# MOUNTAIN-PLAINS CONSORTIUM

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## Compaction Testing of Granular Material


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# Compaction Testing of Granular Material

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## ABSTRACT

The South Dakota Department of Transportation (SDDOT) has identified a need to reevaluate methods in determining whether granular materials have been compacted to the desired density. Practices of other DOTs indicate additional advantages and disadvantages to various in-situ compaction testing devices. Some DOTs are transitioning to dynamic cone penetrometer (DCP) and light weight deflectometer (LWD) methods of testing. Data were analyzed to evaluate the adequacy of using the Ohio Highway Department's Typical Moisture-Density Curves. These data were also analyzed to create a new family of compaction curves based on granular base course and subbase materials previously tested by the SDDOT. The line of optimums of the Ohio Highway Department's Typical Moisture-Density Curves indicates that they may be considered valid for use with the South Dakota base course and subbase granular material. A new family of compaction curves generated from South Dakota base course and subbase granular materials data was also determined to be valid, plotting within the prediction interval.

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## TABLE OF ACRONYMS

| Acronym | Definition |
|---|---|
| AASHTO | American Association of State Highway and Transportation Officials |
| ASTM | American Society for Testing Materials |
| CBR | California Bearing Ratio |
| CH | Clegg Hammer |
| CIV | Clegg Impact Value |
| DCP | Dynamic Cone Penetrometer |
| DOT | Department of Transportation |
| DPI | DCP Penetration Index Value |
| EDG | Electric Density Gauge |
| EIS | Electromagnetic Impedance Spectroscopy |
| ERDC | Engineering Research and Development Center |
| FDR | Full Depth Reclamation |
| FHWA | Federal Highway Administration |
| FWD | Falling Weight Deflectometer |
| GPS | Global Positioning System |
| GR | Grading Number |
| HMA | Hot Mix Asphalt |
| IC | Intelligent Compaction |
| LWD | Light Weight Deflectometer |
| $M_r$ | Resilient Modulus |
| MDI | Moisture Density Indicator |
| MnDOT | Minnesota Department of Transportation |
| MDOT | Mississippi Department of Transportation |
| MSTR | Minimum Sample and Test Requirement |
| NCHRP | National Cooperative Highway Research Program |
| NDG | Nuclear Density Gauge |
| NRC | Nuclear Regulatory Commission |
| ODOT | Ohio Department of Transportation |
| OMC | Optimum Moisture Content |
| PCC | Portland Cement Concrete |
| pcf | Pounds per Cubic Foot |
| PDA | Personal Digital Assistant |
| PI | Principal Investigator |
| PR | Penetration Rate |
| PIV | Penetration Index Value |
| RAP | Reclaimed Asphalt Pavement |
| RTK | Real-Time Kinematic |
| SDDOT | South Dakota Department of Transportation |
| SDG | Soil Density Gauge |
| SDI | Soil Density Indicator |
| TDR | Time Domain Reflectometry |

# EXECUTIVE SUMMARY

The South Dakota Department of Transportation (SDDOT) has identified a need to reevaluate methods in determining whether granular materials have been compacted to the desired density. This includes evaluating the adequacy of using the Ohio Highway Department's Typical Moisture-Density Curves for granular material compaction quality control. This also includes identifying existing methods and possible alternatives for determining target densities of granular materials. Emphases have been placed on determining whether an alternative method of testing compaction of unprocessed and recycled materials should be used.

The current in-place density standard relies on the use of a test strip or moisture density relation curve. Field testing of virgin granular material is almost exclusively conducted using the nuclear density gauge (NDG) or sand cone method. Through extensive literature review of research articles, reports, existing materials manuals, and specifications, it was determined that standard laboratory moisture density relations may not be well correlated with field density tests for granular material compaction. Differences that exist between the compaction of granular materials and fine-grained materials were observed by various research reports. These differences can contribute to errors that arise during compaction quality control of granular materials. The literature review also focused on creating a comprehensive list of in-situ compaction testing devices. The list included devices that directly measure density of compacted soil materials. The list also includes devices that measure values relatable to the strength and stiffness of the compacted soil materials. Each device was summarized with a discussion of advantages and disadvantages to each device.

A survey was conducted to gather additional information of compaction practices utilized by surrounding departments of transportation (DOTs). DOTs that were determined to be using families of compaction curves for granular materials were asked to provide details of their practices. The survey results indicated additional advantages and disadvantages to various in-situ compaction testing devices. Many of the DOTs surveyed had evaluated numerous devices for use in compaction quality control and indicated they would not recommend them. It was noted, however, that the Dynamic Cone Penetrometer (DCP) and Light Weight Deflectometer (LWD) were both recommend by other DOTs.

Data provided by the SDDOT were analyzed to evaluate the adequacy of using the Ohio Highway Department's Typical Moisture-Density Curves. These data were also analyzed to create a new family of compaction curves based on granular base course and subbase materials previously tested by the SDDOT. A line of optimums was created and then compared to the line of optimums of the Ohio Highway Department's Typical Moisture-Density Curves. From the comparison, it was determined that the Ohio Highway Department's Typical Moisture-Density Curves may be overestimating the maximum dry unit weights of South Dakota base course and subbase granular materials. A regression curve was also fitted to maximum dry unit weight and optimum moisture content (OMC) of 474 moisture density relations created from the SDDOT data. Prediction intervals were constructed around the regression curves to create a region in which 95% of all maximum dry unit weights and OMCs would result. The line of optimums of the Ohio Highway Department's Typical Moisture-Density Curves plotted within this region indicated that it may be considered valid for use with the South Dakota base course and subbase granular material. The new family of compaction curves for South Dakota base course and subbase granular materials was also determined to be valid, plotting within the prediction interval.

The research team recommends that the SDDOT take an incremental approach to implementing the DCP for compaction quality control of granular materials, recycled Portland cement concrete (PCC), and recycled hot mix asphalt (HMA) materials. This would also include full depth reclamation (FDR). Implementation would include a pilot project to evaluate the proposed DCP procedures, methods, and specifications. It is also recommended that the SDDOT evaluate the new family of compaction curves for South Dakota's base course and subbase granular materials alongside their current methods as well as using the DCP. This will allow for the SDDOT to evaluate strengths and weaknesses to the recommended changes and address them before full implementation of any new methods. The research team has presented cost estimates for implementation of the DCP and a new family of compaction curves, which would include a pilot project and an instructional course for project inspectors and engineers. This course would allow inspectors and engineers to become familiar with the DCP and correctly implement the proposed methods for compaction quality control of granular materials.

# 1. INTRODUCTION

## 1.1 Problem Description

The SDDOT and other state DOTs have used the Ohio Highway Department's Typical Moisture-Density Curves for the compaction of granular soils. However, the Ohio Department of Transportation (ODOT) Materials Manual states the curves and controls were originally developed to be used on cohesive (clays) soils. Errors or complications arise when trying to extrapolate these principals to granular materials (ODOT, 2017). Therefore, the SDDOT requests that further information be gathered about the Ohio Highway Department's Typical Moisture-Density Curves and an evaluation be conducted to determine the adequacy of their use with South Dakota's granular material.

The SDDOT is also using materials recycled from PCC and HMA as base course and subbase material (SDDOT, 2015a). Recycled materials are placed using the test strip method to determine the effective amount of effort needed to achieve acceptable levels of compaction. The method used for test strips by the SDDOT requires at least 500 feet in length for test strip construction. Test strips work well for large areas but become problematic for small areas (SDDOT, 2015a). New compaction quality control methods may need to be implemented that not only function efficiently for virgin materials but can also be utilized effectively in a wide range of granular materials used in base course and subbase material applications.

SDDOT has identified a need to reevaluate how they determine whether granular material has been adequately compacted. Granular compaction quality control testing by the SDDOT has been conducted by determining target densities and OMCs through standard moisture density relations. In-situ testing is performed using the NDG or traditional sand cone method. Often target density and OMC values do not correlate to in-situ test values. This is due to a variety of factors such as differences in compaction effort and differences in the energy transfer to the soil between the field and laboratory compaction process. Density-based quality control is also relatively dependent on the person conducting the test. Results can vary dependent on the operator creating errors during density-based testing. These differences can contribute greatly to problems expressed by the SDDOT when conducting density-based compaction quality control of granular materials. These problems may be reduced by the implementation of new compaction quality control methods that do not rely on density measurements but rather can be correlated to the material's strength parameters, such as the California Bearing Ratio (CBR).

Some DOTs have started using new methods such as the LWD and DCP with success. These methods are easily correlated with various strength and stiffness parameters. Other states have been working with intelligent compaction (IC) technologies that relate strength parameters of the compacted material in real time from the construction compaction equipment. As other DOTs implement new compaction quality control methods, the SDDOT wishes to examine how other DOTs determine proper levels of compaction in the granular subbase and base course. The SDDOT also wishes to determine whether the current Ohio Highway Department's Typical Moisture-Density Curves are adequate for their needs or should be updated. It may be determined that the SDDOT needs to use different test methods to establish acceptable levels of granular compaction.

## 1.2 Research Objectives

The study has been designed to accomplish three main research objectives:

1) Evaluate the adequacy of using the Ohio Highway Department's Typical Moisture-Density Curves for granular materials.

This objective was accomplished in several ways. An extensive literature review was conducted to gather knowledge of the Ohio Highway Department's Typical Moisture-Density Curves. This included gathering information about how the curves were created and their history of use. Surveys were also utilized to gather information from surrounding DOTs. The survey's primary goal was to determine the extent of use of families of curves by surrounding DOTs. The surveys were also compared to results of the National Cooperative Highway Research Program (NCHRP) survey (Nazzal, 2014). Compaction data provided by the SDDOT were obtained to study the compaction characteristics of granular material types encountered by the SDDOT. The data collected were compared to the Ohio Highway Department's Typical Moisture-Density Curves. Statistical analyses were performed to compare the data to the Ohio Highway Department's Typical Moisture-Density Curves. The analyses are summarized in Chapter 3 of this report.

2) Identify existing and possible alternatives for determining target density of granular bases.

This objective was accomplished by conducting a thorough literature review. The literature was abundant with current studies that contain information that adequately addressed this research objective. Surveys were also sent to surrounding DOTs to gather information on alternative compaction testing methods. A detailed summary of the reviewed literature is presented in Chapter 2 of this report. Chapter 3 presents a summary of the survey results.

3) Determine whether an alternative method of testing compaction of unprocessed and recycled granular material should be used.

Based on the findings of the first two objectives, alternatives were identified that could be beneficial to the SDDOT. The methods that showed the most promise relied on measurements related to stiffness and strength modulus. The determination of the most appropriate methods was selected based on an abbreviated alternatives analysis. The comparison criteria included accuracy, precision, ease of use, repeatability, reliability of data, safety, test time, and the level of expertise required. The team also considered impacts to construction specifications and correlation of device measurement results to material properties (e.g., density, modulus, stiffness, moisture content). Calibration, durability, and compatibility of each method with various granular materials were also considered. Advantages and disadvantages of each device were presented in Chapter 2 of this report. Chapter 4 presents the analysis used to recommend the most desirable alternative field-testing device to meet the SDDOT's needs.

## 1.3 Task Descriptions

The research project was divided into 10 tasks. The following section briefly describes each task and in what chapter of this report the results are presented. A listing of each task along with explanation of activities involved follows.

**Task 1:** Meet with the technical panel to review the project scope and work plan.

A kick off-meeting occurred on August 27, 2015, at the SDDOT office in Pierre, South Dakota. The research team prepared a presentation on the scope and work plan for the project. The meeting also served to gather detailed information on the SDOT's needs in terms of compaction of new and recycled granular materials. It was important to the research team to obtain additional details of the SDDOT's testing methods and specifications as they pertain to granular compaction.

**Task 2:** Review and summarize literature pertinent to compaction testing of granular material.

A comprehensive literature review was conducted on compaction testing of granular materials as it applies to SDDOT compaction testing. The review focused on both project development and compaction testing of granular materials relative to current SDDOT methods and specifications. Alternative compaction testing methods were summarized with advantages and disadvantages to each as it relates to the SDDOT's current needs.

Although this task was mainly a review of the published literature, understanding current SDDOT practices was also important to the project. Therefore, an additional meeting occurred with selected SDDOT technical panel members at the South Dakota State University main campus in Brookings, South Dakota, on June 21, 2016. The meeting was conducted to gather information about current SDDOT methods and specifications. It was important to the research to understand additional details of the SDDOT's difficulties as they pertain to their current granular compaction testing methods. The results of the literature search were used as the basis for completing follow-on research tasks as well as the development of recommendations. The information gathered from this task was evaluated relative to the research objectives and are summarized in Chapter 2 of this report.

**Task 3:** Survey other state DOTs and federal agencies to document their methods, testing frequencies, procedures, equipment, and training requirements for granular compaction testing.

An NCHRP study (Nazzal, 2014) conducted a comprehensive survey of most state DOTs regarding compaction quality control of unbound materials. Additional information needed from DOTs beyond that study was identified to benefit this study. This information was collected through direct survey. Two additional surveys were created to collect needed information to discern the aspects and processes by which they conduct compaction quality control. One survey was sent to surrounding DOTs that did not participate in the NCHRP survey and, to avoid unneeded repetition, another was sent to states that did participate. The surveys were reviewed by the SDDOT technical panel before being forwarded to state DOTs for their responses. The results of the surveys are summarized in Chapter 3.

**Task 4:** Compile data from past SDDOT granular material density tests and compare those data to Ohio Curves to determine whether the curves can be used, new curves are needed, or the department should not use the curves and move to using a different method.

This task required the research team, through the SDDOT Office of Research, to obtain existing data of compaction testing. Data were compiled by the SDDOT after the June 21, 2016, meeting. The data were taken from several SDDOT sources that pertained to granular compaction testing and were provided in a spreadsheet format. The data were then conditioned, analyzed, and compared to the Ohio Highway Department's Typical Moisture-Density Curves. This included statistical analyses of the data to determine the adequacy of using the Ohio Highway Department's Typical Moisture-Density Curves for granular compaction quality control. It also included the creation of a new family of compaction curves to complete the comparative analyses. The lines of optimum for each family were compared to determine if a significant difference existed. A detailed summary of the analyses is presented in Chapter 3 of this report.

**Task 5:** Determine the most appropriate compaction testing method for virgin granular materials and granular materials incorporating recycled materials by analyzing the survey and SDDOT density data.

Based on the information gathered in Task 1 through Task 4, methods for verifying compaction of granular materials were analyzed relative to the SDDOT's needs. The team then compared alternatives summarized in Chapter 2 to recommend which alternatives best matched the needs identified. The needs considered for each alternative were accuracy, precision, ease of use, repeatability, reliability of data, safety, and test time. Calibration, durability, and compatibly also were considered. These aspects of each alternative were compared with the relative cost of each alternative presented in the literature. Advantages and disadvantages of each alternative are summarized in Chapter 2. Recommendations are presented and summarized in Chapter 6. It was the goal of the research team that the recommended new methods be applicable in a wide range of granular and recycled materials and increase on-site testing efficiency.

**Task 6:** Meet with technical panel to review work completed on previous tasks and to present recommendations on adequacy of using Ohio Curves and new compaction testing equipment or procedures.

A meeting between the research team and the technical panel was held in Pierre, South Dakota, on April 11, 2017. The meeting was conducted to present the initial results of the study. That included a summary of the literature review, survey results, tabulated data, analysis methods, and analysis results. The research team also presented recommendations for alternatives for granular compaction quality control and/or a new family of compaction curves. The technical panel confirmed the findings and recommendations, and directed the research team to finalize the project work.

**Task 7:** Prepare policies, procedures, or specifications needed to adopt new or revised compaction testing methods.

Based on the methods recommended by the research team and confirmed by the technical panel, the research team prepared the necessary technical documents for SDDOT implementation. The documents included a DCP procedure, methods for use of the DCP in a variety of material types and applications, and supplemental specifications. A revised method for using the new family of compaction curves was also created. The documents were created to follow current SDDOT formats. These documents were based on existing compaction testing methods gathered in the literature search. The produced documents were sent to the SDDOT Technical Panel for review and comment. The documents are presented in Appendix A.

**Task 8:** Estimate the cost, including personnel and equipment, of changing from current compaction methods.

Based on the procedure, methods, and specifications produced in Task 7, costs the SDDOT will incur to implement the recommended changes were determined. These costs included necessary personnel and equipment costs for implementation. Unit personnel costs were provided by the SDDOT and used to estimate administrative implementation, technical training of field personnel for implementation, and technical support costs. Equipment costs were also estimated and included the necessary field and laboratory equipment to implement the revised and new compaction testing methods. Costs were developed in end-of-project dollars and can be escalated for the year of implementation. Costs are summarized in Chapter 6 of this final report.

**Task 9:** In conformance with Guidelines for Performing Research for the SDDOT, prepare a final report summarizing the research methodology, findings, conclusions, and recommendations.

The report documents the project results, including compaction methods and survey results, findings, conclusions, and recommendations. This report also includes an implementation plan that will guide the SDDOT in maximizing the benefits from the research. This implementation plan is presented in Chapter 6. The final report was submitted to the SDDOT Technical Panel for review and revisions were made to incorporate comments.

**Task 10:** Make an executive presentation to the SDDOT Research Review Board and the conclusion of the project.

An executive presentation will be made by the principal investigator (PI) to the SDDOT Research Review Board in Pierre, South Dakota, at the conclusion of the study. The presentation will summarize the research activities that were accomplished in this project and all conclusions and recommendations that resulted from the research.

# 2. LITERATURE REVIEW

This chapter presents a review of literature relevant to the compaction testing of granular soil materials used by the SDDOT. The review covers literature relevant to compaction fundamentals, field and laboratory compaction, and compaction testing of granular soils. This review also summarizes the suitably of different types of granular families of curves. Additionally, the review documents new technologies developed to establish proper compaction of granular and recycled materials.

## 2.1 Fundamentals

Granular materials have engineering properties that influence their performance and vary with gradation. For granular materials, the key functional properties are stiffness and strength, which are measures directly related to their structural performance (Nazzal, 2014). Stiffness and strength of soils are used in the mechanistic design of pavement thickness (Christopher et al., 2006). The main purpose of compaction is to increase the stiffness and strength of materials by increasing dry unit weight and decreasing the void ratio. The dry unit weight of soil material is used as a measure or proxy of the engineering properties of that soil, but there is no unique relationship between moisture-density measurements and the soil stiffness or strength (Reid, 2001). Thus, there is no direct connection between the design process and compaction quality control of a fill.

Furthermore, the SDDOT currently relies on the Ohio Highway Department's Typical Moisture-Density Curves Set C for development of target densities. Although this family of compaction curves works well for clays for which they were developed, they become problematic when determining target densities of granular materials. The next two sections will include a comprehensive definition of granular materials.

### 2.1.1 Granular Materials

The definition of granular materials differs among different classification systems, AASHTO M 145 (AASHTO, 2015a) and ASTM D 2487-11 (ASTM, 2016a). The American Association of State Highway and Transportation Officials (AASHTO) system used by the SDDOT defines a granular material as a material in which less than 35% of the material by weight passes the No. 200 (0.075-mm) sieve. AASHTO M 145 also groups different soil classifications by sieve analysis particle distributions and ranks them on their suitability for subgrade construction. Granular materials are classified under groups A1, A2, and A-3. Table 2.1 presents the sieve analysis specifications for granular material according to AASHTO standards. It was constructed in close relation to tables presented in AASHTO M 145-2 of the AASHTO Standards Specifications for Transportation Materials and Methods of Sampling and Testing and the AASHTO Provisional Standards Manual (AASHTO, 2015a). The table describes the gradation characteristics and typical constituent materials for each granular material AASHTO grouping. Notice that the group classification for A-2 granular materials is divided into four subgroups or index groups from A-2-4 to A-2-7. The last number of this group classification is known as a partial group index.

**Table 2.1** AASHTO classification of soil-aggregate mixtures for granular materials

| General Classification | Granular Materials (35 percent or less passing No. 200) | | | | | | |
|---|---|---|---|---|---|---|---|
| Group Classification | A-1 | | A-3 | A-2 | | | |
| | A-1-a | A-1-b | | A-2-4 | A-2-5 | A-2-6 | A-2-7 |
| Sieve Analysis, percent passing | | | | | | | |
| 2.00 mm (No. 10) | 50 max | … | … | … | … | … | … |
| 0.425 mm (No. 40) | 30 max | 50 max | 51 min | … | … | … | … |
| 0.075 mm (No. 200) | 15 max | 25 max | 10 max | 35 max | 35 max | 35 max | 35 max |
| Usual types of significant constituent materials | Stone fragments, gravel, and sand | | Fine sand | Silty or clayey gravel and sand | | | |

The particles that pass the No. 200 sieve are referred to as fines and often consist of small plastic and/or non-plastic particles. The range of granular materials can be divided into classifications of free draining and semi-draining based on their interaction with moisture. Drnevich, (2007) characterized free draining material as one that consists of less than 35% non-plastic fines or less than 15% plastic fines. AASHTO differentiates between plastic and non-plastic fines for granular material through a group index formula. The index formula chart is shown in Figure 2.1 and relies on the liquid limit and plasticity index of a material to determine the partial group index number. For granular material between A-2-4 and A-2-7, only the plasticity index is used in the calculation. A-2-4 and A-2-5 materials contain a majority of non-plastic particles within the fines content and are classified as silty granular material. A-2-6 and A-2-7 soils contain a majority of plastic fines and are classified as clayey granular material.

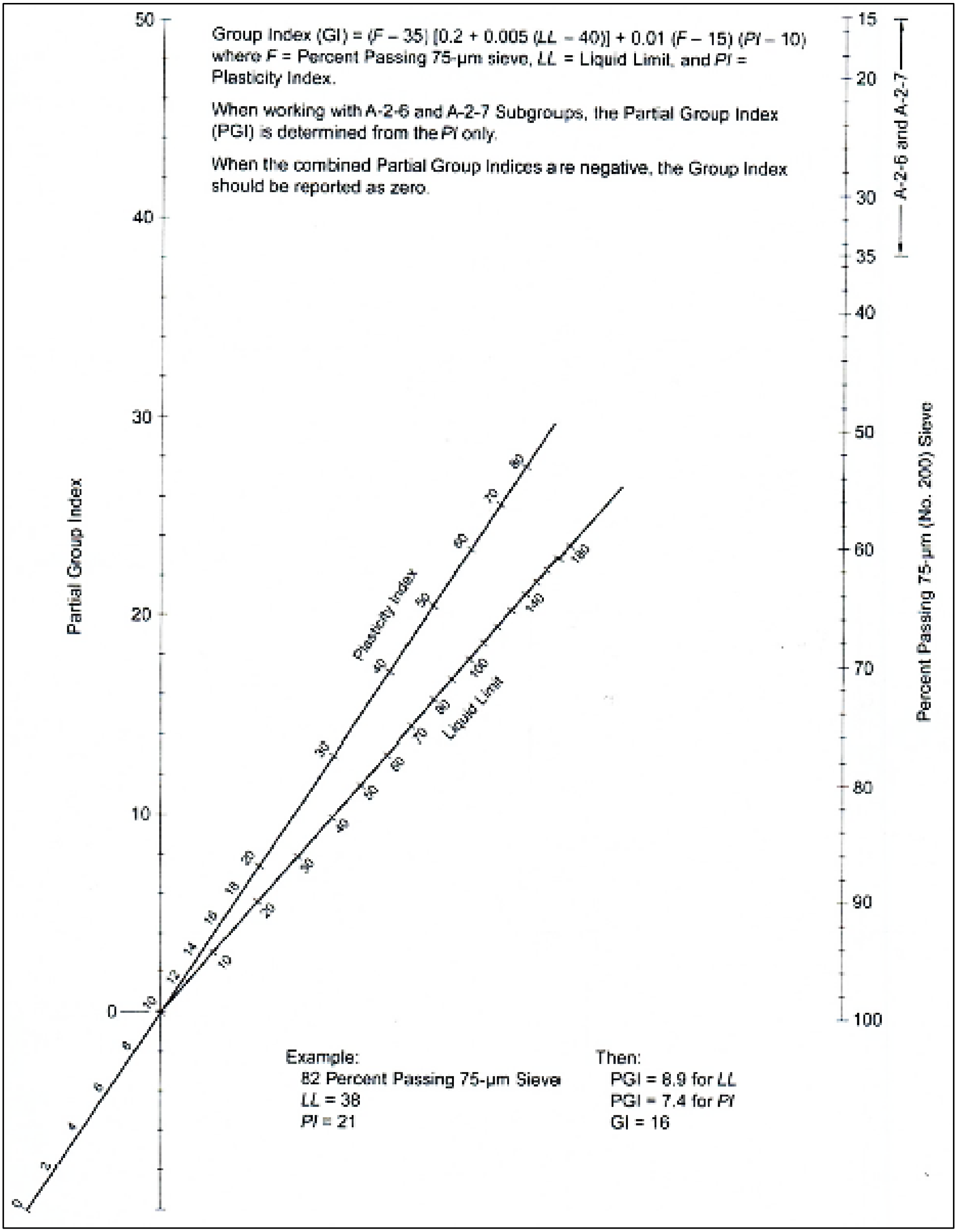


**Figure 2.1** AASHTO M 145 Group Index Chart (AASHTO, 2015a)

Semi-draining materials defined by Drnevich (2007) contain small portions of fine particles from 15% to 35% and develop fairly well-defined maximum dry unit weights and OMCs through traditional laboratory impact compaction testing. For free draining granular materials, a lack of fine particles results in poorly defined maximum dry unit weights. Often relative compaction results for these materials do not correlate well with the materials' engineering properties (Drnevich, 2007). This is due to the effect of moisture on materials of differing gradation, which will be discussed in more detail in the following section.

### 2.1.2 Semi Draining and Free Draining Granular Materials

Drnevich (2007) presented that when compacting granular materials, the effects of moisture content vary between semi-draining and free-draining granular materials. He states that since free-draining materials are constantly draining, two moisture contents can be observed. The first moisture content can be measured immediately before compaction and the second after compaction. For cohesive soils and most semi-draining materials, these two moisture contents are relatively close together; but for free-draining material, these measurements are of greater separation. Moisture content prior to compaction is the most important moisture measurement to establish effective rearrangement of soil particles during compaction. However, the moisture content is typically measured in the field after compaction. Drnevich (2007) states that after compaction, the moisture content will decrease due to the draining characteristics of free-draining materials and potential evaporation depending on weather conditions.

Free-draining materials, however, behave much differently when laboratory impact compaction methods are utilized at varying moisture contents. Figure 2.2 shows that the dry density decreases and then increases as the moisture content approaches the oven dry state; this is caused by the change in capillary stresses as the moisture content decreases. The moisture contents in which these capillary stresses develop are referred to as bulking moisture contents (Drnevich, 2007). At these bulking moisture contents, a curved surface develops at the water-air interface due to the difference between the air and water pressures. Rathje (2006) states that the difference in pressure can be referred to as matric suction, which creates tension stresses that hold soil particles in place and resist the compaction effort. The curved water surface between particles possesses tension that draws particles together and increases sliding friction. These capillary stresses are reduced when moisture is removed or the soil approaches saturation. Ba (2013) presents a correlation between matric suction and the resilience modulus of granular materials. Ba concluded that the resilience modulus correlates better with matric suction than with the compacted moisture content because in-situ matric suction and the resilience modulus both depend on the same stress state.

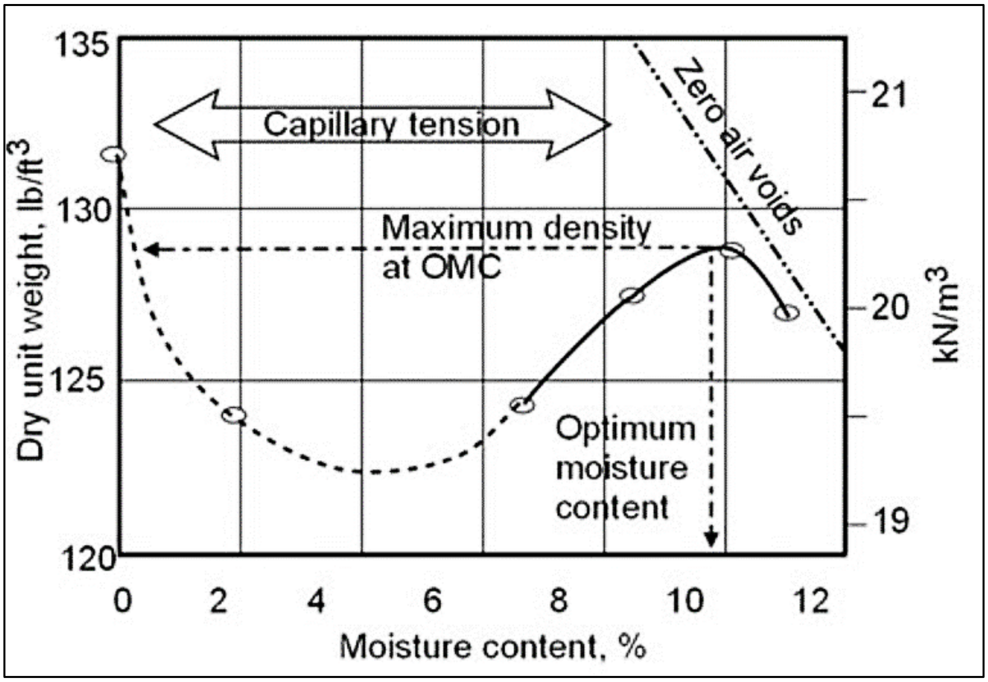


**Figure 2.2** The moisture density relationship for free draining granular soil (Drnevich, 2007)

Drnevich (2007) explained that for many granular materials, the maximum dry unit weight occurs at either the oven-dry or nearly saturated condition. It has been observed that the maximum dry unit weights at saturated conditions are limited to free-draining materials, but effective laboratory compaction at oven-dry condition worked well for materials with up to as much as 30% fines. The complete removal of water from a free draining granular material is rather unrealistic for field applications. Therefore, free draining granular soils require thorough wetting prior to effective compaction.

It has been summarized that water contents can have varying effects on the engineering properties of materials with different gradations. The most common form of laboratory compaction verification specifies that all soil classifications (clays, silts, granular, etc.) effectively compact in a similar fashion at varying moisture contents. It has also been shown that for differing material gradations, the compaction energy can be delivered by more effective methods within a laboratory. These differing methods of delivering compaction energy are also more relatable to compaction energies observed in the field. The methods of delivering effective compaction energy as they relate to testing proper compaction of granular soils are summarized in the following section.

## 2.2 Effective Laboratory Compaction Test Methods

Compaction is the densification of a soil through the expelling of air voids by the application of energy. There are four types of compaction efforts used to measure soil compaction: impact compaction, pressure compaction, kneading compaction, and vibratory compaction. These compaction methods are all useful for both laboratory tests and in-situ compaction using a variety of equipment. Impact compaction tests are the most common compaction verification effort used throughout the engineering industry (Nazzal, 2014). This is most likely because it stems from the first standardized “compaction test” widely accepted by the engineering industry. It is important that laboratory test methods be summarized within this report as they may be influencing problems with the current SDDOT field compaction test methods for granular materials. Therefore, this section will focus on summarizing traditional laboratory impact compaction test methods and laboratory vibratory compaction test methods as they relate to granular compaction.

### 2.2.1 Impact Compaction Methods

The "standard" laboratory impact compaction test used today is known as AASHTO T 99 (AASHTO, 2015b). For the remainder of this report, it will be referred to as the standard laboratory compaction tests. This method is also known throughout the industry as the "Standard Proctor Compaction Test" and was originally developed based on studies performed in the 1930s by R. R. Proctor (Nazzal, 2014). Proctor's study performed penetration resistance tests to determine the indicated saturation resistance for several compacted earth fills. The test was originally designed to simulate the action of a sheep foot roller as a penetration resistance measurement test for fine grained soils such as clays for dam construction. The tests development was influenced by a common on-site method used to evaluate soil compaction at the time known as roller "walk out," in which the feet of the sheep foot roller would begin to move up out of the soil layer upon effective compaction. To illustrate the idea Figure 2.3 shows roller "walk out" was due to an increase in soil bearing capacity because of the compaction and kneading efforts of the roller. However, due to a printing error, the test was adopted by many organizations as a standard compaction test (Nazzal, 2014). Due to the error, soil dry density is now used as a standard of soil compaction testing for most organizations rather than penetration resistance (bearing capacity).

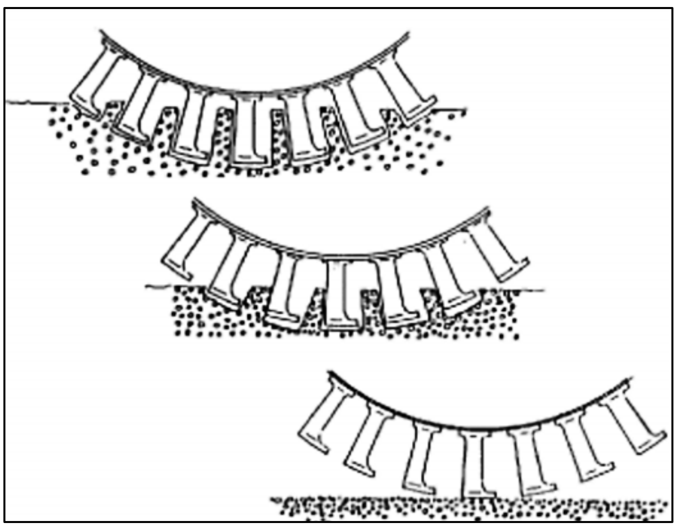

**Figure 2.3** The process of sheep foot roller "walk out"

From Proctor's work, scientists identified a relationship between soil particles and moisture content. Researchers compacted clay samples isolating only moisture content, keeping all other compaction variables constant. By imparting impact energy at varying moisture contents, they discovered that at certain moisture contents called the OMC, a maximum dry unit weight was determined. It was theorized that the moisture between these clay particles acts as lubrication that allow the imparted energy to more easily rearrange fine soil particles into a denser arrangement; however, this was not correct (Drnevich, 2007). Moisture creates hydrogen bonding between clay particles pulling the particles closer together, increasing not only the unit weight but also the strength of the soil. In soil materials that do not contain clay particles, such as granular unbound materials, this reaction does not occur. Figure 2.4 shows this traditional relationship between moisture content and dry unit weight.

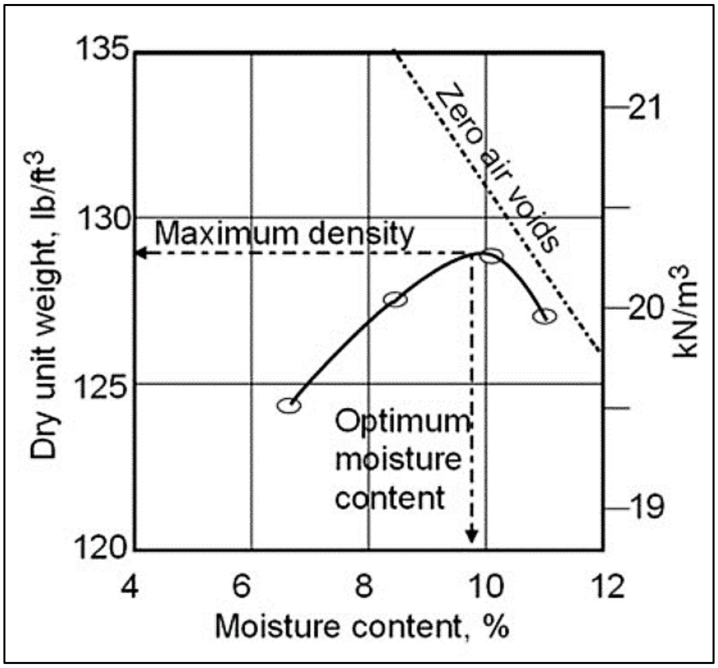


**Figure 2.4** Moisture density relationship cohesive fine grain soils (Drnevich, 2007)

The standard laboratory compaction test involves imparting energy by means of a drop rammer, hence its classification as an impact compaction test method. For cohesive soils, impact compaction is an effective method of delivering compaction effort due to the kneading process that each impact imparts on the soil particles. The kneading process facilitates moisture penetration into soil, allowing hydrogen bonding between clay particles to occur. The standard laboratory compaction test also compacts fine grain soils in a similar fashion to the way they are compacted in the field with the use of a sheep foot roller. When tests are performed at varying moisture contents, a clear peak in the curve develops for cohesive soils.

If the material type or imparted energy in the field differs significantly from the reference material or compaction effort in the lab, the computed relative compaction will not be meaningful and valid (Drnevich, 2007). The compaction energy imparted on fills today is much different than those of the 1930s due to the advancements in compaction equipment used on construction projects today. This presents a problem when relating field compaction measurements to target density values created in the laboratory using impact compaction equipment not designed to be similar in compaction energy. However, changing the number of rammer drops per layer, the weight of the rammer, and the height of each drop modifies the imparted energy.

This problem was addressed to better represent the compaction effort required on large airfields. In 1958, the U.S. Army Corps of Engineers developed a modified proctor test known as AASHTO T 180 (AASHTO, 2015c). For the remainder of this report, this laboratory compaction method will be referred to as the modified laboratory compaction test. The modified laboratory compaction test uses a larger mold with more layers, a heavier drop rammer at a longer drop height, and more drops per lift. It also uses compaction effort approximately 4.5 times greater than that of the standard laboratory compaction test. The differences in parameters between the two tests are shown in Figure 2.5. There is a difference of 4.5 lbs in rammer weight between the two tests and a drop height difference of 6 inches. The modified laboratory compaction test also uses five compaction layers unlike the standard laboratory compaction test, which only specifies three compaction layers. Many problems still arise, however, when performing the modified compaction test on granular materials.

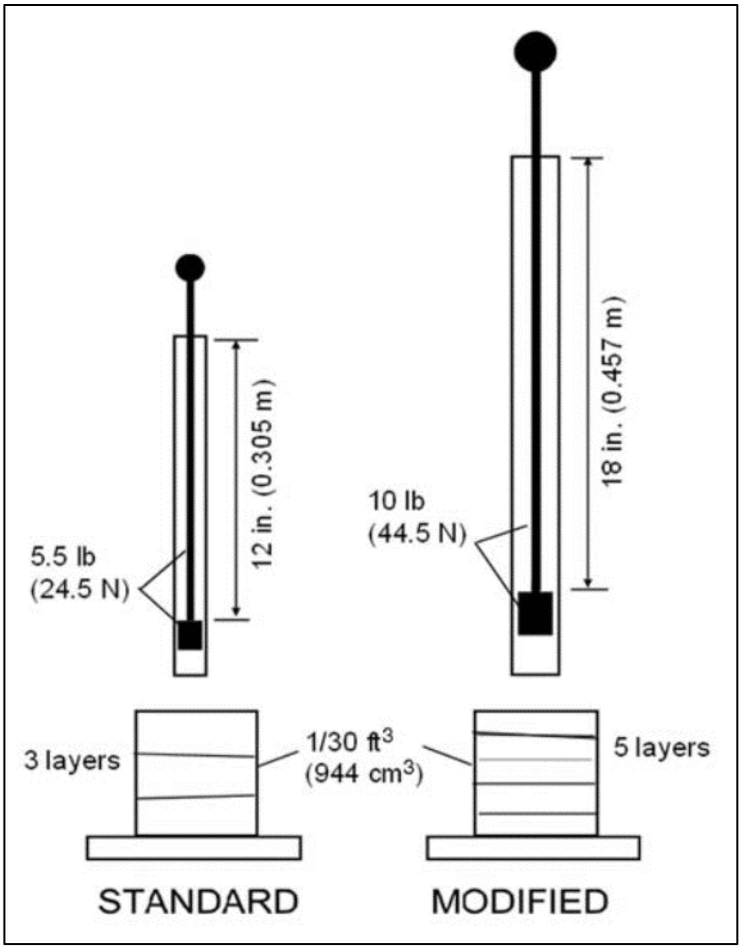


**Figure 2.5** Parameter comparison of standard versus modified laboratory compaction tests (Felt, 1958)

Felt (1958) states that impact compaction is not an appropriate compaction mechanism for compaction of granular soils. Without cohesion of fine clay particles, soil particles displace with each rammer drop when traditional impact compaction tests are performed. As previously discussed, due to the gradation of these soils, the engineering behavior is much different; therefore, laboratory compaction methods must address these differences.

Vibrating roller technology is used to effectively compact granular material in the field, although the laboratory compaction tests use impact compaction. Drnevich (2007) states that 60% of state DOTs specify only 95% of Standard Proctor maximum dry unit weight for compaction control. Drnevich (2007) also observed differences in compaction effort between the field and the laboratory while studying relative compaction in the field. He observed that contractors do not have difficulty achieving required relative compaction in the field, even when moisture contents are not optimum. This could be an indication that the maximum dry unit weights achieved by the standard laboratory compaction tests are inappropriate. It has also been observed that excessive settlement often occurs in granular materials where the specified field compaction is based on standard compaction tests' maximum dry unit weights. These observations support addressing laboratory compaction methods for granular materials.

### 2.2.2 Vibratory Compaction Methods

Drnevich (2007) conducted an evaluation of alternative laboratory test methods for granular soil compaction to address the problems with laboratory testing for maximum dry unit weight of granular materials. The main objective of the evaluation was to assess a laboratory vibrating hammer compaction test as an alternative to the standard laboratory impact compaction test for granular soils. Another main objective of the testing was to develop a better definition of granular soil based upon compaction behavior. Defining a range of soils appropriate for each type of laboratory compaction test, both impact and vibratory, was important to the research.

The testing performed various compaction tests on soils classified by both the AASHTO M 145 (AASHTO, 2015a) and the American Society for Testing Materials ASTM D 2487-11 (ASTM, 2016a) classification systems. The compaction tests performed included vibrating hammer tests, standard laboratory compaction tests, modified laboratory compaction tests, vibrating table compaction tests ASTM D 4253-16 (ASTM, 2016b), and minimum unit weight determinations. The vibrating table method standard states that the test be performed on granular soils with less than 15% passing the No. 200 sieve (fines). However, to compare the various test methods to the vibration hammer compaction method, soils were compacted regardless of the amount of fines present.

Based on compaction curves obtained by the vibrating hammer tests, a normalized family of compaction curves was developed. As moisture contents increased, peaks in dry unit weight did not develop until the ratio of moisture content to saturated moisture content ($w/w_{ZAV}$) was between 0.8 and 1.0. A maximum dry unit weight was obtainable for granular soil samples with moisture contents between 80% and 100% of saturation. Therefore, performing one vibrating hammer compaction test on an oven-dry sample will provide a maximum dry unit weight that can be used to calculate the moisture content range in which effective compaction will occur in the field.

The procedure is similar to the vibrating table test ASTM D 4253-16 (2016b) in which maximum dry unit weight is determined at oven dry or saturated conditions. However, the maximum dry unit weight when using the vibrating hammer tests usually occurs at the oven-dry condition. The vibrating table test, ASTM D 4253-16 (2016b), also does not provide a moisture content range, which is critical for compaction in the field.

In conclusion, a pilot implementation project showed that the vibrating hammer method of compaction can be used when evaluating compaction of aggregate bases. The vibrating hammer test provides a range of moisture contents for the time of compaction to achieve efficient compaction assuming compaction equipment delivers energy similar to the laboratory vibrating hammer compaction test (Drnevich 2007).

## 2.3 Traditional In-Situ Compaction Test Methods

Traditional field compaction test methods have been used for all classifications of soils for decades. These methods include sand-cone test, balloon test, and NDG test. These field test methods have both AASHTO and ASTM standard test methods and versions of these are all currently in use by the SDDOT. The SDDOT, along with several other state agencies, also have test specifications for the use of a family of compaction curves in conjunction with traditional field compaction test methods. These families of compaction curves are created from individual moisture-density relations. One-point density determinations of dry unit weight are plotted with a family of compaction curves to determine target density. Traditional field compaction tests are then compared with target density to determine adequate levels of compaction. The next few sections will summarize traditional field compaction methods and the use of families of compaction curves.

### 2.3.1 Families of Compaction Curves

As previously discussed, laboratory compaction curves that can relate moisture content and dry unit weight have been used for decades to provide engineers the ability to facilitate quality control of compaction on soil construction projects. These curves also can provide useful information on a given soil's sensitivity to water (Horpibulsuk, 2009).

Target field density and OMC is most commonly determined using impact compaction tests. In a survey of 41 DOTs conducted in 2014, most use the standard compaction test method AASHTO T 99 (AASHTO, 2015b) and the modified compaction tests method AASHTO T 180 (AASHTO, 2015c), or a modified version of those standards to establish the target field density value (Nazzal, 2014). However, the SDDOT and two other state DOTs (Delaware and Ohio) indicated that they use the Family of Curves-One-point Proctor Method AASHTO T 272-15 (2015f) based on families of curves they have developed or adopted to determine the target field density value (Nazzal, 2014).

The Family of Curves-One-Point Method AASHTO T 272-15 (2015f) is an impact compaction test that was developed to determine maximum density and OMC of materials utilizing only one point measurement of density and moisture content. The method uses the same standard laboratory compaction test standards as the standard laboratory compaction test previously discussed to determine the density of a field sample at a moisture content assumed to be near optimum. The moisture density relation is then plotted with a family of compaction curves and the closest curve to the point is assumed to be the compaction curve for that material. The curves are predetermined compaction curves with similar shape and geometry of various soils tested.

The SDDOT currently uses a modification of the Ohio Highway Department's Typical Moisture-Density Curves Set C to establish target moisture density values. The Ohio Department of Highways created the first set of curves as it became apparent that individual moisture density curves used in one part of the state could be used by another part. This is provided the curves were made of soils of similar weight regardless of the source of supply (Joslin, 1958). The initial set of curves developed by K. B. Woods was divided by 5-lb intervals of dry unit weight starting at 80 pounds per cubic foot (pcf) and ending at 144-pcf. Divisions were also made for each 2% of moisture. The wet unit weight, dry unit weight, and penetration resistance values were all recorded and then averaged and plotted on graph paper (Joslin, 1958). The first set of curves was created in 1936 from the results of 461 soil embankment samples. The first set of curves, set A, can be seen in Figure 2.6.

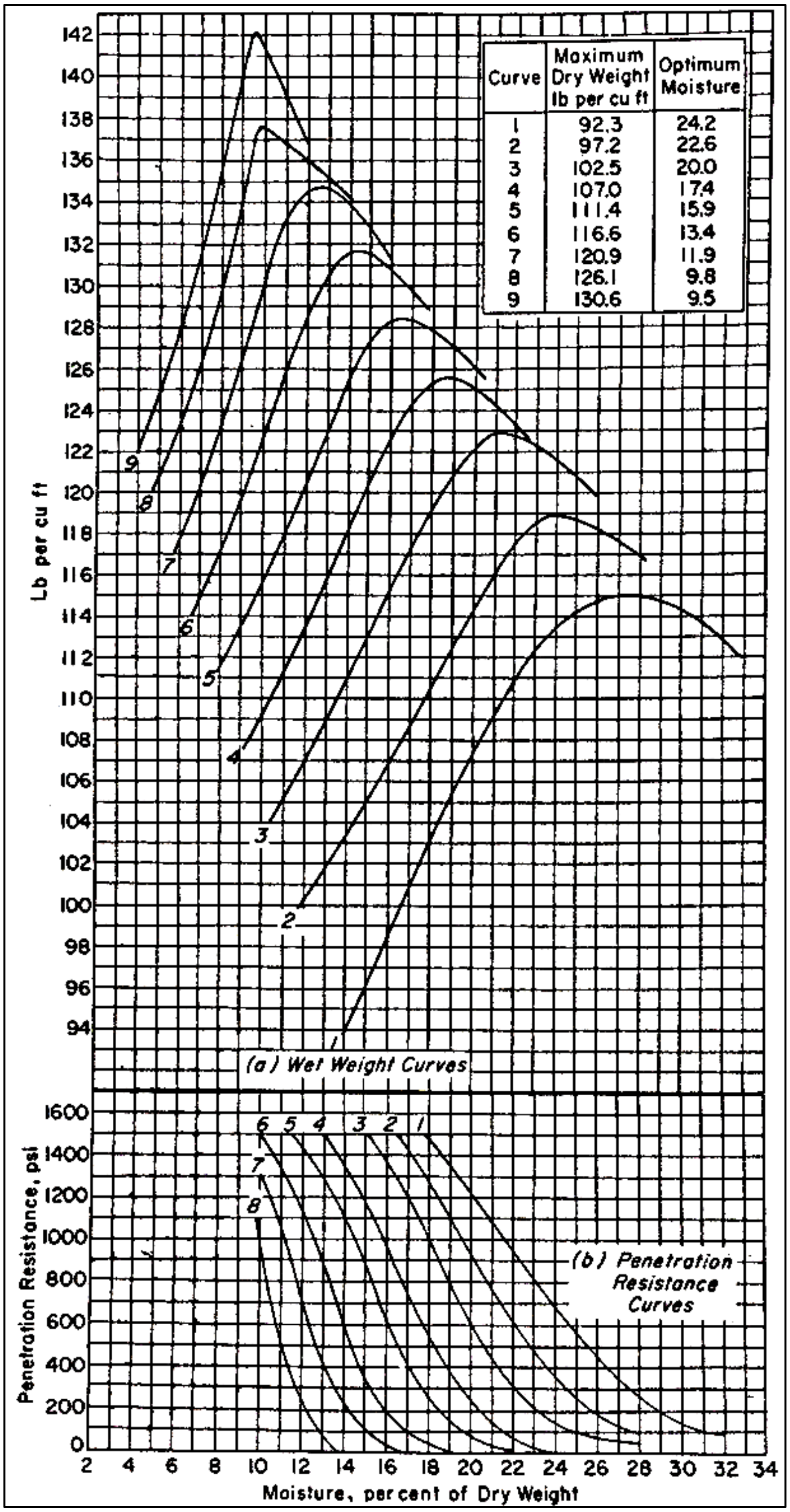

**Figure 2.6** Typical embankment control curves, set A (Joslin, 1958)

Additional compaction data were added to the original curves seen in Figure 2.6 to create two updated sets of typical curves with the most extensive and accurate being the final set, set C, shown in Figure 2.7. In set C, created in 1949, a total of 26 typical curves with dry weights ranging from 81-pcf to 142-pcf were the result of 10,149 tests (Joslin, 1958). Figure 2.7 illustrates set C along with the 26 typical curves labeled from A to Z and includes 13 interpolated curves. The accumulation of curve data was collected from 1935 to 1949 and ended when data no longer improved the typical moisture-density curves (Joslin, 1958). When determining the correct typical curve, the penetration resistance curve was also used to correlate the correct curve. For soils that penetration resistance tests could not be conducted, such as granular soils, the penetration resistance tests were not recommended to aid in the determination of the correct curve. A typical curve circular slide rule was created to increase the efficiency of using the curves in the field seen in Figure 2.8. This allowed engineers in the field to more rapidly select the proper curve of each soil.

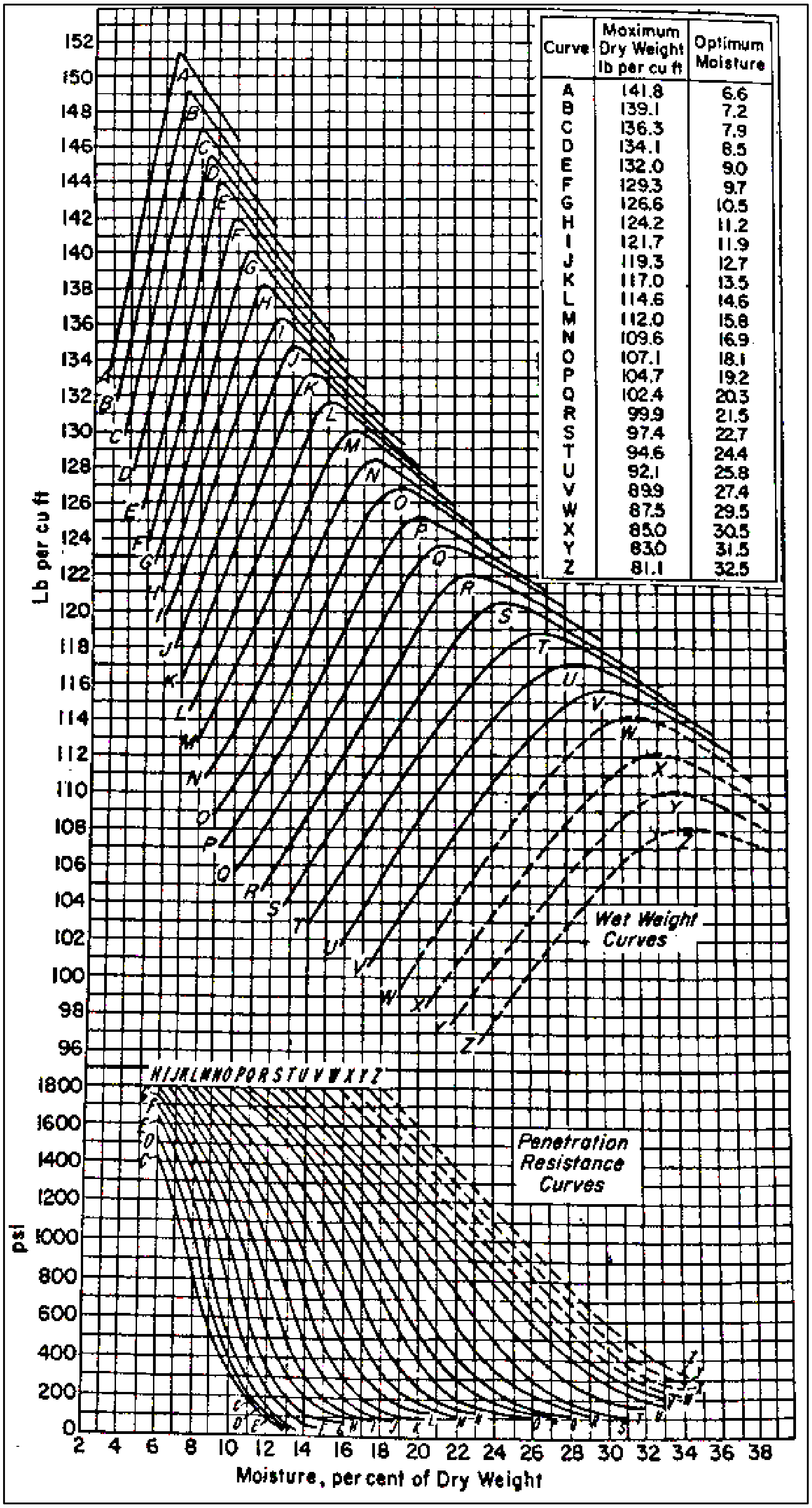


**Figure 2.7** Ohio Highway Department's Typical Moisture-Density Curves, Set C, May 1949 (Joslin, 1958)

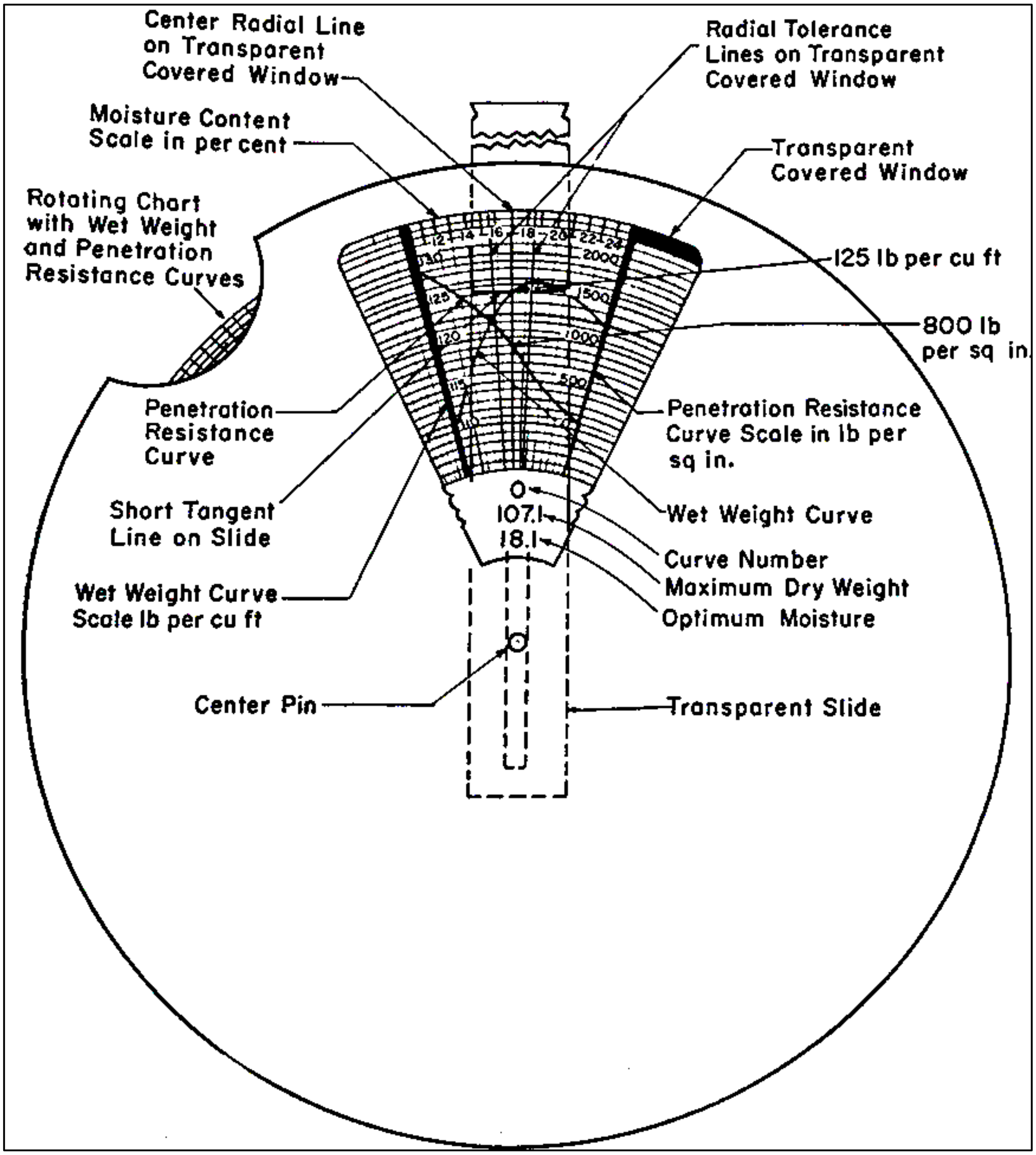


**Figure 2.8** Typical Curve Circular Slide Rule (Joslin, 1958)

The SDDOT adopted Ohio Highway Department's Typical Moisture-Density Curves Set C and added an additional 26 interpolated curves to the model, which doubled the number of typical curves from 26 to 52 as seen in Figure 2.9. The SDDOT also does not conduct penetration resistance tests to aid in the determination of the correct curve; rather, the resulting moisture density relations of standard laboratory compaction tests are compared with the selected curve to verify the use of the compaction curves for each material to be tested. This method is referred to as an end-products method of material testing. Reid (2001) described this method of constantly establishing a target density as time consuming to project inspectors. Additionally, contractors are constantly waiting on feedback from the inspectors, which can delay projects. Reid (2001) also states that in some cases it can take up to an hour to complete just a single one-point determination of dry unit weight.

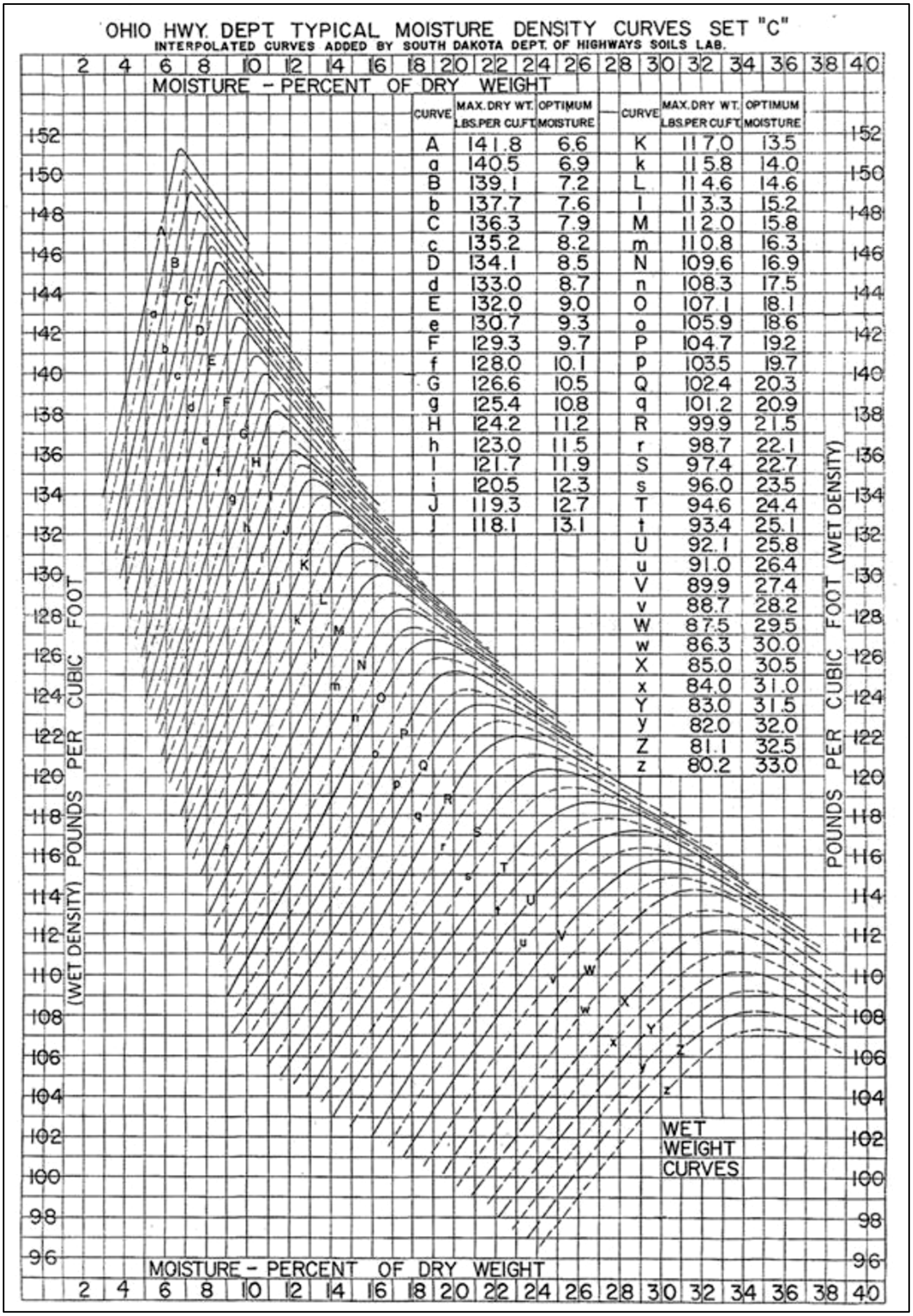


**Figure 2.9** Ohio Highways Department's Typical Moisture-Density Curves, Set C with interpolated curves (SDDOT, 2015a)

According to AASHTO T 272-15 (2015f), the family of compaction curves used to obtain moisture density relationships must adequately represent the entire mass range and all soil types of material for which the family is to be used. If soil types that differ greatly and are not represented on one general family of compaction curves, a separate family of compaction curves can be developed. Furthermore, materials with widely varying geological origins must be carefully checked to determine if separate families are required.

The AASHTO T 272-15 also outlines that the accuracy of a family of compaction curves can be verified by comparing the maximum density and OMC from an individual moisture density relationship with that obtained using the family of compaction curves and the one-point methods. The difference between these values represents the maximum variance expected when the family of compaction curves and the one-point methods are used for the given individual material. Based on the results of the comparison, adjustments to the curve may be needed or certain material types may not be applicable of the given family of compaction curves. A family of compaction curves with fewer moisture density relationships should be examined more closely (AASHTO, 2015f).

### 2.3.2 In-Situ Compaction Verification Using Traditional Sand-Cone Test Method

The standard method for the determination of in-place soil density by means of a sand-cone is performed in accordance with the AASHTO T 191-14 (AASHTO, 2015d). The method is known as a volume replacement test method and is destructive in nature. The procedure requires a small hole be excavated in the compacted soil. The hole is then filled with sand of a predetermined density. The volume of the hole is then measured, and the material extracted is weighed to determine the density of the compacted layer. Figure 2.10 shows the sand-cone apparatus.

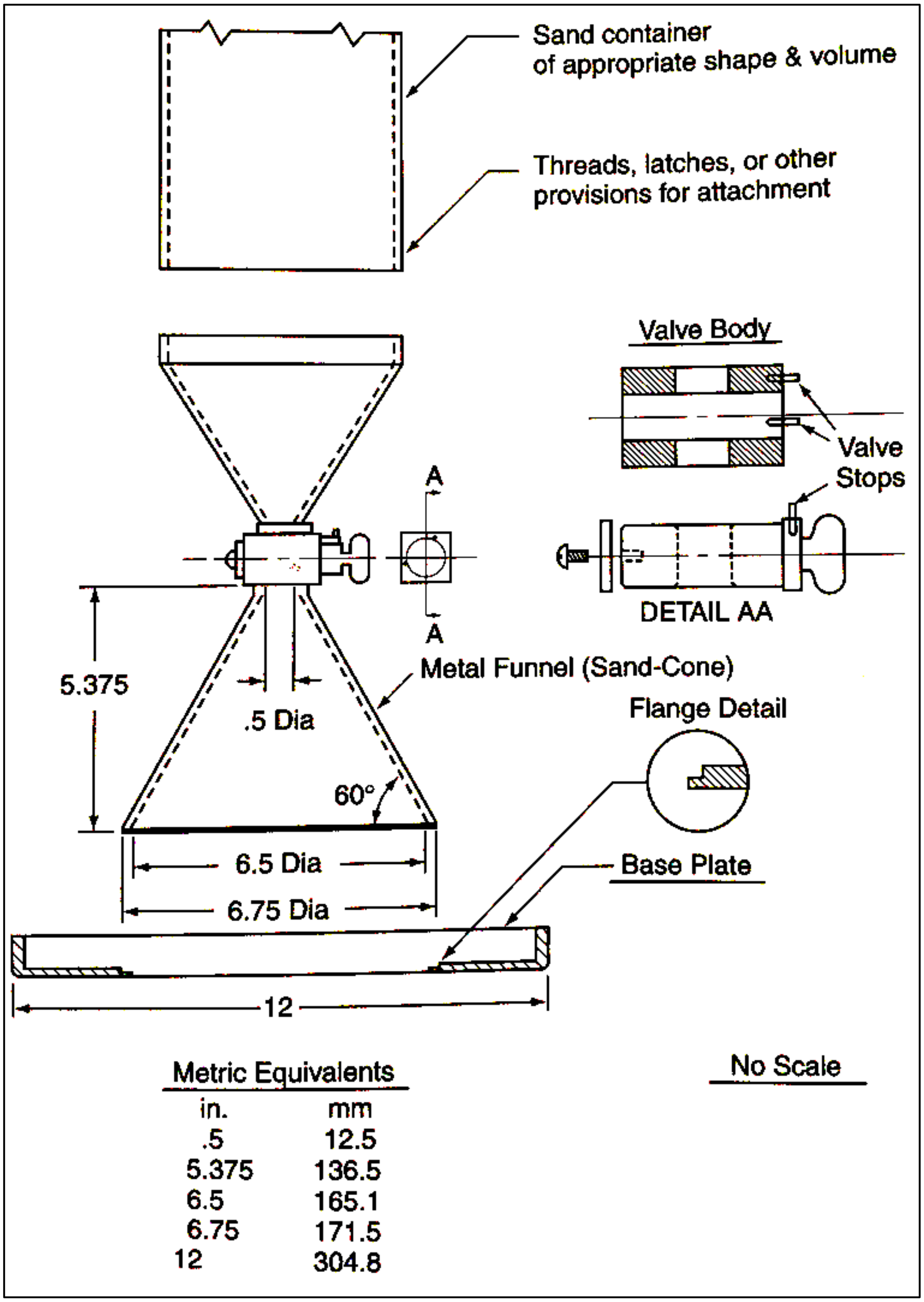


**Figure 2.10** In-situ sand cone density test apparatus (Liu and Evett, 2000)

The accuracy has been found to depend on the experience of the operator. Therefore, it was not found to be repeatable for use as a compaction control tool in the field (Farrag, 2005). Ernest et al. (2013) found that traditional sand cone tests work effectively with a few limitations. Ernest et al. (2013) state that the sand cone method was limited to soils with a particle diameter size of less than 1 inch in effective diameter. They also state it is difficult to conduct tests in cohesionless materials. Methods that replace the sand with steel shot of a known density have also been evaluated and were found to be even less effective than the traditional sand cone (Ernest et. al, 2013).

## 2.3.3 In-Situ Compaction Verification Using Traditional Rubber-Balloon Test Method

The standard method for the determination of in-place soil density by means of a rubber balloon is performed in accordance with the ASTM D 2167-66 (ASTM, 2016f). The rubber-balloon test method is similar to the sand cone test method in that it is a destructive volume replacement test method. The rubber-balloon method differs primarily from the sand cone method in the manner in which the volume of compacted soil removed is determined. In the rubber-balloon method, a quantity of compacted soil is removed and weighed, while the volume is found by measuring the volume of water required to fill the excavated hole. A thin flexible membrane is fitted in the excavated hole and the calibrated rubber-balloon apparatus is then fitted over the hole and filled with water. The volume indicator of the apparatus is then used to find the volume of the hole as seen in Figure 2.11.

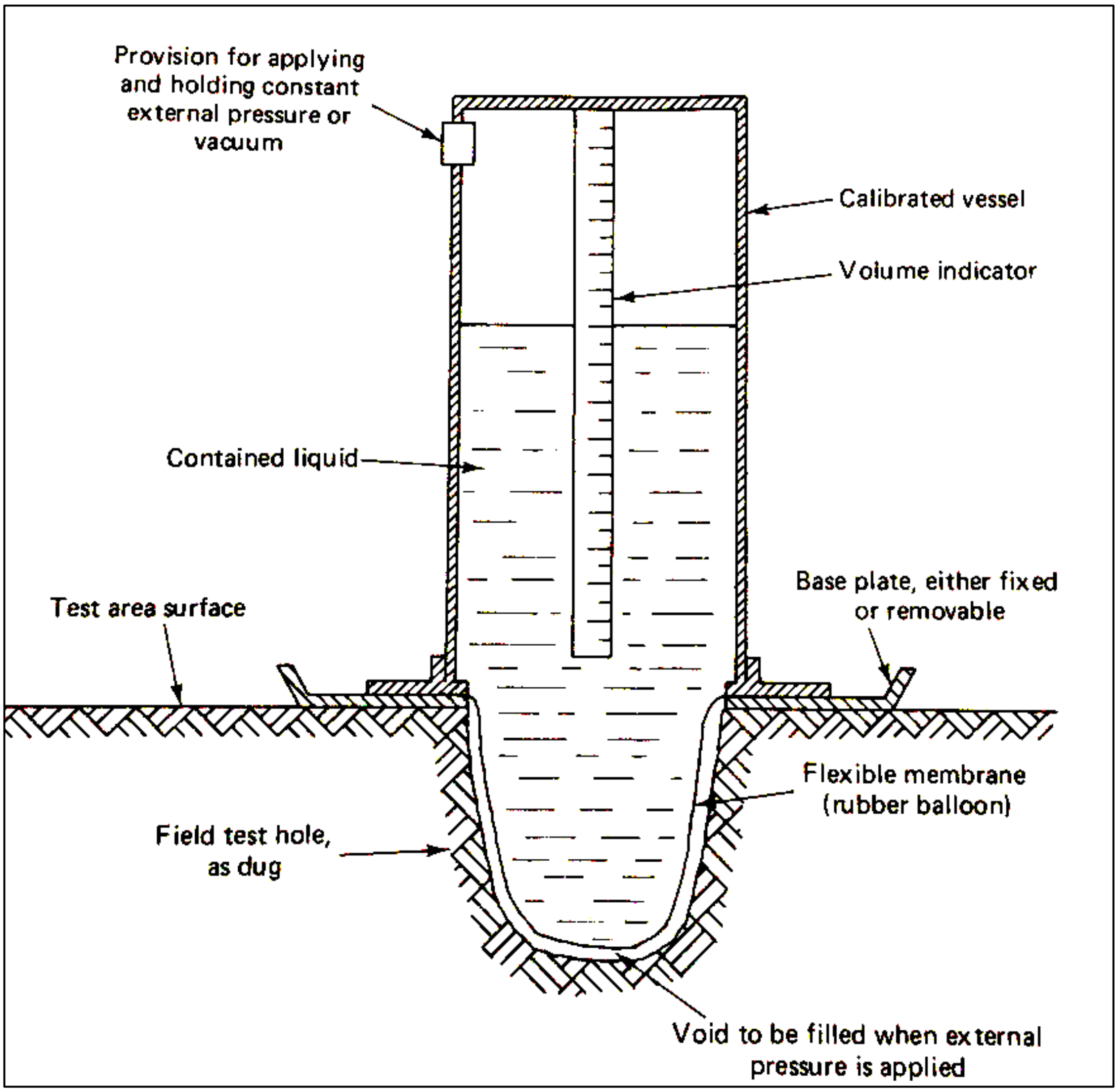


**Figure 2.11** Schematic drawing of calibrated vessel indicating principle (Liu and Evett, 2000)

The main advantage of the rubber-balloon method is that it has been used for decades with success. The disadvantage of the rubber-balloon test method is that the balloon is prone to bursting on jagged aggregates such as granular material. This compromises the test and test hole as it becomes saturated. The test accuracy is also dependent on the experience of the operator, which can prove to be problematic.

