Chapter 200

Soils – 18

Soils are the foundation for transportation construction. Pavement and structures built on the soils rely on engineered soil properties. The soil placement is vital to construction quality. The quality of the pavement mix, design, and construction is meaningless if the soils below the pavement settle, heave, or slide.

Soil and embankment inspectors and testers need to understand basic information about soils, testing procedures to classify soils, and how different soil types behave when they are used as an engineered material (i.e compaction, drainage, stability, etc.). Testers working on a CDOT project are required to be certified with, or under the guidance of a tester certified with the Western Alliance for Quality Transportation Construction (WAQTC) and CDOT's Soils, Excavation, & Embankment Inspection. Because the certifications cover testing in detail, this chapter provides a summary of basic soil mechanics and laboratory testing procedures used to determine soil index and engineering properties.

GENERAL SOIL PROPERTIES

There are three divisions of particle sizes that are determined from a gradation analysis: gravel, sand (course and fine), and fines (silt and clay). Sand and gravel are granular soils that are non-cohesive with particles that are visible to the naked eye. Soils composed primarily of sand and gravel have high strength, a high porosity (i.e. good drainage), and are not prone to long-term post-construction settlement. These soils are also easier to work with to gain adequate compaction during construction. Soils composed primarily of sand; however, are highly erodible.

Natural deposits of granular soils are described based on their in-situ density using the following terms: very loose, loose, medium dense, dense, and very dense. The denser the soil deposit, the higher the strength. This information is collected with field tests during a subsurface investigation program.

Silt and clay are classified as "fines", or particles that pass the No. 200 sieve for a gradation analysis. These particles are not distinguishable by the naked eye. Silt is the courser portion of the fines content (particle sizes varying from 0.002 mm to 0.075 mm). Soils composed primarily of silt are non-cohesive and are characterized by low plasticity. Soils composed primarily of silt are also highly erodible, and the same density terms used to describe sand also apply to silty soils.

Clay is cohesive and can have a high variability in plasticity, depending on the mineralogy of the clay particles present. Clay represents particles smaller than 0.002 mm, or 2 microns (µm) in a soil sample. The terms that are used to describe clayey soils refer to their "consistency" or "cohesiveness": very soft, soft, medium stiff, stiff, very stiff, and hard. The cohesion of a clay soil is an indication of its strength, and softer clay soils are characterized by a lower cohesion or lower strength. This information is also collected with field tests during a subsurface investigation program.

Both silt and clay soils are characterized by low permeability (i.e. water does not flow through these soils quickly and they do not drain well). They have lower strength than sand and gravel, and they can be prone to long-term post-construction settlement. These soils are more difficult to work with during construction to achieve adequate compaction. Because of their low permeability, it is more difficult to moisture condition these soils uniformly to achieve near-optimum moisture conditions for adequate compaction.

The presence of fines within sandy or gravelly soils results in a decrease in strength, a decrease in permeability, and an increase in the likelihood of post-construction settlement.

GRADATION

A gradation analysis is a method used to quantitatively determine the distribution of particle sizes in soils, aggregate, or soil-aggregate mixtures. Colorado Procedure (CP) 21, Mechanical Analysis of Soils, describes the procedure to run this test. This test is also referred to as a grain size analysis, particle size analysis, or sieve analysis. A sufficient amount of soil needs to be sampled to run a representative gradation test. The minimum mass of material required is dependent on the Nominal Maximum Size of aggregate or particle in the sample. The Nominal Maximum Size is defined as the smallest sieve opening through which the entire amount of specimen passes.

ATTERBERG LIMITS

The Atterberg limits define the range of moisture contents in which a soil behaves as a plastic. As the moisture content of a clayey soil increases, the material behavior will change from a solid, to a semi-solid, to plastic, and eventually to a liquid. The specific moisture contents that need to be determined for AASHTO M-145 soil classification are the plastic limit (PL) and the liquid limit (LL). The plastic limit of a soil is the lowest water content at which the soil remains plastic. The liquid limit is the moisture content at which the soil behavior changes from a plastic to a liquid state. The range of moisture contents that a soil behaves as a plastic is referred to as the plasticity index (PI), and is taken as the difference between the liquid limit moisture content and the plastic limit moisture content (PI = LL – PL).

Soils that do not exhibit plastic behavior (clean granular soils) will have a value of zero for the PI, and are referred to as Non Plastic (NP). These soils will have No Value (NV) prescribed for their liquid limit and plastic limit. Soils with higher clay content are characterized by higher liquid limits and higher plasticity indices. If a soil can be rolled into threads after moisture is added, or after the sample is partially dried if it is initially too wet to roll, then the material is considered plastic. If the material cannot be easily rolled, it is likely non-plastic.

The two test procedures used to define the Atterberg limits of a soil are AASHTO T 89, Determining the Liquid Limit of Soils, and AASHTO T 90, Determining the Plastic Limit and Plasticity Index of Soils.

AASHTO SOIL CLASSIFICATION

It is important for the inspector to familiarize themselves with this soil classification system. Project specifications will often require specific soil types be used for various types of backfill (i.e. retaining wall backfill, embankment fill, pipe bedding etc.). For example, many projects will require that "Select Material" be used in the upper 2 feet of an embankment prior to placing aggregate base course or pavement. The following AASHTO soil groups qualify as "Select Material": A-1, A-2-4, and A-3.

The AASHTO Soil Classification system classifies soils into eight major groups based on their grain size distribution and Atterberg limits. These groups are designated A-1 through A-8. Soils that fall within the lower numbered groups are granular (sands and gravels), contain less than 35 percent fines, and tend to be either non-plastic or low plasticity (A-1, A-2, and A-3 soils). Soils that classify within the higher numbered groups have a higher fines content (silt and clay sized particles) and are generally characterized by higher plasticity (A-4, A-5, A-6, and A-7 soils). Peat classifies as an A-8 soil, and this material is characterized by an organic content of 15 percent or more.

To classify a soil using AASHTO M-145, gradation information and the Atterberg limits of a soil must be determined. The sieves used for this classification system are the No. 10, the No. 40, and the No. 200 sieves. To use this classification system, an individual can determine the correct soil classification by process of elimination.

In addition to the major groups and subgroups listed above, additional classification using the liquid limit, plasticity index, and percent fines can be conducted to determine a soils partial group index. The partial group index is a number placed in parentheses after an AASHTO group number: e.g. A-6(5) indicates an A-6 group soil with a partial group index of 5. This number provides an indication of the percent fines a soil contains, the level of plasticity of the fines, and gives an indication of the quality of the soil as a subgrade material. Higher partial group indices indicate poorer quality soils (i.e. an A-6 with a partial group index of 30 is a poorer quality soil than an A-6 with a partial group index of 5).

SOIL COMPACTION

The foundation soils and the materials used to construct embankments must be properly compacted during construction to improve stability, increase the strength of the soils, reduce the likelihood of post-construction settlement, and increase the long term performance of the roadway.

Compaction is by definition, the densification of a soil by removal of air/void space through mechanical energy. To adequately compact any soil with conventional construction equipment, water must be added to the soil to increase the degree of compaction that can be achieved. Water acts as a softening agent and allows soil particles to slip over one another and move into a denser configuration.

As water is added to a completely dry soil, the degree of compaction that can be achieved increases. In other words, the density of the soil that can be achieved increases. However, if too much water is added the soil then begins to behave as a liquid. The soil will simply pump or deform with compactive effort, and an increase to densification can no longer be achieved. The moisture content at which the maximum density of a soil can be attained is referred to as the optimum moisture content. When a soil is compacted at its optimum moisture content, it can be compacted to its maximum dry density.

The test procedures that are used to determine a soil's maximum dry density and optimum moisture content are the Standard and Modified Proctor tests. These tests are described in AASHTO T99 and T180, respectively: Moisture-Density Relations of Soils.

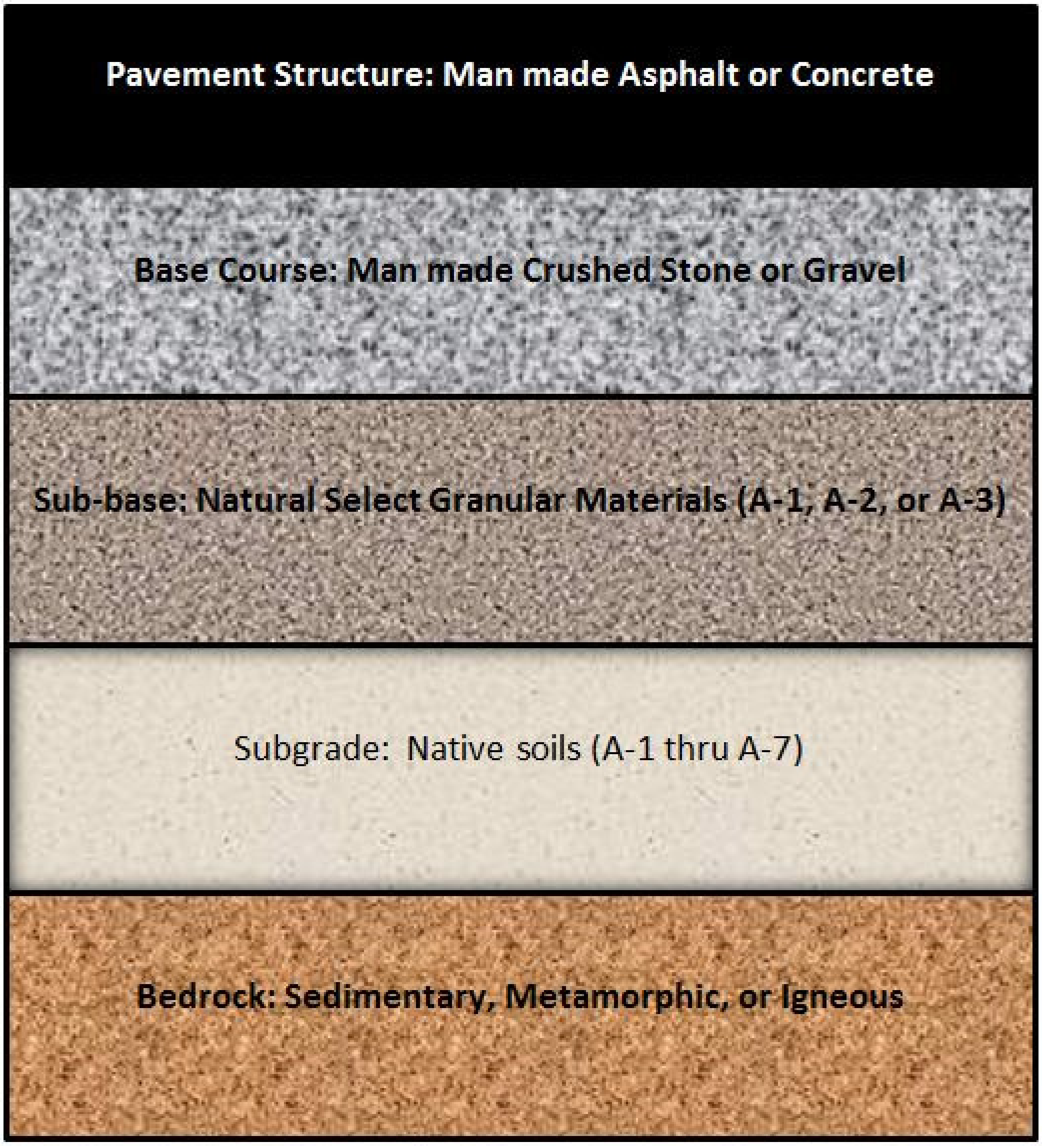
RIPPABILITY

Some rock can be broken down by the process of ripping; drawing a heavy metal tooth through the rock by a piece of construction equipment. The measurement of how easy it is to rip down the rock by a certain piece of equipment is the rippability. The rippability is different for different types of rock and how the rock was formed. To assist in determining what equipment should be used for the rock on a project, references are available such as the Caterpillar® Handbook of Ripping or similar. This manual associates construction equipment with seismic velocities to help plan what equipment should be used. The seismic survey should be performed well in advance of construction to allow for proper construction planning.

SOIL SURVEY & SIMILARIZATION

Preliminary Soil Surveys are conducted prior to new alignments and most widening projects. The purpose of these surveys is to locate the various soil types within proposed roadways above and below profile grade elevations. The extent of each soil type is noted and each type is identified by the AASHTO classification method. The condition of sub-soils upon which embankments will be constructed is determined. This involves moisture content, density, and ground water distribution. Applicable procedures are located within the Soil Survey / Preliminary Soil Profile section on pages 54 thru 77 of this Chapter.

A sample should be taken for each soil encountered except for the material, which might be used as topsoil. If the same soil is found in more than one hole, it may be *similarized* to a soil already sampled. Similarization is the process of combining or eliminating samples from nearby locations the exhibit similar physical properties such as color, grain size, gradation, plasticity, roundness, etc. This increases productivity and efficiency while reducing cost for sample shipment and laboratory analysis. Care should be exercised in similarizing soils and additional samples should be taken where doubt exists. Similarization will be limited to one mile. Soil samples taken in each boring will be visually classified and similarized in the Region by certified inspectors and testers prior to submittal for laboratory analysis.


Pavement Structure: Man made Asphalt or Concrete
Base Course: Man made Crushed Stone or Gravel
Sub-base: Natural Select Granular Materials (A-1, A-2, or A-3)
Subgrade: Native soils (A-1 thru A-7)
Bedrock: Sedimentary, Metamorphic, or Igneous

Region Soil Survey Sampling Checklist - 2018

Preliminary Soil Profile
(refer to FMM Chapter 200 for details)

Sampling of Boring Materials

1. Take one sample per soil type containing at least 33 lbs. (15 kg) of - #4 materials for ***Classification.***
2. A minimum of one boring per 1,000 linear feet of roadway will be done.
3. Minimum depth of 3 feet below proposed finished subgrade is required.
4. At least one boring shall be drilled to a depth of at least 10 feet in order to determine the presence of water.
5. Soil samples taken in each boring will be **visually classified and similarized** in the Region.
6. Soil samples will be logged on the Form #555 by Region personnel.
7. Test holes will be logged individually in numerical order following the convention noted in the Soil Survey / Preliminary Soil Profile, Subsection 6.4.
8. Samples that are similar will be logged after the initially encountered soil type.
9. There will not be more than 1 mile between similarized soil samples.
10. Soil samples for ***Sulfate*** tests will be collected for **each** soil type in **each** boring.
11. Soil and water (if available) samples for Corrosion tests for pipe selection will be collected at inlet or outlet where water or soil contact the pipe or water transport structure.
12. A minimum of 5 lbs. of soil will be sampled for ***Sulfate*** and ***Corrosion*** tests.
13. A minimum of 1/2 quart (500 ml) of water will be sampled for ***Corrosion*** tests.
14. **Sulfate** and **Corrosion** samples will be sealed in a container or bag, marked with the Test No. and logged on Form #555 by placing an “S” for sulfate testing only and a “C” for corrosion tests in the **Sulfate**/**Corrosion** column. A copy of Form #157 and Form #555 will be included in the **Sulfate**/**Corrosion** submittal to be sent to the Central Laboratory **Chemical Unit**.
15. Corrosion tests include Sulfate, Chloride, pH, and Soil Resistivity for pipe material type selection.

Materials Ownership and Forms

1. The soil samples will be logged on the most current Preliminary Soil Survey Form #555.
2. Form #157 will be completed with specified soil tests by Region personnel.
3. Form #157 and Form #555 will be included in the sample bag with the tag (Form #633) marked appropriately.
4. Electronic Form #555 shall be e-mailed to Central Lab Soils Program lab manager.
5. Soil samples will be sent to Region or Central Lab Soil Program for analysis.
6. Samples for ***Sulfate*** and ***Corrosion*** tests will be tagged (Form #633) and sent to the Region Materials Lab or Central Lab’s Chemical Unit with a copy of the Form #157.

Soil Survey of Constructed Roadbeds
(refer to CP 24 for details)

New & Widened Roadways and Sampling of Boring Materials

1. Borings will be drilled in final subgrade prior to pavement overlay.
2. A minimum of one boring per 1,000 linear feet of completed 2-lane roadway will be done.
3. Minimum depth of 2 feet below finished subgrade is required.
4. Take one sample per soil type containing at least 33 lbs (15 kg) of - #4 materials for ***classification.***

Materials Ownership and Documentation

1. ***Field*** or ***Region Lab*** will use CP 20, CP 21, and the Form #564 to complete the soil classification.
2. ***Field* or *Region*** will follow CP 24 and mathematically scalp the gradation on the appropriate sieve and determine if there are significant variations in the material from the preliminary soil survey.
3. **If there are significant variations from the preliminary soil survey,** all +3/8, +#4, and - #4 materials will be separated and retained in separate bags.

4. The sample material with a Form #157 requesting an R-value will be sent to the Region Lab (*) or Central Lab.

5. The soil classification on Form #564 will also be sent to the Region Lab or Central Lab.
6. If ***no*** significant variations are found, record on the Form #219 for project documentation.

Borrow Pits
(refer to Standard Specifications for Road & Bridge Construction for details)

Contractor Source: The cost of complying with Section 106.02, (b) *Contractor Source* requirements, including sampling, testing, and corrective action by the Contractor, shall be included in the work. **CDOT reserves the right to verify the contractor's source.**

Materials Ownership, Sampling, and Forms (FMM QA Schedule)

1. If embankment will support concrete pavement or will be chemically stabilized, during production, one soil sample per 2000 yds^3 or fraction thereof, will be tested for sulfate from the designated source by CDOT project or Region personnel.
2. Results will be documented on Forms #157 and #323.
3. During qualification of a borrow source, one 5 lb. sample of soil, per soil type, will be submitted to the Chemical Unit of the Central Laboratory for sulfate content.

Notes:
1. Region Lab/Soils Program will perform classification of soils.
2. Chemical Unit will perform chemical analysis of soil samples for sulfates.
3. Chemical Unit will provide the Project with the chemical analysis on qualification of borrow sources.
4. For the preliminary soil survey, the Chemical Unit will provide the Region Materials Program with the chemical analysis reports and forward the results to the Soils Program.
5. The Soils Program will input the chemical results onto the electronic Form #555, and forward the completed preliminary soil survey to the Region Materials Program.
6. Chemical Unit will perform chemical analysis of soil samples for corrosion tests and will provide test results to the Region for pipe material type selection.
7. * If the Region Lab has the ability to perform CP-L 3101 then no sample needs to be sent to the Central Lab.

Region Soil Survey Drilling Checklist

Reconnaissance of Drill Site

	Yes	No	N/A
1. Was a reconnaissance survey of the area to be drilled performed?	☐	☐	☐
2. Have landowner clearances and locates been obtained?	☐	☐	☐
3. Have temporary easements been obtained?	☐	☐	☐
4. Have drilling methods been determined?	☐	☐	☐
5. Have roadway condition and type of pavement been noted?	☐	☐	☐
6. Have rock outcrops been noted?	☐	☐	☐
7. Have survey cross sections or profiles been performed?	☐	☐	☐
8. Is there drilling for existing roadway?	☐	☐	☐
9. Is there drilling for new or extension of roadway surface?	☐	☐	☐
10. Have structures and culverts been identified?	☐	☐	☐
11. Has the Soil Survey Field Report, Form # 554 been completed?	☐	☐	☐
12. Have sulfate/corrosion resistance samples been taken?	☐	☐	☐

Preliminary Soil Survey

General
1. Preliminary Soil Survey, Form #555 worksheet available and used? ☐ ☐ ☐
2. Borings drilled in roadway? ☐ ☐ ☐
3. Borings drilling in shoulder? ☐ ☐ ☐
4. Boring drilled in R.O.W.? ☐ ☐ ☐
5. 1 boring per 1,000 linear feet of 2-lane roadway minimum? ☐ ☐ ☐
6. 1 boring per 500 linear feet of 2-lane roadway in cut areas minimum? ☐ ☐ ☐
7. 1 boring to a depth of at least 10 feet?
8. Is the finished grade known? ☐ ☐ ☐
9. Depth of boring minimum of 3-8 feet below finished roadway grade? ☐ ☐ ☐
10. Is the finished grade unknown? ☐ ☐ ☐
11. Depth of boring minimum of 3-8 feet into subgrade material? ☐ ☐ ☐
12. Additional drilling performed after the finished grade is known? ☐ ☐ ☐
13. Water table encountered and depth noted? ☐ ☐ ☐
14. Drilling adjacent to Wetlands? ☐ ☐ ☐
15. Ground water wells established? ☐ ☐ ☐
16. In-situ samples taken? ☐ ☐ ☐
17. Have sulfate/corrosion resistance samples been taken? ☐ ☐ ☐

See next page

Cut Areas
1. Boring location similar to **Figure SS-1** in Chapter 200 of FMM? ☐ ☐ ☐
2. Boring depth similar to **Figure SS-3** in Chapter 200 of FMM? ☐ ☐ ☐
3. Depth of boring minimum of 3 feet below finished roadway grade? ☐ ☐ ☐
4. Additional drilling performed in cut sections needed? ☐ ☐ ☐

Fill Areas
1. Depth of fill up to 20 feet? ☐ ☐ ☐
2. Boring location similar to **Figure SS-2** in Chapter 200 of FMM? ☐ ☐ ☐
3. Depth of fill greater than 20 feet? ☐ ☐ ☐
4. Boring depth 5 feet into hard substratum? ☐ ☐ ☐
5. Boring depth similar to **Figure SS-4** in Chapter 200 of FMM? ☐ ☐ ☐

** If suspicious material is encountered during drilling*
- *Stop Drilling*
- *Do not move the drill rig*
- *Secure area and provide traffic control if necessary*
- *Contact Region Environmental and/or Region Safety Coordinator*

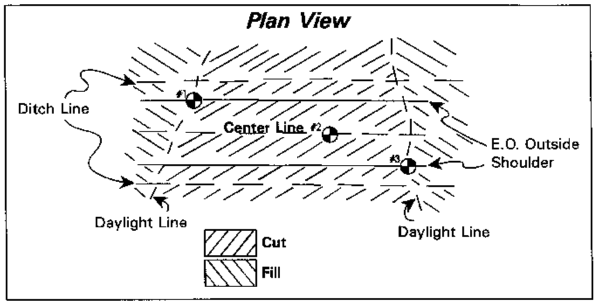


FIGURE SS-1

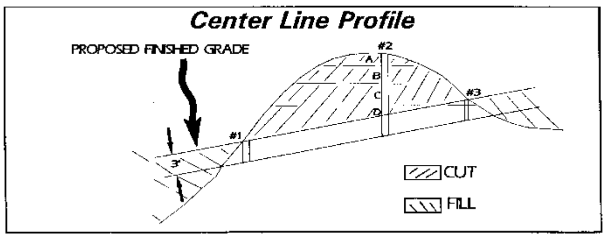


FIGURE SS-2

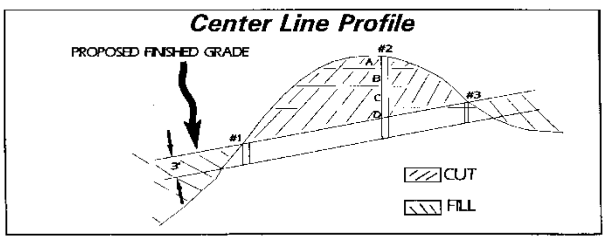


FIGURE SS-3

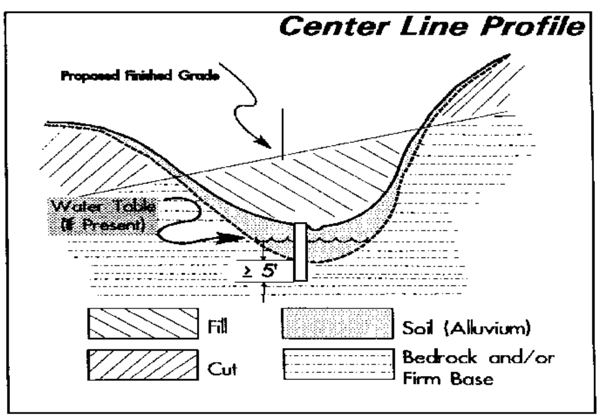


FIGURE SS-4

LABORATORY TESTS

To accurately classify soil by the AASHTO method, a series of standard tests must be performed:

- Dry Preparation of Disturbed Soil Samples - CP 20
- Mechanical Analysis of Soils - CP 21
- Liquid Limit of Soils - AASHTO T 89
- Plastic Limit and Plasticity Index of Soils - AASHTO T 90

A chart indicating soil classification by the AASHTO method can be found on the Page 18 Table of Contents. Although this method separates soils into specific types according to gradation and Atterberg Limits characteristics, further testing is needed to obtain specific soil strength values such as R-values, cohesion, angle of internal friction, etc.

