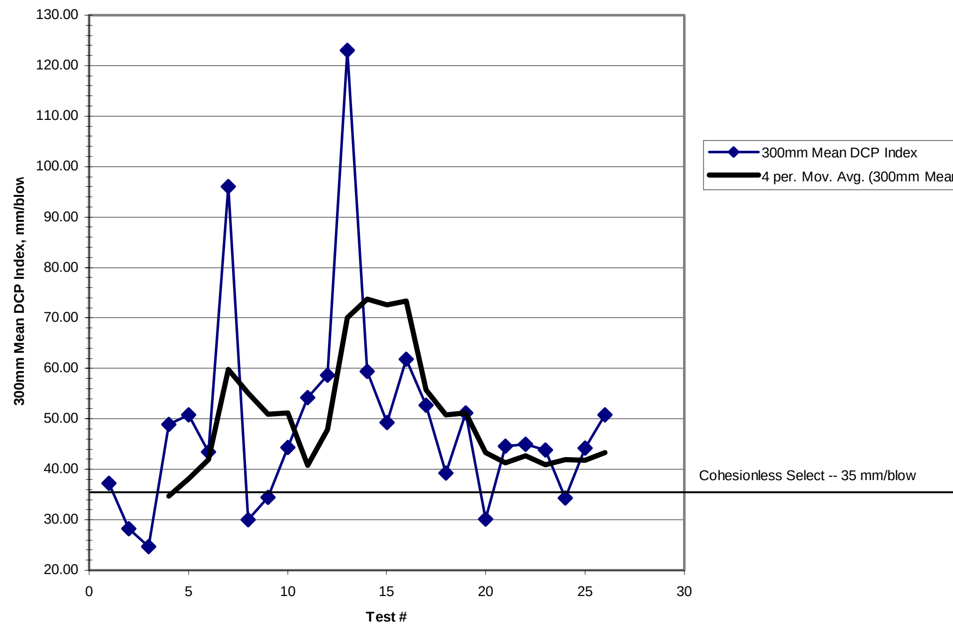
Borrow M Sample 18 Compaction



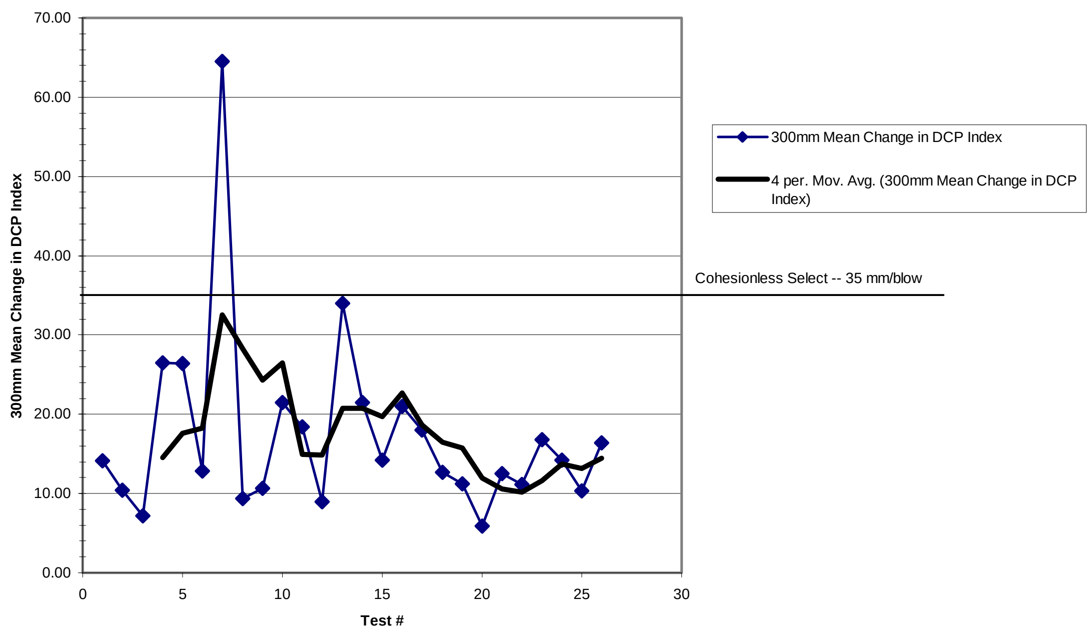
Borrow M Sample 18 Moisture Control



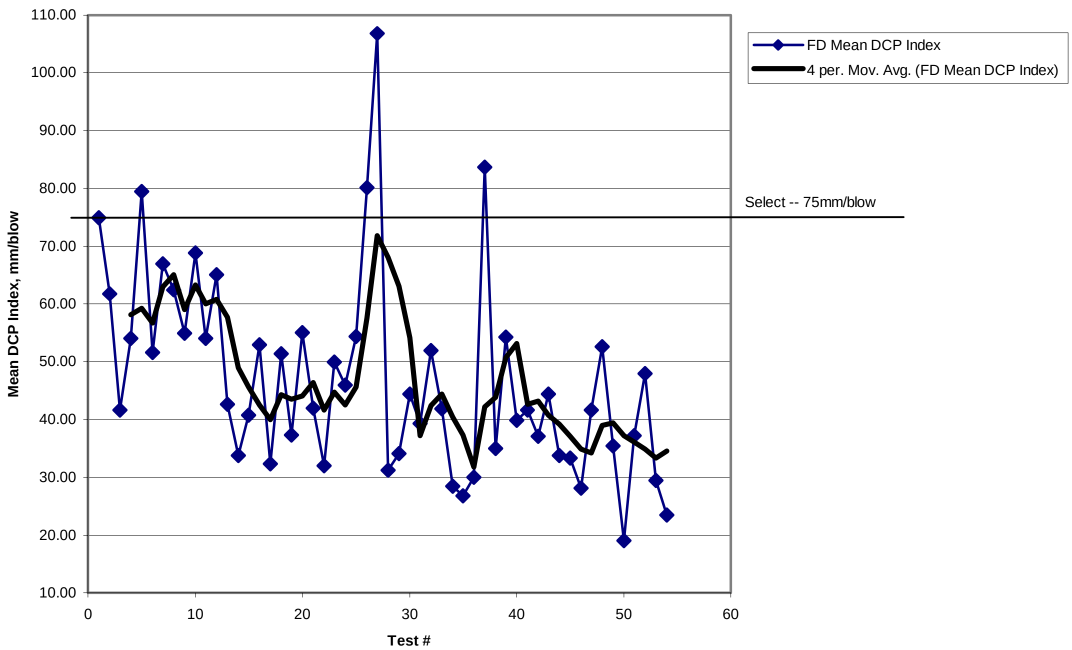
Borrow M Sample 18 300mm Strength / Stability