### 2.3.4 Nuclear Density Gauge Review

The NDG is the most widely used method to determine in-situ unit weight and moisture content by DOTs (Rathje, 2006). The NDG functions by emitting gamma radiation into the material to be tested through a drop-down rod inserted into the compacted material. Detectors in the device read the reflected gamma radiation to determine its wet density (Nazzal, 2014). Denser materials contain more electrons with which the photons of the gamma radiation interact; therefore, they reflect a lower number of photons back to the detectors (Nazzal, 2014). The number of detected photons is used to calculate the density of the tested material based on calibrated relationships.

The NDG also can measure the moisture content of compacted soil as well. The NDG contains a separate americium/beryllium high-energy source and a thermal neutron detector. The high-energy neutrons are retarded as they collide with hydrogen atoms present in moist compacted material. The thermal neutron detector counts the retarded neutrons. This count is proportional to the soil's moisture content. The gauge calculates the moisture content, subtracts it from the soil's in-place wet density, and reports the soil's dry density.

The NDG can be utilized in two different modes, both backscatter and direct transmission mode. The radiation source is placed within the soil layer being tested and radiation then travels through the soil back to the detectors located on the bottom of the NDG in direct transmission. The radiation source emits radiation into the soil layer from the surface where it then reflects back to the detectors in back scatter mode. Figure 2.12 depicts how the NDG operates in both backscatter and direct transmission modes.

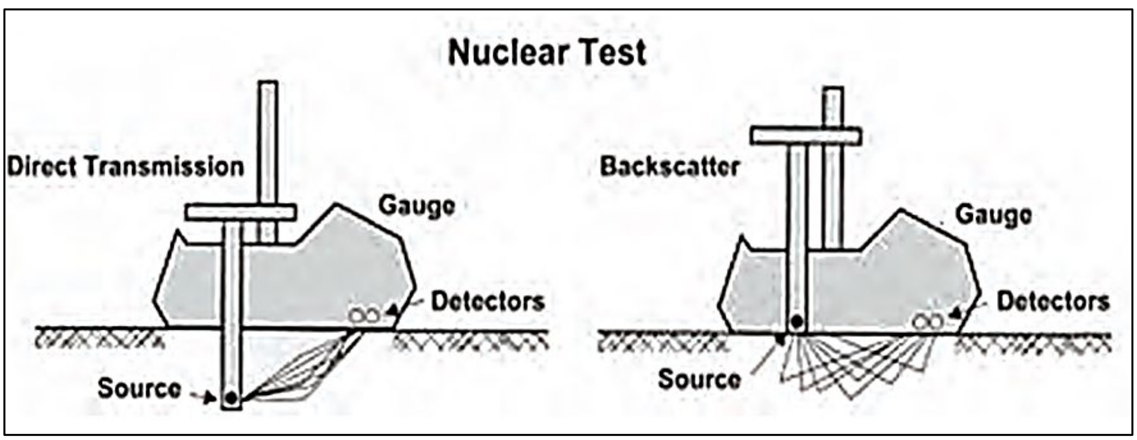


**Figure 2.12** The NDG operation in both backscatter and direct transmission (Nazzal, 2014)

According to Rathje (2006), the neutrons used to measure water content will eventually reach thermalization, which means farther collisions with hydrogen atoms will not slow down the neutrons. This will result in a lower moisture content reading of compacted fills. It was also noted that the NDG might be affected by the chemical composition of the soil tested. This is especially significant when measuring the moisture content of recycled pavement materials commonly used today, where hydrated water molecules are present in the cement (Nazzal, 2014). Therefore, it is not recommended to be used in recycled pavement materials.

Rathje (2006) also states that the NDG requires an initial calibration before each day of use but does not require a soil specific calibration. The calibration uses a reference block and is quick and simple (AASHTO, 2015e). The NDG advantage over other traditional density measurement devices previously discussed, such as the sand cone or rubber-balloon method, is that the test can be conducted rapidly. The holes created when the NDG is used in direct transmission are also much smaller than the excavated holes created using other methods. This decreases the disturbance of compacted layers and results in a more uniform compacted fill.

The main disadvantage to the NDG is also what makes it unique among density measurement devices in that it uses radiation. Due to the potential health and environmental risks associated with using radiation, the Nuclear Regulatory Commission (NRC) requires strict controls over NDG devices. This increases the cost to own and operate the device (Rathje, 2006). Many state agencies now are willing to move to new alternatives to the NDG.

It has become a challenge of many researchers to find a suitable replacement for the NDG. Recent studies (Ernest et al., 2013) have worked to find a suitable replacement for the NDG with a wide range of new technologies in development, and some are being implemented by state agencies making it clear that replacements are near. The Engineering Research and Development Center (ERDC) began a broad ranging study of these new technologies to determine density. These will be discussed in the next section along with summaries of newly developed devices to measure compaction of granular materials (Ernest et al., 2013).

## 2.4 Alternative Density-Based Measurement Test Methods

The NCHRP conducted a study of non-nuclear methods for compaction control of unbound materials (Nazzal, 2014). As part of this study, they collected information from 41 DOTs and Canada on various types of non-nuclear methods for compaction testing of unbounded materials that have been evaluated or implemented. The study also summarized detailed reviews of recent technologies used to measure both in-situ density or the stiffness and strength modulus of unbound soils. The study divides the new technologies into two separate categories: non-nuclear methods for density measurements of unbound materials and non-nuclear methods for in-situ stiffness and/or strength of unbound materials. This study forms the basis for the following discussion. Section 2.4 summarizes density-based measurement test methods and Section 2.5 summarizes stiffness/strength measurement test methods.

The study highlights that the implementation of new non-nuclear testing methods for density measurements would not require significant changes to existing specifications because density-based specifications already exist and have been used for decades by the SDDOT. The integration of new testing methods, which involve stiffness and strength, would require the development of new standard specifications for these new testing methods.

### 2.4.1 Moisture Density Indicator

The moisture density indicator (MDI) consists of four metal spike probes encased in a single probe head. The probe head is connected by a coaxial cable to a time domain reflectometry (TDR) pulse generator. TDR analysis is conducted with the transmission of an impulse into the system and the subsequent observation of energy reflected back to the system. The generator is connected to a personal digital assistant (PDA). During a given test, the spikes are driven into the ground in a triangular fashion with a single probe in the center as shown in Figure 2.13. The center probe acts as a central conductor while the outside probes act as a theoretical coaxial cable. The probes send out electromagnetic waves into the surrounding in-situ soil, which acts as an insulator. The waves then reflect off the soil and return to the probes. The PDA contains software to determine the density and moisture content of the surrounding compacted soil. The device does not currently have an AASHTO standard designation.

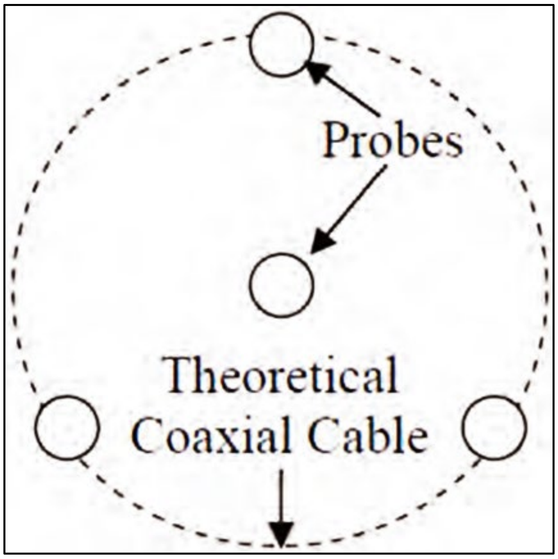


**Figure 2.13** Probe pattern for the MDI (Nazzal, 2014)

The MDI has two operation modes, the first being the one-step mode which measures bulk electrical conductivity and dielectric constant values together for a given soil used to determine the dry density and moisture content. The two-step mode first measures the dielectric constant values of in-situ soil and a soil sample excavated from the field and compacted in a standard laboratory compaction mold. The density of the in-situ soil is then determined by comparing the dielectric constants and the known density of the soil in the compacted mold (Nazzal, 2014). Ernest (2013) evaluated non-nuclear alternatives to the NDG and found that the Soil Density Indicator was the best electrical device overall and had the best combination of accuracy and precision when compared to the NDG. Calibration of the MDI requires determining constants for specific soils, which is performed by measuring the dielectric constants for several samples compacted using standard laboratory compaction tests at varying moisture contents. The obtained data are plotted with these constants versus moisture content to determine calibration constants of a specific soil (Nazzal, 2014).

The MDI has advantages in that studies have indicated the device is repeatable. Rathje et al. (2006) reported a coefficient of variation measurements was less than 15%. They also stated that moisture content measurements were very close to those obtained using the oven dry method. The MDI is also much safer than the NDG as it does not use radiation, which also reduces operational cost of the device. Jackson (2007) indicated problems driving and removing the spikes and reported test times of more than 15 minutes. It was also reported that spikes could bend in base coarse materials. They also reported that although moisture content measurements obtained by the MDI were closely related to NDG measurements, the dry density measurements were consistently lower for the MDI when compared with those of the NDG. Another disadvantage to the MDI is the need to calibrate the MDI for varying materials when using the two-step mode.

### 2.4.2 Electric Density Gauge

The electric density gauge (EDG) uses high frequency radio waves to measure the density and moisture content of soils (Nazzal, 2014). The EDG device and calibration procedure have many similarities when compared to the MDI. The EDG uses four probes driven into the soil to measure the electrical dielectric properties similarly to the MDI, which uses three. Constants required by the device need to be calibrated by measuring the soil compacted in a standard laboratory compaction test mold at varying moisture contents for compacted soil of interest. The EDG determines the dry density and moisture content of the tested material through a transmitted radio frequency. The EDG test is conducted in accordance with an ASTM D 7830 (ASTM, 2016c) standard but does not currently have an AASHTO standard designation.

The EDG shares the same advantages and disadvantages with the MDI. The EDG also does not use nuclear radiation, making it a much safer option over the NDG. The EDG calibration process was found to be complex and time consuming and spikes were found to be difficult to drive into and remove from granular material (Rathje, 2006; Brown, 2007). The numerous parts associated with the EDG were also found to be cumbersome in the field, resulting in additional time to complete the tests. There was no general consensus among studies of reliability and accuracy of measurements when using the EDG (Nazzal, 2014).

### 2.4.3 Soil Density Gauge

The soil density gauge (SDG) is a self-contained unit that uses electromagnetic impedance spectroscopy (EIS) to measure the density and moisture content of various unbound materials (Nazzal, 2014). Much like the two previous devices for determining density, the SDG measures the dielectric properties to soil to determine the density and moisture content. A central ring generates a radio frequency ranged electromagnetic field into the soil and an outer ring receives and measures the dielectric properties (Nazzal, 2014). The SDG also requires calibration for specific compacted soils of interest. This is completed in a similar fashion as the MDI and EDG. Soil samples are compacted in a standard laboratory compaction mold at varying moisture contents and the SDG is then used to measure the dialectic properties. The field testing of unbound materials with the SDG requires five tests to obtain a density and moisture measurement (Nazzal, 2014). The standard method for use of the SDG is ASTM D 7830 (ASTM, 2014). There currently is no AASHTO standard designation for this test method.

Previous studies have indicated that the SDG density and moisture content measurements were repeatable and close to measurements made by the NDG (Nazzal, 2014). The device does not involve driving spikes, which increases the ease of use of the SDG. However, the SDG requires five separate tests to obtain a single density and moisture reading, which makes testing more time consuming. The main advantage of the SDG is that it can provide accurate and repeatable moisture and density measurements if the operators of the SDG have extensive knowledge of this device (Ernest et al., 2013). Ernest et al. (2013) evaluated non-nuclear alternatives to the NDG and found that the Soil Density Indicator was the most practical electrical device and had the highest ranked combination of accuracy and precision when compared with the NDG.

## 2.5 Stiffness / Strength Measurement Tests Methods

It has been previously discussed that moisture density relations are currently used extensively by DOTs for compaction quality control. However, these methods do not directly reflect the engineering properties of granular unbound materials required to establish optimum pavement performance. The main properties used to specify the degree of compaction in the design process are stiffness and strength. These properties are considered measurements of the soil layers' stability and resistance to deformation under load (Nazzal, 2014). White et al. (2007) stated that even small variations in density can have relatively large effects on stiffness and strength. Therefore, errors introduced during traditional density-based compaction quality control can produce potential significant differences in the performance of compacted unbound granular material.

A shift from empirical to mechanistic empirical pavement design procedures has resulted in an increased interest in compaction control specifications that rely on stiffness and strength measurements. This section summarizes stiffness and strength measurement tests methods that have been developed to measure these properties for in-situ compacted unbound granular material. The NCHRP study forms the basis for these methods.

### 2.5.1 Clegg Hammer

The Clegg Hammer (CH) has been utilized since the 1960s and was developed in Australia to measure the stiffness of in-situ soils. The device consists of a flat-end hammer within a guide tube. The CH's basic operation is to measure the deceleration of a free-falling mass from a set height onto a soil surface (Nazzal, 2014). There are several hammer weights available for use. The standard method for CH use is ASTM D 5874-16 (ASTM, 2016d), and there is currently no AASHTO standard designation. An accelerometer attached to the hammer generates a Clegg Impact Value (CIV) upon impact. A target CIV must first be established by compacting a soil of interest in a modified laboratory compaction mold at varying moisture contents. The CH is then used to test the soil at these varying moisture contents to find the maximum CIV, which becomes the target CIV. The process can be time consuming for field inspection. CIV values can be related to the elastic modulus based on elastic plate bearing theory. An advantage of the CH is that it is simple to use and requires minimal training. Farrag (2005) evaluated the CH and found considerable variation in the results when the CH was used on granular unbound materials and was not recommended in these soils.

### 2.5.2 GeoGauge

The GeoGauge device generates a very small dynamic force at varying frequencies to determine the stiffness of a given in-situ soil. These frequencies are smaller than that of operational equipment and other vibration interference. The GeoGauge rests on the soil surface on a ring-shaped foot and weighs approximately 22 lbs (10-kg). The force applied to the soil is measured across a flexible plate by two velocity sensors (Nazzal, 2014). The GeoGauge can be utilized to determine dry density of soils but research has indicated poor correlations (Nazzal, 2014).

The GeoGauge offers quick measurement of the in-situ stiffness of compacted soil (less than 2 minutes), which provides an advantage over other devices. The GeoGauge is also simple to use and requires minimal training (Nazzal, 2014). There is also no current AASHTO standard for the GeoGauge. The GeoGauge was evaluated by Farrag (2005) and it was found to produce rapid results but was sensitive to seating procedure and had poor correlations in granular materials because it was difficult to seat the device in granular material. Another disadvantage of the GeoGauge is that the small applied loads used during a test do not represent stress levels encountered as a result of traffic loads and therefore requires correction.

### 2.5.3 Light Weight Deflectometer

The LWD uses the release of a falling weight from a standard height onto a loading plate (Nazzal, 2014). According to Nazzal (2014), the central deflection of the loading plate upon impact of the falling weight is measured using two methods. The first method integrates the velocity measurements obtained from a velocity transducer to find LWD modulus. The second method uses double integration of the acceleration data obtained from the accelerometer to determine the LWD modulus. Several factors may influence the LWD modulus, such as the falling mass, drop height, plate size, plate contact stress, and load transducer (White et al., 2004). The LWD modulus is comparable to the surface modulus of a layered system having homogeneous properties, assuming constant loading on an elastic half space (Nazzal, 2014). The test currently does not have a standard AASHTO method for granular materials.

The main advantage of the LWD was that it has a relatively quick setup and test time. Indiana and Minnesota DOTs have developed standard test procedures for the LWD. It was also noted that previous research of the LWD had indicated more accurate testing of a larger range of soils such as granular unbound materials (Nazzal, 2014). A disadvantage of the LWD is its low repeatability. Nazzal (2003) reported poor repeatability when testing weak cohesive materials or layers with uneven surfaces.

### 2.5.4 Dynamic Cone Penetrometer

The DCP has been in use since the 1970s and has been used internationally to evaluate in-situ soil layers. The device consists of a rod, drop weight, and a cone penetrator. The basic operation involves dropping a weight from a standard height of 575 mm and recording the number of blows versus depth. The penetration rate (PR) or the penetration index value (PIV) is then calculated in millimeters or inches per blow. Materials with small rates of penetration will have better compaction. The first two blows are referred to as the SEAT and evaluate the top of a compacted layer where there is often less confinement of compacted material. The final three blows when conducting a test measure the PR of the compacted soil deeper in the layer. The equations used to calculate the SEAT and PIV are provided (2.1 and 2.2).

$$SEAT = A - B \qquad (2.1)$$

Where,

A = Penetration reading after 2 initial blows (mm)
B = Penetration reading before 2 initial blows (mm)

$$PIV = \frac{A - B}{3} \qquad (2.2)$$

Where,

PIV = Penetration Index Value (mm/blow)
A = Penetration reading after 5 blows (mm)
B = Penetration reading after 2 blows (mm)

The test can be performed in accordance with the ASTM D 6951 (ASTM, 2016e), however, there is currently no AASHTO standard test method. The DCP can be used to conduct compaction quality control on recycled materials as well as virgin base and subbase materials, making it more versatile than the NDG. The research has developed supplemental specifications and a procedure for utilizing the DCP in granular compaction quality control along with field data worksheets. These documents are presented in Appendix A. The DCP schematic is shown here in Figure 2.14.

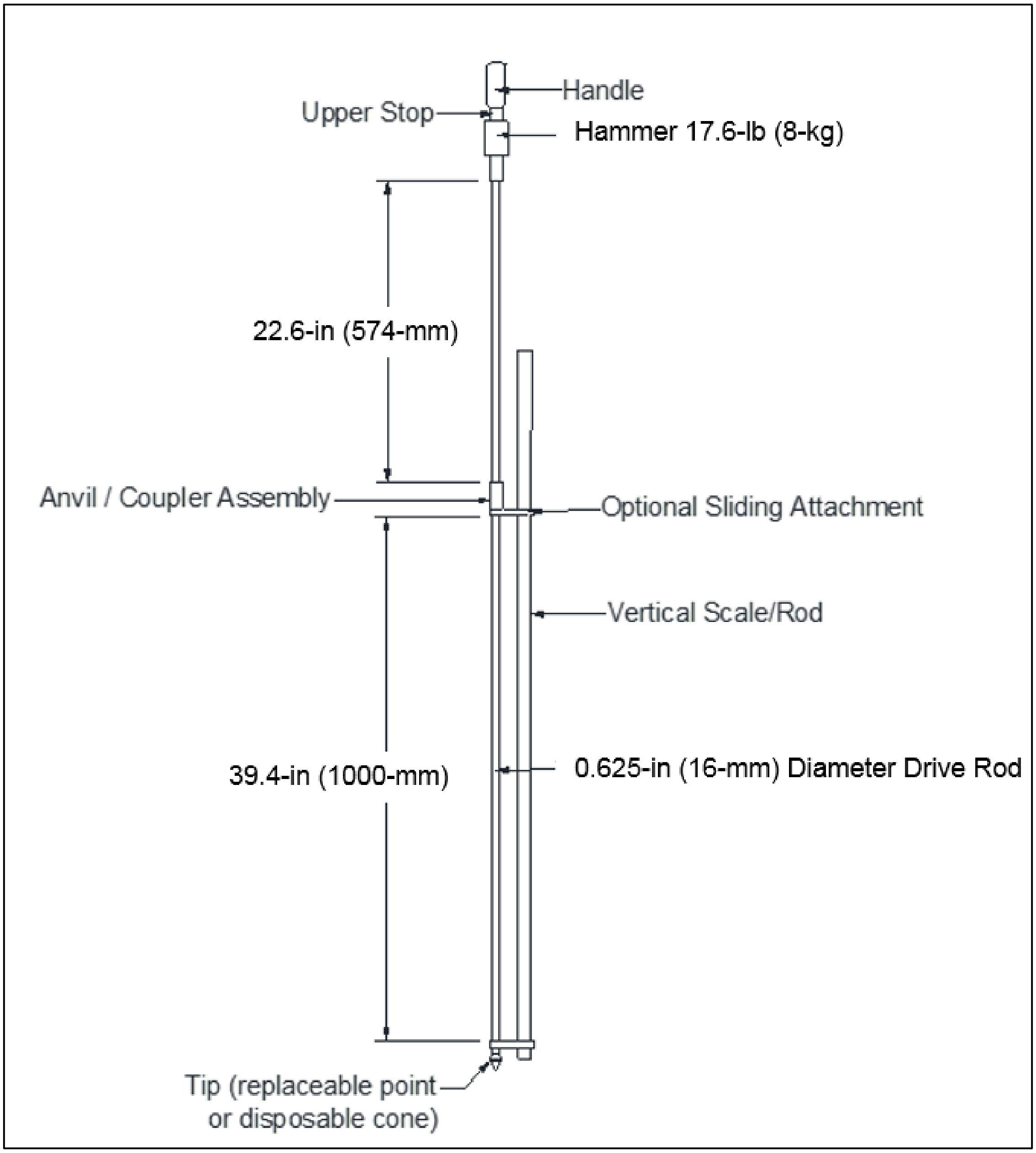


**Figure 2.14** DCP schematic

Amini (2003) summarized that the DCP can be correlated with various modulus and strength-based values. Ese et al. (1995) stated that the DCP could estimate the CBR for aggregate base course. Ese et al. (1995) developed Equation 2.3 for correlating the PIV to the CBR of an aggregate base course. George and Uddin (2000) developed a simple relation between the PIV and the resilience modulus ($M_R$) of both fine grained (Equation 2.4) and course grained soils (Equation 2.5).

$$\log(\mathrm{CBR}) = 2.44 - 1.07\log(\mathrm{PIV}) \qquad (2.3)$$

$$\mathrm{M_R} = 532.1 * \mathrm{PIV}^{-0.492} \qquad (2.4)$$

$$\mathrm{M_R} = 235.3 * \mathrm{PIV}^{-0.475} \qquad (2.5)$$

The device has been field evaluated by Farrag (2005) and was found to be economical and simple to use with minimal training requirements. Farrag (2005) also showed that the DCP produced better results in silty-clay soils than in other soils. Dai and Kremer (2006) indicated that the DCP test is repeatable and the results were considered accurate. The only reported limitation to the DCP found in the literature was that it should be limited to use in materials with a maximum particle size of 2 inches (Nazzal, 2014).

According to the Standard Test Method for the Use of the DCP in Shallow Pavement Applications ASTM D 2487-11, the US Army Corps of Engineers has developed correlations between the PIV and the materials' CBR. Equation 2.6 for a PIV in millimeters/blow and Equation 2.7 for a PIV in inches/blow present these correlations. These correlations could be used to estimate PIV target values for various granular materials by conducting laboratory CBR tests to determine the CBR at OMC.

$$\mathrm{CBR} = \frac{292}{\mathrm{PIV}^{1.12}} \qquad (2.6)$$

$$\mathrm{CBR} = \frac{292}{(\mathrm{PIV}*25.4)^{1.12}} \qquad (2.7)$$

The Minnesota Department of Transportation (MnDOT) has recently implemented the use of the DCP for compaction quality control in its state and has been field testing the DCP as an acceptance tool for the compaction of pavement edge drain trenches since 1993 (Siekmeier et al., 1998). This included methods and specifications for the use of the DCP to conduct compaction quality control of granular subbase and base course and full depth reclamation. MnDOT has published a user guide for DCP, which it uses as a test procedure for their operations. MnDOT also uses PIV values, which it refers to as the DCP penetration index (DPI) that measures the rate of penetration per blow (MnDOT, 2016). MnDOT uses a correlation between the PIV or DPI and the modulus of the soil to develop target PIVs or DPIs. The correlation is presented in Equation 2.8. The correlation was derived from a South African research organization, Transportek (Lockwood et al., 1992) (Siekmeier et al., 2009).

$$E_{\mathrm{PIV}} = 10^{3.04758-[1.06166\log(\mathrm{PIV})]} \qquad (2.8)$$

MnDOT used this modulus correlation to develop target PIV for the DCP. The moisture content and the soil type have a significant influence on the DCP PR (Siekmeier et al., 2009). Therefore, MnDOT developed a table of target values based on the in-situ moisture content and a mechanistic-based description of soil type. This table of target values is presented in Table 2.2. The grading number (GN) is calculated from the sieve analysis information for the material tested. The equation for calculating the GN is presented in Equation 2.9.

**Table 2.2** Table of target PIV and seating requirements

| Grading Number | MC (%) | Maximum Allowable Seating (mm) * | Maximum Allowable PIV (mm/blow) | Grading Number | MC (%) | Maximum Allowable Seating (mm) * | Maximum Allowable PIV (mm/blow) |
|---|---|---|---|---|---|---|---|
| 3.1 – 3.5 | < 5.0 | 40 | 10 | 4.6 – 5.0 | < 5.0 | 65 | 15 |
| | 5.0 – 8.0 | 40 | 12 | | 5.0 – 8.0 | 75 | 19 |
| | > 8.0 | 40 | 16 | | > 8.0 | 85 | 23 |
| 3.6 – 4.0 | < 5.0 | 40 | 10 | 5.1 – 5.5 | < 5.0 | 85 | 17 |
| | 5.0 – 8.0 | 45 | 15 | | 5.0 – 8.0 | 95 | 21 |
| | > 8.0 | 55 | 19 | | > 8.0 | 105 | 25 |
| 4.1 – 4.5 | < 5.0 | 50 | 13 | 5.6 – 6.0 | < 5.0 | 100 | 19 |
| | 5.0 – 8.0 | 60 | 17 | | 5.0 – 8.0 | 115 | 24 |
| | > 8.0 | 70 | 21 | | > 8.0 | 125 | 28 |

$$GN = \frac{1'' + 3/4'' + 3/8'' + \#4 + \#8 + \#40 + \#200}{100} \qquad (2.9)$$

Where,

Sieve numbers = percent passing each sieve

## 2.6 Device Cost

Table 3 contains the estimated device cost for both density-based devices and stiffness/strength-based devices previously discussed. These estimates were summarized in the NCHRP study (Nazzal, 2014). These cost estimates are for the devices only. The most expensive device was the CH and the least expensive was the DCP.

**Table 2.3** Cost estimates for devices summarized

| Measurement Method | Device | Estimated Device Cost |
|---|---|---|
| Density-Based Devices | Moisture Density Indicator (MDI) | ≈ \$6,000 |
| | Electrical Density Gauge (EDG) | ≈ \$11,500 |
| | Soil Density Gauge (SDG) | ≈ \$10,000 |
| | Nuclear Density Gauge (NDG) | ≈ \$6600 |
| Stiffness / Strength Based Devices | Clegg Hammer (CH) | Device ≈ \$3,000, Complete System ≈ \$20,000 |
| | GeoGauge | ≈ \$5,500 |
| | Light Weight Deflectometer (LWD) | Varies among manufactures. Humboldt Deluxe Model HD-4129.3F ≈ \$7,285 |
| | Dynamic Cone Penetrometer (DCP) | ≈ \$1,500 |

## 2.7 Intelligent Compaction

IC is a compaction technology used for the compaction testing of various materials, including soils, aggregates, and asphalt mixtures. The system is attached to construction compaction equipment and typically uses a real-time kinematic (RTK), global positioning systems (GPS), a roller-integrated measurement system (normally accelerometer-based), feedback controls, and onboard real-time display of all IC measurements (Chang et al., 2011). This type of compaction quality control has been used in Europe since the 1970s, and about 80% of all compaction rollers sold in Europe have some type of continuous compaction control system installed (Zambrano et al., 2006). However, interest in IC in the United States has only become apparent in recent years. These systems' main advantage is that they have the ability to make the requirements for field spot testing and laboratory testing unnecessary (Zambrano et al., 2006).

Briaud and Seo (2003) compiled a list of IC research needs. The list included the need to demonstrate IC as a more effective method of compaction verification over other conventional compaction verification methods. Also on the list was a study of effective depth of compaction and a study of draft standard specifications and test methods. Most of the researchers' needs have currently been met and many states are now field testing IC systems. (Chang et al., 2011) reported the results of 16 field demonstrations performed over a three-year span between multiple states including Minnesota and North Dakota. The goals of the demonstrations were to develop an experienced and knowledgeable IC expertise base within DOTs, assist in developing quality control specifications for compaction of roadway materials, and identify and prioritize ongoing research needs for IC equipment and data analysis.

In 2009, field studies in Springville, NY, evaluated the Caterpillar CS683 and the Bomag BW213-DH IC rollers comparing the IC measurement values with various in-situ point measurement values. Various point measurement devices used were the LWD, FWD, DCP, NDG, and SDG. Weak correlations were found between IC measurements and the various point measurements when stiffness/strength devices were used (White, 2009). IC measurements generally correlated better with modulus/stiffness measurements and CBR point measurements than did dry density point measurements (White, 2009). The results of this study provided new information that demonstrated the potential advantages of implementing IC roller operations and various in-situ testing methods into earthwork construction quality control practices (White, 2009).

## 2.8 Current SDDOT Practices

The following section summarizes the SDDOT's current compaction practices. This includes materials encountered, methods of base course and subbase compaction quality control, and recycled and salvaged material compaction quality control. The current SDDOT Standard Specifications for Roads and Bridges SDDOT (2015a) and interviews with selected members of the SDDOT Technical Panel (SDDOT, 2016) were utilized as the basis for this section.

### 2.8.1 Materials Encountered and Gradation Requirements

The requirements for acceptance of aggregates for granular bases are defined in Sections 882.1 to 882.3 of the South Dakota Department of Transportation Standard Specifications (SDDOT, 2015a). Specific requirements for grain size distribution are provided in Table 2.4. The SDDOT use SD 103 to classify materials according to the AASHTO M 145 classification system.

**Table 2.4** SDDOT Specific Requirements for Aggregate Acceptance (SDDOT, 2015a)

| Requirements | Subbase | Base Course | Limestone Ledge Rock Base Course | Limestone Gravel Cushion |
|---|---|---|---|---|
| Sieve | Percent Passing | | | |
| 6 inch | | | | |
| 2 inch | 100 | | | |
| 1 inch | 70 - 100 | 100 | 100 | 100 |
| 3/4 inch | | 80 - 100 | 80 - 100 | 80-100 |
| 1/2 inch | | 68 - 91 | 68 - 90 | 68-90 |
| # 4 | 30 - 70 | 46 - 70 | 42 - 70 | 42-70 |
| # 8 | 22 - 62 | 34 - 58 | 29 - 53 | 29-53 |
| # 40 | 10 - 35 | 13 - 35 | 10 - 28 | 10-28 |
| # 200 | 0.0 - 15.0 | 3.0 - 12.0 | 3.0 - 12.0 | 3.0-12.0 |

Specific requirements for various milled, reclaimed, and salvaged material are found in Section 884.2 of the South Dakota Department of Transportation Standard Specifications (SDDOT, 2015a). Reclaimed asphalt pavement (RAP) along with salvaged materials, such as subbase, base course, and gravel surfacing, all have the same required specific grain size distribution requirements of 100% must pass the 1.5-inch sieve and 95% to 100% must pass the 1-inch sieve.

According to the SDDOT Minimum Sample and Test Requirements (MSTR), when quality tests are required by specification, one sample per 50,000 tons shall be submitted to the SDDOT's laboratory for testing. Aggregate production from the same source used by one or more projects at the same time only require a single minimum test frequency for quality assurance. The sample size is specified as 120 pounds in four bags. Tests are not required for quantities less than 100 tons per day or 500 tons per project (SDDOT, 2015a).

## 2.8.2 Methods of Base Course and Subbase Compaction Quality Control

SDDOT's current methods for compaction control of various granular material is defined in Section 260.3 of the South Dakota Department of Transportation Standard Specifications (SDDOT, 2015a). Base Course material is to be compacted to 97% of maximum dry density. The maximum dry density is determined by the SD 104 Method 4 (SDDOT, 2015b), which has close relation to the AASHTO T 272-15 (AASHTO, 2015c). This method is known as a one-point determination used for more rapid determination of target density when compared with the AASHTO T 180 (AASHTO, 2015c), which is the four-point equivalent. The method requires compacting a single point at approximately optimum moisture in a standard 6-inch mold in a similar manner to the AASHTO T 99 (AASHTO, 2015b). A wet density and moisture are determined for the single point and entered into the family of compaction curves. The curve closest to the wet density and optimum moisture is then adopted as the family curve for that material. The corresponding dry density is then adopted as the target density for the material tested. The SDDOT currently requires a one-point determination for every in-place density test conducted to establish an individual target density for each test. The one-point determination uses material from or adjacent to the hole for each in-place test. If the one-point moisture content deviates from optimum (for the curve selected) by more than 2 percentage points below or 1 percentage point above, a second one-point is required at or nearer to optimum and within the tolerance stated by the SD 104 (SDDOT, 2015b).

Prior to the first in-place density test, a single four-point determination of maximum dry density and optimum moisture is determined for the base course materials to be tested. The four-point determination is conducted in accordance with the SD 104 Method 3 (SDDOT, 2015b). A four-point determination is required to verify if the family of compaction curves is suitable for the material. Once a four-point determination of dry density and optimum moisture is determined, it is compared with the one-point determinations required for each in-place density. When the one-point determination deviates more than 3 pounds from the four-point results, another one-point determination is conducted. Similarly, if moisture in the one-point determination deviates more than 2 percentage points below or 1 percentage point above optimum moisture, another one-point (nearer to optimum moisture) or a new four-point determination should be conducted.

In-situ field density of base course and subbase is determined by one of the following methods:

1) SD 105: Density of Soils/Granular Material In-place by Sand-Cone Method (SDDOT, 2015c)
2) SD 110: Density of Granular Material by Modified Sand-Cone Method for Thin Layers (SDDOT, 2015d)
3) SD 114: Determination of In-place Density of Soils and Aggregates by Nuclear Method (SDDOT, 2015e)

The most common test method for base course materials in South Dakota is SD 105 (SDDOT, 2015c). Each of SDDOT's four regions contains six NDG totaling 24 gauges in all (SDDOT, 2016). In-place density tests are conducted every mile, per lift, per roadbed surface just prior to application of prime or subsequent course according to the SDDOT MSTR (SDDOT, 2015a).

### 2.8.3 Methods of Recycled and Salvaged Compaction Quality Control

A growing practice of the SDDOT is recycling or reclamation of pavement surfaces, base courses, and subbases. Materials classified as recycled materials can be placed into a stockpile while materials classified as reclaim remain in place and are used to form the new road bed. FDR is defined by the processing and blending of the asphalt mix and granular base material and placing, watering, shaping, and compacting the material to the typical section (SDDOT, 2015a). The materials are to meet the standard specifications of asphalt mix and granular base materials outlined in Section 884.3 of the South Dakota Department of Transportation Standard Specifications (SDDOT, 2015a). The FDR process is outlined in Section 280 of the SDDOT Standard Specifications, Section 280.B, and states that material is to be placed in a minimum of two lifts and lift thickness shall not exceed 4 inches in depth (SDDOT, 2015a).

"Section 280.3.C. Compaction and Density Requirements" states that each compacted layer shall meet a minimum of 95% of the target dry density established by Method SD 219 (SDDOT, 2015f) and material shall have a minimum moisture content of 4% uniformly blended throughout the depth of the lift of material (SDDOT, 2015a).

Method SD 219 requires use of a test strip with a minimum length of 500 feet. Four tests sites are selected throughout the test strip (typically in the middle 300 feet). An NDG calibrated and standardized in accordance with SD 114 (2015e) is used to determine the wet density at each test location within the test trip. The test rod of the NDG is inserted into the material so that it is as close to the bottom of the lift as possible but not within 1 inch of the bottom of the layer. Once density is measured, a roller makes four passes over the test strip "one series." After completion of four passes or one series, the NDG is again used to measure wet density at each test location. The average wet density of each series is recorded on the DOT-28 test form. This process is repeated for each series until the increase in average wet density is less than 1.0-pcf. At this time, samples of the material directly below the four NDG test locations are immediately placed in an airtight container for moisture testing. SD 108 is an oven drying method used to determine the moisture content of the material (SDDOT, 2015g). The target dry density is then determined by averaging the four dry density measurements. A minimum of one test strip is performed for each lift. However, the field technician can require additional test strips when there is a significate change in aggregate type, weather conditions, or other controlling factors to check target density. The test strip becomes part of the constructed roadway upon completion of the work (SDDOT, 2015a).

In-place density determinations using Method SD 219 are performed using the NDG. These tests are conducted in the same manner as those previously discussed to determine dry density of the test strip. Moisture determination is conducted for each in-place density test using Method SD 108: Oven Drying Method, and the dry density and percent compaction is subsequently calculated (SDDOT, 2015a).

# 3. DATA COLLECTION AND ANALYSIS

The SDDOT currently uses both four-point moisture density relations and one-point moisture density determinations when conducting granular compaction quality control. The one-point moisture density determinations are plotted on the Ohio Highway Department's Typical Moisture-Density Curves, Set C to obtain target density and OMC as previously discussed in Chapter 2. These curves were the third iteration of a family of compaction curves originally developed for a similar one-point method utilized by the Ohio Highway Department when working with cohesive soils. The SDDOT has since adopted this family of compaction curves and added additional interpolated compaction curves.

During typical granular base and subbase compaction quality control by the SDDOT, four-point moisture density relations are used to verify the use of the family of compaction curves. Then the one-point method described in Chapter 2 is utilized with the Ohio Highway Department's Typical Moisture-Density Curves, Set C to determine target densities. The SDDOT wishes to know if this family of compaction curves is adequate for predicting target density and OMC values for base and subbase granular materials encountered in South Dakota.

## 3.1 Analysis Goals

The development of the Ohio Highway Department's Typical Moisture-Density Curves, Set C was documented in Section 2.3.1 and their use by the SDDOT was documented in Section 2.8.2. This chapter presents the analysis of SDDOT data used to evaluate the Ohio Highway Department's Typical Moisture-Density Curves. This chapter also summarizes the results of a survey administered to other state DOTs to learn more about their compaction practices. Information obtained from the analysis helped evaluate the following questions:

- Should the SDDOT continue to use the Ohio Highway Department's Typical Moisture-Density Curves?
- Should new curves be used by the SDDOT?
- Should other methods other than those currently used by the SDDOT be utilized in determining target density of granular materials?

Therefore, the goal of the data analysis was to provide input that would support answers to these questions. It was first necessary to create a family of compaction curves based solely on four-point compaction data provided by the SDDOT. From these curves, a line of optimums was created allowing for an evaluation of the Ohio Highway Department's Typical Moisture-Density Curves. The new curves were created using data provided by the SDDOT from laboratory moisture density relations of base course and subbase granular soils encountered in South Dakota. The line of optimums of these new compaction curves was then compared with the line of optimums of the Typical Moisture-Density Curves, Set C. This provided a comparison of the differences between maximum dry unit weight and OMC of South Dakota base course and subbase granular material testing and the line of optimums of the Ohio Highway Department's Typical Moisture-Density Curves, Set C. The difference in the corresponding dry unit weight of the two lines of optimums was then statistically tested for differences. The magnitude of this difference could then be quantified.

Standard statistical modeling in engineering usually limits error rates at 5% to 10%. Therefore, a 95% prediction interval on the maximum dry unit weight and OMC of base course and subbase granular materials encountered in by the SDDOT was also developed. The prediction interval indicated a region in which 95% of all base course and subbase granular maximum dry unit weights and OMCs observed by the SDDOT would likely plot. This interval was constructed to provide evidence that would support the adequacy or inadequacy of using the Ohio Highway Department's Typical Moisture-Density Curves. The interval could also provide evidence for the adequacy or inadequacy of any family of compaction curves for which a comparison is made. Lines of optimums that fall within this region may be more adequate when utilized for granular compaction quality control by the SDDOT.

## 3.2 Data Collection and Conditioning

The data used for the analysis were provided by the SDDOT and presented in Appendix B. The data consisted of records of both field and laboratory material testing data. Discarded data included data with unidentifiable errors and incomplete data as will be discussed. This resulting dataset provided a representation of actual SDDOT testing results and provided sampling of South Dakota granular materials.

The SDDOT provided data contained on the DOT-3, DOT-28, DOT-40, and DOT-41 forms from the years 2001 to 2016. The data forms provided are defined in Table 3.1 with examples of each form provided in Appendix B. The data were imported into a spreadsheet format for further analysis. The data fields were evaluated for use in the analysis which was then reviewed by the SDDOT. A table was created for the various data fields along with a general description, definitions, and if the data was deemed useful for this study. These tables can be found in Appendix B. The data was then conditioned by removing data not used in evaluating the goals of the research.

**Table 3.1** Defined SDDOT Data Forms

| Data Form | Definition |
|---|---|
| DOT - 3 | Sieve analysis data for all material types. |
| DOT - 28 | Test strip data for recycled material. |
| DOT - 40 | Moisture density relations for all materials. |
| DOT - 41 | In-situ density testing data utilizing all testing methods. |

Data pertaining to moisture density relations created from base course and subbase materials were of primary interest to this research. Moisture density relations are currently used by the SDDOT to verify the use of a family of compaction curves. Sieve analysis data may have provided general information indicating the drainage parameters of the various granular materials. This could have provided difference between field moisture contents before and after field compaction. Section 2.1.2 discusses the differences in moisture content between semi-draining and free-draining granular materials in further detail. However, given the format of the data, individual sieve analysis information could not be accurately related to individual moisture density relations. This made incorporating sieve analysis data into the analysis impossible. The nature of the test strip data did not allow for the development of compaction curves but may have provided a range of expected maximum density values for recycled materials encountered by the SDDOT. However, this information would be of little value to the current practices of the SDDOT. The SDDOT also does not use test strip data in junction with moisture density curves (SDDOT, 2015a). Therefore, the test strip data was not usable in the analysis.

Extensive conditioning was conducted on the data pertaining to moisture density relations. The conditioning was necessary for several reasons. The research focused on granular materials and the provided data consisted of moisture density relations of all material types. Unrelated data types were deleted. The data did not contain wet and dry unit weight values and moisture contents for individual moisture density relations. However, the data contained all necessary information to calculate these values. To compare the data to the Ohio Highway Department's Typical Moisture-Density Curves these missing values were calculated. The data also contained duplicated moisture density relations. This is likely the result of the SDDOT's use of the same moisture density relations on various project sites when the same material is used (SDDOT, 2015a). The duplicated relations were removed to ensure there was no data skew. The data also contained various levels of data input errors. These errors consisted of unreasonable numbers contained in the data or missing data all together that made accurate determinations of wet and dry density or moisture content impossible. Data with more than 6 moisture density points were removed from the analysis as it would add unnecessary complications to the determination of maximum dry density and OMC. Careful consideration was also made regarding various comments provided for some of the data points provided. Comments that indicated voided or discarded test points were removed when possible. The technical panel also informed the research team that several moisture density relations were examples only and did not reflect real tests. These example tests were also removed. The conditioning prepared the data for comparison to the Ohio Highway Department's Typical Moisture-Density Curves.

The data conditioning process was conducted using Microsoft Excel 2016 with the utilization of Visual Basic Application (VBA) macro programming. The moisture density relation data were imported to a filter table for preliminary data conditioning and the data header "Material Group" was used to filter out all data that did not consist of base course or subbase materials. Salvaged base course and subbase materials were also included. Sample identifiers such as headers "Main PCN," "Contract ID," "Sample ID," and "Test #" were used to organize data origins if necessary. All data not required to calculate the wet unit weight, dry unit weight, and moisture content for each point was removed from the dataset. A VBA macro was used to search and eliminate duplicate data. The macro searched through the column labeled "Sequence Number" and removed entire rows of data that had two consecutive same numbers, indicating a duplicate. The conditioned dataset was checked for quality by manually verifying 10% percent of the dataset.

Wet and dry unit weights were calculated for 2,506 moisture density points resulting in 474 moisture density compaction curves. The next step in the conditioning process was to determine the maximum dry unit weight and OMC of each laboratory moisture density relation. The data were then reorganized into groups of increasing maximum dry unit weight. The majority of the relations based on four points. However, there were also several moisture density relations based on five points. According to SD 104 (SDDOT, 2015b), a smooth curve is to be drawn to connect points established by plotting the results of four or more test points. Therefore, to produce the large number of four point laboratory moisture density relations, a third degree polynomial was utilized to fit each curve for determination of the maximum dry unit weight. This would result in a coefficient of determination of 1.0 and the average coefficient of determination value for five point relations at 0.9575. Various statistics were calculated for each fitted curve, including:

- Standard error values for coefficients, and constants
- Coefficient of determination
- F-statistic
- Degrees of freedom
- Regression sum of squares
- Residual sum of squares

The curve fitting coefficients were then used to calculate the maximum dry unit weight of each moisture density relation. From the coefficients, the local maximum of the fitted curve was calculated. The derivative of each equation with its calculated coefficients and moisture density points was used to determine the maximum point on the curve or peak. VBA macros were created to streamline processing.

The creation of a family of compaction curves was performed by grouping laboratory moisture density relations data by two pcf increments of maximum dry unit weight. Two pcf was recommended by the AASHTO T 272-15 Family of Curves-One-Point Method (AASHTO, 2015f). Figure 3.1 shows all 2,506 data points organized into increments of maximum dry unit weight ranging from 118-pcf to 144-pcf. The data points in each increment were then used to construct a curve representing each increment and create a line of optimums.

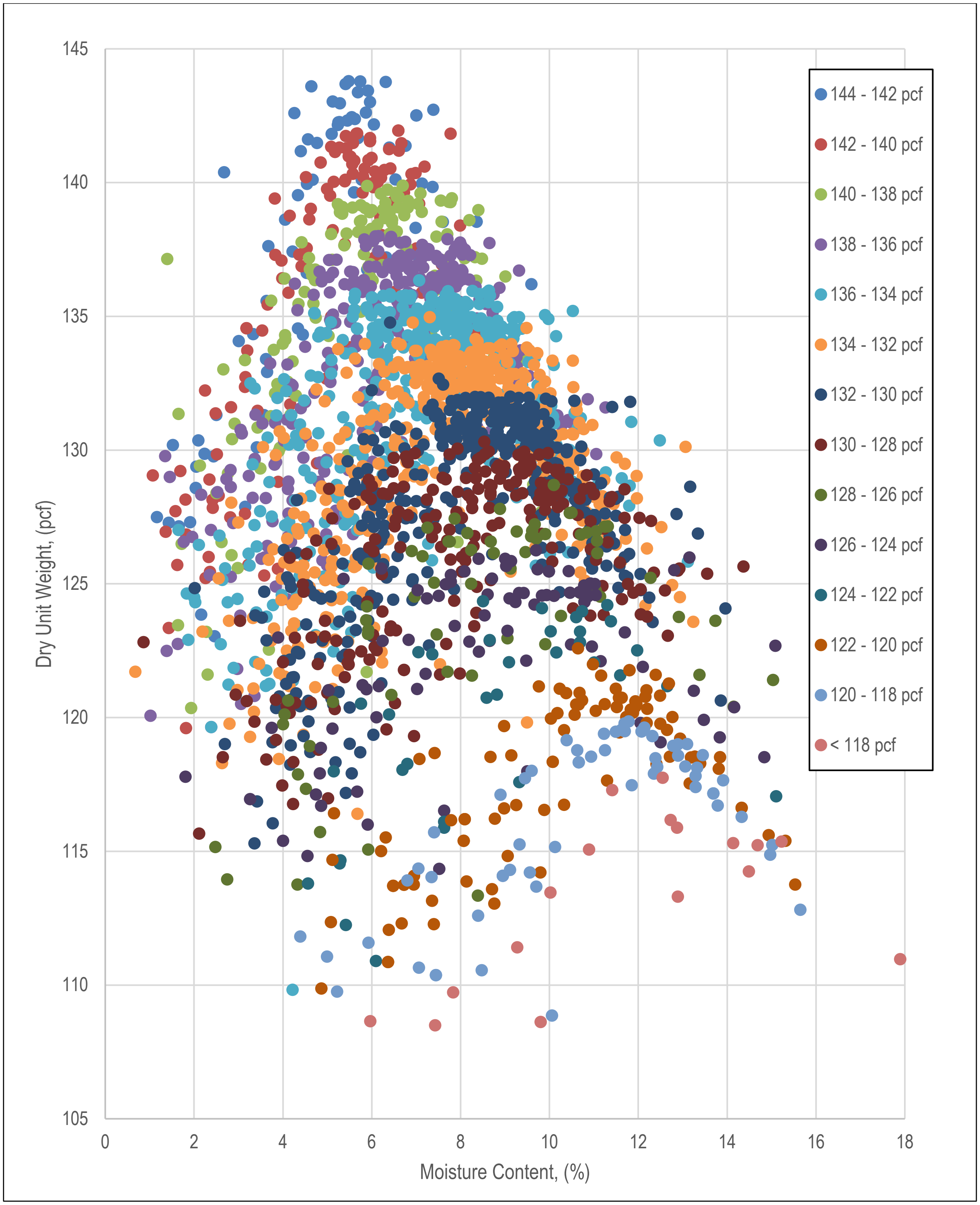


**Figure 3.1** Plotted points used in the analysis

Once separated into two pcf increments, a third-degree polynomial regression curve was used to construct a typical compaction curve for each increment of two pcf of dry unit weight. A third-degree polynomial was determined to have the most appropriate shape characteristics for fitting moisture density curves. The third-degree regression curve also provided the lowest square error, indicating an acceptable fit for the data. The curves were fitted using the least square error method.

The analysis showed that the maximum point on each grouped compaction curve was slightly below a large majority of the individual moisture density relations maximum values. This resulted in the fitted curves being lower than the data points on either side of the maximums as shown in Figure 3.2. The field one-points would correspondingly plot above the appropriate curve. If the maximum dry density and optimum moisture were used from the curve below the plotted one-point, it would under-predict the level of compaction required. Therefore, the average maximum dry density and average OMC were used to construct the curve. When plotting a one-point determination, the curves should act as regions rather than target curves. The one-point should plot on or above a particular curve. Once a curve is identified to use, the tabulated values of the average maximum density and average optimum moisture should be used for the selected curve as the target density and OMC for field testing. Figure 3.2 shows the fitted regression curve for moisture density relations with maximum dry unit weights between 128-pcf and 130-pcf. The orange points are the maximum dry unit weights of the various moisture-density relations and the green point represents the average of all the maximum dry unit weights. If the vertex of each constructed grouped curve was used as the target density and OMC, it may under-estimate the required compaction. Therefore, if the constructed grouped curves are to be used in compaction quality control, the fitted typical curves will act as the boundaries between each incremental region. Therefore, average maximum dry unit weight and OMC for each bounded region was utilized as the target density and OMC for field testing.

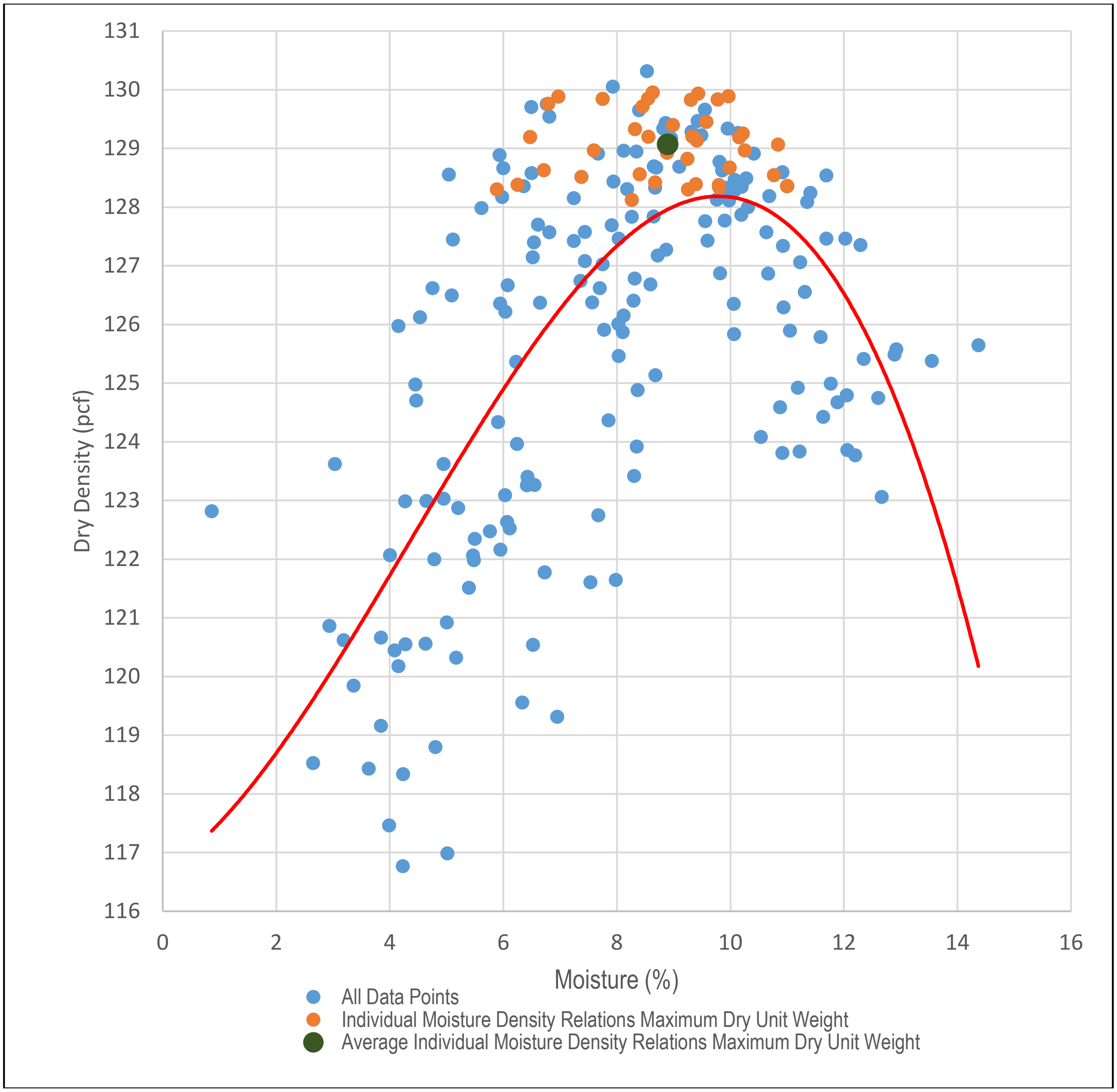


**Figure 3.2** Observed skewed curve phenomenon

The new family of compaction curves contained 14 grouped compaction curves ranging in maximum dry unit weights between 118-pcf and 144-pcf, and the OMC ranged from 6.52% to 13.86%. Each curve was designated a letter from A to N. As previously stated, the new curves were created using a third order polynomial in the following form with the following coefficients: $\gamma_d = aMC^3 + bMC^2 + cMC + d$. The coefficients for each curve are presented in Table 3.2.

Table 3.3 summarizes the family of compaction curves developed in the analysis, which includes the total number of data points, total number of moisture density relations, along with regression coefficients for each fitted curve. These curves were then plotted together to form a line of optimums to be compared to the Ohio Highway Department's Typical Moisture-Density Curves line of optimums. The new curves line of optimums is shown in red on Figure 3.3. Note that the curves in Figure 17 represent the 25% quartile on both sides of the OMC, thus, limiting each curve to the extent of the moisture contents within 25% of the OMC on both the high and low sides of optimum.

**Table 3.2** Curve Coefficients

| Dry Unit Weight Curve | | Curve Coefficients | | | |
|---|---|---|---|---|---|
| Designation | Dry Unit Weight Range, pcf | a | b | c | d |
| A | 144-142 | -0.0432 | 0.0125 | 5.3458 | 118.28 |
| B | 142-140 | -0.0975 | 0.8383 | 1.5279 | 121.69 |
| C | 140-138 | -0.0912 | 0.9955 | -0.6101 | 125.21 |
| D | 138-136 | -0.0546 | 0.6085 | 0.3052 | 122.28 |
| E | 136-134 | -0.0182 | 0.0211 | 3.2200 | 115.85 |
| F | 134-132 | -0.0291 | 0.3078 | 1.3122 | 116.58 |
| G | 132-130 | -0.0190 | 0.1073 | 2.8738 | 109.52 |
| H | 130-128 | -0.0182 | 0.2360 | 0.6080 | 116.68 |
| I | 128-126 | -0.0063 | -0.0573 | 3.1698 | 106.51 |
| J | 126-124 | -0.0120 | 0.1615 | 0.5673 | 114.41 |
| K | 124-122 | -0.0158 | 0.2058 | 1.2603 | 105.23 |
| L | 122-120 | -0.0457 | 1.1763 | -8.4413 | 131.32 |
| M | 120-118 | -0.0496 | 1.3462 | -10.438 | 135.94 |
| N | < 118 | -0.0192 | 0.5216 | -3.4001 | 113.58 |

**Table 3.3** Summary data of new SDDOT Moisture-Density Family of Curves

| Maximum Dry Unit Weight Range | Curve Letter | Maximum Dry Unit Weight of Fitted Curve | Optimum Moisture Content of Fitted Curve | Average Maximum Dry Unit Weight of Individual Moisture-Density Relation Range | Average Optimum Moisture Content of Individual Moisture Density Relation Range | Number of Plotted Data Points | Number of Moisture Density Relations | Regression Coefficient of Fitted Curve |
|---|---|---|---|---|---|---|---|---|
| 142 - 144 | A | 141.7 | 6.5 | 143.1 | 5.9 | 78 | 15 | 0.7342 |
| 140 - 142 | B | 140.3 | 6.5 | 141.0 | 6.0 | 128 | 25 | 0.7494 |
| 138 - 140 | C | 138.4 | 7.0 | 139.0 | 6.4 | 145 | 28 | 0.6023 |
| 136 - 138 | D | 135.8 | 7.7 | 136.8 | 7.1 | 306 | 59 | 0.5564 |
| 134- 136 | E | 133.6 | 8.1 | 135.0 | 7.5 | 409 | 79 | 0.4641 |
| 132 - 134 | F | 132.1 | 8.6 | 133.1 | 8.2 | 454 | 88 | 0.5394 |
| 130 - 132 | G | 130.3 | 9.2 | 131.1 | 8.7 | 400 | 76 | 0.6097 |
| 128 - 130 | H | 128.2 | 9.8 | 129.1 | 8.9 | 220 | 40 | 0.4934 |
| 126 - 128 | I | 126.2 | 10.3 | 127.0 | 9.4 | 66 | 12 | 0.5905 |
| 124 - 126 | J | 124.3 | 10.5 | 125.1 | 9.5 | 86 | 15 | 0.417 |
| 122 -124 | K | 123.0 | 11.1 | 123.1 | 10.2 | 34 | 6 | 0.6198 |
| 120 - 122 | L | 120.4 | 12.1 | 120.8 | 11.6 | 100 | 17 | 0.7319 |
| 118 - 120 | M | 118.9 | 12.5 | 119.3 | 12.2 | 63 | 11 | 0.7227 |
| < 118 | N | 115.6 | 13.9 | 116.4 | 13.5 | 17 | 3 | 0.7341 |
| Average Regression Coefficient of Fitted Curves | | | | | | | | 0.6118 |
| Total Data Points Plotted | | | | | | | | 2506 |
| Total Moisture Density Relations Plotted | | | | | | | | 474 |

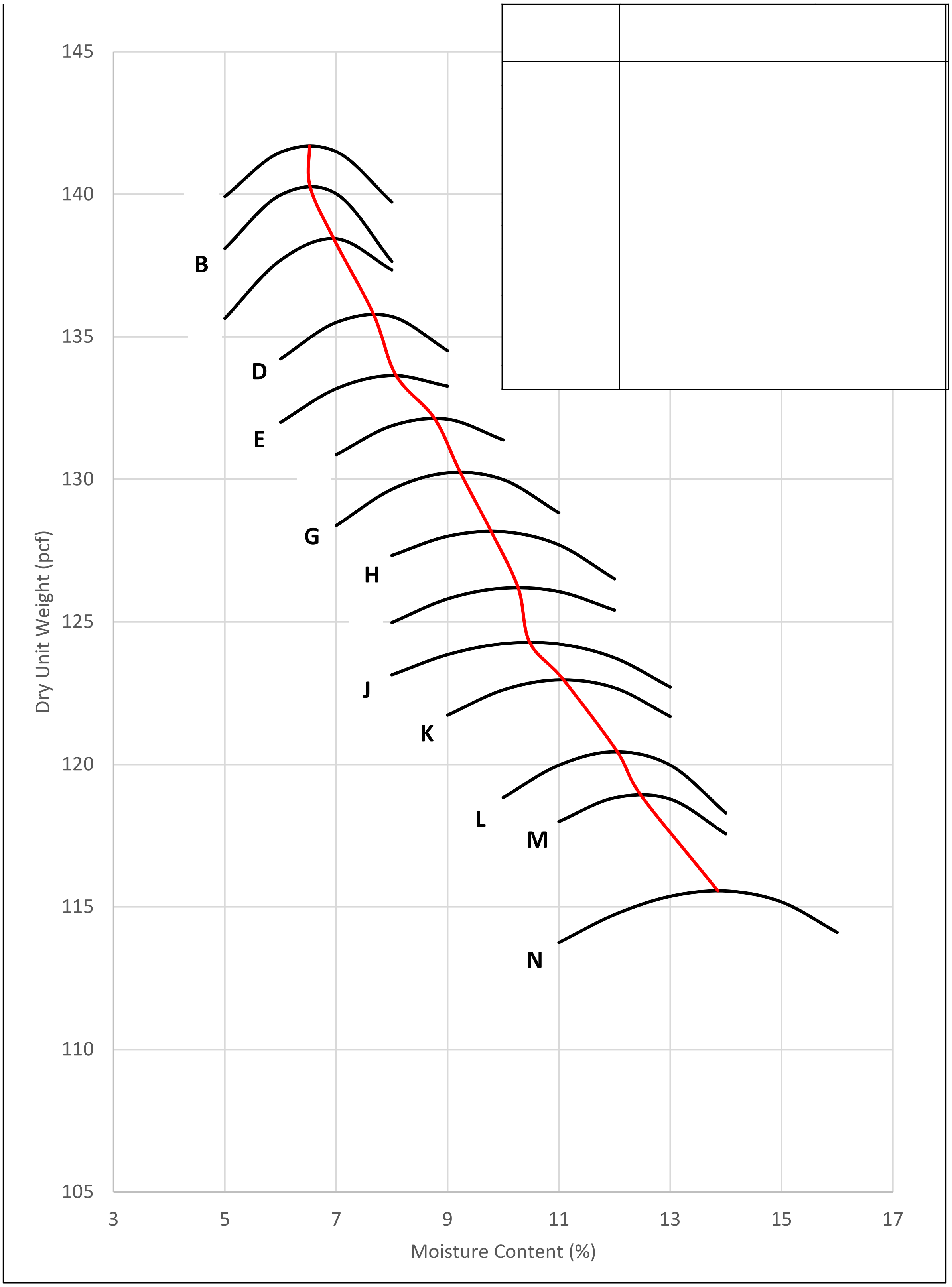


**Figure 3.3** Line of optimums (red line) of fitted curves for new SDDOT Moisture-Density Family of Curves

## 3.3 Lines of Optimums Comparison

The following section documents the statistical analysis used to analyze the relationship between the Ohio Highway Department's Typical Moisture-Density Curves, base course, and subbase granular materials encountered by the SDDOT. This consisted of determining the magnitude of difference in the line of optimums of the Ohio Highway Department's Typical Moisture-Density Curves and the line of optimums determined by base course and subbase granular materials encountered by the SDDOT. Figure 3.4 shows the lines of optimums in the comparison. Although there is a visual difference between the lines, they were statistically tested for significances and magnitude. From visual observation, the Ohio Highway Department's Moisture Density Curves may overestimate compaction. Section 3.4E of the SDDOT Materials Manual Method 104 states that if the maximum density determined by the Ohio Highway Department's Typical Moisture-Density Curves deviates more than 3-pcf from the four-point range, the region materials engineer shall be contacted (SDDOT, 2015b). Therefore, Figure 3.4 also presents dotted lines representing ±3-pcf from line of optimums created from four-point compaction data of SDDOT granular material. The line of optimums of the Ohio Highway Department's Typical Moisture-Density Curves plots outside of this range from 125-pcf to 132.5-pcf and follows just slightly inside this range from 132.5-pcf to 141-pcf. This indicates that the Ohio Highway Department's Typical Moisture-Density Curves may not be adequate for SDDOT granular material.

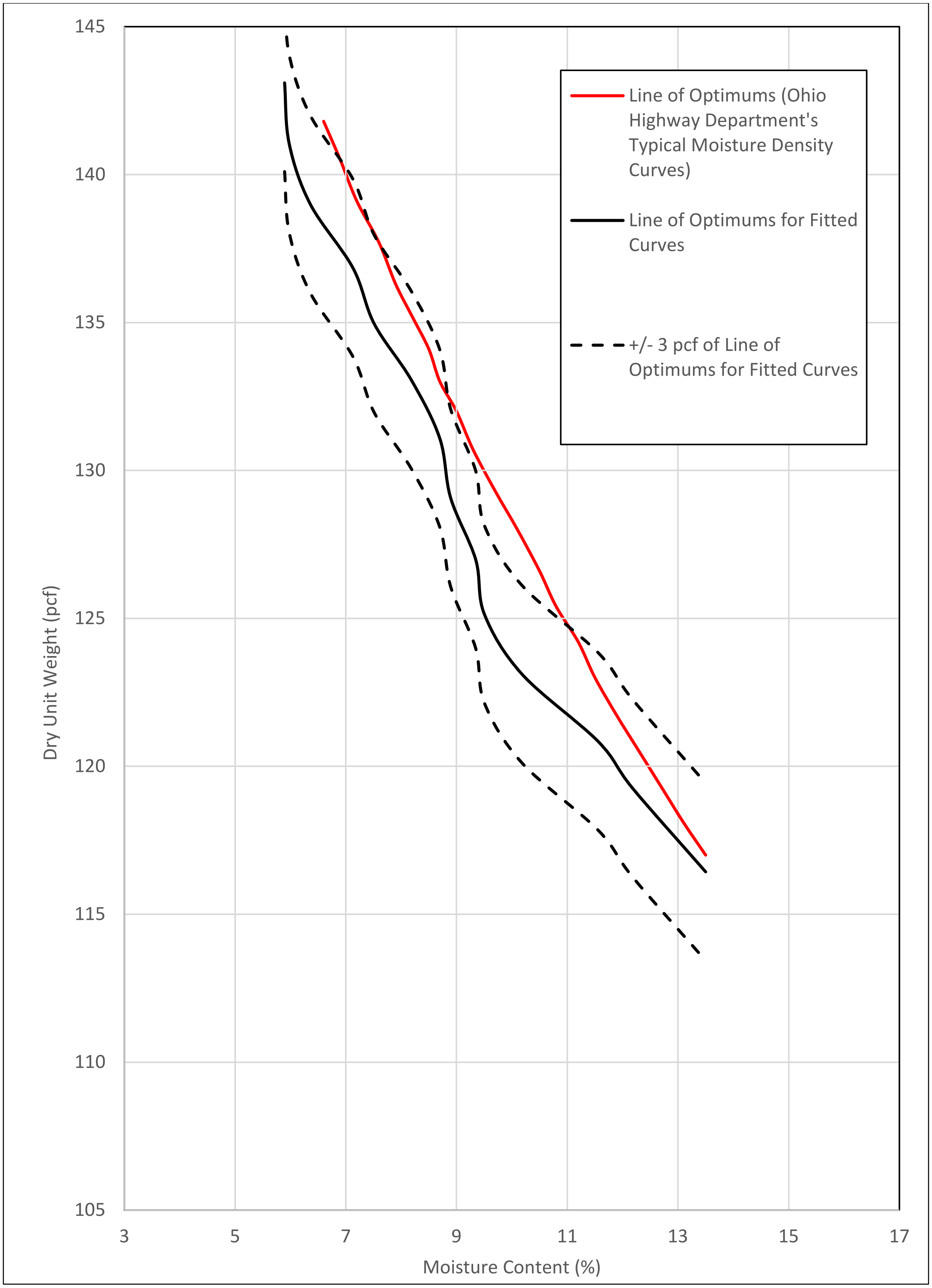


**Figure 3.4** Lines of Optimums Used in Comparison Analysis

A standard t-test was utilized to determine if there was a significant difference in the line of optimums of the Ohio Highway Department's Typical Moisture-Density Curves and the line of optimums of the newly created curves. A t-test is a statistical hypothesis test used to determine if two sets of data are significantly different from each other. Dry unit weights on each line of optimums were obtained at randomly selected moisture contents. The difference in maximum dry unit weight were averaged and statistically compared to zero. The following hypotheses were used to test if the average difference, $\mu$ was significant.

$$H_0: \mu = 0$$

$$H_1: \mu \neq 0$$

The null hypothesis, $H_0$ stated that the average difference was not significantly different than zero at a 95% confidence level. The analysis was to disprove the null hypotheses by providing evidence that indicates a significant difference. Table 3.4 presents the moisture contents and dry unit weights sampled including the calculated difference in dry unit weight between the lines of optimums. Moisture contents sampled ranged from 7 to 13 percent. The observed difference in dry unit weight ranged from 1.0-pcf to 4.8-pcf. The mean difference was 2.8-pcf which was statistically proven to be different than zero at a 95 percent confidence level. The t-statistic was 6.38-pcf which was within the rejection region of ±2.44 pcf. The test statistics are shown in Table 3.5.

**Table 3.4** Samples used for lines of optimums comparison

| Predictor Values Moisture Content, % | Ohio Dry Density Line of Optimums (Maximum Dry Unit Weight, pcf) | SD Materials Line of Optimums (Maximum Dry Unit Weight, pcf) | Difference in Maximum Dry Unit Weight, (pcf) |
|---|---|---|---|
| 7 | 140.0 | 137.2 | 2.8 |
| 8 | 136.0 | 133.6 | 2.4 |
| 9 | 132.0 | 128.8 | 3.2 |
| 10 | 128.4 | 123.6 | 4.8 |
| 11 | 124.9 | 121.7 | 3.2 |
| 12 | 121.8 | 119.6 | 2.2 |
| 13 | 118.5 | 117.5 | 1.0 |

**Table 3.5** t-Test Statistics

| Test Statistics | | | | |
|---|---|---|---|---|
| Mean Difference (pcf) | Sample Variance (pcf) | Number of Samples | T-Statistic (pcf) | Rejection Region (pcf) |
| 2.8 | 1.34676025 | 7 | 6.38 | ±2.4469 |

The test had $n$-1 degrees of freedom and a 95 percent confidence level was selected. As previously stated, the calculated test statistic was within the determined rejection region. Therefore, the null hypothesis was rejected at a 95 percent confidence level. This indicates that on average, the line of optimums of the Ohio Highway Department's Typical Moisture-Density Curves may be overestimating the level of compaction required for adequate levels of compaction by nearly three pcf. This would contribute to a 2 to 2.5 percent difference in maximum dry unit weight predictions. The results would require over compaction in the field in order to meet target densities determined by the currently used Ohio Highway Department's Typical Moisture-Density Curves.

## 3.4 Determining Adequacy of Families of Curves

The SDDOT currently compares the maximum unit weight and the OMC of four-point compaction data to the Ohio Highway Department's Typical Moisture-Density Curves to determine if the curves are valid to be used. Therefore, this study was interested in constructing a region or prediction interval in which 95% of all maximum dry unit weights of base course and subbase materials encountered by the SDDOT would occur. The line of optimums of any family of compaction curves could then be plotted with this interval. Families of compaction curves line of optimums that plot within this region may be considered potentially valid for use with the South Dakota granular base course and subbase materials.

The creation of a prediction interval for South Dakota granular material requires the data be normally distributed. Therefore, histograms were created for all the maximum dry unit weights and OMCs. These data were obtained from all the previously used moisture density relations, which included base course and subbase granular material. The histograms are presented in Figure 3.5 and Figure 3.6. Although the data representing dry unit weights appear to have a slight rightward skew, the data appear to be normally distributed.