Other laboratory tests to determine engineering values are as follows:

- Compaction - AASHTO T 99 (Standard)
- Compaction - AASHTO T 180 (Modified)
- Consolidation/Swell Potential – AASHTO T 216
- Expansion Pressure and Resistance Values – T 190
- Triaxial Compression - AASHTO T 234
- Direct Shear Test - AASHTO T 236
- Permeability - AASHTO T 215

EXPANSIVE SOILS

Soils considered to be expansive are those which exhibit a high volume change with an increase in moisture content. These soils usually occur in bedrock formations, are dense and fairly dry, and normally have a high liquid limit and plastic index. Problems from expansive soils usually occur in cut areas and in the transition from cut to fill areas. Embankments constructed from the same type of soil which has been reworked and compacted at 95% of maximum dry density at optimum moisture as determined by AASHTO T 99, have not known much distress.

The problems caused by expansive or swelling soils have been of great concern to highway engineers for many years and is the subject of continued research. Some of the remedial measures, which have met with success in cut areas of expansive soils are:

1. The use of a membrane directly on the finished sub-grade through cut sections. The membrane is usually placed in the ditch section and up the back slope to an elevation equal to that of the wearing course.
2. The placement of plant mix bituminous base directly on the sub-grade. Membranes are sometimes used in the ditch section in conjunction with this procedure to provide better drainage.
3. The sub-excavation of expansive material and backfilling with impermeable material at 95% of maximum dry density and close to optimum moisture as determined in accordance with AASHTO T 99. It has been found that clean granular material should not be used to backfill sub-excavations, as it tends to collect water thereby wetting the sub-grade and increasing the swell potential.

When expansive soils are encountered on a project the Region Materials Engineer should be contacted. More information on swelling soils is available in the Soil Survey portion of this Chapter.

Soil sampling and test methods appear in the CP portion of the Field Materials Manual. Examples and explanations of CDOT Forms can be located in the Table of Contents on Page 19 along with many useful charts, nomographs, and instructions.

UNSTABLE SOILS

Soil, when tested in accordance with AASHTO T 190 as modified by CP-L 3101, will be analyzed for stability. Soil is unstable when the following criteria are met (see FIGURE 200-1):

- The decrease of R-value from 400 psi to 300 psi is 10 or greater, and
- The optimum moisture of AASHTO T 99 or T 180 is greater than the exudation moisture at 300 psi.

The statement ‘This material meets the criteria as “unstable” as defined in Subsection 3.4 of CP-L 3101 in Appendix X3 and will be written in the notes section on Form #323.

Projects where unstable soil is used, with moisture control during construction, should be carefully monitored. A test section should be considered. The unstable soil should be compacted at a moisture content of 1% to 2% below optimum moisture.

Other potential remediation alternatives for unstable soil may include the following:

- Mechanical improvement, including the use of a geosynthetics such as geotextile or geogrid.
- Chemical treatment such as cement, fly ash or cement/fly ash combination.

Region Materials should be contacted when unstable soils are encountered on a project.

Mica in Soils

When a soil contains an appreciable amount of mica, it has the tendency to significantly decrease its physical property or engineering index.

For example, a relatively low R-value was found in a soil classified as A-1-b-(0) from a preliminary soil survey. The R-value should not be the single factor for completing the pavement design. The significance of the R-value test result should be re-evaluated. It is recommended that the roadway distress be observed and documented and the FWD data should also be conducted and evaluated for the determination of the final design parameter.

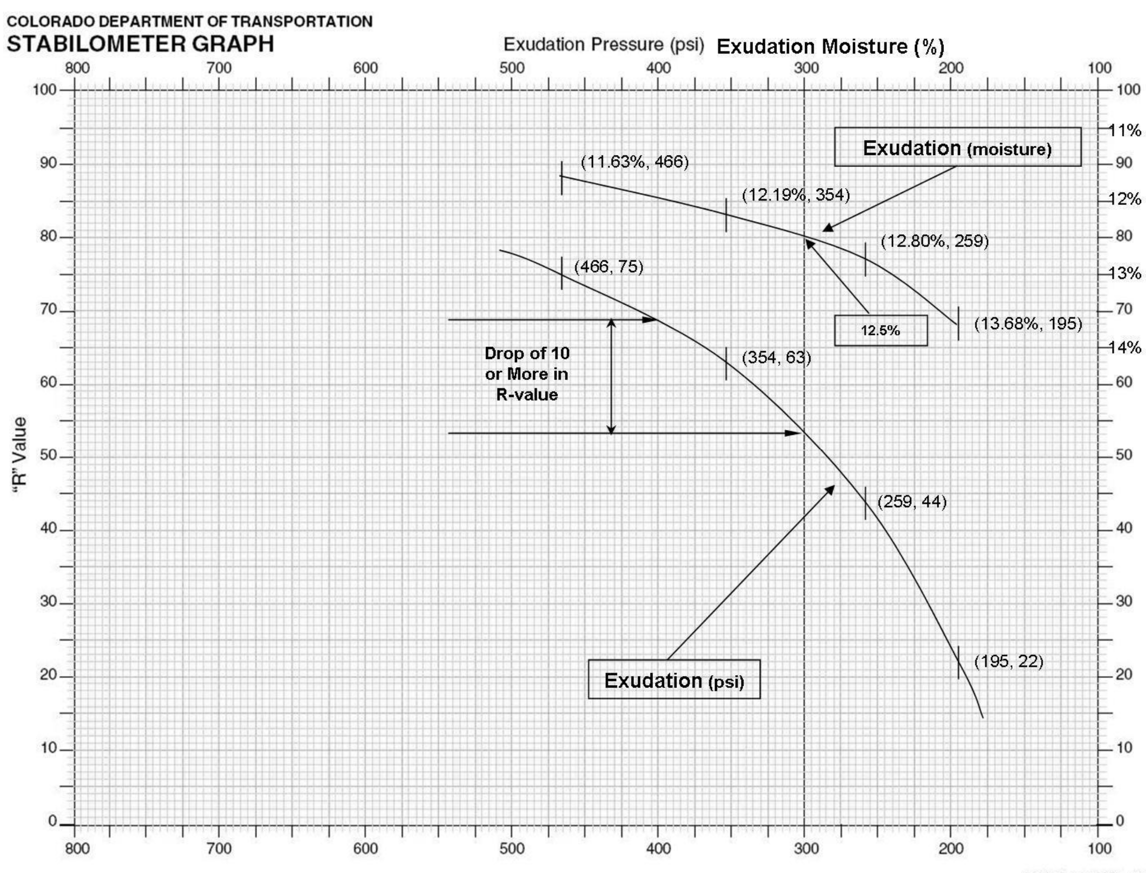


FIGURE 200-1

ITEM 203, COMPACTION

Proper compaction of embankments is necessary to provide a stable base for roadway pavement. It must be understood that the foundation soil directly beneath the embankment has to be strong enough to support it. Insufficient strength of foundation soil could cause damage by shear failure, slip outs, or displacement of underlying soft material by outward plastic flow. Highly compressible soil in the foundation could result in excessive settlement.

Embankment strength is dependent upon three basic conditions: (1) Moisture Content, (2) Compactive Effort, and (3) Soil Characteristics. The soils engineer has reasonable control over the first two, but usually has no way of altering the material being placed in the embankment. Because of this, it is essential that embankment material be accurately classified using the AASHTO method and that the soil samples tested truly represent the material being used.

Optimum moisture and maximum density values are determined according to either AASHTO T 99 (Standard) or AASHTO T 180 (Modified) as called for in the plans. These values are determined by the Central Laboratory on representative samples taken during the preliminary soil survey and are provided to field personnel prior to construction. It is the responsibility of the Engineer to assure that the optimum moisture and maximum density of the in-place embankment material meet the requirements in Subsection 203.07 of the Standard Specifications.

Procedure

Roadway embankment material must be placed in horizontal layers. Material placed in lifts shall not exceed eight inches (200 mm) in thickness prior to compaction. When material consists predominately of rock over eight inches (200 mm), lift thickness may equal the average rock dimension but shall not exceed three feet (1 m). Rocky material should be uniformly distributed throughout the embankment to assure thorough consolidation.

Embankment material, which contains more than 50% (by weight (mass)) of particles retained on the No. 4 sieve, is considered rock embankment. Rock embankment shall be compacted according to Subsection 203.08 of the Standard Specifications.

Field Equipment

Type of compaction equipment to be used by the Contractor is optional unless otherwise specified on the plans. The Contractor, however, must meet density and percent moisture requirements. Common types of compaction equipment used are:

- **Sheepsfoot Roller -** Used with silt and clay.
- **Rubber Tired Rollers -** Used with granular or cohesive soils.
- **Smooth-Wheel Rollers -** Used with base coarse materials and for finishing operations.
- **Vibratory Rollers -** Used with granular soils.

Roller Hours

When "Roller Hours" are specified on a project, estimated yardage (volume) shall be documented on CDOT Form #212. The estimated yardage (volume) shall be placed in the appropriate section as instructed on the CDOT Form #212 (example in this chapter) and shall be marked "for information only". In-place density tests should be taken for documentation when practical. A brief statement on the type, weight (mass), and effectiveness of the roller should be included under "Remarks". To identify the CDOT Form #212 as an "information only report", write "Roller Hours" in the space provided after "other" (under modified AASHTO T 180).

Field Tests

A minimum of one moisture density test must be taken for each 2000 cubic yards (1500 m^3) of embankment material placed. Changes in embankment material may require more tests. The following test methods are acceptable and are published in this Field Materials Manual:

CP 80	In-Place Density and Moisture Content of Soil and Soil-Aggregate by the Nuclear Method
CP 23	Determining Maximum Dry Density and Optimum Moisture of the Total Sample of Soil-Rock Mixture
CP 25	Calculation of Percent Relative Compaction of Soils and Soil-Rock Mixtures

AASHTO T 191 Density of Soil In-Place by the Sand-Cone Method

Results of these field tests must be recorded and retained in project files on CDOT Form #212. Moisture content and relative compaction requirements are listed in Subsection 203.07 of the Standard Specifications.

Zero Air Voids Density

The Zero Air Voids Density Tabulation shown in this Chapter represents the dry density that would be obtained at the various moisture contents if there were no air voids present, i.e., when all voids between soil particles are filled with moisture. At a given moisture content and specific gravity, the zero air voids density represents the maximum density that can be obtained in the given soil.

The in-place dry density and the in-place moisture from the test results on CDOT Form #212 should be checked against the zero air voids density. For clays and silts a specific gravity of 2.70 may be used and 2.65 for other materials. The in-place dry density should never exceed the zero air voids density at the in-place moisture and the specific gravity of the material. If it does, some of the data is erroneous. To avoid using incorrect density values, the tester should check the Zero Air Voids Density Tabulation (Page 11) whenever a percent relative compaction figure of 105% or more is calculated.

ITEM 206, STRUCTURE BACKFILL

Section 206 of the Standard Specifications lists two classes of Structure Backfill. They are: Class 1, which is graded, granular material meeting the requirements of Subsection 703.08 (a), and Class 2 which shall be composed of suitable material developed on the project. Field personnel are to indicate on the CDOT Form #157, accompanying the sample, which method of determining maximum density (AASHTO T 99 or T 180) is applicable to the material submitted.

The density required for Class 1 Structure Backfill will be not less than 95% of maximum density determined in accordance with AASHTO T 180. More information on Structure Backfill, Class 1 appears in Chapter 300 of this Manual.

The density required for Class 2 Structure Backfill shall conform to Subsection 203.07 and unless otherwise designated, the type of compaction shall be the same as that specified for the project. If not specified, or if there is no contract pay item, Class 2 Structure Backfill shall be placed in accordance with AASHTO T 180.

It has become a policy of the CDOT that in the event a Contractor elects to substitute aggregate base course for Class 2 Structure Backfill, the maximum density determination and percent relative compaction will be the same as for Class 1 Structure Backfill.

NOTE: When using Class 2 Structure Backfill that is composed of an appreciable amount of plus Number 4 material, Subsection 206.03, paragraph 3 should be strictly adhered to. See also Subsection 703.08, paragraph (b) for further requirements when plus Number 4 material is present. This is very important, in order not to cause any damage to the structure. Class 1 Backfill material should be used if there is any doubt about placing the Class 2 material in the 6" (150 mm) lift required. The use of "too rocky to test" in lieu of the actual testing should be used very sparingly; therefore, it may apply when more than 50% of the material is retained on the ¾" sieve. Almost all Class 2 Backfill should be tested.

TABLE 200-1, ZERO AIR VOIDS DENSITY TABULATION

	Dry Density (ZAVD)					
Moisture, % of Dry Wt.	@ 2.65 SP. GR.		@ 2.70 SP. GR.		@ 2.75 SP. GR.	
	lb/ft^3	kg/m^3	lb/ft^3	kg/m^3	lb/ft^3	kg/m^3
9.0	133.5	2138.4	135.5	2170.5	137.6	2204.1
9.5	132.1	2116.0	134.1	2148.1	136.1	2180.1
10.0	130.7	2093.6	132.7	2125.6	134.6	2156.1
10.5	129.4	2072.8	131.3	2103.2	133.2	2133.6
11.0	128.3	2055.1	129.9	2080.8	131.7	2109.6
11.5	126.7	2029.5	128.6	2060.0	130.3	2087.2
12.0	125.5	2010.3	127.3	2039.1	129.0	2066.4
12.5	124.2	1989.5	126.0	2018.3	127.7	2045.5
13.0	123.0	1970.3	124.7	1997.5	126.4	2024.7
13.5	121.8	1951.0	123.5	1978.3	125.1	2003.9
14.0	120.6	1931.8	122.3	1959.0	123.9	1984.7
14.5	119.5	1914.2	121.1	1939.8	122.7	1965.4
15.0	118.3	1895.0	120.0	1922.2	121.5	1946.2
15.5	117.2	1877.3	118.8	1903.0	120.3	1927.0
16.0	116.1	1859.7	117.7	1885.4	119.2	1909.4
16.5	115.1	1843.7	116.6	1867.7	118.0	1890.2
17.0	114.0	1826.1	115.5	1850.1	117.0	1874.1
17.5	113.0	1810.1	114.4	1832.5	115.8	1854.9
18.0	112.0	1794.0	113.4	1816.5	114.8	1838.9
18.5	111.0	1778.0	112.4	1800.5	113.7	1821.3
19.0	110.0	1762.0	111.4	1784.4	112.7	1805.3
19.5	109.0	1746.0	110.4	1768.4	111.7	1789.2
20.0	108.1	1731.6	109.4	1752.4	110.7	1773.2
20.5	107.2	1717.2	108.5	1738.0	109.7	1757.2
21.0	106.2	1701.1	107.5	1722.0	108.8	1742.8
21.5	105.3	1686.7	106.6	1707.6	107.8	1726.8
22.0	104.5	1673.9	105.7	1693.1	106.9	1712.4
22.5	103.6	1659.5	104.8	1678.7	106.0	1697.9
23.0	102.7	1645.1	103.9	1664.3	105.1	1683.5
23.5	101.9	1632.3	103.1	1651.5	104.2	1669.1
24.0	101.1	1619.5	102.2	1637.1	103.4	1656.3
24.5	100.3	1606.6	101.4	1624.3	102.5	1641.9
25.0	99.5	1593.8	100.6	1611.4	101.7	1629.1
25.5	98.7	1581.0	99.8	1598.6	100.9	1616.2
26.0	97.9	1568.2	99.0	1585.8	100.1	1603.4
26.5	97.2	1557.0	98.2	1573.0	99.3	1590.6
27.0	96.4	1544.2	97.4	1560.2	98.5	1577.8
27.5	95.7	1533.0	96.7	1549.0	97.7	1565.0
28.0	94.9	1520.1	96.0	1537.8	97.0	1553.8
28.5	94.2	1508.9	95.2	1524.9	96.2	1541.0
29.0	93.5	1497.7	94.5	1513.7	95.5	1529.7
29.5	92.8	1486.5	93.8	1502.5	94.7	1516.9
30.0	92.1	1475.3	93.1	1491.3	94.0	1505.7
30.5	91.4	1464.1	92.4	1480.1	93.3	1494.5
31.0	90.8	1454.5	91.7	1468.9	92.6	1483.3
31.5	90.1	1443.2	91.0	1457.7	91.9	1472.1
32.0	89.5	1433.6	90.4	1448.1	91.3	1462.5
32.5	88.8	1422.4	89.7	1436.8	90.6	1451.3
33.0	88.2	1412.8	89.1	1427.2	90.0	1441.6
33.5	87.5	1401.6	88.5	1417.6	89.3	1430.4
34.0	87.0	1393.6	87.8	1406.4	88.7	1420.8
34.5	86.4	1384.0	87.2	1396.8	88.1	1411.2
35.0	85.8	1374.4	86.6	1387.2	87.4	1400.0
35.5	85.2	1364.8	86.0	1377.6	86.8	1390.4

ITEM 206, FILTER MATERIAL

It is extremely difficult to write standard specifications that would produce an ideal filter material covering all conditions for backfill around sub-drains. A protective filter is a pervious material that will allow the free infiltration of water but will prevent the entrance of soil into the filter. A standard specification for such a material cannot be anymore than a good guide for the average conditions encountered, and often, engineering experience, intelligently applied, will indicate that some slight deviation from a standard specification is desirable.

A good standard specification covering the average condition would include a material equivalent to a good concrete sand. Experience has proven that coarse backfill is definitely not a proper material to be used in some sub-drain trenches.

The Basic Problem

Much of the problem of selecting the right aggregates for drainage systems stems from the need of satisfying two conflicting requirements. (1) The aggregates must have pores that are large enough to permit water to flow readily through the layer. (2) Drainage layers in contact with soil must be fine enough to prevent the trench soil from washing through the pores of the aggregate with resultant clogging of the system (usually the pores will not clog if the 15% size of the filter is not more than 5 times the 85% size of the soil). Meeting both requirements with one material sometimes can be nearly impossible. If it should become necessary to choose between one requirement or the other, the first one should have precedence. One solution in difficult cases is the use of graded filters having two or more layers. One layer or zone of aggregate should be fine enough to hold the soil in place. In addition, one or more coarser layers may be used to provide the needed water removing capacity. Graded filters of two or more layers are very common in dams. However, a desire to simplify construction has led to the widespread use of a single layer for most pavement drainage.

Water-Removing Capabilities

Drainage materials for highways and airports often are considered "pervious" or "free draining" if their permeability is about 5 ft. (1.5 m) a day. Most aggregate being used in drainage systems probably is about this pervious. Fine concrete aggregate is rather widely used as a drainage material. If on the coarse side of Standard AASHTO Specifications, fine concrete aggregate can have a permeability of 10 to 20 ft. (3 m to 6 m) per day perhaps higher. However, on the fine side of AASHTO Specifications, its permeability may be in the vicinity of 1 ft. (300 mm) per day and possibly as low as 0.1 ft (30 mm).

On the other hand, clean pea gravel can have a permeability of many thousand ft. (meters) per day. Not only is the permeability of drainage aggregates highly variable but the needs of drainage systems also vary widely.

It is believed that the needs of projects should be approximated in some manner before designs are established and aggregate qualities adopted.

A rational analysis can be helpful in answering important questions, such as: "What are the water-removing capabilities of various aggregate?" "What aggregate is needed for a particular job?" and, "What features of a design will perform a drainage job most economically?"

Some of the possibilities of a rational analysis of filter performance are illustrated in Figure 200-2. Five classes of aggregate are rated in terms of three different drainage conditions. The aggregates vary from the finest graded AASHTO concrete sand to 1/2 in. (12.7 mm) gravel. Permeabilities vary from 1 to 80,000 ft. (0.3 m to 24 500 m) a day. The kinds of aggregates and their assumed permeabilities are given at the bottom of Figure 200-2.

The top bar graph in 200-2 compares the five aggregates on the basis of the speed with which water can flow horizontally in a pervious base. (Basic Problems, Water-Removing Capabilities, and Graphs, Figures 200-2 and 200-3 are based on empirical values from investigations by the U.S. Waterways Experiment Station. The following conclusions were published in the Vicksburg Report.

Filter Material

From the laboratory study of the filter materials and also from the observations of their performance in the flume tests, the following conclusions were made:

a. A fine material will not wash through a filter material if the 15% size of the filter material is less than 5 times as large as the 85% size of the fine base materials.

b. In addition to meeting the above size specifications, the grain size curves for filter and base materials should be approximately parallel in order to minimize washing of the fine base material into the filter material.

c. Filter materials should be packed densely in order to reduce the possibility of any change in the gradation due to movement of the fines.

d. A filter material is no more likely to fail when flow is in an upward direction than otherwise, unless the seepage pressure becomes sufficient to cause flotation or a "quick" condition of the filter.

e. A well-graded filter material is less susceptible to running through the drainpipe openings than a uniform material of the same average size. However, even a filter material having a wide range of gradation cannot be used successfully over a drainpipe having large openings, since enough fine particles to cause serious clogging will move out of the well graded material into the pipe.

Underdrains

Tests on the rate-of-surface infiltration through the filter into the pipes indicate the following:

a. The rate of infiltration through the filter bed was not materially limited or affected by any of the pipes tested, as long as they did not become clogged.

b. Large openings in the drainpipe resulted in a somewhat higher rate of infiltration, but also increased the tendency for filter material to collect in and clog the pipe.

c. Drainpipes with perforations around only half, or less, of their circumference drain the filter more rapidly then when the perforations are up, but less material will wash in when the perforations are down.

The tendencies for the filter material to wash into and clog the pipe are of primary importance in comparing the various commercial pipes. Tests performed to determine the amount of materials washed into underdrain pipes show the following:

a. Perforated drainpipes having many small openings, preferably on the underside of the pipe only, and porous concrete pipes, are less subject to infiltration of small gravel and sand than other types of drainpipe. The smallest quantities of filter material were washed into the porous concrete, the perforated metal and the perforated concrete pipes. The quantity of material washed into the perforated clay with perforations all around the circumference was excessive.

b. The perforated metal and perforated concrete pipe should be placed with perforations down.

c. In the tests of the plain concrete and the clay skip pipes, both of which had drainage concentrated at the joints, serious quantities of the filter materials washed into the pipe.

d. The porous concrete with a bevel or lap joint and the perforated concrete and clay with a bell and spigot joint should be placed with the joints tight and preferably sealed with mortar.

e. The porous concrete pipe will also drain without clogging in clean, medium fine sands without other filter media, providing the joints are tight.

When it is feasible to design and use a graded filter, consisting of several larger layers with coarse gravel near the openings of the pipe, pipes with the larger openings would probably operate satisfactorily. Another guide for the design of a good filter material is shown in Figure 200-4. Figure 200-4 uses the term "Uniformity Coefficient". This term with "Effective Size" is associated mainly with sanitary engineering. The American Water Works Association defines both terms and can provide additional information.

Effective Size D_{10} (diameter at the 10% finer point on the gradation curve) is widely known as an effective size.

Uniformity Coefficient (C_u) is the ratio of the diameter at the 60% finer point and that at the 10% finer point of the gradation curve.

$$C_U = \frac{D_{60}}{D_{10}} \quad \textbf{\textit{this is a requirement in certain specifications}}$$

Recommended Filter Classes

The CDOT Standard Specifications, Section 206, refers to several classes of filter material. Subsection 703.09 tabulates the grading specifications for three classes: Class A, Class B, and Class C.

Class A has a permeability of approximately 10,000 to 100,000 ft. (3000 to 30 500 m) per day.

Class B has a permeability of approximately 100 to 1,000 ft. (30 to 300 m) per day.

Class C has a permeability of approximately 1 ft. to 10 ft. (0.3 to 3 m) per day.

The Project Engineer should select the class of filter material required for the project based on the following criteria:

First, select a representative sample of the trench soil and determine the gradation of the minus 3" (75 mm) portion. Then, select the class filter according to the following table:

TABLE 200-2, RECOMMENDED FILTER CLASSES

Sieve Size or Designation	**Percentage of soil passing designated sieves (1)**		
	Use Class 1, B or C (2)	Use Class B or C (2)	Use Class C
No. 10 No. 40	less than 85, & less than 25	less than 85	more than 85
(1) Based on the minus 3" (75 mm) portion of the soil adjacent to the filter material. (2) To drain large quantities of water, use the most open grading recommended.			

This table is based on the following criteria: The D15 size of the filter should not be more than five times the D85 size of the soil.

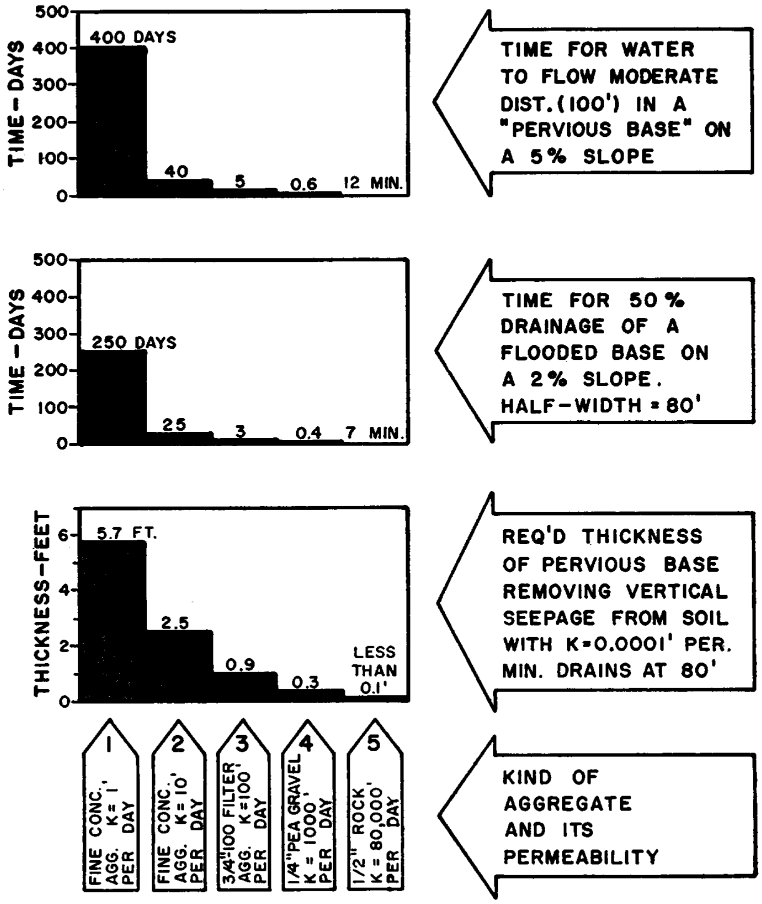


Fig. 1 A comparison of potential performance of several drainage aggregates.