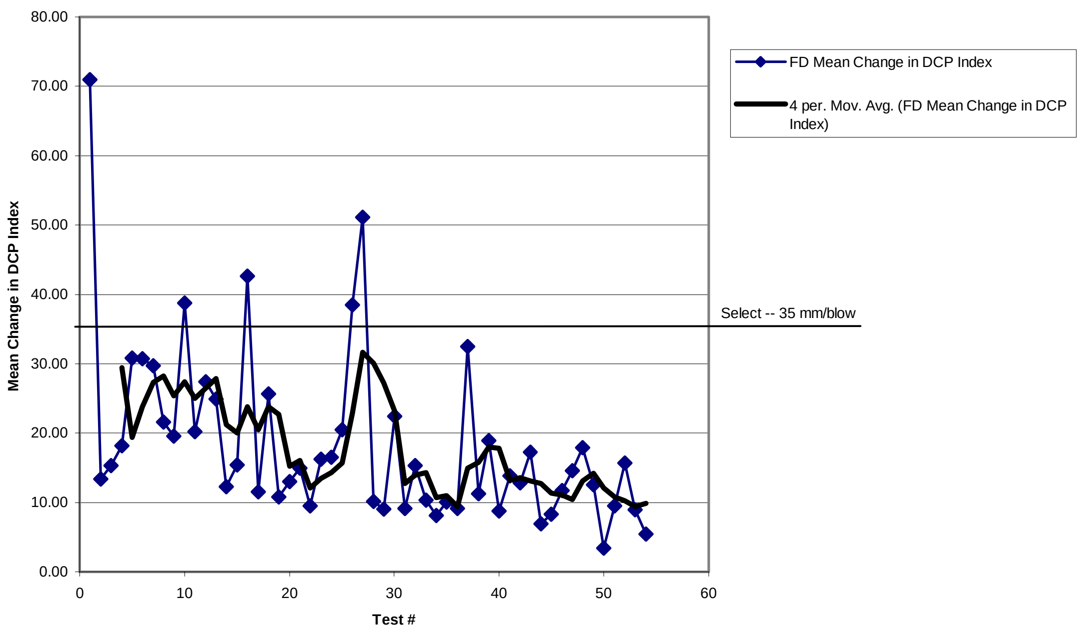
Borrow M Sample 18 300mm Uniformity



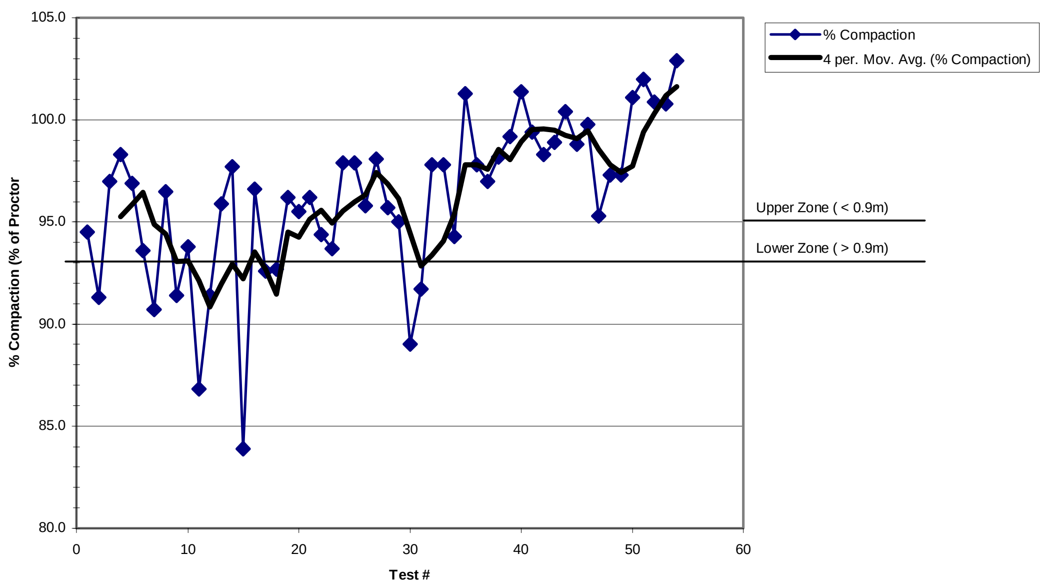
Borrow D Sample 5 Full Depth Strength / Stability