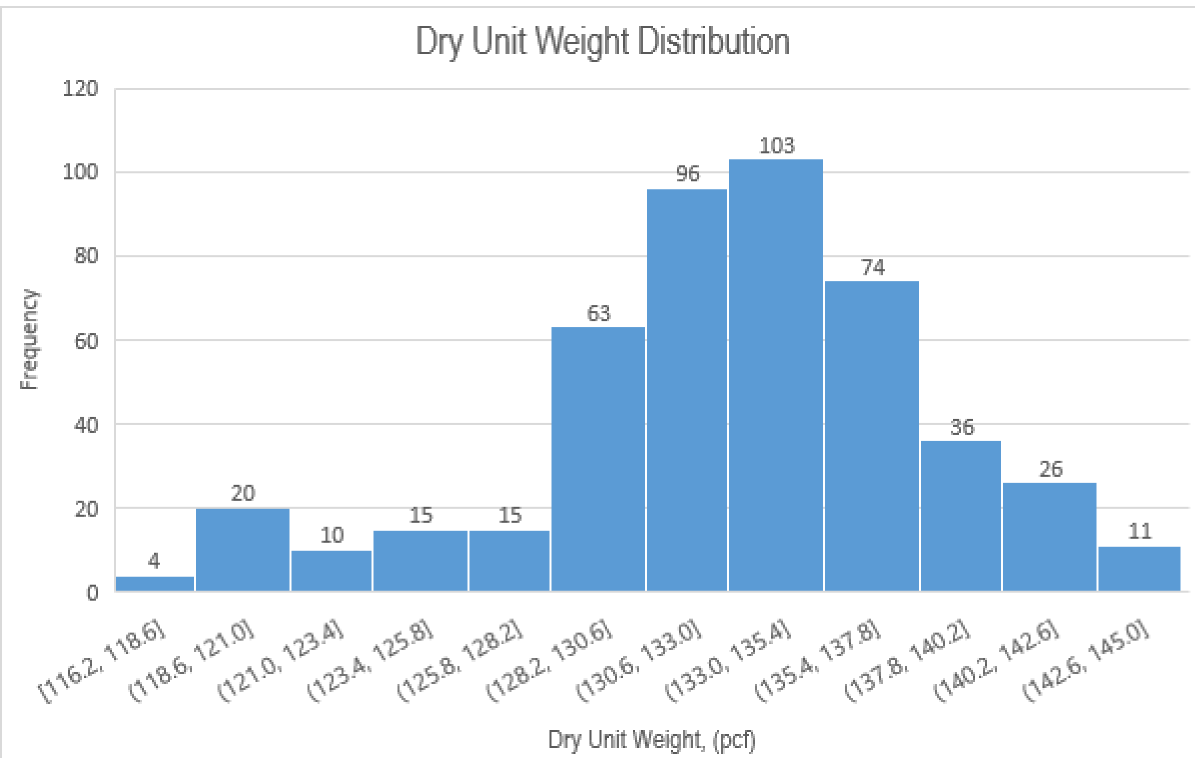


**Figure 3.5** Dry Unit Weight Distribution

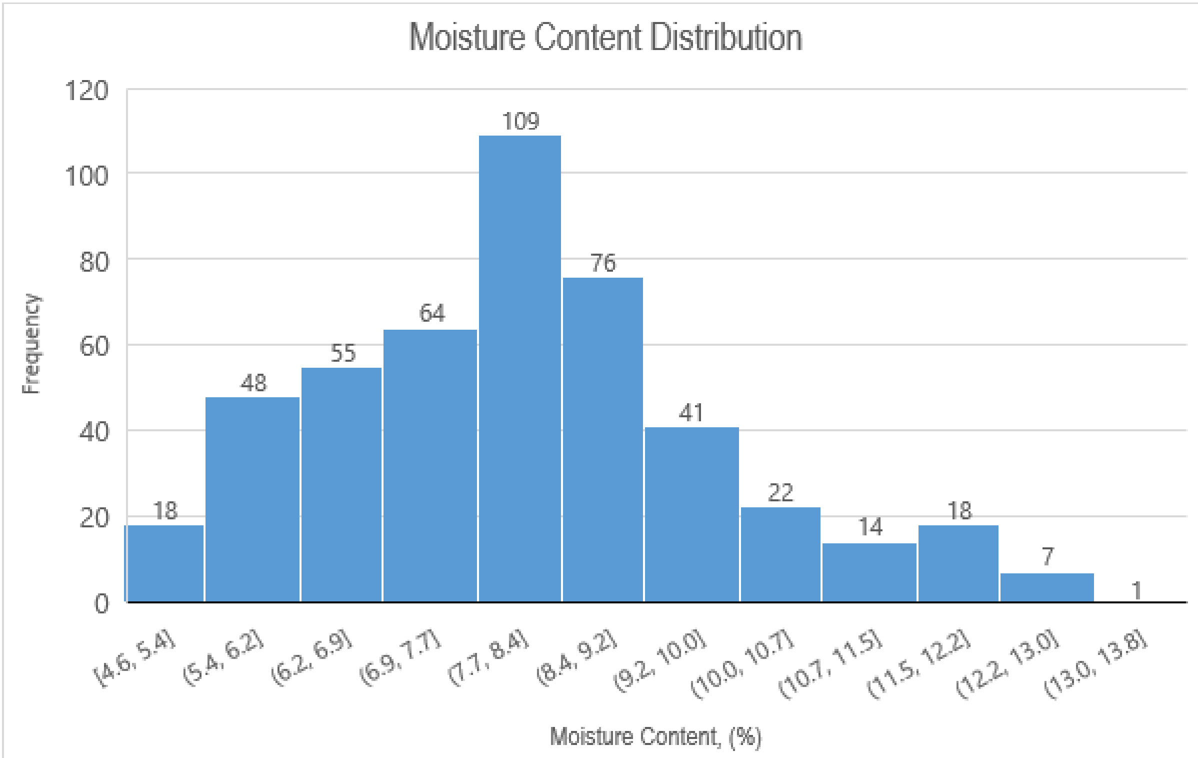

**Figure 3.6** OMC Distribution

The data were then plotted and fitted with several regression models. The regression lines were fitted using the least squares method. It was found that linear, third degree polynomial, and exponential regression models all had low standard and residual standard errors with adjusted coefficients of determination all above 0.60. Each of the regression models are presented in Figure 3.7 along with the equation for the model and the coefficients of determination. The blue points represent the maximum dry unit weights and OMCs of 474 granular base course and subbase SDDOT moisture density relations used to develop the family of compaction curves. The coefficients of determination for the various models ranged from 0.6407 to 0.6641. The coefficient of determination measures the proportional reduction in variability about the average resulting from the fitting of the regression model.

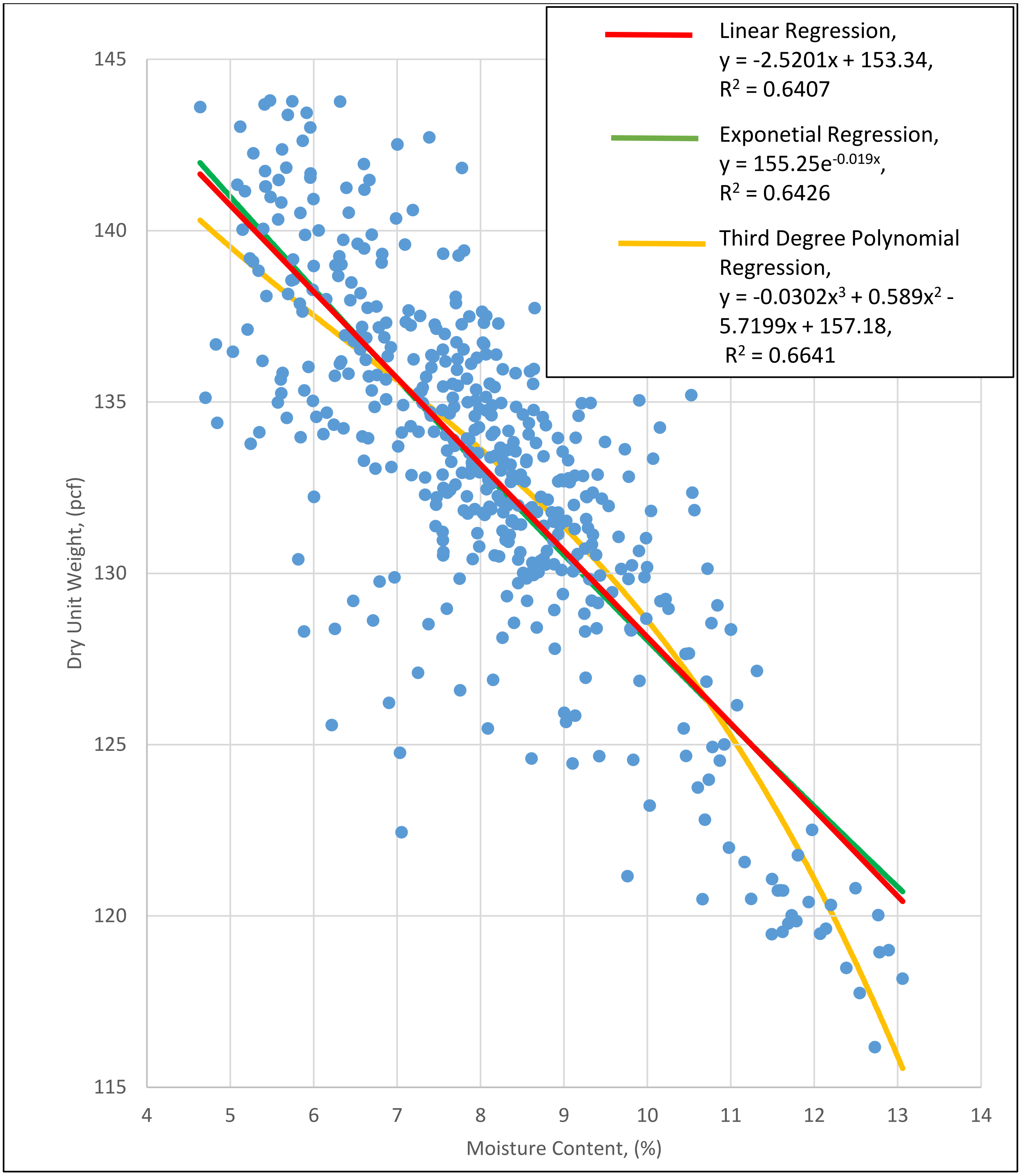


**Figure 3.7** Fitted regression lines for granular moisture density relations

The residual and standardized residual plots were also analyzed for each model. The residuals represent the measured difference between the observed and predicted dependent variable, which for this case was dry unit weight. The residual plots are presented in Figure 3.8 through Figure 3.10 and the standardized residual plots are presented in Figure 3.11 through Figure 3.13. The plots were examined to confirm that the residuals were random and not conforming to any observed structure or trend within the data. Observed trends or structures would indicate an invalid model was fit for the data. The orange points shown in the standardized residual plots are considered outliers because they are outside three standard deviations.

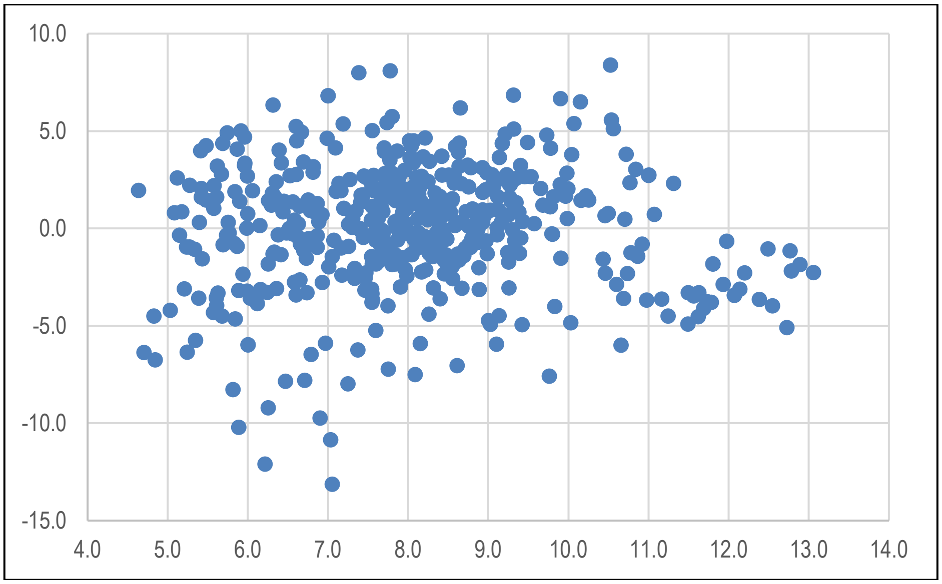


**Figure 3.8** Residual plot for the linear regression model

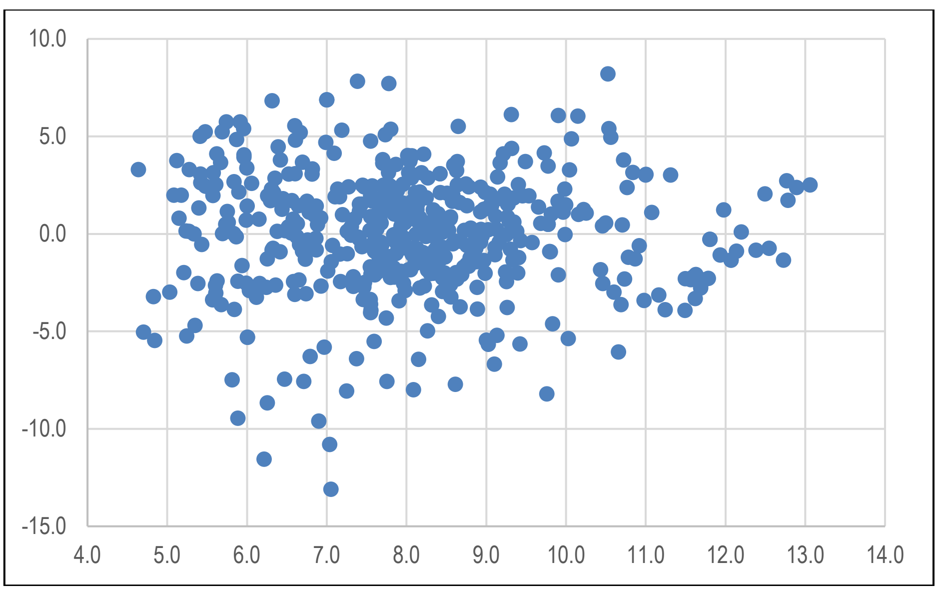


**Figure 3.9** Residual plot for the third degree polynomial model

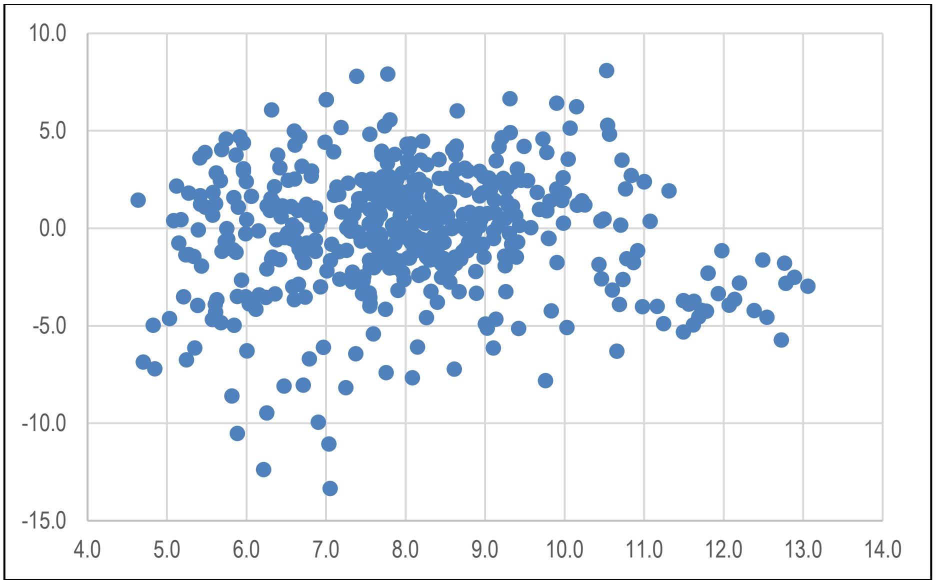


**Figure 3.10** Residual plot for the exponential model

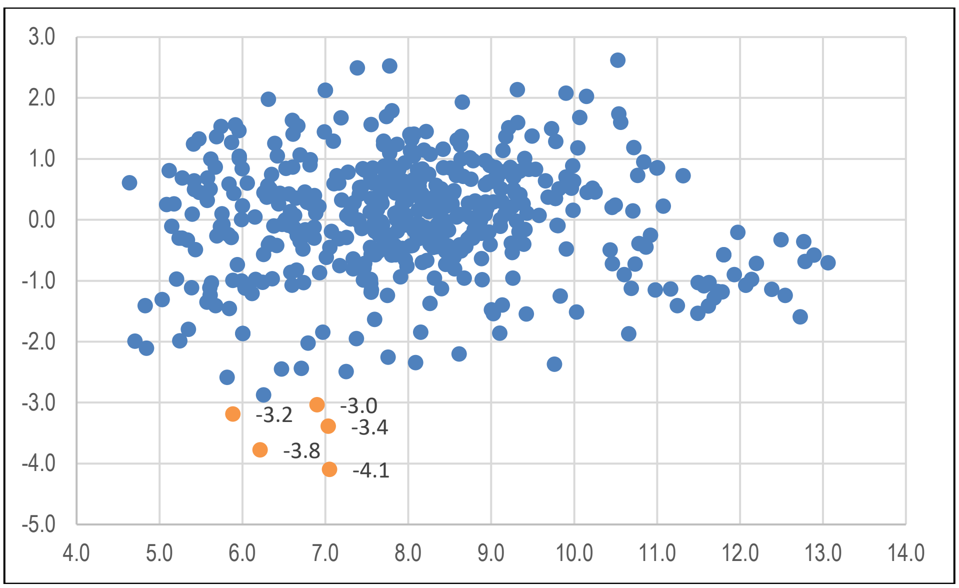


**Figure 3.11** Standardized residual plot for the linear model

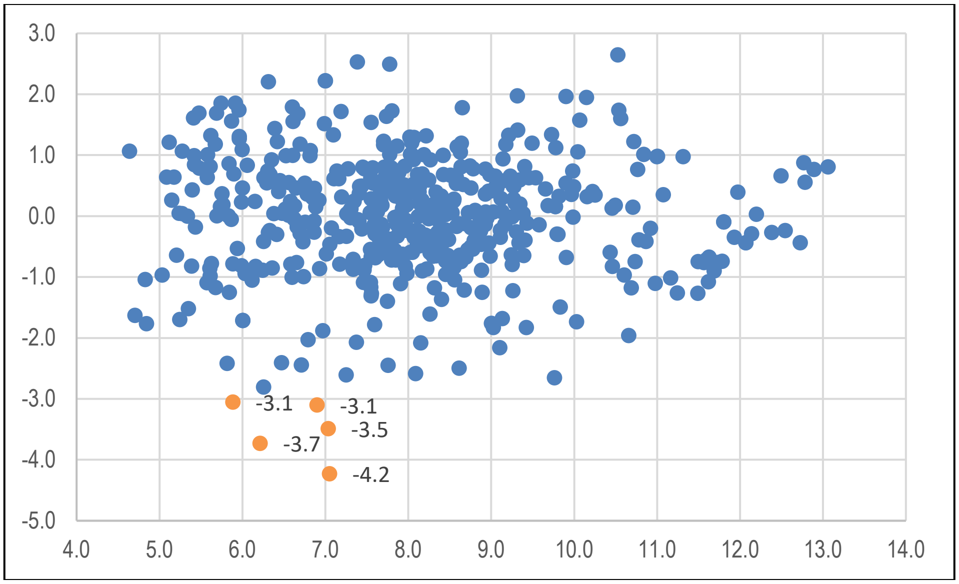

**Figure 3.12** Standardized residual plot for the third-degree polynomial model

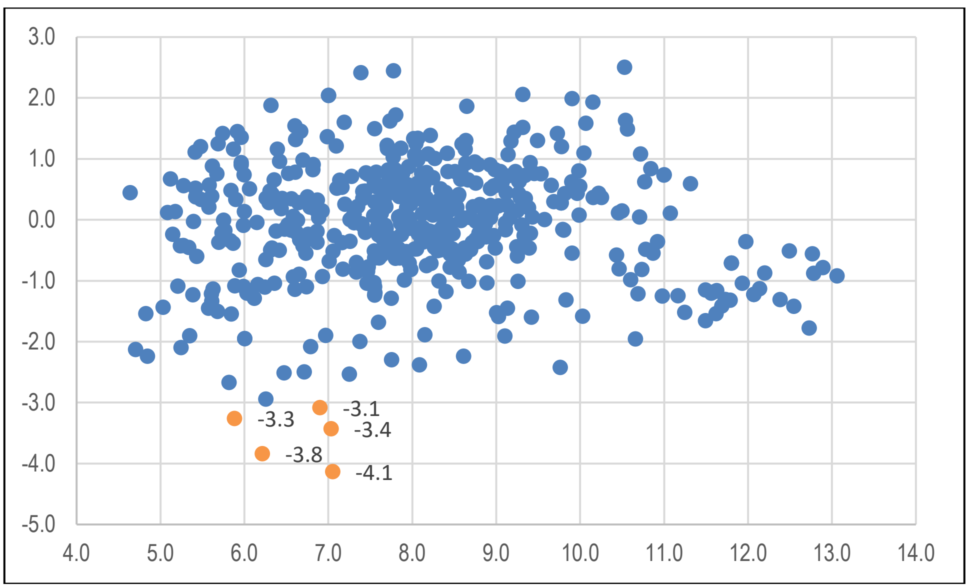

Figure 3.13 Standardized residual plot for the exponential model

The residual and standardized residual plots did not indicate a preferred model. Table 3.6 presents the adjusted coefficient of determination, standard error, and residual standard deviation of each model. The adjusted coefficient of determination provides a proportional reduction in the mean square error rather than in the sum of squared errors. This balances the model fit against its complexity. The number of predictor variables in the model increases the model's complexity. The residual standard deviation may be a better indication of a model's fit than the coefficient of determination. The residual standard deviation for each model was calculated using Equation 3.3 where $n$ was the number of samples. Therefore, based on the adjusted coefficient of determination, the polynomial model was selected for the creation of a prediction interval.

**Table 3.6** Additional regression model statistics

| | Standard Error | Residual Standard Error | Adjusted Coefficient of Determination |
|---|---|---|---|
| Linear Model | 3.206 | 3.206 | 0.640 |
| Polynomial Model | 3.103 | 3.103 | 0.662 |
| Exponential Model | 3.015 | 3.236 | 0.642 |

$$S = \sqrt{\frac{\Sigma(X - X_m)^2}{n-2}} \qquad (3.3)$$

Where,

$S$ = residual standard deviation
$n$ = number of data points used
$X$ = individual moisture contents for each point used
$X_m$ = mean moisture content of the fitted regression curve

The prediction interval was calculated using Equation 3.4. The prediction interval is a range of values that, based on the selected polynomial model, creates a region in which 95% of the maximum dry unit weights and optimum moistures should lie. This region therefore has a 5% error rate. Note that determined alpha level, $t_\alpha$, was 1.96 for a 95% confidence level. The value, *n,* was the number of data points used, 473. The standard error, $SE$ was calculated to be 3.103. The sum of squared error, $SS_{XX}$, was calculated to be 1359. The mean moisture content, $X_m$, was found to be 8.1. When an error occurs, the maximum dry unit weight and optimum moisture will lie outside the region created by the prediction interval. The prediction interval is presented in yellow in Figure 3.14 along with the fitted polynomial regression model in red.

$$Yp = Y \pm t_\alpha SE\sqrt{1 + \frac{1}{n} + \frac{(X - X_m)^2}{SS_{XX}}} \qquad (3.4)$$

Where,

$Yp$ = calculated dry unit weight boundaries of the interval
$Y$ = known dry unit weight of the fitted regression curve
$t_\alpha$ = alpha level (based on selected confidence level)
$SE$ = standard error
$n$ = number of data points used
$SS_{XX}$ = sum of squared error
$X$ = known moisture contents for the fitted regression curve
$X_m$ = mean moisture content

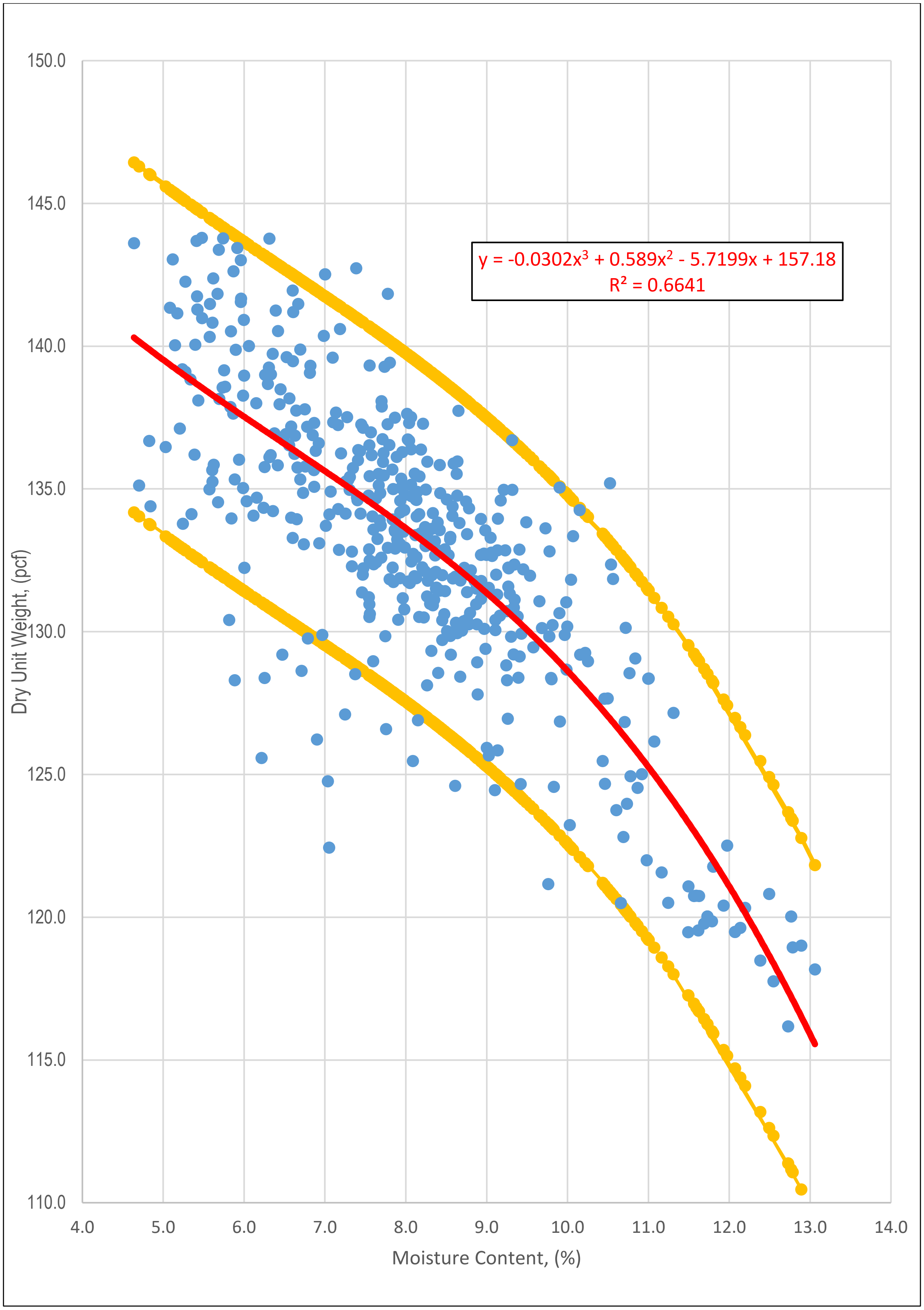


**Figure 3.14** Prediction interval for South Dakota granular subbase and base course materials

The Ohio Highway Department's Typical Moisture-Density Curves line of optimums was also plotted within the prediction interval and regression model to determine if they may be considered potentially valid for use with South Dakota granular base course and subbase materials. The resulting plot is shown in Figure 3.15. The Ohio Highway Department's Typical Moisture-Density Curves are presented in green. The fitted regression line is presented in red and the prediction interval is presented in yellow. The resulting plot indicates that the Ohio Highway Department's Typical Moisture-Density Curves line of optimums does plot inside the prediction interval. This provides evidence that they may be considered valid for use with South Dakota granular base course and subbase materials. It is important to note that the line of optimums follows the fitted regression line relatively close for dry unit weight values from approximately 121-pcf to 130-pcf. This may indicate that South Dakota base course and subbase materials with maximum dry unit weights within this range may be accurately predicted by the Ohio Highway Department's Typical Moisture-Density Curves. However, the line of optimums trends upward away from the fitted regression for dry unit weights greater than 130-pcf and less than 121-pcf. This could result in overestimation of maximum dry unit weights for South Dakota granular subbase and base course materials within these ranges.

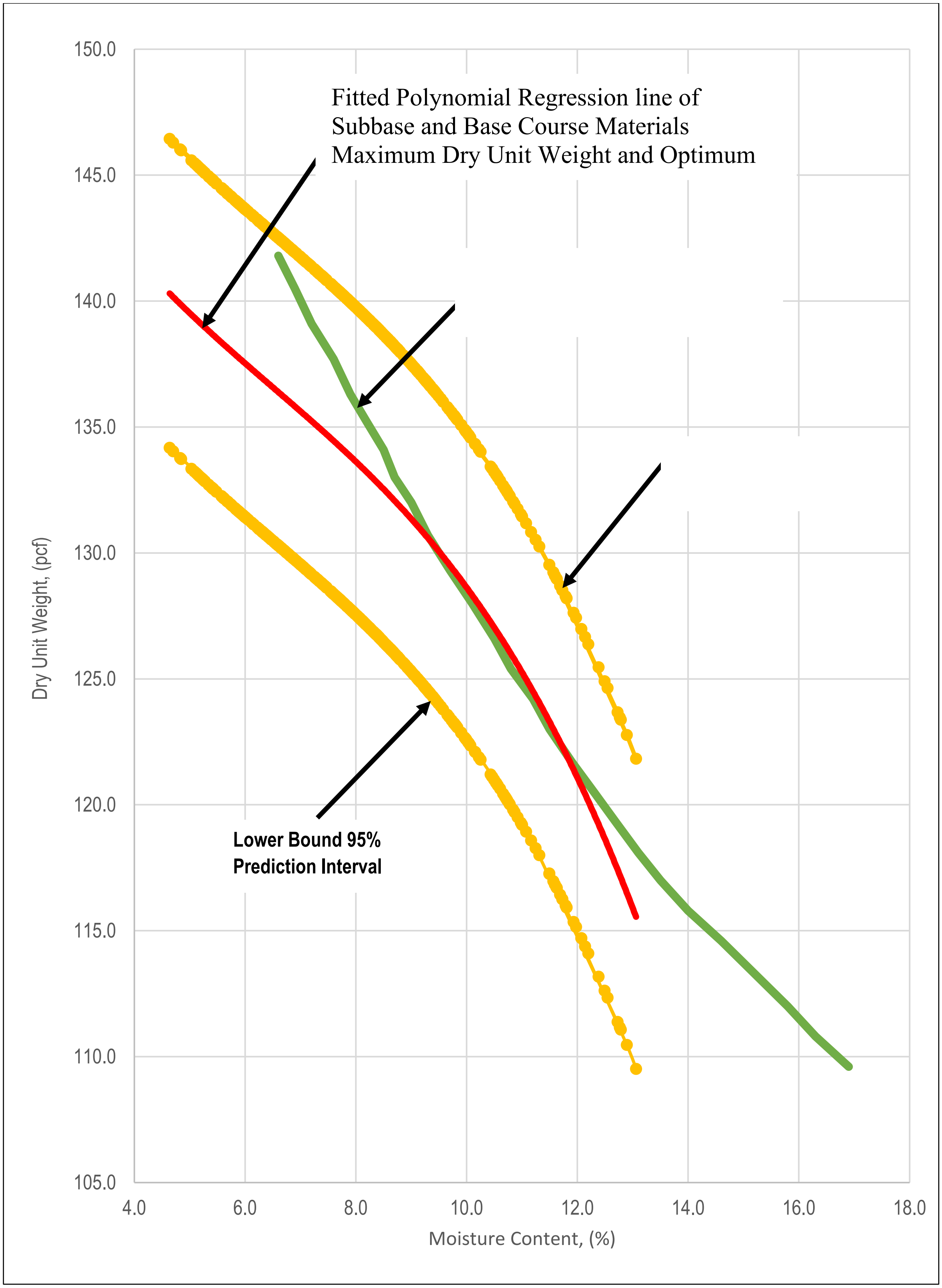


**Figure 3.15** Line of optimums plotted within the 95% prediction interval

## 3.5 Summary of Survey Results

This research conducted a survey of other state DOTs to document their methods, procedures, equipment, and training requirements for granular compaction testing. The survey also intended to collect data on alternative testing methods utilized by surrounding DOTs and DOTs utilizing families of compaction curves through the literature review. The NCHRP conducted a comprehensive survey of state DOTs to document compaction methods and practices (Nazzal, 2014). Therefore, to avoid generating duplicated information, two separate but similar questionnaires were created to gather new information. One questionnaire (Form 1) was sent to DOTs that had responded to the NCHRP Synthesis Survey, and the other questionnaire (Form 2) was sent to those who did not respond to the NCHRP Synthesis Survey. Survey Questionnaire Form 1 is presented first followed by Survey Questionnaire Form 2 in Appendix C. Table 3.7 lists the states that received a questionnaire, which form was sent, and those who replied. The response rate for the surveys was 44%.

**Table 3.7** Survey recipients

| State DOT Recipients | Form Received | Responded |
|---|---|---|
| North Dakota | Form 1 | No |
| Montana | Form 1 | No |
| Minnesota | Form 1 | Yes |
| Nebraska | Form 1 | No |
| Indiana | Form 1 | No |
| Ohio | Form 1 | Yes |
| Wyoming | Form 2 | No |
| Iowa | Form 2 | Yes |
| Texas | Form 2 | Yes |
| Response Rate | | 44% |

The questionnaires consisted of 14 questions designed to be answered quickly to increase the response rate. Table 3.8 presents relevant information from the surveys. Detailed responses can be found in Appendix C. Minnesota was the only state to use a strength measurement device, the DCP. All other respondents used density measurement devices to conduct compaction quality control. All of the respondents except for Texas have implemented families of curves on granular material for field projects. The survey provided several options of the various DOTs to select when asked their experience using families of curves. Options were: implemented in field projects, demonstrated in usage, evaluated, and not used. The intent of the options was to gauge how extensively each DOT has used families of curves. Those that have specifications and test procedures were to select the option “Implemented in Field Projects.” DOTs that have selected “Demonstrated Usage” are those that have implemented families of curves in pilot projects. DOTs that have evaluated families of curves while conducting research would select the option “Evaluated.” It was also noted that all respondents used field microwave, NDG, and oven or stovetop methods to determine moisture content. The Minnesota DOT also used Speedy Moisture Testers. Compaction quality control on HMA and PCC recycled materials is performed by all the responding states except Iowa.

**Table 3.8** Survey response information of interest

| State | Compaction Test Method | Compaction Specification | Usage of Families of Curves | Materials Utilized by Curves |
|---|---|---|---|---|
| Minnesota | Dynamic Cone Penetrometer | 1-points and 4-points | Implemented in field projects and demonstrated in usage | Sands, gravels, and limestone |
| Iowa | Sand Cone and Balloon | 1-points and 4-points | Implemented in field projects | Sands |
| Ohio | Nuclear Density Gauge | 1-points and test strips | Implemented in field projects | Sand and gravels |
| Texas | Sand Cone, Electric Density Gauge, Soil Density Indicator, and Nuclear Density Gauge | 4-point | Not used or Evaluated | N/A |

# 4. DISCUSSION OF ALTERNATIVES

An objective of the research was to determine whether an alternate method of testing compaction of unprocessed and recycled granular material should be used. These alternatives are presented in this chapter. The various compaction testing methods have been divided into two general categories: density-based and stiffness/strength based. These categories relate to what parameter is measured when performing a test. Density-based methods depend on obtaining a measure of dry unit weight and moisture content to determine acceptable levels of compaction. Stiffness/strength-based methods measure soil resistance to dynamic and static loading and correlate directly to engineering input into the design such as mechanistic empirical pavement design. The following section will discuss and present the alternatives comparison used.

## 4.1 Alternatives Comparison

A criteria list was developed to rank test devices based on the list of alternatives presented in Chapter 2. These criteria are presented in with general descriptions for each. The alternatives were ranked from 1 to 3 relative to the other alternatives. For example, a relatively inexpensive test device would receive a rank of 1 for relative cost. An expensive test device would receive a 3, with moderately expensive devices receiving a 2. The devices were scored relative to the other alternatives. This scheme was used for the criteria listed in Table 4.1. The criteria list was then used to score the test devices. The scoring of each test devices was based on information presented in the literature review and survey results previously presented in Chapter 2 and Chapter 3.

**Table 4.1** Decision Criteria

| Criteria List | Description of Criteria |
|---|---|
| Relative Cost | Relates the cost of the device relative to the other alternatives. |
| Ease of Use | A measure of how easy it is to operate the device. |
| Repeatability | A measure of how repeatable results are. |
| Reliability | A measure of the structural and technical reliability of the device. |
| Accuracy | How well the device measures actual soil properties. This is generally a measure of possible device testing error. |
| Safety | A measure of how safe the device is to operate. |
| Test Time | A measure of how long it takes to conduct a test. |
| Correlations | A comparison of the number of correlations between measurements and soil properties. |
| Expertise Level | A measure of the level of technical ability required to operate the equipment. |

The results of the scoring are presented in Table 4.2 with the lowest scores representing the most desirable options. The devices were grouped into three categories. The first category was for devices currently used by the SDDOT, which are all density-based. The second category was for other density-based devices from the literature review. The final category was for stiffness/strength-based devices. The lowest score from currently used SDDOT devices was the NDG with the sand cone device scoring close in comparison. The DCP had the lowest overall score.

**Table 4.2** Criteria Scoring Scheme

| Device Category | | Relative Cost | Ease of Use | Repeatability | Reliability | Accuracy | Safety | Test Time | Correlations | Expertise Level | Total Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Current SDDOT (Density-Based) | Sand Cone | 1 | 1 | 3 | 2 | 3 | 2 | 3 | 3 | 1 | 19 |
| | Rubber Balloon | 1 | 3 | 3 | 2 | 3 | 2 | 3 | 3 | 1 | 21 |
| | Nuclear Density Gauge (NDG) | 3 | 1 | 2 | 1 | 2 | 2 | 1 | 3 | 2 | 17 |
| Density-Based | Moisture Density Indicator (MDI) | 2 | 3 | 1 | 3 | 2 | 2 | 3 | 3 | 3 | 22 |
| | Electric Density Gauge (EDG) | 3 | 3 | 1 | 3 | 2 | 2 | 3 | 3 | 3 | 23 |
| | Soil Density Gauge (SDG) | 3 | 3 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 22 |
| Stiffness/ Strength-Based | Clegg Hammer (CH) | 3 | 2 | 3 | 1 | 3 | 1 | 3 | 2 | 1 | 19 |
| | GeoGauge | 2 | 3 | 3 | 1 | 3 | 2 | 2 | 3 | 2 | 21 |
| | Light Weight Deflectometer (LWD) | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 13 |
| | Dynamic Cone Penetrometer (DCP) | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 11 |

## 4.2 Discussion of Scoring

Considerations for each criterion were carefully examined. Most of the criteria are considered linked in one form or another. “Relative Cost” considerations include not only the cost of the device but also the cost to implement and to train operators. Training and implementation are also considered when scoring the criteria “Level of Expertise” and “Ease of use.” The following subsections discuss in detail how each device was scored.

### 4.2.1 Current SDDOT (Density-Based) Devices

The category presented in Table 4.2 as Current SDDOT Devices presents three density-based devices currently used by the SDDOT. These devices were the sand cone, rubber balloon, and NDG. The relative cost to own and operate the sand cone and rubber balloon are low compared with other methods. However, the cost of owning and operating an NDG includes cost to own, store, and operate as well as inspector certification, which costs much more than other alternatives. The sand cone and rubber balloon received scores of 2 because of the need to kneel on the job site to operate these devices, which therefore increases the risk of being unseen by passing construction equipment and the traveling public.

The results obtained from the sand cone and rubber balloon have been previously shown to be operator dependent. Therefore, these devices received high scores for repeatability, reliability, and accuracy. The NDG scored slightly better in these categories as the results are not as reliant on the operator. The NDG does not perform well in recycled materials and therefore received a 2 for accuracy. The NDG also has been found to be a durable device that can be used with limited maintenance throughout its lifetime, hence the low reliability score.

All the devices currently used by the SDDOT require a relatively low level of expertise to operate. It is important to note, however, that the operator must have regulatory mandated training to operate the NDG. Results are obtained relatively quickly when using the NDG, which makes it very attractive to some DOTs. The sand cone has a time-consuming calibration process and test results require considerable time. The rubber balloon was noted in studies to break in rock materials, resulting in a failed test. These findings make the rubber balloon device a relatively undesirable option as tests can be difficult to perform in granular material.

### 4.2.2 Density-Based Devices

The category presented in Table 4.2 as Density-Based Devices presents three alternative density-based devices currently not used by the SDDOT. These devices include the MDI, the EDG, and the SDG. All of these devices received moderate cost scores because they do not require training to own and operate. These devices are still expensive when compared with other devices such as the sand cone or DCP. These devices also require the operator to kneel on the job site, putting the operator at risk of injury from construction equipment or the traveling public.

The literature found that all three of these devices, when operated correctly, can produce results similar to the NDG and therefore received a 2 for accuracy. The literature review also found these three devices to be repeatable. Reliability of these devices varied between studies; however, a common criticism was the bending of spike probes in densely compacted granular materials. Therefore, these devices all scored high for reliability.

It was reported that there was a high level of expertise required to operate all three of these devices, and performing testing was a time consuming and complicated process. This resulted in high scores for expertise level, ease of use, and test time. The findings resulted in these devices being relatively undesirable alternatives. It is also important to note that widespread use of these devices by other DOTs was not found, although some have evaluated their use. This may be an indication of disadvantages associated with these devices.

These devices, along with those currently used by the SDDOT, do not have direct correlations to soil properties and therefore received high scores for correlations. The lack of correlations between density-based methods and soil properties presents disadvantages to these devices. Pavement design uses mechanistic empirical design criteria that use soil properties, such as resilience modulus, to determine pavement thickness as input.

### 4.2.3 Stiffness / Strength Based Devices

The last category presented in Table 4.2 is Stiffness/Strength-Based Devices. This category included the CH, the GeoGauge, the LWD, and the DCP. The relative cost of owning and operating these devices varied. The least expensive to own and operate was the DCP with a cost to own of approximately $1,500. The CH was approximately $20,000, making it the most expensive device to own. The LWD and GeoGauge were found to have moderate cost values relative to the other devices. A summary of approximate device costs for all the devices summarized was shown Section 2.6. All of the devices in this category other than the GeoGauge can be operated from a standing position and none of them require the use of radiation to obtain measurements. Therefore, these devices received low safety scores. The GeoGauge does require the operator to kneel on the job site, which is the reason for a higher safety score.

The CH and GeoGauge were found to be difficult to seat on granular material, therefore resulting in high scores for repeatability and accuracy. The LWD and DCP were found to obtain repeatable and accurate results. The DCP scored higher for reliability when compared with the alternative devices. The DCP has cone tips that must be replaced after each test, increasing its reliability score. The other three stiffness/strength devices all received low reliability scores.

The level of expertise required to operate these devices is relatively low. The GeoGauge and LWD require understanding the built-in operating systems to correctly perform tests. However, the CH and DCP both require minimal training to operate effectively. Test times for these devices are moderately low with the exception of the CH, which requires the operator to obtain test values from laboratory compaction molds prior to its use in the field. The LWD and DCP are able to rapidly obtain test data in granular material, making them desirable options. The DCP is also easy to operate in both granular and recycled materials, scoring low for ease of use. The literature review noted that the CH GeoGauge and LWD had difficulties performing tests in granular material. The difficulties usually stemmed from the seating of the devices on granular material surfaces. The GeoGauge and CH were also found to be rather heavy and difficult to maneuver around job sites.

The main advantage of stiffness/strength devices is their ability to obtain data that can be easily and effectively correlated to design criteria. All of these devices have the ability to correlate their data to the soil's engineering properties, such as the CBR and resilience modulus. These engineering properties are also used in mechanistic empirical pavement design, thus providing a link between the design of pavement sections and the quality control of pavement support.

# 5. FINDINGS AND CONCLUSIONS

Throughout the research process, numerous findings were obtained that resulted in the recommendations that are presented in Chapter 6. The findings of the research were produced in three general areas. The literature review documented many findings from previous research reports and aided in the understanding of current SDDOT practices and issues when conducting compaction quality control on granular materials. The surveys conducted, coupled with the NCHRP synthesis survey, provided feedback from surrounding DOTs' current compaction quality control methods. The surveys also provided valuable information on the types of alternative devices evaluated by other DOTs. A data analysis was performed on compaction data provided by the SDDOT. The data analysis provided an evaluation of the Ohio Highway Department's Typical Moisture-Density Curves as well as a new set of curves, the SDDOT Base and Subbase Moisture-Density Curves. These new curves were developed from the same data analyses. The following sections will present a summary of the major findings from each of the three general areas.

## 5.1 Literature Findings

The literature review found that granular materials compact and drain fundamentally differently than clays and silts. Studies found that when granular materials are compacted using the standard laboratory compaction test with standard compaction molds, the resulting maximum dry density may be underestimated. Further studies indicated that granular material can be compacted to a higher maximum dry density under laboratory vibratory compaction. The vibrating laboratory compaction method compacts granular material in a similar manner to how it is compacted in the field using a vibrating roller. Effective laboratory compaction of granular material is essential in ensuring adequate density-based compaction in the field. It was also found that density-based compaction quality control results do not directly correlate to the soil properties used in pavement design.

The literature review also reviewed the use of families of compaction curves. It was found that families of curves were originally designed for cohesive soil material such as clay and silty clay. These curves used both wet density and penetration resistance to select proper curve fits. The Ohio Highway Department's Typical Moisture-Density Curves, Set C that are now used by the SDDOT do not include penetration resistance measurements to select the proper curve fit.

There were 10 compaction testing devices researched and summarized in the literature review. The devices were divided into three categories: Current SDDOT (Density-Based), Density-Based, and Stiffness/Strength-Based. The current SDDOT devices were the sand cone, the rubber balloon, and the NDG. The density-based devices were the MDI, EDG, and SDG. The stiffness/strength-based devices were the CH, GeoGauge, LWD, and DCP. Summarized literature found that although the CH was the most expensive to purchase, the NDG was the most expensive to own and operate. That stated, most DOTs still use the NDG for compaction quality control. The various alternatives to the NDG all had issues obtaining quick, repeatable, reliable, and accurate test results. Stiffness/strength-based devices were found to provide quicker testing times and required less expertise to operate. These devices also did not depend on the experience of the operator in contrast to the sand cone and rubber balloon. Studies did show problems seating the CH, GeoGauge, and LWD on granular materials. The summary of each device can be found in Sections 2.4 and 2.5. The scoring evaluation is presented in Chapter 4.

## 5.2 Survey Findings

The research team conducted a survey of other state DOTs to document their methods, procedures, equipment, and training requirements for granular compaction testing. The survey also aimed to collect data on alternative testing methods utilized by surrounding DOTs and DOTs found to be utilizing families of curves through the literature review. Of the nine DOTs surveyed, four responded: Minnesota, Iowa, Ohio, and Texas. The survey results found that Texas was currently using the sand cone, EDG, SDI, and NDG. This indicates that Texas is still focused on density-based compaction quality control along with Iowa and Ohio. The Minnesota DOT has implemented the DCP for compaction quality control and recommended its use for granular materials. All the respondents, with the exception of Texas, indicated that they also use families of curves in projects that use sands and gravels. A copy of the surveys and survey results are presented in Appendix C. A summary of the survey results can be found in Section 3.5.

## 5.3 Data Analysis Findings

The goal of the data analysis task was to provide analysis that would aid in the evaluation of the Ohio Highway Department's Typical Moisture-Density Curves adequacy in determining target dry unit weight. It was first necessary to compare the line of optimums of the Ohio Highway Department's Typical Moisture-Density Curves to the line of optimums created from granular subbase and base course materials encountered by the SDDOT. The results of the comparison indicated that the Ohio Highway Department's curves may be overestimating the maximum density in the field by nearly 3 pcf. This would contribute to a 2% to 2.5% difference in maximum dry unit weight.

A 95% prediction interval on the maximum dry unit weight and optimum moisture of granular subbase and base course materials encountered by the SDDOT was also constructed to evaluate the families of curves. Both the Ohio Highway Department's Typical Moisture-Density Curves and the newly created SDDOT Base and Subbase Moisture-Density Curves fit within the 95% prediction interval. This indicated that both families of curves may be considered valid for compaction quality control of granular materials. The SDDOT Base and Subbase Moisture-Density Curves were developed using base and subbase materials encountered by the SDDOT. The Ohio Highway Department's Typical Moisture-Density Curves were proven to be statistically different than the SDDOT granular material line of optimums by approximately 2.8 pcf. Current SDDOT methods state target densities determined by a family of compaction curves should range within 3 pcf of the maximum dry unit weight from modified laboratory compaction tests. The analysis process was documented in Chapter 3. The data used during the analysis are presented in Appendix B. Procedures, Methods, and Specifications for the SDDOT Base and Subbase Moisture-Density Curves are presented in Appendix A.

## 5.4 Research Conclusions

The findings of the research have found there are many disadvantages associated with density-based compaction quality control. Density-based compaction quality control also does not provide a direct link between the design process and construction quality control of granular material compaction. It was found that many state DOTs still use density-based devices, and some are currently implementing new devices for measuring density. However, previous studies of new density-based quality control devices have noted the unsuitability of these devices in granular material. Minnesota has studied new stiffness and strength measurement devices and is implementing methods, procedures, and specifications for the use of the LWD and DCP. The review of previous studies indicates that the DCP is a viable option for the SDDOT to increase efficiency and reduce the problems encountered using density-based devices on granular base and subbase materials.

The use of families of curves for granular materials is currently in use by surrounding DOTs. The SDDOT currently uses the Ohio Highway Department's Typical Moisture-Density Curves to aid in the determination of maximum dry unit weight and optimum moisture of granular materials. The data analysis found that this may be leading to approximately 2.8-pcf overestimation in maximum unit weight. This could indicate that compacted fills in the field may be overly compacted, leading to unnecessary construction costs. The analysis also indicates that the Ohio Highway Department's Typical Moisture-Density Curves may still be considered valid for use in compaction quality control of granular materials. Therefore, it would be an advantage for the SDDOT to consider using the new SDDOT Family of Moisture-Density Curves for future construction projects.

The conclusions resulting from the research should be implemented by the SDDOT in an incremental process. The DCP can be implemented as a compaction quality control device for granular base and subbase materials. Methods, procedures, and specifications for the device are presented in Appendix A. The use of the Ohio Highway Department's Typical Moisture-Density Curves should be used alongside the new SDDOT Base and Subbase Moisture Density Curves on part of a future project. This would allow the SDDOT to evaluate and compare both families of curves relative to each other. The pilot project would also serve to verify the usage of the DCP as an alternative to field quality control testing. A discussion of these recommendations and the implementation process is presented in Chapter 6. Estimated costs for the recommendations to be implemented are summarized in Table 5.1 based on SDDOT estimates (SDDOT, 2016). These costs include the integration of the new testing reports and forms along with the cost of training and purchasing of the DCP devices.

**Table 5.1** Estimated implementation costs

| | Quantity | Cost | Total |
|---|---|---|---|
| SDDOT Base and Subbase Moisture Density Curves | 20 hours | $69.00 | $1,380.00 |
| 3 New Forms for DCP | 60 hours | $69.00 | $4,140.00 |
| New Reports for DCP | 10 hours | $69.00 | $690.00 |
| DCP Purchase | 24 each | $1,000.00 | $24,000.00 |
| Training | 1 each | $2,000.00 | $2,000.00 |
| Grand Totals | 114 hours | $3,207.00 | $31,589.00 |

# 6. RECOMMENDATIONS AND IMPLEMENTATION

This chapter presents the research team's recommendations to the SDDOT based on the research findings and conclusions. The research team recommends that the new methods, procedures, and specifications recommended be reviewed through an implementation pilot project before full implementation. This pilot project is considered the third recommendation.

## 6.1 The SDDOT Base and Subbase Moisture Density Curves

The research team recommends that the SDDOT use the newly developed SDDOT Base and Subbase Moisture Density Curves from this research for determining the maximum dry unit weight and optimum moisture of granular base and subbase materials.

The research developed a new family of compaction curves to be utilized in base and subbase material compaction quality control. These moisture density curves will be referred to as the SDDOT Base and Subbase Moisture Density Curves. Moisture density relations of base and subbase material types described by the SDDOT were analyzed in the creation of the curves and originated from the curves presented in Figure 17 in Section 3.2. The recommended SDDOT Family of Moisture-Density Curves is represented in Figure 30. These curves were plotted with the regression model discussed in Chapter 3 and are truncated at the general limits of the data used to create them. The line of optimums shown in Figure 3.4 and compared with the prediction interval shown in Figure 3.15 did slightly follow a more effective regression model than the previously plotted Ohio Highway Departments Typical Moisture-Density Curves. Of particular note is that the new curves have been created from moisture density data of granular materials used specifically by the SDDOT, thus making them a more desirable option. The new family of moisture-density curves also does not deviate outside the 95% prediction interval, therefore indicating that they may be considered valid in predicting base and subbase maximum dry densities and optimum moistures. Note that creating the new family of curves was not part of the research defined tasks; they were created as part of satisfying other portions of the defined work for this project. Therefore, their use and implementation will need to be vetted as described in this chapter to be considered for standard field use.

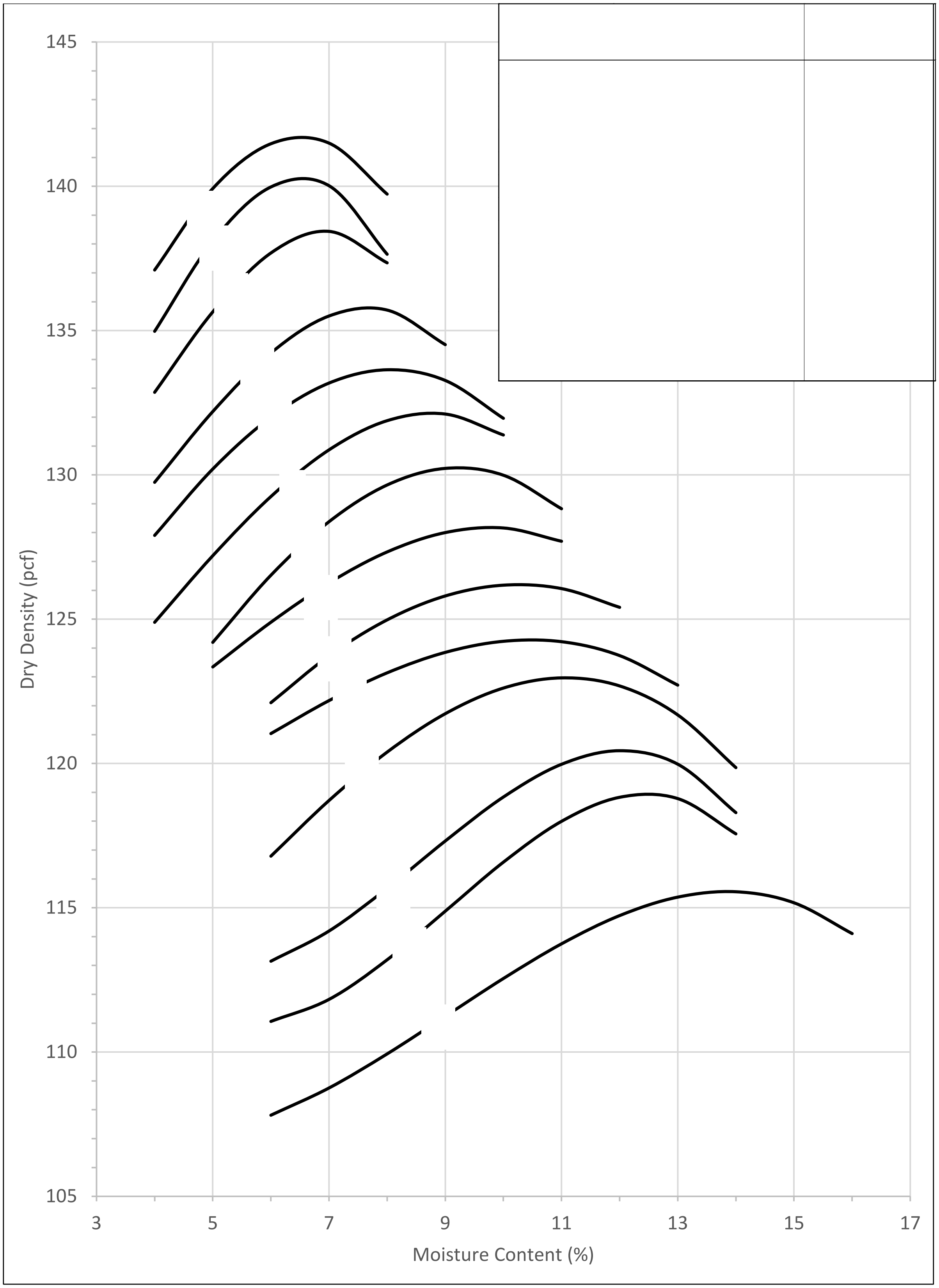


**Figure 6.1** The SDDOT Family of Moisture-Density Curves

The method the SDDOT uses to reduce laboratory data computes the “wet” unit weight as a function of the weight of the mold, the weight of the “wet” material, and a mold factor from a standard proctor test using the SD 104 methods. The dry unit weight is computed from the “wet” unit weight and the moisture content using Equation 6.1.

$$\gamma_w = [(w_w + w_m) - (w_m)] * MF \qquad (6.1)$$

Where,

$\gamma_w$ = wet unit weight, pcf
$w_w$ = weight of wet material, lbs
$w_m$ = weight of mold, lbs
$MF$ = mold factor (typically 13.28 to 13.46 depending upon the mold)

The dry unit weight is subsequently computed using Equation 6.2.

$$\gamma_d = \frac{\gamma_w * 100}{MC + 100} \quad (6.2)$$

Where,

$\gamma_d$ = dry unit weight, pcf
$MC$ = moisture content, %

The research team used dry unit weight for creating the family of curves for several reasons. First, the entire premise of using moisture unit weight relations correlates dry unit weight with moisture content; therefore, we plotted the curves as dry unit weight curves as they were a function of the moisture content. Second, the terminology and use of “wet” densities for compaction testing has substantially been reduced since the SDDOT adopted the use of the family of curves method. Third, the term use is not technically a wet unit weight implying saturation, it is a total unit weight implying the material has some moisture content; as such, moist (total) unit weight does not correlate with moisture content in terms of compaction. Fourth, AASHTO T 272-15 Standard Method of Test for Family of Curves-One-Point Method specifies the use of a family of curves using dry unit weight rather than “wet” unit weight. This method was followed during the construction of the new family of curves. Fifth, SDDOT method 104 specifies the use of dry unit weight. Note that all terms should technically be “unit weight,” not “density,” however, those terms are commonly used interchangeably.

Although the Ohio Highway Department’s Typical Family of Curves is presented as “wet” unit weight curves, each curve is based on a correlation to a maximum dry unit weight and optimum moisture content. The research team supported by the literature found this to be confusing and misleading, and could lead to misinterpretation of the curves and errors. Therefore, dry unit weight curves were selected to be used for the new curves.

The use of this new family of compaction curves may help alleviate problems comparing field in-situ density tests to target densities obtained from the one-point method. This is because the new set of curves provides an expected maximum dry density and optimum moisture rather than providing a fitted curve. The SDDOT Base and Subbase Moisture Density Curves depend on the laboratory determination of maximum dry unit weight and optimum moisture to plot within a region defined between two curves. Within each region, an average maximum dry unit weight and OMC was determined. This average maximum dry unit weight and OMC was determined by averaging all the encountered laboratory moisture density curves in each region or increment as it is referred to in Chapter 3. If the SDDOT decides to use this new family of compaction curves it may have less of a tendency to over-predict maximum dry density of South Dakota base and subbase materials. This would likely save the SDDOT considerable time and cost on projects by reducing the amount of time needed to compact granular materials. The following is a summary of a theoretical example of the recommended new SDDOT Family of Moisture-Density Curves in practice:

- A base course sample has been determined to be granular through a sieve analysis.
- A portion of the sample is compacted and the “1-point determination” for dry density is determined to be 134.0 pcf and a moisture content of approximately 7.6%.
- Entering the SDDOT Base and Subbase Moisture Density Curves, the point plots in the region defined by curve D and curve E as presented in Figure 6.2.
- The point does not plot directly on either curve, therefore the curve below the point is selected, curve E.
- According to Table 3.3 the predicted average (i.e., “target”) maximum dry density and optimum moisture are 135.0 pcf and 7.5%. These values will be used as the target values for field testing.

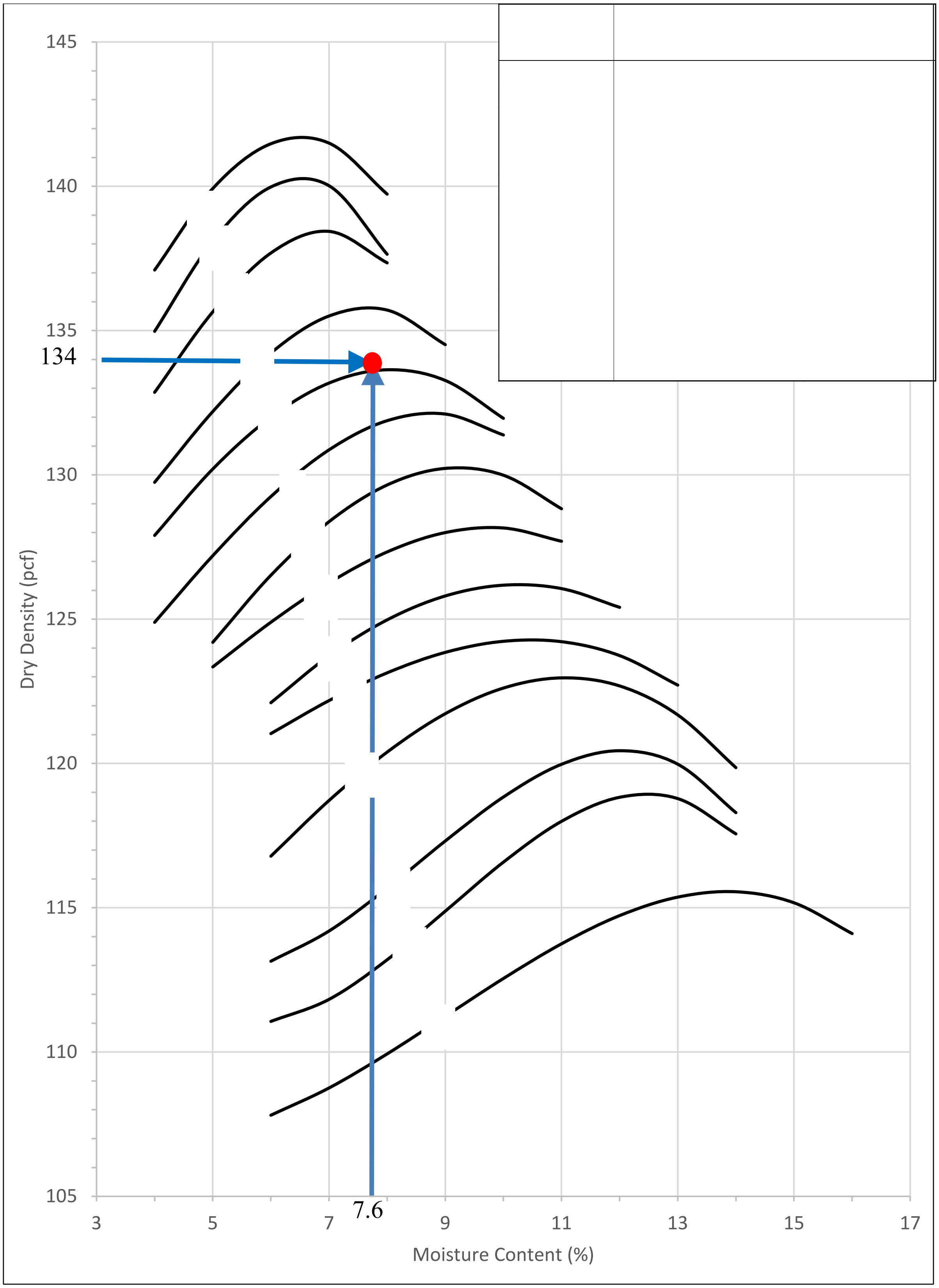


**Figure 6.2** The plotted example using the SDDOT Family of Moisture-Density Curves

## 6.2 The Dynamic Cone Penetrometer

The research team recommends that the SDDOT use the DCP for compaction quality control of granular base and subbase materials as well as milled, reclaimed, salvaged, and FDR materials all with maximum particle size of less than or equal to 2.0 inches.

The DCP was determined to be the most desirable alternative to current density-based granular compaction quality control. The device was well documented in the literature review and can be correlated to the CBR and resilience modulus of various material types. These correlations were presented in Section 2.4.5. The DCP costs much less than other alternatives with a price to own at approximately $1,500 per device. Cost estimates for the implementation of the DCP device are presented in Section 5.4. The DCP, when properly implemented, could save project inspectors considerable time and result in increased efficiency of field compaction quality control.

This research has presented two methods for compaction quality control using the DCP. A method was presented for determining adequate compaction of base and subbase granular materials with a maximum particle size of less than or equal to 1.5 inches. The second method is intended to be utilized with milled, reclaimed, salvaged, and FDR materials with a maximum particle size of less than or equal to 2.0 inches. These methods were developed to be similar to methods already being used with success in other DOTs, particularly the MnDOT, and are presented in Appendix A. SEAT and DPI values of 20 mm and 15 mm, respectively, were recommended and used by MnDOT for use of the DCP in recycled concrete pavements when used as a base course. The SDDOT will need to evaluate the gradations on their salvaged asphalt, FDR, and recycled concrete to calculate a specific grading number (GN) and the appropriate specification method. Given the materials are likely different in South Dakota than those in Minnesota, the SDDOT should perform field comparisons between its current methods and the DCP to make slight changes in GN to ensure a high-quality product. Furthermore, the same approach can be used to correlate resilience modulus used in design for the specified subgrade and base course to DCP test results.

## 6.3 Implementation Plan

It is recommended that the SDDOT implement the new SDDOT Base and Subbase Moisture Density Curves and the methods proposed for the dynamic cone penetrometer (DCP) using an incremental approach as applied to a pilot study.

The implementation of the SDDOT Base and Subbase Moisture Density Curves and the methods proposed for the DCP can be approached incrementally using a pilot study. The approach is outlined as follows:

Both new methods should be assessed individually side-by-side with existing SDDOT methods for evaluating compaction. This will allow for the SDDOT to evaluate which methods work best in achieving its field quality control goals. This will also identify any potential problems with the recommendations that may need to be addressed before full implementation.

- The pilot project should be a project that requires comparison with at least 30 test points. The project should include granular base/subbase granular materials. Note that for projects that use recycled materials, the same number of points should initially be used for assessing these types of materials.

- The pilot study inspectors and engineers should perform current compaction test methods for the various materials encountered alongside the new methods. They should then perform the recommended test methods using the SDDOT Base and Subbase Moisture Density Curves and the DCP. The various test methods should all be conducted within a 5-foot radius to ensure that test results are from similarly compacted materials. The results of the tests should then be compared considering time and cost.

- The results of the currently used Ohio Highway Department's Moisture Density Curves should also be compared with the results of the recommended SDDOT Base and Subbase Moisture Density Curves. The SDDOT should compare the laboratory compaction test results with the target density and OMC determined from each family of compaction curves. The family of compaction curves that determine target density and OMC closest to the laboratory compaction test results will be the more desirable family of compaction curves. The results of the density-based in-situ tests methods should be compared to the acceptable PIV values recommended for each method. This comparison will ensure that the specified acceptable PIV values correlate to adequate levels of compaction for South Dakota granular materials. The acceptable PIV values may need to be adjusted depending on the results.

- Finally, based on the comparison results, the SDDOT can then implement the methods, procedures, and specifications into their construction and specification manuals. This will include purchase of DCP equipment and training project inspectors and engineers. Training should include the fundamentals and use of the DCP device (various components and assembly for job site use). The training would also present the methods, procedures, and specifications to project engineers and how those results would be used to evaluate acceptance of compacted granular materials. Various costs for implementation are presented in Section 5.4.

# 7. RESEARCH BENEFITS

Potential implementation of the SDDOT Base and Subbase Moisture Density Curves may decrease the time required to obtain target density and OMC associated with assessing compacted granular materials. These compaction curves have been developed using the same granular base and subbase materials encountered in the field by the SDDOT. This may lead to better approximations in achieving acceptable percentages of the target density when conducting in-situ field testing. The process of over compacting granular material can add considerable time to the compaction process and increase the budget.

The cost savings and test time efficiency of the using the recommended DCP test methods are the main benefits of the research. The implementation of the DCP would eliminate laboratory standard compaction tests after pilot studies have been completed and assessed. The DCP method would also reduce the reliance of the NDG for the compaction verification of base and subbase granular material. The NDG has strict regulations due to radioactive components. These regulations increase the yearly cost to own and operate the device, estimated at approximately $9,400/year/device. The DCP will only require replacement of cone tips, a much lower yearly maintenance cost. This should decrease the cost of compaction verification of granular materials.

The time required to perform a test using the DCP test methods takes approximately two minutes to complete. The current methods for testing granular materials used by the SDDOT depend on determining target dry density and OMC. It may take over an hour to construct a single 4-point standard moisture density curve to verify the use of the Ohio Highway Department's Typical Moisture-Density Curves. Then it takes additional time to conduct a 1-point standard moisture density determination to obtain a target density and OMC. The SDDOT has stated that often when conducting these methods, project inspectors experience delays in verification of the compacted granular material. The DCP would greatly reduce these inefficiencies and simplify the verification process.

The DCP measures the soils resistance to penetration, which is directly related to the resilience modulus of the material. The correlations presented in this report can be used to link the design criteria used during mechanistic-empirical pavement design to the construction compaction verification process. This is unlike the current density-based methods that lack a direct link to the design process of the pavement. Implementing the DCP would familiarize project inspectors and engineers to the benefits of stiffness/strength-based compaction verification.

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# APPENDIX A: Prepared Procedures, Methods, and Supplemental Specifications

Determination of the Penetration Index Value for Granular Material In-place by the Dynamic Cone Penetrometer Test Methods

1. Scope:

The methods presented are for determining the in-place Penetration Index Value (PIV) for granular material with a maximum particle size of ≤2.0 inches. PIV values are used to assess adequate compaction of granular materials. Two methods are presented for different specified material types.

Definitions.

Compaction: The use of equipment to compress soil, aggregate, or mixture into a smaller volume, thus increasing its dry unit weight and improving its engineering properties; strength and stability.

Dynamic Cone Penetrometer (DCP): The device utilized to determine the in-place Penetration Index Value of granular material layers. The device apparatus within this Method and within the SD ### (DCP Procedure). The procedure for using the device is outlined in detail in SD ### (DCP Procedure).

Penetration Index Value (PIV): The measurement obtained during testing utilizing the DCP. The measurement is the amount of penetration per blow and is calculated in increments of 3 blows. The measurement is recorded in units of mm/blow or inches/blow. The calculation is the reading on the DCP measurement rod in mm or in. after 3 standard test blows minus the reading prior to the standard test blows divided by the 3 standard test blows. This measurement can be correlated to various laboratory strength test such as the California Bearing Ratio Test.

$$\text{PIV} = \frac{\text{Reading after 5 blows} - \text{Reading after 2 blows}}{3}$$

SEAT: The SEAT refers to the initial seating of the DCP cone tip. This requires two initial standard blows. The SEAT is the measurement of penetration measurement in mm or in. after the two initial blows.

2. Apparatus:

2.1 The 17.6-lb. (8-kg) DCP is shown schematically in Figure 1 with replaceable cone schematic shown in Figure 2. It consists of the following components: a 5/8-in. (16-mm) diameter steel drive rod with a replaceable point, a 17.6-lb (8-kg) rammer which is dropped from a fixed height of 22.6-in. (575-mm). The apparatus is typically constructed of stainless steel, with the exception of the replacement point tip, which may be constructed from hardened tool steel or a similar material resistant to wear.