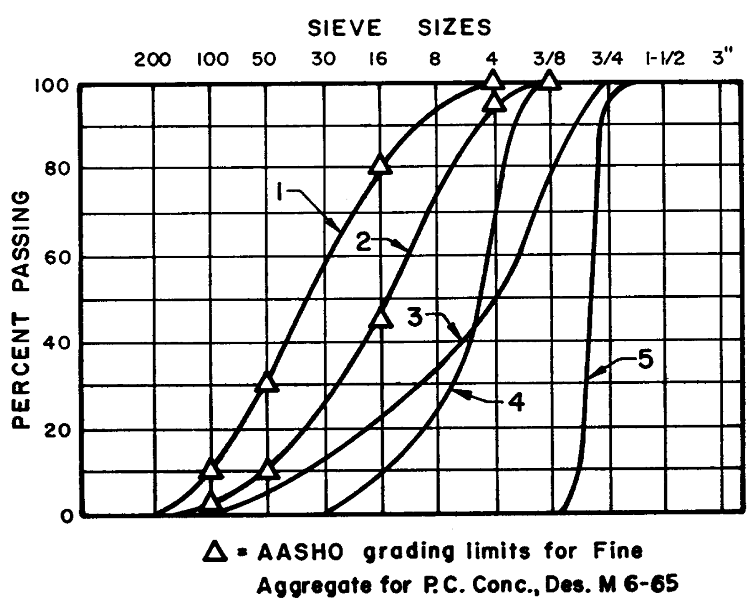


Fig. 2 Grain size curves for five aggregates analyzed in Fig. 1.

FIGURE 200-2 & FIGURE 200-3

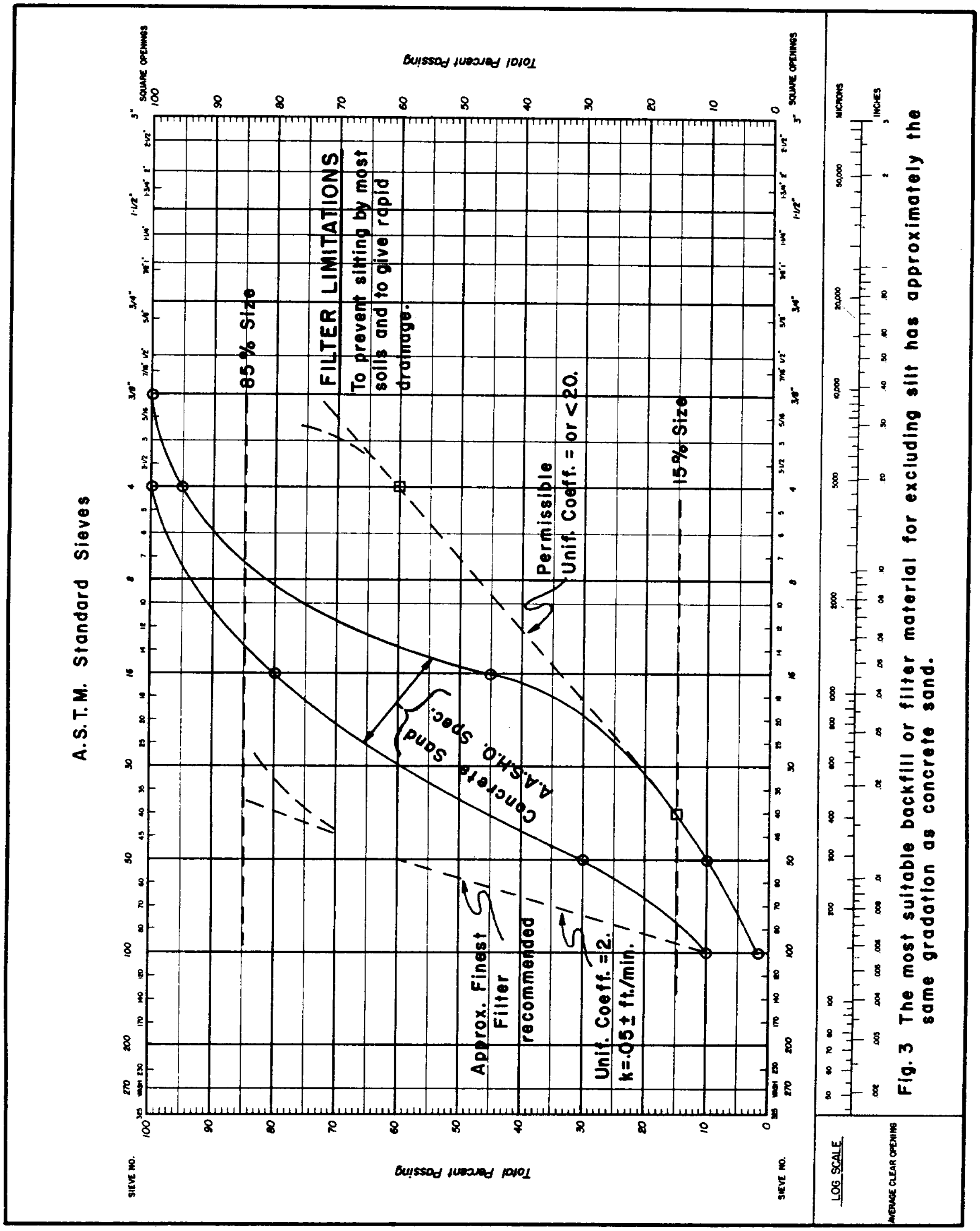

A. S. T. M. Standard Sieves
SIEVE NO.
SQUARE OPENINGS
Total Percent Passing
FILTER LIMITATIONS
To prevent silting by most soils and to give rapid drainage.
85 % Size
15 % Size
Permissible Unif. Coeff. = or <20.
A.A.S.H.O. Spec.
Concrete Sand
Approx. Finest Filter recommended
Unif. Coeff. =2.
k=.05± ft./min.
LOG SCALE
AVERAGE CLEAR OPENING
MICRONS
INCHES
Fig. 3 The most suitable backfill or filter material for excluding silt has approximately the same gradation as concrete sand.

FIGURE 200-4

DEFINITIONS

Alluvial Fan - Deposit formed at the base of a steep valley or canyon wall by steep gradient tributary action. Material usually consists of heterogeneous angular rock and soil.

Angle of Internal Friction - An angle whose tangent is equal to the frictional shear strength of soil divided by the confining stress exerted on that soil. Cohesionless soils tend to exhibit high Angle of Internal Friction (∅) values.

Boulders - All rocks larger than 10 inches in diameter.

Clay - A very fine-grained soil, which passes the No. 200 screen and has a Plastic Index of 11 or more.

Cobbles - Rocks, which range from 3 to 10 inches in diameter.

Cohesion - The capacity of sticking or adhering together. That part of a soils' shear strength, which does not depend on inter-particle friction. Cohesion is the major factor contributing to the shear strength of clay soils.

Compaction - The process of increasing the density of a material by mechanical means, such as, tamping, rolling, vibration, etc.

Consolidation - The process of decreasing the thickness of a soil layer by applying a vertical load.

Degree of Saturation - The ratio of the volume of water to the void volume in a given soil mass.

Density - The mass of a substance per unit volume, usually expressed in pounds per cubic foot (pcf).

Embankment - A raised structure, consisting of soil, aggregate or rock. Usually the material is compacted and is used to support roadway pavement.

Erosion - The removal and transportation of soil or rock by water, ice and gravity.

Escarpment - A steep face terminating highlands abruptly

Glacial Moraine - Deposit of heterogeneous material left by glacial action. Material ranges in size from clay to large boulders.

Gradation - Indicates the range and relative distribution of particles in soil or aggregate.

Gravel - A granular material, which is retained on the No. 10 screen and has a maximum particle size of 3 inches.

Hygroscopic Moisture – Hygroscopic material is soil that readily absorbs water usually from the atmosphere; therefore hygroscopic moisture is the moisture absorbed from the atmosphere. In most cases, the water can be removed from the material by heating.

Internal Friction - The property of individual soil particles to resist movement along adjacent surface areas.

Land forms - Distinct shapes of the earth's surface that have been formed by erosion and deposition of rock or soil. Common examples are stream terraces, alluvial fans, glacial moraines, and sand dunes.

Liquid Limit - The moisture content at which a soil changes from the plastic state of consistency to the liquid state of consistency.

Loess Deposit - A homogeneous, unstratified accumulation of wind blown silt with subordinate amounts of very fine-grained sand.

Maximum Density - The unit dry weight (pounds per cubic foot, (pcf)) of a soil compacted at optimum moisture and at a specific compactive effort.

Optimum Moisture - Percent moisture of a soil, which will yield a maximum dry unit weight for a specified compactive effort.

Permeability - The rate at which a material allows transmission of water.

pH – A measure of the activity of hydrogen ions in a solution. When in balance (pH 7) the soil is said to be neutral. The pH scale covers a continuum ranging from 0 (very acidic) to 14 (very alkaline or basic).

Plastic Index - The numerical difference between the liquid limit and the plastic limit of a soil.

Plasticity - Property of material to be remolded without crumbling under certain moisture conditions.

Plastic Limit - The moisture content at which a soil changes from the semi-solid state of consistency to the plastic state of consistency.

Poorly Graded - Particles sizes of a soil mass that are not evenly distributed.

Pore Water Pressure - The stress imparted by water against soil particles within a saturated soil mass.

Porosity - The ratio of void space of a material to the total volume of its mass, usually expressed as a percent.

Rock - Any naturally formed consolidated aggregate or mass of minerals, which cannot be excavated by manual methods alone. (Pieces of rock, which pass the No. 4 screen, are considered soil particles.)

Sand - A granular soil, which passes the No. 10 screen and is retained on the No. 200 screen.

Sand Dunes - Ridges of mounds formed by wind blown sand. These deposits of sand consist of clean, uniform sand grains.

Silt - A very fine-grained soil, which passes the No. 200 screen and has a Plastic Index of 10 or less.

Residual Soil - Material that is produced by the weathering of bedrock and accumulates or remains in contact with parent rock.

Soil - A loosely cemented, heterogeneous, earthen material, which is composed of particles surrounded by voids of various sizes. Voids may be filled with air, water and gas, or any combination of the same. Particles of soil are produced by physical or chemical disintegration of rock.

Specific Gravity (Absolute) - The ratio of the unit weight of solid matter in a soil to that of distilled water at 68°F (20°C).

Specific Gravity (Apparent) - The ratio of the weight of soil particles (including permeable and impermeable voids) to that of water.

Specific Gravity (Bulk) - The ratio of the weight of a specific volume of soil particles to the same volume of water.

Stream Terrace - Mostly granular material, which has been deposited by stream action to form a level, topped surface with an escarpment on one side.

Stratified - Soil deposited in layers with different and distinct characteristics.

Swelling Soil – Material, which exhibits the ability to increase in volume with an increase in water content. Soils with high swell potential usually contain montmorillonite.

Testable Material – Soils and rock mixtures having 50% or more by weight, at field moisture content, of minus 4 material and the top size material being less than 6 inches in diameter.

Transported Soil - Accumulation of material, which has been transported from its parent rock by water, wind or ice.

Void Ratio - The ratio of the volume of void space to the total volume of the particles within a mass.

CDOT Forms - Applicable for Soils, Examples and Instructions

Form	Title	Page
# **157**	Field Report for Sample Identification or Materials Documentation	22
# 24	Moisture - Density Relation	23 – 24
# **212**	Field Report on Compaction of Earthwork	25
# 219	Soil Survey of the Completed Roadbed	26
# 323	Laboratory Report on Item 203 (Embankment or Borrow)	27 – 28
# 548	Nomograph - to Correct for Percent Rock	29 – 34
# 564	Soils and Aggregates Sieve Analysis When Splitting on the No.4 Sieve	35 – 38
# 584	Moisture - Density Relation Graph	39
# 626	Field Laboratory Test Results	40
# 1003	Stabilometer Graph	41
# 1007	Gradation Chart	42
# 1030	Stabilometer Test	43
# 1045	Gradation Worksheet	44
# 1297	Moisture - Density Report – [computer *output*]	45 - 47
	Soil Classification Tables	48 – 53
	Note: Text, not Examples	54 - 65
# **554**	Soil Survey Field Report	66
# 555	Preliminary Soil Survey	67 – 68
# **157**	Field Report for Sample Identification or Materials Documentation	69

ATTENTION!

All of the referenced CDOT Materials Forms above, except those indicated as "*computer output*", have been revised in 2014. All of these forms state: *Previous editions are obsolete and may not be used*. The use of Materials Forms older than what is indicated in Appendix O of the FMM is not authorized!

The examples of completed forms will be revised as necessary and as time permits in future FMM's.

Instructions for *Manually Developing the Field Sheet Numbers for CDOT Forms* is presented in Appendix O. In Chapter 200 the forms that utilize a Field Sheet are bolded above.

COLORADO DEPARTMENT OF TRANSPORTATION

FIELD REPORT FOR SAMPLE IDENTIFICATION OR MATERIALS DOCUMENTATION

Metric units ☐ yes ☑ no

Region: 1	Field sheet #: 18180-105
Contract ID: C18180	Date Submitted: 02/27/2017
Project No.: FBR 0404-050	
Project Location: US 40 Over Sand Creek	

Material Type: Embankment, Soil			Field Lab phone: 719-555-2525	Cell Phone: 719-555-5353
Material Code (LIMS): 203.03.01.01	Item: 203	Class:	Grading:	Special Provisions: ☑ yes
Previously used on Project No.: FBR 0404-062		Previous CDOT Form #157 F/S No.(s): 123766		☑ CDOT Form #633 (sack) ☐ CDOT Form #634 (can)

- Sample Identification: Quantity & Unit of material submitted, describe tests required, precise location sample removed from (stationing), etc.
- Materials Documentation: Field inspected (describe appearance, weight/dimensions, model/serial number), COC &/or CTR provided , etc.

Submitting (2) canvas bags of soil

CP21 CP 23 T89,T90, & M145

T 99

T 190 SPEC>25

G 51 G 57 CP-L2103 CP-L2104

User ID: KOCHISL

Sample ID (#1): 172Q163536	Sample ID (#2):	Sample ID (#3):
Sample ID (#4):	Sample ID (#5):	Sample ID (#6):

APL/QML Acceptance: APL Ref. No.	Product name:	Date checked:
APL/QML Acceptance: APL Ref. No.	Product name:	Date checked:

Preliminary ☐ Construction ☑ Maintenance ☐ Emergency ☐ — Date needed: 03/13/2017

Contractor: HAMON CONTRACTORS, INC.	Supplier: ON-SITE PIT
Sampled from (Pit, roadway, windrow, stock, etc.): STOCKPILE	Pit name or owner: CITY OF AURORA

Quantity represented: 18,192 CY	Previous quantity: 0	Total quantity to date: 0

Sample submitted: ☑ Yes ☐ No	Shipped specified quantity to: 2 ☑ Central lab ___ ☐ Region lab	Via: CDOT UNIT	Date: 02/27/2017

Sampled or inspected by (print name): LESLIE KOCHIS	Title: EPST III	E-mail: leslie.kochis@state.co.us
Supervisor (Pro./Res./Matls. Engr./Maint. Supt.) (print name): KARL LARSON	Title: CEPM I	Residency: LIMON

Distribution: White copy - CDOT Central Laboratory
(submit white copy only if sample or information is directed to Staff Materials)
Canary copy - Region Materials Engineer
Pink copy - Resident Engineer

CDOT Form #157 4/14

Previous editions are obsolete and may not be used.

CDOT Form # 157
Note: Within Date needed, ASAP is not a date.

CDOT FORM #24 INSTRUCTIONS

This form is primarily a work sheet designed for field use. In addition to the optimum moisture and density determination, the date required in plotting the multi-purpose nomograph on CDOT Form #548 to correct optimum moisture and density and soil classification can be calculated (Instructions included in this chapter).

For further explanation refer to the circled numbers on the example of CDOT Form #24. Details for these circled reference points are as follows:

1 The detailed test procedure for this section of CDOT Form #24 will be found in AASHTO T 99 or AASHTO T 180, whichever is applicable.

NOTE 1: AASHTO T 99 (aka Standard Proctor) or AASHTO T 180 (aka Modified Proctor) require three points to form a curve, with four points being the most common to fully depict a break in the moisture curve.

2 This section is used to calculate the sieve analysis of the minus No. 4 portion of the sample as well as to record the Atterberg limits and classification of the minus No. 4. (See CP 21 and example of CDOT Form #564). It should be clearly understood that only the Minus No. 4 sieve analysis and the classification of the Minus No. 4 are used when making the previously mentioned multi-purpose nomograph. If the classification of the total sample is desired for another purpose (such as the “As Constructed Soil Survey”) then enter it above in Soil Class Total Sample line.

3 This section is used to calculate the bulk specific gravity and absorption of the plus No. 4 rock. This data is used in the rock and moisture correction formula and is required when making the multi-purpose nomograph.

The method of performing these tests is in CP 23 or AASHTO T 85. For aggregates that have a total absorption of more than 2 percent by the above method, the following method for determining “Field Absorption” will be performed and the results used in the moisture correction calculations.

Formula:

$$Field\ absorption = \frac{C_1 - A_1}{A}\ x\ 100$$

Where: C_1 = Weight in grams of specimen from test area prior to drying.
A_1 = Weight in grams of oven dry specimen

NOTE 2: The specimen for C_1 is obtained from the embankment after it has been subjected to the wetting and compaction procedures normal for area. The intention is to determine as nearly as possible the actual moisture content of the rock in-place. The surface of the specimen should be cleaned of all surface coatings with a wire brush prior to weighing.

COLORADO DEPARTMENT OF TRANSPORTATION

MOISTURE - DENSITY RELATION

Lab No. 203-15	Station 123+58	Contract ID C18180	Region 1	Date Tested 04/22/2015
Field Sheet No. 251336	Project No. FBR 0404-050			
Sample ID MAYHEWT1546144103	Project Location US 40 Over Sand Creek			

Type of Compaction

- Standard AASHTO T 99 ■ Method A
- Modified AASHTO T 180 ☐ Method ______

% Soil 87.0% | % Rock 13.0% | Soil class. total sample A-4(0)

Maximum dry density 111.5 ■ lb/ft³ ☐ Kg/m³ | Optimum moisture 14.1 %

Trial No.	Sample mass	Water added	Moisture samples	Percent moisture	Compacted wet mass	Density, ■ lb/ft³ ☐ Kg/m³ Wet	Dry
1	3730 g.	0.0 g.	Wet 453.4 Dry 407.7 Loss 45.7	11.2%	4.00	119.8	107.7
2	3700 g.	74 g.	Wet 431.8 Dry 382.2 Loss 49.6	13.0%	4.18	125.1	110.7
3	3685 g.	150 g.	Wet 472.8 Dry 410.7 Loss 62.1	15.1%	4.29	128.4	111.6
4	3790 g.	230 g.	Wet 386.1 Dry 329.5 Loss 56.6	17.2%	4.25	127.2	108.5
5	3780 g.	305 g.	Wet 652.4 Dry 545.1 Loss 107.3	19.7%	4.2	125.7	105.0
6			Wet Dry Loss				

Remarks
MOLD WT. 8.6 MOLD VOLUME 0.0334

Tested by (Print name) Todd Mayhew | Title EPST III

Previous editions are obsolete and may not be used.

Sieve analysis of - #4

Sieve	Mass	Indiv. %	% Pass.
#4	159.2		87
#10	269.6		78
#40	435.0		64
#200	736.3		38.6
- #200	782.9		
Total	1,198.4		

Liquid limit 30
Plastic index 23
- #4 Soil classification A-4 (0)

Bulk sp. gr. and absorption of rock

A_1 = Oven dry Mass in air	1,675.0
B_1 = S. S. D. Mass in air	1,708.5
Mass H_2O & beaker	1,246.0
Mass of beaker	584.0
M = Mass of H_2O	657.0

$\frac{A_1}{M} = 2.55$

Sp. Gr. X 62.4 = 159.1 ■ lb/ft³ ☐ Kg/m³

Pcf X .9 = 143.2 | Pcf X .95 =

Absorption = $\frac{B_1 - A_1}{A_1}$ X 100 = 2.0 %

CDOT Form #24 3/14

CDOT Form #24

COLORADO DEPARTMENT OF TRANSPORTATION

FIELD REPORT ON COMPACTION OF EARTHWORK

Item # **203, R50 Spec** ☒ Standard (AASHTO T 99) ☐ Modified (AASHTO T 180)

Project No. **IM-0253-151** | Field sheet #

Location **I-25, SH 7 to WCR 16**

Project code (SA#) **11925** | Region **4** | Date **9/9/10**

Test #	Date	Station or Location	Sulfate % or class	AASHTO Classification	Plus #4 matl. %	Relative compaction %	Moisture % Opt.	Moisture % In place	*Cubic yards (m³) represented
118A	6/5/10	407+20, E Shoulder (SB I-25)		A - 1 - B	49	98	9.6	6.2	2000
118B	6/6/10	407+20, E Shoulder (SB I-25)		A - 1 - B	54	99	9.6	5.4	2000
119	6/10/10	374+00, E Shoulder (SB I-25)		A - 1 - B	52	95	9.6	4.1	2000
120	6/14/10	315+05, E Shoulder (SB I-25)		A - 1 - B	67	96	9.6	5.6	2000
121	6/17/10	297+85, Lane 2, (NB I-25)		A - 1 - A (0)	41	100	9.7	3.4	2000
122	6/20/10	288+25, Lane 3, (NB I-25)		A - 1 - A	49	100	9.7	3.6	2000
123	6/20/10	296+90, Lane 1, (NB I-25)		A - 1 - A (0)	44	100	9.7	3.5	2000
124	6/25/10	306+20, Lane 3, (NB I-25)		A - 1 - B	42	100	8.4	3.9	2000
125	6/27/10	257+50, Mainline, (SB I-25)		A - 1 - B	14	100	8.4	4.6	2000

Sheet Total **20,000**

Remarks

118B over 50% rock, untestable per 203.05

Final report ☐ yes ☒ no | Total quantity tested (final report only)

Resident or Project Engineer **Vic Mackie** | Title **P.E. I**

Distribution:
White - region project file
Yellow - region Materials Engineer

* Cubic yards (m³) represented are estimated (use linear feet (m) or square yards (m²) for item 306)

Previous editions are obsolete and may not be used

CDOT Form #212 1/10

CDOT Form #212

COLORADO DEPARTMENT OF TRANSPORTATION

SOIL SURVEY OF THE COMPLETED ROADBED

Investigations shall be to a minimum depth of 600 mm (24 inch) and shall show all variations

Sample No. 55	Region 4	Date 3/2/02	Sheet No.
Project No. IM 0253-151		Project code (SA#) 11925	
Proj. location I-25, SH 7 to WCR 16			

Test No.	Station and Log	Max size	Percent passing 3.0 in. 75.0mm	1.0 in. 25.0mm	3/4 in. 19.0mm	3/8 in. 9.50mm	#4	#10	#40	#200	Liquid limit	Plastic index	Classification & group index	"R" value	Adj. K-value or WSN	Flexible T.I. * used
	Begin @ Sta. 777+00 NBL															
1A	Sta. 775+00 15" rt of CL						100	98	95	85	40	22	A-6-(18)	9		5.56
	Material from Sta. 770+00 to															
	780+00 Curve 148 FS# 81436															
2A	Sta. 785+00 50' rt. of CL						100	98	93	84	47	26	A-7(23)	7		5.56
	Material from Sta.780+00 to															
	790+00 Curve 15A FS# 81438															
3A	Sta. 795+00 25' rt. of CL						100	98	96	85	42	25	A-7(21)	8		5.56
	Material from Sta. 790+00 to															
	800+00 Curve 16A FS# 81440															

☐ Flexible Pavement, ESAL: 985,000	☐ Concrete, thickness:	Design AADT	Design mod. of rupture 650
Reliability 95%	▲ PSI	Subbase type ABC Class 6	& Thickness range 4-6'

Distribution: Region Materials Engineer, Resident Engineer		Component	Type	Str. coeff.	Thickness range
	1.	Surfacing	HMA	44	9"
	2.	ABC	Class6	.12	4"
	3.	LTS	3% Lime	.14	8"
	4.				