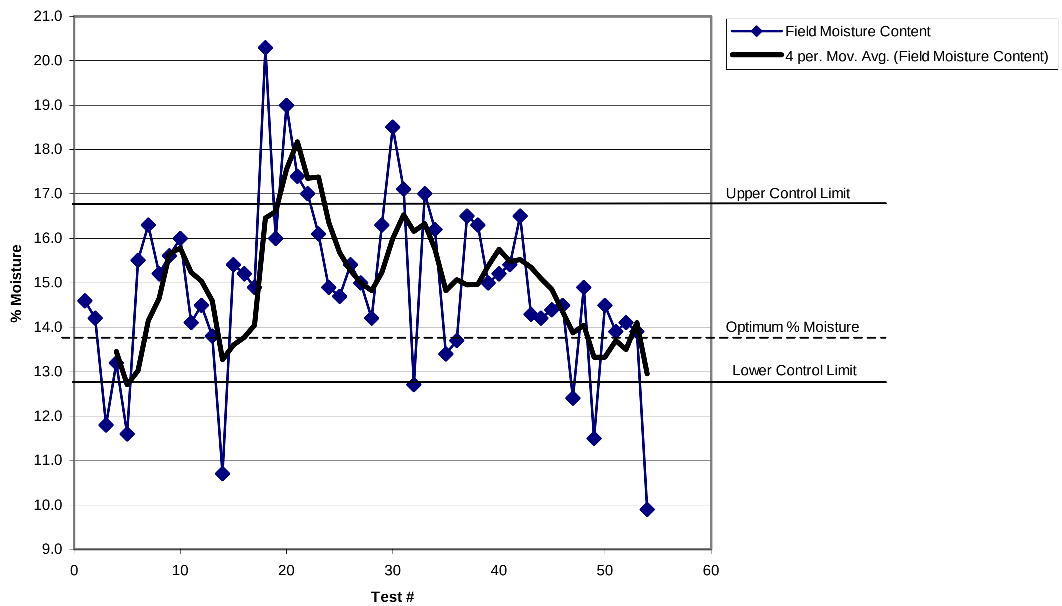
Borrow D Sample 5 Full Depth Uniformity



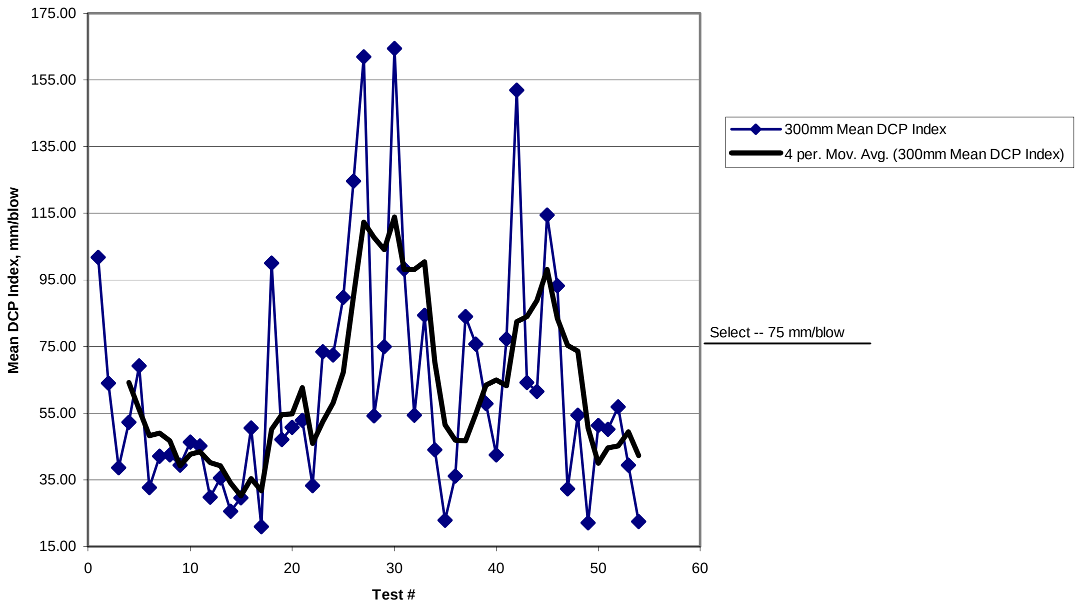