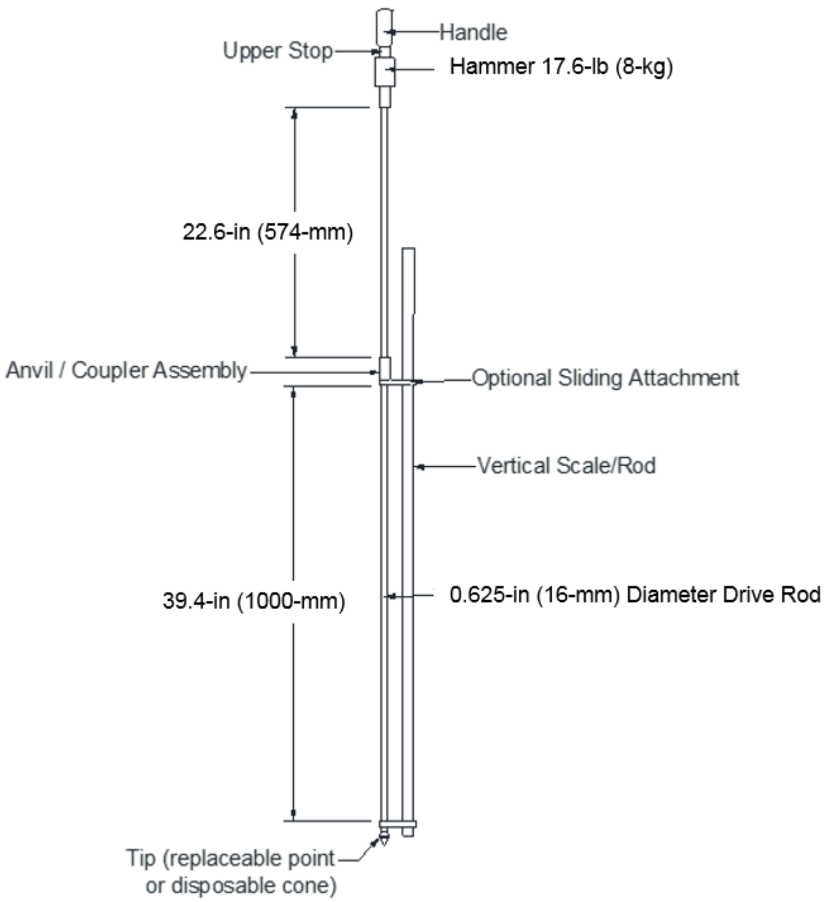


Figure 1. Schematic of DCP

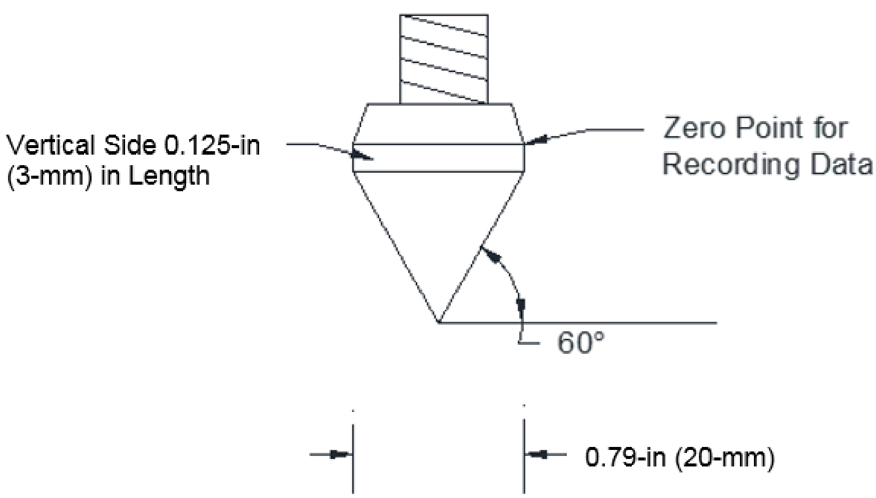


Figure 2. Replaceable Point Tip

2.2 The following tolerances are recommended for the apparatus: Hamer weight-measurement of 17.6-lb. (8.0-kg); tolerance is 0.02-lb. (0.01-kg), Drop of rammer-measurement of 22.6-in. (575-mm), tolerance is 0.04-in. (1.0-mm). Tip angle measurement of 60 degrees included angle; tolerance is 1 degree, and Tip base diameter measurement of 0.79-in. (20-mm); tolerance is 0.01-in. (0.25-mm).

2.3 In addition to the DCP, the following equipment is needed: Tools for assembling the DCP, Lubricating Oil, Thread Locking Compound, and PIV Data Worksheet for recording data (See Attached).

2.4 Depending on the circumstances, the following equipment may also be needed or is recommended: A vertical scale graduated using increments of 0.1 in. (2.0 mm), or measuring rod longer then the longest drive rod if the drive rod(s) are not graduated, an optional sliding attachment for use with a separate scale or measuring rod, and extraction jack.

3. Procedure:

Method 1 For testing virgin aggregate that meets the specific requirements of Subbase, and Base Course as specified by Section 882.2 of SDDOT Standard Specifications for Roads and Bridges.

Method 2 For testing salvaged materials that meet the specific requirements of Milled and Reclaimed as specified by Section 884.2 of SDDOT Standard Specifications for Roads and Bridges. This method is also used when testing Full Depth Reclamation (FDR) asphalt. This method may also be used for materials classified by the SDDOT Standard Specifications for Roads and Bridges as recycled materials.

3.1 Method 1 (Subbase and Base Course)

A. Obtain most recent Sieve Analysis (DOT-3) results for granular material being tested to determine Grading Number (GN). If a sieve analysis has not been previously conducted for the material, conduct a sieve analysis in accordance with SD 202 to obtain results for the GN determination. The analysis shall include the following sieve sizes: 1”, 3/4”, 3/8”, #4, #8, #40, #200. Record the percent passing each sieve and sample ID on DCP Penetration Index Value Worksheet Method 1 under Gradation Data.

B. Calculate the GN to determine SEAT and PIV test acceptance requirements. The GN is calculated by summing the percent passing each of the sieves shown below and dividing the sum by 100. Record GN on DCP Penetration Index Value Worksheet Method 1 under Gradation Data.

$$(GN) = \frac{1'' + {}^{3}/_{4}'' + {}^{3}/_{8}'' + \#4 + \#8 + \#40 + \#200}{100}$$

C. Determine the Moisture Content (MC), SEAT, and PIV test acceptance requirements for the calculated GN.

Table 1: SEAT and PIV requirements.

| Grading Number | MC (%) | Maximum Allowable Seating (mm) | Maximum Allowable PIV (mm/blow) | Grading Number | MC (%) | Maximum Allowable Seating (mm) | Maximum Allowable PIV (mm/blow) |
|---|---|---|---|---|---|---|---|
| 3.1 – 3.5 | < 5.0 | 40 | 10 | 4.6 – 5.0 | < 5.0 | 65 | 15 |
| | 5.0 – 8.0 | 40 | 12 | | 5.0 – 8.0 | 75 | 19 |
| | > 8.0 | 40 | 16 | | > 8.0 | 85 | 23 |
| 3.6 – 4.0 | < 5.0 | 40 | 10 | 5.1 – 5.5 | < 5.0 | 85 | 17 |
| | 5.0 – 8.0 | 45 | 15 | | 5.0 – 8.0 | 95 | 21 |
| | > 8.0 | 55 | 19 | | > 8.0 | 105 | 25 |
| 4.1 – 4.5 | < 5.0 | 50 | 13 | 5.6 – 6.0 | < 5.0 | 100 | 19 |
| | 5.0 – 8.0 | 60 | 17 | | 5.0 – 8.0 | 115 | 24 |
| | > 8.0 | 70 | 21 | | > 8.0 | 125 | 28 |

D. Equipment Check: Before beginning a test, the DCP device shall be inspected for fatigue-damaged parts, in particular the coupler and handle, and excessive wear of the drive rod and replacement point tip. All joints must be securely tightened including the coupler assembly and the replaceable point tip (or the adapter for the disposable cone tip) to drive rod.

E. Locate a level, undisturbed area.

F. To determine the in-situ material SEAT and PIV perform the test in accordance with SD ### (DCP Test Procedure).

G. Record test results on DCP Penetration Index Value Worksheet Method 1 (DOT- ##). If test results do not meet test acceptance requirements, moisture condition the material and compact again before conducting another test.

3.2 Method 2 (Milled, Reclaimed, Salvaged, and FDR)

A. Equipment Check: Before beginning a test, the DCP device shall be inspected for fatigue-damaged parts, in particular the coupler and handle, and excessive wear of the drive rod and replacement point tip. All joints must be securely tightened including the coupler assembly and the replaceable point tip (or the adapter for the disposable cone tip) to drive rod.

B. Locate a level, undisturbed area.

C. To determine the in-situ material SEAT and PIV perform the test in accordance with SD ### (DCP Test Procedure).

D. Record test results on DCP Penetration Index Value Worksheet Method 2 (DOT - ##). If the SEAT value exceeds 0.79-in. (20-mm) relocate to the test to test site at least 12-in. (300-mm) from previous test site and reseat the cone. If the second test site fails the above criteria, compaction is not acceptable, and the area being tested shall be moisture conditioned and compacted again. If the resulting PIV is 15 mm/blow or less, the test passes.

E. No moisture test is required if the hardest penetration requirement is met.

4. Report:

4.1 Calculations.

A. Grading Number (GN)

$$(GN) = \frac{1" + {}^{3}/_{4}" + {}^{3}/_{8}" + \#4 + \#8 + \#40 + \#200}{100}$$

Where the percent passing each sieve is used.

B. SEAT value:

$$\text{SEAT} = \text{A} - \text{B}$$

Where:

A = DCP penetration reading after 2 standard blows in mm or inches.

B = DCP penetration reading before 2 standard blows in mm or inches.

SEAT= DCP Seating value in mm or inches.

C. Penetration Index Value (PIV):

$$PIV = \frac{A - B}{3}$$

Where:

A = DCP penetration reading after 5 standard blows in mm or inches.

B = DCP penetration reading after 2 standard blows in mm or inches.

PIV = Penetration Index Value in mm/blow or inches/blow.

4.2 Report.

A. Report the moisture content to the nearest 0.1 percentage point.
B. Report the SEAT value to the nearest 1.0 mm.
C. Report the PIV value to the nearest 1.0 mm/blow.
D. Provided required information on the DCP Penetration Index Value Worksheet.

5. References:

ASTM D6951
DOT - 3
DOT - ## (DCP Penetration Index Value Worksheet Method 1)
DOT - ## (DCP Penetration Index Value Worksheet Method 2)
SD 108
SD ### (DCP Procedure)

1. Scope:

This test is for determining the in-place Penetration Index Value (PIV) for granular material with a maximum particle size of ≤2.0 inches and have a non-compacted layer thickness of 6 in. or less. PIV values are used to assess adequate compaction of granular materials.

2. Apparatus:

2.1 The 17.6-lb (8-kg) DCP is shown schematically in Figure 1 with replaceable cone schematic shown in Figure 2. It consists of the following components: a 5/8-in. (16-mm) diameter steel drive rod with a replaceable point, and a 17.6-lb (8-kg) rammer which is dropped a fixed height of 22.6-in. (575-mm). The apparatus is typically constructed of stainless steel, with the exception of the replacement point tip, which may be constructed from hardened tool steel or a similar material resistant to wear.

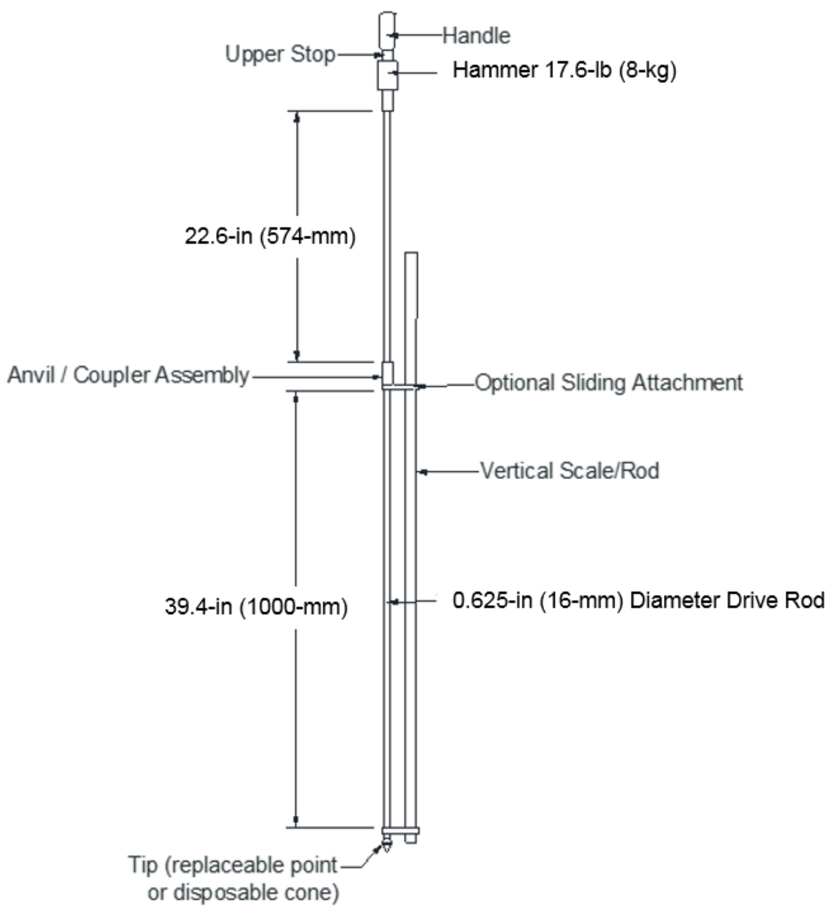


Figure 1 Schematic of DCP

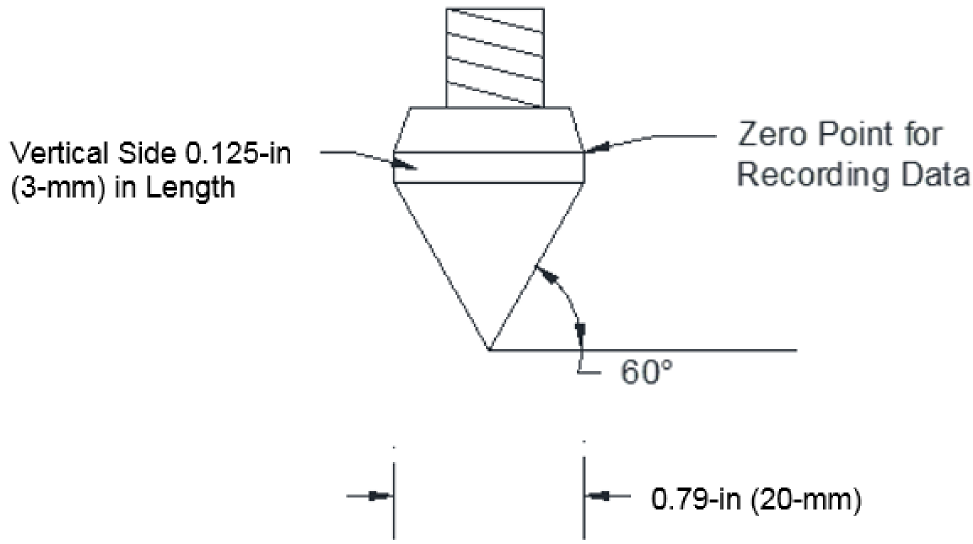


Figure 2. Replaceable Point Tip

2.2 The following tolerances are recommended for the apparatus: Hamer weight-measurement of 17.6-lb (8.0-kg); tolerance is 0.02-lb (0.01-kg), Drop of rammer-measurement of 22.6-in. (575-mm), tolerance is 0.04-in (1.0-mm), Tip angle measurement of 60 degrees included angle; tolerance is 1 degree, and Tip base diameter measurement of 0.79-in (20-mm); tolerance is 0.01-in (0.25-mm).

2.3 In addition to the DCP, the following equipment is needed: Tools for assembling the DCP, Lubricating Oil, Thread Locking Compound, and PIV Data Worksheet for recording data (See Attached).

2.4 Depending on the circumstances, the following equipment may also be needed or is recommended: a vertical scale graduated using increments of 0.04-in (1.0-mm), or measuring rod longer then the longest drive rod if the drive rod(s) are not graduated. An optional sliding attachment for use with a separate scale or measuring rod, and Extraction jack.

3. Procedure:

3.1 Basic Operation

A. The operator holds the device by the handle in a vertical position and lifts and releases the rammer from the standard drop height. The recorder measures and records the total penetration for a given number of blows or the penetration per blow. A single operator can perform both tasks concurrently if required.

3.2 Equipment Check

A. Before beginning a test, the DCP device shall be inspected for fatigue-damaged parts, in particular the coupler and handle, and excessive wear of the drive rod and replacement point tip. All joints must be securely tightened including the coupler assembly and the replaceable point tip (or the adapter for the disposable cone tip) to drive rod.

3.3 Initial Reading and Seating for Testing Granular Materials

A. Locate a level, undisturbed area.
B. The DCP is held vertically and the tip seated such that the top of the widest part of the tip is flush with the surface of the material to be tested. Take an initial reading and record it on the PIV Worksheet. The distance is measured to the nearest 0.04-in (1-mm). Some sliding reference attachments allow the scale/measuring rod to be set/marked at zero when the tip is at the zero point shown in Figure 2.
C. Raise the rammer until it meets the handle, then release the rammer under its own weight and allow it to impact the anvil coupler assembly. Repeat this process one more time for a total of 2 initial drops to complete the seating process. The corresponding penetration is recorded on the PIV Data Worksheet. The distance is measured to the nearest 0.04-in (1-mm).

NOTE: The operator raises the rammer until it makes only light contact with the handle.

3.4 Testing Sequence.

A. Carefully raise the rammer until it meets the handle, then release the rammer under its own weight. Repeat the process two more times for a total of five blows.
B. Measure and record the final penetration measurement after 5 blows on the PIV Data Worksheet.
C. The DCP is extracted from the test hole. An extraction jack may be used to aid in this process.
D. Collect a representative sample from the test hole for a moisture content determination. Weigh the material to the nearest 0.1 g and dry it to a constant weight as per SD 108. Record the moisture content on the PIV Data Worksheet.

NOTE: The presence of large aggregates or rock strata will either stop further penetration or deflect the drive rod. If after 5 blows, the device has not advanced more than 0.08-in (2-mm) or the handle has deflected more than 3-in (75-mm) from the vertical position, the test shall be aborted and the device moved to another test location. The new test location shall be a minimum of 12-in (300-mm) from the prior location to minimize test error.

4. Report:

4.1 Calculations

A. The SEAT measurement is calculated by subtracting the initial reading from the reading after 2 blows.
B. The PIV value is a the reading obtained after 5 blows minus the reading after 2 blows divided by the number of blows (3) as seen in the equation below.

$$\text{PIV} = \frac{\text{Reading after 5 blows} - \text{Reading after 2 blows}}{3}$$

4.2 Report

A. Report the moisture content to the nearest 0.1 percentage point.
B. Report the SEAT value to the nearest 1 mm.
C. Report the PIV value to the nearest 1 mm.

D. Provided required information on the DCP Penetration Index Value Worksheet.

5. References:

ASTM D6951
SD 108

**Sample ID** | # DCP Penetration Index Value Worksheet Method 1 | **DOT -##**

**File No.**

**Subbase and Base Course Granular Materials**

PROJECT____________COUNTY____________________PCN_________________ Date _________Lift __________ of ____________ Lift Thickness _____in.

Tested By _________________________________ Checked By ________________________ Notes ____________________________________________________________

## Gradation Data

Gradation Sample ID Used __________________________

| Sieve | % Passing |
|---|---|
| 1 Inch | |
| 3/4 Inch | |
| 3/8 Inch | |
| # 4 | |
| # 8 | |
| # 40 | |
| # 200 | |
| **GN =** | |

$$(GN) = \frac{1'' + {}^3/_4'' + {}^3/_8'' + \#4 + \#8 + \#40 + \#200}{100}$$

## Penetration Requirements

| Grading Number | MC (% Dry) | Maximum Allowable Seating (mm) | Maximum Allowable PIV (mm/blow) | Grading Number | MC (% Dry) | Maximum Allowable Seating (mm) | Maximum Allowable PIV (mm/blow) |
|---|---|---|---|---|---|---|---|
| 3.1 – 3.5 | < 5.0 | 40 | 10 | 4.6 – 5.0 | < 5.0 | 65 | 15 |
| | 5.0 – 8.0 | 40 | 12 | | 5.0 – 8.0 | 75 | 19 |
| | > 8.0 | 40 | 16 | | > 8.0 | 85 | 23 |
| 3.6 – 4.0 | < 5.0 | 40 | 10 | 5.1 – 5.5 | < 5.0 | 85 | 17 |
| | 5.0 – 8.0 | 45 | 15 | | 5.0 – 8.0 | 95 | 21 |
| | > 8.0 | 55 | 19 | | > 8.0 | 105 | 25 |
| 4.1 – 4.5 | < 5.0 | 50 | 13 | 5.6 – 6.0 | < 5.0 | 100 | 19 |
| | 5.0 – 8.0 | 60 | 17 | | 5.0 – 8.0 | 115 | 24 |
| | > 8.0 | 70 | 21 | | > 8.0 | 125 | 28 |

No moisture test is required when DPI is met for a given GN, for example if GN is 4.8 and DPI is 14, no moisture test is required.

## DCP Data

$$\text{PIV} = \frac{\text{Reading after 5 blows} - \text{Reading after 2 blows}}{3}$$

| Test Information | | | | | | Requirements | | DCP Data (mm) | | | Test Results | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test # | Date | Station | Offset | GN | MC (%) | Maximum Allowable SEAT (mm) | Maximum Allowable PIV (mm/blow) | Initial Reading | Reading after seating (2 Blows) | Reading after 5 blows | SEAT (mm) | SEAT : Pass or Fail | PIV (mm/blow) | PIV: Pass or Fail | **TEST:** Pass or Fail |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |

**Sample ID** | **DCP Penetration Index Value Worksheet Method 2** | **DOT**

**File No.** | **Milled, Reclaimed, and Salvaged Granular Material**

PROJECT____________COUNTY__________________PCN_______________ Date ________Lift __________ of ___________ Lift Thickness _____in.

Tested By ________________________________ Checked By _______________________ Notes ____________________________________________________

$$\mathrm{PIV} = \frac{\mathrm{C} - \mathrm{B}}{3} \qquad \mathrm{SEAT} = \mathrm{B} - \mathrm{A}$$

| **Test Information** | | | | | **Requirements** | | **DCP Data (mm)** | | | **Test Results** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test # | Date | Station | Offset | MC (%) | Maximum Allowable SEAT (mm) | Maximum Allowable PIV (mm/blow) | Initial Reading **(A)** | Reading after seating (2 Blows) **(B)** | Reading after 5 blows **(C)** | SEAT (mm) | SEAT: Pass or Fail | PIV (mm/blow) | PIV: Pass or Fail | **TEST:** Pass or Fail |
| | | | | | | | | | | | | | | |
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STATE OF SOUTH DAKOTA DEPARTMENT OF TRANSPORTATION

SUPPLEMENTAL SPECIFICATIONS TO
2015 STANDARD SPECIFICATIONS FOR ROADS AND BRIDGES October 6, 2017

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All items included in this Supplemental Specification will govern over the Supplemental Specifications for Errata.
MAKE THE FOLLOWING CHANGES TO THE INDICATED SECTIONS:
Section 260.3 B – Page 119 – Delete section and replace with the following:
In Section B:

Subbase and Base Course: Each layer shall be compacted to the specified Penetration Index Value PIV and DCP seating requirements before the next lift is placed and shall be rolled until a uniform and stable surface is obtained. The requirements for acceptance are specified according the materials Grading Number (GN) as described in SD ### (DCP PIV Method 1). In-situ tests shall be conducted in accordance with SD ### (DCP Procedure).
Section 260.3 C – Page 119 – Delete section and replace with the following:
In Section C:

Subbase, Salvaged and Base Course, Salvaged: Each layer shall be compacted to obtain a Penetration Index Value (PIV) of 15 mm/blow or less and shall not have a SEAT in excess of 20 mm. Test shall be conducted in accordance with SD ### (DCP Procedure) and SD ### Method 2 (DCP Methods).

**1.** Material shall have a minimum of 4% moisture uniformly blended throughout the depth of the lift of material. The percent moisture may be adjusted by the Engineer.

Section 280.3 C – Page 124 – Delete section and replace with the following:
In Section C:

Compaction Requirements: The entire lift shall be compacted to obtain Penetration Index Values (PIV) of XXX mm/blow or less. The lift shall not have a SEAT Value more than  mm. The entire lift shall be tested in accordance with SD ### (DCP Procedure) and SD ### Method 1 or 2 (DCP Methods).

**1.** Material shall have a minimum of 4% moisture uniformly blended throughout the depth of the lift of material. The percent moisture may be adjusted by the Engineer.

Moisture-Density Relations of Soils, Aggregates, and Specified Mixtures

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**1.** Scope:

This test is to establish the moisture-density relationship of soils, aggregates and mixtures.
NOTE: Before field control of compaction can be exercised, it is required that the optimum moisture, maximum density values (4-point Method) be determined for the materials prior to, or at the time field compactions are measured.
The purpose of the 4-point determination is to verify if a family of curves is usable for the material. Changing from one family of curves to the other family of curves requires a 4-point determination to validate the change.
Definitions.

Compaction: The act of increasing the unit weight of the soil, aggregate or mixture, by mechanically compressing the material into a closer state of contact. For a given compaction effort, the density of the material tested will normally increase until optimum moisture content is reached, then the density will begin to decrease. It should be noted that there have been cases where the apparent decrease in density was followed by another increase in density. These secondary or "False" plateaus in the moisture-density curve should always be checked to determine the valid data.

The Percent Compaction: This is the ratio of the density of the material, as placed during construction, to the maximum density of a representative specimen of the same material.

Density: The density of a material is the weight per unit volume, in lbs./$ft^3$ in dry condition.

One-Point (Standard) Test: A rapid test where the wet density or dry density and moisture content measurements for the test material are used to select a curve from a family of curves to be the standard.

Four-Point (Standard) Test: The results of four or more moisture-density tests are plotted with density values as the ordinate or vertical scale and the moisture content (Percentage) as the abscissas or horizontal scale. When the plotted points are joined by a smooth curve, the maximum density at optimum moisture may be determined. (Figure 2, 3, 7 and 8) The moisture content corresponding to the peak of the curve shall be termed "Optimum Moisture" of the material. The dry density in lbs./$ft^3$ at optimum moisture content shall be termed the "Maximum Density".

Optimum Moisture: The moisture content corresponding to the maximum density.

Maximum Density: The highest value for density, calculated on the basis of dry weight of material per cubic foot, shown on the moisture density curve.

**2.** Apparatus:

2.1 Molds. A 4" diameter or 6" diameter mold meeting the requirements of AASHTO T 99.

2.2 Rammer. A 5.5 lb. rammer conforming to AASHTO T 99.

NOTE: A mechanical rammer may be used, if approved by the Chief Materials and Surfacing Engineer.

2.3 Sample extruder (Optional) such as a jack, frame, or other device adapted for extruding compacted specimens from the mold.

2.4 Scale or balance having the capacity to weigh any sample which may be tested utilizing this procedure and readable to the nearest 0.01 lb. and also one that is readable to the nearest 0.1 gram.

2.5 Sieves and screens. A 3/4" and a #4 sieve. A #4 rough screen shall be approximately 12" x 18" in size. #4 sieves intended for use in sieve analysis testing shall not be used for pushing wet material through as shown in paragraph 3.2 B.

2.6 Oven.

A. An oven, for determining moisture content, capable of maintaining a temperature of 230° ± 9°F.

B. An oven for drying soil samples at a temperature not exceeding 140°F.

NOTE: Other methods of moisture determination shown in SD 108 may be used.

2.7 Containers for moisture content samples.

2.8 Steel straightedge at least 12" in length.

2.9 Miscellaneous: Tools, plastic bags, beakers, cans, pails, shovel, spatula, knife, spoons and trowel.

**3.** Procedure:

Method 1 Four Point - For testing materials passing a #4 sieve using a 4" mold. Method 2 One Point - For testing material passing a #4 sieve using a 4” mold. Method 3 Four Point - For testing material passing a 3/4” sieve using a 6” mold. Method 4 One Point - For testing material passing a 3/4” sieve using a 6” mold.

NOTE: The method used for determining the 4-point will establish the method used for the 1-point, i.e., if the 4" mold is used for the 4-point, (Method 1) the 4" mold must be used for the 1-point (Method 2). If it is requested to change mold size, a 4-point using that size mold must be completed. The mold without the collar shall be weighed to the nearest 0.01 lb., prior to beginning the test.

3.1 Method 1 (Soil).

A. Obtain a sample of soil weighing approximately 30 lbs.

B. Dry the sample in an oven at a temperature not exceeding 140°F.

C. Using the apparatus described in SD 101, break the sample down to pass the #4 sieve. Care must be taken not to break any rock retained on the #4 sieve. Sieve the sample on a #4 sieve and discard any granular material retained.

D. Reduce the sample to 5 specimens, weighing approximately 5 lbs. each.

E. Thoroughly mix one of the specimens with a measured amount of water to dampen it to approximately 4 to 6 percentage points below optimum.

F. Place the specimen in a plastic bag and seal the top to prevent moisture loss. Allow the specimen to cure for a minimum of 12 hours.

G. Mix the remaining specimens in the same manner as shown in paragraphs E. and F., increasing the measured water by approximately 2 percentage points over the preceding specimen. The percent of increase should be at a uniform rate.

H. The test specimen is then formed in the 4" mold, with collar attached, in three approximately equal layers, to a total compacted depth of approximately 5". Compact each layer using 25 uniformly distributed blows from the rammer dropping free from a height of 12" above the surface of the soil in the mold. Clean rammer head prior to compacting the next layer to ensure the calibrated rammer head is still 5.5 lbs.

NOTE: During compaction, the mold shall rest firmly on a dense, uniform rigid and stable foundation. The following are satisfactory as a base on which to rest the mold during compaction: a block of concrete weighing at least 200 lbs., a sound concrete floor, concrete box culverts, bridges and PCC pavement.

I. Immediately following compaction, remove the extension collar, carefully trim the compacted material even with the top edge of the mold with a knife and straightedge. Holes in the surface of the molded material caused by removal of coarse particles shall be patched with finer material removed in trimming.

Weigh the mold and compacted moist specimen in lbs. to the nearest 0.01 lb. Record the weight on the DOT-40 as "Weight of mold and wet specimen".

J. Remove the moist specimen from the mold, slice vertically through the center of the specimen and take a representative sample from one of the cut faces for moisture determination.

Weigh a moisture test specimen of at least 100 g to the nearest 0.1 g and dry in an oven at 230° ± 9°F to a constant weight as per SD 108.
Other methods of moisture determination shown in SD 108 may be used.

K. After drying, weigh and record the weight of the moisture samples to the nearest 0.1 gram.

L. Test each of the remaining specimens, as shown in paragraphs H. thru K.

NOTE: Continue this series of determinations until there is either a decrease or no change in the wet unit weight per cubic foot. If the plotted points of either the dry density or wet density do not form a curve, additional determinations will be performed to form the curve.

M. Complete the calculations on the DOT-40 as shown in figure 1.

N. Results of the calculations (Moisture content and corresponding wet and dry densities) are plotted on the graph (DOT-40) using density values as ordinates and moisture contents as abscissas. Draw a smooth curve connecting the points established by plotting results of four or more tests, figure 2 & 3.

The moisture content corresponding to the peak of the dry density curve shall be termed "Optimum Moisture" for the compacted material.

O. The dry unit weight density lbs./ft$^3$ of the compacted material at optimum moisture content shall be termed “Maximum Density”.

P. Validation of the family of curves: Prior to using any family of pre-drawn curves, it shall be checked using project material and the 4- point system. This can be done by comparison of wet density curves.

1. Determine the maximum dry density and optimum moisture from the 4-point dry density curve. This should be at the peak of the dry density curve.
2. Select a moisture content 1 1/2 to 2 percentage points below optimum moisture.
3. Using this moisture content, find the corresponding wet density on the wet density curve of the 4-point.
4. Plot this wet density and moisture content on the family of curves proposed for use on the project to determine the curve to be used for the standard.

Select the curve nearest the plotted point. If the plotted point is between 2 curves and there is doubt as to which curve is closest, use the curve below the plot.
The maximum dry density from this curve must be within 3 lbs. of the 4-point maximum dry density. If the curves fail to check within this tolerance, contact the Region Materials Engineer as the family of curves may not be reliable for this material.

3.2 Method 2 (Soil).

A. Obtain a sample of approximately 5 lbs. of soil.

B. Break up the sample using fingers, a trowel or a pine board to push the sample through a #4 rough screen.

C. If the sample appears to be above optimum moisture, dry it sufficiently in an oven at a temperature not exceeding 140° F to bring it to approximately optimum.

If the sample appears too dry, add and mix sufficient water to bring it near optimum.

D. Mold and take a moisture sample, as shown in paragraphs 3.1 H through 3.1 J. (Use form DOT-35 for moisture tests and DOT-41 for density tests.)

E. Using the "1-point determination" wet density and the "1-point" moisture determination, enter the family of curves, figure 4 or figure 5, to obtain the maximum density and optimum moisture. The family of curves must be the one identified by the 4-point determination. (See "NOTE" on page 1 of this procedure.)

Select the curve nearest the plotted point. If the plotted point is between 2 curves and there is doubt as to which curve is closest, use the curve below the plot.

NOTE: If the 1-point moisture content deviates from optimum (for the curve selected) by more than 2 percentage points below or 1 percentage point above, a second 1-point shall be made at or nearer optimum and within the tolerance shown.

3.3 Method 3 (Soils / Granular Material).

A. Obtain a sample of approximately 60 lbs. in accordance with SD 201.

NOTE: The tester may elect to obtain more material and mix individual samples at varying percentages of moisture. If so elected, follow the procedure shown in method 1 and obtain samples approximately 15 lbs. each and use a 3/4" sieve and a 6" mold.

B. Dry the sample in an oven at a temperature not exceeding 140° F.

C. Sieve the sample on a 3/4" sieve, discarding the material retained.

D. Weigh the sample and add sufficient water to bring it to approximately 4 percentage points below optimum.

E. The test specimen is then formed in the 6" mold in three approximately equal layers to a total depth of approximately 5". Compact each layer using 56 uniformly distributed blows from the rammer dropping 12" above the surface of the material in the mold. Clean rammer head prior to compacting the next layer to ensure the calibrated rammer head is still 5.5 lbs.

NOTE: During compaction, the mold shall rest firmly on a dense, uniform, rigid and stable foundation. The following are satisfactory bases on which to rest the mold during compaction: A block of concrete weighing at least 200 lbs., a sound concrete floor, concrete box culverts, bridges and PCC pavement.

F. Immediately following compaction, remove the extension collar and carefully trim the compacted material even with the top edge of the mold with a straightedge. Holes in the surface of the molded material caused by removal of coarse particles shall be patched with finer material removed in trimming.

Weigh the mold and compacted moist specimen in lbs. to the nearest 0.01 lb. Record on a DOT-40 as "Weight of mold and wet specimen".

G. Remove the specimen from the mold, slice vertically through the center of the specimen and take a representative sample from one cut face for moisture determination.

Weigh a moisture test specimen of at least 100 grams for soil and 500 grams for granular material to the nearest 0.1 g and dry in an oven at a temperature of 230° ± 9°F to a constant weight as per SD 108.
Other methods of moisture determination as shown in SD 108 may be used.

H. After drying, weigh and record the weights of the moisture sample to the nearest 0.1 gram.

I. Complete the calculation on the DOT-40 as shown in figure 6.

J. Thoroughly break up the remaining portion of the specimen until it will pass a 3/4" sieve, and add it to the remaining portion of the sample being tested. Add sufficient water to increase moisture content of the sample between 1 and 2 percentage points and repeat the procedure in paragraphs 3.3 E. through 3.3 I.

NOTE: Continue this series of determinations until there is either a decrease or no change in the wet unit weight per cubic foot. If the plotted points of either the dry density or wet density do not form a curve, additional determinations will be performed to form the curve.

K. Results of calculations (Moisture content and corresponding wet and dry densities) are plotted on the graph using density values as ordinates and moisture contents as abscissas. Draw a smooth curve connecting the points established by plotting results of 4 or more tests. (Figure 7 & 8).

L. The moisture content corresponding to the peak of the dry density curve shall be termed "Optimum Moisture" for the compacted material.

M. The dry unit weight corresponding to the peak of the dry density curve shall be termed "Maximum Density" of the compacted material.

N. Prior to using any family of pre-drawn curves, it shall be checked, using project material and the 4-point system. This can be done by comparison of the dry density curves.

1. Determine the maximum dry density and optimum moisture from the 4-point dry density curve. This should be at the peak of the dry density curve.
2. Locate the dry density and moisture content on the family of curves proposed for use on the project to determine the curve to be used for the standard.

Select the curve nearest the point. If the point is between 2 curves and there is doubt as to which curve is closest, use the curve below the point.
The maximum dry density from this curve must be within ± 3 lbs./cu. ft. of the 4-point maximum dry density. If the curves fail to check within this tolerance, contact the Region Materials Engineer as the family of curves may not be reliable for this material.

3.4 Method 4 (Soils / Granular Material).

A. Obtain a sample of approximately 15 Ibs.

B. Sieve the sample on a 3/4" sieve and discard any material retained.

C. If the sample appears to be above optimum moisture, dry it sufficiently in an oven at a temperature not exceeding 140° F to bring it to approximately optimum.

If the sample appears dry, add and mix sufficient water to bring it near optimum.

D. Mold and take a moisture sample, as shown in paragraphs 3.3 E. through 3.3 I. (Use the DOT-41 for density tests.)

E. Using the "1-point determination" dry density and the "1-point" moisture determination, enter the family of curves Figure 9 to obtain the target maximum dry density and optimum moisture.

The family of curves must be the one identified by the 4-point determination. (See "NOTE" on page 1 of this procedure.)
Select the curve nearest the plotted point. If the plotted point is between 2 curves and there is doubt as to which curve is closest, use the curve below the plot.
NOTE: The peak of the curves presented in Figure 9 are not to be used as the target maximum dry density and optimum moisture. Use the table values corresponding for each curve letter for target values when conducting in-situ density testing. The maximum dry density provided by the table for the selected curve by the 1-point ("U" on the DOT- 41) shall not deviate from the maximum dry density determined by the 4-point curve established for the material by more than +/- 3 lbs./cu. Ft. The moisture content of the 1-point specimen will be no more than 1 percentage point above, or 2 percentage points below optimum moisture provided in the table for the curve selected. If either of these conditions exist, a second 1-point, closer to optimum will be made.
When changes in gradation occur which may affect density results, additional 4-point determinations shall be made, as directed by the Region Materials Engineer.

3.5 When Methods 2 and 4 are used in conjunction with SD 105 and SD 106, the material for testing is taken from or adjacent to the in-place density test hole and the DOT-41 form is used.

**4.** Report:

4.1 Calculations.

Calculate the moisture content and corresponding dry unit weight in lbs./ft$^3$ as follows:

$$w = \frac{A - B}{B - C} \times 100$$

and

$$W = \frac{W1 \times 100}{w + 100}$$

Where:

w = Percentage of moisture in specimen, based on dry weight of soil.
A = Weight of container and wet soil/granular material.
B = Weight of container and dry soil/granular material.
C = Weight of container.
W = Dry weight in lbs./ft$^3$ of compacted material.
$W_1$ = Wet weight in lbs./ft$^3$ of compacted material.

4.2 Report.

A. Report the following:

(1) The optimum moisture content, as a percentage, to the nearest 0.1.

(2) The maximum density in $lbs./ft^3$ to the nearest 0.1 lb.

(3) Test results will be reported on form DOT-40.

**5.** References:

AASHTO T 99
SD 101
SD 105
SD 106
SD 108
SD 201
SD 205
DOT-35
DOT-40
DOT-41

DOT-40
9-14
File No. 16
SOUTH DAKOTA DEPARTMENT OF TRANSPORTATION
DENSITY SHEET
PROJECT IM 090-7(14)125 COUNTY Washington PCN 7140

OPERATOR Marv C. Cleason CHECKED BY RJH DATE 8/8/96

| | | | | | | |
|---|---|---|---|---|---|---|
| Specimen Number | 1 | 2 | 3 | 4 | 5 | |
| Can Number | 9 | 3 | 2 | 8 | 4 | |
| Weight of Can and Wet Material | 164.7 | 192.7 | 142.0 | 121.7 | 133.2 | |
| Weight of Can and Dry Material | 151.0 | 174.2 | 127.0 | 107.2 | 117.0 | |
| Weight Loss (Moisture) Speedy Reading | 13.7 | 18.5 | 15.0 | 14.5 | 16.2 | |
| Weight of Can | 14.0 | 16.0 | 17.5 | 13.9 | 15.8 | |
| Weight of Dry Material | 137.0 | 158.2 | 109.5 | 93.3 | 101.2 | |
| Percent Moisture | 10.0 | 11.7 | 13.7 | 15.5 | 16.0 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Weight of Mold and Wet Specimen | 13.83 | 14.10 | 14.21 | 14.11 | 13.96 | |
| Weight of Mold | 9.71 | 9.71 | 9.71 | 9.71 | 9.71 | |
| Weight of Wet Specimen | 4.12 | 4.39 | 4.50 | 4.40 | 4.25 | |
| Factor of Mold No. 2-90 | 29.98 | 29.98 | 29.98 | 29.98 | 29.98 | |
| Wet Density Wet Wt. x Factor | 123.5 | 131.6 | 134.9 | 131.9 | 127.4 | |
| Dry Density PCF | 112.3 | 117.8 | 118.6 | 114.2 | 109.8 | |

Figure 1
PLOT WET AND DRY CURVES ON REVERSE SIDE

DOT-40
1-95

DENSITY SHEET
File # 16

COUNTY Washington PROJECT I96-7 (14) 513 PCN 7140
FIELD NO. 2 LAB NO. 278 DATE 8-8-96
SOURCE Borrow Pit #6 TYPE OF MATERIAL Clay
4-POINT DATA: OPTIMUM MOISTURE 13.1 MAXIMUM DENSITY 118.8
CURVE VALIDATION: FAMILY Ohio CURVE Small J MAX. DENSITY 118.1
GRANULAR MATERIAL 4-POINT RANGE ____ TO ____

(SEE REVERSE SIDE FOR CALCULATIONS)

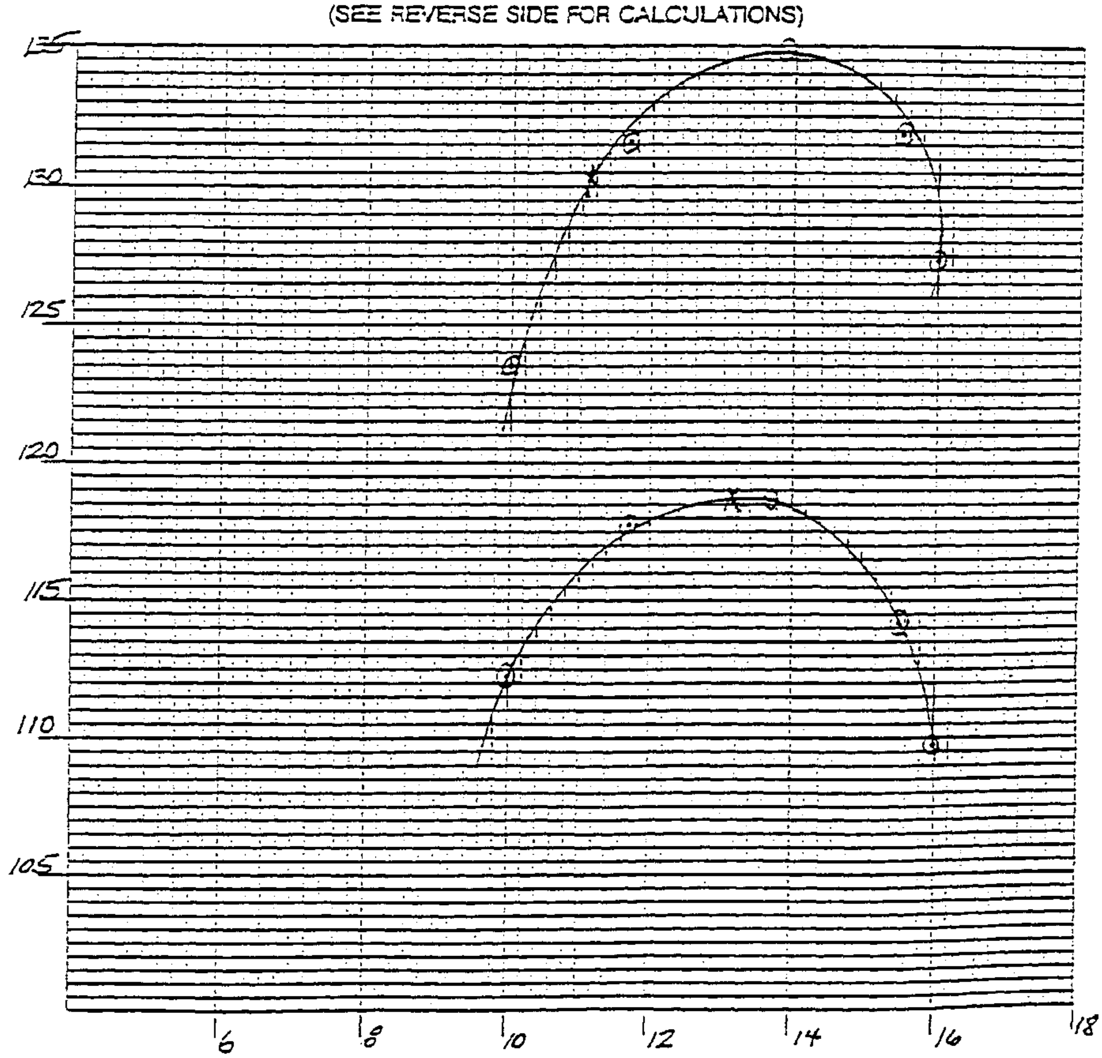



Figure 2

Figure 2

**Sample ID** 2204757 **Density Sheet** **DOT - 40**
**File No.** (09/2004)

County Aurora, Ziebach PCN/PROJECT B015 PH 0066(00)15

Field # 01 Tested By Tester, One Date Tested 04/22/2015 12:00 am

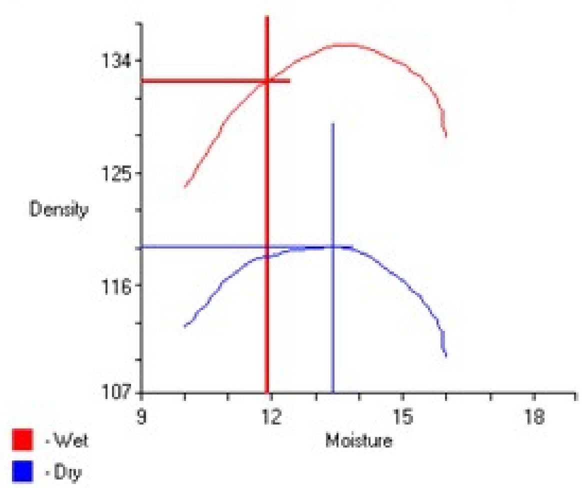
Checked By Tester, Two

Source Borrow #6 Material Type Unclassified Excavation

Comment

| Specimen Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Weight of Can and Wet Material | 164.70 | 192.7 | 142.00 | 121.70 | 133.20 | | |
| Weight of Can and Dry Material | 151.00 | 174.20 | 127.00 | 107.20 | 117.00 | | |
| Weight Loss (Moisture) Speedy Reading | 13.7 | 18.5 | 15.0 | 14.5 | 16.2 | 0.0 | 0.0 |
| Weight of Can | 14.0 | 16.0 | 17.5 | 13.9 | 15.8 | | |
| Weight of Dry Material | 137.0 | 158.2 | 109.5 | 93.3 | 101.2 | | |
| Percent Moisture | 10. | 11.7 | 13.7 | 15.5 | 16. | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Weight of Mold and Specimen | 13.83 | 14.10 | 14.21 | 14.11 | 13.96 | | |
| Weight of Mold | 9.71 | 9.71 | 9.71 | 9.71 | 9.71 | 9.71 | 9.71 |
| Weight of Wet Specimen | 4.120 | 4.390 | 4.500 | 4.400 | 4.250 | | |
| Factor of Mold No. 2-90 | 29.980 | 29.980 | 29.980 | 29.980 | 29.980 | 29.980 | 29.980 |
| Wet Density Wet Wt. x Factor Kg/m or PCF 1000 for metric | 123.5 | 131.6 | 134.9 | 131.9 | 127.4 | | |
| Dry Density Kg/m or PCF | 112.3 | 117.8 | 118.6 | 114.2 | 109.8 | | |

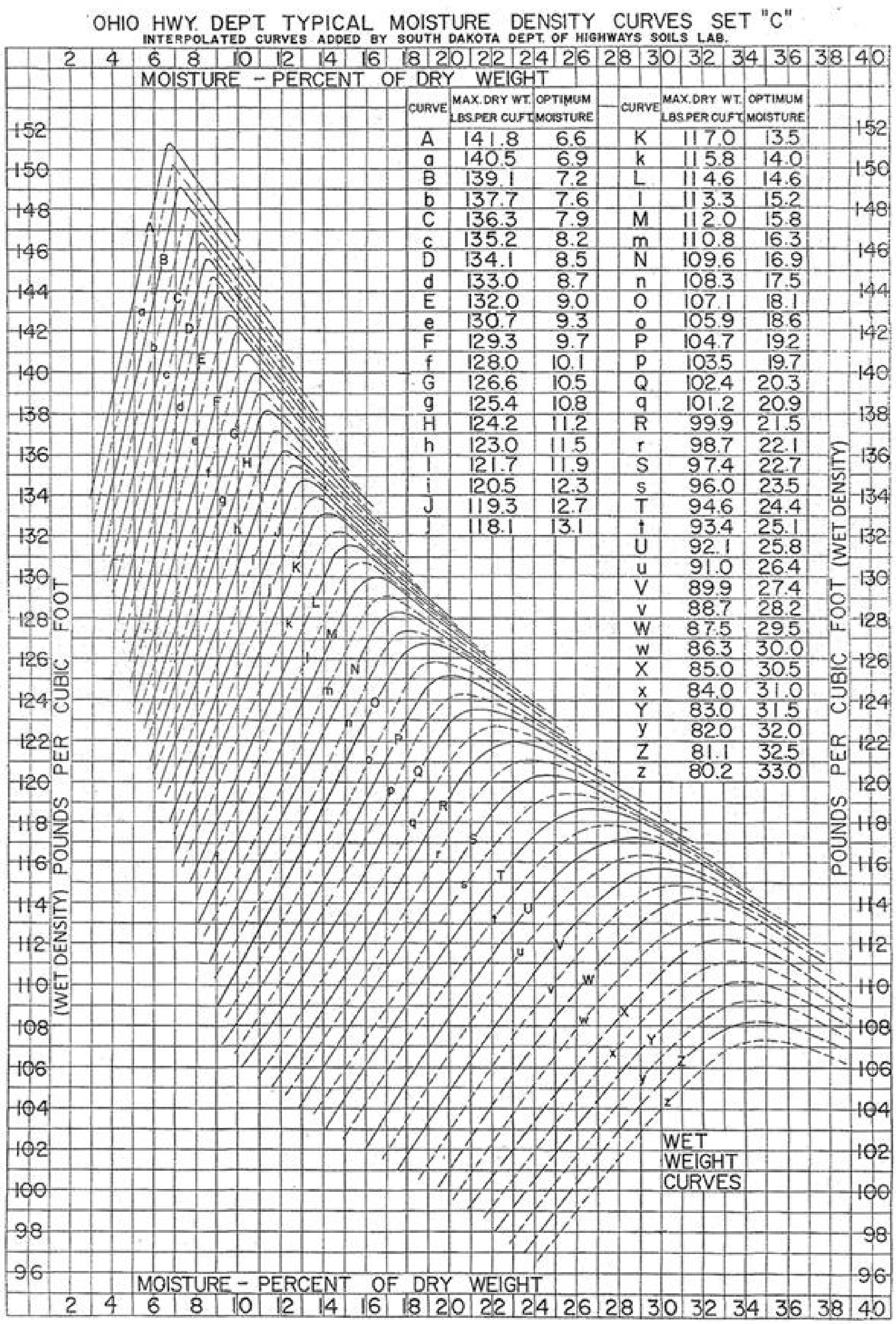



Wet Density: 132.0 Wet Moisture: 11.9

Dry Maximum Density: 118.7 Dry Optimum Moisture: 13.4

Four-Point Range: 115.7 - 121.7 Curve and Family: J

Figure 3




| CURVE | MAX. DRY WT. LBS. PER CU. FT. | OPTIMUM MOISTURE | CURVE | MAX. DRY WT. LBS. PER CU. FT. | OPTIMUM MOISTURE |
|---|---|---|---|---|---|
| A | 141.8 | 6.6 | K | 117.0 | 13.5 |
| a | 140.5 | 6.9 | k | 115.8 | 14.0 |
| B | 139.1 | 7.2 | L | 114.6 | 14.6 |
| b | 137.7 | 7.6 | l | 113.3 | 15.2 |
| C | 136.3 | 7.9 | M | 112.0 | 15.8 |
| c | 135.2 | 8.2 | m | 110.8 | 16.3 |
| D | 134.1 | 8.5 | N | 109.6 | 16.9 |
| d | 133.0 | 8.7 | n | 108.3 | 17.5 |
| E | 132.0 | 9.0 | O | 107.1 | 18.1 |
| e | 130.7 | 9.3 | o | 105.9 | 18.6 |
| F | 129.3 | 9.7 | P | 104.7 | 19.2 |
| f | 128.0 | 10.1 | p | 103.5 | 19.7 |
| G | 126.6 | 10.5 | Q | 102.4 | 20.3 |
| g | 125.4 | 10.8 | q | 101.2 | 20.9 |
| H | 124.2 | 11.2 | R | 99.9 | 21.5 |
| h | 123.0 | 11.5 | r | 98.7 | 22.1 |
| I | 121.7 | 11.9 | S | 97.4 | 22.7 |
| i | 120.5 | 12.3 | s | 96.0 | 23.5 |
| J | 119.3 | 12.7 | T | 94.6 | 24.4 |
| j | 118.1 | 13.1 | t | 93.4 | 25.1 |
| | | | U | 92.1 | 25.8 |
| | | | u | 91.0 | 26.4 |
| | | | V | 89.9 | 27.4 |
| | | | v | 88.7 | 28.2 |
| | | | W | 87.5 | 29.5 |
| | | | w | 86.3 | 30.0 |
| | | | X | 85.0 | 30.5 |
| | | | x | 84.0 | 31.0 |
| | | | Y | 83.0 | 31.5 |
| | | | y | 82.0 | 32.0 |
| | | | Z | 81.1 | 32.5 |
| | | | z | 80.2 | 33.0 |

Figure 4

| | MAX. DRY WT. LBS./CU.FT. | OPT. MOIST. | | MAX. DRY WT. LBS./CU.FT. | OPT. MOIST. |
|---|---|---|---|---|---|
| 1 | 85.0 | 33.4 | 11 | 79.9 | 38.4 |
| 2 | 84.5 | 33.9 | 12 | 79.4 | 38.9 |
| 3 | 84.1 | 34.3 | 13 | 79.0 | 39.4 |
| 4 | 83.5 | 34.8 | 14 | 78.5 | 40.0 |
| 5 | 83.0 | 35.3 | 15 | 77.9 | 40.6 |
| 6 | 82.5 | 35.9 | 16 | 77.4 | 40.9 |
| 7 | 81.9 | 36.4 | 17 | 76.9 | 41.4 |
| 8 | 81.4 | 36.9 | 18 | 76.4 | 41.9 |
| 9 | 81.0 | 37.3 | 19 | 76.0 | 42.4 |
| 10 | 80.5 | 37.8 | 20 | 75.5 | 42.9 |

## FAMILY OF CURVES FOR LIGHT WEIGHT SOILS

**When using this family of curves, the moisture content in the 1-point shall not be more than 2% below, or more than 1% above the optimum moisture**

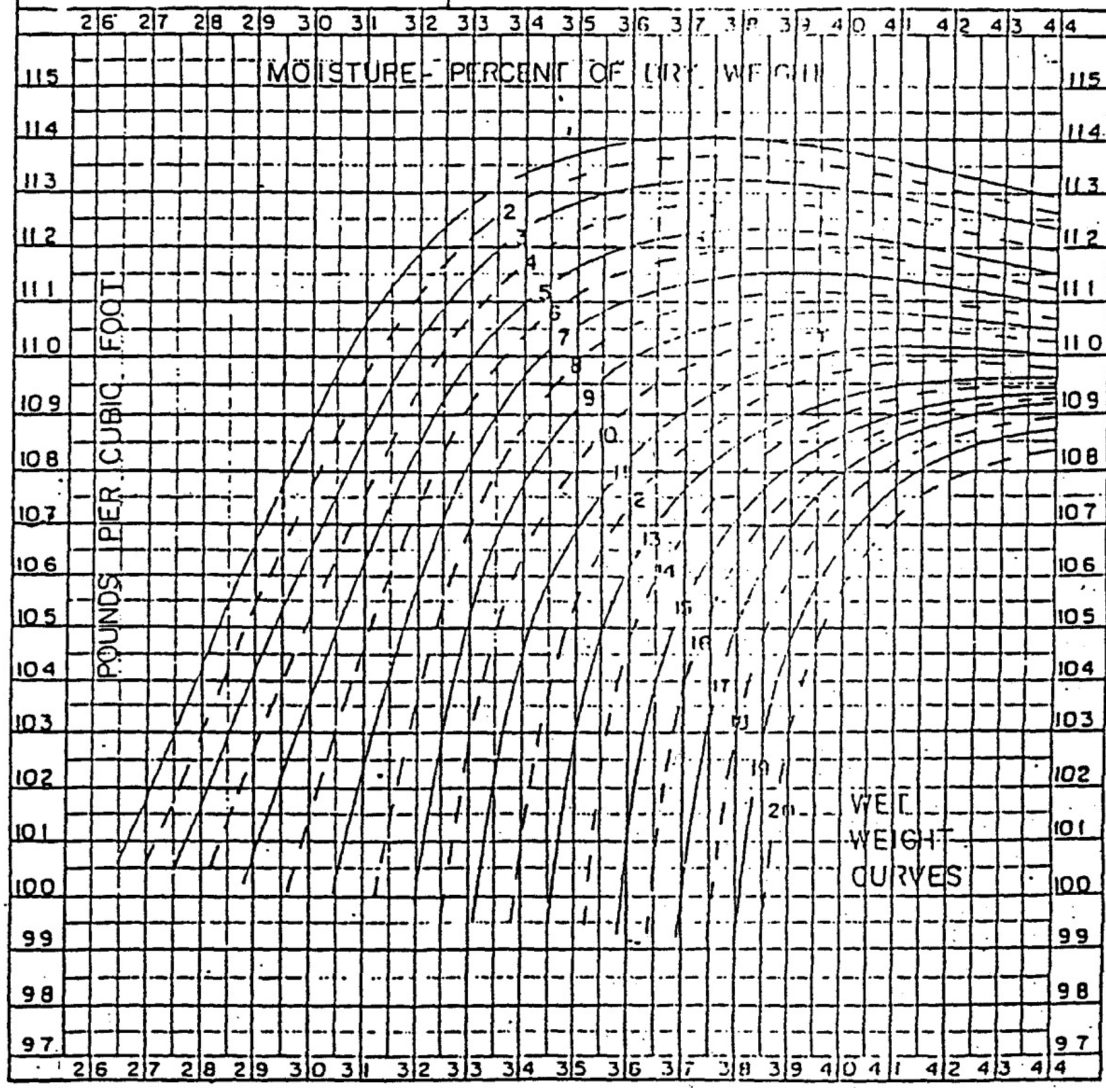



Figure 5

DOT-40
9-14
File No.__17.2______
SOUTH DAKOTA DEPARTMENT OF TRANSPORTATION
DENSITY SHEET

| | | | | | |
|---|---|---|---|---|---|
| PROJECT | IM 090-7(14)125 | COUNTY | Washington | PCN | 7140 |

CHECKED BY RJH

OPERATOR Marv C. Cleason

DATE 8/8/96

| | | | | | | |
|---|---|---|---|---|---|---|
| Specimen Number | 1 | 2 | 3 | 4 | 5 | |
| Can Number | 77 | 89 | 32 | 47 | 71 | |
| Weight of Can and Wet Material | 631.1 | 655.2 | 651.4 | 624.9 | 668.7 | |
| Weight of Can and Dry Material | 602.2 | 619.3 | 607.3 | 574.8 | 609.6 | |
| Weight Loss (Moisture) Speedy Reading | 28.9 | 35.9 | 44.1 | 50.1 | 59.1 | |
| Weight of Can | 76.0 | 84.0 | 82.0 | 79.0 | 81.0 | |
| Weight of Dry Material | 526.2 | 535.3 | 525.3 | 495.8 | 528.6 | |
| Percent Moisture | 5.5 | 6.7 | 8.4 | 10.1 | 11.2 | |
| Weight of Mold and Wet Specimen | 22.58 | 23.06 | 23.45 | 23.40 | 23.19 | |
| Weight of Mold | 12.72 | 12.72 | 12.72 | 12.72 | 12.72 | |
| Weight of Wet Specimen | 9.86 | 10.34 | 10.73 | 10.68 | 10.47 | |
| Factor of Mold No. 2-67 | 13.24 | 13.24 | 13.24 | 13.24 | 13.24 | |
| Wet Density Wet Wt. x Factor | 130.5 | 136.9 | 142.1 | 141.4 | 138.6 | |
| Dry Density PCF | 123.7 | 128.3 | 131.1 | 128.4 | 124.6 | |

PLOT WET AND DRY CURVES ON REVERSE SIDE

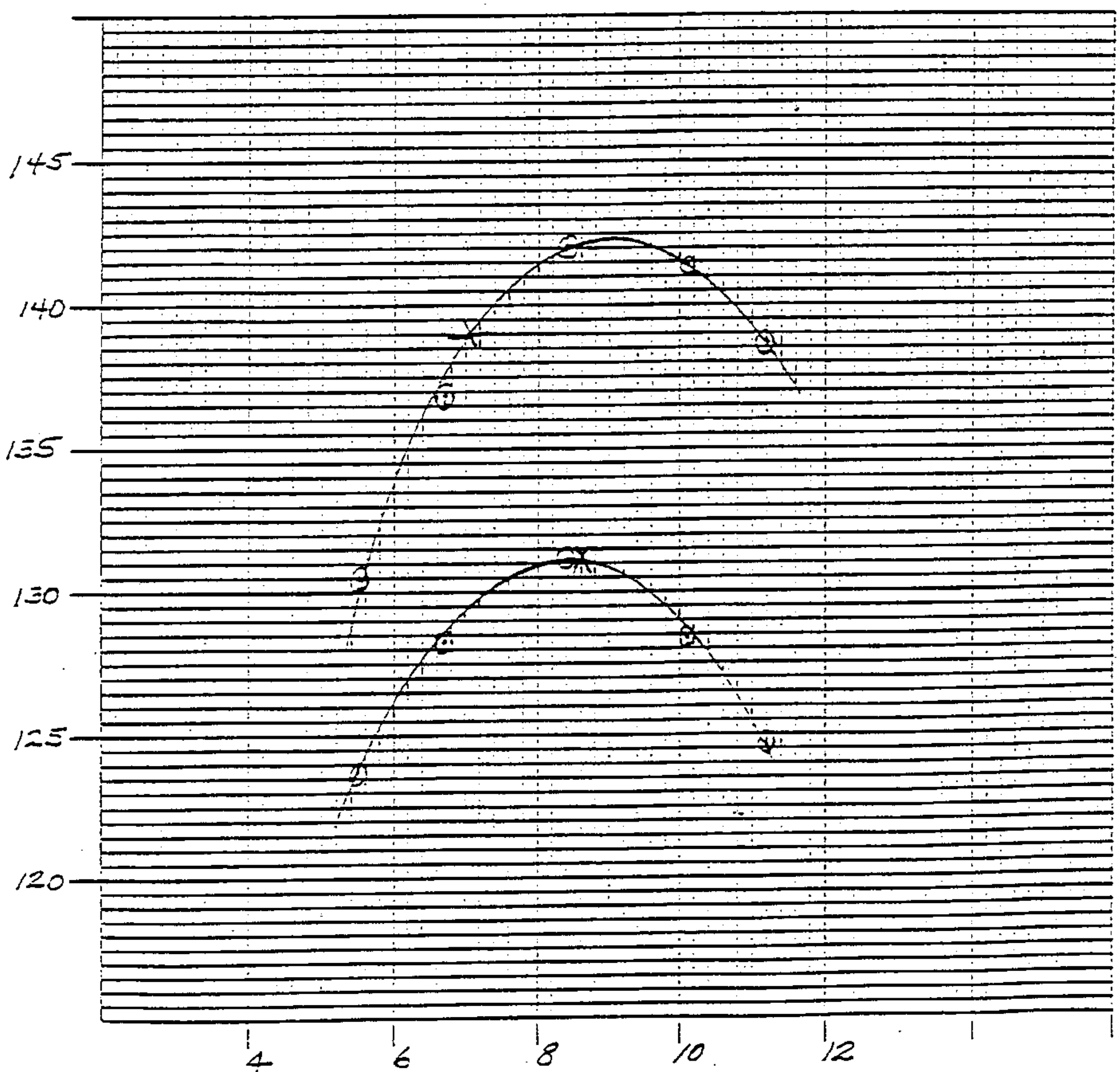
Figure 6

DOT-40
1-95

DENSITY SHEET
File # 17.2

COUNTY Washington PROJECT I96-4(14) 111 PCN 1423
FIELD NO. 6 LAB NO. H 92-46 DATE 8-8-96
SOURCE Plans Pit #2 TYPE OF MATERIAL Base Course
4-POINT DATA: OPTIMUM MOISTURE 8.6 MAXIMUM DENSITY 131.1
CURVE VALIDATION: FAMILY Ohio CURVE Little d MAX. DENSITY 133.0
GRANULAR MATERIAL 4-POINT RANGE 128.1 TO 134.1

(SEE REVERSE SIDE FOR CALCULATIONS)




(Reverse side of DOT-40)

Figure 7

**Sample ID** 2204758

**File No.**

# Density Sheet

**DOT - 40**
**9-15**

County Aurora, Ziebach

PCN/PROJECT B015 PH 0066(00)15

Field # 01

Tested By Tester, One

Date Tested 04/22/2015

Checked By Tester, Two

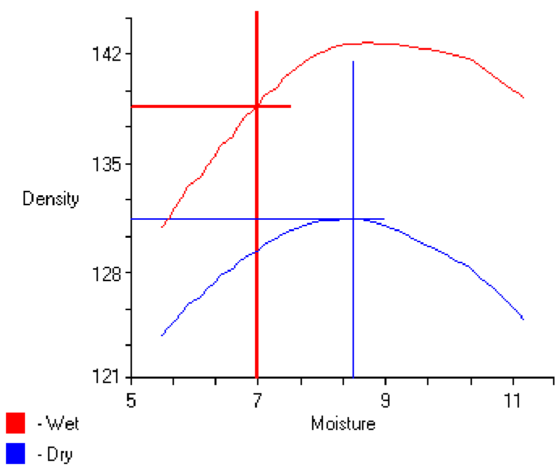
Source Jones Pit

Material Type Base Course

Comment

| Specimen Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Weight of Can and Wet Material | 631.4 | 654.9 | 651.3 | 625.0 | 669.1 | | |
| Weight of Can and Dry Material | 602.5 | 619.0 | 607.2 | 574.9 | 610.0 | | |
| Weight Loss (Moisture) Speedy Reading | 28.9 | 35.9 | 44.1 | 50.1 | 59.1 | 0.0 | 0.0 |
| Weight of Can | 76.3 | 83.7 | 81.9 | 79.1 | 81.4 | | |
| Weight of Dry Material | 526.2 | 535.3 | 525.3 | 495.8 | 528.6 | | |
| Percent Moisture | 5.5 | 6.7 | 8.4 | 10.1 | 11.2 | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Weight of Mold and Specimen | 22.58 | 23.06 | 23.45 | 23.40 | 23.19 | | |
| Weight of Mold | 12.72 | 12.72 | 12.72 | 12.72 | 12.72 | 12.72 | 12.72 |
| Weight of Wet Specimen | 9.86 | 10.34 | 10.73 | 10.68 | 10.47 | | |
| Factor of Mold No. 2-67 | 13.24 | 13.24 | 13.24 | 13.24 | 13.24 | 13.24 | 13.24 |
| Wet Density Wet Wt. x Factor | 130.5 | 136.9 | 142.1 | 141.4 | 138.6 | | |
| Dry Density | 123.7 | 128.3 | 131.1 | 128.4 | 124.6 | | |




| | | | |
|---|---|---|---|
| Wet Density: | 138.1 | Wet Moisture: | 7.0 |
| Dry Maximum Density: | 131.1 | Dry Optimum Moisture: | 8.5 |
| Four-Point Range: | 128.1 - 134.1 | Curve and Family: | d |

Figure 8

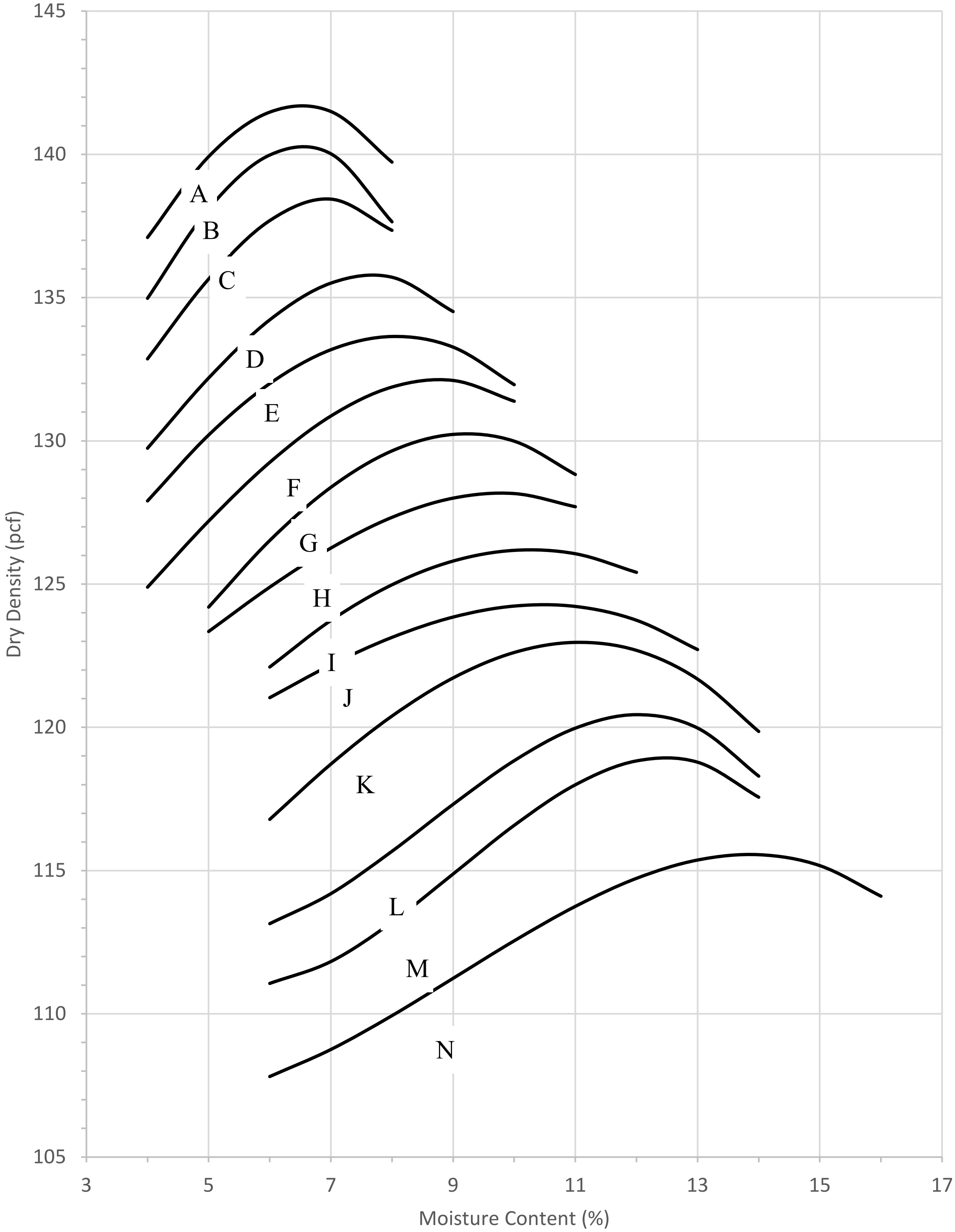

145
140
135
130
125
120
115
110
105
Dry Density (pcf)
3
5
7
9
11
13
15
17
Moisture Content (%)
A
B
C
D
E
F
G
H
I
J
K
L
M
N

Figure 9

# APPENDIX B: DATA ANALYSIS

Examples of each of the DOT data forms are provided in Figures B-1 through B-4.