Notes and samples by: Fidel Gonzales

Approved by (Resident or Project Engineer): Corey Stewart

Checked and distributed by (Region Materials Section): Rose McDonald

*Thickness index (T.I.) = $T_1 \times S.C._1 + T_2 \times S.C._2 + T_3 \times S.C._3 + ...$ T=Thickness, S.C.=Strength Coefficient

CDOT Form #219 3/05

CDOT Form # 219

COLORADO DEPARTMENT OF TRANSPORTATION

LABORATORY REPORT ON ITEM 203 (EMBANKMENT OR BORROW)

☐ Preliminary
☒ Construction

Project No.	Project code (SA#)	Field sheet #
IM 0253-151	11925	144740

Proj. location: I-25, SH7 to WCR 16

Region: 4 | Date: 6/16/03

Test No.	Station and Log	Max size	Percent Passing 3	1	3/4	3/8	#4	#10	#40	#200	LL	PI	Class, and Group Index	M_R(K) P.S.I.	R Value	SSE*
1	255+25	2"	100	97	94	81	66	53	29	14	NV	NP	A-1-b(0)		80	0
2	275+30	2"	100	98	95	80	65	54	30	15	NV	NP	A-1-b(0)		81	2
3	325+50	2"	100	97	95	81	64	55	31	16	NV	NP	A-1-b(0)		80	1

This Form is used in the Field / Region

Notes and samples by:

☐ T 99 ☐ T 180
☒ Rigid pavement
☐ Flexible pavement

18^k EDLA

Regional factor

Serviceability Index

Are special corrosive resistant culverts required? ☐ Yes ☒ No

*SSE = Sulfate, Severity of Potential Exposure. Class 0-3

CDOT Form #323 4/06

CDOT Form #323

COLORADO DEPARTMENT OF TRANSPORTATION
Gradation Report

Project ID 11925 **Location** SH 7, TO WCR 16
Project IM 0253-151 **Source** WINDROW **Report Date** 3/12/2004
F.S. # 149152 **Region** 04 **Construction** 3200
Engineer C.K. Su, Soils and Rockfall Program Manager **Working Days** 13
Comments R-Value >= 50

Test #	Lab #	SP?	Station	Depth	LL	PL	PI	%Moist	R-Val	Group Class(GI)	mr
	2004-0047	Yes	195 + 00 West Shoulder	0.0' - 1.0'	NV	NP	NP	0.2	79	A-1-b(0)	33975

Gradations:

mm	75	25	19	9.5	#4	#10	#40	#200
in	3	1	3/4	3/8				
%Pass			100	99	93	80	33	7.4
As Run			100	99	93	80	33	7.4

Proctor:

MDD :	117.3
OMC :	11.4
SpG :	2.59
Abs :	1.1

Lab Performing Work:

Atterberg :	CDOT	T180 :	
Direct Shear :		Mechanical Analysis :	CDOT
R-Value :	CDOT	Other :	
T99 :	CDOT		

This form is generated by the central laboratory

Key

	SP? = Meets special provision requirements?	MDD = Maximum Dry Density
LL = Liquid Limit (AASHTO T89)	R-Val = Stab R-Value (CP-L3101)	OMC = Optimum Moisture Content
PL = Plastic Limit (AASHTO T90)	mr = Resilient Modulus (psi)	SpG = Bulk Specific Gravity
PI = Plastic Index (AASHTO T90)	GI = Group Index	Abs = Absorption

Page 1 of 1

CDOT #323 11/2002

CDOT Form #323

CDOT FORM #548 INSTRUCTIONS

The purpose of any nomograph is usually to eliminate the necessity of performing time consuming mathematical calculations. This is of special interest to field materials personnel needing results as quickly as possible. With this in mind, CDOT Form #548 has been developed and the instructions for plotting a nomograph are given as well as the directions for its use.

This nomograph combines, on one graph, the corrections for maximum dry density, optimum moisture and soil classification. The procedure and reason for correcting the maximum dry density and optimum moisture of the minus No. 4 curve for the percent rock in the density test are in Colorado Procedure 21 and the instructions for CDOT Form #31.

The reasons for correcting the soil classification for rock are not as well understood; therefore the following explanation is given: It has been common practice to classify the total sample, including rock, when running a moisture-density curve. The curve, of course, is run only on the minus No. 4 portion of the sample, but has been identified by the classification of the total sample. In a soil-rock mixture the probability of an in-place density test having the same percent of rock as the sample on which the curve was run and classification made is quite unlikely.

In some instances when the classification changes from an A-4 to A-2-4 (or vice versa), the required percent relative compaction changes 5 percent. For example, assume the following sample was selected for a moisture-density curve and soil classification:

Minus No. 4	= 50 percent
Minus No. 200	= 33 percent
Liquid Limit	= 37
Plastic Index	= 9
Classification	= A-2-4(0)

This same material with no plus No. 4 would have 66 percent minus No. 200 and classify A-4 (5).

The classification changes from an A-4 to an A-2-4 at 35 percent minus No. 200. To find the percent rock at which this change occurs, divide 35 by the percent minus No. 200 in the minus No. 4 (66%) and subtract from 100 or:

35/66 = 53
100 - 53 = 47% rock

Between 0 and 47 percent rock the Group Index will change regressively from 5 to 0. This change would not affect the percent compaction required, but the correct Group Index makes the report (CDOT Form #212) more accurate.

Calculating the correct Group Index or classification change for each in-place density of a soil-rock material would be very time consuming. However, it is quite a simple procedure to incorporate these changes in the nomograph as will be shown.

The instructions and example for CDOT Form # 24 explains that the Form has been designed especially for use when plotting a multi-purpose nomograph on CDOT Form #548. The example of CDOT Form #24 shows the same data as will be used in the following instructions. This nomograph should be plotted at the same time a moisture-density curve is made on soils, which it is anticipated will contain rock in the amount that will require corrections to be made.

EXAMPLE:

Required Data:

	Optimum dry density of minus No. 4	= 115.0
	Optimum moisture of minus No. 4	= 16.5
*	Bulk specific gravity of plus No. 4	= 2.55
	Field moisture (absorption) of plus No. 4	= 2.0
**	Percent minus No. 200 in minus No. 4	= 80
	Liquid Limit	= 35
	Plastic Index	= 7

* Bulk specific gravity of 2.55 x 62.4 = 159.1 lbs/cu ft

** If the moisture-density curve has been run in the field the material will have been classified and the percent minus No. 200 in the minus No. 4 will be known. If the Materials Section supplied the curve, the sieve analysis and classification of the total sample will be found on the Preliminary Soil Survey report, CDOT Form #555. The percent minus No. 200 in the total sample can be converted to percent minus No. 200 in the minus No. 4 by dividing the percent minus No. 200 by the percent minus No. 4 x 100.

ROCK CORRECTION:

Locate the maximum dry density of the minus No. 4 soil on scale 1. Locate the density of the plus No. 4 rock or bulk specific gravity of the plus No. 4 rock on scale 2. Connect these points with a straight line. Locate the percentage of the total sample retained on the No. 4 sieve on scale 5 and project vertically to intersect the sloping line between scales 1 and 2. This point of intersection read on scale 1 is the maximum dry density, corrected for rock.

MOISTURE CORRECTION:

Locate the optimum moisture of the minus No. 4 soil on scale 3 and the field absorption of the plus No. 4 rock on scale 4. Connect these points with a straight line. Locate the percentage of the total sample retained on the No. 4 sieve on scale 5 and project vertically to intersect the sloping line between scales 3 and 4. This point of intersection, read on scale 3 is the optimum moisture, corrected for rock.

CLASSIFICATION AND GROUP INDEX:

To obtain the actual Group Index for the material from a field density test, the percent minus No. 200 must be known. By starting with the percent minus No. 200 in the minus No. 4 (0% rock) the percent minus No. 200 can be calculated for any percent plus No. 4 rock as follows: Subtract the percent rock from 100 and multiply the difference by the percent minus No. 200 in the minus No. 4. Using CDOT Form # 548-A, make this calculation for each 10 percent increase in rock to 60 percent as shown in the following example:

Percent rock at which the total sample will contain 35% minus No. 200

100 minus (35/percent minus No. 200 in the minus No. 4)

100 - (35/ <u>80</u> %) = <u>56</u> %

* Round off Partial Group Index for liquid limit to 2 places. Place the classification with the actual group indices in the spaces provided on scale 5 of CDOT Form #548. It will be noted that the exact point of Group Index change may not fall on the even 10 percent lines, however it is close enough. Also, when there are two or more changes in group index within 10 percent change in rock, interpolation will be necessary.

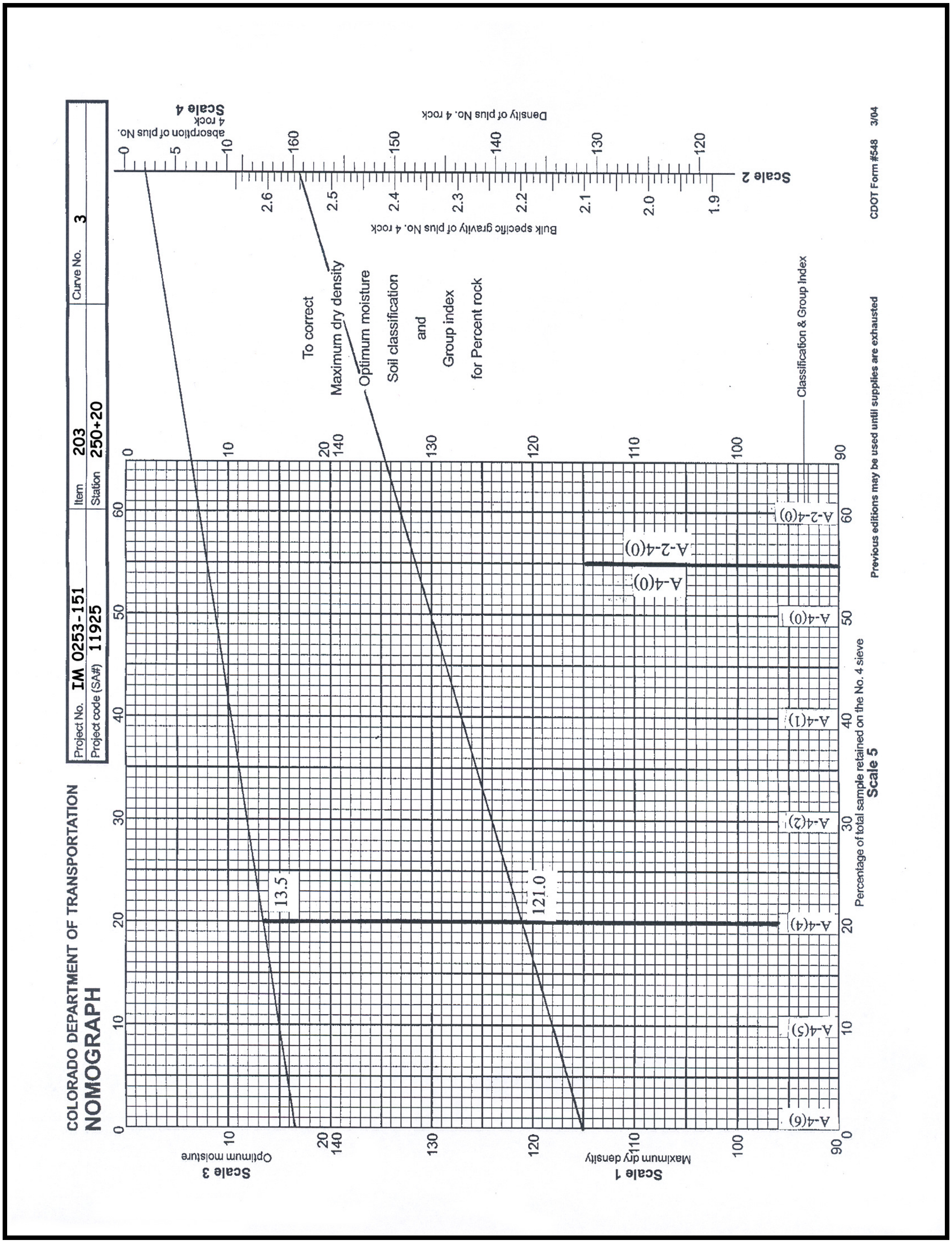
Plot a separate nomograph using CDOT Form #548 for each moisture-density curve, which requires these corrections to be made.

The percentage of plus No. 4 material from the test hole as determined by CP 23, Section 3.5, is plotted on the nomograph and the corrected values for maximum dry density, optimum moisture and classification or Group Index determined.

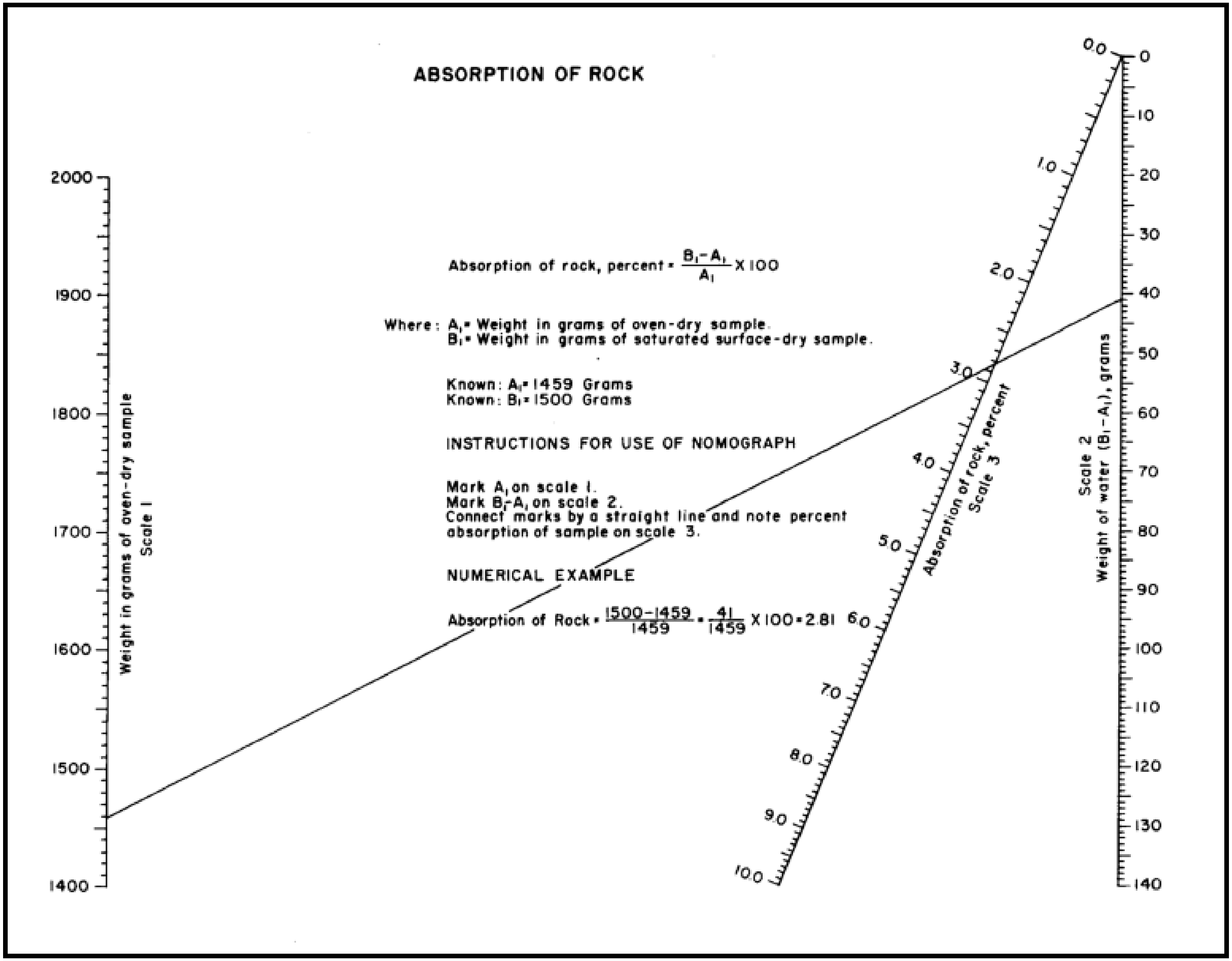
It should be understood that the use of the nomograph, or calculating by formula, in no way relieves the test person of the necessity of determining the proper minus No. 4 moisture-density curve on which these corrections are made. See CDOT Form #31 instructions for the proper procedure.

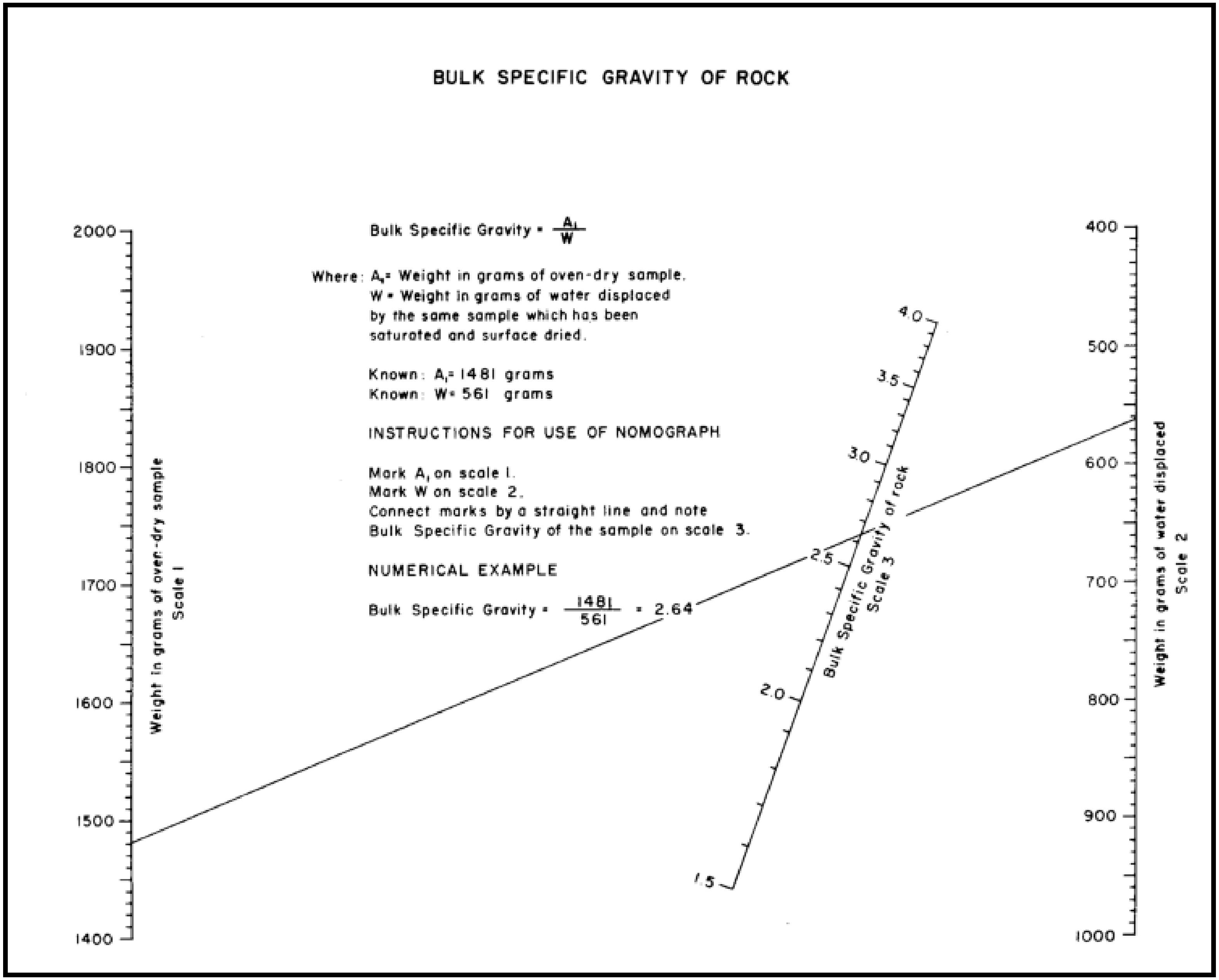
Minus No. 4 Soils Data	% - No. 200 *80*	L.L. *35*	P.I. *7*	Classification *A-4(6)*

100 minus Percent + No. 4	90	80	70	60	50	40
Percent - No. 200 in - No. 4	*80*	*80*	*80*	*80*	*80*	*80*
Corrected Percent - No. 200	*72*	*64*	*56*	*48*	*40*	*32*
Partial G.I. For L.L.	*6.48*	*5.08*	*3.68*	*2.28*	*0.88*	*0*
Partial G.I. For P.I.	*-1.71*	*-1.47*	*-1.23*	*-0.99*	*-0.75*	*-0.51*
Group Index	*4.77*	*3.61*	*2.45*	*1.29*	*.13*	*0*
Classification	*A-4(5)*	*A-4(4)*	*A-4(2)*	*A-4(1)*	*A-4(0)*	*A-2-4(0)*



CDOT Form #548


ABSORPTION OF ROCK
Absorption of rock, percent = $\frac{B_1 - A_1}{A_1} \times 100$
Where: A_1 = Weight in grams of oven-dry sample.
B_1 = Weight in grams of saturated surface-dry sample.
Known: A_1 = 1459 Grams
Known: B_1 = 1500 Grams
INSTRUCTIONS FOR USE OF NOMOGRAPH
Mark A_1 on scale 1.
Mark B_1-A_1 on scale 2.
Connect marks by a straight line and note percent absorption of sample on scale 3.
NUMERICAL EXAMPLE
Absorption of Rock = $\frac{1500-1459}{1459} = \frac{41}{1459} \times 100 = 2.81$
Weight in grams of oven-dry sample
Scale 1
2000
1900
1800
1700
1600
1500
1400
Absorption of rock, percent
Scale 3
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Scale 2
Weight of water (B_1-A_1), grams
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140


BULK SPECIFIC GRAVITY OF ROCK
Bulk Specific Gravity = $\frac{A_1}{W}$
Where: A_1 = Weight in grams of oven-dry sample.
W = Weight in grams of water displaced by the same sample which has been saturated and surface dried.
Known: A_1 = 1481 grams
Known: W = 561 grams
INSTRUCTIONS FOR USE OF NOMOGRAPH
Mark A_1 on scale 1.
Mark W on scale 2.
Connect marks by a straight line and note Bulk Specific Gravity of the sample on scale 3.
NUMERICAL EXAMPLE
Bulk Specific Gravity = $\frac{1481}{561}$ = 2.64
2000
1900
1800
1700
1600
1500
1400
Weight in grams of oven-dry sample
Scale 1
4.0
3.5
3.0
2.5
2.0
1.5
Bulk Specific Gravity of rock
Scale 3
400
500
600
700
800
900
1000
Weight in grams of water displaced
Scale 2

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CDOT FORM #564 INSTRUCTIONS (SOILS)

This is a multi-purpose form used for both soils and aggregate sieve analysis when the maximum size of the material is larger than 1 inch. These instructions are for when this form is used to enter and calculate the Mechanical Analysis of Soils (CP 21). Examples when used for Aggregate Base Course will be found in Chapter 300.

1. **Sample Weight**: This is the weight of the total sample before sieving and before any moisture correction is made.

2. Enter the **sieve** sizes used. The sieves shown must be those used to report on CDOT Form # 219, however additional sieves may be used between those listed to avoid overloading.

3. Normally, only the **wet weight** of the minus No. 4 material and the total wet weight after the sieving operation are recorded in this column. The total of this column and the total sample weight (1) should agree closely. Any significant difference indicates an error in weighing or adding.

4. Enter the weights retained on each sieve above and including No. 4, either accumulatively (Example 1) or individually (Example 2). The **dry weight** of the minus No. 4 is found by dividing the total wet weight of minus No. 4 by (one hundred plus the percent moisture in the minus No. 4) and multiplying by 100.
Example:

$$\frac{13455.9}{100+8.0} \times 100 = 12459.2 \ \ grams \ \text{minus} \ No.4$$

5. The **moisture sample** is taken at the same time as the minus No.4 wash sample. Calculate the percent moisture by dividing the loss by the dry weight and multiplying by 100.

6. The **percent** retained on each sieve (**accumulatively or individually**) is found by dividing the dry weight retained on that sieve by the total dry weight and multiplying by 100. Similarly, the percent passing the No. 4 sieve is calculated by dividing the dry weight of minus No. 4 by the total dry weight and multiplying by 100.
Example:

$$\frac{1617.7}{15964.0} x \, 100 = 10.13 \, \%$$

$$\frac{12460.3}{15964.0} x \, 100 = 78.05 \, \%$$

7. The moist weight of the minus No. 4 material selected for sieve analysis is corrected to **dry weight** by dividing the moist weight by (one hundred plus the percent moisture) and multiplying by 100.
Example:

$$\frac{772.2}{100+7.99} x \, 100 = 715.07 \ \ grams \ \ dry \ \ weight$$

8. **Minus #4 wash** - Enter the sieve sizes used (No. 10 and No. 40 for soils), weigh the amount retained on each sieve (accumulatively or individually). Calculate the **weight** of minus No. 200 by subtracting the total weight retained on the No. 200 from the total dry weight before washing. Calculate the individual percentage of each sieve by dividing each weight by the total dry weight of the minus No. 4 wash sample and multiply by 100.