Borrow D Sample 5 Compaction



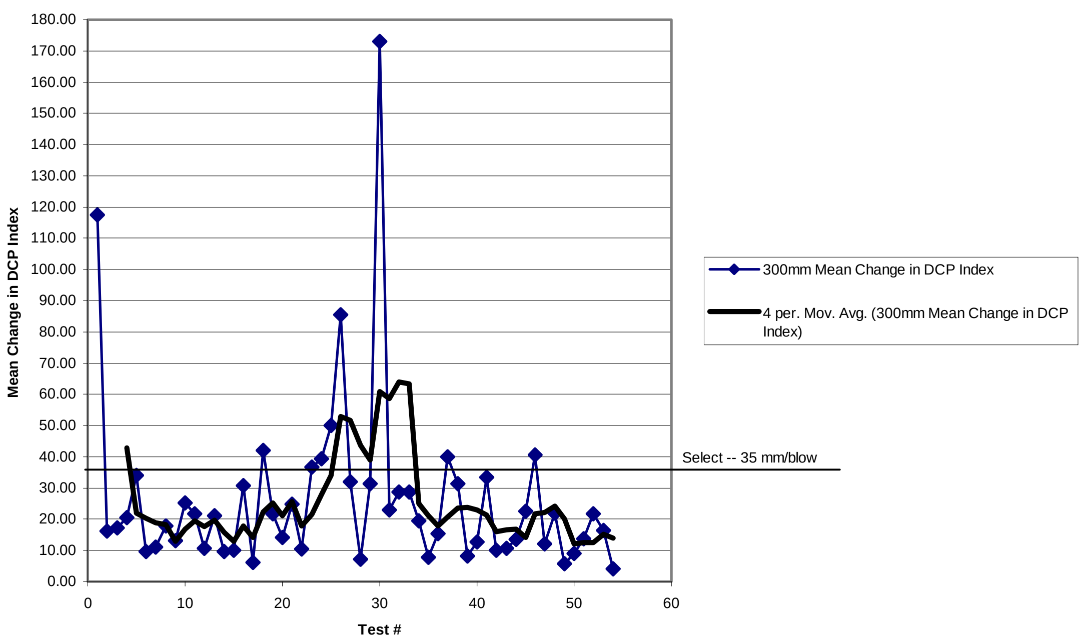
Borrow D Sample 5 Moisture Control