**Sample ID** 2203565 **Sieve Analysis and P.I. Worksheet** **DOT - 3 (Combined)**

**File No.** **9-14**

PROJECT PH 0066(00)15 COUNTY Aurora, Ziebach PCN B015

Charge to (If not above project)

Field No. 01 Date Sampled 03/10/2015 12:00 am Date Tested 03/10/2015 12:00 am

Sampled By Tester, One Tested By Tester, One Checked By Tester, Two

Material Type Base Course Source Richland Pit

Taken @ 180.5 tons Lot No. Sublot No.

Weight Ticket Number or Station Ticket #76427, Sta. 26+25 Lift 1 of 3

% moist. = (wet wt. - dry wt.) / dry wt. x 100 =

**Original Dry Sample Wt.** (0.1g) 7318.0

| Sieve Size mm | in | F.M. * | Retained (.1g) | % total ret.(0.1%) | % pass. (0.1%) | % pass. (rounded) | Spec Req. |
|---|---|---|---|---|---|---|---|
| 100 | 4 | | | | | | |
| 75 | 3 | | | | | | |
| 62.5 | 2 1/2 | | | | | | |
| 50 | 2 | | | | | | |
| 37.5 | 1 1/2 | | | | | | |
| 31.5 | 1 1/4 | | | | | | |
| 25 | 1 | | 0.0 | 0.0 | 100.0 | **100** | **100-100** |
| 19 | 3/4 | | 167.6 | 2.3 | 97.7 | **98** | **80-100** |
| 16 | 5/8 | | 240.6 | 3.3 | 94.4 | **94** | |
| 12.5 | 1/2 | | 351.7 | 4.8 | 89.6 | **90** | **68-91** |
| 9.5 | 3/8 | * | 338.8 | 4.6 | 85.0 | **85** | |
| 6.25 | 1/4 | | 625.2 | 8.5 | 76.5 | **77** | |
| 4.75 | #4 | * | 586.2 | 8.0 | 68.5 | **69** | **46-70** |
| Pan | | | 5008.1 | 68.4 | | | |
| **Total** | | | 7318.2 | | | | |

Dust Chk.: wt. before washing(0.1g); wt. after washing (0.1g); loss from washing; % - #200

**+ #4 Gradation Check:** within 0.3% of original dry wt. 0.0

| Sieve Size mm | # | | retained (0.1g) | % total ret.(0.1%) | % total X % pa.#4(0.1%) | % pass. (0.1%) | % pass. (rounded) | Spec Req. |
|---|---|---|---|---|---|---|---|---|
| 3.35 | 6 | | | | | | | |
| 2.36 | 8 | * | 136.5 | 21.6 | 14.8 | 53.7 | **54** | **34-58** |
| 2.00 | 10 | | 28.2 | 4.5 | 3.1 | 50.6 | **51** | |
| 1.70 | 12 | | | | | | | |
| 1.18 | 16 | * | 67.1 | 10.6 | 7.3 | 43.3 | **43** | |
| 0.850 | 20 | | 62.7 | 9.9 | 6.8 | 36.5 | **37** | |
| 0.600 | 30 | * | 75.8 | 12.0 | 8.2 | 28.3 | **28** | |
| 0.425 | 40 | | 61.4 | 9.7 | 6.6 | 21.7 | **22** | **13-35** |
| 0.300 | 50 | * | 55.6 | 8.8 | 6.0 | 15.7 | **16** | |
| 0.180 | 80 | | 34.4 | 5.4 | 3.7 | 12.0 | **12** | |
| 0.150 | 100 | * | 4.8 | 0.8 | 0.5 | 11.5 | **12** | |
| 0.075 | 200 | | 10.6 | 1.7 | 1.2 | 10.3 | **10.3** | **3.0-12.0** |
| PAN | dry | | 1.7 | 95.1 | 10.3 | wt. before washing (0.1g) | | 631.9 |
| PAN | wash | | 93.4 | 15.1 | | wt. after washing (0.1g) | | 538.5 |
| **TOTAL** | | | 632.20 | | | **loss from washing (-#200)** | | 93.4 |

Coarse x % Retain/Design =

Chip x % Retain/Design =

Fine x % Pass/Design =

Total/Combined - #200

**- #4 Gradation check:** within 0.3% of the wt. before washing 0.1

| **Liquid Limit** | | **L.L.** | **P.L.** |
|---|---|---|---|
| **a.** can number | | 45 | 19 |
| **b.** wt. can + wet soil | (.01g) | 29.87 | 28.34 |
| **c.** wt. can + dry soil | (.01g) | 28.14 | 27.11 |
| **d.** wt. of water (b - c) | (.01g) | 1.73 | 1.23 |
| **e.** wt. of can | (.01g) | 19.92 | 20.17 |
| **f.** wt. of dry soil (c - e) | (.01g) | 8.22 | 6.94 |
| **g.** Liquid Limit (d/f x j x 100) | (0.1) | 21.2 | N.P. ☐ |
| **h.** Plastic Limit (d/f x 100) | (0.1) | N.A. | 17.7 |
| **I.** P. I. ( g- h ) | (0.1) | 3.5 | |
| **Liquid Limit** N.C. ☐ | (g. rounded) | 21 | N.A. |
| **Plasticity Index** | (i. rounded) | 4 | |

**j.** corr. # blows 26 22 = 0.9846, 23 = 0.9899, 24 = 0.9952, 25 = 1.0000, 26 = 1.0050, 27 = 1.0100, 28 = 1.0138

wt. - #40 181.40 / wt. - #4 611.20 x % pass.#4 = 20.3

(± 3.0% VARIABLE of Acc. % pass. (0.1%) on the #40)

SPECIFICATION L.L. 0-25

SPECIFICATION P.I. 0-6

| **+ #4 % Particles less than 1.95 SP. GR.** | | |
|---|---|---|
| Specific gravity of solution (1.95 ± 0.01) | | . |
| wt. of lightweight particles | (0.1 g) | |
| weight of + #4 material | (0.1 g) | |
| % lightweight particles | | |
| SPECIFICATION | | - |

| **- #4 % Particles less than 1.95 SP. GR.** | | |
|---|---|---|
| Specific gravity of solution (1.95 ± 0.01) | | . |
| wt. of lightweight particles | (0.1 g) | |
| weight of - #4 material | (0.1 g) | |
| % lightweight particles | | |
| SPECIFICATION | | - |

| **Crushed Particles Test** | |
|---|---|
| weight of crushed particles | 447.0 |
| weight of total + #4 sample | 1015.9 |
| percent of crushed particles | 44 |
| SPECIFICATION 1 or more FF, min. | 30-100 |

| | | | | | |
|---|---|---|---|---|---|
| Natural Sand | .00 | Natural Fines | .00 | Na. Rock | .00 |
| Ma.Sand | .00 | Filler | .00 | Cr.Rock | .00 |
| Cr.Fines | .00 | Add Rock | .00 | | .00 |

*Figure B-1: DOT-3 worksheet (Sieve Analysis).*

**Sample ID** 2205425

**File No.**

# Test Strip Worksheet

**DOT - 28**
**9-14**

PROJECT PH 0066(00)15 COUNTY Aurora, Ziebach PCN B015

Test No. 02 Test Date 04/29/2016 Lift 2 of 3 Thickness 4"

Tested By Tester, One Checked By Tester, Two

Nuclear Gauge No. MQ 778 Test Mode 2" DIRECT TRANSMISSION

## NUCLEAR GAUGE WET DENSITY lb/ft$^3$

| | STATION 32+50 | STATION 33+50 | STATION 34+50 | STATION 35+50 | AVERAGE |
|---|---|---|---|---|---|
| 1st Reading Total Passes 4 | 125.7 | 131.5 | 130.9 | 126.6 | 128.7 |
| 2nd Reading Total Passes 8 | 128.5 | 133.8 | 133.1 | 130.2 | 131.4 |
| 3rd Reading Total Passes 12 | 131.4 | 134.2 | 133.6 | 132.0 | 132.8 |
| 4th Reading Total Passes 16 | 132.4 | 134.7 | 134.5 | 131.9 | 133.4 |
| 5th Reading Total Passes ____ | | | | | |
| 6th Reading Total Passes ____ | | | | | |
| 7th Reading Total Passes ____ | | | | | |

## MOISTURE AND DRY DENSITY DETERMINATION

| | | | | |
|---|---|---|---|---|
| A. Final Wet Density | 132.4 | 134.7 | 134.5 | 131.9 |
| B. Weight of Can and Wet Material | 2643.3 | 2476.9 | 2701.7 | 2519.8 |
| C. Weight of Can and Dry Material | 2524.4 | 2368.4 | 2584.1 | 2407.0 |
| D. Weight of Moisture (B - C) | 118.9 | 108.5 | 117.6 | 112.8 |
| E. Weight of Can | 452.4 | 344.3 | 574.8 | 311.9 |
| F. Weight of Dry Material (C - E) | 2072.0 | 2024.1 | 2009.3 | 2095.1 |
| G. % Moisture (D x 100) / F | 5.7 | 5.4 | 5.9 | 5.4 |
| H. Dry Density (A x 100) / (100 + G) | 125.3 | 127.8 | 127.0 | 125.1 |

Average Dry Density 126.3

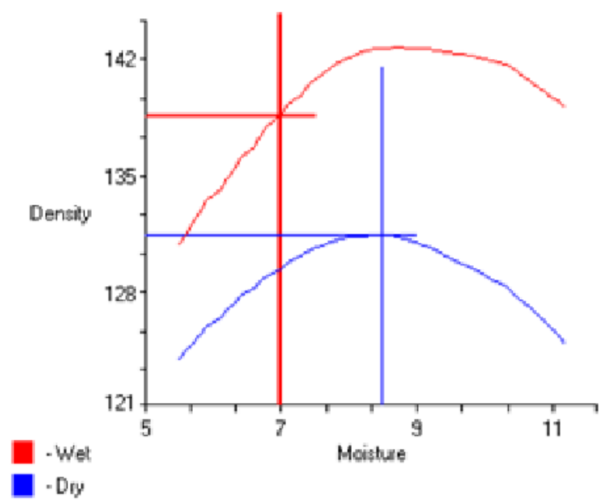
*Figure B-2: DOT-28 worksheet (Test Strip).*

**Sample ID** 2204758 **Density Sheet** **DOT - 40**
**File No.** 9-15

County Aurora, Ziebach PCN/PROJECT B015 PH 0066(00)15
Field # 01 Tested By Tester, One Date Tested 04/22/2015
Checked By Tester, Two
Source Jones Pit Material Type Base Course
Comment

| Specimen Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Weight of Can and Wet Material | 631.4 | 654.9 | 651.3 | 625.0 | 669.1 | | |
| Weight of Can and Dry Material | 602.5 | 619.0 | 607.2 | 574.9 | 610.0 | | |
| Weight Loss (Moisture) Speedy Reading | 28.9 | 35.9 | 44.1 | 50.1 | 59.1 | 0.0 | 0.0 |
| Weight of Can | 76.3 | 83.7 | 81.9 | 79.1 | 81.4 | | |
| Weight of Dry Material | 526.2 | 535.3 | 525.3 | 495.8 | 528.6 | | |
| Percent Moisture | 5.5 | 6.7 | 8.4 | 10.1 | 11.2 | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Weight of Mold and Specimen | 22.58 | 23.06 | 23.45 | 23.40 | 23.19 | | |
| Weight of Mold | 12.72 | 12.72 | 12.72 | 12.72 | 12.72 | 12.72 | 12.72 |
| Weight of Wet Specimen | 9.86 | 10.34 | 10.73 | 10.68 | 10.47 | | |
| Factor of Mold No. 2-67 | 13.24 | 13.24 | 13.24 | 13.24 | 13.24 | 13.24 | 13.24 |
| Wet Density Wet Wt. x Factor | 130.5 | 136.9 | 142.1 | 141.4 | 138.6 | | |
| Dry Density | 123.7 | 128.3 | 131.1 | 128.4 | 124.6 | | |




| | | | |
|---|---|---|---|
| Wet Density: | 138.1 | Wet Moisture: | 7.0 |
| Dry Maximum Density: | 131.1 | Dry Optimum Moisture: | 8.5 |
| Four-Point Range: | 128.1 - 134.1 | Curve and Family: | d |

*Figure B-3: DOT-40 worksheet (Four-Point Laboratory Compaction Test)*

**Sample ID** 2205560 **Density Report** **DOT - 41**

**File No.** **9-16**

County: Aurora, Ziebach — PCN/PROJECT: B015 PH 0066(00)15

Station: 47+15 — Dist. From CL: 13' L — Width (Gravel): 52.00

Depth: 4" (from top of Subgrade or Pipe) (Hole - Gravel) — Field #: 07

Tested By: Tester (TEST), One — Checked By: Tester (TEST), Two — Date: 05/01/2015

WORK AREA REPRESENTED (Circle what applies)

EMBANKMENT — STA. TO STA. — (per half mile, for each roadbed)
Zone 1(0-1ft.) — Zone 2(1-3 ft.) — Zone 3(3-5 ft.) — Zone 4(5 ft. to base, 1 per 5 ft.)

BRIDGE END EMBANKMENT — STA. TO STA.
1 per zone within plan limits — 3 equal zones when backwall is less than 7 ft. — 4 equal zones when backwall is 7 ft. or greater
Zone 1 — Zone 2 — Zone 3 — Zone 4

BERM — STA. TO STA. — (100 ft. from Bridge End)
Zone 1(0-1ft.) — Zone 2(1-3 ft.) — Zone 3(3-5 ft.) — Zone 4(5 ft. to base, 1 per 5 ft.)

PIPE
- CROSS — 24" or Smaller — undercut — (1/2 way up) (0-2 ft. Above)
- STORM — 30" to 72" — undercut — (Lower 1/2) (Upper 1/2) (0-2 ft. Above)
- INTERSECTION — 72" or more — undercut — (Bottom 1/3) (Middle 1/3) (Top 1/3) (0-2 ft. Above)

After Minimum for size pipe installation ☐ 1 per 3 ft. of backfill beginning at 2' above top of pipe

SUBBASE — STA. TO STA. — LIFT

BASE COURSE — STA. TO STA. 36+00 to 67+50 — LIFT 2 of 3

| Curve Used | Standard Density: Maximum Density | Optimum Moisture % | Granular Material 4-Point Range | |
|---|---|---|---|---|
| | U. 126.3 | | . | SPECIFICATION: 95 %<br>% Obtained 100 X (G/U): 97 % |

**Balloon Method**

| | |
|---|---|
| B. Wt. Undried Matl. from Hole | |
| C. Volumeter Reading in Hole | |
| D. Initial Volumeter Reading | |
| E. Volume of Test Hole (C - D) | |
| F. Wet Density (B / E) | |
| G. Dry Density F / (100 + M) x 100 | |

**Sand Density**

| | | |
|---|---|---|
| A. Std. Sand PCF | | |
| B. Wt. Undried Matl. from Hole | | |
| C. Initial Wt. Sand | | |
| D. Final Wt. Sand Plus Cone Sand | | |
| E. Volume of Test Hole (C - D) / A | | |
| F. Wet Density (B / E) | | |
| G. Dry Density F / (100 + M) x 100 | | |

**Nuclear Method**

Meter No. MQ 778

Test Mode 2" DIRECT TRANSMISSION

| | | |
|---|---|---|
| A. Wet Density from Gauge | 128.70 | |
| ± Corr. * | | = 128.7 |
| B. Dry Density A / (100 + M-Field) x 100 | | 122.0 |

**1-Point Density Determination**

| | | |
|---|---|---|
| O. Weight of Mold & Specimen | | |
| P. Weight of Mold | | |
| Q. Wet Wt. of Molded Specimen (O- P) | | |
| R. Factor of Mold No. Used in Test | | |
| S. Wet Density (Q x R) | | |
| T. Dry Density S / (100 + M [1-PT]) x 100 | | |

**Moisture Determinations**

| | 1-Point | Field |
|---|---|---|
| H. Wt. of Wet Matl. and Container | | 3120.4 |
| I. Wt. of Dry Matl. and Container | | 3009.9 |
| J. Wt. of Moisture (H - I) | | 110.5 |
| K. Wt. of Container | | 990.2 |
| L. Wt. of Dry Matl. (I - K) | | 2019.7 |
| M. Percent Moisture Field (J x 100) / L | | 5.5 |

**Rock Determination**

| | |
|---|---|
| A. Total Sample Weight | |
| B. Weight of Material Retained on 3/4" Sieve | |
| C. Percent Retained On 3/4" Sieve (B x 100)/A | |

* Correction from DOT-39. If there is no correction or, if the correction has been applied to the meter show "NA".

1-Point Not Made this Test, Refer to Test Strip Maximum Density: 126.30

*Figure B-4: DOT-41 worksheet (Field Density Test).*

The data field definitions for each of the four DOT data forms are provided in Tables B-1 through B-4.

**Table B-1: Data fields for DOT-3 worksheet (Sieve Analysis).**

| Data Field | Definition | Comment |
|---|---|---|
| Main PCN | Main Project Contract Number | Useful. Main PCN will be used to organize and link data from the various forms together. |
| Contract ID | Contract Identification Number | Useful. Contract ID will also be used to organize and link data from the various forms together. |
| Sample ID | Sample Identification Number | Useful. Used to track problematic or irregular samples within the data sets. |
| Sample Comment | Sample Comment | Useful. May provide additional information about samples. |
| Source_Desc | Description of source Location | Useful. May provide information about the sample variance observed among different regions. |
| Lift_Min | Lift tested | Ignored for DOT-40. Not particularly relevant to 4-Point testing. |
| Lift_Max | Total number of lifts to be tested. | Ignored for DOT-40. Not particularly relevant to 4-Point testing. |
| Lot_Nbr | Used for only asphalt concrete paving | Not used. |
| Sub_Lot_Nbr | Used for only asphalt concrete paving | Not used. |
| Station_Desc | Station location on project. | Not used. |
| Mat_Type_Name | Material type | Useful. Provides information that is key to grouping samples together. |
| Producer_Addr_Desc | Used on DOT-1 for material that was shipped to the project. Provides quarry location. Seldom used | Not used. |

| Data Field | Definition | Comment |
|---|---|---|
| Requirement Type | Type of test run. | Useful. |
| Purpose | Reason for running test. | Useful. |
| DOT Form | The DOT form used for test (DOT-3). | Useful. |
| Test # | Test number | Useful. |
| Material Group | Material group of material tested. | Useful. Provides information that is key to grouping samples together. |
| Material | Type of material tested. | Useful. Provides information that is key to grouping samples together. |
| Item_Qty | Comes from CM&P. Quantity of the material to be used on the project. Tons or cubic yard. | Not used. |
| SBI_Nbr | Special Bid Item number | Not used. |
| SBI_Desc | Special Bid Item Description | Not used. |
| Test_DateTime | Date and Time of test. | Useful. May provide insight into sample variance. |
| Prepared_Ind | Check box used to show if the test is prepared (final) or draft. I would not use any unprepared tests. | Useful. |
| Test Form Comment | Comments on test form. | Useful. May provide additional information about samples. |
| File_Nbr | File Number. | Not used. |
| IA_Observed_Ind | Check box used when the Independent Assurance test is done by observation. No actual testing done. Ignore these tests. | Useful. |
| Specification Group | Type of specifications used for test. | Useful. |
| Tolerance Group | Tolerance used between the acceptance and independent assurance test. Ignore | Not used. |
| Test --> | Course sieves analysis. | Useful. |

| Data Field | Definition | Comment |
|---|---|---|
| Measure_Unit | Measurement unit. In this case grams, g. | Useful. |
| Sample_Wgt | Sample weight retained. | Useful. |
| 4 in. sieve | Sample weight retained. | Ignored. Not required for Base Course or Salvage. |
| 3 in. sieve | Sample weight retained. | Ignored. Not required for Base Course or Salvage. |
| 2 1/2 in. sieve | Sample weight retained. | Ignored. Not required for Base Course or Salvage. Recycled PCC has 100% passing the 2 1/2" sieve. |
| 2 in. sieve | Sample weight retained. | Ignored. Not required for Base Course or Salvage. Subbase has 100% passing the 2" sieve. |
| 1 1/2 in. sieve | Sample weight retained. | Ignored. Not required for Base Course or Salvage. Salvage has a 100% passing the 1 1/2" sieve. |
| 1 1/4 in. sieve | Sample weight retained. | Useful. |
| 1 in. sieve | Sample weight retained. | Useful. |
| 3/4 in. sieve | Sample weight retained. | Useful. |
| 5/8 in. sieve | Sample weight retained. | Useful. |
| 1/2 in. sieve | Sample weight retained. | Useful. |
| 3/8 in. sieve | Sample weight retained. | Useful. |
| 1/4 in. sieve | Sample weight retained. | Useful. |
| #4 sieve | Sample weight retained. | Useful. |
| Upper Pan | Sample weight retained. | Useful. |
| Sample_Before_Wash_Wgt | Sample weight before wash. | Useful. |
| Sample_After_Wash_Wgt | Sample weight after wash. | Useful. |
| Wet_Sample_Wgt | Wet sample weight. | Useful. |
| Combined_Minus_200_Ind | Used for determining the combined - #200. Not used for base course or salvage. Mainly for AC, PCC & chip seals | Not used. |
| Upper Sieves Waivered | Waiver of upper sieves. | Useful. Base course should not have sieves waived. A waiver means that the percent passing is not compared to the specs. |

| Data Field | Definition | Comment |
| --- | --- | --- |
| Test --> | Fine sieves. | Useful. |
| Sample_Before_Wash_Wgt | Sample weight before wash. | Useful. |
| Sample_After_Wash_Wgt | Sample weight after wash. | Useful. |
| #6 sieve | Sample weight retained. | Useful. |
| #8 sieve | Sample weight retained. | Useful. |
| #10 sieve | Sample weight retained. | Useful. |
| #12 sieve | Sample weight retained. | Useful. |
| #16 sieve | Sample weight retained. | Useful. |
| #20 sieve | Sample weight retained. | Useful. |
| #30 sieve | Sample weight retained. | Useful. |
| #40 sieve | Sample weight retained. | Useful. |
| #50 sieve | Sample weight retained. | Useful. |
| #80 sieve | Sample weight retained. | Useful. |
| #100 sieve | Sample weight retained. | Useful. |
| #200 sieve | Sample weight retained. | Useful. |
| Lower Pan | Sample weight retained. | Useful. |
| 3/8 in. sieve | Sample weight retained. | Useful. |
| 1/4 in. sieve | Sample weight retained. | Useful. |
| #4 sieve | Sample weight retained. | Useful. |
| Combined_Minus_200_Ind | Used for determining the combined - #200. Not used for base course or salvage. Mainly for AC, PCC & chip seals | Not used. |
| Lower Sieves Waivered | Waiver of upper sieves. | Useful. Base course should not have sieves waived. A waiver means that the percent passing is not compared to the specs. |
| Test --> | Liquid Limit Test | Useful. Key to analyzing moisture sensitivity. |
| Liquid_Limit_Blow_Qty | Number of test blows required. | Useful. Key to analyzing moisture sensitivity. |
| Can_Nbr | Can Number. | Useful. Key to analyzing moisture sensitivity. |
| Can_Plus_Wet_Soil_Wgt | Can weight plus wet soil weight. | Useful. Key to analyzing moisture sensitivity. |
| Can_Plus_Dry_Soil_Wgt | Can weight plus dry soil weight. | Useful. Key to analyzing moisture sensitivity. |
| Sample_Minus_4_Wgt | Used to determine if there is enough - #40 | Not used. |

| Data Field | Definition | Comment |
|---|---|---|
| | material. SD 207. Ignore | |
| Sample_Minus_40_Wgt | Used to determine if there is enough - #40 material. SD 207. Ignore | Not used. |
| Can_Wgt | Weight of can. | Useful. Key to analyzing moisture sensitivity. |
| Non_Controllable_Ind | Check box used if the material is uncontrollable in the LL machine. SD 207 | Not used. |
| Skip_Acceptability_Ind | Used for soils only. Ignore | Not used. |
| Liquid Limit Waivered | Waiver Liquid Limit Test. | Useful. Key to analyzing moisture sensitivity. |
| Test --> | Plastic Limit Test | Useful. Key to analyzing moisture sensitivity. |
| Can_Nbr | Can Number. | Useful. Key to analyzing moisture sensitivity. |
| Can_Plus_Wet_Soil_Wgt | Can weight plus wet soil | Useful. Key to analyzing moisture sensitivity. |
| Can_Plus_Dry_Soil_Wgt | Can weight plus dry soil | Useful. Key to analyzing moisture sensitivity. |
| Can_Wgt | Can weight. | Useful. Key to analyzing moisture sensitivity. |
| Non_Plastic_Ind | Check box used if the material cannot be rolled. Non-plastic. SD 207 | Not used. |
| Plastic Limit Waivered | Waiver of Plastic Limit. | Useful. Key to analyzing moisture sensitivity. |
| Test --> | Crushed Particles Test. | Useful. |
| Sample_Wgt | Sample weight | Useful. |
| Crushed_Pieces_Wgt | Weight of crushed pieces. | Useful. |
| Fractured_Faces_Nbr | Number of fractured faces. | Useful. |
| Crushed Particles Waivered | Waiver of Crushed Particles test. | Useful. |
| Test --> | Light weight particles test. + #4 | Not used. |
| Plus_4_Sample_Wgt | Weight of sample. | Not used. |

| Data Field | Definition | Comment |
|---|---|---|
| Plus_4_Lt_Particles_Wgt | Weight of the floating Lt. Wgt. Particles | Not used. |
| Plus_4_Specific_Gravity | Specific Gravity. | Not used. |
| Light Weight Particles +#4 Waivered | Waiver of light weight particles test. | Not used. |
| Test --> | Light weight particles test. - #4 | Not used. |
| Minus_4_Sample_Wgt | Weight of sample. | Not used. |
| Minus_4_Lt_Particles_Wgt | Weight of the floating Lt. Wgt. Particles | Not used. |
| Minus_4_Specific_Gravity | Specific Gravity. | Not used. |
| Light Weight Particles -#4 Waivered | Waiver of light weight particles test. | Not used. |
| Test --> | Not an actual test. The values are the % passing the +4 sieves and what is retained on the - #4 sieves. There is nothing shown for base course. | Not used. |
| Fine_Aggregate_Pct | Percent Fine aggregate in sample. | Useful. |
| Coarse_Aggregate_Pct | Percent coarse aggregate in sample. | Useful. |
| Combined Minus 200 Waivered | Waiver of minus 200 | Useful. |

**Table B-2: Data fields for DOT-28 worksheet (Test Strip).**

| Data Field | Definition | Comments |
|---|---|---|
| Main PCN | Main Project Contract Number | Useful. Main PCN will be used to organize and link data from the various forms together. |
| Contract ID | Contract Identification Number | Useful. Contract ID will also be used to organize and link data from the various forms together. |
| Sample ID | Sample Identification Number | Useful. Used to track problematic or irregular samples within the data sets. |
| Sample Comment | Sample Comment | Useful. May provide additional information about samples. |
| Source_Desc | Description of source Location | Useful. May provide information about the sample variance observed among different regions. |
| Lift_Min | Lift tested | Not used for DOT-40. Not particularly relevant to 4-Point testing. |
| Lift_Max | Total number of lifts to be tested. | Not used for DOT-40. Not particularly relevant to 4-Point testing. |
| Lot_Nbr | Used for only asphalt concrete paving | Not used. |
| Sub_Lot_Nbr | Used for only asphalt concrete paving | Not used. |
| Station_Desc | Station location on project. | Not used. |
| Mat_Type_Name | Material type | Useful. Provides information that is key to grouping samples together. |
| Producer_Addr_Desc | Used on DOT-1 for material that was shipped to the project. Provides quarry location. Seldom used | Not used. |
| Requirement Type | Type of test run. | Useful. |
| Purpose | Reason for running test. | Useful. |
| DOT Form | The DOT form used for test (DOT-28). | Useful. |
| Test # | Test number | Useful. |
| Material Group | Material group of material tested. | Useful. Provides information that is key to grouping samples together. |

| Data Field | Definition | Comments |
|---|---|---|
| Material | Type of material tested. | Useful. Provides information that is key to grouping samples together. |
| Item_Qty | Comes from CM&P. Quantity of the material to be used on the project. (Tons or cubic yards) | Not used. |
| SBI_Nbr | Special Bid Item number | Not used. |
| SBI_Desc | Special Bid Item Description | Not used. |
| Test_DateTime | Date and Time of test. | Useful. May provide insight into sample variance. |
| Prepared_Ind | Check box used to show if the test is prepared (final) or draft. I would not use any unprepared tests. | Useful. |
| Test Form Comment | Comments on test form. | Useful. May provide additional information about samples. |
| File_Nbr | File Number. | Not used. |
| IA_Observed_Ind | No Independent Assurance. Will always be N. Ignore. | Not used. |
| Specification Group | There is not one for test strips | Not used. |
| Tolerance Group | No actual tolerances for DOT-28. Ignore | Not used. |
| Gauge Desc | Type of Nuclear Density Gauge used. | Useful. All gauges will be Troxler 3430 or 3440. |
| Nuclear Test Type | Type of Nuclear Density test conducted and depth of transmission. | Useful. |
| Std_Cnt | Standard Count recorded by Nuclear Density Gauge prior to testing. | Useful. This has no value. Ignore |
| Passes_Nbr_1 | Number of roller passes at reading 1 | Useful. |
| Passes_Nbr_2 | Number of roller passes at reading 2 | Useful. |
| Passes_Nbr_3 | Number of roller passes at reading 3 | Useful. |
| Passes_Nbr_4 | Number of roller passes at reading 4 | Useful. |
| Passes_Nbr_5 | Number of roller passes at reading 5 | Useful. |
| Passes_Nbr_6 | Number of roller passes at reading 6 | Useful. |

| Data Field | Definition | Comments |
|---|---|---|
| Passes_Nbr_7 | Number of roller passes at reading 7 | Useful. |
| Seq_Nbr | This signals that the following data can be found under the first column on the SD 219. The following data would be that of the first test station in the test strip. | Useful. |
| Density_Pct_1 | Wet Density reading 1 at station 1 | Useful. |
| Density_Pct_2 | Wet Density reading 2 at station 1 | Useful. |
| Density_Pct_3 | Wet Density reading 3 at station 1 | Useful. |
| Density_Pct_4 | Wet Density reading 4 at station 1 | Useful. |
| Density_Pct_5 | Wet Density reading 5 at station 1 | Useful. |
| Density_Pct_6 | Wet Density reading 6 at station 1 | Useful. |
| Density_Pct_7 | Wet Density reading 7 at station 1 | Useful. |
| Wet_Mat_Plus_Container_Wgt | Wet material and container weight of first test station. | Useful. |
| Dry_Mat_Plus_Container_Wgt | Dry material and container weight of first test station. | Useful. |
| Container_Wgt | Container weight of first test station. | Useful. |
| Seq_Nbr | This signals that the following data can be found under the second column on the SD 219. The following data would be that of the second test station in the test strip. | Useful. |
| Density_Pct_1 | Wet Density reading 1 at station 2 | Useful. |
| Density_Pct_2 | Wet Density reading 2 at station 2 | Useful. |
| Density_Pct_3 | Wet Density reading 3 at station 2 | Useful. |
| Density_Pct_4 | Wet Density reading 4 at station 2 | Useful. |
| Density_Pct_5 | Wet Density reading 5 at station 2 | Useful. |

| Data Field | Definition | Comments |
|---|---|---|
| Density_Pct_6 | Wet Density reading 6 at station 2 | Useful. |
| Density_Pct_7 | Wet Density reading 7 at station 2 | Useful. |
| Wet_Mat_Plus_Container_Wgt | Wet material and container weight of second test station. | Useful. |
| Dry_Mat_Plus_Container_Wgt | Dry material and container weight of second test station. | Useful. |
| Container_Wgt | Container weight of second test station. | Useful. |
| Seq_Nbr | This signals that the following data can be found under the third column on the SD 219. The following data would be that of the third test station in the test strip. | Useful. |
| Density_Pct_1 | Wet Density reading 1 at station 3 | Useful. |
| Density_Pct_2 | Wet Density reading 2 at station 3 | Useful. |
| Density_Pct_3 | Wet Density reading 3 at station 3 | Useful. |
| Density_Pct_4 | Wet Density reading 4 at station 3 | Useful. |
| Density_Pct_5 | Wet Density reading 5 at station 3 | Useful. |
| Density_Pct_6 | Wet Density reading 6 at station 3 | Useful. |
| Density_Pct_7 | Wet Density reading 7 at station 3 | Useful. |
| Wet_Mat_Plus_Container_Wgt | Wet material and container weight of third test station. | Useful. |
| Dry_Mat_Plus_Container_Wgt | Dry material and container weight of third test station. | Useful. |
| Container_Wgt | Container weight of third test station. | Useful. |
| Seq_Nbr | This signals that the following data can be found under the fourth column on the SD 219. The following data would be that of the fourth test station in the test strip. | Useful. |

| Data Field | Definition | Comments |
|---|---|---|
| Density_Pct_1 | Wet Density reading 1 at station 1 | Useful. |
| Density_Pct_2 | Wet Density reading 2 at station 1 | Useful. |
| Density_Pct_3 | Wet Density reading 3 at station 1 | Useful. |
| Density_Pct_4 | Wet Density reading 4 at station 1 | Useful. |
| Density_Pct_5 | Wet Density reading 5 at station 1 | Useful. |
| Density_Pct_6 | Wet Density reading 6 at station 1 | Useful. |
| Density_Pct_7 | Wet Density reading 7 at station 1 | Useful. |
| Wet_Mat_Plus_Container_Wgt | Wet material and container weight of fourth test station. | Useful. |
| Dry_Mat_Plus_Container_Wgt | Dry material and container weight of fourth test station. | Useful. |
| Container_Wgt | Container weight of fourth test station. | Useful. |

**Table B-3: The data fields for DOT-40 worksheet (Four-Point Laboratory Compaction Test).**

| Data Fields | Definition | Comments |
|---|---|---|
| Main PCN | Main Project Contract Number | Useful. Main PCN will be used to organize and link data from the various forms together. |
| Contract ID | Contract Identification Number | Useful. Contract ID will also be used to organize and link data from the various forms together. |
| Sample ID | Sample Identification Number | Useful. Used to track problematic or irregular samples within the data sets. |
| Sample Comment | Sample Comment | Useful. May provide additional information about samples. |
| Source_Desc | Description of source Location | Useful. May provide information about the sample variance observed among different regions. |
| Lift_Min | Lift tested | Not used for DOT-40. Not particularly relevant to 4-Point testing. |
| Lift_Max | Total number of lifts to be tested. | Ignored for DOT-40. Not particularly relevant to 4-Point testing. |
| Lot_Nbr | Used for only asphalt concrete paving | Not used. |
| Sub_Lot_Nbr | Used for only asphalt concrete paving | Not used. |
| Station_Desc | Station location on project. | Useful. |
| Mat_Type_Name | Material type | Useful. Provides information that is key to grouping samples together. |
| Producer_Addr_Desc | Used on DOT-1 for material that was shipped to the project. Provides quarry location. Seldom used | Not used. |
| Requirement Type | Type of test run. | Useful. |
| Purpose | Reason for running test. | Useful. |
| DOT Form | The DOT form used for test (DOT-40). | Useful. |
| Test # | Test number | Useful. |
| Material Group | Material group of material tested. | Useful. Provides information that is key to grouping samples together. |
| Material | Type of material tested. | Useful. Provides information that is key to grouping samples together. |

| Data Fields | Definition | Comments |
|---|---|---|
| Item_Qty | Comes from CM&P. Quantity of the material to be used on the project. (Tons or cubic yards) | Not used. |
| SBI_Nbr | Special Bid Item number | Not used. |
| SBI_Desc | Special Bid Item Description | Not used. |
| Test_DateTime | Date and Time of test. | Useful. May provide insight into sample variance. |
| Prepared_Ind | Check box used to show if the test is prepared (final) or draft. I would not use any unprepared tests. | Useful. |
| Test Form Comment | Comments on test form. | Useful. May provide additional information about samples. |
| File_Nbr | File Number. | Not used. |
| IA_Observed_Ind | No Independent Assurance. Will always be N. Ignore. | Not used. |
| Specification Group | Type of specifications used for test. | Useful. |
| Tolerance Group | No actual tolerances for DOT-40. Ignore | Not used. |
| Density Curve Letter | Density curve letter designation for material tested. | Useful. Will be key in analyzing the effectiveness of the Ohio Curves. |
| Density Curve Family | Density curve family designation for material tested. | Useful. Will be key in analyzing the effectiveness of the Ohio Curves. |
| Seq_Nbr | This defines which specimen number the following data belongs to. (defines the data column on the DOT-40) | Useful. |
| Mold_Nbr | Mold number used for test. | Useful. |
| Mold_Wgt | Weight of the mold used for the test. | Useful. |
| Mold_Factor | Mold factor number used for the test. | Useful. |
| Mold_Plus_Wet_Mat_Wgt | Weight of the mold and wet material. | Useful. |
| Wet_Mat_Plus_Container_Wgt | Weight of wet material and container. | Useful. |
| Dry_Mat_Plus_Container_Wgt | Weight of dry material and container. | Useful. |
| Container_Wgt | Container weight. | Useful. |

**Table B-4: The data fields for DOT-41 worksheets (Field Density Test).**

| Data Fields | Definition | Comments |
|---|---|---|
| Main PCN | Main Project Contract Number | Useful. Main PCN will be used to organize and link data from the various forms together. |
| Contract ID | Contract Identification Number | Useful. Contract ID will also be used to organize and link data from the various forms together. |
| Sample ID | Sample Identification Number | Useful. Used to track problematic or irregular samples within the data sets. |
| Sample Comment | Sample Comment | Useful. May provide additional information about samples. |
| Source_Desc | Description of source Location | Useful. May provide information about the sample variance observed among different regions. |
| Lift_Min | Lift tested | Not used for DOT-40. Not particularly relevant to 4-Point testing. |
| Lift_Max | Total number of lifts to be tested. | Not used for DOT-40. Not particularly relevant to 4-Point testing. |
| Lot_Nbr | Used for only asphalt concrete paving | Not used. |
| Sub_Lot_Nbr | Used for only asphalt concrete paving | Not used. |
| Station_Desc | Station location on project. | Not used. |
| Mat_Type_Name | Material type | Useful. Provides information that is key to grouping samples together. |
| Producer_Addr_Desc | Used on DOT-1 for material that was shipped to the project. Provides quarry location. Seldom used | Not used. |
| Requirement Type | Type of test run. | Useful. |
| Purpose | Reason for running test. | Useful. |
| DOT Form | The DOT form used for test (DOT-40). | Useful. |
| Test # | Test number | Useful. |
| Material Group | Material group of material tested. | Useful. Provides information that is key to grouping samples together. |

| Data Fields | Definition | Comments |
|---|---|---|
| Material | Type of material tested. | Useful. Provides information that is key to grouping samples together. |
| Item_Qty | Comes from CM&P. Quantity of the material to be used on the project. Tons or cubic yards. | Not used. |
| SBI_Nbr | Special Bid Item number | Not used. |
| SBI_Desc | Special Bid Item Description | Not used. |
| Test_DateTime | Date and Time of test. | Useful. May provide insight into sample variance. |
| Prepared_Ind | Check box used to show if the test is prepared (final) or draft. I would not use any unprepared tests. | Useful. |
| Test Form Comment | Comments on test form. | Useful. May provide additional information about samples. |
| File_Nbr | File Number. | Not used. |
| IA_Observed_Ind | No Independent Assurance. Will always be N. Ignore. | Not used. |
| Specification Group | Type of specifications used for test. | Useful. |
| Tolerance Group | No tolerances. Ignore | Not used. |
| Wet_Mat_Wgt | Weight of wet material. | Useful. |
| Initial_Volumeter | Initial volumeter reading. | Useful. |
| Hole_Volumeter | Volumeter reading in hole. | Useful. |
| Balloon Method Waivered | Waiver of Balloon Method. | Useful. |
| Std_Sand_Density | Density of test sand used for the test. | Useful. |
| Wet_Mat_Wgt | Weight of wet material from test hole. | Useful. |
| Initial_Sand_Wgt | Initial weight of sand in sand cone and sand cone apparatus. | Useful. |
| Final_Sand_Wgt | Final weight of sand in sand cone and sand cone apparatus. | Useful. |
| Cone_Sand_Wgt | Weight of sand cone apparatus | Useful. |

| Data Fields | Definition | Comments |
|---|---|---|
| Sand Method Waivered | Waiver of sand cone method. | Useful. |
| Wet_Density_Correction_Factor | Wet Density Correction factor used for test. | Useful. |
| Moisture_Pct_Correction_Factor | Percent moisture correction factor used for test. | Useful. You probably will not see any correction factors after 06 |
| Std_Cnt | Standard count recorded prior to testing. | Not used. |
| Std_Moisture_Cnt | Moisture standard count recorded prior to testing. | Not used. |
| Nuclear Test Type | Type of Nuclear Density test conducted and depth of transmission. | Useful. |
| Nuclear Gauge | Type of Nuclear Density Gauge used. | Useful. All gauges will be Troxler 3430 or 3440. |
| Corrected_Moisture | Quit using Nuclear moisture for the in place density in 06. | Useful. |
| Waiver_Ind | I think that this was used to waive the nuclear moisture. Before 06? | Useful. |
| Wet_Density_Amt | Wet Density recorded from Gauge. | Useful. |
| Moisture_Pct | Percent moisture recorded from Gauge. (not used) | Useful. |
| Dry_Density_Amt | Dry Density recorded from Gauge. (not used) | Useful. |
| Dry_Density_From_Gauge_Ind | Dry Density from Gauge used. (no) | Useful. |
| Density_Waiver_Ind | Waiver of Nuclear Method. | Useful. |
| Density Curve Letter | Density curve letter designation for material tested. | Useful. Will be key in analyzing the effectiveness of the Ohio Curves. |
| Density Curve Family | Density curve family designation for material tested. | Useful. Will be key in analyzing the effectiveness of the Ohio Curves. |
| Mold_Nbr | Mold number used for test. | Useful. Will be key in analyzing the effectiveness of the Ohio Curves. |
| Mold_Wgt | Weight of Mold used for test. | Useful. Will be key in analyzing the effectiveness of the Ohio Curves. |
| Mold_Factor | Mold factor used for test. | Useful. Will be key in analyzing the effectiveness of the Ohio Curves. |

| Data Fields | Definition | Comments |
|---|---|---|
| Mold_Plus_Wet_Mat_Wgt | Weight of mold and wet material used for test. | Useful. Will be key in analyzing the effectiveness of the Ohio Curves. |
| Wet_Mat_Plus_Container_Wgt | Weight of wet material and container. | Useful. Will be key in analyzing the effectiveness of the Ohio Curves. |
| Dry_Mat_Plus_Container_Wgt | Weight of dry material and container. | Useful. Will be key in analyzing the effectiveness of the Ohio Curves. |
| Container_Wgt | Weight of container | Useful. Will be key in analyzing the effectiveness of the Ohio Curves. |
| Test_Strip_Val | This is the dry density from the test strip DOT-28 | Useful. |
| Wet_Mat_Plus_Container_Wgt | Weight of wet material and container. | Useful. |
| Dry_Mat_Plus_Container_Wgt | Weight of dry material and container. | Useful. |
| Container_Wgt | Weight of container | Useful. |
| Field Moisture Waivered | Waiver of field moisture. | Useful. |
| Sample_Wgt | Weight of total sample. | Useful. |
| Nbr4_Sieve_Wgt | Weigh of sample retained on the #4 sieve. | Useful. |
| Rock Determination Waivered | Waiver of rock determination. | Useful. |

The data selected to be used in the analysis presented in Chapter 3 was collected from DOT-40 worksheets. The data are presented in Tables B-5 through B-18.

**Table B-5: DOT-40 points used for compaction curves with a maximum dry unit weight below 118 pcf.**

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 6394 | 2144 | 1441023 | IA01 | 1 | 119.3 | 108.6 | 9.8 |
| 6394 | 2144 | 1441023 | IA01 | 2 | 127.9 | 113.3 | 12.9 |
| 6394 | 2144 | 1441023 | IA01 | 3 | 132.2 | 115.2 | 14.7 |
| 6394 | 2144 | 1441023 | IA01 | 4 | 130.8 | 111.0 | 17.9 |
| 6250 | 4529 | 2191541 | 01 | 1 | 115.1 | 108.7 | 6.0 |
| 6250 | 4529 | 2191541 | 01 | 2 | 118.3 | 109.7 | 7.8 |
| 6250 | 4529 | 2191541 | 01 | 3 | 124.8 | 113.5 | 10.0 |
| 6250 | 4529 | 2191541 | 01 | 4 | 130.7 | 117.3 | 11.4 |
| 6250 | 4529 | 2191541 | 01 | 5 | 131.6 | 115.3 | 14.1 |
| 03W1 | 4835 | 2209280 | 01 | 1 | 116.6 | 108.5 | 7.4 |
| 03W1 | 4835 | 2209280 | 01 | 2 | 121.7 | 111.4 | 9.3 |
| 03W1 | 4835 | 2209280 | 01 | 3 | 127.6 | 115.1 | 10.9 |
| 03W1 | 4835 | 2209280 | 01 | 4 | 130.8 | 115.9 | 12.9 |
| 03W1 | 4835 | 2209280 | 01 | 5 | 130.8 | 114.2 | 14.5 |

**Table B-6: DOT- 40 points used for compaction curves with a maximum dry unit weight between 118 pcf to 120 pcf.**

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 1230 | 1511 | 1127153 | 07 | 1 | 132.8 | 118.2 | 12.4 |
| 1230 | 1511 | 1127153 | 01 | 2 | 119.9 | 110.6 | 8.5 |
| 1230 | 1511 | 1127153 | 07 | 3 | 124.7 | 113.7 | 9.7 |
| 1230 | 1511 | 1127153 | 01 | 4 | 131.5 | 118.5 | 10.9 |
| 6180 | 2104 | 1467173 | 01 | 1 | 116.6 | 111.1 | 5.0 |
| 6180 | 2104 | 1467173 | 01 | 2 | 124.3 | 115.7 | 7.4 |
| 6180 | 2104 | 1467173 | 01 | 3 | 128.9 | 117.7 | 9.4 |
| 6180 | 2104 | 1467173 | 01 | 4 | 133.4 | 119.5 | 11.6 |
| 00QD | 2177 | 1416832 | IA01 | 1 | 119.8 | 108.9 | 10.1 |
| 00QD | 2177 | 1416832 | IA01 | 2 | 134.5 | 118.6 | 13.5 |
| 00QD | 2177 | 1416832 | IA01 | 4 | 134.0 | 117.7 | 13.9 |
| 00QD | 2177 | 1416832 | IA01 | 5 | 133.0 | 116.3 | 14.3 |
| 01QT | 3332 | 2154783 | 01 | 1 | 124.7 | 114.3 | 9.1 |
| 01QT | 3332 | 2154783 | 01 | 2 | 131.4 | 117.5 | 11.9 |
| 01QT | 3332 | 2154783 | 01 | 3 | 132.5 | 117.9 | 12.3 |
| 01QT | 3332 | 2154783 | 01 | 4 | 130.5 | 112.8 | 15.6 |
| 6662 | 3499 | 2108075 | 01 | 1 | 118.5 | 110.6 | 7.1 |
| 6662 | 3499 | 2108075 | 01 | 2 | 125.1 | 114.2 | 9.6 |
| 6662 | 3499 | 2108075 | 01 | 3 | 131.4 | 118.8 | 10.6 |
| 6662 | 3499 | 2108075 | 01 | 4 | 133.0 | 117.4 | 13.3 |
| 6662 | 3499 | 2108075 | 01 | 5 | 132.1 | 114.9 | 15.0 |
| 6662 | 3499 | 2115708 | 02 | 1 | 116.7 | 111.8 | 4.4 |
| 6662 | 3499 | 2115708 | 02 | 2 | 121.7 | 113.9 | 6.8 |
| 6662 | 3499 | 2115708 | 02 | 3 | 127.5 | 117.1 | 8.9 |
| 6662 | 3499 | 2115708 | 02 | 4 | 131.5 | 119.2 | 10.4 |
| 6662 | 3499 | 2115708 | 02 | 5 | 134.6 | 119.0 | 13.1 |
| 0254 | 3772 | 2135210 | 02 | 1 | 115.5 | 109.8 | 5.2 |
| 0254 | 3772 | 2135210 | 02 | 2 | 122.4 | 114.0 | 7.3 |
| 0254 | 3772 | 2135210 | 02 | 3 | 129.3 | 118.0 | 9.6 |
| 0254 | 3772 | 2135210 | 02 | 4 | 133.5 | 119.5 | 11.7 |
| 0254 | 3772 | 2135210 | 02 | 5 | 133.5 | 117.8 | 13.3 |
| 037K | 4539 | 2190975 | 03 | 1 | 118.6 | 110.4 | 7.4 |
| 037K | 4539 | 2190975 | 03 | 2 | 124.3 | 114.1 | 9.0 |
| 037K | 4539 | 2190975 | 03 | 3 | 130.9 | 118.3 | 10.7 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 037K | 4539 | 2190975 | 03 | 4 | 134.0 | 119.3 | 12.3 |
| 037K | 4539 | 2190975 | 03 | 5 | 133.2 | 117.2 | 13.7 |
| 027U | 4553 | 2190978 | 01 | 1 | 118.2 | 111.6 | 5.9 |
| 027U | 4553 | 2190978 | 01 | 2 | 122.0 | 112.6 | 8.4 |
| 027U | 4553 | 2190978 | 01 | 3 | 126.8 | 115.2 | 10.1 |
| 027U | 4553 | 2190978 | 01 | 4 | 132.1 | 118.8 | 11.2 |
| 027U | 4553 | 2190978 | 01 | 5 | 133.9 | 118.1 | 13.3 |
| 027U | 4553 | 2190978 | 01 | 6 | 132.5 | 115.2 | 15.0 |
| 04UK | 4715 | 2195561 | 01 | 1 | 118.6 | 110.4 | 7.4 |
| 04UK | 4715 | 2195561 | 01 | 2 | 124.3 | 114.1 | 9.0 |
| 04UK | 4715 | 2195561 | 01 | 3 | 130.9 | 118.3 | 10.7 |
| 04UK | 4715 | 2195561 | 01 | 4 | 134.0 | 119.3 | 12.3 |
| 04UK | 4715 | 2195561 | 01 | 5 | 133.2 | 117.2 | 13.7 |
| 02RX | 4838 | 2210956 | 03 | 1 | 122.4 | 114.3 | 7.1 |
| 02RX | 4838 | 2210956 | 03 | 2 | 126.0 | 115.3 | 9.3 |
| 02RX | 4838 | 2210956 | 03 | 3 | 132.8 | 119.4 | 11.2 |
| 02RX | 4838 | 2210956 | 03 | 4 | 133.9 | 118.6 | 12.9 |
| 02RX | 4838 | 2210956 | 03 | 5 | 132.8 | 116.7 | 13.8 |

**Table B-7: DOT-40 points used for compaction curves with a maximum dry unit weight between 120 pcf to 122 pcf.**

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 3834 | 743 | 1023635 | 01 | 1 | 120.5 | 114.7 | 5.1 |
| 3834 | 743 | 1023635 | 01 | 2 | 122.8 | 115.5 | 6.3 |
| 3834 | 743 | 1023635 | 01 | 3 | 128.8 | 118.5 | 8.7 |
| 3834 | 743 | 1023635 | 01 | 4 | 133.6 | 120.6 | 10.7 |
| 3834 | 743 | 1023635 | 01 | 5 | 132.9 | 118.3 | 12.4 |
| 5946 | 1679 | 1263658 | 02 | 1 | 122.1 | 115.0 | 6.2 |
| 5946 | 1679 | 1263658 | 02 | 2 | 127.5 | 118.7 | 7.4 |
| 5946 | 1679 | 1263658 | 02 | 3 | 133.5 | 121.1 | 10.2 |
| 5946 | 1679 | 1263658 | 02 | 4 | 133.6 | 118.5 | 12.7 |
| 5946 | 1679 | 1293294 | 01 | 1 | 121.5 | 113.2 | 7.4 |
| 5946 | 1679 | 1293294 | 01 | 2 | 126.4 | 116.2 | 8.8 |
| 5946 | 1679 | 1293294 | 01 | 3 | 132.8 | 120.1 | 10.6 |
| 5946 | 1679 | 1293294 | 01 | 4 | 134.9 | 120.5 | 12.0 |
| 5946 | 1679 | 1293294 | 01 | 5 | 134.1 | 118.5 | 13.2 |
| 5666 | 1710 | 1255868 | 002 | 1 | 125.2 | 116.2 | 7.8 |
| 5666 | 1710 | 1255868 | 002 | 2 | 132.0 | 120.0 | 10.0 |
| 5666 | 1710 | 1255868 | 002 | 3 | 135.5 | 120.8 | 12.2 |
| 5666 | 1710 | 1255868 | 002 | 4 | 134.1 | 118.3 | 13.4 |
| 6555 | 1865 | 1428545 | 01 | 1 | 115.2 | 109.9 | 4.9 |
| 6555 | 1865 | 1428545 | 01 | 2 | 119.2 | 112.1 | 6.4 |
| 6555 | 1865 | 1428545 | 01 | 3 | 123.5 | 113.6 | 8.7 |
| 6555 | 1865 | 1428545 | 01 | 4 | 130.9 | 117.6 | 11.3 |
| 6555 | 1865 | 1428545 | 01 | 5 | 136.7 | 121.6 | 12.4 |
| 6555 | 1865 | 1428545 | 01 | 6 | 133.1 | 115.4 | 15.3 |
| 5996 | 2149 | 1474202 | 01 | 1 | 121.4 | 113.7 | 6.7 |
| 5996 | 2149 | 1474202 | 01 | 2 | 129.4 | 118.6 | 9.1 |
| 5996 | 2149 | 1474202 | 01 | 3 | 133.8 | 120.9 | 10.7 |
| 5996 | 2149 | 1474202 | 01 | 4 | 134.6 | 119.2 | 12.9 |
| 5996 | 2149 | 1474202 | 01 | 5 | 131.4 | 113.8 | 15.5 |
| 00RV | 2449 | 2082105 | 01 | 1 | 122.4 | 116.4 | 5.2 |
| 00RV | 2449 | 2082105 | 01 | 2 | 126.8 | 118.4 | 7.1 |
| 00RV | 2449 | 2082105 | 01 | 3 | 130.4 | 119.7 | 9.0 |
| 00RV | 2449 | 2082105 | 01 | 4 | 135.6 | 122.6 | 10.6 |
| 00RV | 2449 | 2082105 | 01 | 5 | 135.8 | 121.0 | 12.2 |
| 021E | 3268 | 2125943 | 03 | 1 | 122.0 | 114.1 | 7.0 |
| 021E | 3268 | 2125943 | 03 | 2 | 127.1 | 116.6 | 9.0 |
| 021E | 3268 | 2125943 | 03 | 3 | 133.5 | 120.9 | 10.4 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 021E | 3268 | 2125943 | 03 | 4 | 134.5 | 120.3 | 11.9 |
| 021E | 3268 | 2125943 | 03 | 5 | 134.4 | 119.8 | 12.2 |
| 6179 | 3335 | 2108010 | 01 | 1 | 121.7 | 113.8 | 6.9 |
| 6179 | 3335 | 2108010 | 01 | 2 | 127.5 | 116.7 | 9.2 |
| 6179 | 3335 | 2108010 | 01 | 3 | 133.3 | 120.5 | 10.6 |
| 6179 | 3335 | 2108010 | 01 | 4 | 134.5 | 120.2 | 11.9 |
| 6179 | 3335 | 2108010 | 01 | 5 | 133.0 | 117.5 | 13.2 |
| 00GR | 3504 | 2124079 | 03 | 1 | 122.9 | 113.0 | 8.8 |
| 00GR | 3504 | 2124079 | 03 | 2 | 128.8 | 116.7 | 10.3 |
| 00GR | 3504 | 2124079 | 03 | 3 | 134.5 | 120.3 | 11.8 |
| 00GR | 3504 | 2124079 | 03 | 4 | 134.4 | 118.1 | 13.8 |
| 6666 | 3780 | 2140984 | Field02 | 1 | 118.1 | 112.4 | 5.1 |
| 6666 | 3780 | 2140984 | Field02 | 2 | 119.8 | 112.3 | 6.7 |
| 6666 | 3780 | 2140984 | Field02 | 3 | 123.1 | 113.9 | 8.1 |
| 6666 | 3780 | 2140984 | Field02 | 4 | 128.1 | 116.5 | 9.9 |
| 6666 | 3780 | 2140984 | Field02 | 5 | 133.3 | 119.4 | 11.6 |
| 6666 | 3780 | 2140984 | Field02 | 6 | 135.0 | 120.6 | 11.9 |
| 02D0 | 3912 | 2138565 | 01 | 1 | 125.4 | 114.2 | 9.8 |
| 02D0 | 3912 | 2138565 | 01 | 2 | 133.5 | 120.3 | 11.0 |
| 02D0 | 3912 | 2138565 | 01 | 3 | 134.7 | 119.8 | 12.5 |
| 02D0 | 3912 | 2138565 | 01 | 4 | 132.9 | 115.6 | 14.9 |
| 02PL | 4069 | 2179351 | 01 | 1 | 120.6 | 112.3 | 7.4 |
| 02PL | 4069 | 2179351 | 01 | 2 | 125.2 | 114.8 | 9.1 |
| 02PL | 4069 | 2179351 | 01 | 3 | 131.9 | 119.5 | 10.3 |
| 02PL | 4069 | 2179351 | 01 | 4 | 134.7 | 119.5 | 12.6 |
| 02PL | 4069 | 2179351 | 01 | 5 | 134.9 | 118.5 | 13.8 |
| 02RX | 4838 | 2203985 | 01 | 1 | 117.9 | 110.9 | 6.4 |
| 02RX | 4838 | 2203985 | 01 | 2 | 124.7 | 115.4 | 8.1 |
| 02RX | 4838 | 2203985 | 01 | 3 | 132.4 | 120.2 | 10.2 |
| 02RX | 4838 | 2203985 | 01 | 4 | 136.7 | 121.3 | 12.7 |
| 02RX | 4838 | 2203985 | 01 | 5 | 133.3 | 116.6 | 14.3 |
| 02RX | 4838 | 2204566 | 02 | 1 | 121.1 | 113.7 | 6.5 |
| 02RX | 4838 | 2204566 | 02 | 2 | 125.6 | 116.2 | 8.1 |
| 02RX | 4838 | 2204566 | 02 | 3 | 130.3 | 118.3 | 10.1 |
| 02RX | 4838 | 2204566 | 02 | 4 | 134.3 | 120.4 | 11.5 |
| 02RX | 4838 | 2204566 | 02 | 5 | 134.3 | 118.5 | 13.3 |
| 035Z | 4892 | 2203783 | 01 | 1 | 117.9 | 110.9 | 6.4 |
| 035Z | 4892 | 2203783 | 01 | 2 | 124.7 | 115.4 | 8.1 |
| 035Z | 4892 | 2203783 | 01 | 3 | 132.4 | 120.2 | 10.2 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 035Z | 4892 | 2203783 | 01 | 4 | 136.7 | 121.3 | 12.7 |
| 035Z | 4892 | 2203783 | 01 | 5 | 133.3 | 116.6 | 14.3 |
| 035Z | 4892 | 2204479 | 02 | 1 | 121.1 | 113.7 | 6.5 |
| 035Z | 4892 | 2204479 | 02 | 2 | 125.6 | 116.2 | 8.1 |
| 035Z | 4892 | 2204479 | 02 | 3 | 130.3 | 118.3 | 10.1 |
| 035Z | 4892 | 2204479 | 02 | 4 | 134.3 | 120.4 | 11.5 |
| 035Z | 4892 | 2204479 | 02 | 5 | 134.3 | 118.5 | 13.3 |

**Table B-8: DOT-40 points used for compaction curves with a maximum dry unit weight between 122 pcf to 124 pcf.**

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 02KH | 3139 | 2099125 | 01 | 1 | 119.0 | 113.8 | 4.6 |
| 02KH | 3139 | 2099125 | 01 | 2 | 127.5 | 120.5 | 5.8 |
| 02KH | 3139 | 2099125 | 01 | 3 | 131.4 | 122.4 | 7.4 |
| 02KH | 3139 | 2099125 | 01 | 4 | 131.5 | 120.9 | 8.8 |
| 3151 | 1438 | 1077471 | 02 | 1 | 120.6 | 114.5 | 5.3 |
| 3151 | 1438 | 1077471 | 02 | 2 | 126.3 | 118.3 | 6.8 |
| 3151 | 1438 | 1077471 | 02 | 3 | 131.1 | 120.7 | 8.6 |
| 3151 | 1438 | 1077471 | 02 | 4 | 136.3 | 124.1 | 9.8 |
| 3151 | 1438 | 1077471 | 02 | 5 | 135.5 | 122.1 | 11.0 |
| 5893 | 1860 | 1432788 | IA02 | 1 | 124.1 | 118.0 | 5.1 |
| 5893 | 1860 | 1432788 | IA02 | 2 | 127.8 | 120.1 | 6.4 |
| 5893 | 1860 | 1432788 | IA02 | 3 | 133.5 | 122.9 | 8.7 |
| 5893 | 1860 | 1432788 | IA02 | 4 | 137.7 | 123.6 | 11.4 |
| 6651 | 2517 | 1467440 | 01 | 1 | 120.7 | 114.7 | 5.3 |
| 6651 | 2517 | 1467440 | 01 | 2 | 125.9 | 118.0 | 6.7 |
| 6651 | 2517 | 1467440 | 01 | 3 | 133.2 | 122.1 | 9.1 |
| 6651 | 2517 | 1467440 | 01 | 4 | 138.2 | 124.2 | 11.3 |
| 6651 | 2517 | 1467440 | 01 | 5 | 136.5 | 121.2 | 12.7 |
| 6666 | 3780 | 2149071 | Field03 | 1 | 118.3 | 112.2 | 5.4 |
| 6666 | 3780 | 2149071 | Field03 | 2 | 124.7 | 115.9 | 7.6 |
| 6666 | 3780 | 2149071 | Field03 | 3 | 134.9 | 122.4 | 10.2 |
| 6666 | 3780 | 2149071 | Field03 | 4 | 135.7 | 121.6 | 11.6 |
| 6666 | 3780 | 2149071 | Field03 | 5 | 134.7 | 117.1 | 15.1 |
| I2WD | 4511 | 2177719 | 01 | 1 | 117.7 | 110.9 | 6.1 |
| I2WD | 4511 | 2177719 | 01 | 2 | 125.0 | 116.1 | 7.6 |
| I2WD | 4511 | 2177719 | 01 | 3 | 128.6 | 117.6 | 9.3 |
| I2WD | 4511 | 2177719 | 01 | 4 | 136.4 | 123.2 | 10.7 |
| I2WD | 4511 | 2177719 | 01 | 5 | 134.9 | 124.4 | 8.5 |

**Table B-9: DOT-40 points used for curves with a maximum dry unit weight between 124 pcf to 126 pcf.**

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 6124 | 978 | 1024902 | Field # 01 | 1 | 120.8 | 117.0 | 3.3 |
| 6124 | 978 | 1024902 | | 2 | 125.7 | 119.6 | 5.1 |
| 6124 | 978 | 1024902 | Field # 01 | 3 | 131.3 | 122.9 | 6.8 |
| 6124 | 978 | 1024902 | | 4 | 136.2 | 124.2 | 9.7 |
| 6124 | 978 | 1024902 | Field # 01 | 5 | 136.1 | 122.7 | 11.0 |
| 6124 | 978 | 1024902 | | 6 | 134.2 | 119.8 | 12.0 |
| 6553 | 1403 | 1086354 | 01 | 1 | 124.6 | 118.9 | 4.9 |
| 6553 | 1403 | 1086354 | 01 | 2 | 128.6 | 121.2 | 6.2 |
| 6553 | 1403 | 1086354 | 01 | 3 | 132.8 | 122.5 | 8.4 |
| 6553 | 1403 | 1086354 | 01 | 4 | 138.4 | 124.9 | 10.8 |
| 6553 | 1403 | 1086354 | 01 | 5 | 137.4 | 120.4 | 14.2 |
| 5893 | 1860 | 1430366 | IA01 | 1 | 133.1 | 123.4 | 7.9 |
| 5893 | 1860 | 1430366 | IA01 | 2 | 135.8 | 124.3 | 9.2 |
| 5893 | 1860 | 1430366 | IA01 | 3 | 137.1 | 124.5 | 10.1 |
| 5893 | 1860 | 1430366 | IA01 | 4 | 138.3 | 124.6 | 11.0 |
| 5893 | 1860 | 1430366 | IA01 | 5 | 136.1 | 119.9 | 13.5 |
| 6947 | 1990 | 1439066 | 01 | 1 | 122.4 | 116.7 | 4.9 |
| 6947 | 1990 | 1439066 | 01 | 2 | 129.6 | 121.1 | 7.0 |
| 6947 | 1990 | 1439066 | 01 | 3 | 136.1 | 125.2 | 8.7 |
| 6947 | 1990 | 1439066 | 01 | 4 | 137.0 | 121.0 | 13.2 |
| 6947 | 1990 | 1439066 | 01 | 5 | 136.1 | 118.5 | 14.8 |
| 01AW | 2385 | 1462410 | 01 | 1 | 123.9 | 117.2 | 5.7 |
| 01AW | 2385 | 1462410 | 01 | 2 | 130.4 | 121.6 | 7.2 |
| 01AW | 2385 | 1462410 | 01 | 3 | 136.3 | 124.7 | 9.3 |
| 01AW | 2385 | 1462410 | 01 | 4 | 135.7 | 122.1 | 11.2 |
| 0122 | 2415 | 1468287 | 01 | 1 | 122.9 | 116.0 | 5.9 |
| 0122 | 2415 | 1468287 | 01 | 2 | 133.5 | 122.9 | 8.7 |
| 0122 | 2415 | 1468287 | 01 | 3 | 137.0 | 124.6 | 9.9 |
| 0122 | 2415 | 1468287 | 01 | 4 | 135.8 | 119.3 | 13.8 |
| 6865 | 4888 | 2207946 | 01 | 1 | 122.7 | 117.1 | 4.7 |
| 6865 | 4888 | 2207946 | 01 | 2 | 130.5 | 122.9 | 6.2 |
| 6865 | 4888 | 2207946 | 01 | 3 | 134.4 | 123.8 | 8.5 |
| 6865 | 4888 | 2207946 | 01 | 4 | 138.0 | 124.7 | 10.7 |
| 6865 | 4888 | 2207946 | 01 | 5 | 137.6 | 123.2 | 11.7 |
| 3096 | 1332 | 1071758 | 01 | 1 | 119.9 | 117.8 | 1.8 |
| 3096 | 1332 | 1071758 | 01 | 2 | 127.8 | 123.0 | 3.9 |
| 3096 | 1332 | 1071758 | 01 | 3 | 131.9 | 125.2 | 5.4 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 3096 | 1332 | 1071758 | 01 | 4 | 133.9 | 124.6 | 7.5 |
| 6689 | 1666 | 1256991 | 01 | 1 | 120.1 | 114.8 | 4.6 |
| 6689 | 1666 | 1256991 | 01 | 2 | 128.2 | 121.1 | 5.9 |
| 6689 | 1666 | 1256991 | 01 | 3 | 134.6 | 125.0 | 7.7 |
| 6689 | 1666 | 1256991 | 01 | 4 | 137.8 | 125.5 | 9.7 |
| 6555 | 1865 | 1449851 | 04 | 1 | 122.9 | 114.3 | 7.5 |
| 6555 | 1865 | 1449851 | 04 | 2 | 129.2 | 118.0 | 9.5 |
| 6555 | 1865 | 1449851 | 04 | 3 | 135.6 | 122.7 | 10.5 |
| 6555 | 1865 | 1449851 | 04 | 4 | 141.6 | 125.5 | 12.8 |
| 6555 | 1865 | 1449851 | 04 | 5 | 141.2 | 122.7 | 15.1 |
| 1189 | 2148 | 1416560 | IA01 | 1 | 127.1 | 121.0 | 5.0 |
| 1189 | 2148 | 1416560 | IA01 | 2 | 135.1 | 125.3 | 7.8 |
| 1189 | 2148 | 1416560 | IA01 | 3 | 138.0 | 125.5 | 10.0 |
| 1189 | 2148 | 1416560 | IA01 | 4 | 137.7 | 124.3 | 10.8 |
| 5996 | 2149 | 1474911 | 02 | 1 | 125.4 | 116.5 | 7.6 |
| 5996 | 2149 | 1474911 | 02 | 2 | 133.7 | 122.1 | 9.5 |
| 5996 | 2149 | 1474911 | 02 | 3 | 136.6 | 121.9 | 12.1 |
| 5996 | 2149 | 1474911 | 02 | 4 | 134.0 | 119.1 | 12.5 |
| 5967 | 2172 | 1414274 | IA01 | 1 | 127.1 | 121.0 | 5.0 |
| 5967 | 2172 | 1414274 | IA01 | 2 | 134.8 | 125.1 | 7.8 |
| 5967 | 2172 | 1414274 | IA01 | 3 | 138.0 | 125.5 | 10.0 |
| 5967 | 2172 | 1414274 | IA01 | 4 | 137.7 | 124.3 | 10.8 |
| 02NG | 3488 | 2102415 | 01 | 1 | 124.1 | 119.6 | 3.8 |
| 02NG | 3488 | 2102415 | 01 | 2 | 128.2 | 121.2 | 5.8 |
| 02NG | 3488 | 2102415 | 01 | 3 | 132.9 | 122.8 | 8.2 |
| 02NG | 3488 | 2102415 | 01 | 4 | 138.5 | 126.3 | 9.7 |
| 02NG | 3488 | 2102415 | 01 | 5 | 138.8 | 125.0 | 11.0 |
| 000U | 3773 | 2128124 | 01 | 1 | 120.0 | 115.4 | 4.0 |
| 000U | 3773 | 2128124 | 01 | 2 | 123.6 | 117.9 | 4.8 |
| 000U | 3773 | 2128124 | 01 | 3 | 127.3 | 120.0 | 6.1 |
| 000U | 3773 | 2128124 | 01 | 4 | 133.5 | 124.5 | 7.2 |
| 000U | 3773 | 2128124 | 01 | 5 | 136.5 | 125.9 | 8.4 |
| 000U | 3773 | 2128124 | 01 | 6 | 134.4 | 123.2 | 9.1 |