9. Calculate the **percent passing** each sieve for both the total sample, below the 3 in. to and including the No. 4, and the minus No. 4 wash sample as follows:

Weighing accumulatively (Example No. 1)
Percent passing each sieve = 100 minus the percent retained on that sieve.

Weighing individually (Example No. 2)
Percent passing each sieve = the percent retained on that sieve subtracted from the percent passing the sieve above.

10. Calculate the **percent passing** the No. 10, 40, and 200 sieves for the **total sample**. Multiply the percent passing these sieves in the **wash** sample by the percent passing the No. 4 in the **total** sample and divide by 100.
Example:

$$\frac{94.8\% x 78.05\%}{100\%} = 74.0\%$$

11. Transfer total sample **percent passing** for the **No. 10, No. 40, and No. 200** from the -#4 split sample section (reference number 8, bottom of the form).

12. The Atterberg Limit work sheet (CDOT Form #564-1) is on the reverse side of this form. Enter the results of **Atterberg** test to the nearest whole number here.

13. For **classification**, material above the 3 in. sieve shall be noted, but not used for classifying the soil. See AASHTO M 145, Subsection 4.1.5.

COLORADO DEPARTMENT OF TRANSPORTATION

SOILS AND AGGREGATES SIEVE ANALYSIS WHEN SPLITTING ON THE No. 4 SIEVE

Project no. IM 0253-151
Project code (SA#) 11925
Item 203 Class R-50 (spec)

Pit name Goose Haven | Station 2588+15 13' Lt. | Test no. 13A | Sample weight 16959.6 | Date 12/17/04

Sieve	Wet wt.	Dry wt.	Individual percentage		Percent passing	Specs
②	③	⑤	⑥			
3"			0.0		100.0	
2"		341.1	2.14		97.9	
1 1/2"		758.1	4.75		95.3	
1"		1617.7	10.13		89.9	
3/4"		2103.2	13.17	⑨	86.8	
1/2"		2698.7	16.90		83.1	
3/8"		2967.9	18.59		81.4	
+ #4		3503.7	21.95		78.1	
- #4	13455.9	12460.3	78.05	#10	74.0	⑩
Total	16959.6	15964.0	100.0	#40	56.5	
		⑧		#200	10.5	

Liquid limit 33 ①
Plastic limit 18 ⑪
Plastic index 15
Soil class. A-2-6(0)
"R" value 33 ⑫
Sampled by Ken Kaiser
Tested by J.Grinder

Moisture correction

Plus #4 moisture sample	
Wet weight	
Dry weight	
Loss	
% moisture	

Minus #4 moisture sample ④	
Wet weight	702.6
Dry weight	650.6
Loss	52.0
% moisture	7.99

Minus #4 wash

Wet weight (grams) 772.2
⑦ Dry weight (grams) 715.07

Sieve	Weight (grams)	Individual percentage		Percent passing
# 10	37.1	5.19		94.8
# 40	197.4	27.61	⑨	72.4
#200	618.9	86.55		13.3
- #200	96.1	13.44		
Total	715.0	99.99		

NOTE: Save all material until calculations are completed in case a check is necessary

Pit name Goose Haven | Station 2588+15 13' Lt. | Test no. 13A | Sample weight 16959.6 | Date 12/17/04

Sieve	Wet wt.	Dry wt.	Individual percentage		Percent passing	Specs
3"		0.0	0.0		100.0	
2"		341.1	2.14		97.9	
1 1/2"		417.0	2.61		95.3	
1"		859.6	5.38		89.9	
3/4"		485.5	3.04		86.8	
1/2"		595.5	3.73		83.1	
3/8"		269.2	1.69		81.4	
+ #4		535.8	3.36		78.1	
- #4	13455.9	12460.3	78.05	#10	74.0	
Total	16959.6	15964.0	100.0	#40	56.5	
				#200	10.5	

Liquid limit 33
Plastic limit 18
Plastic index 15
Soil class. A-2-6(0)
"R" value 33
Sampled by Ken Kaiser
Tested by J.Grinder

Moisture correction

Plus #4 moisture sample	
Wet weight	
Dry weight	
Loss	
% moisture	

Minus #4 moisture sample	
Wet weight	702.6
Dry weight	650.6
Loss	52.0
% moisture	7.99

Minus #4 wash

Wet weight (grams) 772.2
Dry weight (grams) 715.07

Sieve	Weight (grams)	Individual percentage		Percent passing
# 10	37.1	5.19		94.8
# 40	160.3	22.42		72.4
#200	421.5	58.95		13.4
- #200	96.1	13.44		
Total	715.0	100.00		

Page 1 of 2 CDOT Form #564 4/07

CDOT Form #564, Page 1

CDOT FORM #564-1 Atterberg Limit Work Sheet

This Form, which is on the reverse side of CDOT Form #564, is a field work sheet used to enter and calculate data for the determination of the liquid limit, plastic limit, and plastic index of soils according to AASHTO T 89, Mechanical Method (alternate) and T 90.

Note that this procedure requires at least two groove closures shall be observed before one is accepted for the record, so as to assure the accepted number of blows is truly characteristic of soil under test. The moisture specimen need be taken only from the accepted trial.

For accuracy equal to that obtained using the standard 3-point method, the acceptable number of blows for groove closure shall be between 22 and 28 (as shown in the example).

When the liquid limit cannot be determined on the soil, report the liquid limit as NV (no value).

ATTERBERG LIMIT WORK SHEET | Tested by | Project code 11925

	LIQUID LIMIT			PLASTIC LIMIT			
Can number		17		18			Test # 12
Number of taps	22	23					Date 3/5/03
A- wt. can + wet soil		30.22		18.88			L.L. 32
B- wt. can + dry soil		26.40		18.28			P.L. 16
C- wt. H_2O (A - B)		3.82		0.60			P.I. 16
D- wt. can		14.44		14.58			
E- wt. dry soil (B -D)		11.96		3.70			
F- % moist. (C / E)100		31.9		16.2			
Nomographic chart		31.6					
Can number							Test #
Number of taps							Date
A- wt. can + wet soil							L.L.
B- wt. can + dry soil							P.L.
C- wt. H_2O (A - B)							P.I.
D- wt. can							
E- wt. dry soil (B -D)							
F- % moist. (C / E)100							
Nomographic chart							

WATER SOLUBLE SULFATES WORK SHEET		Project No.
Sample I.D.		Sample location
Soil Description		Tested by
Sample date	Date received	Test date

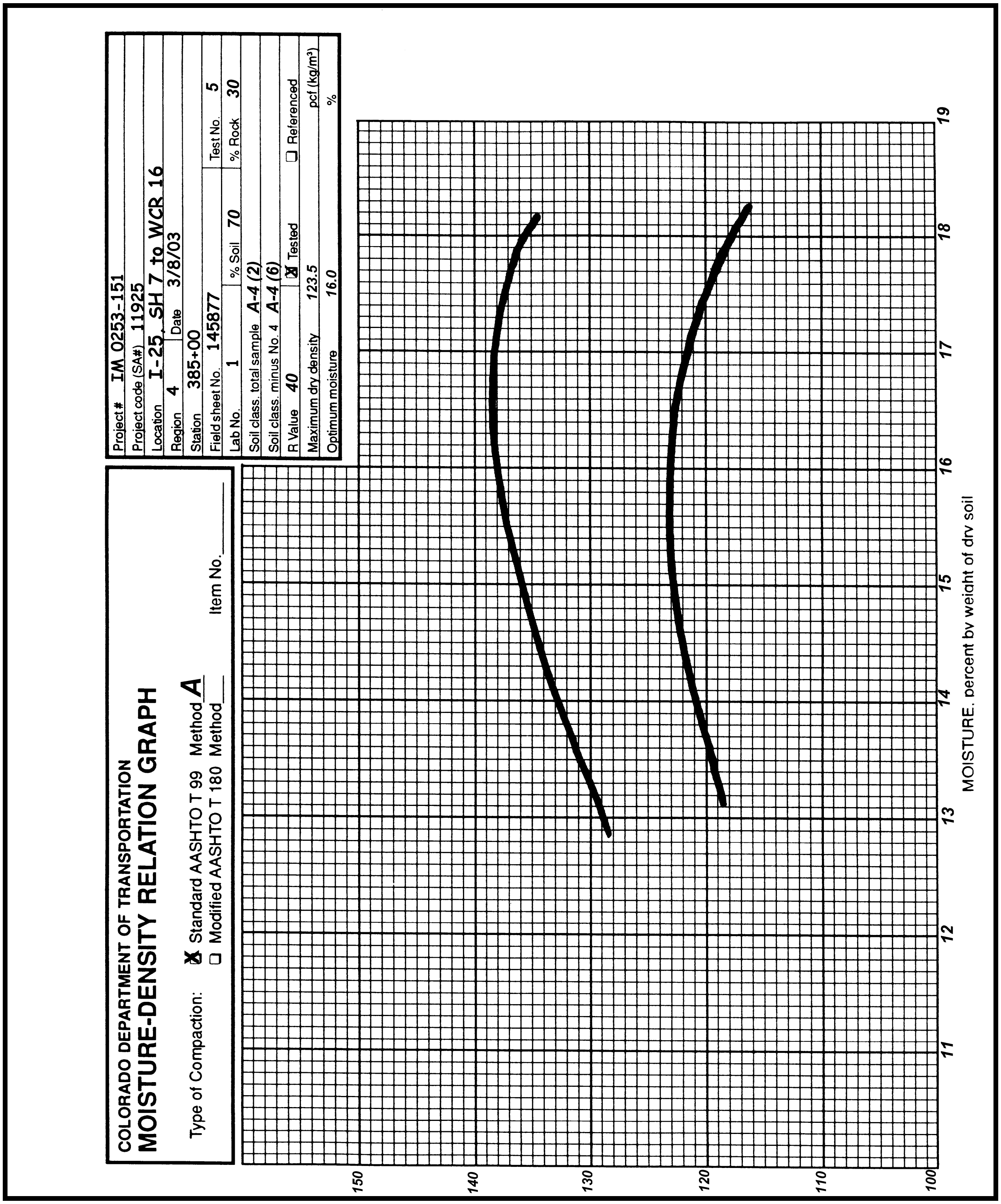
Sample bottle I.D.	A) Number of dilutions: = y
Saturation date	B) Final dilution (10^y:1)
Saturation time	C) Reading:
Test start time	D) Corrected reading
	E) Sulfate concentration
	E = (B x D) (❑ mg/L ❑ ppm ❑ %)

Simplified Procedure

1) Dry soil (<140° F/60° C) and process through the #4 sieve.
2) Process a representative sample through a #40 sieve.
3) Place a 25g representative sample into clean flask or container.
4) Add 250ml distilled water and shake well. (10:1 dilution)
5) Let stand undisturbed for a minimum of 16 hrs maintaining the solution @ 140° F (+/- 5° F).
6) Pipet 25ml of standing solution and deposit into clean 500ml flask (do not disturb sediment). If sample exhibits turbidity then filter until clear.
7) Dilute test sample to 250ml by adding 225ml of distilled water. (100:1 dilution)
8) Pipet 10ml of sample into sample cells (1 blank, 1 reaction sample).
9) Add reagent to 1 cell, shake well and let stand a minimum of 5 min. and not more than 10 min.
10) Place blank into colorimeter and zero the meter.
11) Replace blank with reacted sample and take reading.
12) Record the reading. (mg/L to 10, ppm to 10, % to 0.01)
13) If the reading exceeds the limits of the meter discard test sample and blank. Clean the sample cells. Dilute sample further by taking 25ml from the 10:1 test sample (step 4) and dilute to 500ml. (200:1 dilution) Repeat steps 8 -12. Continue dilutions until a reading is obtained.

Page 2 of 2 CDOT Form #564 4/07

CDOT Form #564, Page 2



CDOT Form #584

COLORADO DEPARTMENT OF TRANSPORTATION FIELD LABORATORY TEST RESULTS	Project No. FBR 0404-050	Contract ID C18180
	Project Location US 40 Over Sand Creek	

Contractor/Supplier: Hamon Contractors Attention: Larry Jones	Item 206	Class Class 1	Lot

TEST NO.	6	7	8	9	10	Item Description	
DATE	4/25/2017	4/25/2017	4/27/2017	4/28/2017	4/28/2017	Str. Backfill CL 1	
STATION	956+23	989+22	1001+58	1015+89	1020+01		
LOCATION	EBL	EBL	EBL	EBL	EBL	Specs	Failing Test #
QUANTITY	200 CY	200 CY	200 CY	200 CY	200 CY		
Sieve							
Sieve 2"	100	100	100	100	100	100	
Sieve 1"	100	100	100	100	100		
Sieve 1/2"	99	100	98	96	100		
Sieve 3/8"	75	78	81	85	81		
Sieve #4	65	66	68	70	67	30-100	
Sieve #10	59	58	60	61	59		
Sieve #40	47	49	47	46	46		
Sieve #50	35	38	36	35	34	10-60	
Sieve #100	22	25	23	25	24		
Sieve #200	11.2	11.5	12.9	15.8	15.6	5-20	
L.L.	25	28	30	29	28	< or = 35	
P.I.	5	6	5	6	6	< or = 6	
% Bitumen							
Max SpG							
Voids							
VMA							
% Rel. Comp.	96%	98%	98%	96%	97%	>95%	
% Moisture	9.5	10.1	9.5	9.8	8.9	8.5-10.5	
Slump							
% Air							
Flex/Cyl PSI							
Other:							

Note: Record "Test No." of the corresponding Sample ID (SM/LIMS). Remarks (below):

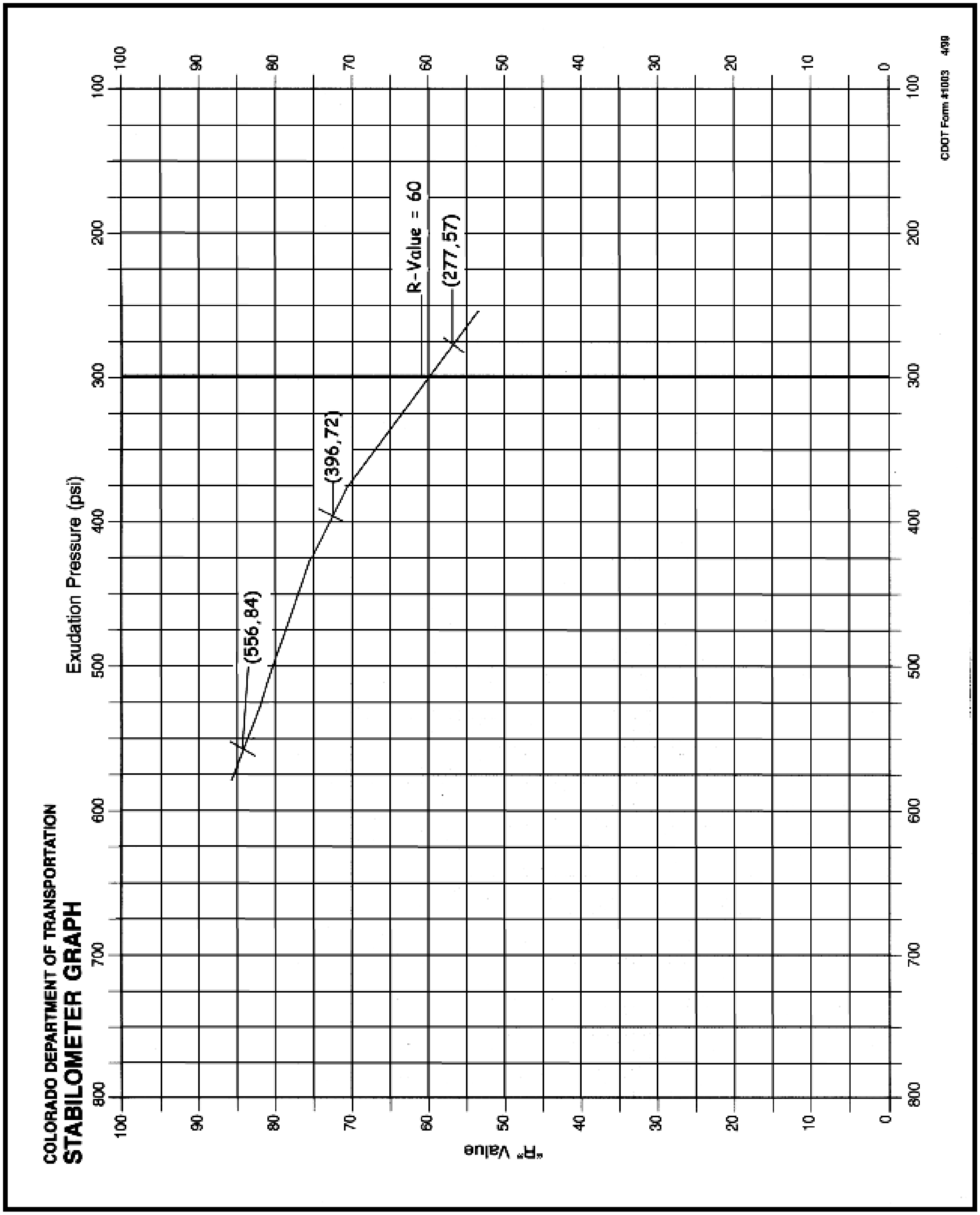
CDOT (print name)	CDOT (sign name)	Date	Time
Leslie Kochis		04/28/2017	8:05 am
Contractor's Representative (print name)	Contractor's Representative (sign name)	Date	Time
Larry Jones		4/29/2017	9:10 am

Original - ☑ Contractor
Copy 1 - ☐ Tester
Copy 2 - ☐ Project Engineer

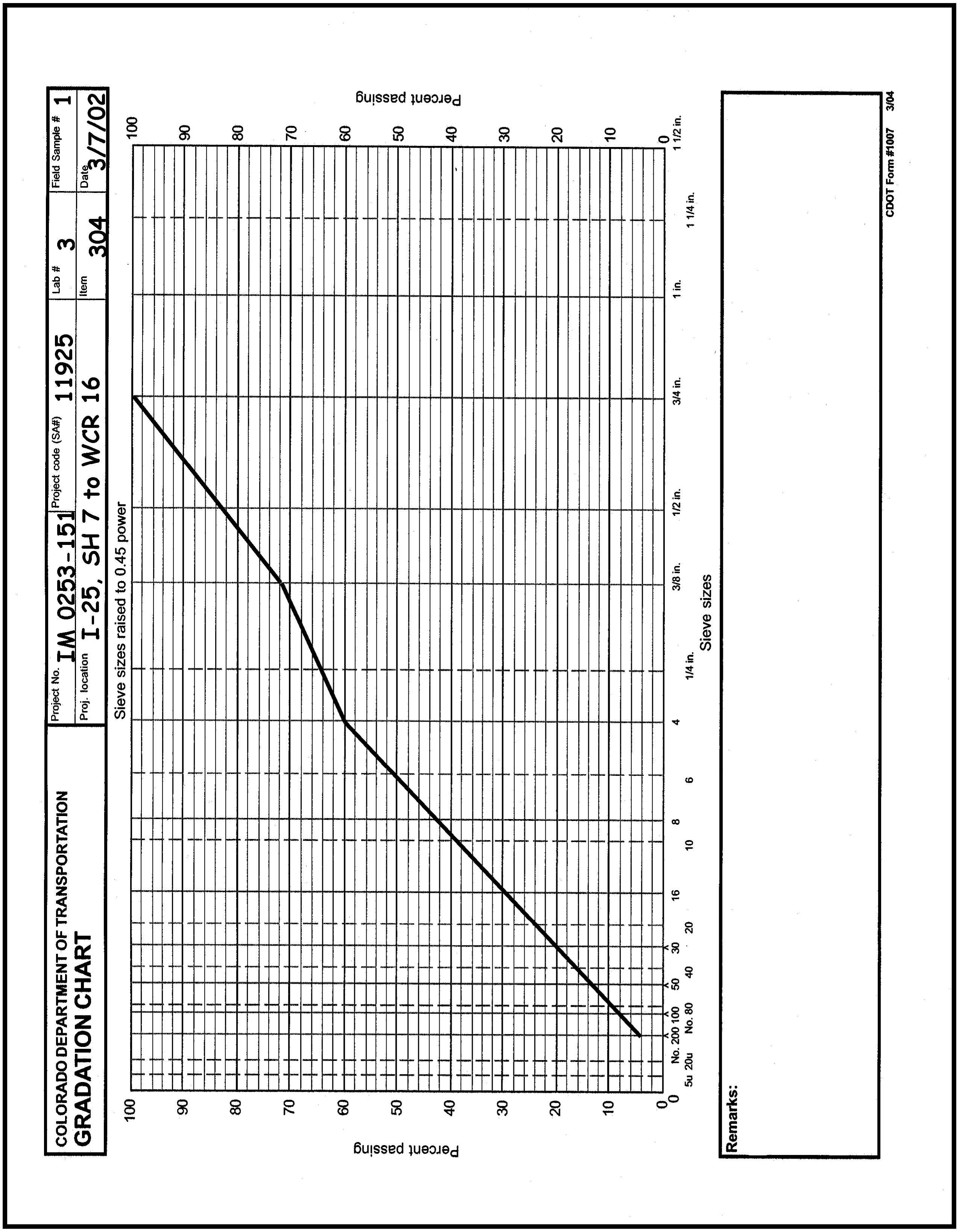
Previous editions are obsolete and may not be used.