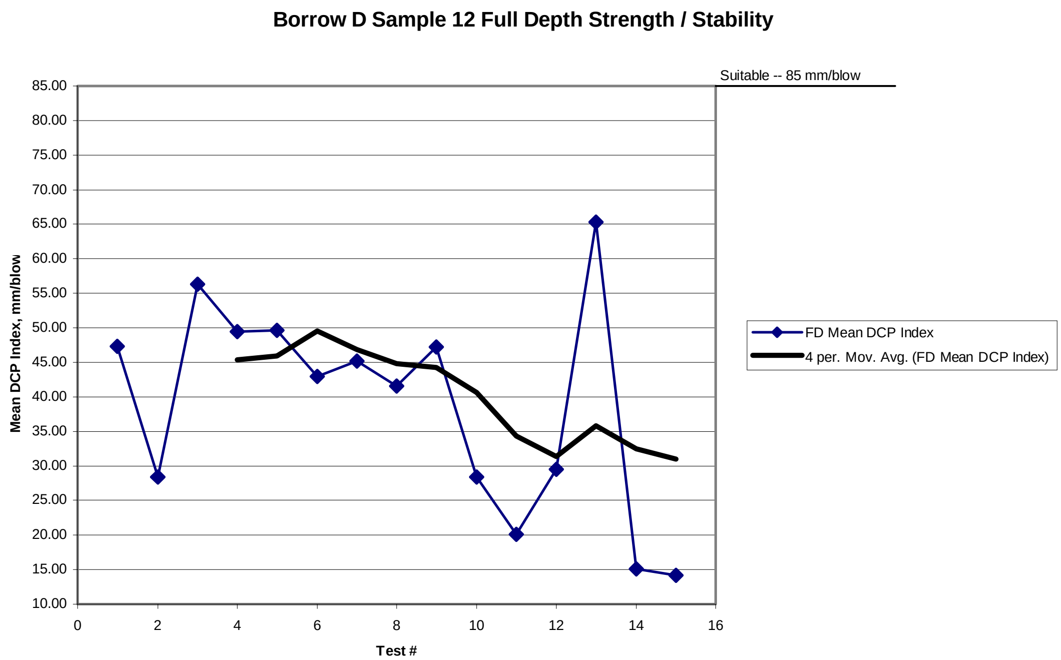


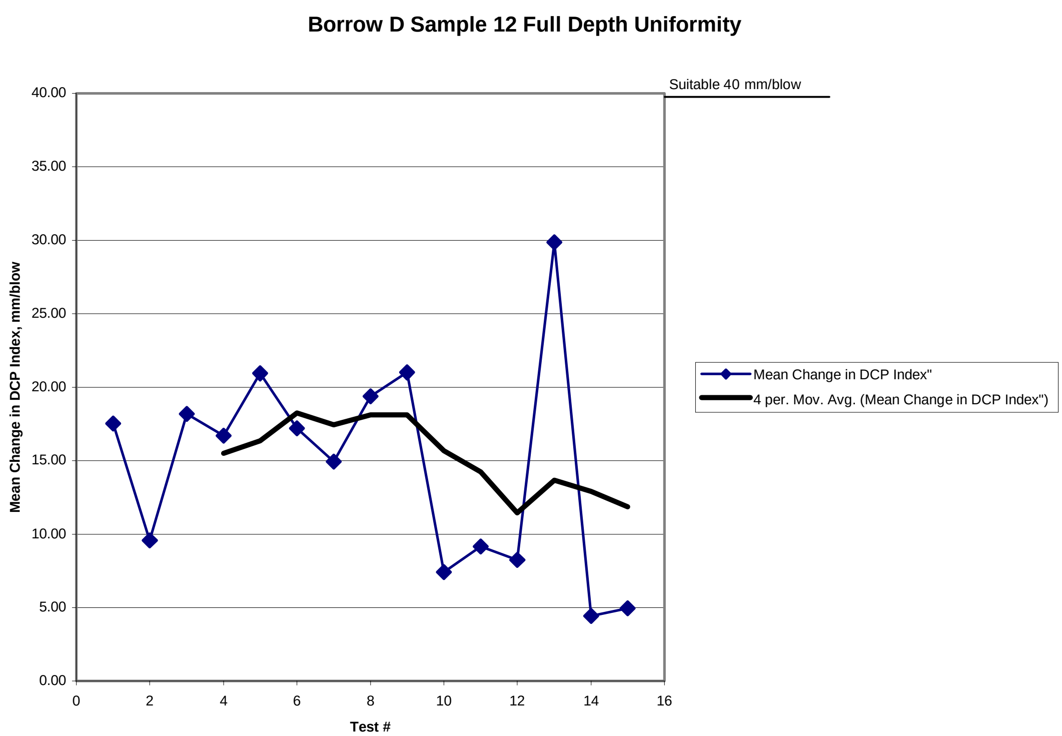
Borrow D Sample 5 300mm Strength / Stability