**Table B-10: DOT-40 points used for compaction curves with a maximum dry unit weight between 126 pcf to 128 pcf.**

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 0566 | 952 | 1077254 | 01 | 1 | 123.0 | 117.9 | 4.3 |
| 0566 | 952 | 1077254 | 01 | 2 | 130.6 | 123.3 | 5.9 |
| 0566 | 952 | 1077254 | 01 | 3 | 134.3 | 125.0 | 7.4 |
| 0566 | 952 | 1077254 | 01 | 4 | 122.9 | 113.3 | 8.4 |
| 6124 | 978 | 1019292 | 02 | 1 | 126.8 | 120.6 | 5.1 |
| 6124 | 978 | 1019292 | 02 | 2 | 136.4 | 126.6 | 7.7 |
| 6124 | 978 | 1019292 | 02 | 3 | 137.0 | 125.6 | 9.1 |
| 6124 | 978 | 1019292 | 02 | 4 | 136.5 | 123.8 | 10.3 |
| 4793 | 1053 | 1030365 | 02 | 1 | 132.3 | 123.1 | 7.5 |
| 4793 | 1053 | 1030365 | 02 | 2 | 139.0 | 126.7 | 9.7 |
| 4793 | 1053 | 1030365 | 02 | 3 | 141.0 | 127.0 | 11.1 |
| 4793 | 1053 | 1030365 | 02 | 4 | 140.6 | 125.2 | 12.3 |
| 5637 | 1193 | 1043515 | 01 | 1 | 118.7 | 113.8 | 4.3 |
| 5637 | 1193 | 1043515 | 01 | 2 | 121.9 | 115.1 | 5.9 |
| 5637 | 1193 | 1043515 | 01 | 3 | 131.6 | 121.6 | 8.3 |
| 5637 | 1193 | 1043515 | 01 | 4 | 138.1 | 126.2 | 9.5 |
| 5637 | 1193 | 1043515 | 01 | 5 | 138.5 | 124.8 | 11.0 |
| 5637 | 1193 | 1043515 | 01 | 6 | 137.9 | 121.6 | 13.4 |
| 5881 | 1197 | 1054567 | 1 | 1 | 118.0 | 115.2 | 2.5 |
| 5881 | 1197 | 1054567 | 1 | 2 | 124.4 | 118.9 | 4.6 |
| 5881 | 1197 | 1054567 | 1 | 3 | 133.2 | 124.5 | 7.0 |
| 5881 | 1197 | 1054567 | 1 | 4 | 138.9 | 126.8 | 9.6 |
| 5881 | 1197 | 1054567 | 1 | 5 | 138.4 | 124.5 | 11.1 |
| 1245 | 1847 | 1404333 | 01 | 1 | 122.6 | 117.3 | 4.5 |
| 1245 | 1847 | 1404333 | 01 | 2 | 128.6 | 120.8 | 6.4 |
| 1245 | 1847 | 1404333 | 01 | 3 | 135.3 | 125.0 | 8.2 |
| 1245 | 1847 | 1404333 | 01 | 4 | 140.6 | 126.6 | 11.1 |
| 1245 | 1847 | 1404333 | 01 | 5 | 137.4 | 120.4 | 14.1 |
| 4460 | 2416 | 1478797 | 03 | 1 | 121.3 | 115.7 | 4.8 |
| 4460 | 2416 | 1478797 | 03 | 2 | 134.1 | 123.0 | 9.1 |
| 4460 | 2416 | 1478797 | 03 | 3 | 140.7 | 126.9 | 10.8 |
| 4460 | 2416 | 1478797 | 03 | 4 | 139.7 | 123.8 | 12.9 |
| 022E | 4074 | 2188570 | 01 | 1 | 117.1 | 114.0 | 2.7 |
| 022E | 4074 | 2188570 | 01 | 2 | 124.5 | 119.8 | 4.0 |
| 022E | 4074 | 2188570 | 01 | 3 | 133.2 | 125.7 | 5.9 |
| 022E | 4074 | 2188570 | 01 | 4 | 136.7 | 126.3 | 8.2 |
| 04D0 | 4548 | 2188262 | IA01 | 1 | 130.9 | 123.6 | 5.9 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 04D0 | 4548 | 2188262 | IA01 | 2 | 135.0 | 126.0 | 7.1 |
| 04D0 | 4548 | 2188262 | IA01 | 3 | 137.6 | 126.6 | 8.7 |
| 04D0 | 4548 | 2188262 | IA01 | 4 | 134.9 | 122.7 | 9.9 |
| 5858 | 1218 | 1046249 | 01 | 1 | 131.1 | 121.7 | 7.7 |
| 5858 | 1218 | 1046249 | 01 | 2 | 139.5 | 127.2 | 9.7 |
| 5858 | 1218 | 1046249 | 01 | 3 | 140.6 | 123.6 | 13.7 |
| 5858 | 1218 | 1046249 | 01 | 4 | 139.7 | 121.4 | 15.0 |
| 021K | 3882 | 2155027 | 01 | 1 | 125.6 | 120.6 | 4.1 |
| 021K | 3882 | 2155027 | 01 | 2 | 130.4 | 123.1 | 5.9 |
| 021K | 3882 | 2155027 | 01 | 3 | 137.5 | 127.4 | 7.9 |
| 021K | 3882 | 2155027 | 01 | 4 | 139.2 | 127.0 | 9.6 |
| 021K | 3882 | 2155027 | 01 | 5 | 138.0 | 124.7 | 10.7 |
| 02QR | 4524 | 2189354 | 01 | 1 | 125.0 | 120.1 | 4.0 |
| 02QR | 4524 | 2189354 | 01 | 2 | 131.5 | 124.2 | 5.9 |
| 02QR | 4524 | 2189354 | 01 | 3 | 137.2 | 126.1 | 8.7 |
| 02QR | 4524 | 2189354 | 01 | 4 | 141.7 | 128.7 | 10.1 |
| 02QR | 4524 | 2189354 | 01 | 5 | 141.4 | 127.1 | 11.2 |

**Table B-11: DOT-40 points used for compaction curves with a maximum dry unit weight between 128 pcf to 130 pcf.**

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 5636 | 911 | 1017378 | 02 | 1 | 130.0 | 121.8 | 6.7 |
| 5636 | 911 | 1017378 | 02 | 2 | 139.8 | 128.7 | 8.7 |
| 5636 | 911 | 1017378 | 02 | 3 | 142.6 | 128.6 | 10.9 |
| 5636 | 911 | 1017378 | 02 | 4 | 139.8 | 124.8 | 12.0 |
| 6440 | 912 | 1007190 | 1 | 1 | 127.8 | 122.0 | 4.8 |
| 6440 | 912 | 1007190 | 1 | 2 | 135.2 | 128.0 | 5.6 |
| 6440 | 912 | 1007190 | 1 | 3 | 134.8 | 126.4 | 6.6 |
| 6440 | 912 | 1007190 | 1 | 4 | 130.8 | 121.6 | 7.5 |
| 5635 | 955 | 1019413 | 01 | 1 | 130.0 | 121.8 | 6.7 |
| 5635 | 955 | 1019413 | 01 | 2 | 139.8 | 128.7 | 8.7 |
| 5635 | 955 | 1019413 | 01 | 3 | 142.6 | 128.6 | 10.9 |
| 5635 | 955 | 1019413 | 01 | 4 | 139.8 | 124.8 | 12.0 |
| 5956 | 1146 | 1039485 | 01 | 1 | 133.2 | 125.4 | 6.2 |
| 5956 | 1146 | 1039485 | 01 | 2 | 138.6 | 128.4 | 7.9 |
| 5956 | 1146 | 1039485 | 01 | 3 | 142.4 | 127.5 | 11.7 |
| 5956 | 1146 | 1039485 | 01 | 4 | 143.6 | 128.5 | 11.7 |
| 5956 | 1146 | 1039485 | 01 | 5 | 143.7 | 125.6 | 14.4 |
| 5856 | 1152 | 1038741 | 01 | 1 | 131.4 | 121.6 | 8.0 |
| 5856 | 1152 | 1038741 | 01 | 2 | 139.7 | 127.4 | 9.6 |
| 5856 | 1152 | 1038741 | 01 | 3 | 142.9 | 128.2 | 11.4 |
| 5856 | 1152 | 1038741 | 01 | 4 | 141.7 | 125.5 | 12.9 |
| 5854 | 1169 | 1049158 | 02 | 1 | 125.2 | 120.2 | 4.2 |
| 5854 | 1169 | 1049158 | 02 | 2 | 131.7 | 124.0 | 6.2 |
| 5854 | 1169 | 1049158 | 02 | 3 | 137.7 | 127.5 | 8.0 |
| 5854 | 1169 | 1049158 | 02 | 4 | 140.9 | 127.9 | 10.2 |
| 5854 | 1169 | 1049158 | 02 | 5 | 138.9 | 124.4 | 11.6 |
| 5627 | 1363 | 1100342 | 02 | 1 | 121.7 | 116.8 | 4.2 |
| 5627 | 1363 | 1100342 | 02 | 2 | 129.4 | 122.2 | 6.0 |
| 5627 | 1363 | 1100342 | 02 | 3 | 136.4 | 126.6 | 7.7 |
| 5627 | 1363 | 1100342 | 02 | 4 | 140.6 | 128.1 | 9.8 |
| 5627 | 1363 | 1100342 | 02 | 5 | 138.9 | 124.9 | 11.2 |
| 4699 | 1614 | 1277909 | 01 | 1 | 118.1 | 115.7 | 2.1 |
| 4699 | 1614 | 1277909 | 01 | 2 | 125.3 | 120.7 | 3.8 |
| 4699 | 1614 | 1277909 | 01 | 3 | 132.6 | 126.6 | 4.8 |
| 4699 | 1614 | 1277909 | 01 | 4 | 135.8 | 128.2 | 6.0 |
| 4699 | 1614 | 1277909 | 01 | 5 | 135.7 | 125.9 | 7.8 |
| 5946 | 1679 | 1253892 | 01 | 1 | 123.3 | 118.3 | 4.2 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 5946 | 1679 | 1253892 | 01 | 2 | 131.3 | 123.3 | 6.5 |
| 5946 | 1679 | 1253892 | 01 | 3 | 139.9 | 128.7 | 8.7 |
| 5946 | 1679 | 1253892 | 01 | 4 | 140.4 | 126.9 | 10.7 |
| 5946 | 1679 | 1253892 | 01 | 5 | 137.7 | 123.8 | 11.2 |
| 5558 | 1742 | 1261606 | 01 | 1 | 128.4 | 120.5 | 6.5 |
| 5558 | 1742 | 1261606 | 01 | 2 | 136.4 | 126.2 | 8.1 |
| 5558 | 1742 | 1261606 | 01 | 3 | 141.2 | 128.3 | 10.1 |
| 5558 | 1742 | 1261606 | 01 | 4 | 138.8 | 123.9 | 12.1 |
| 6555 | 1865 | 1442944 | 02 | 1 | 123.9 | 119.8 | 3.4 |
| 6555 | 1865 | 1442944 | 02 | 2 | 129.7 | 123.6 | 4.9 |
| 6555 | 1865 | 1442944 | 02 | 3 | 136.5 | 128.9 | 5.9 |
| 6555 | 1865 | 1442944 | 02 | 4 | 137.1 | 127.6 | 7.4 |
| 6555 | 1865 | 1442944 | 02 | 5 | 138.3 | 127.2 | 8.7 |
| 6555 | 1865 | 1442947 | 03 | 1 | 122.1 | 117.5 | 4.0 |
| 6555 | 1865 | 1442947 | 03 | 2 | 126.1 | 120.6 | 4.6 |
| 6555 | 1865 | 1442947 | 03 | 3 | 131.3 | 123.4 | 6.4 |
| 6555 | 1865 | 1442947 | 03 | 4 | 136.5 | 127.1 | 7.4 |
| 6555 | 1865 | 1442947 | 03 | 5 | 138.4 | 127.8 | 8.3 |
| 5586 | 2103 | 1467177 | 01 | 1 | 123.9 | 122.8 | 0.9 |
| 5586 | 2103 | 1467177 | 01 | 2 | 127.4 | 123.6 | 3.0 |
| 5586 | 2103 | 1467177 | 01 | 3 | 134.0 | 127.4 | 5.1 |
| 5586 | 2103 | 1467177 | 01 | 4 | 136.7 | 127.4 | 7.2 |
| 003T | 2145 | 1416841 | IA01 | 1 | 121.7 | 118.5 | 2.6 |
| 003T | 2145 | 1416841 | IA01 | 2 | 128.7 | 123.0 | 4.6 |
| 003T | 2145 | 1416841 | IA01 | 3 | 136.1 | 127.7 | 6.6 |
| 003T | 2145 | 1416841 | IA01 | 4 | 138.1 | 124.6 | 10.9 |
| 00S3 | 2165 | 1461515 | 01 | 1 | 122.7 | 118.4 | 3.6 |
| 00S3 | 2165 | 1461515 | 01 | 2 | 129.5 | 122.5 | 5.8 |
| 00S3 | 2165 | 1461515 | 01 | 3 | 136.9 | 127.0 | 7.8 |
| 00S3 | 2165 | 1461515 | 01 | 4 | 141.4 | 128.5 | 10.1 |
| 00S3 | 2165 | 1461515 | 01 | 5 | 140.5 | 124.7 | 12.6 |
| 4460 | 2416 | 1476917 | 02 | 1 | 127.0 | 120.9 | 5.0 |
| 4460 | 2416 | 1476917 | 02 | 2 | 131.7 | 124.3 | 5.9 |
| 4460 | 2416 | 1476917 | 02 | 3 | 138.8 | 128.3 | 8.2 |
| 4460 | 2416 | 1476917 | 02 | 4 | 140.4 | 127.8 | 9.9 |
| 5649 | 2427 | 2068606 | Field01 | 1 | 128.7 | 122.1 | 5.5 |
| 5649 | 2427 | 2068606 | Field01 | 2 | 135.5 | 125.5 | 8.0 |
| 5649 | 2427 | 2068606 | Field01 | 3 | 141.4 | 128.8 | 9.8 |
| 5649 | 2427 | 2068606 | Field01 | 4 | 138.9 | 123.8 | 12.2 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 00Z6 | 3246 | 2086228 | 01 | 1 | 128.2 | 123.0 | 4.3 |
| 00Z6 | 3246 | 2086228 | 01 | 2 | 134.4 | 126.7 | 6.1 |
| 00Z6 | 3246 | 2086228 | 01 | 3 | 140.4 | 130.1 | 7.9 |
| 00Z6 | 3246 | 2086228 | 01 | 4 | 141.3 | 128.6 | 9.9 |
| 00Z6 | 3246 | 2086228 | 01 | 5 | 140.1 | 126.3 | 10.9 |
| I1MU | 3248 | 2083448 | 01 | 1 | 127.6 | 119.3 | 7.0 |
| I1MU | 3248 | 2083448 | 01 | 2 | 134.3 | 123.9 | 8.4 |
| I1MU | 3248 | 2083448 | 01 | 3 | 141.2 | 128.0 | 10.3 |
| I1MU | 3248 | 2083448 | 01 | 4 | 142.8 | 127.5 | 12.0 |
| 01KY | 3342 | 2091131 | 01 | 1 | 125.7 | 120.5 | 4.3 |
| 01KY | 3342 | 2091131 | 01 | 2 | 131.2 | 123.3 | 6.4 |
| 01KY | 3342 | 2091131 | 01 | 3 | 138.9 | 127.8 | 8.6 |
| 01KY | 3342 | 2091131 | 01 | 4 | 140.9 | 128.1 | 10.0 |
| 01KY | 3342 | 2091131 | 01 | 5 | 139.7 | 125.0 | 11.8 |
| 02NP | 3490 | 2103796 | 01 | 1 | 131.8 | 126.1 | 4.5 |
| 02NP | 3490 | 2103796 | 01 | 2 | 138.4 | 129.5 | 6.8 |
| 02NP | 3490 | 2103796 | 01 | 3 | 140.9 | 129.4 | 8.9 |
| 02NP | 3490 | 2103796 | 01 | 4 | 141.0 | 128.3 | 9.9 |
| 5656 | 3556 | 2120459 | IA01 | 1 | 130.5 | 123.1 | 6.0 |
| 5656 | 3556 | 2120459 | IA01 | 2 | 136.9 | 126.4 | 8.3 |
| 5656 | 3556 | 2120459 | IA01 | 3 | 140.7 | 129.2 | 9.0 |
| 5656 | 3556 | 2120459 | IA01 | 4 | 137.2 | 124.1 | 10.5 |
| 010Q | 3608 | 2141800 | 01 | 1 | 127.1 | 119.6 | 6.3 |
| 010Q | 3608 | 2141800 | 01 | 2 | 136.1 | 125.9 | 8.1 |
| 010Q | 3608 | 2141800 | 01 | 3 | 141.7 | 129.5 | 9.4 |
| 010Q | 3608 | 2141800 | 01 | 4 | 140.9 | 126.6 | 11.3 |
| 01D9 | 3638 | 2108446 | 01 | 1 | 124.5 | 120.6 | 3.2 |
| 01D9 | 3638 | 2108446 |  | 2 | 129.3 | 122.9 | 5.2 |
| 01D9 | 3638 | 2108446 | 01 | 3 | 135.9 | 126.4 | 7.6 |
| 01D9 | 3638 | 2108446 |  | 4 | 140.7 | 129.3 | 8.8 |
| 01D9 | 3638 | 2108446 | 01 | 5 | 139.8 | 125.9 | 11.0 |
| 01T6 | 3662 | 2135692 | 01 | 1 | 130.5 | 125.0 | 4.4 |
| 01T6 | 3662 | 2135692 | 01 | 2 | 135.7 | 127.4 | 6.5 |
| 01T6 | 3662 | 2135692 | 01 | 3 | 140.5 | 129.6 | 8.4 |
| 01T6 | 3662 | 2135692 | 01 | 4 | 141.5 | 128.7 | 9.9 |
| 01T6 | 3662 | 2135692 | 01 | 5 | 141.3 | 127.1 | 11.2 |
| 033V | 3827 | 2155333 | 01 | 1 | 129.1 | 123.0 | 4.9 |
| 033V | 3827 | 2155333 | 01 | 2 | 136.4 | 128.7 | 6.0 |
| 033V | 3827 | 2155333 | 01 | 3 | 138.5 | 129.8 | 6.8 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 033V | 3827 | 2155333 | 01 | 4 | 137.3 | 126.8 | 8.3 |
| 021K | 3882 | 2155028 | 02 | 1 | 126.5 | 120.3 | 5.2 |
| 021K | 3882 | 2155028 | 02 | 2 | 134.1 | 124.4 | 7.9 |
| 021K | 3882 | 2155028 | 02 | 3 | 141.3 | 129.3 | 9.3 |
| 021K | 3882 | 2155028 | 02 | 4 | 137.3 | 123.8 | 10.9 |
| 0255 | 3915 | 2145668 | 01 | 1 | 133.7 | 123.4 | 8.3 |
| 0255 | 3915 | 2145668 | 01 | 2 | 142.3 | 128.9 | 10.4 |
| 0255 | 3915 | 2145668 | 01 | 3 | 143.0 | 127.4 | 12.3 |
| 0255 | 3915 | 2145668 | 01 | 4 | 141.8 | 125.6 | 12.9 |
| 00D0 | 3980 | 2173471 | 01 | 1 | 124.4 | 120.9 | 2.9 |
| 00D0 | 3980 | 2173471 | 01 | 2 | 130.3 | 124.7 | 4.5 |
| 00D0 | 3980 | 2173471 | 01 | 3 | 136.9 | 128.6 | 6.5 |
| 00D0 | 3980 | 2173471 | 01 | 4 | 135.3 | 124.9 | 8.4 |
| 034S | 4176 | 2202584 | 01 | 1 | 127.0 | 122.1 | 4.0 |
| 034S | 4176 | 2202584 | 01 | 2 | 133.9 | 126.4 | 5.9 |
| 034S | 4176 | 2202584 | 01 | 3 | 139.7 | 128.9 | 8.3 |
| 034S | 4176 | 2202584 | 01 | 4 | 141.4 | 128.3 | 10.2 |
| 034S | 4176 | 2202584 | 01 | 5 | 140.9 | 125.4 | 12.3 |
| 6963 | 4322 | 2169903 | IA01 | 1 | 135.0 | 128.6 | 5.0 |
| 6963 | 4322 | 2169903 | IA01 | 2 | 135.4 | 127.1 | 6.5 |
| 6963 | 4322 | 2169903 | IA01 | 3 | 137.4 | 128.2 | 7.2 |
| 6963 | 4322 | 2169903 | IA01 | 4 | 139.4 | 129.0 | 8.1 |
| 6963 | 4322 | 2169903 | IA01 | 5 | 138.5 | 125.8 | 10.1 |
| 01RP | 4426 | 2205871 | IA01 | 1 | 129.1 | 122.3 | 5.5 |
| 01RP | 4426 | 2205871 | IA01 | 2 | 138.8 | 128.9 | 7.7 |
| 01RP | 4426 | 2205871 | IA01 | 3 | 140.4 | 128.7 | 9.1 |
| 01RP | 4426 | 2205871 | IA01 | 4 | 139.3 | 126.9 | 9.8 |
| 036J | 4432 | 2188548 | 01 | 1 | 125.4 | 120.4 | 4.1 |
| 036J | 4432 | 2188548 | 01 | 2 | 130.0 | 122.5 | 6.1 |
| 036J | 4432 | 2188548 | 01 | 3 | 136.1 | 126.0 | 8.0 |
| 036J | 4432 | 2188548 | 01 | 4 | 140.0 | 127.8 | 9.6 |
| 036J | 4432 | 2188548 | 01 | 5 | 142.6 | 128.1 | 11.4 |
| 036J | 4432 | 2188548 | 01 | 6 | 142.4 | 125.4 | 13.5 |
| 037L | 4435 | 2189535 | 01 | 1 | 131.2 | 126.0 | 4.2 |
| 037L | 4435 | 2189535 | 01 | 2 | 136.5 | 128.4 | 6.4 |
| 037L | 4435 | 2189535 | 01 | 3 | 141.4 | 130.3 | 8.5 |
| 037L | 4435 | 2189535 | 01 | 4 | 141.7 | 128.5 | 10.3 |
| 037L | 4435 | 2189535 | 01 | 5 | 138.6 | 123.1 | 12.7 |
| 038X | 4518 | 2185993 | 01 | 1 | 122.9 | 117.0 | 5.0 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 038X | 4518 | 2185993 | 01 | 2 | 132.2 | 122.7 | 7.7 |
| 038X | 4518 | 2185993 | 01 | 3 | 138.6 | 127.3 | 8.9 |
| 038X | 4518 | 2185993 | 01 | 4 | 141.5 | 129.2 | 9.5 |
| 038X | 4518 | 2185993 | 01 | 5 | 141.9 | 128.2 | 10.7 |
| 038X | 4518 | 2185993 | 01 | 6 | 139.5 | 124.7 | 11.9 |
| 041D | 4570 | 2201706 | 01 | 1 | 124.5 | 118.8 | 4.8 |
| 041D | 4570 | 2201706 | 01 | 2 | 133.8 | 126.2 | 6.0 |
| 041D | 4570 | 2201706 | 01 | 3 | 137.6 | 126.7 | 8.6 |
| 041D | 4570 | 2201706 | 01 | 4 | 142.4 | 129.3 | 10.1 |
| 041D | 4570 | 2201706 | 01 | 5 | 140.4 | 125.8 | 11.6 |
| 041D | 4570 | 2202223 | 02 | 1 | 130.1 | 122.6 | 6.1 |
| 041D | 4570 | 2202223 | 02 | 2 | 137.8 | 127.7 | 7.9 |
| 041D | 4570 | 2202223 | 02 | 3 | 142.0 | 129.7 | 9.6 |
| 041D | 4570 | 2202223 | 02 | 4 | 141.2 | 127.3 | 10.9 |
| 6488 | 4587 | 2220342 | IA01 | 1 | 123.7 | 119.2 | 3.8 |
| 6488 | 4587 | 2220342 | IA01 | 2 | 128.7 | 122.0 | 5.5 |
| 6488 | 4587 | 2220342 | IA01 | 3 | 136.3 | 127.6 | 6.8 |
| 6488 | 4587 | 2220342 | IA01 | 4 | 136.0 | 125.1 | 8.7 |
| 035E | 5109 | 2225302 | IA01 | 1 | 132.9 | 126.5 | 5.1 |
| 035E | 5109 | 2225302 | IA01 | 2 | 138.1 | 129.7 | 6.5 |
| 035E | 5109 | 2225302 | IA01 | 3 | 139.5 | 128.3 | 8.7 |
| 035E | 5109 | 2225302 | IA01 | 4 | 139.1 | 126.4 | 10.1 |
| 04F8 | 5521 | 2230390 | 01 | 1 | 128.1 | 121.5 | 5.4 |
| 04F8 | 5521 | 2230390 | 01 | 2 | 136.1 | 126.7 | 7.4 |
| 04F8 | 5521 | 2230390 | 01 | 3 | 142.2 | 129.3 | 9.9 |
| 04F8 | 5521 | 2230390 | 01 | 4 | 141.1 | 127.6 | 10.6 |

**Table B-12: DOT-40 points used for compaction curves with a maximum dry unit weight between 130 pcf to 132 pcf.**

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 4084 | 910 | 1011274 | 1 | 1 | 136.8 | 127.4 | 7.4 |
| 4084 | 910 | 1011274 | 1 | 2 | 140.9 | 129.5 | 8.8 |
| 4084 | 910 | 1011274 | 1 | 3 | 143.4 | 129.9 | 10.4 |
| 4084 | 910 | 1011274 | 1 | 4 | 140.7 | 126.0 | 11.7 |
| 5636 | 911 | 1008686 | 01 | 1 | 131.6 | 124.3 | 5.9 |
| 5636 | 911 | 1008686 | 01 | 2 | 141.4 | 130.8 | 8.1 |
| 5636 | 911 | 1008686 | 01 | 3 | 144.2 | 131.9 | 9.3 |
| 5636 | 911 | 1008686 | 01 | 4 | 142.4 | 128.7 | 10.6 |
| 5823 | 967 | 1009253 | IAS01 | 1 | 136.8 | 127.4 | 7.4 |
| 5823 | 967 | 1009253 | IAS01 | 2 | 140.9 | 129.3 | 8.9 |
| 5823 | 967 | 1009253 | IAS01 | 3 | 143.5 | 130.0 | 10.4 |
| 5823 | 967 | 1009253 | IAS01 | 4 | 141.0 | 126.1 | 11.8 |
| 077N | 968 | 1020592 | 01 | 1 | 135.6 | 127.6 | 6.2 |
| 077N | 968 | 1020592 | 01 | 2 | 138.1 | 129.1 | 7.0 |
| 077N | 968 | 1020592 | 01 | 3 | 143.6 | 131.5 | 9.2 |
| 077N | 968 | 1020592 | 01 | 4 | 143.7 | 130.6 | 10.0 |
| 597M | 1004 | 1020707 | Field-01 | 1 | 129.2 | 124.7 | 3.6 |
| 597M | 1004 | 1020707 | Field-01 | 2 | 136.0 | 128.7 | 5.6 |
| 597M | 1004 | 1020707 | Field-01 | 3 | 142.6 | 132.7 | 7.5 |
| 597M | 1004 | 1020707 | Field-01 | 4 | 143.3 | 130.5 | 9.8 |
| 597M | 1004 | 1020707 | Field-01 | 5 | 142.9 | 128.2 | 11.5 |
| 4793 | 1053 | 1029175 | 01 | 1 | 133.4 | 126.1 | 5.7 |
| 4793 | 1053 | 1029175 | 01 | 2 | 139.1 | 130.0 | 7.0 |
| 4793 | 1053 | 1029175 | 01 | 3 | 142.5 | 131.1 | 8.7 |
| 4793 | 1053 | 1029175 | 01 | 4 | 141.5 | 128.8 | 9.9 |
| 5994 | 1078 | 1035175 | 01 | 1 | 130.8 | 124.5 | 5.1 |
| 5994 | 1078 | 1035175 |  | 2 | 136.4 | 128.3 | 6.4 |
| 5994 | 1078 | 1035175 | 01 | 3 | 125.0 | 120.4 | 3.8 |
| 5994 | 1078 | 1035175 |  | 4 | 141.0 | 130.7 | 7.8 |
| 5994 | 1078 | 1035175 | 01 | 5 | 142.2 | 130.0 | 9.4 |
| 5837 | 1134 | 1053354 | 02 | 1 | 128.8 | 122.3 | 5.3 |
| 5837 | 1134 | 1053354 | 02 | 2 | 138.3 | 129.1 | 7.1 |
| 5837 | 1134 | 1053354 | 02 | 3 | 143.6 | 131.3 | 9.4 |
| 5837 | 1134 | 1053354 | 02 | 4 | 142.0 | 127.6 | 11.3 |
| 5837 | 1134 | 1058909 | 03 | 1 | 126.7 | 120.5 | 5.1 |
| 5837 | 1134 | 1058909 | 03 | 2 | 133.7 | 125.1 | 6.9 |
| 5837 | 1134 | 1058909 | 03 | 3 | 141.6 | 130.4 | 8.6 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 5837 | 1134 | 1058909 | 03 | 4 | 141.5 | 127.8 | 10.7 |
| 5626 | 1162 | 1116208 | 01 | 1 | 127.3 | 120.9 | 5.3 |
| 5626 | 1162 | 1116208 | 01 | 2 | 135.2 | 127.2 | 6.3 |
| 5626 | 1162 | 1116208 | 01 | 3 | 140.9 | 130.7 | 7.8 |
| 5626 | 1162 | 1116208 | 01 | 4 | 140.1 | 127.6 | 9.8 |
| 6241 | 1200 | 1057515 | 01 | 1 | 136.2 | 128.4 | 6.1 |
| 6241 | 1200 | 1057515 | 01 | 2 | 140.6 | 130.5 | 7.8 |
| 6241 | 1200 | 1057515 | 01 | 3 | 143.0 | 131.3 | 9.0 |
| 6241 | 1200 | 1057515 | 01 | 4 | 143.3 | 129.1 | 11.0 |
| 5624 | 1222 | 1124681 | 01BC | 1 | 130.5 | 124.7 | 4.6 |
| 5624 | 1222 | 1124681 | 01BC | 2 | 137.2 | 129.1 | 6.3 |
| 5624 | 1222 | 1124681 | 01BC | 3 | 142.6 | 131.8 | 8.2 |
| 5624 | 1222 | 1124681 | 01BC | 4 | 141.0 | 128.0 | 10.2 |
| 3731 | 1352 | 1092195 | Field # 1 | 1 | 128.1 | 123.7 | 3.5 |
| 3731 | 1352 | 1092195 | Field # 1 | 2 | 136.5 | 129.1 | 5.7 |
| 3731 | 1352 | 1092195 | Field # 1 | 3 | 142.0 | 131.1 | 8.3 |
| 3731 | 1352 | 1092195 | Field # 1 | 4 | 141.7 | 128.1 | 10.6 |
| 5627 | 1363 | 1096632 | 01 | 1 | 124.6 | 119.3 | 4.5 |
| 5627 | 1363 | 1096632 | 01 | 2 | 133.6 | 125.4 | 6.5 |
| 5627 | 1363 | 1096632 | 01 | 3 | 141.4 | 130.4 | 8.4 |
| 5627 | 1363 | 1096632 | 01 | 4 | 142.5 | 130.2 | 9.5 |
| 5627 | 1363 | 1096632 | 01 | 5 | 140.5 | 126.5 | 11.1 |
| 5627 | 1363 | 1127524 | 03 | 1 | 126.1 | 120.9 | 4.3 |
| 5627 | 1363 | 1127524 | 03 | 2 | 134.5 | 126.6 | 6.2 |
| 5627 | 1363 | 1127524 | 03 | 3 | 141.2 | 130.0 | 8.6 |
| 5627 | 1363 | 1127524 | 03 | 4 | 141.3 | 128.8 | 9.7 |
| 5627 | 1363 | 1260941 | 04 | 1 | 126.7 | 121.5 | 4.2 |
| 5627 | 1363 | 1260941 | 04 | 2 | 133.7 | 126.1 | 6.0 |
| 5627 | 1363 | 1260941 | 04 | 3 | 140.9 | 130.1 | 8.3 |
| 5627 | 1363 | 1260941 | 04 | 4 | 141.2 | 128.3 | 10.1 |
| 5627 | 1363 | 1260941 | 04 | 5 | 139.5 | 126.2 | 10.5 |
| 5622 | 1404 | 1078612 | 01 | 1 | 130.1 | 123.6 | 5.3 |
| 5622 | 1404 | 1078612 | 01 | 2 | 137.0 | 128.5 | 6.6 |
| 5622 | 1404 | 1078612 | 01 | 3 | 142.2 | 130.7 | 8.8 |
| 5622 | 1404 | 1078612 | 01 | 4 | 140.2 | 127.3 | 10.1 |
| 519N | 1532 | 1131150 | 01 | 1 | 126.6 | 119.4 | 6.0 |
| 519N | 1532 | 1131150 | 01 | 2 | 137.0 | 127.6 | 7.3 |
| 519N | 1532 | 1131150 | 01 | 3 | 137.2 | 127.1 | 8.0 |
| 519N | 1532 | 1131150 | 01 | 4 | 144.3 | 131.3 | 9.9 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 519N | 1532 | 1131150 | 01 | 5 | 144.0 | 127.6 | 12.9 |
| 4824 | 1598 | 1272903 | IA01 | 1 | 134.8 | 127.1 | 6.0 |
| 4824 | 1598 | 1272903 | IA01 | 2 | 138.8 | 130.1 | 6.7 |
| 4824 | 1598 | 1272903 | IA01 | 3 | 142.3 | 131.8 | 8.0 |
| 4824 | 1598 | 1272903 | IA01 | 4 | 140.4 | 128.6 | 9.2 |
| 0370 | 1801 | 1412746 | IA01 | 1 | 124.5 | 117.9 | 5.6 |
| 0370 | 1801 | 1412746 | IA01 | 2 | 139.7 | 128.2 | 9.0 |
| 0370 | 1801 | 1412746 | IA01 | 3 | 138.1 | 125.7 | 9.8 |
| 0370 | 1801 | 1412746 | IA01 | 4 | 139.5 | 125.8 | 10.9 |
| 00FG | 1814 | 1328572 | 01 | 1 | 134.5 | 125.4 | 7.3 |
| 00FG | 1814 | 1328572 | 01 | 2 | 141.3 | 130.4 | 8.4 |
| 00FG | 1814 | 1328572 | 01 | 3 | 142.0 | 128.6 | 10.4 |
| 00FG | 1814 | 1328572 | 01 | 4 | 142.0 | 128.2 | 10.7 |
| 5992 | 1845 | 1403763 | 01 | 1 | 126.1 | 120.6 | 4.6 |
| 5992 | 1845 | 1403763 | 01 | 2 | 134.5 | 126.7 | 6.2 |
| 5992 | 1845 | 1403763 | 01 | 3 | 142.4 | 131.4 | 8.4 |
| 5992 | 1845 | 1403763 | 01 | 4 | 143.3 | 130.1 | 10.2 |
| 5992 | 1845 | 1403763 | 01 | 5 | 140.7 | 126.4 | 11.3 |
| 00S0 | 2074 | 1435861 | 02 | 1 | 133.6 | 125.7 | 6.3 |
| 00S0 | 2074 | 1435861 | 02 | 2 | 141.6 | 130.8 | 8.3 |
| 00S0 | 2074 | 1435861 | 02 | 3 | 144.1 | 131.5 | 9.6 |
| 00S0 | 2074 | 1435861 | 02 | 4 | 142.7 | 128.5 | 11.0 |
| 00S0 | 2074 | 1451148 | 01 | 1 | 139.5 | 130.9 | 6.5 |
| 00S0 | 2074 | 1451148 | 01 | 2 | 142.8 | 131.7 | 8.4 |
| 00S0 | 2074 | 1451148 | 01 | 3 | 143.9 | 131.3 | 9.5 |
| 00S0 | 2074 | 1451148 | 01 | 4 | 142.3 | 128.5 | 10.7 |
| 5632 | 2111 | 1445811 | 01 | 1 | 120.9 | 116.9 | 3.4 |
| 5632 | 2111 | 1445811 | 01 | 2 | 131.4 | 124.4 | 5.7 |
| 5632 | 2111 | 1445811 | 01 | 3 | 138.1 | 128.1 | 7.8 |
| 5632 | 2111 | 1445811 | 01 | 4 | 143.8 | 131.1 | 9.7 |
| 5632 | 2111 | 1445811 | 01 | 5 | 139.8 | 124.8 | 12.1 |
| 00KY | 2125 | 2096314 | IA01 | 1 | 130.4 | 124.6 | 4.7 |
| 00KY | 2125 | 2096314 | IA01 | 2 | 139.8 | 130.6 | 7.0 |
| 00KY | 2125 | 2096314 | IA01 | 3 | 143.3 | 132.0 | 8.6 |
| 00KY | 2125 | 2096314 | IA01 | 4 | 142.0 | 128.6 | 10.5 |
| 001D | 2135 | 1422646 | Field01 | 1 | 126.2 | 121.3 | 4.1 |
| 001D | 2135 | 1422646 | Field01 | 2 | 133.0 | 124.4 | 6.9 |
| 001D | 2135 | 1422646 | Field01 | 3 | 143.4 | 134.8 | 6.4 |
| 001D | 2135 | 1422646 | Field01 | 4 | 144.3 | 131.6 | 9.7 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 001D | 2135 | 1422646 | Field01 | 5 | 142.2 | 127.5 | 11.5 |
| 4168 | 2171 | 1463126 | 01 | 1 | 125.7 | 120.7 | 4.2 |
| 4168 | 2171 | 1463126 | 01 | 2 | 132.0 | 124.4 | 6.1 |
| 4168 | 2171 | 1463126 | 01 | 3 | 139.7 | 129.7 | 7.8 |
| 4168 | 2171 | 1463126 | 01 | 4 | 141.7 | 129.2 | 9.7 |
| 4168 | 2171 | 1463126 | 01 | 5 | 139.9 | 125.7 | 11.3 |
| 00UU | 2178 | 1445640 | IA01 | 1 | 141.5 | 131.1 | 7.9 |
| 00UU | 2178 | 1445640 | IA01 | 2 | 142.3 | 129.4 | 10.0 |
| 00UU | 2178 | 1445640 | IA01 | 3 | 146.6 | 131.6 | 11.4 |
| 00UU | 2178 | 1445640 | IA01 | 4 | 145.6 | 128.6 | 13.2 |
| 6194 | 2284 | 1483414 | 01 | 1 | 126.6 | 121.5 | 4.2 |
| 6194 | 2284 | 1483414 | 01 | 2 | 136.0 | 128.1 | 6.2 |
| 6194 | 2284 | 1483414 | 01 | 3 | 142.5 | 132.4 | 7.6 |
| 6194 | 2284 | 1483414 | 01 | 4 | 143.3 | 131.0 | 9.4 |
| 6194 | 2284 | 1483414 | 01 | 5 | 142.8 | 128.2 | 11.4 |
| 6194 | 2284 | 1483686 | 01 | 1 | 126.1 | 120.5 | 4.6 |
| 6194 | 2284 | 1483686 | 01 | 2 | 133.2 | 125.2 | 6.3 |
| 6194 | 2284 | 1483686 | 01 | 3 | 141.3 | 130.6 | 8.2 |
| 6194 | 2284 | 1483686 | 01 | 4 | 142.7 | 129.5 | 10.2 |
| 6194 | 2284 | 1483686 | 01 | 5 | 141.2 | 126.8 | 11.4 |
| 010U | 2304 | 1438089 | 01 | 1 | 123.9 | 119.0 | 4.2 |
| 010U | 2304 | 1438089 | 01 | 2 | 135.0 | 127.2 | 6.1 |
| 010U | 2304 | 1438089 | 01 | 3 | 141.7 | 131.2 | 7.9 |
| 010U | 2304 | 1438089 | 01 | 4 | 141.5 | 128.4 | 10.2 |
| H059 | 2344 | 1481286 | IA01 | 1 | 125.5 | 118.7 | 5.7 |
| H059 | 2344 | 1481286 | IA01 | 2 | 131.6 | 122.7 | 7.3 |
| H059 | 2344 | 1481286 | IA01 | 3 | 140.8 | 129.2 | 9.0 |
| H059 | 2344 | 1481286 | IA01 | 4 | 143.5 | 129.6 | 10.7 |
| H059 | 2344 | 1481286 | IA01 | 5 | 137.4 | 120.6 | 13.9 |
| 00J0 | 2414 | 1475127 | 01 | 1 | 130.6 | 124.9 | 4.5 |
| 00J0 | 2414 | 1475127 | 01 | 2 | 138.0 | 130.0 | 6.1 |
| 00J0 | 2414 | 1475127 | 01 | 3 | 143.2 | 131.4 | 9.0 |
| 00J0 | 2414 | 1475127 | 01 | 4 | 143.1 | 128.3 | 11.5 |
| 0122 | 2415 | 1467353 | IA01 | 1 | 130.4 | 123.0 | 6.0 |
| 0122 | 2415 | 1467353 | IA01 | 2 | 138.8 | 128.4 | 8.1 |
| 0122 | 2415 | 1467353 | IA01 | 3 | 143.2 | 130.6 | 9.7 |
| 0122 | 2415 | 1467353 | IA01 | 4 | 141.9 | 127.0 | 11.7 |
| 00HA | 2436 | 1469838 | 01 | 1 | 130.2 | 123.3 | 5.6 |
| 00HA | 2436 | 1469838 | 01 | 2 | 139.2 | 129.3 | 7.6 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 00HA | 2436 | 1469838 | 01 | 3 | 142.0 | 129.6 | 9.6 |
| 00HA | 2436 | 1469838 | 01 | 4 | 141.5 | 127.7 | 10.8 |
| 00RV | 2449 | 2088598 | 03 | 1 | 131.6 | 126.2 | 4.3 |
| 00RV | 2449 | 2088598 | 03 | 2 | 138.9 | 130.7 | 6.3 |
| 00RV | 2449 | 2088598 | 03 | 3 | 142.9 | 131.7 | 8.5 |
| 00RV | 2449 | 2088598 | 03 | 4 | 142.0 | 128.4 | 10.5 |
| 6564 | 2453 | 1465370 | 01 | 1 | 132.8 | 126.3 | 5.2 |
| 6564 | 2453 | 1465370 | 01 | 2 | 141.1 | 131.5 | 7.3 |
| 6564 | 2453 | 1465370 | 01 | 3 | 143.1 | 131.8 | 8.5 |
| 6564 | 2453 | 1465370 | 01 | 4 | 140.4 | 126.5 | 11.0 |
| 6922 | 2525 | 1478626 | 01 | 1 | 132.5 | 125.7 | 5.3 |
| 6922 | 2525 | 1478626 | 01 | 2 | 138.1 | 128.2 | 7.7 |
| 6922 | 2525 | 1478626 | 01 | 3 | 143.0 | 130.9 | 9.3 |
| 6922 | 2525 | 1478626 | 01 | 4 | 140.2 | 125.7 | 11.6 |
| 01AK | 2553 | 1475417 | IA02 | 1 | 129.0 | 122.4 | 5.4 |
| 01AK | 2553 | 1475417 | IA02 | 2 | 133.2 | 125.9 | 5.8 |
| 01AK | 2553 | 1475417 | IA02 | 3 | 141.5 | 131.1 | 7.9 |
| 01AK | 2553 | 1475417 | IA02 | 4 | 141.6 | 127.6 | 11.0 |
| 6962 | 2716 | 2076871 | 01 | 1 | 133.3 | 126.1 | 5.7 |
| 6962 | 2716 | 2076871 | 01 | 2 | 140.9 | 130.1 | 8.2 |
| 6962 | 2716 | 2076871 | 01 | 3 | 145.0 | 131.9 | 9.9 |
| 6962 | 2716 | 2076871 | 01 | 4 | 143.1 | 128.8 | 11.2 |
| 00XF | 2789 | 2077299 | IA01 | 1 | 128.1 | 122.2 | 4.8 |
| 00XF | 2789 | 2077299 | IA01 | 2 | 130.9 | 123.6 | 5.9 |
| 00XF | 2789 | 2077299 | IA01 | 3 | 135.9 | 126.9 | 7.1 |
| 00XF | 2789 | 2077299 | IA01 | 4 | 139.3 | 125.6 | 11.0 |
| 00XF | 2789 | 2077657 | IA02 | 1 | 132.0 | 124.6 | 6.0 |
| 00XF | 2789 | 2077657 | IA02 | 2 | 137.1 | 128.1 | 7.0 |
| 00XF | 2789 | 2077657 | IA02 | 3 | 142.1 | 131.2 | 8.3 |
| 00XF | 2789 | 2077657 | IA02 | 4 | 140.8 | 126.9 | 10.9 |
| 01T4 | 2931 | 2086285 | 01 | 1 | 128.8 | 121.3 | 6.2 |
| 01T4 | 2931 | 2086285 | 01 | 2 | 134.6 | 124.8 | 7.8 |
| 01T4 | 2931 | 2086285 | 01 | 3 | 142.7 | 130.3 | 9.5 |
| 01T4 | 2931 | 2086285 | 01 | 4 | 145.8 | 131.8 | 10.6 |
| 00FI | 2966 | 2085979 | 01 | 1 | 122.2 | 119.0 | 2.7 |
| 00FI | 2966 | 2085979 | 01 | 2 | 128.0 | 123.8 | 3.4 |
| 00FI | 2966 | 2085979 | 01 | 3 | 133.7 | 128.1 | 4.3 |
| 00FI | 2966 | 2085979 | 01 | 4 | 138.2 | 130.4 | 6.0 |
| 00D1 | 3077 | 2089430 | 01 | 1 | 128.9 | 122.2 | 5.5 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 00D1 | 3077 | 2089430 | 01 | 2 | 137.3 | 128.1 | 7.2 |
| 00D1 | 3077 | 2089430 | 01 | 3 | 142.8 | 130.2 | 9.6 |
| 00D1 | 3077 | 2089430 | 01 | 4 | 140.0 | 125.3 | 11.7 |
| 00GU | 3171 | 2103483 | 01 | 1 | 136.8 | 128.1 | 6.8 |
| 00GU | 3171 | 2103483 | 01 | 2 | 141.0 | 130.1 | 8.4 |
| 00GU | 3171 | 2103483 | 01 | 3 | 143.3 | 130.8 | 9.6 |
| 00GU | 3171 | 2103483 | 01 | 4 | 140.9 | 127.0 | 10.9 |
| 024A | 3189 | 2092510 | 02 | 1 | 130.1 | 124.9 | 4.2 |
| 024A | 3189 | 2092510 | 02 | 2 | 136.1 | 127.7 | 6.6 |
| 024A | 3189 | 2092510 | 02 | 3 | 141.8 | 131.1 | 8.2 |
| 024A | 3189 | 2092510 | 02 | 4 | 141.8 | 128.9 | 10.1 |
| 6884 | 3196 | 2108335 | 01 | 1 | 139.3 | 126.4 | 10.2 |
| 6884 | 3196 | 2108335 | 01 | 2 | 141.6 | 129.9 | 9.0 |
| 6884 | 3196 | 2108335 | 01 | 3 | 119.2 | 115.3 | 3.4 |
| 6884 | 3196 | 2108335 | 01 | 4 | 125.7 | 120.4 | 4.4 |
| 6884 | 3196 | 2108501 | 02 | 1 | 134.5 | 127.2 | 5.8 |
| 6884 | 3196 | 2108501 | 02 | 2 | 140.0 | 130.2 | 7.6 |
| 6884 | 3196 | 2108501 | 02 | 3 | 141.8 | 130.4 | 8.7 |
| 6884 | 3196 | 2108501 | 02 | 4 | 120.4 | 116.0 | 3.8 |
| 00RL | 3202 | 2100391 | 01 | 1 | 127.0 | 122.1 | 4.0 |
| 00RL | 3202 | 2100391 | 01 | 2 | 135.0 | 127.5 | 5.9 |
| 00RL | 3202 | 2100391 | 01 | 3 | 140.9 | 129.3 | 8.9 |
| 00RL | 3202 | 2100391 | 01 | 4 | 138.8 | 126.4 | 9.8 |
| 024G | 3324 | 2109472 | 01 | 1 | 125.5 | 120.8 | 3.9 |
| 024G | 3324 | 2109472 | 01 | 2 | 136.3 | 128.7 | 5.9 |
| 024G | 3324 | 2109472 | 01 | 3 | 141.4 | 131.7 | 7.4 |
| 024G | 3324 | 2109472 | 01 | 4 | 142.7 | 129.8 | 9.9 |
| 024G | 3324 | 2109472 | 01 | 5 | 142.6 | 129.1 | 10.4 |
| 02D2 | 3382 | 2105686 | 01 | 1 | 130.4 | 125.2 | 4.1 |
| 02D2 | 3382 | 2105686 | 01 | 2 | 135.7 | 127.9 | 6.1 |
| 02D2 | 3382 | 2105686 | 01 | 3 | 140.6 | 130.4 | 7.9 |
| 02D2 | 3382 | 2105686 | 01 | 4 | 140.8 | 128.3 | 9.7 |
| 02N9 | 3398 | 2113204 | 01 | 1 | 125.3 | 119.9 | 4.6 |
| 02N9 | 3398 | 2113204 | 01 | 2 | 134.3 | 126.5 | 6.1 |
| 02N9 | 3398 | 2113204 | 01 | 3 | 141.3 | 130.1 | 8.6 |
| 02N9 | 3398 | 2113204 | 01 | 4 | 141.5 | 127.4 | 11.0 |
| 02QE | 3586 | 2134142 | IA01 | 1 | 127.2 | 122.2 | 4.2 |
| 02QE | 3586 | 2134142 | IA01 | 2 | 133.6 | 126.1 | 5.9 |
| 02QE | 3586 | 2134142 | IA01 | 3 | 138.4 | 129.6 | 6.8 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 02QE | 3586 | 2134142 | IA01 | 4 | 137.1 | 126.1 | 8.7 |
| 6954 | 3609 | 2128693 | 01 | 1 | 130.5 | 124.4 | 4.9 |
| 6954 | 3609 | 2128693 | 01 | 2 | 136.6 | 128.1 | 6.7 |
| 6954 | 3609 | 2128693 | 01 | 3 | 140.9 | 130.0 | 8.4 |
| 6954 | 3609 | 2128693 | 01 | 4 | 142.6 | 129.5 | 10.1 |
| 02ZK | 3642 | 2129310 | Field01 | 1 | 124.2 | 118.7 | 4.6 |
| 02ZK | 3642 | 2129310 | Field01 | 2 | 133.7 | 126.0 | 6.1 |
| 02ZK | 3642 | 2129310 | Field01 | 3 | 140.6 | 130.1 | 8.1 |
| 02ZK | 3642 | 2129310 | Field01 | 4 | 143.5 | 131.0 | 9.6 |
| 6666 | 3780 | 2129310 | Field01 | 5 | 141.0 | 126.5 | 11.5 |
| 6666 | 3780 | 2132005 | 01 | 1 | 125.5 | 120.4 | 4.2 |
| 6666 | 3780 | 2132005 | 01 | 2 | 134.8 | 126.8 | 6.3 |
| 6666 | 3780 | 2132005 | 01 | 3 | 141.1 | 130.4 | 8.2 |
| 6666 | 3780 | 2132005 | 01 | 4 | 142.0 | 128.1 | 10.8 |
| 02SA | 3990 | 2132005 | 01 | 5 | 139.7 | 124.5 | 12.2 |
| 02SA | 3990 | 2172465 | 01 | 1 | 127.0 | 120.4 | 5.5 |
| 02SA | 3990 | 2172465 | 01 | 2 | 136.7 | 127.6 | 7.2 |
| 02SA | 3990 | 2172465 | 01 | 3 | 142.1 | 130.3 | 9.0 |
| 02SA | 3990 | 2172465 | 01 | 4 | 140.5 | 127.6 | 10.1 |
| 02Q1 | 4076 | 2177486 | 01 | 1 | 123.5 | 117.2 | 5.4 |
| 02Q1 | 4076 | 2177486 | 01 | 2 | 134.3 | 126.0 | 6.6 |
| 02Q1 | 4076 | 2177486 | 01 | 3 | 142.1 | 130.4 | 8.9 |
| 02Q1 | 4076 | 2177486 | 01 | 4 | 139.3 | 124.8 | 11.6 |
| 020A | 4078 | 2206213 | 01 | 1 | 131.8 | 124.3 | 6.0 |
| 020A | 4078 | 2206213 | 01 | 2 | 139.7 | 129.2 | 8.1 |
| 020A | 4078 | 2206213 | 01 | 3 | 142.9 | 130.1 | 9.8 |
| 020A | 4078 | 2206213 | 01 | 4 | 141.4 | 124.1 | 14.0 |
| 01DA | 4174 | 2202341 | 01 | 1 | 130.6 | 123.8 | 5.5 |
| 01DA | 4174 | 2202341 | 01 | 2 | 139.5 | 130.2 | 7.2 |
| 01DA | 4174 | 2202341 | 01 | 3 | 143.0 | 131.1 | 9.1 |
| 01DA | 4174 | 2202341 | 01 | 4 | 141.3 | 127.7 | 10.6 |
| 00K2 | 4218 | 2168559 | 01 | 1 | 129.1 | 123.5 | 4.5 |
| 00K2 | 4218 | 2168559 | 01 | 2 | 136.3 | 127.5 | 6.9 |
| 00K2 | 4218 | 2168559 | 01 | 3 | 142.0 | 131.2 | 8.3 |
| 00K2 | 4218 | 2168559 | 01 | 4 | 141.6 | 128.4 | 10.3 |
| 026V | 4225 | 2167157 | 01 | 1 | 123.2 | 118.2 | 4.2 |
| 026V | 4225 | 2167157 | 01 | 2 | 125.6 | 119.0 | 5.5 |
| 026V | 4225 | 2167157 | 01 | 3 | 133.8 | 125.2 | 6.9 |
| 026V | 4225 | 2167157 | 01 | 4 | 140.6 | 129.8 | 8.4 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 01QH | 4250 | 2167157 | 01 | 5 | 137.4 | 124.7 | 10.2 |
| 01QH | 4250 | 2175406 | 01 | 1 | 127.4 | 124.8 | 2.0 |
| 01QH | 4250 | 2175406 | 01 | 2 | 130.3 | 125.1 | 4.1 |
| 01QH | 4250 | 2175406 | 01 | 3 | 136.7 | 129.6 | 5.5 |
| 01QH | 4250 | 2175406 | 01 | 4 | 140.2 | 129.8 | 8.0 |
| 01TM | 4253 | 2175406 | 01 | 5 | 140.0 | 125.2 | 11.8 |
| 01TM | 4253 | 2172719 | 01 | 1 | 124.5 | 118.3 | 5.2 |
| 01TM | 4253 | 2172719 | 01 | 2 | 132.5 | 124.4 | 6.5 |
| 01TM | 4253 | 2172719 | 01 | 3 | 141.5 | 130.7 | 8.3 |
| 01TM | 4253 | 2172719 | 01 | 4 | 144.1 | 131.5 | 9.6 |
| 6649 | 4259 | 2172719 | 01 | 5 | 143.8 | 126.9 | 13.3 |
| 02QR | 4524 | 2192142 | 02 | 1 | 127.4 | 122.9 | 3.6 |
| 02QR | 4524 | 2192142 | 02 | 2 | 136.9 | 129.3 | 5.9 |
| 02QR | 4524 | 2192142 | 02 | 3 | 141.0 | 130.4 | 8.2 |
| 02QR | 4524 | 2192142 | 02 | 4 | 140.4 | 126.4 | 11.0 |
| 037G | 4526 | 2185997 | 01 | 1 | 123.6 | 119.1 | 3.8 |
| 037G | 4526 | 2185997 | 01 | 2 | 132.1 | 124.5 | 6.1 |
| 037G | 4526 | 2185997 | 01 | 3 | 141.0 | 130.7 | 7.9 |
| 037G | 4526 | 2185997 | 01 | 4 | 140.8 | 128.5 | 9.6 |
| 026B | 4533 | 2186206 | 02 | 1 | 128.9 | 122.9 | 4.9 |
| 026B | 4533 | 2186206 | 02 | 2 | 135.3 | 126.7 | 6.7 |
| 026B | 4533 | 2186206 | 02 | 3 | 141.5 | 130.3 | 8.6 |
| 026B | 4533 | 2186206 | 02 | 4 | 141.1 | 128.5 | 9.8 |
| 026B | 4533 | 2188332 | 01 | 1 | 131.3 | 126.3 | 4.0 |
| 026B | 4533 | 2188332 | 01 | 2 | 135.9 | 128.5 | 5.7 |
| 026B | 4533 | 2188332 | 01 | 3 | 141.7 | 131.5 | 7.8 |
| 026B | 4533 | 2188332 | 01 | 4 | 142.9 | 130.4 | 9.5 |
| 037K | 4539 | 2188332 | 01 | 5 | 140.0 | 126.1 | 11.0 |
| 037K | 4539 | 2208864 | 01 | 1 | 126.9 | 120.7 | 5.1 |
| 037K | 4539 | 2208864 | 01 | 2 | 136.1 | 127.4 | 6.8 |
| 037K | 4539 | 2208864 | 01 | 3 | 143.0 | 131.1 | 9.1 |
| 037K | 4539 | 2208864 | 01 | 4 | 142.2 | 128.6 | 10.5 |
| 00YW | 4706 | 2216947 | IA01 | 1 | 127.7 | 122.4 | 4.4 |
| 00YW | 4706 | 2216947 | IA01 | 2 | 135.1 | 127.5 | 5.9 |
| 00YW | 4706 | 2216947 | IA01 | 3 | 140.5 | 130.6 | 7.6 |
| 00YW | 4706 | 2216947 | IA01 | 4 | 139.2 | 128.0 | 8.7 |
| 04E1 | 4909 | 2214660 | IAS01 | 1 | 135.5 | 128.5 | 5.5 |
| 04E1 | 4909 | 2214660 | IAS01 | 2 | 143.0 | 131.7 | 8.6 |
| 04E1 | 4909 | 2214660 | IAS01 | 3 | 144.1 | 131.6 | 9.5 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 04E1 | 4909 | 2214660 | IAS01 | 4 | 140.5 | 125.4 | 12.0 |
| 03DL | 4986 | 2229749 | 01 | 1 | 129.5 | 122.8 | 5.5 |
| 03DL | 4986 | 2229749 | 01 | 2 | 137.3 | 128.6 | 6.7 |
| 03DL | 4986 | 2229749 | 01 | 3 | 143.5 | 131.7 | 9.0 |
| 03DL | 4986 | 2229749 | 01 | 4 | 142.2 | 128.9 | 10.3 |
| 01QS | 5127 | 2222918 | 01 | 1 | 131.4 | 124.2 | 5.8 |
| 01QS | 5127 | 2222918 | 01 | 2 | 141.0 | 131.3 | 7.4 |
| 01QS | 5127 | 2222918 | 01 | 3 | 142.7 | 130.7 | 9.2 |
| 01QS | 5127 | 2222918 | 01 | 4 | 142.5 | 128.4 | 11.0 |
| 02J1 | 5149 | 2229134 | 01 | 1 | 127.7 | 122.5 | 4.3 |
| 02J1 | 5149 | 2229134 | 01 | 2 | 139.5 | 130.8 | 6.6 |
| 02J1 | 5149 | 2229134 | 01 | 3 | 142.5 | 129.8 | 9.8 |
| 02J1 | 5149 | 2229134 | 01 | 4 | 138.8 | 123.6 | 12.3 |