CDOT Form #626 5/14

CDOT Form #626



CDOT Form #1003



CDOT Form #1007

COLORADO DEPARTMENT OF TRANSPORTATION

STABILOMETER TEST

Project code (SA#)	Project no.	Location	Source
11925	IM 0253-151	I-25, SH 7 to WCR 16	Pit

F.S.#	Region	Lab ID	Station	Start date
141641	04	2003-0088		3/03/2003

Comments

R-Val >=50

					% Passing (as rec'd)	% Passing (as run)
300 P.S.I. reported R-Value	74	Setup Weights				
Classification	A-4(0)	- 3/4 + 3/8 (g)	0	3"		
				1"		
Plastic index	NP	- 3/8 + #4 (g)	0	3/4"		
		Total with Soil (g)	1100	3/8"		
				#4	100	100
				#10	100	100
				#40	96	96
				#200	40	40

Cylinder no.	4	5	6			
C.C. H_2O added	65	70	76			
% H_2O added	5.91	6.36	6.91			
Pressure on foot, psi	350	325	300			
Exudation pressure, psi	446	335	151			
Exudation pressure, pounds	5465	4105	1850			
STABILOMETER						
2000 160	26	29	37			
Turns displacement	3.50	3.62	3.86			
R-Value	79	76	68			
DENSITY OF SAMPLE						
Height of sample (x.xx")	2.51	2.52	2.50			
Weight of cylinder & sample (g)	3231	3244	3223			
Cylinder tare weight (g)	2124	2115	2115			
Wet weight of sample (g)	1107	1129	1108			
Compaction moisture, %	10.70	11.17	11.74			
Dry density, lbs./cu. ft.	120.8	120.6	120.2			

Orig. weight (g)	250.0
Dry weight (g)	239.2
Hygro, %	4.52

CDOT Form #1030 12/05

CDOT Form #1030

COLORADO DEPARTMENT OF TRANSPORTATION

GRADATION WORK SHEET

Project code (SA#) 11925	Function 3200	Proj. location I-25, SH 7 to WCR 16
Project No. IM 0253-151		Source Stockpile
F.S. # 1022234	Field test #4	Region 4
Lab ID # 02		Station 585+65 6' lt. of CL

Comments

Att. ☒ MA ☒ T 99 ☐ T 180 ☐ R-Value ☒ Shear ☐ other ☐

Date received: 3/9/03

Report by: Vic Mackie

	Wt. Ret.		% Ret.	Total % Pass	As Run
3"	0		0	100	
1"	3.3		6.6	93	
3/4"	4.4		8.8	91	100
3/8"	5.7		11.4	89	98
+ # 4	6.7		13.4		
- # 4	* 43.2	Dry Wt.	86.6		
Total	49.9		100		

Moisture sample: [(Wet Wt. 274 g - Dry Wt. 267 g) ÷ Dry Wt. 267 g] x 100 = 2.62 % Moisture

Total Sample: [Wet Wt. 538 ÷ (100 + % H_2O)] x 100 = 524 Dry Wt.*

Wet Wt. Wash 538	Dry Wt. Wash 524	Corr. wt. 524

	Wt. Ret.	% Ret.	% Pass	Total % Pass	As Run
# 4				87	96
# 10	15.0	2.9	97.1	84	92
# 40	54.0	10.3	89.7	78	86
# 200	310.0	59.2	40.8	35	38

Classification A-2-4(0)	L.L. NV
Sp. Gr. 2.58	P.L. NP
% Abs. 1.45	P.I. NP

CDOT Form #1045 3/04

COLORADO DEPARTMENT OF TRANSPORTATION
Soil Moisture - Density Report

Project ID	11925	**Location**	SH 7 TO WCR 16		
Project	IM 0253-151	**Source**	ROADWAY	**Report Date**	11/18/2003
F.S. #	149044	**Region**	04	**Construction**	3200
Engineer	Tim Aschenbrener - Matls./Geotech. Sect. Engr.				
Comments	R-Value >= 50				

Test #	Lab #	LL	PL	PI	R-Value	Group Class(GI)	Corps of Engineers	Sp. G.	Absorption
	2003-0724	NV	NP	NP	77	A-2-4(0)	Silty Sand		

Gradations:

	#4	#10	#40	#200
%Pass	98	95	70	22
As Run -4 Mat.	100	97	71	22

Lab Tests: **Method** T99A

Test	#1	#2	#3	#4	#5
Moisture	7.1	9.0	11.3	13.4	
Dry Density	118.0	120.5	120.8	117.2	

Moisture Chart:

%H2O	Dry Density	%H2O	Dry Density	%H2O	Dry Density
7.5	118.7	9.5	120.9	11.5	120.6
7.6	118.8	9.6	120.9	11.6	120.5
7.7	119.0	9.7	121.0	11.7	120.4
7.8	119.1	9.8	121.0	11.8	120.3
7.9	119.2	9.9	121.0	11.9	120.2
8.0	119.4	10.0	121.1	12.0	120.0
8.1	119.5	10.1	121.1	12.1	119.9
8.2	119.6	10.2	121.1	12.2	119.7
8.3	119.8	10.3	121.1	12.3	119.6
8.4	119.9	10.4	121.1	12.4	119.4
8.5	120.0	10.5	121.1	12.5	119.2
8.6	120.1	10.6	121.1	12.6	119.0
8.7	120.2	10.7	121.1	12.7	118.8
8.8	120.3	10.8	121.0	12.8	118.6
8.9	120.4	10.9	121.0	12.9	118.4
9.0	120.5	11.0	121.0	13.0	118.2
9.1	120.6	11.1	120.9	13.1	117.9
9.2	120.7	11.2	120.8	13.2	117.7
9.3	120.7	11.3	120.8	13.3	117.4
9.4	120.8	11.4	120.7	13.4	117.2

Optimum Moisture 10.4 **Maximum Dry Density** 121.1

Page 1 of 1 **CDOT #1297 9/2002**

CDOT Form #1297

COLORADO DEPARTMENT OF TRANSPORTATION
Soil Moisture - Density Report

Soil Classifications: **Lab #** 2002-0854

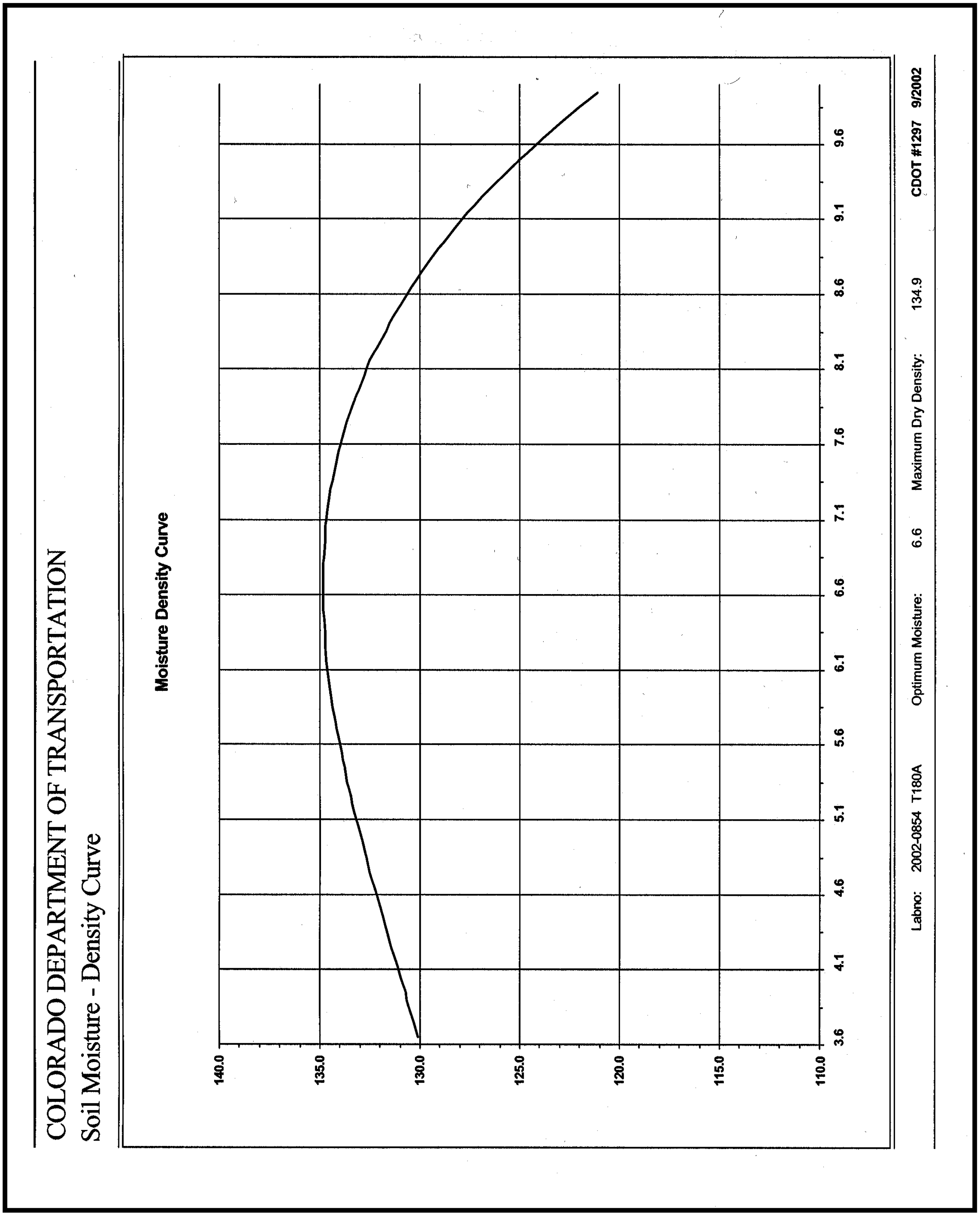
% +4 Mat'l	Soil Class		% +4 Mat'l	Soil Class	
0	A-2-4(0)	Silty or Clayey Gravel and Sand	35	A-1-b(0)	Stone Fragments, Gravel, and Sand
5	A-2-4(0)	Silty or Clayey Gravel and Sand	40	A-1-b(0)	Stone Fragments, Gravel, and Sand
10	A-1-b(0)	Stone Fragments, Gravel, and Sand	45	A-1-a(0)	Stone Fragments, Gravel, and Sand
15	A-1-b(0)	Stone Fragments, Gravel, and Sand	50	A-1-a(0)	Stone Fragments, Gravel, and Sand
20	A-1-b(0)	Stone Fragments, Gravel, and Sand	55	A-1-a(0)	Stone Fragments, Gravel, and Sand
25	A-1-b(0)	Stone Fragments, Gravel, and Sand	60	A-1-a(0)	Stone Fragments, Gravel, and Sand
30	A-1-b(0)	Stone Fragments, Gravel, and Sand			

Rock Correction Chart: **-4 Material Class:** A-2-4(0) Silty or Clayey Gravel and Sand

%+4	%H2O	Dry Density	%+4	%H2O	Dry Density	%+4	%H2O	Dry Density
0	6.6	134.9	20	5.5	137.1	40	4.4	139.2
1	6.6	135.0	21	5.5	137.2	41	4.4	139.4
2	6.5	135.1	22	5.4	137.3	42	4.3	139.5
3	6.5	135.2	23	5.4	137.4	43	4.3	139.6
4	6.4	135.3	24	5.3	137.5	44	4.2	139.7
5	6.3	135.4	25	5.2	137.6	45	4.1	139.8
6	6.3	135.5	26	5.2	137.7	46	4.1	139.9
7	6.2	135.6	27	5.1	137.8	47	4.0	140.0
8	6.2	135.7	28	5.1	137.9	48	4.0	140.1
9	6.1	135.8	29	5.0	138.0	49	3.9	140.2
10	6.1	136.0	30	5.0	138.2	50	3.9	140.3
11	6.0	136.1	31	4.9	138.3	51	3.8	140.5
12	6.0	136.2	32	4.9	138.4	52	3.8	140.6
13	5.9	136.3	33	4.8	138.5	53	3.7	140.7
14	5.9	136.4	34	4.7	138.6	54	3.6	140.8
15	5.8	136.5	35	4.7	138.7	55	3.6	140.9
16	5.7	136.6	36	4.6	138.8	56	3.5	141.0
17	5.7	136.7	37	4.6	138.9	57	3.5	141.1
18	5.6	136.8	38	4.5	139.0	58	3.4	141.2
19	5.6	136.9	39	4.5	139.1	59	3.4	141.3

Optimum Moisture 6.6 **Maximum Dry Density** 134.9

Page 2 of 2 **CDOT #1297 9/2002**



CDOT Form #1297

CLASSIFICATION OF SOILS AND SOIL-AGGREGATE MIXTURES

General Classification	Granular Materials (35% or less passing No. 200)							Silt-Clay Materials (More than 35% passing No. 200)			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5, A-7-6
Sieve Analysis Percent passing: No. 10 (2.00 mm) No. 40 (0.425 mm) No. 200 (.075 mm)	 50 max. 30 max. 15 max.	 -- 50 max. 25 max.	 -- 51 min. 10 max.	 -- -- 35 max.	 -- -- 35 max.	 -- -- 35 max.	 -- -- 35 max.	 -- -- 36 min.	 -- -- 36 min.	 -- -- 36 min.	 -- -- 36 min.
Characteristics of Fraction passing No. 40: (0.425 mm) Liquid limit Plasticity index	-- 6 max.		-- N.P.	40 max. 10 max.	41 min. 10 max.	40 max. 11 min.	41 min. 11 min.	40 max. 10 max.	41 min. 10 max.	40 max. 11 min.	41 min. 11 min.*
Usual Types of Significant Constituent Materials	Stone Fragments, Gravel and Sand		Fine Sand	Silty or Clayey Gravel and Sand				Silty Soils		Clayey Soils	
General Rating as Subgrade	Excellent to Good							Fair to Poor			

*Plasticity index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity index of A-7-6 subgroup is greater than LL minus 30.

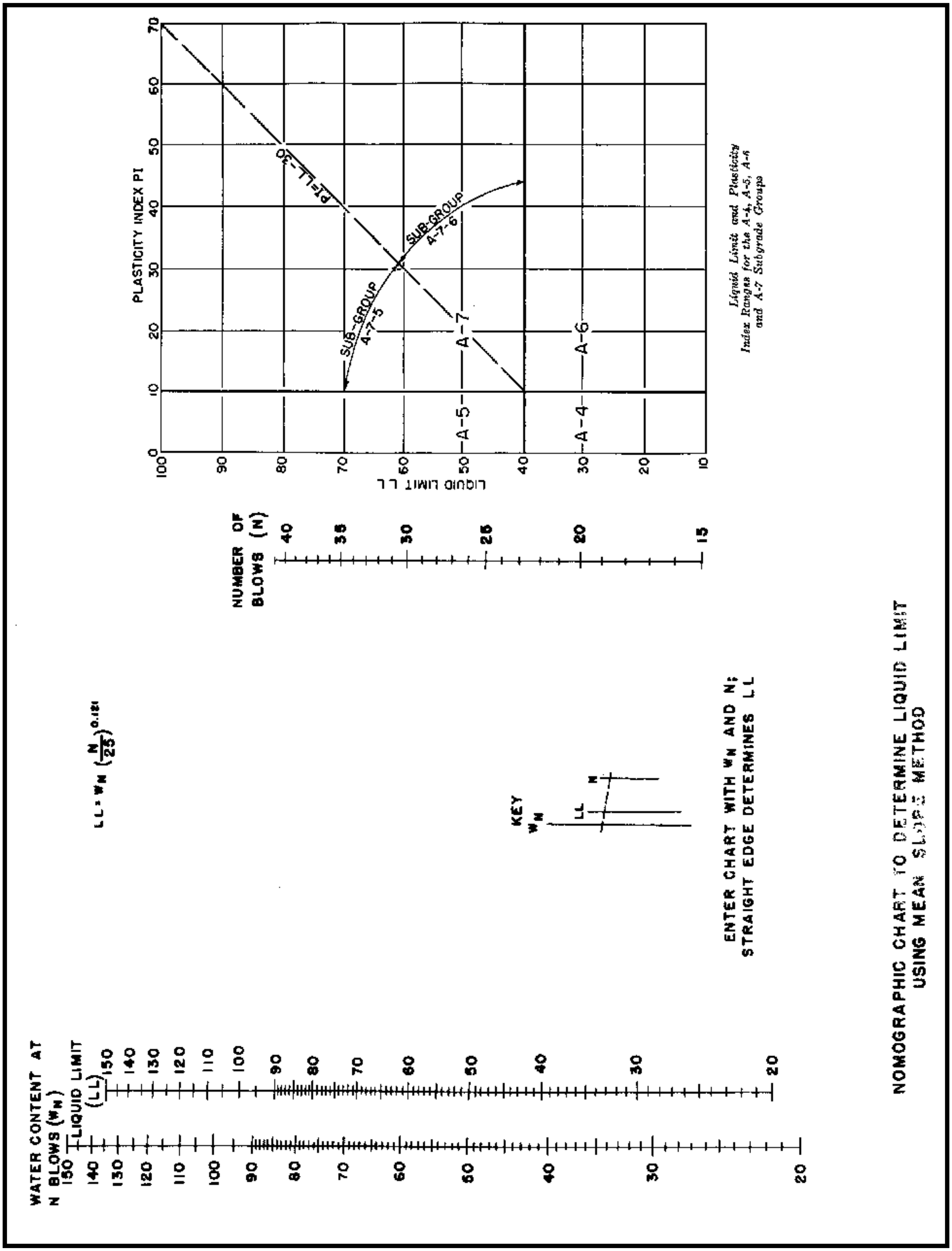
The classification of soils and soil-aggregate mixtures for highway construction purposes shall be in accordance with AASHTO M 145 with the following exceptions:

The quantitative determination of the distribution of particle size shall be in accordance with Colorado Procedure 21 for Mechanical Analysis of Soils, instead of AASHTO T 11 and T 27 or T 88.

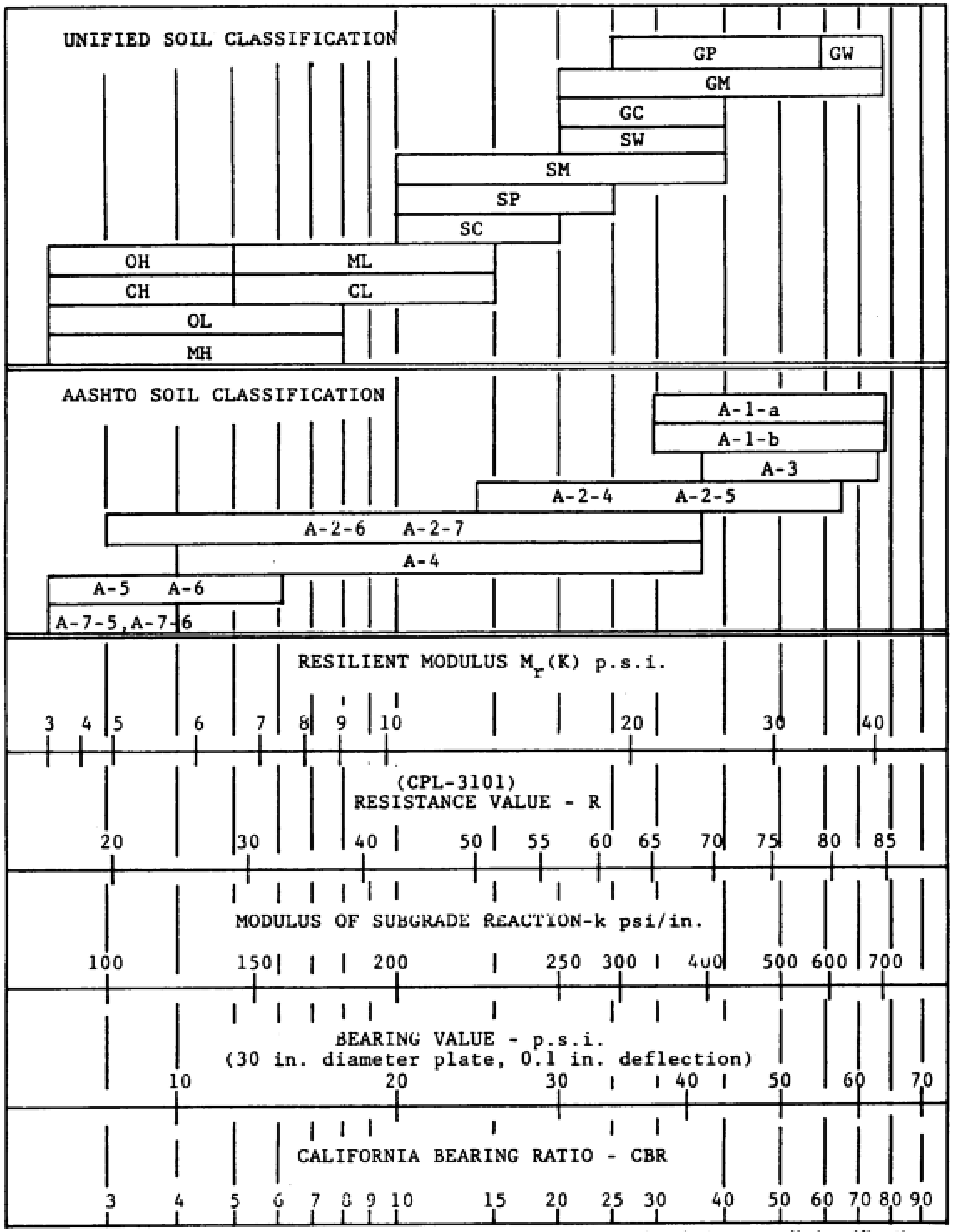
With the required test data from the Liquid and Plastic Limit tests and the Mechanical Analysis test, proceed from left to right in the classification table and the correct group will be found by process of elimination. The first group from the left into which the test data fit is the correct classification.

The Group Index, which is used to further evaluate the soils within each group, may be determined by use of the numerical table as follows: Using the table for the partial Group Index for Liquid Limit (Chapter 200, Chart 2), locate the Liquid Limit on the left side and the percent minus No. 200 along the top. The intersecting column is the partial Group Index for the Liquid Limit. Using the table for the partial Group Index for Plastic Index (Chapter 200, Chart 3), locate the Plastic Index on the left side and the percent minus No. 200 along the top. The intersecting column is the partial Group Index for the Plastic Index. Add the two partial Group Indices algebraically and round to the closest whole number.

All limiting test values are shown as whole numbers. If fractional numbers appear on test reports, convert to the nearest whole number for purposes of classification. Group Index values should always be shown in parentheses after group symbol as: A-2-6(3), A-4(0), A-7-6(17), etc.


NOMOGRAPHIC CHART TO DETERMINE LIQUID LIMIT
USING MEAN SLOPE METHOD
ENTER CHART WITH W_N AND N;
STRAIGHT EDGE DETERMINES LL
$LL = W_N \left(\frac{N}{25}\right)^{0.121}$
KEY
W_N
LL
N
WATER CONTENT AT N BLOWS (W_N)
LIQUID LIMIT (LL)
NUMBER OF BLOWS (N)
PLASTICITY INDEX PI
LIQUID LIMIT LL
PI=LL-30
SUB-GROUP A-7-5
SUB-GROUP A-7-6
A-7
A-6
A-5
A-4
Liquid Limit and Plasticity Index Ranges for the A-4, A-5, A-6 and A-7 Subgrade Groups

GENERAL RELATIONSHIPS BETWEEN SOIL CLASSIFICATIONS AND BEARING VALUES



This chart can be used for quick reference when it is necessary to correlate between soil classification and R value, modulus, or bearing value. It should not be used as the basis for pavement design, but may give the designer an indication of what conditions exist in the field.

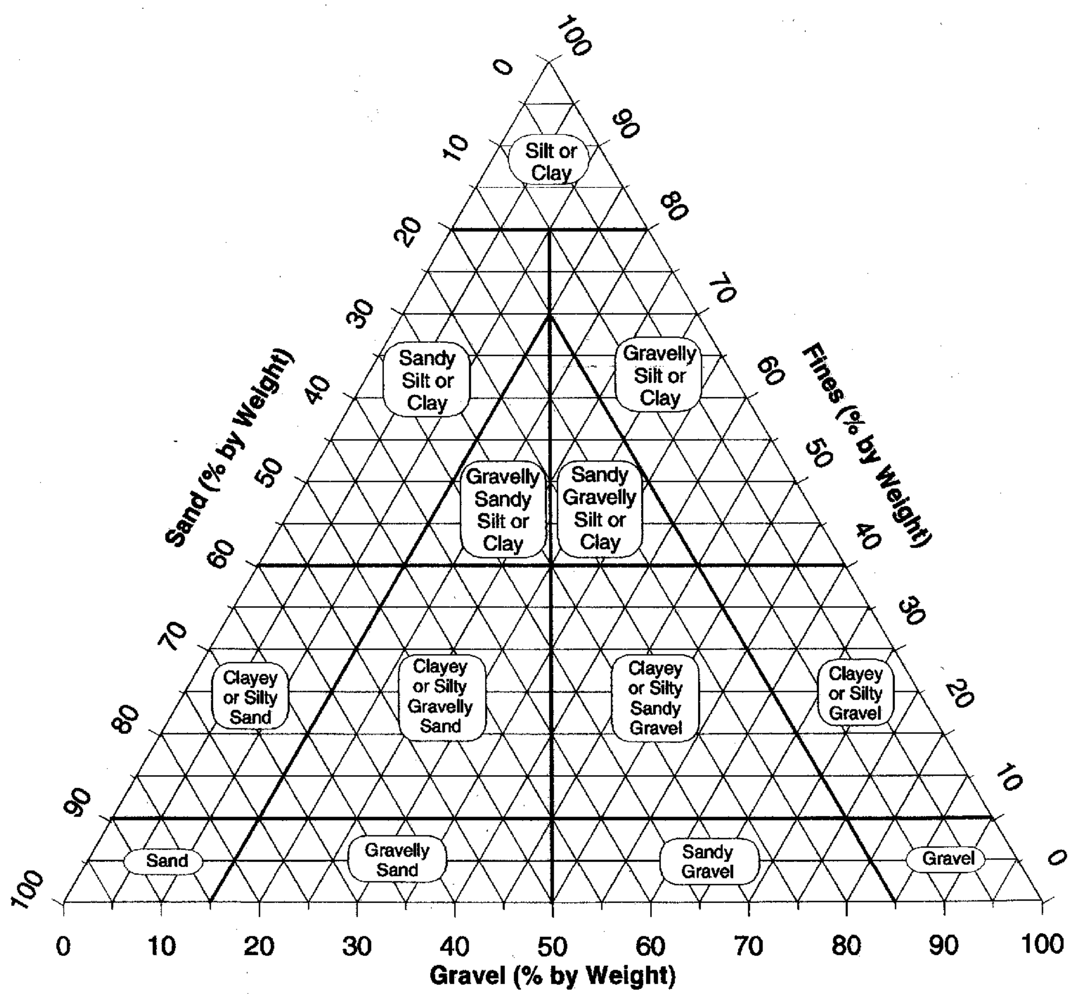
US Army Corps of Engineers Soil Triangle

Notes:

1. Identification based on following grain size ranges:
   GRAVEL: 3" to No. 10 Sieve
   SAND: No. 10 Sieve to No. 200 Sieve

2. Soil is classified as "Silt" or "Clay" depending on the values of the Liquid Limit (LL) and Plastic Index (PI) of the minus No. 40 soil fraction as follows:
   SILT: LL 28 or less and PI of 6 or less
   CLAY: LL over 28 or PI over 6

3. Sieve size designations are US Standards.



US Army Corps of Engineers Soil Triangle

Determining the Percent of Sand, Gravel, and Fines

Consider the following mechanical analysis performed on a sample with a dry weight of 890.4 grams. The material has been found to have a Liquid Limit of 30, and a Plastic Limit of 13.

Sieve Size	Retained	% Retained	% Passing
25mm	0.0	0.0	100.0
19mm	10.6	1.19	98.81
12.5mm	126.2	14.17	85.83
9.5mm	240.2	26.98	73.02
#4	359.3	40.35	59.65
#10	376.3	42.26	57.74
#40	541.9	60.86	39.14
#200	746.6	83.85	16.15

Gravel = 3" to #10 Sieve = 100.0 - 57.7 = 42.3% by weight

Sand = #10 to #200 Sieve = 57.7 - 16.2 = 41.5% by weight

Fines = -#200 Sieve = 100 - (42.3 + 41.5) = 16.2% by weight

Drawing the Classification

Draw a diagonal line at Gravel = 42.3%. In this case, the line traverses from left to right.