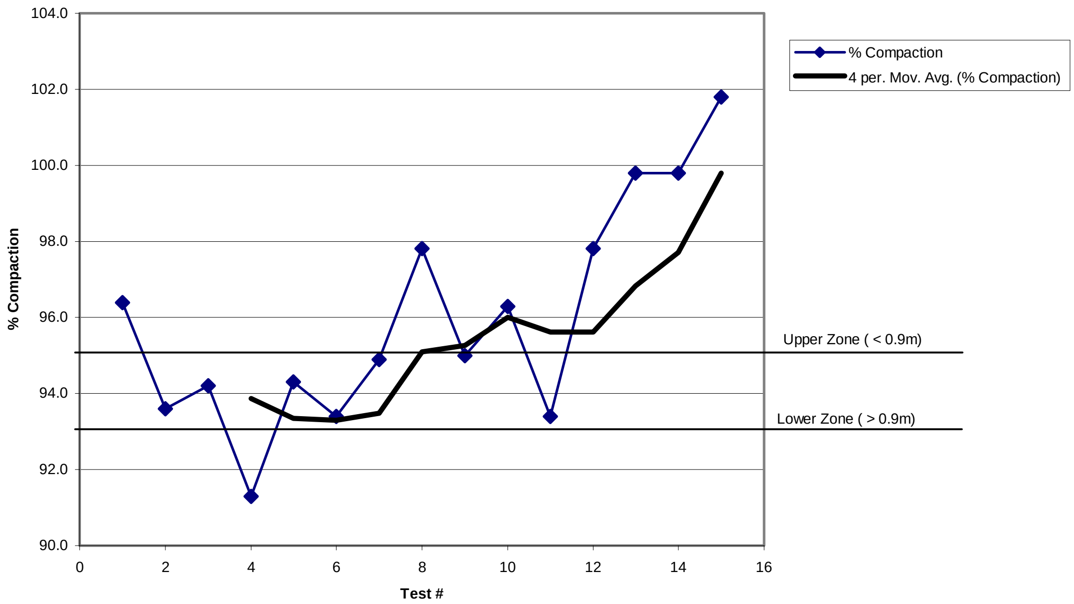
Borrow D Sample 5 300mm Uniformity



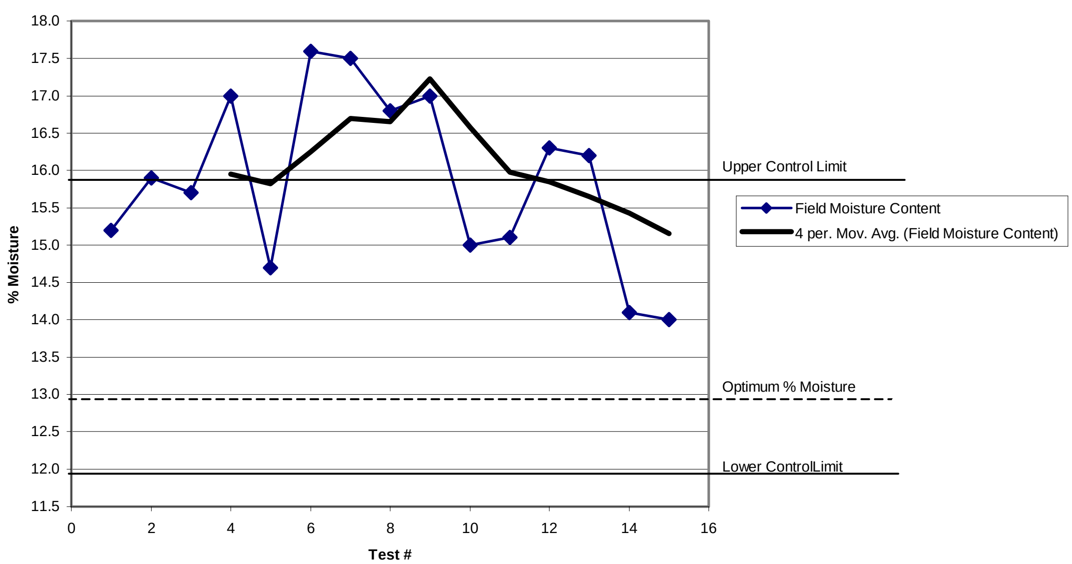

Borrow D Sample 12 Full Depth Strength / Stability
Suitable -- 85 mm/blow
Mean DCP Index, mm/blow
Test #
FD Mean DCP Index
4 per. Mov. Avg. (FD Mean DCP Index)
85.00
80.00
75.00
70.00
65.00
60.00
55.00
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
0
2
4
6
8
10
12
14
16


Borrow D Sample 12 Full Depth Uniformity