**Table B-13: DOT-40 points used for compaction curves with a maximum dry unit weight between 132 pcf to 134 pcf.**

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 4795 | 888 | 1023682 | 01 4-pt | 1 | 131.9 | 124.7 | 5.8 |
| 4795 | 888 | 1023682 | 01 4-pt | 2 | 139.7 | 130.5 | 7.0 |
| 4795 | 888 | 1023682 | 01 4-pt | 3 | 143.4 | 132.2 | 8.5 |
| 4795 | 888 | 1023682 | 01 4-pt | 4 | 142.7 | 130.0 | 9.8 |
| 3834 | 743 | 1023644 | 02 | 1 | 128.4 | 125.2 | 2.6 |
| 3834 | 743 | 1023644 | 02 | 2 | 134.0 | 127.6 | 5.0 |
| 3834 | 743 | 1023644 | 02 | 3 | 140.0 | 129.2 | 8.4 |
| 3834 | 743 | 1023644 | 02 | 4 | 147.3 | 134.6 | 9.5 |
| 3834 | 743 | 1023644 | 02 | 5 | 145.5 | 131.5 | 10.6 |
| 5856 | 1152 | 1039482 | 02 | 1 | 131.6 | 124.4 | 5.8 |
| 5856 | 1152 | 1039482 | 02 | 2 | 139.4 | 130.3 | 7.0 |
| 5856 | 1152 | 1039482 | 02 | 3 | 143.3 | 132.0 | 8.5 |
| 5856 | 1152 | 1039482 | 02 | 4 | 142.5 | 129.8 | 9.8 |
| 5854 | 1169 | 1038931 | 01 | 1 | 132.8 | 125.7 | 5.6 |
| 5854 | 1169 | 1038931 | 01 | 2 | 141.6 | 131.6 | 7.6 |
| 5854 | 1169 | 1038931 | 01 | 3 | 143.7 | 131.6 | 9.2 |
| 5854 | 1169 | 1038931 | 01 | 4 | 142.2 | 128.0 | 11.1 |
| 6280 | 1475 | 1116123 | 01 | 1 | 140.9 | 130.9 | 7.6 |
| 6280 | 1475 | 1116123 | 01 | 2 | 144.2 | 132.0 | 9.3 |
| 6280 | 1475 | 1116123 | 01 | 3 | 143.6 | 129.8 | 10.6 |
| 6280 | 1475 | 1116123 | 01 | 4 | 134.6 | 126.7 | 6.3 |
| 6974 | 2025 | 1460282 | 01 | 1 | 134.5 | 127.0 | 5.9 |
| 6974 | 2025 | 1460282 | 01 | 2 | 142.5 | 132.3 | 7.7 |
| 6974 | 2025 | 1460282 | 01 | 3 | 142.9 | 129.9 | 10.0 |
| 6974 | 2025 | 1460282 | 01 | 4 | 141.4 | 127.2 | 11.2 |
| 6463 | 2351 | 2067606 | Field01 | 1 | 129.7 | 122.1 | 6.2 |
| 6463 | 2351 | 2067606 | Field01 | 2 | 140.7 | 130.4 | 7.9 |
| 6463 | 2351 | 2067606 | Field01 | 3 | 145.0 | 131.0 | 10.7 |
| 6463 | 2351 | 2067606 | Field01 | 4 | 139.9 | 123.6 | 13.2 |
| 00GU | 3171 | 2104269 | 02 | 1 | 124.2 | 120.2 | 3.3 |
| 00GU | 3171 | 2104269 | 02 | 2 | 134.5 | 128.1 | 5.0 |
| 00GU | 3171 | 2104269 | 02 | 3 | 142.0 | 132.4 | 7.3 |
| 00GU | 3171 | 2104269 | 02 | 4 | 143.4 | 131.0 | 9.5 |
| 00GU | 3171 | 2104269 | 02 | 5 | 140.9 | 125.0 | 12.8 |
| 02K8 | 3305 | 2088198 | 01 | 1 | 126.2 | 122.0 | 3.5 |
| 02K8 | 3305 | 2088198 | 01 | 2 | 135.4 | 127.8 | 6.0 |
| 02K8 | 3305 | 2088198 | 01 | 3 | 140.5 | 130.8 | 7.4 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 02K8 | 3305 | 2088198 | 01 | 4 | 144.8 | 132.1 | 9.6 |
| 02K8 | 3305 | 2088198 | 01 | 5 | 143.0 | 127.1 | 12.5 |
| 002B | 3537 | 2131461 | 01 | 1 | 127.5 | 122.5 | 4.1 |
| 002B | 3537 | 2131461 | 01 | 2 | 134.8 | 127.9 | 5.3 |
| 002B | 3537 | 2131461 | 01 | 3 | 142.4 | 132.4 | 7.6 |
| 002B | 3537 | 2131461 | 01 | 4 | 142.6 | 131.2 | 8.6 |
| 0371 | 3758 | 2126795 | 01 | 1 | 133.2 | 127.5 | 4.5 |
| 0371 | 3758 | 2126795 | 01 | 2 | 139.7 | 130.8 | 6.8 |
| 0371 | 3758 | 2126795 | 01 | 3 | 143.6 | 132.0 | 8.8 |
| 0371 | 3758 | 2126795 | 01 | 4 | 141.1 | 127.4 | 10.7 |
| 0254 | 3772 | 2135461 | 03 | 1 | 131.3 | 125.1 | 5.0 |
| 0254 | 3772 | 2135461 | 03 | 2 | 141.1 | 131.6 | 7.2 |
| 0254 | 3772 | 2135461 | 03 | 3 | 142.5 | 131.3 | 8.5 |
| 0254 | 3772 | 2135461 | 03 | 4 | 138.8 | 130.2 | 6.6 |
| 025X | 4224 | 2160444 | 02 | 1 | 131.9 | 126.7 | 4.1 |
| 025X | 4224 | 2160444 | 02 | 2 | 136.3 | 128.5 | 6.0 |
| 025X | 4224 | 2160444 | 02 | 3 | 142.8 | 132.4 | 7.9 |
| 025X | 4224 | 2160444 | 02 | 4 | 144.4 | 131.5 | 9.8 |
| 025X | 4224 | 2160444 | 02 | 5 | 144.7 | 129.7 | 11.5 |
| 040K | 4569 | 2190688 | 01 | 1 | 127.2 | 121.1 | 5.1 |
| 040K | 4569 | 2190688 | 01 | 2 | 136.7 | 128.8 | 6.1 |
| 040K | 4569 | 2190688 | 01 | 3 | 141.7 | 130.3 | 8.8 |
| 040K | 4569 | 2190688 | 01 | 4 | 139.8 | 126.4 | 10.6 |
| 03C6 | 4724 | 2186339 | 01 | 1 | 134.7 | 126.7 | 6.4 |
| 03C6 | 4724 | 2186339 | 01 | 2 | 138.1 | 128.9 | 7.1 |
| 03C6 | 4724 | 2186339 | 01 | 3 | 144.6 | 132.2 | 9.4 |
| 03C6 | 4724 | 2186339 | 01 | 4 | 143.9 | 129.9 | 10.8 |
| 038E | 4829 | 2207613 | IA01 | 1 | 123.1 | 118.4 | 3.9 |
| 038E | 4829 | 2207613 | IA01 | 2 | 134.7 | 127.7 | 5.5 |
| 038E | 4829 | 2207613 | IA01 | 3 | 142.1 | 132.8 | 7.1 |
| 038E | 4829 | 2207613 | IA01 | 4 | 141.9 | 130.4 | 8.8 |
| 038E | 4829 | 2207613 | IA01 | 5 | 139.9 | 126.8 | 10.3 |
| B015 | 5024 | 2204758 | 01 | 1 | 130.5 | 124.6 | 4.8 |
| B015 | 5024 | 2204758 | 01 | 2 | 136.9 | 129.4 | 5.8 |
| B015 | 5024 | 2204758 | 01 | 3 | 142.1 | 132.4 | 7.3 |
| B015 | 5024 | 2204758 | 01 | 4 | 141.4 | 130.1 | 8.7 |
| B015 | 5024 | 2204758 | 01 | 5 | 138.6 | 126.4 | 9.7 |
| I3R3 | 5182 | 2220021 | 01 | 1 | 127.3 | 121.1 | 5.1 |
| I3R3 | 5182 | 2220021 | 01 | 2 | 139.7 | 130.3 | 7.2 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| I3R3 | 5182 | 2220021 | 01 | 3 | 144.2 | 132.1 | 9.2 |
| I3R3 | 5182 | 2220021 | 01 | 4 | 144.1 | 130.6 | 10.3 |
| 675R | 914 | 1068200 | 01 | 1 | 129.3 | 122.9 | 5.2 |
| 675R | 914 | 1068200 | 01 | 2 | 138.0 | 129.0 | 7.0 |
| 675R | 914 | 1068200 | 01 | 3 | 143.6 | 132.4 | 8.4 |
| 675R | 914 | 1068200 | 01 | 4 | 143.2 | 129.7 | 10.5 |
| 4185 | 925 | 1012188 | 01 | 1 | 128.8 | 122.1 | 5.4 |
| 4185 | 925 | 1012188 | 01 | 2 | 138.8 | 129.2 | 7.4 |
| 4185 | 925 | 1012188 | 01 | 3 | 145.3 | 132.7 | 9.5 |
| 4185 | 925 | 1012188 | 01 | 4 | 144.6 | 129.5 | 11.7 |
| 3913 | 1093 | 1049793 | 02 | 1 | 125.9 | 123.2 | 2.2 |
| 3913 | 1093 | 1049793 | 02 | 2 | 130.2 | 125.2 | 4.0 |
| 3913 | 1093 | 1049793 | 02 | 3 | 136.4 | 129.3 | 5.6 |
| 3913 | 1093 | 1049793 | 02 | 4 | 143.1 | 133.1 | 7.5 |
| 3913 | 1093 | 1049793 | 02 | 5 | 144.8 | 132.4 | 9.4 |
| 5837 | 1134 | 1035951 | 01 | 1 | 128.1 | 121.8 | 5.2 |
| 5837 | 1134 | 1035951 | 01 | 2 | 139.5 | 130.4 | 7.0 |
| 5837 | 1134 | 1035951 | 01 | 3 | 144.3 | 132.1 | 9.2 |
| 5837 | 1134 | 1035951 | 01 | 4 | 142.1 | 128.9 | 10.2 |
| X101 | 1154 | 1070477 | 01 | 1 | 123.1 | 119.8 | 2.8 |
| X101 | 1154 | 1070477 | 01 | 2 | 131.0 | 125.7 | 4.2 |
| X101 | 1154 | 1070477 | 01 | 3 | 139.5 | 132.0 | 5.7 |
| X101 | 1154 | 1070477 | 01 | 4 | 141.9 | 132.6 | 7.0 |
| X101 | 1154 | 1070477 | 01 | 5 | 141.8 | 131.1 | 8.1 |
| 5822 | 1163 | 1056626 | 01 | 1 | 137.6 | 129.0 | 6.7 |
| 5822 | 1163 | 1056626 | 01 | 2 | 142.9 | 131.9 | 8.3 |
| 5822 | 1163 | 1056626 | 01 | 3 | 144.6 | 132.7 | 9.0 |
| 5822 | 1163 | 1056626 | 01 | 4 | 142.7 | 129.4 | 10.3 |
| 5854 | 1169 | 1052107 | 03 | 1 | 133.8 | 128.2 | 4.4 |
| 5854 | 1169 | 1052107 | 03 | 2 | 140.9 | 132.2 | 6.6 |
| 5854 | 1169 | 1052107 | 03 | 3 | 143.8 | 133.5 | 7.8 |
| 5854 | 1169 | 1052107 | 03 | 4 | 141.6 | 128.6 | 10.1 |
| 6198 | 1198 | 1077420 | IA01 | 1 | 143.4 | 128.9 | 11.2 |
| 6198 | 1198 | 1077420 | IA01 | 2 | 142.7 | 131.9 | 8.2 |
| 6198 | 1198 | 1077420 | IA01 | 3 | 130.8 | 123.4 | 6.1 |
| 6198 | 1198 | 1077420 | IA01 | 4 | 145.4 | 132.1 | 10.0 |
| 4876 | 1251 | 1058780 | 001 | 1 | 135.7 | 130.5 | 4.0 |
| 4876 | 1251 | 1058780 | 001 | 2 | 141.4 | 133.2 | 6.2 |
| 4876 | 1251 | 1058780 | 001 | 3 | 143.4 | 132.5 | 8.2 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 4876 | 1251 | 1058780 | 001 | 4 | 143.7 | 131.2 | 9.6 |
| 5855 | 1354 | 1073996 | 01 | 1 | 128.0 | 122.6 | 4.3 |
| 5855 | 1354 | 1073996 | 01 | 2 | 136.1 | 127.9 | 6.4 |
| 5855 | 1354 | 1073996 | 01 | 3 | 143.6 | 132.6 | 8.3 |
| 5855 | 1354 | 1073996 | 01 | 4 | 142.9 | 129.0 | 10.8 |
| 5855 | 1354 | 1079252 | 02 | 1 | 131.3 | 125.7 | 4.5 |
| 5855 | 1354 | 1079252 | 02 | 2 | 139.8 | 131.5 | 6.3 |
| 5855 | 1354 | 1079252 | 02 | 3 | 144.1 | 132.6 | 8.7 |
| 5855 | 1354 | 1079252 | 02 | 4 | 143.8 | 130.5 | 10.2 |
| 6681 | 1406 | 1078961 | ia01 | 1 | 141.3 | 132.9 | 6.3 |
| 6681 | 1406 | 1078961 | ia01 | 2 | 142.5 | 132.5 | 7.5 |
| 6681 | 1406 | 1078961 | ia01 | 3 | 145.7 | 132.6 | 9.9 |
| 6681 | 1406 | 1078961 | ia01 | 4 | 145.3 | 130.9 | 11.0 |
| 6681 | 1406 | 1078961 | ia01 | 5 | 136.5 | 130.6 | 4.5 |
| 568N | 1549 | 1128196 | 01 | 1 | 131.1 | 127.3 | 3.0 |
| 568N | 1549 | 1128196 | 01 | 2 | 138.6 | 132.3 | 4.8 |
| 568N | 1549 | 1128196 | 01 | 3 | 141.8 | 133.1 | 6.5 |
| 568N | 1549 | 1128196 | 01 | 4 | 143.7 | 133.2 | 7.9 |
| 5899 | 1595 | 1260328 | 01 | 1 | 130.5 | 125.9 | 3.7 |
| 5899 | 1595 | 1260328 | 01 | 2 | 138.3 | 130.5 | 5.9 |
| 5899 | 1595 | 1260328 | 01 | 3 | 143.2 | 133.0 | 7.6 |
| 5899 | 1595 | 1260328 | 01 | 4 | 143.9 | 131.9 | 9.0 |
| 5899 | 1595 | 1260328 | 01 | 5 | 142.9 | 129.3 | 10.5 |
| 4699 | 1614 | 1301527 | 01 | 1 | 131.0 | 124.4 | 5.3 |
| 4699 | 1614 | 1301527 | 01 | 2 | 140.9 | 130.7 | 7.8 |
| 4699 | 1614 | 1301527 | 01 | 3 | 146.0 | 133.7 | 9.2 |
| 4699 | 1614 | 1301527 | 01 | 4 | 145.7 | 131.7 | 10.6 |
| 5960 | 1662 | 1294521 | Field01 | 1 | 124.6 | 121.0 | 3.0 |
| 5960 | 1662 | 1294521 | Field01 | 2 | 134.9 | 128.6 | 4.9 |
| 5960 | 1662 | 1294521 | Field01 | 3 | 144.1 | 134.8 | 6.9 |
| 5960 | 1662 | 1294521 | Field01 | 4 | 142.9 | 131.4 | 8.7 |
| 6689 | 1666 | 1259765 | 02 | 1 | 132.3 | 125.9 | 5.1 |
| 6689 | 1666 | 1259765 | 02 | 2 | 141.8 | 132.5 | 7.0 |
| 6689 | 1666 | 1259765 | 02 | 3 | 145.7 | 133.9 | 8.9 |
| 6689 | 1666 | 1259765 | 02 | 4 | 144.5 | 131.5 | 9.9 |
| 5631 | 1684 | 1260403 | 01 | 1 | 123.0 | 116.4 | 5.7 |
| 5631 | 1684 | 1260403 | 01 | 2 | 131.2 | 122.0 | 7.5 |
| 5631 | 1684 | 1260403 | 01 | 3 | 143.9 | 132.0 | 9.0 |
| 5631 | 1684 | 1260403 | 01 | 4 | 141.5 | 127.7 | 10.8 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 6452 | 1714 | 1296891 | 01 | 1 | 129.6 | 122.9 | 5.5 |
| 6452 | 1714 | 1296891 | 01 | 2 | 138.5 | 129.2 | 7.2 |
| 6452 | 1714 | 1296891 | 01 | 3 | 144.9 | 132.8 | 9.1 |
| 6452 | 1714 | 1296891 | 01 | 4 | 142.6 | 128.3 | 11.2 |
| 6937 | 1779 | 1404335 | 01 | 1 | 133.2 | 126.6 | 5.2 |
| 6937 | 1779 | 1404335 | 01 | 2 | 140.8 | 131.8 | 6.8 |
| 6937 | 1779 | 1404335 | 01 | 3 | 144.8 | 133.1 | 8.8 |
| 6937 | 1779 | 1404335 | 01 | 4 | 142.2 | 128.3 | 10.8 |
| 6176 | 1924 | 1423003 | 01 | 1 | 135.6 | 128.2 | 5.8 |
| 6176 | 1924 | 1423003 | 01 | 2 | 143.7 | 133.7 | 7.5 |
| 6176 | 1924 | 1423003 | 01 | 3 | 143.7 | 131.4 | 9.4 |
| 6176 | 1924 | 1423003 | 01 | 4 | 142.2 | 127.9 | 11.2 |
| 4319 | 1952 | 1460688 | 01 | 1 | 128.9 | 123.0 | 4.8 |
| 4319 | 1952 | 1460688 | 01 | 2 | 134.7 | 127.1 | 6.0 |
| 4319 | 1952 | 1460688 | 01 | 3 | 142.1 | 132.1 | 7.6 |
| 4319 | 1952 | 1460688 | 01 | 4 | 142.9 | 129.0 | 10.8 |
| 6690 | 1954 | 1431648 | 01 | 1 | 132.8 | 126.9 | 4.7 |
| 6690 | 1954 | 1431648 | 01 | 2 | 143.8 | 132.6 | 8.4 |
| 6690 | 1954 | 1431648 | 01 | 3 | 146.0 | 133.2 | 9.7 |
| 6690 | 1954 | 1431648 | 01 | 4 | 147.4 | 133.3 | 10.5 |
| 6690 | 1954 | 1431648 | 01 | 5 | 147.1 | 130.1 | 13.1 |
| I0EY | 2054 | 1430604 | 01 | 1 | 136.6 | 130.1 | 5.0 |
| I0EY | 2054 | 1430604 | 01 | 2 | 143.0 | 133.7 | 7.0 |
| I0EY | 2054 | 1430604 | 01 | 3 | 142.1 | 130.0 | 9.3 |
| I0EY | 2054 | 1430604 | 01 | 4 | 123.2 | 119.3 | 3.3 |
| 6563 | 2101 | 1416575 | 01 | 1 | 132.7 | 125.6 | 5.6 |
| 6563 | 2101 | 1416575 | 01 | 2 | 142.3 | 132.2 | 7.6 |
| 6563 | 2101 | 1416575 | 01 | 3 | 144.7 | 132.1 | 9.5 |
| 6563 | 2101 | 1416575 | 01 | 4 | 141.7 | 126.3 | 12.2 |
| 00U8 | 2122 | 1480874 | 01 | 1 | 126.4 | 121.7 | 3.9 |
| 00U8 | 2122 | 1480874 | 01 | 2 | 136.2 | 130.2 | 4.7 |
| 00U8 | 2122 | 1480874 | 01 | 3 | 142.2 | 133.1 | 6.8 |
| 00U8 | 2122 | 1480874 | 01 | 4 | 143.4 | 133.2 | 7.6 |
| 6324 | 2235 | 2077273 | IA01 | 1 | 124.7 | 119.4 | 4.5 |
| 6324 | 2235 | 2077273 | IA01 | 2 | 140.7 | 132.1 | 6.5 |
| 6324 | 2235 | 2077273 | IA01 | 3 | 142.4 | 132.9 | 7.2 |
| 6324 | 2235 | 2077273 | IA01 | 4 | 141.1 | 129.5 | 8.9 |
| 011J | 2241 | 1413652 | 01 | 1 | 133.0 | 125.9 | 5.6 |
| 011J | 2241 | 1413652 | 01 | 2 | 143.6 | 132.8 | 8.1 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 011J | 2241 | 1413652 | 01 | 3 | 146.5 | 133.7 | 9.5 |
| 011J | 2241 | 1413652 | 01 | 4 | 142.4 | 128.3 | 11.0 |
| 5319 | 2360 | 2213226 | 01 | 1 | 129.9 | 123.7 | 5.0 |
| 5319 | 2360 | 2213226 | 01 | 2 | 138.3 | 129.6 | 6.8 |
| 5319 | 2360 | 2213226 | 01 | 3 | 143.8 | 132.8 | 8.3 |
| 5319 | 2360 | 2213226 | 01 | 4 | 142.2 | 129.4 | 9.9 |
| 00YD | 2375 | 1430142 | Field01 | 1 | 131.1 | 124.5 | 5.3 |
| 00YD | 2375 | 1430142 | Field01 | 2 | 143.0 | 132.8 | 7.7 |
| 00YD | 2375 | 1430142 | Field01 | 3 | 145.3 | 132.7 | 9.5 |
| 00YD | 2375 | 1430142 | Field01 | 4 | 141.5 | 126.7 | 11.7 |
| 4460 | 2416 | 1480106 | 04 | 1 | 130.7 | 124.4 | 5.1 |
| 4460 | 2416 | 1480106 | 04 | 2 | 133.4 | 125.7 | 6.2 |
| 4460 | 2416 | 1480106 | 04 | 3 | 140.7 | 130.9 | 7.5 |
| 4460 | 2416 | 1480106 | 04 | 4 | 144.7 | 132.9 | 8.9 |
| 5649 | 2427 | 1476517 | Field # 01 | 1 | 125.9 | 120.5 | 4.5 |
| 5649 | 2427 | 1476517 | Field # 01 | 2 | 136.5 | 127.7 | 6.9 |
| 5649 | 2427 | 1476517 | Field # 01 | 3 | 143.8 | 132.3 | 8.7 |
| 5649 | 2427 | 1476517 | Field # 01 | 4 | 140.5 | 125.9 | 11.6 |
| 1976 | 2437 | 2111893 | 01 | 1 | 126.9 | 121.1 | 4.7 |
| 1976 | 2437 | 2111893 | 01 | 2 | 137.3 | 129.1 | 6.3 |
| 1976 | 2437 | 2111893 | 01 | 3 | 143.8 | 133.3 | 7.9 |
| 1976 | 2437 | 2111893 | 01 | 4 | 143.0 | 129.7 | 10.3 |
| 00RW | 2558 | 2137920 | 02 | 1 | 132.4 | 126.9 | 4.4 |
| 00RW | 2558 | 2137920 | 02 | 2 | 138.9 | 131.1 | 5.9 |
| 00RW | 2558 | 2137920 | 02 | 3 | 143.2 | 132.2 | 8.3 |
| 00RW | 2558 | 2137920 | 02 | 4 | 142.3 | 128.7 | 10.5 |
| H060 | 2608 | 1482211 | 01 | 1 | 130.1 | 122.5 | 6.2 |
| H060 | 2608 | 1482211 | 01 | 2 | 141.1 | 131.0 | 7.7 |
| H060 | 2608 | 1482211 | 01 | 3 | 144.3 | 130.6 | 10.5 |
| H060 | 2608 | 1482211 | 01 | 4 | 140.6 | 124.5 | 12.9 |
| 6716 | 2633 | 2070709 | 01 | 1 | 134.8 | 128.6 | 4.9 |
| 6716 | 2633 | 2070709 | 01 | 2 | 143.4 | 133.5 | 7.4 |
| 6716 | 2633 | 2070709 | 01 | 3 | 143.5 | 131.4 | 9.3 |
| 6716 | 2633 | 2070709 | 01 | 4 | 138.8 | 125.4 | 10.7 |
| 6962 | 2716 | 2080667 | 02 | 1 | 125.1 | 121.1 | 3.3 |
| 6962 | 2716 | 2080667 | 02 | 2 | 135.3 | 128.5 | 5.3 |
| 6962 | 2716 | 2080667 | 02 | 3 | 143.5 | 133.7 | 7.3 |
| 6962 | 2716 | 2080667 | 02 | 4 | 143.1 | 131.3 | 9.0 |
| 00X4 | 2804 | 2097623 | 01 | 1 | 121.4 | 118.3 | 2.6 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 00X4 | 2804 | 2097623 | 01 | 2 | 129.8 | 124.4 | 4.3 |
| 00X4 | 2804 | 2097623 | 01 | 3 | 136.3 | 129.1 | 5.6 |
| 00X4 | 2804 | 2097623 | 01 | 4 | 142.1 | 132.8 | 7.0 |
| 00X4 | 2804 | 2097623 | 01 | 5 | 141.7 | 130.7 | 8.5 |
| 01X1 | 2876 | 1483150 | 01 | 1 | 130.6 | 124.9 | 4.6 |
| 01X1 | 2876 | 1483150 | 01 | 2 | 138.9 | 130.4 | 6.5 |
| 01X1 | 2876 | 1483150 | 01 | 3 | 143.9 | 133.4 | 7.8 |
| 01X1 | 2876 | 1483150 | 01 | 4 | 143.7 | 131.0 | 9.7 |
| 01T2 | 2953 | 2083162 | 01 | 1 | 132.0 | 125.6 | 5.1 |
| 01T2 | 2953 | 2083162 | 01 | 2 | 142.8 | 132.9 | 7.5 |
| 01T2 | 2953 | 2083162 | 01 | 3 | 144.5 | 133.6 | 8.2 |
| 01T2 | 2953 | 2083162 | 01 | 4 | 141.2 | 128.1 | 10.2 |
| 00FI | 2966 | 2085782 | 01 | 1 | 134.7 | 130.1 | 3.6 |
| 00FI | 2966 | 2085782 | 01 | 2 | 140.1 | 132.9 | 5.4 |
| 00FI | 2966 | 2085782 | 01 | 3 | 142.8 | 134.0 | 6.6 |
| 00FI | 2966 | 2085782 | 01 | 4 | 127.1 | 123.6 | 2.8 |
| 024A | 3189 | 2092501 | 01 | 1 | 128.8 | 123.5 | 4.2 |
| 024A | 3189 | 2092501 | 01 | 2 | 136.1 | 128.2 | 6.1 |
| 024A | 3189 | 2092501 | 01 | 3 | 143.2 | 132.5 | 8.0 |
| 024A | 3189 | 2092501 | 01 | 4 | 141.7 | 128.9 | 9.9 |
| 02FW | 3280 | 2087013 | Field01 | 1 | 127.8 | 123.7 | 3.3 |
| 02FW | 3280 | 2087013 | Field01 | 2 | 136.5 | 129.7 | 5.3 |
| 02FW | 3280 | 2087013 | Field01 | 3 | 140.9 | 131.0 | 7.5 |
| 02FW | 3280 | 2087013 | Field01 | 4 | 145.3 | 134.1 | 8.4 |
| 02FW | 3280 | 2087013 | Field01 | 5 | 142.6 | 128.0 | 11.4 |
| 6559 | 3373 | 2108751 | 01 | 1 | 131.3 | 125.4 | 4.7 |
| 6559 | 3373 | 2108751 | 01 | 2 | 139.6 | 130.8 | 6.7 |
| 6559 | 3373 | 2108751 | 01 | 3 | 145.3 | 133.8 | 8.6 |
| 6559 | 3373 | 2108751 | 01 | 4 | 141.7 | 128.0 | 10.8 |
| 01X8 | 3560 | 2108581 | Field # 1 | 1 | 135.7 | 127.4 | 6.5 |
| 01X8 | 3560 | 2108581 | Field # 1 | 2 | 143.5 | 132.9 | 8.0 |
| 01X8 | 3560 | 2108581 | Field # 1 | 3 | 144.9 | 130.8 | 10.8 |
| 01X8 | 3560 | 2108581 | Field # 1 | 4 | 143.5 | 128.2 | 12.0 |
| 02P2 | 3597 | 2132715 | 01 | 1 | 132.5 | 126.3 | 4.9 |
| 02P2 | 3597 | 2132715 | 01 | 2 | 141.3 | 131.8 | 7.2 |
| 02P2 | 3597 | 2132715 | 01 | 3 | 144.6 | 133.0 | 8.7 |
| 02P2 | 3597 | 2132715 | 01 | 4 | 141.7 | 128.6 | 10.1 |
| 01T6 | 3662 | 2136529 | 02 | 1 | 131.1 | 126.3 | 3.8 |
| 01T6 | 3662 | 2136529 | 02 | 2 | 138.7 | 131.1 | 5.8 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 01T6 | 3662 | 2136529 | 02 | 3 | 144.4 | 133.9 | 7.8 |
| 01T6 | 3662 | 2136529 | 02 | 4 | 142.9 | 130.2 | 9.8 |
| 03BE | 3765 | 2125872 | 01 | 1 | 133.1 | 127.6 | 4.3 |
| 03BE | 3765 | 2125872 | 01 | 2 | 138.7 | 130.2 | 6.5 |
| 03BE | 3765 | 2125872 | 01 | 3 | 143.9 | 132.7 | 8.4 |
| 03BE | 3765 | 2125872 | 01 | 4 | 142.7 | 129.5 | 10.2 |
| 03BP | 3774 | 2129296 | 03 | 1 | 134.8 | 129.8 | 3.8 |
| 03BP | 3774 | 2129296 | 03 | 2 | 140.9 | 133.4 | 5.6 |
| 03BP | 3774 | 2129296 | 03 | 3 | 143.7 | 133.4 | 7.7 |
| 03BP | 3774 | 2129296 | 03 | 4 | 142.7 | 130.1 | 9.7 |
| I2BQ | 3796 | 2116158 | 01 | 1 | 129.5 | 124.2 | 4.2 |
| I2BQ | 3796 | 2116158 | 01 | 2 | 137.5 | 129.5 | 6.2 |
| I2BQ | 3796 | 2116158 | 01 | 3 | 143.5 | 133.3 | 7.6 |
| I2BQ | 3796 | 2116158 | 01 | 4 | 142.9 | 131.1 | 9.0 |
| 3106 | 3826 | 2134143 | 01 | 1 | 126.4 | 121.5 | 4.0 |
| 3106 | 3826 | 2134143 | 01 | 2 | 129.9 | 123.8 | 5.0 |
| 3106 | 3826 | 2134143 | 01 | 3 | 137.9 | 129.1 | 6.8 |
| 3106 | 3826 | 2134143 | 01 | 4 | 141.2 | 126.9 | 11.3 |
| 00CP | 3879 | 2150910 | 01 | 1 | 131.7 | 125.3 | 5.1 |
| 00CP | 3879 | 2150910 | 01 | 2 | 143.5 | 133.4 | 7.6 |
| 00CP | 3879 | 2150910 | 01 | 3 | 144.6 | 132.1 | 9.5 |
| 00CP | 3879 | 2150910 | 01 | 4 | 144.5 | 129.0 | 12.0 |
| 01R5 | 3896 | 2169747 | IA01 | 1 | 137.3 | 130.4 | 5.3 |
| 01R5 | 3896 | 2169747 | IA01 | 2 | 142.6 | 133.2 | 7.1 |
| 01R5 | 3896 | 2169747 | IA01 | 3 | 144.4 | 132.3 | 9.1 |
| 01R5 | 3896 | 2169747 | IA01 | 4 | 138.6 | 125.1 | 10.8 |
| 03HK | 3938 | 2159117 | 03 | 1 | 130.9 | 125.3 | 4.5 |
| 03HK | 3938 | 2159117 | 03 | 2 | 137.8 | 130.2 | 5.9 |
| 03HK | 3938 | 2159117 | 03 | 3 | 144.0 | 133.5 | 7.9 |
| 03HK | 3938 | 2159117 | 03 | 4 | 139.3 | 124.2 | 12.2 |
| 01FG | 3973 | 2139352 | Field # 01 | 1 | 128.9 | 122.8 | 4.9 |
| 01FG | 3973 | 2139352 | Field # 01 | 2 | 139.0 | 129.9 | 7.0 |
| 01FG | 3973 | 2139352 | Field # 01 | 3 | 144.5 | 132.7 | 8.9 |
| 01FG | 3973 | 2139352 | Field # 01 | 4 | 144.3 | 130.6 | 10.5 |
| 02DC | 4029 | 2139994 | 01 | 1 | 135.3 | 128.5 | 5.3 |
| 02DC | 4029 | 2139994 | 01 | 2 | 140.8 | 132.0 | 6.7 |
| 02DC | 4029 | 2139994 | 01 | 3 | 141.9 | 129.6 | 9.4 |
| 02DC | 4029 | 2139994 | 01 | 4 | 122.5 | 121.7 | 0.7 |
| 042Q | 4969 | 2207958 | 01 | 1 | 129.3 | 124.4 | 4.0 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 042Q | 4969 | 2207958 | 01 | 2 | 138.3 | 130.5 | 5.9 |
| 042Q | 4969 | 2207958 | 01 | 3 | 144.0 | 133.9 | 7.6 |
| 042Q | 4969 | 2207958 | 01 | 4 | 141.6 | 129.1 | 9.7 |
| 035U | 4839 | 2206302 | 01 | 1 | 130.9 | 125.7 | 4.2 |
| 035U | 4839 | 2206302 | 01 | 2 | 136.9 | 129.3 | 5.9 |
| 035U | 4839 | 2206302 | 01 | 3 | 142.7 | 132.7 | 7.5 |
| 035U | 4839 | 2206302 | 01 | 4 | 142.0 | 129.7 | 9.5 |
| 04PQ | 4669 | 2205312 | IA01 | 1 | 127.5 | 122.9 | 3.7 |
| 04PQ | 4669 | 2205312 | IA01 | 2 | 133.1 | 126.3 | 5.4 |
| 04PQ | 4669 | 2205312 | IA01 | 3 | 139.6 | 130.8 | 6.7 |
| 04PQ | 4669 | 2205312 | IA01 | 4 | 142.8 | 133.1 | 7.3 |
| 04PQ | 4669 | 2205312 | IA01 | 5 | 131.2 | 119.8 | 9.5 |
| 020K | 4681 | 2210177 | IA01 | 1 | 128.4 | 123.2 | 4.2 |
| 020K | 4681 | 2210177 | IA01 | 2 | 137.7 | 130.7 | 5.4 |
| 020K | 4681 | 2210177 | IA01 | 3 | 142.3 | 133.0 | 7.0 |
| 020K | 4681 | 2210177 | IA01 | 4 | 142.0 | 131.4 | 8.0 |
| 02Q1 | 4076 | 2173817 | 03 | 1 | 136.3 | 128.6 | 6.0 |
| 02Q1 | 4076 | 2173817 | 03 | 2 | 144.1 | 133.4 | 8.0 |
| 02Q1 | 4076 | 2173817 | 03 | 3 | 144.2 | 131.5 | 9.7 |
| 02Q1 | 4076 | 2173817 | 03 | 4 | 141.0 | 126.5 | 11.5 |
| 03JD | 4103 | 2154415 | 01 | 1 | 131.6 | 125.1 | 5.2 |
| 03JD | 4103 | 2154415 | 01 | 2 | 141.5 | 132.0 | 7.2 |
| 03JD | 4103 | 2154415 | 01 | 3 | 144.3 | 132.9 | 8.5 |
| 03JD | 4103 | 2154415 | 01 | 4 | 140.3 | 126.5 | 10.8 |
| 022X | 4178 | 2178179 | IA01 | 1 | 135.8 | 130.7 | 3.9 |
| 022X | 4178 | 2178179 | IA01 | 2 | 136.9 | 125.5 | 9.1 |
| 022X | 4178 | 2178179 | IA01 | 3 | 137.8 | 127.7 | 8.0 |
| 022X | 4178 | 2178179 | IA01 | 4 | 140.8 | 132.4 | 6.3 |
| 025X | 4224 | 2160289 | 01 | 1 | 131.1 | 125.6 | 4.3 |
| 025X | 4224 | 2160289 | 01 | 2 | 136.5 | 128.9 | 5.9 |
| 025X | 4224 | 2160289 | 01 | 3 | 144.5 | 133.4 | 8.3 |
| 025X | 4224 | 2160289 | 01 | 4 | 143.1 | 130.6 | 9.5 |
| 025Z | 4345 | 2192347 | 02 | 1 | 134.3 | 127.1 | 5.7 |
| 025Z | 4345 | 2192347 | 02 | 2 | 142.9 | 132.5 | 7.8 |
| 025Z | 4345 | 2192347 | 02 | 3 | 143.9 | 131.8 | 9.2 |
| 025Z | 4345 | 2192347 | 02 | 4 | 141.7 | 127.4 | 11.2 |
| 037L | 4435 | 2189006 | 01 | 1 | 128.0 | 123.3 | 3.8 |
| 037L | 4435 | 2189006 | 01 | 2 | 137.7 | 130.1 | 5.9 |
| 037L | 4435 | 2189006 | 01 | 3 | 143.4 | 133.1 | 7.8 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 037L | 4435 | 2189006 | 01 | 4 | 143.2 | 130.8 | 9.4 |
| 037K | 4539 | 2188965 | 02 | 1 | 132.5 | 127.0 | 4.3 |
| 037K | 4539 | 2188965 | 02 | 2 | 139.4 | 131.2 | 6.2 |
| 037K | 4539 | 2188965 | 02 | 3 | 143.3 | 132.2 | 8.4 |
| 037K | 4539 | 2188965 | 02 | 4 | 140.4 | 127.6 | 10.0 |
| 03L6 | 4630 | 2185899 | 01 | 1 | 130.9 | 125.8 | 4.0 |
| 03L6 | 4630 | 2185899 | 01 | 2 | 139.3 | 131.3 | 6.0 |
| 03L6 | 4630 | 2185899 | 01 | 3 | 143.8 | 133.2 | 8.0 |
| 03L6 | 4630 | 2185899 | 01 | 4 | 141.0 | 128.5 | 9.7 |
| 02WN | 3636 | 2179444 | 01 | 1 | 126.2 | 121.2 | 4.1 |
| 02WN | 3636 | 2179444 | 01 | 2 | 133.8 | 125.9 | 6.3 |
| 02WN | 3636 | 2179444 | 01 | 3 | 143.0 | 132.3 | 8.1 |
| 02WN | 3636 | 2179444 | 01 | 4 | 145.3 | 132.3 | 9.8 |
| 6678 | 2639 | 2076074 | 01 | 1 | 131.7 | 128.0 | 2.8 |
| 6678 | 2639 | 2076074 | 01 | 2 | 138.3 | 131.8 | 4.9 |
| 6678 | 2639 | 2076074 | 01 | 3 | 141.5 | 131.1 | 7.9 |
| 6678 | 2639 | 2076074 | 01 | 4 | 141.4 | 129.3 | 9.3 |

**Table B-14: DOT-40 points used for compaction curves with a maximum dry unit weight between 134 pcf to 136 pcf.**

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 5770 | 1005 | 1039193 | 01 | 1 | 136.8 | 132.5 | 3.3 |
| 5770 | 1005 | 1039193 | 01 | 2 | 139.6 | 132.9 | 5.1 |
| 5770 | 1005 | 1039193 | 01 | 3 | 143.2 | 135.2 | 5.9 |
| 5770 | 1005 | 1039193 | 01 | 4 | 143.2 | 133.7 | 7.1 |
| 5770 | 1005 | 1039193 | 01 | 5 | 141.9 | 133.8 | 6.0 |
| 5852 | 1055 | 1015210 | 01 | 1 | 134.5 | 127.4 | 5.6 |
| 5852 | 1055 | 1015210 | 01 | 2 | 142.9 | 133.5 | 7.1 |
| 5852 | 1055 | 1015210 | 01 | 3 | 145.3 | 132.4 | 9.7 |
| 5852 | 1055 | 1015210 | 01 | 4 | 142.5 | 128.5 | 11.0 |
| 6035 | 1073 | 1052292 | Field#1 | 1 | 125.7 | 121.3 | 3.7 |
| 6035 | 1073 | 1052292 | Field#1 | 2 | 134.9 | 128.2 | 5.2 |
| 6035 | 1073 | 1052292 | Field#1 | 3 | 144.8 | 135.3 | 7.0 |
| 6035 | 1073 | 1052292 | Field#1 | 4 | 146.0 | 133.3 | 9.5 |
| 6035 | 1073 | 1052292 | Field#1 | 5 | 143.9 | 128.7 | 11.8 |
| 6379 | 1330 | 1076206 | 01 | 1 | 135.7 | 126.5 | 7.3 |
| 6379 | 1330 | 1076206 | 01 | 2 | 141.4 | 131.0 | 8.0 |
| 6379 | 1330 | 1076206 | 01 | 3 | 147.3 | 135.4 | 8.8 |
| 6379 | 1330 | 1076206 | 01 | 4 | 146.8 | 134.4 | 9.2 |
| 6379 | 1330 | 1076206 | 01 | 5 | 146.6 | 133.2 | 10.1 |
| 3151 | 1438 | 1073817 | 01 | 1 | 133.8 | 129.5 | 3.3 |
| 3151 | 1438 | 1073817 | 01 | 2 | 140.2 | 133.4 | 5.1 |
| 3151 | 1438 | 1073817 | 01 | 3 | 143.5 | 133.5 | 7.5 |
| 3151 | 1438 | 1073817 | 01 | 4 | 142.8 | 131.7 | 8.4 |
| 6242 | 1491 | 1123197 | 01 | 1 | 128.9 | 123.1 | 4.7 |
| 6242 | 1491 | 1123197 | 01 | 2 | 137.7 | 129.6 | 6.3 |
| 6242 | 1491 | 1123197 | 01 | 3 | 144.5 | 133.8 | 8.0 |
| 6242 | 1491 | 1123197 | 01 | 4 | 143.6 | 129.9 | 10.5 |
| 4824 | 1598 | 1322738 | 01 | 1 | 132.9 | 126.6 | 5.0 |
| 4824 | 1598 | 1322738 | 01 | 2 | 138.3 | 129.9 | 6.4 |
| 4824 | 1598 | 1322738 | 01 | 3 | 144.9 | 134.5 | 7.7 |
| 4824 | 1598 | 1322738 | 01 | 4 | 143.1 | 131.4 | 8.9 |
| I747 | 1843 | 1289646 | 001 | 1 | 139.5 | 131.6 | 6.0 |
| I747 | 1843 | 1289646 | 001 | 2 | 143.4 | 133.8 | 7.1 |
| I747 | 1843 | 1289646 | 001 | 3 | 146.3 | 134.9 | 8.5 |
| I747 | 1843 | 1289646 | 001 | 4 | 143.2 | 130.3 | 10.0 |
| 00RR | 1879 | 1305221 | 01 | 1 | 134.8 | 128.3 | 5.1 |
| 00RR | 1879 | 1305221 | 01 | 2 | 144.1 | 134.1 | 7.4 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 00RR | 1879 | 1305221 | 01 | 3 | 144.0 | 131.4 | 9.6 |
| 00RR | 1879 | 1305221 | 01 | 4 | 142.1 | 127.8 | 11.2 |
| 4438 | 1921 | 1444575 | 1 | 1 | 132.2 | 127.7 | 3.5 |
| 4438 | 1921 | 1444575 | 1 | 2 | 140.7 | 134.3 | 4.8 |
| 4438 | 1921 | 1444575 | 1 | 3 | 143.6 | 133.9 | 7.3 |
| 4438 | 1921 | 1444575 | 1 | 4 | 145.1 | 134.3 | 8.0 |
| 6701 | 2021 | 1449921 | 01 | 1 | 129.1 | 127.0 | 1.7 |
| 6701 | 2021 | 1449921 | 01 | 2 | 129.8 | 125.7 | 3.3 |
| 6701 | 2021 | 1449921 | 01 | 3 | 137.8 | 131.9 | 4.5 |
| 6701 | 2021 | 1449921 | 01 | 4 | 137.5 | 129.3 | 6.4 |
| 6477 | 2041 | 1407988 | 01 | 1 | 130.7 | 124.0 | 5.5 |
| 6477 | 2041 | 1407988 | 01 | 2 | 135.1 | 125.9 | 7.4 |
| 6477 | 2041 | 1407988 | 01 | 3 | 143.9 | 132.1 | 9.0 |
| 6477 | 2041 | 1407988 | 01 | 4 | 143.9 | 128.9 | 11.6 |
| 3782 | 2428 | 2103427 | Field01 | 1 | 131.4 | 124.5 | 5.6 |
| 3782 | 2428 | 2103427 | Field01 | 2 | 140.4 | 131.6 | 6.6 |
| 3782 | 2428 | 2103427 | Field01 | 3 | 144.5 | 132.2 | 9.3 |
| 3782 | 2428 | 2103427 | Field01 | 4 | 142.4 | 128.8 | 10.5 |
| 6461 | 2430 | 2067613 | 01 | 1 | 126.9 | 124.6 | 1.8 |
| 6461 | 2430 | 2067613 | 01 | 2 | 136.8 | 132.3 | 3.4 |
| 6461 | 2430 | 2067613 | 01 | 3 | 141.1 | 134.4 | 5.0 |
| 6461 | 2430 | 2067613 | 01 | 4 | 140.5 | 131.3 | 7.0 |
| 00GW | 2440 | 1471974 | 01 | 1 | 135.0 | 129.2 | 4.5 |
| 00GW | 2440 | 1471974 | 01 | 2 | 141.6 | 132.6 | 6.8 |
| 00GW | 2440 | 1471974 | 01 | 3 | 145.5 | 134.5 | 8.1 |
| 00GW | 2440 | 1471974 | 01 | 4 | 143.6 | 130.0 | 10.4 |
| 00RV | 2449 | 2087435 | 02 | 1 | 136.2 | 130.6 | 4.3 |
| 00RV | 2449 | 2087435 | 02 | 2 | 142.5 | 134.3 | 6.1 |
| 00RV | 2449 | 2087435 | 02 | 3 | 143.0 | 132.6 | 7.8 |
| 00RV | 2449 | 2087435 | 02 | 4 | 141.0 | 128.3 | 9.9 |
| 003J | 2461 | 1468071 | IA01 | 1 | 132.8 | 127.1 | 4.5 |
| 003J | 2461 | 1468071 | IA01 | 2 | 141.4 | 132.8 | 6.4 |
| 003J | 2461 | 1468071 | IA01 | 3 | 144.5 | 133.3 | 8.5 |
| 003J | 2461 | 1468071 | IA01 | 4 | 142.9 | 130.7 | 9.4 |
| 00RW | 2558 | 2136538 | 01 | 1 | 132.4 | 127.0 | 4.2 |
| 00RW | 2558 | 2136538 | 01 | 2 | 140.7 | 132.9 | 5.9 |
| 00RW | 2558 | 2136538 | 01 | 3 | 144.4 | 134.0 | 7.7 |
| 00RW | 2558 | 2136538 | 01 | 4 | 142.0 | 129.6 | 9.6 |
| 00WY | 2640 | 2067321 | 01 | 1 | 135.2 | 130.5 | 3.7 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 00WY | 2640 | 2067321 | 01 | 2 | 142.2 | 134.6 | 5.7 |
| 00WY | 2640 | 2067321 | 01 | 3 | 143.8 | 134.2 | 7.1 |
| 00WY | 2640 | 2067321 | 01 | 4 | 142.8 | 130.7 | 9.3 |
| 6437 | 2117 | 1464795 | 01 | 1 | 128.4 | 125.1 | 2.6 |
| 6437 | 2117 | 1464795 | 01 | 2 | 143.2 | 134.8 | 6.3 |
| 6437 | 2117 | 1464795 | 01 | 3 | 144.6 | 133.4 | 8.4 |
| 6437 | 2117 | 1464795 | 01 | 4 | 141.4 | 128.1 | 10.3 |
| 6253 | 2151 | 1440952 | IA01 | 1 | 141.1 | 131.5 | 7.3 |
| 6253 | 2151 | 1440952 | IA01 | 2 | 142.4 | 132.1 | 7.8 |
| 6253 | 2151 | 1440952 | IA01 | 3 | 147.3 | 134.9 | 9.2 |
| 6253 | 2151 | 1440952 | IA01 | 4 | 140.4 | 126.6 | 10.9 |
| 6324 | 2235 | 2078490 | IA02 | 1 | 130.0 | 123.2 | 5.5 |
| 6324 | 2235 | 2078490 | IA02 | 2 | 138.4 | 129.4 | 7.0 |
| 6324 | 2235 | 2078490 | IA02 | 3 | 142.9 | 132.6 | 7.8 |
| 6324 | 2235 | 2078490 | IA02 | 4 | 139.3 | 126.2 | 10.4 |
| 01QN | 2920 | 2086132 | 02 | 1 | 130.8 | 125.3 | 4.4 |
| 01QN | 2920 | 2086132 | 02 | 2 | 140.6 | 132.5 | 6.1 |
| 01QN | 2920 | 2086132 | 02 | 3 | 145.4 | 134.8 | 7.9 |
| 01QN | 2920 | 2086132 | 02 | 4 | 144.0 | 131.4 | 9.5 |
| 021E | 3268 | 2106283 | 01 | 1 | 137.3 | 130.0 | 5.6 |
| 021E | 3268 | 2106283 | 01 | 2 | 143.4 | 134.3 | 6.8 |
| 021E | 3268 | 2106283 | 01 | 3 | 144.8 | 132.7 | 9.1 |
| 021E | 3268 | 2106283 | 01 | 4 | 144.5 | 131.3 | 10.1 |
| 01KY | 3342 | 2093748 | 02 | 1 | 132.5 | 125.7 | 5.4 |
| 01KY | 3342 | 2093748 | 02 | 2 | 138.9 | 130.2 | 6.7 |
| 01KY | 3342 | 2093748 | 02 | 3 | 146.6 | 134.6 | 8.9 |
| 01KY | 3342 | 2093748 | 02 | 4 | 142.2 | 129.0 | 10.3 |
| 02NE | 3486 | 2102285 | 01 | 1 | 132.4 | 126.9 | 4.3 |
| 02NE | 3486 | 2102285 | 01 | 2 | 142.9 | 134.4 | 6.3 |
| 02NE | 3486 | 2102285 | 01 | 3 | 144.9 | 133.8 | 8.3 |
| 02NE | 3486 | 2102285 | 01 | 4 | 142.4 | 129.4 | 10.0 |
| 02VL | 3506 | 2105982 | 01 | 1 | 125.6 | 121.2 | 3.6 |
| 02VL | 3506 | 2105982 | 01 | 2 | 131.4 | 125.3 | 4.9 |
| 02VL | 3506 | 2105982 | 01 | 3 | 143.8 | 133.6 | 7.7 |
| 02VL | 3506 | 2105982 | 01 | 4 | 146.1 | 134.1 | 8.9 |
| 02VL | 3506 | 2105982 | 01 | 5 | 142.9 | 128.7 | 11.1 |
| 02QD | 3539 | 2145738 | 01 | 1 | 131.7 | 125.1 | 5.3 |
| 02QD | 3539 | 2145738 | 01 | 2 | 143.0 | 133.6 | 7.0 |
| 02QD | 3539 | 2145738 | 01 | 3 | 145.3 | 132.7 | 9.4 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 02QD | 3539 | 2145738 | 01 | 4 | 142.3 | 125.8 | 13.1 |
| 01RV | 3568 | 2152672 | IA01 | 1 | 134.6 | 127.7 | 5.4 |
| 01RV | 3568 | 2152672 | IA01 | 2 | 142.0 | 133.2 | 6.6 |
| 01RV | 3568 | 2152672 | IA01 | 3 | 140.8 | 129.6 | 8.6 |
| 01RV | 3568 | 2152672 | IA01 | 4 | 126.2 | 121.8 | 3.6 |
| H034 | 3599 | 2132225 | 01 | 1 | 133.1 | 125.9 | 5.7 |
| H034 | 3599 | 2132225 | 01 | 2 | 142.1 | 132.8 | 7.0 |
| H034 | 3599 | 2132225 | 01 | 3 | 145.1 | 133.1 | 9.0 |
| H034 | 3599 | 2132225 | 01 | 4 | 144.5 | 131.9 | 9.6 |
| H034 | 3599 | 2132401 | 02 | 1 | 136.2 | 127.8 | 6.5 |
| H034 | 3599 | 2132401 | 02 | 2 | 144.3 | 134.0 | 7.7 |
| H034 | 3599 | 2132401 | 02 | 3 | 144.5 | 131.2 | 10.1 |
| H034 | 3599 | 2132401 | 02 | 4 | 141.5 | 127.6 | 10.9 |
| 01T6 | 3662 | 2135698 | 01 | 1 | 133.6 | 128.1 | 4.3 |
| 01T6 | 3662 | 2135698 | 01 | 2 | 142.0 | 133.5 | 6.3 |
| 01T6 | 3662 | 2135698 | 01 | 3 | 144.3 | 133.1 | 8.4 |
| 01T6 | 3662 | 2135698 | 01 | 4 | 141.3 | 128.7 | 9.8 |
| 03BP | 3774 | 2128723 | 01 | 1 | 135.9 | 130.2 | 4.4 |
| 03BP | 3774 | 2128723 | 01 | 2 | 142.4 | 133.8 | 6.4 |
| 03BP | 3774 | 2128723 | 01 | 3 | 143.3 | 132.2 | 8.4 |
| 03BP | 3774 | 2128723 | 01 | 4 | 137.9 | 125.7 | 9.7 |
| 03BP | 3774 | 2128803 | 02 | 1 | 135.6 | 130.2 | 4.1 |
| 03BP | 3774 | 2128803 | 02 | 2 | 142.1 | 134.1 | 6.0 |
| 03BP | 3774 | 2128803 | 02 | 3 | 142.7 | 132.3 | 7.8 |
| 03BP | 3774 | 2128803 | 02 | 4 | 141.1 | 128.3 | 9.9 |
| 01D3 | 3910 | 2136435 | Field#01 | 1 | 136.2 | 129.3 | 5.3 |
| 01D3 | 3910 | 2136435 | Field#01 | 2 | 143.9 | 134.4 | 7.1 |
| 01D3 | 3910 | 2136435 | Field#01 | 3 | 144.3 | 131.6 | 9.7 |
| 01D3 | 3910 | 2136435 | Field#01 | 4 | 143.7 | 130.6 | 10.0 |
| 0255 | 3915 | 2146134 | 02 | 1 | 134.3 | 127.0 | 5.7 |
| 0255 | 3915 | 2146134 | 02 | 2 | 143.7 | 133.0 | 8.0 |
| 0255 | 3915 | 2146134 | 02 | 3 | 146.6 | 134.5 | 9.0 |
| 0255 | 3915 | 2146134 | 02 | 4 | 145.3 | 131.4 | 10.6 |
| 021B | 4084 | 2165374 | 01 | 1 | 138.9 | 132.8 | 4.6 |
| 021B | 4084 | 2165374 | 01 | 2 | 142.4 | 134.2 | 6.1 |
| 021B | 4084 | 2165374 | 01 | 3 | 139.1 | 129.6 | 7.3 |
| 021B | 4084 | 2165374 | 01 | 4 | 128.1 | 124.4 | 3.0 |
| 025Z | 4345 | 2202746 | 03 | 1 | 129.5 | 124.6 | 4.0 |
| 025Z | 4345 | 2202746 | 03 | 2 | 138.3 | 130.6 | 6.0 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 025Z | 4345 | 2202746 | 03 | 3 | 143.8 | 134.1 | 7.3 |
| 025Z | 4345 | 2202746 | 03 | 4 | 144.9 | 132.4 | 9.4 |
| 025Z | 4345 | 2202746 | 03 | 5 | 142.2 | 129.1 | 10.2 |
| I2TX | 4397 | 2182904 | IA01 | 1 | 128.8 | 123.5 | 4.3 |
| I2TX | 4397 | 2182904 | IA01 | 2 | 138.8 | 131.0 | 5.9 |
| I2TX | 4397 | 2182904 | IA01 | 3 | 146.0 | 134.7 | 8.4 |
| I2TX | 4397 | 2182904 | IA01 | 4 | 144.2 | 131.0 | 10.1 |
| 02CZ | 4645 | 2204559 | 01 | 1 | 134.2 | 127.3 | 5.4 |
| 02CZ | 4645 | 2204559 | 01 | 2 | 142.6 | 132.5 | 7.6 |
| 02CZ | 4645 | 2204559 | 01 | 3 | 146.1 | 134.2 | 8.8 |
| 02CZ | 4645 | 2204559 | 01 | 4 | 143.4 | 130.7 | 9.7 |
| 03QH | 4702 | 2201260 | 01 | 1 | 137.7 | 130.6 | 5.4 |
| 03QH | 4702 | 2201260 | 01 | 2 | 145.9 | 134.9 | 8.2 |
| 03QH | 4702 | 2201260 | 01 | 3 | 146.1 | 134.1 | 9.0 |
| 03QH | 4702 | 2201260 | 01 | 4 | 142.3 | 128.5 | 10.8 |
| 035A | 4833 | 2205858 | 01 | 1 | 114.5 | 109.8 | 4.2 |
| 035A | 4833 | 2205858 | 01 | 2 | 137.1 | 129.1 | 6.2 |
| 035A | 4833 | 2205858 | 01 | 3 | 143.9 | 133.8 | 7.6 |
| 035A | 4833 | 2205858 | 01 | 4 | 143.4 | 130.2 | 10.2 |
| 04GN | 4952 | 2220090 | 01 | 1 | 132.0 | 126.2 | 4.6 |
| 04GN | 4952 | 2220090 | 01 | 2 | 141.1 | 132.2 | 6.7 |
| 04GN | 4952 | 2220090 | 01 | 3 | 145.2 | 133.4 | 8.8 |
| 04GN | 4952 | 2220090 | 01 | 4 | 142.9 | 130.2 | 9.8 |
| I3PJ | 5084 | 2213132 | 01 | 1 | 125.2 | 122.9 | 1.9 |
| I3PJ | 5084 | 2213132 | 01 | 2 | 131.5 | 127.2 | 3.4 |
| I3PJ | 5084 | 2213132 | 01 | 3 | 136.0 | 129.5 | 5.0 |
| I3PJ | 5084 | 2213132 | 01 | 4 | 143.5 | 134.8 | 6.4 |
| I3PJ | 5084 | 2213132 | 01 | 5 | 144.8 | 134.5 | 7.7 |
| 315N | 1171 | 1030715 | 01 | 1 | 125.4 | 121.9 | 2.9 |
| 315N | 1171 | 1030715 | 01 | 2 | 136.2 | 130.5 | 4.3 |
| 315N | 1171 | 1030715 | 01 | 3 | 140.8 | 134.3 | 4.8 |
| 315N | 1171 | 1030715 | 01 | 4 | 141.5 | 135.1 | 4.7 |
| 6897 | 1257 | 1054586 | 1 | 1 | 134.7 | 128.2 | 5.0 |
| 6897 | 1257 | 1054586 | 1 | 2 | 144.9 | 135.1 | 7.3 |
| 6897 | 1257 | 1054586 | 1 | 3 | 146.4 | 133.5 | 9.7 |
| 6897 | 1257 | 1054586 | 1 | 4 | 143.7 | 129.2 | 11.3 |
| 1948 | 1663 | 1262759 | 02 | 1 | 136.9 | 130.6 | 4.8 |
| 1948 | 1663 | 1262759 | 02 | 2 | 143.8 | 134.4 | 7.0 |
| 1948 | 1663 | 1262759 | 02 | 3 | 146.5 | 134.2 | 9.2 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 1948 | 1663 | 1262759 | 02 | 4 | 142.9 | 129.7 | 10.2 |
| 5865 | 1671 | 1255917 | 01 | 1 | 141.7 | 133.6 | 6.0 |
| 5865 | 1671 | 1255917 | 01 | 2 | 146.0 | 136.3 | 7.1 |
| 5865 | 1671 | 1255917 | 01 | 3 | 144.8 | 134.2 | 7.9 |
| 5865 | 1671 | 1255917 | 01 | 4 | 143.7 | 132.0 | 8.9 |
| 5865 | 1671 | 1255917 | 01 | 5 | 136.8 | 131.3 | 4.2 |
| 6481 | 1888 | 1437147 | IA01 | 1 | 124.6 | 121.2 | 2.8 |
| 6481 | 1888 | 1437147 | IA01 | 2 | 132.3 | 127.2 | 4.0 |
| 6481 | 1888 | 1437147 | IA01 | 3 | 144.5 | 134.9 | 7.1 |
| 6481 | 1888 | 1437147 | IA01 | 4 | 146.2 | 135.8 | 7.7 |
| 6481 | 1888 | 1437147 | IA01 | 5 | 145.1 | 134.1 | 8.2 |
| 6146 | 1933 | 1404236 | 01 | 1 | 139.1 | 132.7 | 4.8 |
| 6146 | 1933 | 1404236 | 01 | 2 | 129.0 | 125.6 | 2.7 |
| 6146 | 1933 | 1404236 | 01 | 3 | 142.8 | 133.8 | 6.7 |
| 6146 | 1933 | 1404236 | 01 | 4 | 140.7 | 131.2 | 7.2 |
| 6181 | 1951 | 1434381 | 01 | 1 | 128.8 | 122.5 | 5.1 |
| 6181 | 1951 | 1434381 | 01 | 2 | 141.4 | 132.8 | 6.5 |
| 6181 | 1951 | 1434381 | 01 | 3 | 145.4 | 133.7 | 8.8 |
| 6181 | 1951 | 1434381 | 01 | 4 | 142.5 | 128.3 | 11.1 |
| 6702 | 1955 | 1439391 | 01 | 1 | 127.0 | 124.5 | 2.0 |
| 6702 | 1955 | 1439391 | 01 | 2 | 130.7 | 126.4 | 3.4 |
| 6702 | 1955 | 1439391 | 01 | 3 | 141.6 | 134.8 | 5.1 |
| 6702 | 1955 | 1439391 | 01 | 4 | 139.5 | 130.8 | 6.7 |
| 3783 | 2110 | 1464928 | Field02 | 1 | 130.9 | 124.5 | 5.1 |
| 3783 | 2110 | 1464928 | Field02 | 2 | 144.2 | 135.0 | 6.9 |
| 3783 | 2110 | 1464928 | Field02 | 3 | 146.6 | 134.7 | 8.8 |
| 3783 | 2110 | 1464928 | Field02 | 4 | 143.0 | 127.9 | 11.8 |
| 00UU | 2178 | 1450590 | IA02 | 1 | 129.9 | 123.5 | 5.2 |
| 00UU | 2178 | 1450590 | IA02 | 2 | 141.6 | 130.9 | 8.1 |
| 00UU | 2178 | 1450590 | IA02 | 3 | 148.4 | 134.9 | 10.0 |
| 00UU | 2178 | 1450590 | IA02 | 4 | 146.6 | 130.4 | 12.5 |
| 6788 | 2269 | 1455103 | 01 | 1 | 132.9 | 126.5 | 5.1 |
| 6788 | 2269 | 1455103 | 01 | 2 | 140.8 | 131.6 | 7.0 |
| 6788 | 2269 | 1455103 | 01 | 3 | 144.9 | 131.9 | 9.8 |
| 6788 | 2269 | 1455103 | 01 | 4 | 143.1 | 130.0 | 10.1 |
| 000Z | 2369 | 1466756 | 01 | 1 | 124.4 | 120.9 | 2.9 |
| 000Z | 2369 | 1466756 | 01 | 2 | 140.8 | 133.6 | 5.4 |
| 000Z | 2369 | 1466756 | 01 | 3 | 143.6 | 135.2 | 6.3 |
| 000Z | 2369 | 1466756 | 01 | 4 | 142.8 | 135.3 | 5.6 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 000Y | 2925 | 2067934 | 01 | 1 | 136.7 | 131.0 | 4.4 |
| 000Y | 2925 | 2067934 | 01 | 2 | 145.1 | 135.8 | 6.9 |
| 000Y | 2925 | 2067934 | 01 | 3 | 145.6 | 133.9 | 8.7 |
| 000Y | 2925 | 2067934 | 01 | 4 | 145.2 | 131.2 | 10.7 |
| 00FI | 2966 | 2093486 | 02 | 1 | 136.3 | 131.3 | 3.9 |
| 00FI | 2966 | 2093486 | 02 | 2 | 143.6 | 135.3 | 6.2 |
| 00FI | 2966 | 2093486 | 02 | 3 | 142.8 | 132.3 | 8.0 |
| 00FI | 2966 | 2093486 | 02 | 4 | 140.1 | 128.2 | 9.3 |
| 01DH | 2985 | 2083512 | 01 | 1 | 132.6 | 127.3 | 4.1 |
| 01DH | 2985 | 2083512 | 01 | 2 | 139.6 | 131.5 | 6.2 |
| 01DH | 2985 | 2083512 | 01 | 3 | 144.8 | 134.7 | 7.5 |
| 01DH | 2985 | 2083512 | 01 | 4 | 145.4 | 133.2 | 9.1 |
| 02A2 | 3205 | 2146553 | 01 | 1 | 129.1 | 126.5 | 2.1 |
| 02A2 | 3205 | 2146553 | 01 | 2 | 137.1 | 131.9 | 3.9 |
| 02A2 | 3205 | 2146553 | 01 | 3 | 144.5 | 135.7 | 6.4 |
| 02A2 | 3205 | 2146553 | 01 | 4 | 143.5 | 132.9 | 8.0 |
| 00GR | 3504 | 2108181 | 01 | 1 | 137.6 | 132.2 | 4.1 |
| 00GR | 3504 | 2108181 | 01 | 2 | 143.9 | 135.7 | 6.0 |
| 00GR | 3504 | 2108181 | 01 | 3 | 144.9 | 134.2 | 8.0 |
| 00GR | 3504 | 2108181 | 01 | 4 | 142.3 | 130.1 | 9.3 |
| 01TF | 3520 | 2152663 | 01 | 1 | 130.1 | 124.7 | 4.3 |
| 01TF | 3520 | 2152663 | 01 | 2 | 138.0 | 130.8 | 5.5 |
| 01TF | 3520 | 2152663 | 01 | 3 | 144.2 | 135.0 | 6.8 |
| 01TF | 3520 | 2152663 | 01 | 4 | 144.0 | 134.1 | 7.4 |
| 02KL | 3596 | 2126809 | 01 | 1 | 125.9 | 122.7 | 2.6 |
| 02KL | 3596 | 2126809 | 01 | 2 | 128.9 | 124.2 | 3.8 |
| 02KL | 3596 | 2126809 | 01 | 3 | 139.4 | 131.5 | 6.0 |
| 02KL | 3596 | 2126809 | 01 | 4 | 143.8 | 135.2 | 6.4 |
| 02KL | 3596 | 2126809 | 01 | 5 | 142.5 | 131.0 | 8.7 |
| 02P2 | 3597 | 2154959 | 02 | 1 | 133.2 | 125.6 | 6.0 |
| 02P2 | 3597 | 2154959 | 02 | 2 | 139.0 | 129.7 | 7.2 |
| 02P2 | 3597 | 2154959 | 02 | 3 | 146.8 | 134.5 | 9.1 |
| 02P2 | 3597 | 2154959 | 02 | 4 | 146.6 | 131.1 | 11.8 |
| 01QR | 3783 | 2129630 | 01 | 1 | 126.2 | 122.1 | 3.4 |
| 01QR | 3783 | 2129630 | 01 | 2 | 135.4 | 128.7 | 5.2 |
| 01QR | 3783 | 2129630 | 01 | 3 | 141.8 | 133.2 | 6.4 |
| 01QR | 3783 | 2129630 | 01 | 4 | 146.1 | 135.6 | 7.8 |
| 01QR | 3783 | 2129630 | 01 | 5 | 147.1 | 134.5 | 9.4 |
| 3106 | 3826 | 2134559 | 02 | 1 | 131.6 | 126.0 | 4.5 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 3106 | 3826 | 2134559 | 02 | 2 | 136.4 | 128.8 | 5.9 |
| 3106 | 3826 | 2134559 | 02 | 3 | 143.5 | 133.7 | 7.3 |
| 3106 | 3826 | 2134559 | 02 | 4 | 142.9 | 129.7 | 10.2 |
| 033V | 3827 | 2132472 | 01 | 1 | 126.8 | 124.3 | 2.0 |
| 033V | 3827 | 2132472 | 01 | 2 | 130.2 | 126.1 | 3.2 |
| 033V | 3827 | 2132472 | 01 | 3 | 138.7 | 132.0 | 5.0 |
| 033V | 3827 | 2132472 | 01 | 4 | 145.1 | 135.1 | 7.5 |
| 033V | 3827 | 2132472 | 01 | 5 | 146.2 | 134.7 | 8.6 |
| 00ZH | 4024 | 2155063 | 01 | 1 | 134.2 | 127.0 | 5.7 |
| 00ZH | 4024 | 2155063 | 01 | 2 | 139.8 | 131.4 | 6.4 |
| 00ZH | 4024 | 2155063 | 01 | 3 | 146.7 | 134.8 | 8.8 |
| 00ZH | 4024 | 2155063 | 01 | 4 | 143.5 | 130.4 | 10.1 |
| 02Q6 | 4242 | 2191307 | 01 | 1 | 133.6 | 127.3 | 4.9 |
| 02Q6 | 4242 | 2191307 | 01 | 2 | 142.4 | 134.3 | 6.0 |
| 02Q6 | 4242 | 2191307 | 01 | 3 | 145.0 | 134.5 | 7.8 |
| 02Q6 | 4242 | 2191307 | 01 | 4 | 143.6 | 130.4 | 10.1 |
| 025Z | 4345 | 2191455 | 01 | 1 | 132.9 | 126.5 | 5.0 |
| 025Z | 4345 | 2191455 | 01 | 2 | 143.3 | 134.0 | 7.0 |
| 025Z | 4345 | 2191455 | 01 | 3 | 147.5 | 135.8 | 8.7 |
| 025Z | 4345 | 2191455 | 01 | 4 | 144.7 | 130.8 | 10.6 |
| 03QG | 4425 | 2194825 | IA01 | 1 | 122.5 | 119.6 | 2.4 |
| 03QG | 4425 | 2194825 | IA01 | 2 | 126.5 | 121.4 | 4.2 |
| 03QG | 4425 | 2194825 | IA01 | 3 | 137.3 | 129.8 | 5.8 |
| 03QG | 4425 | 2194825 | IA01 | 4 | 144.2 | 134.6 | 7.2 |
| 03QG | 4425 | 2194825 | IA01 | 5 | 142.5 | 130.5 | 9.2 |
| 03QG | 4425 | 2194825 | IA01 | 6 | 138.8 | 126.1 | 10.0 |
| 01TH | 4523 | 2209171 | 01 | 1 | 128.1 | 123.9 | 3.4 |
| 01TH | 4523 | 2209171 | 01 | 2 | 134.9 | 129.0 | 4.6 |
| 01TH | 4523 | 2209171 | 01 | 3 | 139.9 | 132.1 | 5.9 |
| 01TH | 4523 | 2209171 | 01 | 4 | 144.8 | 135.7 | 6.7 |
| 044U | 4683 | 2203766 | 01 | 1 | 127.7 | 124.3 | 2.8 |
| 044U | 4683 | 2203766 | 01 | 2 | 138.0 | 132.7 | 4.0 |
| 044U | 4683 | 2203766 | 01 | 3 | 143.9 | 135.7 | 6.0 |
| 044U | 4683 | 2203766 | 01 | 4 | 142.1 | 131.7 | 7.9 |
| 0454 | 4801 | 2201692 | IA01 | 1 | 133.6 | 128.8 | 3.7 |
| 0454 | 4801 | 2201692 | IA01 | 2 | 141.0 | 133.6 | 5.5 |
| 0454 | 4801 | 2201692 | IA01 | 3 | 144.6 | 135.0 | 7.1 |
| 0454 | 4801 | 2201692 | IA01 | 4 | 141.2 | 130.4 | 8.2 |
| 028T | 4895 | 2205894 | 01 | 1 | 128.3 | 123.8 | 3.6 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 028T | 4895 | 2205894 | 01 | 2 | 138.3 | 131.2 | 5.4 |
| 028T | 4895 | 2205894 | 01 | 3 | 143.5 | 134.6 | 6.6 |
| 028T | 4895 | 2205894 | 01 | 4 | 143.2 | 131.7 | 8.8 |
| 03B0 | 4900 | 2215221 | 01 | 1 | 130.1 | 126.8 | 2.6 |
| 03B0 | 4900 | 2215221 | 01 | 2 | 134.2 | 128.3 | 4.6 |
| 03B0 | 4900 | 2215221 | 01 | 3 | 141.8 | 133.4 | 6.3 |
| 03B0 | 4900 | 2215221 | 01 | 4 | 146.3 | 135.6 | 7.9 |
| 03B0 | 4900 | 2215221 | 01 | 5 | 143.3 | 130.8 | 9.6 |
| 00KB | 4913 | 2222395 | 01 | 1 | 134.1 | 127.2 | 5.4 |
| 00KB | 4913 | 2222395 | 01 | 2 | 138.3 | 130.1 | 6.3 |
| 00KB | 4913 | 2222395 | 01 | 3 | 146.9 | 135.5 | 8.4 |
| 00KB | 4913 | 2222395 | 01 | 4 | 144.9 | 131.7 | 10.0 |
| 0511 | 4938 | 2212386 | 01 | 1 | 140.9 | 131.9 | 6.8 |
| 0511 | 4938 | 2212386 | 01 | 2 | 143.1 | 133.7 | 7.1 |
| 0511 | 4938 | 2212386 | 01 | 3 | 146.1 | 135.4 | 7.9 |
| 0511 | 4938 | 2212386 | 01 | 4 | 143.3 | 130.0 | 10.2 |
| 037U | 5502 | 2226559 | 01 | 1 | 132.3 | 127.5 | 3.7 |
| 037U | 5502 | 2226559 | 01 | 2 | 141.9 | 133.6 | 6.2 |
| 037U | 5502 | 2226559 | 01 | 3 | 145.6 | 135.5 | 7.5 |
| 037U | 5502 | 2226559 | 01 | 4 | 143.6 | 131.4 | 9.3 |

**Table B-15: DOT-40 points used for compaction curves with a maximum dry unit weight between 136 pcf to 138 pcf.**

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 1177 | 944 | 1004625 | Field 01 | 1 | 125.4 | 121.8 | 3.0 |
| 1177 | 944 | 1004625 | Field 01 | 2 | 134.4 | 127.7 | 5.2 |
| 1177 | 944 | 1004625 | Field 01 | 3 | 144.5 | 135.2 | 6.8 |
| 1177 | 944 | 1004625 | Field 01 | 4 | 144.0 | 132.0 | 9.0 |
| 5625 | 1032 | 1027874 | 1 | 1 | 134.4 | 129.5 | 3.8 |
| 5625 | 1032 | 1027874 | 1 | 2 | 141.7 | 134.1 | 5.7 |
| 5625 | 1032 | 1027874 | 1 | 3 | 146.1 | 136.7 | 6.9 |
| 5625 | 1032 | 1027874 | 1 | 4 | 147.5 | 136.1 | 8.3 |
| 5625 | 1032 | 1027874 | 1 | 5 | 145.5 | 133.5 | 9.0 |
| 3913 | 1093 | 1030404 | 01 | 1 | 131.1 | 128.3 | 2.2 |
| 3913 | 1093 | 1030404 | 01 | 2 | 141.1 | 135.2 | 4.3 |
| 3913 | 1093 | 1030404 | 01 | 3 | 144.3 | 136.7 | 5.6 |
| 3913 | 1093 | 1030404 | 01 | 4 | 142.2 | 133.9 | 6.1 |
| 5853 | 1129 | 1026363 | 01 | 1 | 130.5 | 126.0 | 3.6 |
| 5853 | 1129 | 1026363 | 01 | 2 | 135.6 | 129.2 | 4.9 |
| 5853 | 1129 | 1026363 | 01 | 3 | 143.7 | 135.0 | 6.5 |
| 5853 | 1129 | 1026363 | 01 | 4 | 143.2 | 131.2 | 9.1 |
| 5956 | 1146 | 1042452 | 03 | 1 | 133.8 | 128.5 | 4.1 |
| 5956 | 1146 | 1042452 | 03 | 2 | 142.2 | 134.8 | 5.5 |
| 5956 | 1146 | 1042452 | 03 | 3 | 146.5 | 136.5 | 7.4 |
| 5956 | 1146 | 1042452 | 03 | 4 | 145.4 | 132.8 | 9.5 |
| 377N | 1293 | 1039245 | 01 | 1 | 132.0 | 126.8 | 4.1 |
| 377N | 1293 | 1039245 | 01 | 2 | 140.6 | 132.7 | 6.0 |
| 377N | 1293 | 1039245 | 01 | 3 | 146.6 | 136.2 | 7.7 |
| 377N | 1293 | 1039245 | 01 | 4 | 145.2 | 132.2 | 9.8 |
| 4528 | 1645 | 1291920 | 01 | 1 | 127.6 | 123.8 | 3.0 |
| 4528 | 1645 | 1291920 | 01 | 2 | 136.1 | 129.6 | 5.0 |
| 4528 | 1645 | 1291920 | 01 | 3 | 146.5 | 136.9 | 7.0 |
| 4528 | 1645 | 1291920 | 01 | 4 | 145.4 | 133.8 | 8.7 |
| 6346 | 1668 | 1314477 | 01 | 1 | 129.5 | 124.4 | 4.1 |
| 6346 | 1668 | 1314477 | 01 | 2 | 137.1 | 129.4 | 5.9 |
| 6346 | 1668 | 1314477 | 01 | 3 | 143.2 | 134.1 | 6.8 |
| 6346 | 1668 | 1314477 | 01 | 4 | 142.0 | 130.7 | 8.7 |
| 5999 | 1674 | 1271152 | 1 | 1 | 132.8 | 128.2 | 3.6 |
| 5999 | 1674 | 1271152 | 1 | 2 | 139.8 | 133.1 | 5.0 |
| 5999 | 1674 | 1271152 | 1 | 3 | 146.4 | 136.9 | 7.0 |
| 5999 | 1674 | 1271152 | 1 | 4 | 144.5 | 133.6 | 8.2 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 5663 | 1826 | 1352940 | 01 | 1 | 135.5 | 129.7 | 4.5 |
| 5663 | 1826 | 1352940 | 01 | 2 | 139.5 | 131.9 | 5.8 |
| 5663 | 1826 | 1352940 | 01 | 3 | 147.5 | 137.1 | 7.5 |
| 5663 | 1826 | 1352940 | 01 | 4 | 147.1 | 135.5 | 8.6 |
| 5863 | 1864 | 1429556 | 01 | 1 | 138.0 | 132.4 | 4.2 |
| 5863 | 1864 | 1429556 | 01 | 2 | 145.2 | 136.7 | 6.2 |
| 5863 | 1864 | 1429556 | 01 | 3 | 147.6 | 136.9 | 7.8 |
| 5863 | 1864 | 1429556 | 01 | 4 | 145.5 | 133.1 | 9.3 |
| 3139 | 1944 | 1466032 | 001 | 1 | 130.9 | 129.0 | 1.5 |
| 3139 | 1944 | 1466032 | 001 | 2 | 142.6 | 135.3 | 5.4 |
| 3139 | 1944 | 1466032 | 001 | 3 | 146.3 | 136.1 | 7.5 |
| 3139 | 1944 | 1466032 | 001 | 4 | 147.5 | 136.4 | 8.2 |
| 001A | 1971 | 1420547 | 01 | 1 | 130.0 | 127.0 | 2.4 |
| 001A | 1971 | 1420547 | 01 | 2 | 136.0 | 131.0 | 3.8 |
| 001A | 1971 | 1420547 | 01 | 3 | 141.8 | 134.8 | 5.2 |
| 001A | 1971 | 1420547 | 01 | 4 | 144.0 | 133.9 | 7.6 |
| 3783 | 2110 | 1461585 | Field01 | 1 | 134.2 | 127.4 | 5.3 |
| 3783 | 2110 | 1461585 | Field01 | 2 | 144.2 | 135.3 | 6.6 |
| 3783 | 2110 | 1461585 | Field01 | 3 | 145.7 | 133.7 | 9.0 |
| 3783 | 2110 | 1461585 | Field01 | 4 | 142.6 | 128.6 | 10.9 |
| 5342 | 2438 | 1479731 | Field01 | 1 | 124.9 | 120.8 | 3.4 |
| 5342 | 2438 | 1479731 | Field01 | 2 | 133.9 | 126.9 | 5.6 |
| 5342 | 2438 | 1479731 | Field01 | 3 | 144.1 | 134.6 | 7.1 |
| 5342 | 2438 | 1479731 | Field01 | 4 | 144.1 | 131.4 | 9.6 |
| 6185 | 2636 | 2071926 | Field # 1 | 1 | 132.5 | 128.2 | 3.3 |
| 6185 | 2636 | 2071926 | Field # 1 | 2 | 139.3 | 132.5 | 5.1 |
| 6185 | 2636 | 2071926 | Field # 1 | 3 | 145.9 | 136.3 | 7.1 |
| 6185 | 2636 | 2071926 | Field # 1 | 4 | 142.9 | 130.0 | 9.9 |
| 01PT | 2667 | 2070057 | 01 | 1 | 124.2 | 120.5 | 3.1 |
| 01PT | 2667 | 2070057 | 01 | 2 | 135.0 | 128.8 | 4.8 |
| 01PT | 2667 | 2070057 | 01 | 3 | 144.7 | 135.5 | 6.8 |
| 01PT | 2667 | 2070057 | 01 | 4 | 143.5 | 131.0 | 9.6 |
| 020G | 3067 | 2092282 | Field01 | 1 | 132.9 | 129.3 | 2.8 |
| 020G | 3067 | 2092282 | Field01 | 2 | 142.8 | 135.9 | 5.1 |
| 020G | 3067 | 2092282 | Field01 | 3 | 146.8 | 137.0 | 7.1 |
| 020G | 3067 | 2092282 | Field01 | 4 | 145.3 | 132.8 | 9.4 |
| 020G | 3067 | 2103425 | Field02 | 1 | 131.0 | 126.4 | 3.7 |
| 020G | 3067 | 2103425 | Field02 | 2 | 141.4 | 133.9 | 5.6 |
| 020G | 3067 | 2103425 | Field02 | 3 | 146.6 | 136.8 | 7.2 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 020G | 3067 | 2103425 | Field02 | 4 | 146.2 | 131.9 | 10.9 |
| 02FM | 3286 | 2094453 | 01 | 1 | 133.0 | 127.2 | 4.6 |
| 02FM | 3286 | 2094453 | 01 | 2 | 143.6 | 134.7 | 6.6 |
| 02FM | 3286 | 2094453 | 01 | 3 | 147.4 | 136.7 | 7.9 |
| 02FM | 3286 | 2094453 | 01 | 4 | 144.4 | 130.9 | 10.3 |
| 02FS | 3288 | 2099484 | 01 | 1 | 121.3 | 120.1 | 1.0 |
| 02FS | 3288 | 2099484 | 01 | 2 | 124.8 | 122.8 | 1.6 |
| 02FS | 3288 | 2099484 | 01 | 3 | 131.7 | 128.4 | 2.5 |
| 02FS | 3288 | 2099484 | 01 | 4 | 138.2 | 133.2 | 3.7 |
| 02FS | 3288 | 2099484 | 01 | 5 | 143.6 | 136.6 | 5.1 |
| 02FS | 3288 | 2099484 | 01 | 6 | 139.0 | 130.3 | 6.7 |
| 020J | 3401 | 2100956 | 01 | 1 | 133.5 | 128.1 | 4.2 |
| 020J | 3401 | 2100956 | 01 | 2 | 144.3 | 136.4 | 5.8 |
| 020J | 3401 | 2100956 | 01 | 3 | 144.0 | 134.4 | 7.2 |
| 020J | 3401 | 2100956 | 01 | 4 | 145.4 | 134.5 | 8.1 |
| 020J | 3401 | 2100956 | 01 | 5 | 144.7 | 131.9 | 9.7 |
| 02ND | 3485 | 2101797 | 01 | 1 | 136.5 | 131.1 | 4.1 |
| 02ND | 3485 | 2101797 | 01 | 2 | 143.7 | 135.5 | 6.1 |
| 02ND | 3485 | 2101797 | 01 | 3 | 146.4 | 135.5 | 8.0 |
| 02ND | 3485 | 2101797 | 01 | 4 | 143.7 | 136.1 | 5.5 |
| 02NK | 3489 | 2103794 | 01 | 1 | 136.4 | 130.5 | 4.5 |
| 02NK | 3489 | 2103794 | 01 | 2 | 145.3 | 136.3 | 6.6 |
| 02NK | 3489 | 2103794 | 01 | 3 | 146.1 | 134.8 | 8.3 |
| 02NK | 3489 | 2103794 | 01 | 4 | 144.5 | 131.7 | 9.7 |
| 01DE | 3552 | 2123815 | 01 | 1 | 132.2 | 128.6 | 2.8 |
| 01DE | 3552 | 2123815 | 01 | 2 | 137.4 | 131.6 | 4.4 |
| 01DE | 3552 | 2123815 | 01 | 3 | 144.2 | 136.7 | 5.5 |
| 01DE | 3552 | 2123815 | 01 | 4 | 143.9 | 132.6 | 8.6 |
| 01DE | 3552 | 2123815 | 01 | 5 | 124.2 | 122.5 | 1.4 |
| 6954 | 3609 | 2139054 | IA02 | 1 | 133.6 | 126.1 | 5.9 |
| 6954 | 3609 | 2139054 | IA02 | 2 | 138.4 | 129.6 | 6.8 |
| 6954 | 3609 | 2139054 | IA02 | 3 | 137.1 | 126.1 | 8.7 |
| 6954 | 3609 | 2139054 | IA02 | 4 | 137.4 | 129.6 | 6.0 |
| 01D9 | 3638 | 2112583 | 02 | 1 | 135.0 | 128.8 | 4.8 |
| 01D9 | 3638 | 2112583 | 02 | 2 | 145.1 | 135.9 | 6.8 |
| 01D9 | 3638 | 2112583 | 02 | 3 | 146.5 | 136.3 | 7.4 |
| 01D9 | 3638 | 2112583 | 02 | 4 | 144.9 | 132.7 | 9.2 |
| 01FP | 3707 | 2135201 | 01 | 1 | 142.0 | 136.2 | 4.3 |
| 01FP | 3707 | 2135201 | 01 | 2 | 143.8 | 135.9 | 5.8 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 01FP | 3707 | 2135201 | 01 | 3 | 144.0 | 135.1 | 6.6 |
| 01FP | 3707 | 2135201 | 01 | 4 | 134.6 | 130.6 | 3.1 |
| 03BJ | 3767 | 2122447 | 01 | 1 | 137.7 | 131.8 | 4.5 |
| 03BJ | 3767 | 2122447 | 01 | 2 | 146.4 | 137.3 | 6.6 |
| 03BJ | 3767 | 2122447 | 01 | 3 | 146.9 | 135.1 | 8.7 |
| 03BJ | 3767 | 2122447 | 01 | 4 | 144.8 | 131.1 | 10.4 |
| 03BR | 3768 | 2126793 | 01 | 1 | 132.1 | 127.3 | 3.8 |
| 03BR | 3768 | 2126793 | 01 | 2 | 138.3 | 130.7 | 5.8 |
| 03BR | 3768 | 2126793 | 01 | 3 | 145.7 | 135.8 | 7.3 |
| 03BR | 3768 | 2126793 | 01 | 4 | 141.9 | 130.0 | 9.2 |
| 00KR | 3875 | 2167844 | 01 | 1 | 136.3 | 129.3 | 5.5 |
| 00KR | 3875 | 2167844 | 01 | 2 | 142.7 | 133.4 | 7.0 |
| 00KR | 3875 | 2167844 | 01 | 3 | 147.3 | 136.8 | 7.7 |
| 00KR | 3875 | 2167844 | 01 | 4 | 144.6 | 132.7 | 8.9 |
| 03D3 | 3913 | 2154925 | 01 | 1 | 132.0 | 125.9 | 4.9 |
| 03D3 | 3913 | 2154925 | 01 | 2 | 138.7 | 131.0 | 5.8 |
| 03D3 | 3913 | 2154925 | 01 | 3 | 146.8 | 136.4 | 7.6 |
| 03D3 | 3913 | 2154925 | 01 | 4 | 145.3 | 132.4 | 9.7 |
| 03HK | 3938 | 2158507 | 02 | 1 | 141.2 | 133.7 | 5.6 |
| 03HK | 3938 | 2158507 | 02 | 2 | 146.4 | 137.1 | 6.7 |
| 03HK | 3938 | 2158507 | 02 | 3 | 147.3 | 137.3 | 7.3 |
| 03HK | 3938 | 2158507 | 02 | 4 | 142.5 | 129.4 | 10.1 |
| 4437 | 4077 | 2158898 | 01 | 1 | 134.1 | 127.4 | 5.2 |
| 4437 | 4077 | 2158898 | 01 | 2 | 144.5 | 135.6 | 6.6 |
| 4437 | 4077 | 2158898 | 01 | 3 | 145.9 | 134.8 | 8.3 |
| 4437 | 4077 | 2158898 | 01 | 4 | 144.2 | 129.8 | 11.1 |
| 035V | 4190 | 2159900 | 01 | 1 | 134.1 | 128.8 | 4.1 |
| 035V | 4190 | 2159900 | 01 | 2 | 143.9 | 136.1 | 5.7 |
| 035V | 4190 | 2159900 | 01 | 3 | 145.9 | 135.6 | 7.6 |
| 035V | 4190 | 2159900 | 01 | 4 | 142.9 | 130.8 | 9.3 |
| 025Z | 4345 | 2191455 | 01 | 1 | 132.9 | 126.5 | 5.0 |
| 025Z | 4345 | 2191455 | 01 | 2 | 143.3 | 134.0 | 7.0 |
| 025Z | 4345 | 2191455 | 01 | 3 | 147.5 | 135.8 | 8.7 |
| 025Z | 4345 | 2191455 | 01 | 4 | 144.7 | 130.8 | 10.6 |
| 03QG | 4425 | 2194825 | IA01 | 1 | 122.5 | 119.6 | 2.4 |
| 03QG | 4425 | 2194825 | IA01 | 2 | 126.5 | 121.4 | 4.2 |
| 03QG | 4425 | 2194825 | IA01 | 3 | 137.3 | 129.8 | 5.8 |
| 03QG | 4425 | 2194825 | IA01 | 4 | 144.2 | 134.6 | 7.2 |
| 03QG | 4425 | 2194825 | IA01 | 5 | 142.5 | 130.5 | 9.2 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 03QG | 4425 | 2194825 | IA01 | 6 | 138.8 | 126.1 | 10.0 |
| 01TH | 4523 | 2209171 | 01 | 1 | 128.1 | 123.9 | 3.4 |
| 01TH | 4523 | 2209171 | 01 | 2 | 134.9 | 129.0 | 4.6 |
| 01TH | 4523 | 2209171 | 01 | 3 | 139.9 | 132.1 | 5.9 |
| 01TH | 4523 | 2209171 | 01 | 4 | 144.8 | 135.7 | 6.7 |
| 04D0 | 4548 | 2190357 | IA02 | 1 | 136.5 | 131.0 | 4.2 |
| 04D0 | 4548 | 2190357 | IA02 | 2 | 141.7 | 134.9 | 5.1 |
| 04D0 | 4548 | 2190357 | IA02 | 3 | 144.0 | 134.3 | 7.2 |
| 04D0 | 4548 | 2190357 | IA02 | 4 | 141.8 | 130.9 | 8.4 |
| 6161 | 4563 | 2204663 | 01 | 1 | 131.9 | 126.6 | 4.2 |
| 6161 | 4563 | 2204663 | 01 | 2 | 140.4 | 132.3 | 6.2 |
| 6161 | 4563 | 2204663 | 01 | 3 | 145.6 | 135.7 | 7.3 |
| 6161 | 4563 | 2204663 | 01 | 4 | 144.7 | 132.3 | 9.3 |
| 038D | 4899 | 2206544 | 01 | 1 | 128.8 | 125.3 | 2.8 |
| 038D | 4899 | 2206544 | 01 | 2 | 135.6 | 130.3 | 4.0 |
| 038D | 4899 | 2206544 | 01 | 3 | 144.3 | 136.1 | 6.0 |
| 038D | 4899 | 2206544 | 01 | 4 | 145.5 | 135.3 | 7.5 |
| 051L | 5011 | 2214781 | 01 | 1 | 131.6 | 126.2 | 4.3 |
| 051L | 5011 | 2214781 | 01 | 2 | 139.9 | 132.2 | 5.8 |
| 051L | 5011 | 2214781 | 01 | 3 | 145.9 | 136.1 | 7.2 |
| 051L | 5011 | 2214781 | 01 | 4 | 144.8 | 132.4 | 9.3 |
| 04AE | 6034 | 2227768 | 01 | 1 | 128.8 | 126.6 | 1.8 |
| 04AE | 6034 | 2227768 | 01 | 2 | 133.2 | 129.0 | 3.2 |
| 04AE | 6034 | 2227768 | 01 | 3 | 141.6 | 134.7 | 5.1 |
| 04AE | 6034 | 2227768 | 01 | 4 | 145.2 | 135.8 | 6.9 |
| 04AE | 6034 | 2227768 | 01 | 5 | 143.7 | 132.7 | 8.3 |
| 5862 | 1422 | 1081029 | 01-info | 1 | 138.4 | 132.1 | 4.7 |
| 5862 | 1422 | 1081029 | 01 | 2 | 146.1 | 136.4 | 7.1 |
| 5862 | 1422 | 1081029 | 01-info | 3 | 148.5 | 137.6 | 7.9 |
| 5862 | 1422 | 1081029 | 01 | 4 | 143.3 | 130.6 | 9.7 |
| 6229 | 1537 | 1273567 | 03 | 1 | 130.4 | 125.9 | 3.5 |
| 6229 | 1537 | 1273567 | 03 | 2 | 140.9 | 133.3 | 5.7 |
| 6229 | 1537 | 1273567 | 03 | 3 | 148.8 | 137.8 | 8.0 |
| 6229 | 1537 | 1273567 | 03 | 4 | 145.8 | 133.5 | 9.3 |
| 6229 | 1537 | 1278018 | 02 | 1 | 132.9 | 127.6 | 4.1 |
| 6229 | 1537 | 1278018 | 02 | 2 | 144.0 | 136.3 | 5.6 |
| 6229 | 1537 | 1278018 | 02 | 3 | 147.3 | 136.8 | 7.7 |
| 6229 | 1537 | 1278018 | 02 | 4 | 146.2 | 133.7 | 9.4 |
| 6146 | 1933 | 1403727 | 01 | 1 | 129.2 | 126.8 | 2.0 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 6146 | 1933 | 1403727 | 01 | 2 | 135.8 | 131.3 | 3.4 |
| 6146 | 1933 | 1403727 | 01 | 3 | 142.9 | 136.3 | 4.9 |
| 6146 | 1933 | 1403727 | 01 | 4 | 145.5 | 136.3 | 6.7 |
| 00UY | 2079 | 1414996 | 01 | 1 | 132.4 | 128.9 | 2.7 |
| 00UY | 2079 | 1414996 | 01 | 2 | 139.9 | 133.9 | 4.5 |
| 00UY | 2079 | 1414996 | 01 | 3 | 145.9 | 137.4 | 6.1 |
| 00UY | 2079 | 1414996 | 01 | 4 | 147.5 | 137.5 | 7.2 |
| 6922 | 2525 | 1480056 | 02 | 1 | 135.8 | 129.5 | 4.8 |
| 6922 | 2525 | 1480056 | 02 | 2 | 142.1 | 134.0 | 6.0 |
| 6922 | 2525 | 1480056 | 02 | 3 | 146.2 | 134.9 | 8.4 |
| 6922 | 2525 | 1480056 | 02 | 4 | 141.0 | 128.4 | 9.9 |
| 01AK | 2553 | 1475202 | IA01 | 1 | 135.2 | 127.6 | 5.9 |
| 01AK | 2553 | 1475202 | IA01 | 2 | 138.3 | 129.4 | 6.9 |
| 01AK | 2553 | 1475202 | IA01 | 3 | 145.2 | 135.2 | 7.4 |
| 01AK | 2553 | 1475202 | IA01 | 4 | 148.1 | 136.1 | 8.9 |
| 01AK | 2553 | 1475202 | IA01 | 5 | 146.4 | 131.6 | 11.3 |
| I1ZS | 3494 | 2102031 | 01 | 1 | 135.6 | 131.0 | 3.5 |
| I1ZS | 3494 | 2102031 | 01 | 2 | 142.2 | 135.8 | 4.7 |
| I1ZS | 3494 | 2102031 | 01 | 3 | 145.0 | 136.9 | 5.9 |
| I1ZS | 3494 | 2102031 | 01 | 4 | 147.5 | 137.5 | 7.3 |
| 02Q5 | 3770 | 2137589 | IA01 | 1 | 134.0 | 129.7 | 3.4 |
| 02Q5 | 3770 | 2137589 | IA01 | 2 | 144.0 | 137.1 | 5.0 |
| 02Q5 | 3770 | 2137589 | IA01 | 3 | 146.1 | 137.8 | 6.0 |
| 02Q5 | 3770 | 2137589 | IA01 | 4 | 144.9 | 134.8 | 7.5 |
| 023C | 3890 | 2142555 | 01 | 1 | 139.9 | 133.1 | 5.1 |
| 023C | 3890 | 2142555 | 01 | 2 | 146.1 | 136.8 | 6.8 |
| 023C | 3890 | 2142555 | 01 | 3 | 143.1 | 131.3 | 9.0 |
| 023C | 3890 | 2142555 | 01 | 4 | 141.7 | 128.1 | 10.6 |
| 023C | 3890 | 2154348 | 02 | 1 | 138.0 | 132.4 | 4.2 |
| 023C | 3890 | 2154348 | 02 | 2 | 145.2 | 136.9 | 6.1 |
| 023C | 3890 | 2154348 | 02 | 3 | 147.1 | 135.6 | 8.4 |
| 023C | 3890 | 2154348 | 02 | 4 | 144.7 | 131.3 | 10.2 |
| 02CY | 3978 | 2172044 | 01 | 1 | 131.5 | 129.8 | 1.4 |
| 02CY | 3978 | 2172044 | 01 | 2 | 134.7 | 130.8 | 3.0 |
| 02CY | 3978 | 2172044 | 01 | 3 | 140.3 | 133.6 | 5.0 |
| 02CY | 3978 | 2172044 | 01 | 4 | 146.6 | 137.8 | 6.4 |
| 02CY | 3978 | 2172044 | 01 | 5 | 145.4 | 133.4 | 9.0 |
| 0377 | 4085 | 2162161 | 01 | 1 | 129.7 | 124.9 | 3.8 |
| 0377 | 4085 | 2162161 | 01 | 2 | 133.2 | 126.9 | 5.0 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 0377 | 4085 | 2162161 | 01 | 3 | 138.9 | 130.9 | 6.1 |
| 0377 | 4085 | 2162161 | 01 | 4 | 144.8 | 131.0 | 10.5 |
| I2Y7 | 4474 | 2182106 | 01 | 1 | 138.7 | 133.2 | 4.1 |
| I2Y7 | 4474 | 2182106 | 01 | 2 | 146.4 | 138.0 | 6.1 |
| I2Y7 | 4474 | 2182106 | 01 | 3 | 146.1 | 136.3 | 7.2 |
| I2Y7 | 4474 | 2182106 | 01 | 4 | 130.9 | 127.3 | 2.9 |
| 05M5 | 6031 | 2223821 | 01 | 1 | 128.3 | 125.3 | 2.3 |
| 05M5 | 6031 | 2223821 | 01 | 2 | 134.5 | 129.5 | 3.8 |
| 05M5 | 6031 | 2223821 | 01 | 3 | 142.0 | 135.1 | 5.1 |
| 05M5 | 6031 | 2223821 | 01 | 4 | 145.1 | 134.9 | 7.6 |
| 5956 | 1146 | 1040580 | 02 | 1 | 132.0 | 125.7 | 5.0 |
| 5956 | 1146 | 1040580 | 02 | 2 | 141.0 | 132.9 | 6.1 |
| 5956 | 1146 | 1040580 | 02 | 3 | 143.3 | 134.4 | 6.6 |
| 5956 | 1146 | 1040580 | 02 | 4 | 148.6 | 137.5 | 8.1 |
| 5956 | 1146 | 1040580 | 02 | 5 | 147.7 | 135.8 | 8.7 |