Draw a diagonal line at Sand = 41.5%. In this case, the line traverses from left to right.

Draw a horizontal line at Fines = 16.2%. The three lines should intersect in the blocked area of Clayey or Silty Sandy Gravel.

Determining Silt or Clay

Using the criteria above the triangle, determine the characteristics of the - #40 material.

In this case, both the Liquid Limit and Plastic Limit exceed the criteria for silt. Note that when determining “Clay”, only one of the criteria needs to be met. When determining “Silt”, both criteria need to be met.

The classification for this material will be “Clayey Sandy Gravel.”

Note: When a classification falls on a horizontal line, choose the conservative value, the value directly above. When the classification falls on a vertical or diagonal line, then choose the classification to the left.

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Soil Survey / Preliminary Soil Profile

Procedure for Preliminary Survey: Overview 55
Soil Survey 56
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Soil Identification and Description 70
Rock Identification and Description...71
Rock Classification Table...72
Determination of Need for Culvert Protection 73

PROCEDURE FOR PRELIMINARY SURVEY: OVERVIEW

1. Scope

1.1 This set of guidelines generally follows the current practices CDOT personnel use for obtaining soil profiles. It is intended to establish standardized procedures for use by the Region Materials personnel in the performance of uniform and adequate soils investigations. It is not a design manual.

2. Problem Types of Concern

2.1 The recommendations presented herein are oriented toward the solution of such problems as:

Pavement design
Slope design
Slope appearance
Cost
Landslides
Embankment subsidence and settlement
Excavation characteristics
Expansive materials
Drainage
Compaction characteristics

2.2 All of these problems are directly related to:

- The character and distribution of soil and rock bodies, both inside and outside of the right-of-way.
- The influence of surface and sub-surface water on these materials.

3. Use of Soil Profiles

3.1 With the proper amount and type of samples and field information, the designers are provided with data denoting the types of materials to be encountered, the vertical and horizontal boundaries of the changes in these materials, and their strength and deformation characteristics. Adequate preliminary investigation will help prevent uneconomical over-design and unforeseen failure resulting from under-design.

4. Standard Investigations

4.1 Proper investigations to achieve these goals cannot be dictated by a rigidly prescribed set of procedures, although certain basic requirements must be satisfied in each investigation. Both the detail and extent of the investigation will vary depending on the individual problem, the nature of the project under consideration, and the allowable risk of failure.

5. More Extensive Investigations

5.1 Investigations may sometimes need to go beyond the minimum soil profile recommendation presented within this document. Projects in special problem areas or in areas of rough terrain are the most likely to require more extensive investigations. Such studies are especially recommended for high-speed, multi-lane facilities in rough terrain. The Region Geologist and/or the Geotechnical Unit of the Central Laboratory or by outside consultants will conduct these studies.

6. Soil Survey Classification

6.1 Soil surveys may be classified as reconnaissance or preliminary, depending upon the type of information developed and the stage of project development during which each is performed.

7. Reconnaissance Soil Surveys

7.1 Reconnaissance surveys are general in nature and are performed during Phase II (Corridor Location study) of project development under the CDOT Action Plan.

7.1.1 The information developed during these surveys is used in preparation of Environmental Impact Statements for proposed projects. These surveys are performed only if the necessary information cannot be obtained from existing data, such as soil maps, test reports from previous projects in the area, etc.

7.1.2 Information required from reconnaissance surveys:

a) AASHTO classification of all major soil types present in the corridor.

b) Identification of landforms or geologic formations with which each is associated.

c) Description of specific engineering problems associated with each.

7.1.3 This information will be included in the soils and geology reconnaissance report prepared for each project and should be developed through joint effort of Region Materials Personnel and the Geologist assigned to the project.

7.1.4 The field survey, if required, will consist only of identifying the major soils present and obtaining representative bulk samples of each.

7.1.5 Usually, no line will have been established at this point in the project development and sample locations may be selected without regard for line and grade.

7.1.6 Samples may be taken by the most convenient method available. The primary considerations in sampling will be that the samples are representative of the major soil types and large enough to permit accurate laboratory classification.

7.1.7 The survey may be performed either by Region Materials Personnel or by the Geologist concerned, as determined by mutual agreement.

8. Preliminary Soil Surveys

Preliminary soil surveys are performed during Phase III (Preliminary Design) of project development under the CDOT Action Plan. The information developed during these surveys is used in project design and preparation of cost estimates and must therefore be as accurate as possible. These surveys are performed on all new alignments and most widening projects.

8.1 The information required from preliminary soil surveys is described in detail in *The Soil Survey* section of these guidelines, together with recommended procedures for obtaining the information.

8.2 One of the most important items to be determined during the survey is the relationship between soil boundaries and the line and grade of the proposed project. If soil survey personnel do not know the location of line and grade at the time of the investigation, they cannot be certain that the soil conditions encountered in the test holes represent conditions to be encountered during construction. In particular, they cannot be sure that the soil conditions have been sampled to below finished grade if they do not know where finished grade will be located.

8.3 It is important to identify the presence of sulfates in soils at project locations. This can be determined by visiting the following website:
http://websoilsurvey.nrcs.usda.gov/app/
This website can provide soil engineering properties as well as approximate location, depth, and concentrations of sulfates.

8.4 Once the presence of sulfates on project locations is suspected the preliminary soils survey needs to address the sampling and testing of soil layers in these locations. During the preliminary soil survey, 1 sample, per soil type, will be tested per 1000 linear feet of two-lane roadway or fraction thereof. The boring depth for the preliminary soils survey will be a minimum of 3 feet below the proposed finished grade with at least one boring to a minimum depth of 10 feet. The sample size will be a minimum of 5 lbs. per soil type. Where water is present at drainages, a minimum 1 pint sample will be taken. CP-L 2103 will be used in the testing of sulfates in water or soil and can be performed in the field or by the Region Lab if adequate facilities and equipment are available.

SOIL SURVEY

1. Soil and Rock Classification and Description

1.1 Soil and rock materials encountered in test holes or surface outcrops should be identified and described as indicated in Appendices B through D of these guidelines. Accurate descriptions of soil or rock encountered in the field are important to the economic planning of the project design. Avoid complicated descriptions (not relevant to design or construction problems).

2. Sampling Methods

2.1 Test holes can be drilled or dug by hand, power auger, power rotary drill, backhoe, or any other practical method. In any case, it is of the utmost importance to use the method which will insure the attainment of representative, uncontaminated samples whether bulk samples, undisturbed samples, core samples, drill cutting samples, or split-spoon samples. Care should be taken to make sure that loose, sloughed soil or rock in the bottom of the test holes is not mixed in with samples representing the given depth. Where uncertainty exists as to the reliability of a sample, it is better that it be discarded.

NOTE 1: In the following paragraphs, the term "drilled" is used to mean any appropriate method for advancing a test hole.

3. Horizontal Distribution of Test Holes

3.1 Test holes will be spaced no farther apart than 500 feet in continuous cut sections and no farther apart than 1000 feet under any circumstance.

3.2 In addition, test holes should be drilled wherever there is any variation in soil or geological conditions, base gravels, and/or pavement thicknesses.

3.3 Time should be taken to obtain a sufficient number of test holes to outline sub-surface complexities.

3.4 During the design phase of the project, if it is determined that additional data or samples are needed, such will be obtained and a supplemental report submitted.

4. Proposed Widening Projects

4.1 On roadway widening projects, holes along the edge of the pavement will usually yield sufficient information.

4.2 Since there is, at times, considerable lag between the time of the preliminary soil profile and actual construction, holes drilled through the existing pavement should be held to a minimum. Such holes present maintenance problems, and excessive drilling in the traffic flow presents needless hazards.

4.3 Test holes can usually be drilled on the shoulder of the present road close enough to the pavement to obtain thickness measurements and required samples.

4.4 When taking soil surveys on proposed widening jobs, attention should be given to areas where CMP, RCP, or box culverts may be extended, replaced, or added. Quite often these areas will require muck removal. Such requirement for muck excavation should be reported with respect to stationing, distance from survey line, and approximate depth. If it is not practical to drill test holes in the muck, it may be possible to get a rough estimate of depth by probing with a bar or rod.

5. Proposed New Line and/or Grade

These guidelines should be followed if:

- Different soil conditions are anticipated
- Cuts are to be made

5.1 For cut sections, test holes should be spaced as shown in Figure SS-1. At locations 1 and 3, test holes should be drilled on proposed outside shoulder line (edge of pavement) at the daylight line between cut and fill. An additional test hole should be drilled at location 2 (highest elevation of terrain on center line). For embankments whose maximum height will be more than 20 feet, test holes should be drilled on centerline, as shown in Figure SS-2.

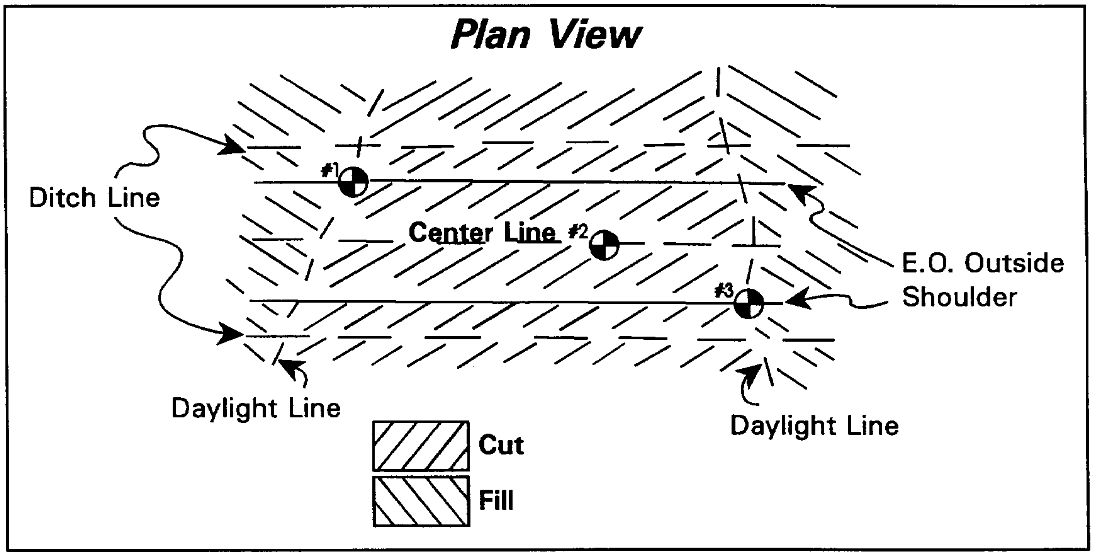

FIGURE SS-1. Recommended location of test holes in the cut section.

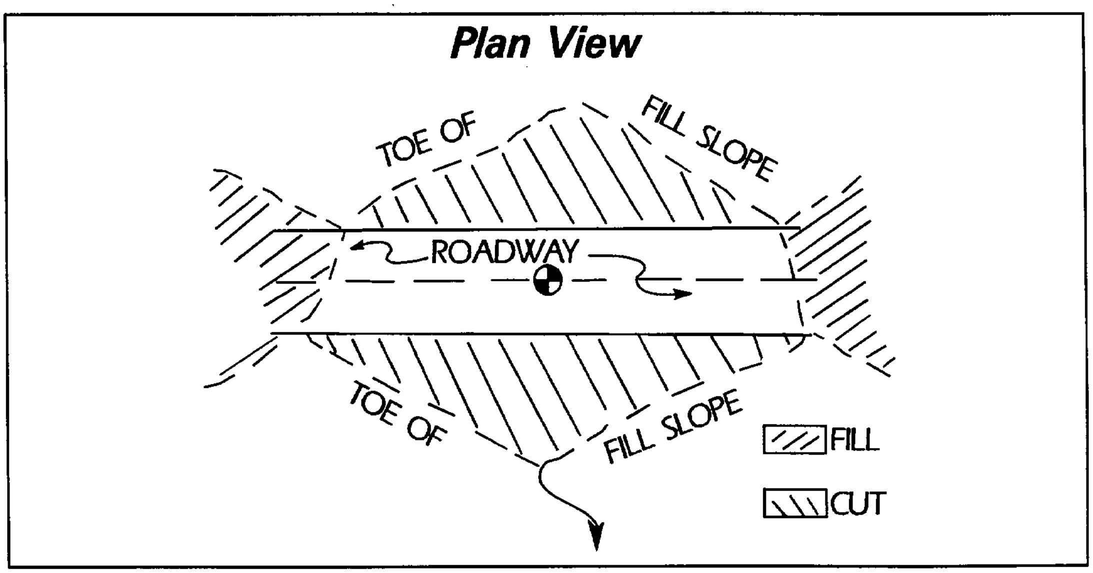

FIGURE SS-2. Recommended location of test holes in fill section.

6. Test Hole Depths and Sampling Recommendations

6.1 Test holes shall extend at least 3 feet below finished grade with at least one boring to a depth of at least 10 feet. If that depth is greater than the depth capability of the equipment available to Region personnel, the Geotechnical Section of the Central Laboratory or commercial drilling contractors will be requested to provide drilling services. Such services would be performed under supervision of Region personnel, assisted by Central Laboratory Geologists if desired.

6.2 If topsoil is going to be required on the project, the lateral extent and depth of material, which could be utilized for topsoil, should be noted on the CDOT Form #554.

6.3 A sample should be taken for each soil encountered except for the material, which might be used as topsoil. If the same soil is found in more than one hole, it may be similarized to a soil already sampled. However, care should be exercised in similarizing soils and additional samples should be taken where doubt exists. Similarization will be limited to one mile.

6.4 Test holes should be numbered consecutively from Hole #1, preferably beginning at the smaller station. Each soil layer encountered in the test hole shall be identified by the hole number followed by letter A, B, C, etc. In Hole #1,the first layer would be 1-A, the second 1-B, etc. Each layer shall be sampled in bulk or similarized. A bulk sample should be composed of at least one full sack and should weigh at least 33 lbs.

6.5 For proposed cut sections the depths of test holes and sampling requirements should be as shown in Figure SS-3. As per test hole location 2, Figure SS-3, soil and/or rock layers A, B, C, and D should be separately sampled or similarized.

6.6 For embankments whose proposed maximum height is more than 20 feet, the depths of test holes and the sampling recommendations should be as shown in Figure SS-4. Unless the bedrock or firm base as diagramed in Figure SS-4 is too hard for the drilling method being employed, all test holes (such as Location #1, Figure SS-4) should penetrate at least 5 feet into the hard substratum. Where the depth from existing ground to the top of the substratum is more than 20 feet, such as at major river crossings, this recommendation can be waived. However, in such cases the desirability of drilling to hard bedrock should be considered in at least one test hole. Test borings for major structures as logged by the Geotechnical Section of the Central Laboratory will be suitable for this purpose if available.

6.7 Where alluvial soils as shown in Figure SS-4 are composed of soft, compressible, fine-grained materials, it may be advisable to request a foundation investigation by the Geotechnical Section of the Central Laboratory.

6.8 For at-grade sections all test holes shall extend at least 3 feet below existing ground. All soils shall be sampled in bulk or similarized.

7. Hydrological Conditions

7.1 The distribution and mode of occurrence of surface and sub-surface water should be noted and included as part of all reports.

7.2 Where free water is encountered in any test hole, the water level is to be checked and noted on the CDOT Form #555 along with the date and hour of the observation.

7.3 In cases where a high water table is suspected, it is recommended that the test hole be drilled or dug at least to the elevation of the water table and preferably a few feet below. Where possible, the hole is to be left open for a period of at least 24 hours and the water level, date, and hour recorded.

7.4 The location of all springs should be determined both horizontally and vertically with respect to centerline and grade line. The location of lakes, ponds, swampy areas, and reservoirs should be noted. Notes should especially be taken if the water is expected to influence the stability of pavements, cut slopes, or embankments.

7.5 The normal annual precipitation at the project site should be determined from the most recent isohyetal map.

8. Piping

Piping (definition): *Mechanical movement of particles due to seepage*

8.1 Areas requiring culverts, foundations, and ditch linings should be investigated to determine whether the soil is subject to piping.

8.2 Piping often occurs in silts, fine sands, and loosely compacted material.

8.3 Concentration of seepage into a few channels may cause piping.

8.4 If the preliminary investigation indicates conditions and soils that could cause piping, the Staff Hydraulics Unit should be requested to make a thorough investigation.

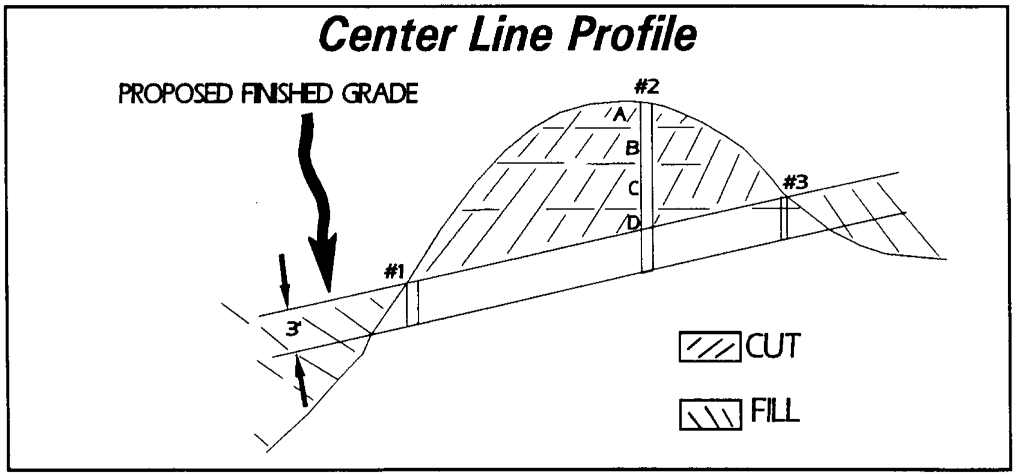

FIGURE SS-3. Recommended depth of test holes in cut sections.

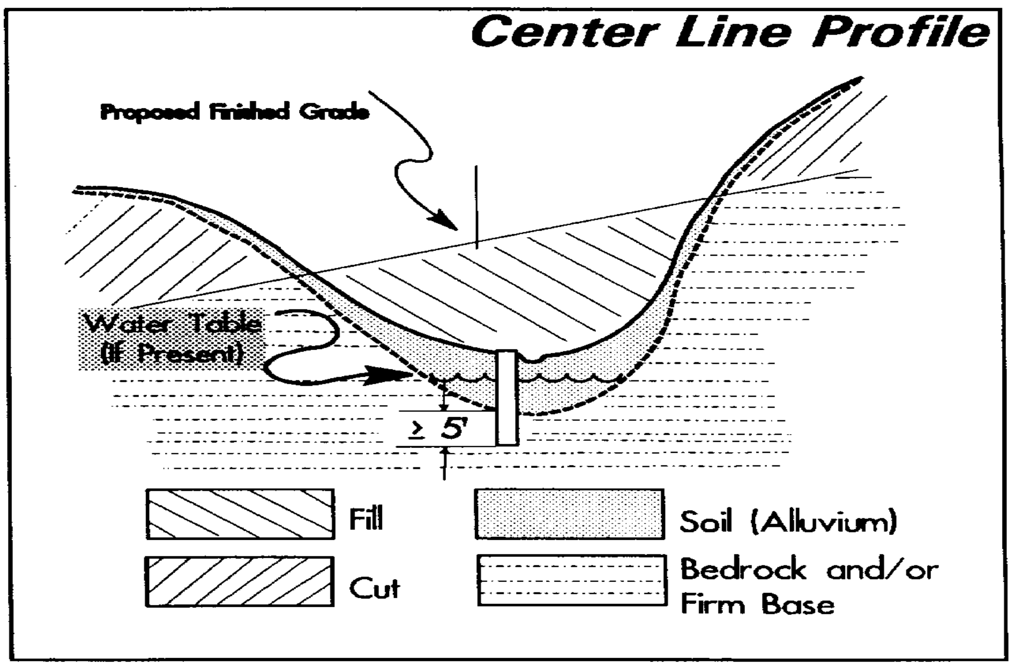

FIGURE SS-4. Recommended depths of test holes in fill.

9. Condition of Existing Pavements

9.1 The condition of existing concrete or asphalt pavements should be taken into account for stabilization and may be noted on a station-to-station basis on the CDOT Form #903. This information is used for assignment of strength coefficients.

9.2 Type and thickness of existing pavement and type of stabilization previously used should also be reported.

10. Frost

10.1 In areas of severe frost action, the soil should be checked for frost susceptibility.

10.2 If necessary, recommendation should be made for the removal and replacement of frost-susceptible soil with non-frost heaving material. Non-frost heaving material should be replaced to a depth of one third-to one half the estimated frost penetration.

10.3 The ground water table (perched tables or aquifers included) should be checked on all projects and in areas of severe frost action. The bottom of ditch linings should be kept at least three feet above the water table (unless the foundation materials are free draining sands or gravels).

11. Adjacent Terrain

11.1 This information is used primarily by the CDOT Staff Hydraulics Unit in determining rainfall runoff factors in the design of drainage structures.

11.2 Rather than noting conditions on a station-to-station basis, a general statement relative to the project as a whole should be made.

11.3 If there are distinct breaks over the length of the project, each type of terrain should be noted. Such designations as rolling grassland, steep timbered slopes, paved commercial etc. are appropriate.

12. Regional Factor

12.1 Deleted

13. Excavation Characteristics

13.1 During the investigation, notes should be kept concerning the estimated excavation characteristics of all soil or rock materials encountered.

13.2 Materials should be classified as:
a) Common excavation
b) Ripping required, or
c) Pre-blasting required

13.3 It is often necessary to construct shallow embankments from cuts or borrow pits containing boulders too large to be buried in the fills. The disposal of such boulders can be a problem on each project where this condition occurs. If such oversized material is encountered during the investigation, it should be noted on the CDOT Form #555 in order that the Project Manager can include a NOTE in the plans that this material will usually become the property of the Prime Contractor, and it is required that he dispose of the material as per local laws and applicable State regulations.

14. Embankment Foundations

14.1 The construction of highways over weak, compressible soils presents some of the more difficult problems in soil mechanics.

14.2 If embankments are constructed over foundation soils having insufficient strength to support the added load, shear failure or slip-outs may occur, or the underlying soft material may displace by outward plastic flow.

14.3 If the foundation soil is highly compressible, excessive settlement of the embankment may occur, resulting in damage or destruction of the pavement, damage to structures, or hazards to traffic due to distortion of the profile and cross section of the roadbed. Such settlement may occur even if the strength of the foundation is high enough to preclude shear failure.

14.4 For the above reasons, it is recommended that Region personnel request that a foundation investigation be performed by the Geotechnical Section of the Central Laboratory where embankments more than 20 feet in height will be constructed on soft foundation soils.

15. Swelling Soils

15.1 Swelling soils are common in Colorado and are frequently encountered during highway construction. To minimize damage to roadways from swelling action, it is necessary that these soils be recognized when encountered in the field and that the boundaries of the soils along the project be determined during the preliminary soil survey.

15.2 A detailed map showing boundaries of swelling soil areas classified by amount of swell potential has been published by the Colorado Land Use Commission and has been distributed to all CDOT Regions. This map should be consulted prior to commencing any soils survey, whether reconnaissance or preliminary.

15.3 It is sometimes difficult to identify swelling soils visually, but the following criteria are often helpful:

15.3.1 *Texture* - When dry, the natural surface exposures of swelling soils usually exhibit an irregular or pebbly texture resembling Popcorn.

15.3.2 Plasticity - All swelling soils are plastic and most are highly plastic. The presence of plasticity can be determined in the field by moistening a sample and attempting to roll a thread in the palm of the hand.

15.3.3 *Bentonite Clay* - A common clay causing swell in soils is bentonite, which usually occurs in shales, either as fine particles invisible to the naked eye or as thin, light colored bands which contrast with the darker color of the shale and are oriented parallel to the bedding. The bands range in color from light tan to light greenish gray and may range in thickness from a fraction of an inch to as much as two or three inches. Pieces of this material will adhere to the tongue and will break down in a matter of minutes if dropped into water.

15.4 If any of these characteristics are noted during the soil survey (particularly in those areas indicated on the map) or if the possibility of swell is suspected for any other reason, notation to this effect should be made on the CDOT Form #554.

15.5 Even though a soil contains expansive clays, it may not swell if the in-place moisture is high enough. It is therefore important to know the actual moisture content of the soil in order to assess the possibility of problems due to swell. For this reason, if swelling soils are identified or suspected during the soil survey, moisture samples should be taken at or slightly below the elevation of the proposed grade line in those areas where the soils are present.

15.6 Problems due to expansive soils usually occur in cut areas and in transitions from cut to fill areas. They could also occur in fill areas where moderate to high swelling soils are used for fill. These soils are usually identified by:

The liquid limit
Plasticity index
Expansion pressure
Swell-consolidation

15.7 The liquid limit and plasticity index usually correlate with swell potential in the laboratory. However, they may not be related to the swell potential in the field because of moisture content, density, and chemicals in the in-situ soil.