Suitable 40 mm/blow
Mean Change in DCP Index, mm/blow
Test #
Mean Change in DCP Index"
4 per. Mov. Avg. (Mean Change in DCP Index")
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
2
4
6
8
10
12
14
16

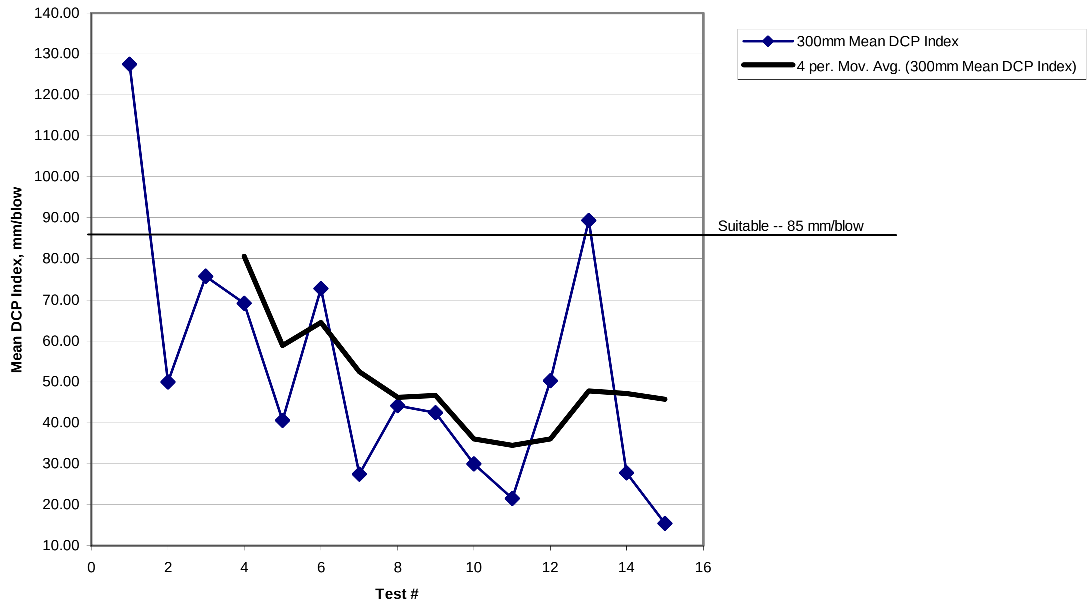
Borrow D Sample 12 Compaction



Borrow D Sample 12 Moisture Control



Borrow D Sample 12 300mm Strength / Stability



Borrow D Sample 12 300mm Uniformity