**Table B-16: DOT-40 points used for compaction curves with a maximum dry unit weight between 138 pcf to 140 pcf.**

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 6223 | 1161 | 1028708 | 01 | 1 | 132.7 | 129.1 | 2.8 |
| 6223 | 1161 | 1028708 | 01 | 2 | 138.8 | 133.7 | 3.8 |
| 6223 | 1161 | 1028708 | 01 | 3 | 143.5 | 137.2 | 4.6 |
| 6223 | 1161 | 1028708 | 01 | 4 | 146.8 | 139.1 | 5.6 |
| 6223 | 1161 | 1028708 | 01 | 5 | 144.5 | 136.3 | 6.0 |
| 4876 | 1251 | 1080909 | 002 | 1 | 135.0 | 130.0 | 3.9 |
| 4876 | 1251 | 1080909 | 002 | 2 | 141.8 | 135.5 | 4.7 |
| 4876 | 1251 | 1080909 | 002 | 3 | 148.6 | 139.5 | 6.6 |
| 4876 | 1251 | 1080909 | 002 | 4 | 150.0 | 138.6 | 8.2 |
| 4876 | 1251 | 1080909 | 002 | 5 | 148.6 | 137.2 | 8.3 |
| 4998 | 1439 | 1086460 | 01 | 1 | 137.7 | 132.4 | 4.0 |
| 4998 | 1439 | 1086460 | 01 | 2 | 147.2 | 138.9 | 6.0 |
| 4998 | 1439 | 1086460 | 01 | 3 | 147.7 | 137.1 | 7.7 |
| 4998 | 1439 | 1086460 | 01 | 4 | 144.5 | 132.1 | 9.4 |
| 6229 | 1537 | 1127463 | 01 | 1 | 137.2 | 132.1 | 3.8 |
| 6229 | 1537 | 1127463 | 01 | 2 | 142.9 | 136.5 | 4.7 |
| 6229 | 1537 | 1127463 | 01 | 3 | 146.2 | 136.9 | 6.8 |
| 6229 | 1537 | 1127463 | 01 | 4 | 146.0 | 133.4 | 9.4 |
| 5933 | 1539 | 1274800 | 02 | 1 | 141.4 | 135.0 | 4.7 |
| 5933 | 1539 | 1274800 | 02 | 2 | 142.9 | 135.2 | 5.8 |
| 5933 | 1539 | 1274800 | 02 | 3 | 148.3 | 138.0 | 7.5 |
| 5933 | 1539 | 1274800 | 02 | 4 | 145.6 | 133.4 | 9.2 |
| 5863 | 1864 | 1448774 | 02 | 1 | 138.0 | 132.6 | 4.1 |
| 5863 | 1864 | 1448774 | 02 | 2 | 146.3 | 138.2 | 5.9 |
| 5863 | 1864 | 1448774 | 02 | 3 | 147.5 | 136.5 | 8.0 |
| 5863 | 1864 | 1448774 | 02 | 4 | 145.2 | 132.9 | 9.2 |
| 3732 | 1889 | 1422724 | 01 | 1 | 137.7 | 132.0 | 4.3 |
| 3732 | 1889 | 1422724 | 01 | 2 | 144.6 | 136.5 | 6.0 |
| 3732 | 1889 | 1422724 | 01 | 3 | 150.1 | 139.3 | 7.8 |
| 3732 | 1889 | 1422724 | 01 | 4 | 145.3 | 132.4 | 9.7 |
| 6556 | 2181 | 1804140 | 1 | 1 | 138.9 | 133.3 | 4.2 |
| 6556 | 2181 | 1804140 | 1 | 2 | 147.8 | 138.9 | 6.4 |
| 6556 | 2181 | 1804140 | 1 | 3 | 149.0 | 138.5 | 7.6 |
| 6556 | 2181 | 1804140 | 1 | 4 | 129.7 | 126.1 | 2.8 |
| 6287 | 2221 | 1410730 | 21125 | 1 | 141.0 | 134.3 | 5.0 |
| 6287 | 2221 | 1410730 | 21125 | 2 | 147.6 | 138.6 | 6.5 |
| 6287 | 2221 | 1410730 | 21125 | 3 | 145.6 | 135.1 | 7.8 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 6287 | 2221 | 1410730 | 21125 | 4 | 141.1 | 128.7 | 9.6 |
| H100 | 2336 | 2204583 | 01 | 1 | 122.7 | 120.4 | 1.9 |
| H100 | 2336 | 2204583 | 01 | 2 | 139.3 | 134.0 | 4.0 |
| H100 | 2336 | 2204583 | 01 | 3 | 147.2 | 139.1 | 5.9 |
| H100 | 2336 | 2204583 | 01 | 4 | 148.8 | 137.2 | 8.5 |
| 01QN | 2920 | 2084790 | 01 | 1 | 139.6 | 134.1 | 4.1 |
| 01QN | 2920 | 2084790 | 01 | 2 | 146.9 | 138.0 | 6.4 |
| 01QN | 2920 | 2084790 | 01 | 3 | 145.0 | 133.9 | 8.3 |
| 01QN | 2920 | 2084790 | 01 | 4 | 144.8 | 132.0 | 9.7 |
| 02KH | 3139 | 2102524 | 01 | 1 | 133.5 | 131.4 | 1.6 |
| 02KH | 3139 | 2102524 | 01 | 2 | 137.6 | 133.4 | 3.1 |
| 02KH | 3139 | 2102524 | 01 | 3 | 145.1 | 138.1 | 5.1 |
| 02KH | 3139 | 2102524 | 01 | 4 | 146.0 | 136.0 | 7.4 |
| 02KH | 3139 | 2116953 | 02 | 1 | 136.6 | 133.0 | 2.7 |
| 02KH | 3139 | 2116953 | 02 | 2 | 141.9 | 136.4 | 4.0 |
| 02KH | 3139 | 2116953 | 02 | 3 | 146.2 | 138.9 | 5.3 |
| 02KH | 3139 | 2116953 | 02 | 4 | 146.9 | 137.6 | 6.8 |
| 02G1 | 3284 | 2087317 | 01 | 1 | 133.9 | 129.6 | 3.4 |
| 02G1 | 3284 | 2087317 | 01 | 2 | 143.2 | 136.8 | 4.7 |
| 02G1 | 3284 | 2087317 | 01 | 3 | 148.6 | 139.7 | 6.3 |
| 02G1 | 3284 | 2087317 | 01 | 4 | 149.0 | 139.2 | 7.0 |
| 025B | 3338 | 2116328 | IA01 | 1 | 127.1 | 122.5 | 3.7 |
| 025B | 3338 | 2116328 | IA01 | 2 | 136.9 | 129.8 | 5.5 |
| 025B | 3338 | 2116328 | IA01 | 3 | 145.9 | 136.9 | 6.6 |
| 025B | 3338 | 2116328 | IA01 | 4 | 145.1 | 133.5 | 8.7 |
| 020J | 3401 | 2104182 | 01 | 1 | 132.2 | 129.4 | 2.1 |
| 020J | 3401 | 2104182 | 01 | 2 | 140.7 | 135.6 | 3.7 |
| 020J | 3401 | 2104182 | 01 | 3 | 146.0 | 137.8 | 6.0 |
| 020J | 3401 | 2104182 | 01 | 4 | 144.2 | 134.3 | 7.3 |
| 00GR | 3504 | 2110045 | 02 | 1 | 139.7 | 134.3 | 4.0 |
| 00GR | 3504 | 2110045 | 02 | 2 | 146.9 | 138.4 | 6.1 |
| 00GR | 3504 | 2110045 | 02 | 3 | 145.7 | 135.2 | 7.8 |
| 00GR | 3504 | 2110045 | 02 | 4 | 143.5 | 131.2 | 9.4 |
| 03Q4 | 4068 | 2151077 | 02 | 1 | 124.4 | 121.6 | 2.3 |
| 03Q4 | 4068 | 2151077 | 02 | 2 | 133.8 | 129.3 | 3.5 |
| 03Q4 | 4068 | 2151077 | 02 | 3 | 141.4 | 135.5 | 4.4 |
| 03Q4 | 4068 | 2151077 | 02 | 4 | 145.1 | 137.0 | 6.0 |
| 02Q1 | 4076 | 2173813 | 02 | 1 | 128.9 | 121.7 | 5.9 |
| 02Q1 | 4076 | 2173813 | 02 | 2 | 136.6 | 126.6 | 7.9 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 02Q1 | 4076 | 2173813 | 02 | 3 | 141.8 | 129.1 | 9.8 |
| 02Q1 | 4076 | 2173813 | 02 | 4 | 140.2 | 127.7 | 9.8 |
| 0357 | 4180 | 2166515 | 02 | 1 | 142.0 | 135.9 | 4.5 |
| 0357 | 4180 | 2166515 | 02 | 2 | 144.9 | 136.8 | 5.9 |
| 0357 | 4180 | 2166515 | 02 | 3 | 148.8 | 138.9 | 7.1 |
| 0357 | 4180 | 2166515 | 02 | 4 | 148.3 | 137.2 | 8.1 |
| 0357 | 4180 | 2166515 | 02 | 5 | 136.2 | 131.3 | 3.7 |
| 02SE | 4219 | 2166562 | 01 | 1 | 129.9 | 126.6 | 2.6 |
| 02SE | 4219 | 2166562 | 01 | 2 | 137.6 | 132.5 | 3.9 |
| 02SE | 4219 | 2166562 | 01 | 3 | 144.1 | 137.1 | 5.1 |
| 02SE | 4219 | 2166562 | 01 | 4 | 148.1 | 138.8 | 6.7 |
| 049J | 4324 | 2172989 | 01 | 1 | 135.2 | 130.1 | 3.9 |
| 049J | 4324 | 2172989 | 01 | 2 | 145.1 | 137.7 | 5.4 |
| 049J | 4324 | 2172989 | 01 | 3 | 148.3 | 139.1 | 6.6 |
| 049J | 4324 | 2172989 | 01 | 4 | 146.7 | 136.5 | 7.4 |
| 02AB | 4514 | 2197078 | 02 | 1 | 134.0 | 129.6 | 3.4 |
| 02AB | 4514 | 2197078 | 02 | 2 | 142.8 | 136.4 | 4.7 |
| 02AB | 4514 | 2197078 | 02 | 3 | 146.9 | 138.1 | 6.4 |
| 02AB | 4514 | 2197078 | 02 | 4 | 144.8 | 134.1 | 8.0 |
| 3465 | 4586 | 2204159 | 01 | 1 | 131.6 | 128.4 | 2.5 |
| 3465 | 4586 | 2204159 | 01 | 2 | 136.8 | 131.3 | 4.2 |
| 3465 | 4586 | 2204159 | 01 | 3 | 145.3 | 137.3 | 5.8 |
| 3465 | 4586 | 2204159 | 01 | 4 | 147.7 | 136.3 | 8.4 |
| 6925 | 4588 | 2203731 | 01 | 1 | 134.1 | 130.4 | 2.9 |
| 6925 | 4588 | 2203731 | 01 | 2 | 139.1 | 137.1 | 1.4 |
| 6925 | 4588 | 2203731 | 01 | 3 | 146.5 | 139.1 | 5.3 |
| 6925 | 4588 | 2203731 | 01 | 4 | 146.1 | 136.8 | 6.8 |
| 04DA | 5050 | 2224917 | 02 | 1 | 128.7 | 126.5 | 1.7 |
| 04DA | 5050 | 2224917 | 02 | 2 | 134.8 | 131.0 | 2.9 |
| 04DA | 5050 | 2224917 | 02 | 3 | 143.9 | 137.8 | 4.4 |
| 04DA | 5050 | 2224917 | 02 | 4 | 146.0 | 137.8 | 5.9 |
| 020U | 5120 | 2224562 | 01 | 1 | 125.5 | 123.5 | 1.6 |
| 020U | 5120 | 2224562 | 01 | 2 | 129.3 | 125.6 | 3.0 |
| 020U | 5120 | 2224562 | 01 | 3 | 136.3 | 130.6 | 4.4 |
| 020U | 5120 | 2224562 | 01 | 4 | 145.5 | 136.9 | 6.2 |
| 020U | 5120 | 2224562 | 01 | 5 | 150.6 | 139.0 | 8.4 |
| 03C2 | 5178 | 2226043 | 02 | 1 | 126.0 | 123.2 | 2.3 |
| 03C2 | 5178 | 2226043 | 02 | 2 | 135.3 | 130.8 | 3.4 |
| 03C2 | 5178 | 2226043 | 02 | 3 | 143.1 | 136.8 | 4.6 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 03C2 | 5178 | 2226043 | 02 | 4 | 148.3 | 139.6 | 6.2 |
| 03C2 | 5178 | 2226043 | 02 | 5 | 148.8 | 136.5 | 9.0 |

**Table B-17: DOT-40 points used for compaction curves with a maximum dry unit weight between 140 pcf to 142 pcf.**

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 3864 | 1170 | 1092095 | 01 | 1 | 125.1 | 123.3 | 1.4 |
| 3864 | 1170 | 1092095 | 01 | 2 | 131.2 | 128.1 | 2.4 |
| 3864 | 1170 | 1092095 | 01 | 3 | 139.2 | 134.5 | 3.5 |
| 3864 | 1170 | 1092095 | 01 | 4 | 146.5 | 140.2 | 4.5 |
| 3864 | 1170 | 1092095 | 01 | 5 | 145.7 | 137.2 | 6.2 |
| 5658 | 1450 | 1261746 | 1 | 1 | 121.8 | 119.6 | 1.8 |
| 5658 | 1450 | 1261746 | 02 | 2 | 131.6 | 127.6 | 3.1 |
| 5658 | 1450 | 1261746 | 1 | 3 | 141.5 | 135.9 | 4.1 |
| 5658 | 1450 | 1261746 | 02 | 4 | 148.3 | 139.8 | 6.0 |
| 107N | 1462 | 1083366 | 01 | 1 | 130.4 | 129.1 | 1.1 |
| 107N | 1462 | 1083366 | 01 | 2 | 133.1 | 129.8 | 2.5 |
| 107N | 1462 | 1083366 | 01 | 3 | 142.6 | 137.3 | 3.8 |
| 107N | 1462 | 1083366 | 01 | 4 | 148.9 | 140.4 | 6.1 |
| 107N | 1462 | 1083366 | 01 | 5 | 148.4 | 137.3 | 8.1 |
| 5586 | 2103 | 1467520 | 02 | 1 | 134.6 | 131.4 | 2.5 |
| 5586 | 2103 | 1467520 | 02 | 2 | 144.7 | 139.4 | 3.8 |
| 5586 | 2103 | 1467520 | 02 | 3 | 148.8 | 141.3 | 5.3 |
| 5586 | 2103 | 1467520 | 02 | 4 | 149.0 | 139.6 | 6.7 |
| 00E4 | 2182 | 1430197 | 02 | 1 | 130.5 | 128.1 | 1.8 |
| 00E4 | 2182 | 1430197 | 02 | 2 | 138.0 | 133.7 | 3.2 |
| 00E4 | 2182 | 1430197 | 02 | 3 | 146.7 | 139.8 | 5.0 |
| 00E4 | 2182 | 1430197 | 02 | 4 | 147.3 | 138.7 | 6.2 |
| 00DV | 2252 | 1414276 | 01 | 1 | 128.0 | 125.2 | 2.3 |
| 00DV | 2252 | 1414276 | 01 | 2 | 136.0 | 131.5 | 3.4 |
| 00DV | 2252 | 1414276 | 01 | 3 | 147.7 | 140.1 | 5.4 |
| 00DV | 2252 | 1414276 | 01 | 4 | 148.9 | 140.2 | 6.2 |
| 6292 | 2264 | 2080343 | 01 | 1 | 143.6 | 137.4 | 4.5 |
| 6292 | 2264 | 2080343 | 01 | 2 | 148.4 | 140.2 | 5.8 |
| 6292 | 2264 | 2080343 | 01 | 3 | 147.2 | 137.5 | 7.0 |
| 6292 | 2264 | 2080343 | 01 | 4 | 145.7 | 135.0 | 7.9 |
| 6436 | 2717 | 2079075 | 01 | 1 | 129.8 | 125.3 | 3.6 |
| 6436 | 2717 | 2079075 | 01 | 2 | 139.3 | 132.7 | 5.0 |
| 6436 | 2717 | 2079075 | 01 | 3 | 145.5 | 134.3 | 8.3 |
| 6436 | 2717 | 2079075 | 01 | 4 | 143.8 | 132.5 | 8.5 |
| 00RE | 3296 | 2098574 | 01 | 1 | 129.8 | 125.7 | 3.2 |
| 00RE | 3296 | 2098574 | 01 | 2 | 135.7 | 129.5 | 4.8 |
| 00RE | 3296 | 2098574 | 01 | 3 | 145.5 | 137.2 | 6.1 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 00RE | 3296 | 2098574 | 01 | 4 | 145.2 | 133.9 | 8.5 |
| 00X9 | 3607 | 2133080 | 01 | 1 | 131.4 | 129.2 | 1.7 |
| 00X9 | 3607 | 2133080 | 01 | 2 | 136.8 | 132.5 | 3.2 |
| 00X9 | 3607 | 2133080 | 01 | 3 | 145.0 | 138.6 | 4.6 |
| 00X9 | 3607 | 2133080 | 01 | 4 | 148.6 | 140.0 | 6.1 |
| I1ZZ | 3610 | 2103548 | 01 | 1 | 128.4 | 125.4 | 2.4 |
| I1ZZ | 3610 | 2103548 | 01 | 2 | 140.4 | 135.4 | 3.7 |
| I1ZZ | 3610 | 2103548 | 01 | 3 | 146.6 | 139.5 | 5.1 |
| I1ZZ | 3610 | 2103548 | 01 | 4 | 149.5 | 139.9 | 6.9 |
| H021 | 3634 | 2126475 | 01 | 1 | 129.2 | 126.8 | 1.8 |
| H021 | 3634 | 2126475 | 01 | 2 | 138.8 | 134.6 | 3.2 |
| H021 | 3634 | 2126475 | 01 | 3 | 147.6 | 140.7 | 4.8 |
| H021 | 3634 | 2126475 | 01 | 4 | 149.2 | 140.8 | 5.9 |
| 02ZN | 3663 | 2126396 | 01 | 1 | 129.2 | 126.8 | 1.8 |
| 02ZN | 3663 | 2126396 | 01 | 2 | 138.8 | 134.6 | 3.2 |
| 02ZN | 3663 | 2126396 | 01 | 3 | 147.6 | 140.7 | 4.8 |
| 02ZN | 3663 | 2126396 | 01 | 4 | 149.2 | 140.8 | 5.9 |
| 00L5 | 3778 | 2145514 | IA01 | 1 | 130.4 | 125.6 | 3.9 |
| 00L5 | 3778 | 2145514 | IA01 | 2 | 141.2 | 133.8 | 5.5 |
| 00L5 | 3778 | 2145514 | IA01 | 3 | 148.8 | 139.5 | 6.7 |
| 00L5 | 3778 | 2145514 | IA01 | 4 | 144.5 | 131.8 | 9.7 |
| 00QC | 3832 | 2151550 | 01 | 1 | 136.9 | 132.7 | 3.2 |
| 00QC | 3832 | 2151550 | 01 | 2 | 143.8 | 137.5 | 4.5 |
| 00QC | 3832 | 2151550 | 01 | 3 | 148.8 | 141.0 | 5.5 |
| 00QC | 3832 | 2151550 | 01 | 4 | 148.2 | 140.0 | 5.9 |
| 023D | 3931 | 2160089 | 01 | 1 | 135.2 | 132.2 | 2.2 |
| 023D | 3931 | 2160089 | 01 | 2 | 142.5 | 137.1 | 4.0 |
| 023D | 3931 | 2160089 | 01 | 3 | 148.5 | 140.7 | 5.6 |
| 023D | 3931 | 2160089 | 01 | 4 | 147.3 | 136.9 | 7.6 |
| 03HK | 3938 | 2152515 | 01 | 1 | 133.8 | 128.8 | 3.9 |
| 03HK | 3938 | 2152515 | 01 | 2 | 145.1 | 137.7 | 5.4 |
| 03HK | 3938 | 2152515 | 01 | 3 | 149.3 | 140.5 | 6.3 |
| 03HK | 3938 | 2152515 | 01 | 4 | 145.3 | 135.0 | 7.6 |
| 00D0 | 3980 | 2157953 | 01 | 1 | 131.9 | 128.9 | 2.3 |
| 00D0 | 3980 | 2157953 | 01 | 2 | 143.3 | 137.3 | 4.4 |
| 00D0 | 3980 | 2157953 | 01 | 3 | 149.9 | 141.8 | 5.7 |
| 00D0 | 3980 | 2157953 | 01 | 4 | 148.3 | 139.3 | 6.5 |
| 022E | 4074 | 2194424 | 01 | 1 | 128.7 | 126.9 | 1.4 |
| 022E | 4074 | 2194424 | 01 | 2 | 135.3 | 131.6 | 2.8 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 022E | 4074 | 2194424 | 01 | 3 | 141.9 | 136.4 | 4.0 |
| 022E | 4074 | 2194424 | 01 | 4 | 150.0 | 141.5 | 6.0 |
| 00YX | 4173 | 2184259 | 01 | 1 | 130.9 | 127.8 | 2.4 |
| 00YX | 4173 | 2184259 | 01 | 2 | 144.5 | 138.8 | 4.2 |
| 00YX | 4173 | 2184259 | 01 | 3 | 147.7 | 139.6 | 5.8 |
| 00YX | 4173 | 2184259 | 01 | 4 | 147.2 | 135.3 | 8.8 |
| 0297 | 4233 | 2178531 | IA01 | 1 | 131.6 | 128.3 | 2.6 |
| 0297 | 4233 | 2178531 | IA01 | 2 | 137.7 | 132.2 | 4.2 |
| 0297 | 4233 | 2178531 | IA01 | 3 | 148.2 | 140.0 | 5.9 |
| 0297 | 4233 | 2178531 | IA01 | 4 | 147.3 | 136.6 | 7.8 |
| I2TX | 4397 | 2183565 | IA02 | 1 | 145.3 | 138.2 | 5.1 |
| I2TX | 4397 | 2183565 | IA02 | 2 | 146.6 | 138.0 | 6.2 |
| I2TX | 4397 | 2183565 | IA02 | 3 | 145.6 | 135.9 | 7.1 |
| I2TX | 4397 | 2183565 | IA02 | 4 | 144.8 | 135.9 | 6.5 |
| 028L | 4439 | 2189750 | 01 | 1 | 128.9 | 126.0 | 2.3 |
| 028L | 4439 | 2189750 | 01 | 2 | 137.2 | 131.7 | 4.2 |
| 028L | 4439 | 2189750 | 01 | 3 | 141.9 | 135.0 | 5.1 |
| 028L | 4439 | 2189750 | 01 | 4 | 151.3 | 141.9 | 6.6 |
| 1162 | 4992 | 2222983 | 01 | 1 | 127.7 | 125.7 | 1.6 |
| 1162 | 4992 | 2222983 | 01 | 2 | 136.5 | 132.4 | 3.1 |
| 1162 | 4992 | 2222983 | 01 | 3 | 145.5 | 139.0 | 4.6 |
| 1162 | 4992 | 2222983 | 01 | 4 | 149.1 | 139.2 | 7.1 |
| 04QE | 4719 | 2203697 | 01 | 1 | 129.7 | 127.7 | 1.6 |
| 04QE | 4719 | 2203697 | 01 | 2 | 131.1 | 127.5 | 2.8 |
| 04QE | 4719 | 2203697 | 01 | 3 | 142.9 | 136.9 | 4.4 |
| 04QE | 4719 | 2203697 | 01 | 4 | 150.0 | 140.3 | 6.9 |
| 04QE | 4719 | 2203697 | 01 | 5 | 149.5 | 138.4 | 8.0 |

**Table B-18: DOT-40 points used for compaction curves with a maximum dry unit weight between 142 pcf to 144 pcf.**

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 01BP | 3075 | 2087523 | 01 | 1 | 138.2 | 133.4 | 3.6 |
| 01BP | 3075 | 2087523 | 01 | 2 | 146.3 | 140.0 | 4.5 |
| 01BP | 3075 | 2087523 | 01 | 3 | 150.1 | 142.3 | 5.5 |
| 01BP | 3075 | 2087523 | 01 | 4 | 150.3 | 141.3 | 6.4 |
| H079 | 4116 | 2158306 | 01 | 1 | 134.6 | 131.3 | 2.5 |
| H079 | 4116 | 2158306 | 01 | 2 | 144.2 | 138.6 | 4.1 |
| H079 | 4116 | 2158306 | 01 | 3 | 149.7 | 142.3 | 5.2 |
| H079 | 4116 | 2158306 | 01 | 4 | 149.7 | 141.7 | 5.7 |
| 02S8 | 4907 | 2207599 | 01 | 1 | 131.2 | 128.6 | 2.0 |
| 02S8 | 4907 | 2207599 | 01 | 2 | 136.0 | 131.3 | 3.6 |
| 02S8 | 4907 | 2207599 | 01 | 3 | 147.5 | 139.6 | 5.6 |
| 02S8 | 4907 | 2207599 | 01 | 4 | 150.1 | 138.5 | 8.4 |
| 04GR | 5512 | 2227605 | 01 | 1 | 131.2 | 128.6 | 2.0 |
| 04GR | 5512 | 2227605 | 01 | 2 | 136.0 | 131.3 | 3.6 |
| 04GR | 5512 | 2227605 | 01 | 3 | 147.5 | 139.6 | 5.6 |
| 04GR | 5512 | 2227605 | 01 | 4 | 150.1 | 138.5 | 8.4 |
| 3864 | 1170 | 1087625 | 01 | 1 | 129.0 | 127.5 | 1.2 |
| 3864 | 1170 | 1087625 | 01 | 2 | 133.1 | 130.4 | 2.1 |
| 3864 | 1170 | 1087625 | 01 | 3 | 144.1 | 140.4 | 2.7 |
| 3864 | 1170 | 1087625 | 01 | 4 | 148.7 | 142.6 | 4.3 |
| 3864 | 1170 | 1087625 | 01 | 5 | 145.9 | 137.2 | 6.3 |
| 3151 | 1438 | 1256497 | 03 | 1 | 140.3 | 134.3 | 4.4 |
| 3151 | 1438 | 1256497 | 03 | 2 | 144.8 | 136.7 | 5.9 |
| 3151 | 1438 | 1256497 | 03 | 3 | 143.1 | 133.5 | 7.2 |
| 3151 | 1438 | 1256497 | 03 | 4 | 142.8 | 136.6 | 4.5 |
| 6688 | 1653 | 1261743 | 01 | 1 | 132.8 | 129.9 | 2.2 |
| 6688 | 1653 | 1261743 | 01 | 2 | 140.5 | 135.6 | 3.6 |
| 6688 | 1653 | 1261743 | 01 | 3 | 148.2 | 141.5 | 4.8 |
| 6688 | 1653 | 1261743 | 01 | 4 | 148.0 | 138.3 | 7.0 |
| 4259 | 1694 | 1294082 | 01 | 1 | 132.0 | 129.4 | 2.0 |
| 4259 | 1694 | 1294082 | 01 | 2 | 142.7 | 137.6 | 3.7 |
| 4259 | 1694 | 1294082 | 01 | 3 | 149.6 | 142.2 | 5.2 |
| 4259 | 1694 | 1294082 | 01 | 4 | 129.1 | 127.3 | 1.4 |
| 4259 | 1694 | 1294082 | 01 | 5 | 150.1 | 139.8 | 7.4 |
| 1939 | 2167 | 1414190 | 01 | 1 | 129.3 | 127.1 | 1.7 |
| 1939 | 2167 | 1414190 | 01 | 2 | 138.8 | 134.3 | 3.3 |
| 1939 | 2167 | 1414190 | 01 | 3 | 148.1 | 141.6 | 4.6 |

| Main PCN | Contract ID | Sample ID | Test # | Seq_Nbr | Wet Density (pcf) | Dry Density (pcf) | Moisture Content (%) |
|---|---|---|---|---|---|---|---|
| 1939 | 2167 | 1414190 | 01 | 4 | 150.8 | 142.2 | 6.0 |
| 01PQ | 2626 | 2067336 | 01 | 1 | 132.2 | 130.2 | 1.5 |
| 01PQ | 2626 | 2067336 | 01 | 2 | 138.1 | 134.1 | 3.0 |
| 01PQ | 2626 | 2067336 | 01 | 3 | 147.4 | 141.2 | 4.4 |
| 01PQ | 2626 | 2067336 | 01 | 4 | 149.3 | 140.1 | 6.5 |
| 01B5 | 2930 | 2080354 | 01 | 1 | 126.5 | 123.8 | 2.2 |
| 01B5 | 2930 | 2080354 | 01 | 2 | 140.4 | 134.5 | 4.3 |
| 01B5 | 2930 | 2080354 | 01 | 3 | 148.2 | 140.1 | 5.8 |
| 01B5 | 2930 | 2080354 | 01 | 4 | 149.3 | 136.2 | 9.6 |
| 02G1 | 3284 | 2094340 | 02 | 1 | 131.9 | 127.9 | 3.2 |
| 02G1 | 3284 | 2094340 | 02 | 2 | 143.2 | 137.4 | 4.2 |
| 02G1 | 3284 | 2094340 | 02 | 3 | 150.3 | 142.4 | 5.6 |
| 02G1 | 3284 | 2094340 | 02 | 4 | 149.9 | 140.0 | 7.1 |
| 01BT | 3554 | 2130660 | 01 | 1 | 137.8 | 132.9 | 3.6 |
| 01BT | 3554 | 2130660 | 01 | 2 | 149.0 | 141.8 | 5.1 |
| 01BT | 3554 | 2130660 | 01 | 3 | 150.9 | 141.4 | 6.8 |
| 01BT | 3554 | 2130660 | 01 | 4 | 126.1 | 123.0 | 2.5 |
| 0358 | 4421 | 2189275 | 01 | 1 | 129.7 | 127.3 | 1.9 |
| 0358 | 4421 | 2189275 | 01 | 2 | 134.5 | 130.1 | 3.4 |
| 0358 | 4421 | 2189275 | 01 | 3 | 146.7 | 140.1 | 4.7 |
| 0358 | 4421 | 2189275 | 01 | 4 | 149.7 | 141.7 | 5.7 |
| 0358 | 4421 | 2189275 | 01 | 5 | 149.1 | 138.5 | 7.6 |
| 04DA | 5050 | 2224599 | 01 | 1 | 132.9 | 129.8 | 2.4 |
| 04DA | 5050 | 2224599 | 01 | 2 | 145.6 | 139.5 | 4.3 |
| 04DA | 5050 | 2224599 | 01 | 3 | 150.5 | 143.0 | 5.3 |
| 04DA | 5050 | 2224599 | 01 | 4 | 146.9 | 137.2 | 7.0 |

The optimum moisture content and maximum dry unit weight determinations developed from the data are presented in Tables B-19 to B-32.

**Table B-19: OMC and maximum dry unit weight determinations less than 118 pcf.**

| Maximum Dry Unit Weight (pcf) | OMC (%) |
|---|---|
| 115.4 | 15.2 |
| 117.8 | 12.5 |
| 116.2 | 12.7 |

**Table B-20: OMC and maximum dry unit weight determinations between 118 pcf and 120 pcf.**

| Maximum Dry Unit Weight (pcf) | OMC (%) |
|---|---|
| 119.8 | 11.7 |
| 119.5 | 11.6 |
| 119.0 | 12.9 |
| 118.2 | 13.1 |
| 118.5 | 12.4 |
| 119.9 | 11.8 |
| 119.5 | 11.5 |
| 119.5 | 12.1 |
| 118.9 | 12.8 |
| 119.5 | 12.1 |
| 119.6 | 12.1 |

**Table B-21: OMC and maximum dry unit weight determinations between 120 pcf and 122 pcf.**

| Maximum Dry Unit Weight (pcf) | OMC (%) |
|---|---|
| 120.5 | 10.7 |
| 121.2 | 9.8 |
| 120.7 | 11.6 |
| 121.1 | 11.5 |
| 120.0 | 12.8 |
| 120.5 | 11.2 |
| 122.0 | 11.0 |
| 121.6 | 11.2 |
| 120.7 | 11.6 |
| 120.8 | 12.5 |
| 120.4 | 11.9 |
| 120.8 | 11.6 |
| 120.3 | 12.2 |
| 121.8 | 11.8 |
| 120.0 | 11.7 |
| 121.8 | 11.8 |
| 120.0 | 11.7 |

**Table B-22: OMC and maximum dry unit weight determinations between 122 pcf and 124 pcf.**

| Maximum Dry Unit Weight (pcf) | OMC (%) |
|---|---|
| 122.4 | 7.1 |
| 123.2 | 10.0 |
| 123.8 | 10.6 |
| 124.0 | 10.7 |
| 122.5 | 12.0 |
| 122.8 | 10.7 |

**Table B-23: OMC and maximum dry unit weight determinations between 124 pcf and 126 pcf.**

| Maximum Dry Unit Weight (pcf) | OMC (%) |
|---|---|
| 124.5 | 9.1 |
| 124.5 | 10.9 |
| 124.7 | 10.5 |
| 124.6 | 9.8 |
| 124.7 | 9.4 |
| 124.9 | 10.8 |
| 124.6 | 8.6 |
| 124.8 | 7.0 |
| 125.6 | 6.2 |
| 125.7 | 9.0 |
| 126.0 | 13.2 |
| 125.9 | 9.0 |
| 125.0 | 10.9 |
| 125.8 | 9.1 |
| 125.5 | 10.4 |
| 125.5 | 8.1 |

**Table B-24: OMC and maximum dry unit weight determinations between 126 pcf and 128 pcf.**

| Maximum Dry Unit Weight (pcf) | OMC (%) |
|---|---|
| 126.2 | 6.9 |
| 126.6 | 7.8 |
| 126.9 | 9.9 |
| 126.1 | 11.1 |
| 127.0 | 9.3 |
| 126.8 | 10.7 |
| 127.2 | 11.3 |
| 127.1 | 7.2 |
| 126.9 | 8.2 |
| 127.7 | 10.5 |
| 127.8 | 8.9 |
| 127.6 | 10.5 |

**Table B-25: OMC and maximum dry unit weight determinations between 128 pcf and 130 pcf.**

| Maximum Dry Unit Weight (pcf) | OMC (%) |
|---|---|
| 129.8 | 9.8 |
| 128.3 | 5.9 |
| 129.8 | 9.8 |
| 129.1 | 9.4 |
| 128.5 | 10.8 |
| 128.4 | 9.4 |
| 128.3 | 9.3 |
| 129.2 | 6.5 |
| 129.2 | 9.3 |
| 128.3 | 9.8 |
| 128.5 | 7.4 |
| 128.1 | 8.3 |
| 128.4 | 6.3 |
| 129.7 | 8.5 |
| 128.7 | 10.0 |
| 128.4 | 8.7 |
| 129.0 | 10.3 |
| 130.0 | 8.6 |
| 128.4 | 11.0 |
| 128.4 | 9.8 |
| 129.8 | 7.7 |
| 129.9 | 9.4 |
| 129.9 | 10.0 |
| 128.8 | 9.2 |
| 129.4 | 9.0 |
| 129.8 | 6.8 |
| 129.5 | 9.6 |
| 129.1 | 10.8 |
| 128.6 | 6.7 |
| 128.9 | 8.9 |
| 129.2 | 8.6 |
| 129.3 | 8.3 |
| 128.4 | 11.0 |
| 129.8 | 8.6 |
| 129.3 | 10.2 |
| 128.6 | 8.4 |
| 129.2 | 10.2 |
| 129.0 | 7.6 |
| 129.9 | 7.0 |
| 129.8 | 9.3 |

**Table B-26: OMC and maximum dry unit weight determinations between 130 pcf and 132 pcf.**

| Maximum Dry Unit Weight (pcf) | OMC (%) |
|---|---|
| 129.8 | 9.8 |
| 128.3 | 5.9 |
| 129.8 | 9.8 |
| 129.1 | 9.4 |
| 128.5 | 10.8 |
| 128.4 | 9.4 |
| 128.3 | 9.3 |
| 129.2 | 6.5 |
| 129.2 | 9.3 |
| 128.3 | 9.8 |
| 128.5 | 7.4 |
| 128.1 | 8.3 |
| 128.4 | 6.3 |
| 129.7 | 8.5 |
| 128.7 | 10.0 |
| 128.4 | 8.7 |
| 129.0 | 10.3 |
| 130.0 | 8.6 |
| 128.4 | 11.0 |
| 128.4 | 9.8 |
| 129.8 | 7.7 |
| 129.9 | 9.4 |
| 129.9 | 10.0 |
| 128.8 | 9.2 |
| 129.4 | 9.0 |
| 129.8 | 6.8 |
| 129.5 | 9.6 |
| 129.1 | 10.8 |
| 128.6 | 6.7 |
| 128.9 | 8.9 |
| 129.2 | 8.6 |
| 129.3 | 8.3 |
| 128.4 | 11.0 |
| 129.8 | 8.6 |
| 129.3 | 10.2 |
| 128.6 | 8.4 |
| 129.2 | 10.2 |
| 129.0 | 7.6 |
| 129.9 | 7.0 |
| 129.8 | 9.3 |

**Table B-27: OMC and maximum dry unit weight determinations between 132 pcf and 134 pcf.**

| Maximum Dry Unit Weight (pcf) | OMC (%) | Maximum Dry Unit Weight (pcf) | OMC (%) |
|---|---|---|---|
| 132.0 | 7.5 | 132.9 | 7.8 |
| 132.1 | 8.4 | 132.9 | 8.0 |
| 132.1 | 8.4 | 133.0 | 8.2 |
| 132.1 | 8.2 | 133.1 | 6.7 |
| 132.1 | 8.8 | 133.1 | 7.9 |
| 132.2 | 9.5 | 133.1 | 6.9 |
| 132.2 | 7.5 | 133.1 | 7.9 |
| 132.2 | 9.3 | 133.2 | 8.4 |
| 132.2 | 8.7 | 133.2 | 7.9 |
| 132.2 | 6.0 | 133.2 | 8.5 |
| 132.2 | 9.3 | 133.3 | 7.6 |
| 132.2 | 7.8 | 133.3 | 8.3 |
| 132.3 | 8.2 | 133.3 | 6.6 |
| 132.3 | 7.3 | 133.3 | 9.0 |
| 132.4 | 10.5 | 133.3 | 8.6 |
| 132.4 | 9.3 | 133.3 | 10.1 |
| 132.4 | 7.6 | 133.4 | 8.1 |
| 132.4 | 7.6 | 133.4 | 8.8 |
| 132.5 | 8.1 | 133.4 | 8.2 |
| 132.5 | 7.6 | 133.5 | 8.0 |
| 132.6 | 7.7 | 133.5 | 8.0 |
| 132.6 | 8.1 | 133.5 | 7.9 |
| 132.7 | 9.1 | 133.6 | 9.0 |
| 132.7 | 8.4 | 133.6 | 8.4 |
| 132.7 | 8.5 | 133.6 | 7.9 |
| 132.7 | 8.9 | 133.6 | 7.6 |
| 132.7 | 9.0 | 133.6 | 8.3 |
| 132.7 | 8.1 | 133.6 | 8.3 |
| 132.7 | 9.0 | 133.6 | 9.7 |
| 132.8 | 8.4 | 133.7 | 8.2 |
| 132.8 | 8.5 | 133.7 | 7.0 |
| 132.8 | 9.1 | 133.7 | 7.7 |
| 132.8 | 7.3 | 133.8 | 5.2 |
| 132.8 | 9.8 | 133.8 | 8.7 |
| 132.8 | 9.2 | 133.8 | 8.4 |
| 132.9 | 9.1 | 133.8 | 9.5 |
| 132.9 | 7.2 | 133.9 | 7.7 |
| 132.9 | 8.4 | 133.9 | 7.9 |
| 132.9 | 9.4 | 133.9 | 7.8 |
| 132.9 | 7.5 | 133.9 | 6.7 |

| Maximum Dry Unit Weight (pcf) | OMC (%) | Maximum Dry Unit Weight (pcf) | OMC (%) |
|---|---|---|---|
| 132.9 | 8.5 | 134.0 | 8.9 |
| 132.9 | 7.9 | 134.0 | 9.1 |
| 134.2 | 8.3 | 134.0 | 5.8 |
| 135.0 | 7.3 | 134.0 | 6.6 |

**Table B-28: OMC and maximum dry unit weight determinations between 134 pcf and 136 pcf.**

| Maximum Dry Unit Weight (pcf) | OMC (%) | Maximum Dry Unit Weight (pcf) | OMC (%) |
|---|---|---|---|
| 134.0 | 8.1 | 135.0 | 5.6 |
| 134.0 | 7.6 | 135.0 | 7.8 |
| 134.1 | 8.6 | 135.0 | 6.0 |
| 134.1 | 6.1 | 135.0 | 7.9 |
| 134.1 | 7.1 | 135.0 | 9.9 |
| 134.1 | 5.3 | 135.1 | 6.9 |
| 134.1 | 8.2 | 135.1 | 4.7 |
| 134.1 | 7.3 | 135.1 | 7.7 |
| 134.1 | 7.4 | 135.1 | 8.1 |
| 134.2 | 7.9 | 135.2 | 10.5 |
| 134.2 | 6.4 | 135.3 | 5.6 |
| 134.3 | 10.1 | 135.3 | 7.3 |
| 134.3 | 8.0 | 135.3 | 7.3 |
| 134.3 | 7.2 | 135.3 | 5.9 |
| 134.3 | 8.8 | 135.3 | 6.7 |
| 134.3 | 6.2 | 135.4 | 7.9 |
| 134.4 | 8.6 | 135.4 | 7.3 |
| 134.4 | 4.8 | 135.4 | 8.2 |
| 134.5 | 5.7 | 135.4 | 7.6 |
| 134.6 | 8.7 | 135.5 | 7.7 |
| 134.6 | 6.0 | 135.5 | 8.6 |
| 134.6 | 7.9 | 135.5 | 7.7 |
| 134.6 | 9.2 | 135.5 | 8.1 |
| 134.6 | 7.4 | 135.7 | 5.6 |
| 134.6 | 8.1 | 135.7 | 6.9 |
| 134.6 | 8.1 | 135.7 | 7.8 |
| 134.6 | 8.5 | 135.7 | 7.3 |
| 134.7 | 7.6 | 135.7 | 6.7 |
| 134.7 | 6.2 | 135.8 | 6.3 |
| 134.7 | 7.4 | 135.8 | 6.8 |
| 134.7 | 8.1 | 135.8 | 6.4 |
| 134.8 | 7.5 | 135.8 | 8.4 |
| 134.8 | 8.6 | 135.8 | 5.6 |
| 134.8 | 8.0 | 135.9 | 8.6 |
| 134.9 | 8.4 | 135.9 | 7.7 |
| 134.9 | 7.7 | 136.0 | 8.3 |
| 134.9 | 6.7 | 136.0 | 8.6 |
| 134.9 | 8.1 | 135.0 | 9.3 |
| 134.9 | 7.1 | 135.0 | 8.2 |
| 135.0 | 9.2 | | |

**Table B-29: OMC and maximum dry unit weight determinations between 136 pcf and 138 pcf.**

| Maximum Dry Unit Weight (pcf) | OMC (%) | Maximum Dry Unit Weight (pcf) | OMC (%) |
|---|---|---|---|
| 135.0 | 7.9 | 137.3 | 8.2 |
| 135.7 | 6.7 | 137.3 | 8.0 |
| 135.8 | 8.4 | 137.3 | 6.9 |
| 136.0 | 7.4 | 137.3 | 7.1 |
| 136.0 | 5.9 | 137.5 | 7.9 |
| 136.1 | 6.3 | 137.5 | 7.3 |
| 136.1 | 7.9 | 137.5 | 8.1 |
| 136.2 | 6.3 | 137.6 | 8.0 |
| 136.2 | 7.6 | 137.6 | 5.9 |
| 136.2 | 5.4 | 137.7 | 7.1 |
| 136.2 | 6.6 | 137.7 | 8.6 |
| 136.2 | 7.2 | 137.7 | 6.6 |
| 136.3 | 7.7 | 137.8 | 6.8 |
| 136.3 | 8.0 | 137.9 | 5.8 |
| 136.3 | 7.4 | 137.9 | 7.7 |
| 136.3 | 6.9 | 138.0 | 6.4 |
| 136.4 | 7.4 | 138.0 | 6.1 |
| 136.4 | 8.2 | 136.7 | 7.7 |
| 136.4 | 8.1 | 136.8 | 6.5 |
| 136.5 | 5.0 | 136.9 | 6.6 |
| 136.5 | 7.5 | 136.9 | 6.8 |
| 136.5 | 6.6 | 136.9 | 6.5 |
| 136.5 | 7.8 | 136.9 | 6.4 |
| 136.6 | 6.9 | 137.0 | 7.6 |
| 136.7 | 4.8 | 137.1 | 5.2 |
| 136.7 | 8.0 | 137.1 | 7.5 |
| 136.7 | 9.3 | 137.2 | 6.8 |
| 136.7 | 8.0 | 137.2 | 6.6 |
| 137.3 | 7.4 | 137.2 | 7.2 |
| 137.3 | 7.8 | | |

**Table B-30: OMC and maximum dry unit weight determinations between 138 pcf and 140 pcf.**

| Maximum Dry Unit Weight (pcf) | OMC (%) |
|---|---|
| 138.1 | 7.7 |
| 138.1 | 5.4 |
| 138.2 | 5.7 |
| 138.2 | 6.6 |
| 138.3 | 6.0 |
| 138.5 | 6.5 |
| 138.5 | 5.7 |
| 138.6 | 5.8 |
| 138.7 | 6.3 |
| 138.8 | 5.3 |
| 139.0 | 6.0 |
| 139.0 | 6.3 |
| 139.0 | 6.3 |
| 139.1 | 6.8 |
| 139.1 | 5.3 |
| 139.2 | 5.8 |
| 139.2 | 5.2 |
| 139.3 | 6.3 |
| 139.3 | 7.7 |
| 139.3 | 6.8 |
| 139.3 | 7.6 |
| 139.4 | 7.8 |
| 139.5 | 6.6 |
| 139.6 | 7.1 |
| 139.6 | 6.5 |
| 139.7 | 6.4 |
| 139.9 | 5.9 |
| 139.9 | 6.7 |

**Table B-31: OMC and maximum dry unit weight determinations between 140 pcf and 142 pcf.**

| Maximum Dry Unit Weight (pcf) | OMC (%) |
|---|---|
| 140.0 | 6.1 |
| 140.0 | 5.1 |
| 140.0 | 5.4 |
| 140.3 | 5.6 |
| 140.4 | 7.0 |
| 140.5 | 5.8 |
| 140.5 | 6.4 |
| 140.6 | 7.2 |
| 140.8 | 5.6 |
| 140.9 | 6.0 |
| 141.0 | 5.5 |
| 141.1 | 5.2 |
| 141.2 | 6.6 |
| 141.2 | 6.4 |
| 141.3 | 5.4 |
| 141.3 | 5.4 |
| 141.3 | 5.1 |
| 141.5 | 6.7 |
| 141.5 | 5.6 |
| 141.5 | 6.0 |
| 141.7 | 6.0 |
| 141.7 | 5.4 |
| 141.8 | 7.8 |
| 141.8 | 5.7 |
| 141.9 | 6.6 |

**Table B-32: OMC and maximum dry unit weight determinations between 142 pcf and 144 pcf.**

| Maximum Dry Unit Weight (pcf) | OMC (%) |
|---|---|
| 142.3 | 5.3 |
| 142.4 | 5.6 |
| 142.5 | 7.0 |
| 142.5 | 7.0 |
| 142.6 | 5.9 |
| 142.7 | 7.4 |
| 143.0 | 6.0 |
| 143.0 | 5.1 |
| 143.4 | 5.7 |
| 143.4 | 5.9 |
| 143.6 | 4.6 |
| 143.7 | 5.4 |
| 143.8 | 6.3 |
| 143.8 | 5.7 |
| 143.8 | 5.5 |

# APPENDIX C: SURVEYS

Form 1:
Dear Survey Participant:
The South Dakota Department of Transportation has contracted with the South Dakota State University Department of Civil Engineering to conduct research on methods of granular material compaction testing. The research is to evaluate new methods and technologies for granular material compaction control and verification.
The main objectives of the research is as follows:

- Evaluate the adequacy of using families of curves for granular materials
- Identify existing and possible alternatives for determining target density of granular bases
- Determine whether an alternative method of testing compaction of unprocessed and recycled granular materials should be used

This survey has been designed to gather information from other agencies regarding current methods, testing frequencies, equipment, and training requirements for granular compaction control and verification.
The survey will be supplementary to NCHRP Synthesis 456 - Non-Nuclear Methods for Compaction Control of Unbound Materials, which was conducted in the spring of 2013 and completed by your agency.
This survey is being sent to state departments of transportation. Your cooperation in completing the questionnaire will ensure the success of this research. If you are not the appropriate person at your agency to complete this questionnaire, please kindly reply and let us know who the correct person is.
Please complete and submit this survey by September 30th 2016. We estimate it should take approximately 5-10 minutes to complete. We are happy to conduct the survey via telephone conference if that is more convenient for you. When finished or if you have any questions, please email or contact the Principal Investigator Dr. Allen Jones at allen.jones@sdstate.edu or 605-688-6467. Note that any supporting materials you wish to send can also be sent directly to Dr. Allen Jones.

1. Please select all types of materials in which compaction quality control has been used by your agency. (Select all that apply)

**Options:** (Sands, Gravel, Limestone, Recycled HMA, Recycled PCC, and Other)

2. If density-based criterion is utilized by your agency during quality control of granular materials, please indicate the method used to determine target density. (Select all that apply)

**Options:** (Standard 4-Point Proctor, Modified 4-Point Proctor, Standard 1-Point Proctor, Modified 1-Point Proctor, Test Strip, and Other)

3. What is your agency's experience with using families of curves developed from laboratory test data to determine target density for granular materials?

**Options:** (Implemented in field projects, Evaluated in research studies only, Demonstrated in usage, Plan to use in the future, Not used or evaluated,

4. If families of curves for granular materials are used by your agency, have the families of curves been adopted from another state agency?

**Options:** (Yes, No, I don't know, and Families of curves not used)

5. If families of curves are used for which of the following granular materials are they used to determine target density? (Select all that apply)

**Options:** (Sands, Gravels, Limestone, Recycled HMA, Recycled PCC, None, and Families of curves not used)

6. Would you recommend the use of any of the non-nuclear density devices implemented or evaluated by your agency for compaction quality control of granular materials?
   **Options:** (Yes, No, I don't know, and Not used)

If Yes, please provide the device used.

7. Would your agency recommend the use of any of the stiffness/strength measurement devices used or evaluated by your agency for compaction quality control of granular materials?
   **Options:** (Yes, No, I don't know, and Not used)

If Yes, please provide the device used.

8. Has your agency implemented or evaluated any Intelligent Compaction (IC) systems for compaction quality control of granular materials?

**Options:** (Yes, No, I don't know)

9. Based on your agency's experience would you recommend the use of Intelligent Compaction (IC) systems for compaction quality control of granular materials?
   **Options:** (Yes, No, I don't know, and Not used)
10. Does your agency currently conduct compaction quality control of granular Bridge End Back Fill?
    **Options:** (Yes, No, I don't know)
11. Please specify which of the following devices your agency would recommend for determining in-situ moisture content of granular materials? (Select all that apply)

**Options:** (Moisture Analyzer, DOT600, Speedy Moisture Tester, Field Microwave, Moisture Density Indicator, Electrical Density Gauge, Time Domain Reflectometry Devices (Nuclear Density Gauge), Oven or Stovetop, and Other)

12. Based on the stated objectives of our research and the questions asked within this survey; please feel free to provide any additional information that may be useful to our work. (e.g. additional granular material research studies, procedures, specifications, equipment, methods, etc.)
13. May our research team contact your agency regarding the questions provided within this survey?

**Options:** (Yes or No)

If Yes, Please provide the following contact information: (Name, Position, Email, Phone number)

14. Additional comments:

Thank you for taking our survey. Your response is very important to us. If you have any questions or comments, again please feel free to contact Dr. Allen Jones at allen.jones@sdstate.edu or 605-695-6467.

Form 2:

Dear Survey Participant:
The South Dakota Department of Transportation has contracted with the South Dakota State University Department of Civil Engineering to conduct research on methods of granular material compaction testing. The research is to evaluate new methods and technologies for granular material compaction control and verification.
The main objectives of the research is as follows:

- Evaluate the adequacy of using families of curves for granular materials
- Identify existing and possible alternatives for determining target density of granular bases
- Determine whether an alternative method of testing compaction of unprocessed and recycled granular materials should be used

This survey has been designed to gather information from other agencies regarding current methods, testing frequencies, equipment, and training requirements for granular compaction control and verification.
The survey results will be compared to NCHRP Synthesis 456 - Non-Nuclear Methods for Compaction Control of Unbound Materials, which was conducted in the spring of 2013.
This survey is being sent to state departments of transportation. Your cooperation in completing the questionnaire will ensure the success of this research. If you are not the appropriate person at your agency to complete this questionnaire, please kindly reply and let us know who the correct person is.
Please complete and submit this survey by September 30th 2016. We estimate it should take approximately 5-10 minutes to complete. We are happy to conduct the survey via telephone conference if that is more convenient for you. When finished or if you have any questions, please email or contact the Principal Investigator Dr. Allen Jones at allen.jones@sdstate.edu or 605-688-6467. Note that any supporting materials you wish to send can also be sent directly to Dr. Allen Jones.

1. Please select all types of materials in which compaction quality control has been use by your agency. (Select all that apply)

**Options:** (Sands, Gravel, Limestone, Recycled HMA, Recycled PCC, and Other)

2. If density-based criterion is utilized by your agency during quality control of granular materials, please indicate the method used to determine target density. (Select all that apply)

**Options:** (Standard 4-Point Proctor, Modified 4-Point Proctor, Standard 1-Point Proctor, Modified 1-Point Proctor, Test Strip, and Other)

3. What is your agency's experience with using families of curves developed from laboratory test data to determine target density for granular materials?

**Options:** (Implemented in field projects, Evaluated in research studies only, Demonstrated in usage, Plan to use in the future, and Not used or evaluated)

4. If families of curves for granular materials are used by your agency, have they been adopted from another state agency?

**Options:** (Yes, No, I don't know, and Families of curves not used)

5. If families of curves are used for which of the following granular materials are they used to determine target density? (Select all that apply)

**Options:** (Sands, Gravels, Limestone, Recycled HMA, Recycled PCC, None, and Families of curves not used)

6. Which of the following non-nuclear density devices have your agency implemented or evaluated for compaction quality control of granular materials? (Select all that Apply)

**Options:** (Sand Cone, Balloon Method, Electrical Density Gauge (EDG), Soil Density Indicator (SDI), and Other)

7. Would you recommend the use of any of the non-nuclear density devices implemented or evaluated by your agency for compaction quality control of granular materials?

**Options:** (Yes, No, I don't know, and Not used)
If Yes, please provide name the device used.

8. Which of the following stiffness / strength measurement devices have your agency implemented or evaluated for compaction quality control of granular materials? (Select all that Apply)

**Options**: (Clegg Hammer (CH), GeoGauge, Dynamic Cone Penetrometer (DCP), Light Weight Deflectometer (LWD), Portable Seismic Property Analyzer, Soil Compaction Supervisor (SCS), Briaud Compaction Devise (BCD), Other, and None)

9. Would your agency recommend the use of any of the stiffness/strength measurement devices for compaction quality control of granular materials?

**Options:** (Yes, No, I don't know, and Not used)
If Yes, please provide the device used.

10. Has your agency implemented or evaluated any Intelligent Compaction (IC) systems for compaction quality control of granular materials?

**Options:** (Yes, No, and I don't know)

11. Based on your agency's experience would you recommend the use of Intelligent Compaction (IC) systems for compaction quality control of granular materials?
    **Options:** (Yes, No, I don't know, and Not used)
12. Does your agency currently conduct compaction quality control on granular Bridge End Back Fill?
    **Options:** (Yes, No, and I don't know)
13. Please specify which of the following devices your agency would recommend for determining in-situ moisture content of granular materials? (Select all that apply)
    **Options:** (Moisture Analyzer, DOT600, Speedy Moisture Tester, Field Microwave, Moisture Density Indicator, Electrical Density Gauge, Time Domain Reflectometry Devices (Nuclear Density Gauge), Oven or Stovetop, and Other)
14. Based on the stated objectives of our research and the questions asked within this survey; please feel free to provide any additional information that may be useful to our work. (e.g. additional granular material research studies, procedures, specifications, equipment, methods, etc.)

15. May our research team contact your agency regarding the questions provided within this survey?
    **Options:** (Yes or No)
    If Yes, Please provide the following contact information: (Name, Position, Email, Phone number)
16. Additional comments:

Thank you for taking our survey. Your response is very important to us. If you have any questions or comments, again please feel free to contact Dr. Allen Jones at allen.jones@sdstate.edu or 605-695-6467.

The response to each question from each respondent are presented in Tables C-1 and C-2.

**Table C-1: Detailed Responses to survey Form 1.**

| Question Number | Minnesota DOT | Ohio DOT |
|---|---|---|
| 1. Please select all types of materials in which compaction quality control has been used by your agency. (Select all that apply) | Sand, Gravel Limestone, Recycled HMA, Recycled PCC | Sands, Gravel, Limestone, Recycled HMA, Recycled PCC. |
| 2. If density-based criterion is utilized by your agency during quality control of granular materials, please indicate the method used to determine target density. (Select all that apply) | Standard 4-Point Proctor, Standard 1-Point Proctor | Standard 1-Point Proctor, Test Strip. |
| 3. What is your agency's experience with using families of curves developed from laboratory test data to determine target density for granular materials? | Implemented in field projects, Demonstrated in usage | Implemented in field projects. |
| 4. If families of curves for granular materials are used by your agency, have the families of curves been adopted from another state agency? | I don't know | No. |
| 5. If families of curves are used for which of the following granular materials are they used to determine target density? (Select all that apply) | Sands, Gravels, Limestone | Sands, Gravels. |
| 6. Would you recommend the use of any of the non-nuclear density devices implemented or evaluated by your agency for compaction quality control of granular materials? If Yes, please provide the device used. | Yes, DCP | Do not use. |
| 7. Would your agency recommend the use of any of the stiffness/strength measurement devices used or evaluated by your agency for compaction quality control of granular materials? If Yes, please provide the device used. | No | Do not use. |
| 8. Has your agency implemented or evaluated any Intelligent Compaction (IC) systems for compaction quality control of granular materials? | Yes | Yes. |

| Question Number | Minnesota DOT | Ohio DOT |
| --- | --- | --- |
| 9. Based on your agency's experience would you recommend the use of Intelligent Compaction (IC) systems for compaction quality control of granular materials? | No | No. |
| 10. Does your agency currently conduct compaction quality control of granular Bridge End Back Fill? | Yes | Yes. |
| 11. Options: (Moisture Analyzer, DOT600, Speedy Moisture Tester, Field Microwave, Moisture Density Indicator, Electrical Density Gauge, Time Domain Reflectometry Devices (Nuclear Density Gauge), Oven or Stovetop, and Other) | Speedy Moisture Tester, Field microwave, NDG, Oven or Stovetop | Field Microwave, NDG, Oven or Stovetop. |

**Table C-2: Detailed Responses to survey Form 2.**

| Question Number | Indiana DOT | Texas DOT |
|---|---|---|
| 1. Please select all types of materials in which compaction quality control has been use by your agency. (Select all that apply) | Sands. | All of them. |
| 2. If density-based criterion is utilized by your agency during quality control of granular materials, please indicate the method used to determine target density. | Standard 4-Point Proctor, Standard 1-Point Proctor. | Standard 4-Point Proctor. |
| 3. What is your agency's experience with using families of curves developed from laboratory test data to determine target density for granular materials? | Implemented in field projects. | Not used or evaluated. |
| 4. If families of curves for granular materials are used by your agency, have they been adopted from another state agency? | I don't know. | Families of Curves not used. |
| 5. If families of curves are used for which of the following granular materials are they used to determine target density? (Select all that apply) | Sands. | Families of Curves not used. |
| 6. Which of the following non-nuclear density devices have your agency implemented or evaluated for compaction quality control of granular materials? (Select all that Apply) | Sand Cone, Balloon, Other. | Sand Cone, Electrical Density Gauge (EDG), Soil Density Indicator (SDI), NDG. |
| 7. Would you recommend the use of any of the non-nuclear density devices implemented or evaluated by your agency for compaction quality control of granular materials? If Yes, please provide name the device used. | I don't know. | No. |
| 8. Which of the following stiffness / strength measurement devices have your agency implemented or evaluated for compaction quality control of granular materials? (Select all that Apply) | Clegg Hammer, GeoGauge, DCP, LWD. | Clegg Hammer, GeoGauge, DCP, LWD, Portable Seismic Property Analyzer, Briaud Compaction Device. |
| 9. Would your agency recommend the use of any of the stiffness/strength measurement devices for compaction quality control of granular materials? If Yes, please provide the device used. | I don't know. | Yes, LWD. |

| Question Number | Indiana DOT | Texas DOT |
|---|---|---|
| 10. Has your agency implemented or evaluated any Intelligent Compaction (IC) systems for compaction quality control of granular materials? | Yes. | Yes. |
| 11. Based on your agency's experience would you recommend the use of Intelligent Compaction (IC) systems for compaction quality control of granular materials? | No. Not at this point. | Yes. |
| 12. Does your agency currently conduct compaction quality control on granular Bridge End Back Fill? | No. | No. |
| 13. Please specify which of the following devices your agency would recommend for determining in-situ moisture content of granular materials? (Select all that apply) | Field microwave, NDG, Oven or Stovetop. | Field microwave, Oven or Stovetop. |