15.8 Many potential high-swelling soils in areas of high ground water have taken on enough moisture so that additional swelling is not a problem. But certain dry, dense and often un-weathered soils must be treated to lesson swell potential.

15.9 Remedial measures for cut areas in swelling soil will normally consist of one of the following:

15.9.1 **Sub-excavation of potential expansive soil**. Dry dense un-weathered shales and dry dense clays.

Backfilling with impermeable soil at 95 percent of maximum dry density and at optimum moisture in accordance with AASHTO Designation T 99. This treatment should carry through the cut area and transitions from cut to fill until the depth of fill is approximately equal to the depth of treatment.

Soil with a plasticity index of over 50 should be placed in the bottom of the fills less than 50 feet high or wasted (disposed of offsite).

The backfill soil should be uniform and all lenses or pockets of very high swelling soil should be removed and replaced with the predominant type of soil, which has a plasticity index under 50. Drainage ditches must be below the sub-grade level in the cut areas and must have enough grade to allow rapid runoff of surface water.

15.9.2 **Treatment of the Sub-Grade.** With swelling retarding chemicals such as lime, flyash or lime/fly ash combination.

The reactivity of the chemicals to the sub-grade should be first determined. It is widely known that sulfate-bearing material when introduced with lime will induce further heaving of the sub-grade.

The depth of the treatment should be determined using the sub-grade information such as thickness and swelling potential of the swelling material. The amount of chemicals to be introduced will be determined by the trial mix results obtained in the Soils/Rockfall Unit of the Central Laboratory.

15.9.3 **A combination of the above two methods.** The type of treatment should be based on a thorough investigation. When a choice of treatments is available, the most economical treatment should be used.

15.9.3.1 Depth of sub-grading may be reduced by having a trained soil technician or engineer check the soil as it is being excavated.

15.9.3.2 The zones or pockets containing the worst material would be excavated according to the table below and replaced with a material similar to the better surrounding material which required less depth of treatment.

Better material obtained from the borrow area should always be used in the upper fill. If swelling soil is the only available borrow source for the upper fill, treatment of the top few inches of the sub-grade by the chemicals should be considered. Moisture control during construction should be carefully observed. It is recommended that all swelling soils to be used as fill be compacted to moisture contents at or above optimum moisture.

Suggested Treatment Below Normal Subgrade Elevation

Projects on Interstate and Primary System	
Plasticity Index	**Depth of Treatment**
10 to 20	2 feet
20 to 30	3 feet
30 to 40	4 feet
40 to 50	5 feet
*Over 50	6 feet

Projects on Secondary and State Systems	
Plasticity Index	**Depth of Treatment**
10 to 30	2 feet
30 to 50	3 feet
*Over 50	4 feet

** Excavate and waste, replace with better impermeable material.*

If a treatment is determined to be necessary, then the type of treatment shall be determined by the Region Materials Engineer or it may be advisable to request additional analysis by the Soils/Rockfall Unit of the Central Laboratory.

Mathematically Scalping a Gradation

(Instructions for when a Preliminary Soil Survey has been performed.)

When less than 75 percent is passing the 3/4 inch sieve, divide the 3/8 inch sieve percent by the 1 inch sieve percent and then multiply the quotient by 100. The result will yield the "as run" gradation reported on CDOT Form #555. Perform this calculation on each successive sieve. When more than 75 percent is passing the 3/4 inch sieve, use the 3/4 inch sieve percent as a divisor and then perform the same calculation on each successive sieve.

			< 75%					
Sieve	**3**	**1**	**3/4**	**3/8**	**#4**	**#10**	**#40**	**#200**
% Passing	100	(66)	61	(50)	45	41	28	16
As Run		100	100	76	68	62	42	24

Scalp
(50 / 66) * 100 = 76

			> 75%					
Sieve	**3**	**1**	**3/4**	**3/8**	**#4**	**#10**	**#40**	**#200**
% Passing	100	99	(98)	(95)	90	80	57	21
As Run		100	100	97	92	82	58	21

Scalp
(95 / 98) * 100 = 97

Cumulative Setup for a R-Value

			< 75%					
Sieve	**3**	**1**	**3/4**	**3/8**	**#4**	**#10**	**#40**	**#200**
% Passing	100	(66)	61	(50)	45	41	28	16
As Run		100	100	76	68	62	42	24

Scalp
(50 / 66) * 100 = 76

R-value Setup

100	76	68	
	X	X	
	12	12	
+ 3/8	288		(100-76) * 12 = 288
+ #4	384		(100-68) * 12 = 384
- #4	1200		

Sieve	**3**	**1**	**> 75%** **3/4**	**3/8**	**#4**	**#10**	**#40**	**#200**
% Passing	100	99	98	95	90	80	57	21
As Run		100	100	97	92	82	58	21

Scalp

		R-value Setup		
				(95 / 98) * 100 = 97
	100	97	92	
		X	X	
		11	11	
+ 3/8		33		(100-97) * 11 = 33
+ #4		88		(100-92) * 11 = 88
- #4		1100		

<u>CDOT Forms #554, #555, and #157; Examples and Instructions</u>

CDOT Form #554 shall be used as the first sheet on each Soil Survey.

Full distribution, as indicated on the form, will be made at the time samples are transmitted to the Central Laboratory.

The report number from the CDOT Form #554 shall be placed on all of CDOT Form #555 sheets included in the Soil Survey.

The CDOT Form #555 may be used in place of the field notebook. However, the electronic Form #555 shall be e-mailed to the Soils Program Laboratory Manager when samples have been submitted to the Central laboratory.

The Region office may elect to type the information from the field notebook or original CDOT Form #555 onto another Form #555. A hard copy of CDOT Form #554 and #555 shall accompany samples submitted to the Central Laboratory.

A copy of CDOT Form #555 may be made for Region Materials Laboratory files. No other distribution of the partially completed Form #555 is necessary.

When samples have been processed in the Central Laboratory, the CDOT Form #555 will be completed and distributed.

Distribution of photocopies will be made as indicated on CDOT Form #554.

Serial #1267

COLORADO DEPARTMENT OF TRANSPORTATION
SOIL SURVEY FIELD REPORT

Report	000023				
Project #	IM 0253-151				
Location	I-25, SH 7 to WCR 16				
Function 3200	Part. P	Project code (SA#) 11925	Region 4	Date 5/5/02	

Begin station 189+00	End station 569+00	Length 5.3 KM. → MI.
Equations (stations) 212+00 Bk =212+10 Ah		
Structures (stations) 240+00, E-12-B, Crow Creek; 312+00,E-17-A, Deer Creek; 640+00,E-18-F, Dry Wash		
Type of construction New Alignment		Compaction type: T99
No. of test holes 25	No. of samples 17	Proposed pavement type Flexible
Adjacent terrain data Rolling Hills		
Perform tests for swelling soil Yes	Water sample 1	
Are old uncoated culverts corroding? Yes	If yes, or area does not contain uncoated pipe, either descriptive documentation, samples or both are required per "Soil Survey Procedure" in the Design Manual.	
Record number and type of samples submitted for corrosion analysis. If submitted on separate CDOT Form #157, give report No.	1 Water 2 Soil	
Type of drilling equipment used 4" Auger	Resident Engineer Dave Forsyth	

Comments

Swampy area between Sta. 345+50 - 348+25.
Existing landslide on hillside @ Sta. 350+00 30' Lt.

Centerline located adjacent to pond between Sta. 410+25 - 410+00.

All excavation will be common except rock outcrop between Sta. 470+20 & 472+50 which will require blasting.

Large boulders (2'-3') embedded in grade @ Sta. 514+00

Sampled by Fidel Gonzales	Title E/PS Tech III	Supervisor (Proj./Res./Matls.) signature Corey Stewart / P.E. I
White - Staff Materials & Geotechnical Yellow - Resident Engineer's Office (Project file) Pink - Region Materials office		Address 1050 Lee Hill Rd. Boulder, Co. 80302

CDOT Form #554 1/01

CDOT Form #554

COLORADO DEPARTMENT OF TRANSPORTATION

PRELIMINARY SOIL SURVEY

User ID MAYHEWT

Form #157 No. 351633 | Form #554 No. 25687 | Date Submitted: 04/17/2015

Region: 1 | Contract ID: C18180

Project No. FBR 0404-050

Project Location: US 40 Over Sand Creek

Note 1: If samples are submitted leave sieve analysis section blank
Note 2: Comments should be placed in the discription column of the form
Note 3: Sulfate content expressed as a percent (Dry soil), or ppm in water.

Sample ID/ Station & Log	Test No.	Description	Sulfate Content (SO_4)	Percent passing 3"	1"	3/4"	3/8"	#4	#10	#40	#200	Liquid limit	Plastic Index	Classification & Group Index	Mois-ture %	R-Val	M_R P.S.I.
MP 97 to 103.3																	
MP 97+20 8' LT																	
0" to 5"	1A	HMA															
5" to18"	1B	ABC-sample													0.7		
18" to 40"(refusal)	1C	Red, Gravelly, silt-sm	0.02												0.8		
MP 98+00 6' RT																	
0" to 5"	2A	HMA															
5" to16"	2B	ABC, similar to 1B															
16" to 30"(refusal)	2C	Brown,gravelly,silt-sm	0.00												1.1		
MP 99+00 8' RT																	
0" to 8"	3A	HMA															
8" to12"	3B	ABC, similar to 1B															
12" to 28"(refusal)	3C	Similar to 2C	0.00														

☐ CDOT Central Lab
☐ Region Materials Engineer
☐ Resident Engineer

Previous editions are obsolete and may not be used.

CDOT Form #555 5/14

CDOT Form #555, as submitted by the Region

COLORADO DEPARTMENT OF TRANSPORTATION

PRELIMINARY SOIL SURVEY

Form #157 No. 351633 | Form #554 No. 25687 | Date Submitted: 04/17/2015

Region: 1 | Contract ID: C18180

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MP 97 to 103.3																	
MP 97+20 8' LT																	
0" to 5"	1A	HMA															
5" to18"	1B	ABC-sample				100	87	64	49	29	19.5	28	8	A-2-4(0)	0.7	73	28853
18" to 40"(refusal)	1C	Red, Gravelly, silt-sm	0.02			100	86	74	62	48	33.1	26	11	A-2-6(0)	0.8	50	25317
MP 98+00 6' RT																	
0" to 5"	2A	HMA															
5" to16"	2B	ABC, similar to 1B												A-2-4(0)		73	28853
16" to 30"(refusal)	2C	Brown,gravelly,silt-sm	0.00			100	76	59	50	36	22.8	28	11	A-2-6(0)	1.1	55	19492
MP 99+00 8' RT																	
0" to 8"	3A	HMA															
8" to12"	3B	ABC, similar to 1B												A-2-4(0)			28853
12" to 28"(refusal)	3C	Similar to 2C	0.00											A-2-6(0)			19492

☐ CDOT Central Lab
☐ Region Materials Engineer
☐ Resident Engineer

Previous editions are obsolete and may not be used.

CDOT Form #555 5/14

CDOT Form #555, as completed by the Central Laboratory

COLORADO DEPARTMENT OF TRANSPORTATION

FIELD REPORT FOR SAMPLE IDENTIFICATION OR MATERIALS DOCUMENTATION

Metric units ☐ yes ☑ no

Region: 1	Field sheet #: 18180-136		
Contract ID: C18180	Date Submitted: 03/16/2017		
Project No.: FBR 0404-050			
Project Location: US 40 Over Sand Creek			
Material Type: Embankment, Soil		Field Lab phone: 719-555-2525	Cell Phone: 719-555-5353
Material Code (LIMS): 203.03.01.01	Item: 203	Class:	Grading:
Special Provisions: ☑ yes			
Previously used on Project No.:	Previous CDOT Form #157 F/S No.(s):	☑ CDOT Form #633 (sack)	☐ CDOT Form #634 (can)

- Sample Identification: Quantity & Unit of material submitted, describe tests required, precise location sample removed from (stationing), etc.
- Materials Documentation: Field inspected (describe appearance, weight/dimensions, model/serial number), COC &/or CTR provided , etc.

Submitting (6) canvas bags of soil for preliminary soil survey.

Please complete the following tests: T89, T90, and M145 T-190 (Min 50)

Soil Survey enclosed in bag #1

User ID: KOCHISL

Sample ID (#1): 173G113625	Sample ID (#2): 173G3738	Sample ID (#3): 173G114101
Sample ID (#4): 173G114523	Sample ID (#5): 173G115236	Sample ID (#6): 173G120559

APL/QML Acceptance: APL Ref. No.	Product name:	Date checked:
APL/QML Acceptance: APL Ref. No.	Product name:	Date checked:

Preliminary	Construction	Maintenance	Emergency	Date needed
☑	☐	☐	☐	04/01/2017

Contractor: Hamon Contractors	Supplier: On-site pit
Sampled from (Pit, roadway, windrow, stock, etc.): Roadway	Pit name or owner:

Quantity represented	Previous quantity	Total quantity to date
1/LANE MILE, MIN		

Sample submitted:	Shipped specified quantity to:	Via	Date
☑ Yes ☐ No	6 ☑ Central lab ___ ☐ Region lab	CDOT	03/17/2017

Sampled or inspected by (print name)	Title	E-mail
LESLIE KOCHIS	EPST III	leslie.kochis@dot.state.co.us

Supervisor (Pro./Res./Matls. Engr./Maint. Supt.) (print name)	Title	Residency
KARL LARSON	CEPM I	LIMON

Distribution: White copy - CDOT Central Laboratory (submit white copy only if sample or information is directed to Staff Materials)
Canary copy - Region Materials Engineer
Pink copy - Resident Engineer

CDOT Form #157 4/14

Previous editions are obsolete and may not be used.

CDOT Form #157

SOIL IDENTIFICATION AND DESCRIPTION

1.1 For engineering purposes soil is defined as any naturally occurring unconsolidated material composed of mineral grains with gases or liquids occupying the inter-granular spaces.

1.2 A complete soil identification for engineering purposes includes (a) a description of grain size, (b) color, (c) consistency, (d) moisture content, and (e) other descriptive factors, preferably in that order.

1.2.1 *Grain Size Distribution*: The soil should be primarily identified by the dominant grain size fraction present. The sub-dominant grain size fractions present may be noted as modifiers of the dominant grain size. Example: Sand, silty; gravel, sandy.

1.2.2 *Color:* Without the use of a standard color chart, soil color cannot be precisely determined due primarily to different lighting under different weather conditions. Moreover, the same soil sample will shade differently with varying moisture content. Accordingly field notes as to color should be broad and general unless the soils exhibit some unique color shade such as a distinct red or green.

1.2.3 *Consistency:* Consistency of a soil can be defined as that soil's resistance to penetration. It is related to the soil's density, degree of cementation, and moisture content. The strength and consolidation characteristics of all soils are strongly and directly related to consistency. If "extremely soft clayey soils" or "loose sands and gravel" are encountered in test holes, notation to this effect should be included in the field logs.

1.2.4 *Moisture Content:* For engineering purposes the field moisture content, especially in fine-grained soils, is very important. The moisture has a very strong influence on such engineering properties as compaction, shear strength, slope stability, and consolidation under embankment loads. It is recommended that the field moisture content of all soils encountered, whether sampled or not, be estimated and noted on the CDOT Form #555 as follows:

1) **Cohesive Soils**

a) Dry - loose or crumbly, cannot be formed into a pellet.

b) Moist - can be formed into a pellet.

c) Wet - exudes free moisture when squeezed.

2) **Granular Soils.** The above tests cannot always be successfully applied to granular materials since these soils often will not form into pellets. In such cases, the moisture content must be visually estimated, using the terms "dry", moist", or "wet".

1.2.5 *Other Descriptive Factors*: Soils often possess other characteristics not described by the above four factors which may influence the engineering behavior of the material and should be reported. These include, but are not limited to the following:

1.2.5.1 *Unusual structure:* "Honeycomb" texture or inter-bedded thin layers of alternating fine and coarse material may indicate low strength.

1.2.5.2 *Presence of roots or decayed organic material at depth in a test hole*. May indicate a buried soil horizon. These usually have low strength.

1.2.5.3 *Presence of unusual minerals.* Whitish streaks or crack fillings of caliche indicate the presence of sulfate minerals, which may be detrimental to concrete or metal structures. Streaks, coatings, or crack-fillings of reddish-brown or yellowish-brown iron minerals indicate that ground water has been present in the past and therefore could return.

1.2.5.4 *Presence of man-made material . . .* such as broken glass, cinders, concrete, and metal fragments, etc, indicates that the soil is actually fill. While constructed fills such as highway embankments usually have adequate strength, other types of fills, particularly old dumps, may be very weak and may grow weaker with time if they contain large amounts of degradable or compressible material (tin cans, paper, plastic, etc.).

1.2.5.5 *Oversize Material:* If materials such as gravel, cobbles, or boulders are present but in relatively small amounts, they may be mentioned separately.

Example of the system of description:

◆ Clay, sandy, brown, soft, wet.

◆ Silt, sandy, light tan, firm, moist.

- ◆ Contains streaks of caliche and occasional 1' - 2' boulders.

ROCK IDENTIFICATION AND DESCRIPTION

Rock (Definition)- For engineering purposes rock is defined as a naturally occurring mineralogical aggregate, which in an intact, unfractured sample will yield a laboratory unconfined compressive strength greater than or equal to 200 psi.

Rock (Description) - A complete rock description for engineering purposes includes:

Classification Reference is made to the Rock Classification Table. This is a relatively simple but practical system which can be used by the field person, whether geologist, engineer, or technician.

Color
As for soils (See *Soil Identification and Description*, 1.2.2)

Hardness and Degree of Cementation
Soft - Can be scratched with a fingernail.

Moderately Hard - Can be scratched easily with a knife but cannot be scratched with a fingernail.

Hard - Difficult to scratch with a knife.

Very Hard - Cannot be scratched with a knife

Partings in the Rock
Including fractures, faults, and joints:

Intact - No partings.

Widely fractured - Partings more than 10 feet apart.

Closely fractured - Partings less than 10 feet apart but more than 6 inches apart.

Brecciated partings - Less than 6 inches apart.

Moisture content - Moisture content in rock cannot be determined by simple tests such as those used for soil, but should be estimated visually. As with soils, the terms dry, moist, and wet are adequate for field description.

Rock Classification Table

Sedimentary Rocks	* Coarse-grained	**Conglomerate**	Dominant grain size is boulders or gravel.
		Sandstone	Dominant grain size is sand.
	**Fine-grained	**Shale**	Thin-bedded. Dominant grain size is clay and silt.
		Limestone	Usually light-colored, composed of calcite and/or dolomite (will usually effervesce with dilute HCl).
Igneous and Metamorphic Rocks	*Coarse-grained	**Gneiss**	Composed of alternating bands of different colored minerals.
		Schist	Major component is mica-layered structure.
		Marble	Coarse-grained limestone.
		Granite	Granular, ranging in color from light to medium gray to salmon pink.
		Diorite	Contains approximately equal proportions of dark and light colored minerals.
		Gabbro	Granular dark gray to black.
	** Fine	**Rhyolite**	Nearly white to light gray.
		Quartzite	Composed entirely of quartz.
		Andesite	Medium gray.
		Basalt	Dark gray to black (sometimes porous or vesicular).

*** * Fine-grained:** Individual crystals or fragments, which compose the rock, *cannot* be seen with the unaided eye.

*** Coarse-grained:** Individual crystals or fragments, which compose the rock, *can* be seen with unaided eye.

DETERMINATION OF NEED FOR CULVERT PROTECTION

1. Field Observations and Sampling

1.1 The best time to observe, sample, or report conditions indicating the need for corrosion protection of culverts is on the preliminary soil survey (CDOT Form #554). However, completed soil surveys should be reviewed where it seems necessary. If additional samples are required, submit on a CDOT Form #157.

1.2 Past performance of culvert material is the best source of information. The local Maintenance Foreman can provide a history of culvert performance in the area. Observation of culverts on projects in adjacent areas of similar soil conditions will also provide useful information. Uncoated galvanized pipe, which shows no corrosion after at least two years of service, does not require soil or water sampling. However, a coated pipe, which shows no corrosion, may be in an environment that would attack an uncoated pipe. Samples of both the soil in contact with the pipe and the water going through it would provide this information.

1.3 The condition of the interior of a culvert tells only part of the story. In most cases, the corrosive substances are in the soil in contact with the pipe, rather than in the water. Therefore, to truly appraise the amount of corrosive attack, it is necessary to expose and examine some of the exterior of the pipe. The presence of extensive rust spots would indicate a serious condition. A soil sample should be taken near the corrosion to determine if it is due to a high or low pH, or to some corrosive salts. The extent and location of the corrosion would be noted on the CDOT Form #554.

1.4 Crystals, encrustations and alkali deposits in the streambed near the waterline, are signs of a possibly corrosive water. Stains on the rocks are usually associated with minerals, therefore a tailing dump or mine drainage should be looked for upstream. If found, it should be noted on the CDOT Form #554.

1.5 Water that seeps out of the ground or from some layer in an embankment will probably have variations in the amount of dissolved salts from season to season, depending on the volume of water moving through the soil and the amount and availability of soluble mineral matter. It may be necessary to sample such water in spring, summer, and fall to be sure.

1.6 Alkali deposits on the soil, soils from Mancos and Pierre Shales, and fine silty soils should be suspected.

1.7 The Central Laboratory recommends that all suspected soils and water be sampled. The accompanying CDOT Form #554 or #157 should mention the conditions that prompted the sampling, and the exact location in reference to the proposed or existing culvert.

1.8 Soil and water samples will be run in the Laboratory to determine pH, hardness, alkali content, etc. Recommendations from the Laboratory concerning required protective action may be based on evaluation of one or several of these test results and their interactions.

1.8.1 Unusual stains, encrustations of salt, or alkali, even unpleasant odors, should be mentioned on the CDOT Form #554 or #157, as these are indicative of conditions which may cause culvert corrosion. The possible existence of an abrasive condition should also be noted. A serious problem should be discussed with the Hydraulics Unit for a possible solution.

1.9 A water sample should be at least a pint in volume and be in a clean, uncontaminated container. The soil sample should weigh at least a pound and be sent in a plastic bag.

1.10 On the basis of field observations and laboratory tests (where deemed necessary) the Region shall recommend to the Staff Design Engineer the types of culvert to be used and their location.

2. Corrosion Resistance Levels

2.1 The class of pipe required to resist abrasion and corrosion shall be determined using the *CDOT Pipe Material Selection Policy*.

Liquid Limit Determination from Blow Counts & Water Contents

NOTE: This mathematical formula replaces Chart 1, Pages 1 thru 8, from Field Materials Manuals prior to the 2011 FMM.

LL = Liquid Limit
W_N = Moisture Content of Sample at N blows
N = Number of blows to close ½ inch gap of material in the liquid limit cup is between 22 to 28 blows

$LL = (W_N)\ (N/25)^{.121}$

N	$(N/25)^{.121}$	N	$(N/25)^{.121}$
22	0.985	26	1.005
23	0.990	27	1.009
24	0.995	28	1.014
25	1.000		

<u>EXAMPLE:</u>

$LL = (W_N)(N/25)^{.121}$

Where:

W_N = 16.3% moisture
N = 26 blows to closure

$LL = (16.3)(26/25)^{.121}$

From the above table find N = 26, then use the corresponding number next to 26 and below $(N/25)^{.121}$

This number is 1.005

Multiply W_N (16.3) x (1.005)

LL = 16.38
Round to the nearest 0.1, or 16.4
Round this to the nearest whole number, or 16
Liquid Limit = 16

Partial Group Index for Liquid Limit & Plasticity Index

NOTE 1: This mathematical formula replaces Chart 2, Pages 1 thru 3, from Field Materials Manual prior to the 2012 FMM.

Determining the Partial Group Index for Liquid Limit

Note: If the % passing the #200 sieve is $\leq$ 35%, then the LL partial group index will be 0.

EXAMPLE: Soil has been classified, utilizing AASHTO M 145, as an A-2-6 soil. What is the partial group index?

Equation: (F-35)[0.2+0.005(LL-40)]

Where: F = % passing the #200 sieve
LL = Liquid Limit of that soil

Example: F = 39.9 % = (39.9-35) [0.2 + 0.005 (32-40)]
LL = 32 = (4.9) [0.2 + 0.005 (-8)]
= (4.9) [0.2 + (-0.04)]
= (4.9) [0.16]
Partial Group Index for Liquid Limit = 0.78

NOTE 2: This mathematical formula replaces Chart 3, Pages 1 thru 5, from Field Materials Manual prior to the 2012 FMM.

Determining the Partial Group Index for Plasticity Index

Equation: 0.1[(F-15)(PI-10)]

Where: F = % passing the #200 Sieve
PI = Plasticity Index of that soil

Example: F = 39.9 = 0.01[(39.9-15)(16-10)]
PI = 16 = 0.01[(24.9)(6)]
= 0.01[(149.4)
Partial Group Index for Plasticity Index = 1.49

Total Partial Group Index = Partial Group Index for Liquid Limit + Partial Group Index for Plasticity Index

Example:
0.78 + 1.49 = 2.27 or 2

Completed Soil Classification would be: A-2-6(2)

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