# CONSTRUCTION INSPECTORS REFERENCE GUIDE

# GRADING

Technical Training &
Certification Program

Iowa Department of Transportation

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## *I. Introduction*

Grading work is the foundation building project for the highway. This foundation is usually built only once. Hence, it is very important to build it properly. The foundation must be strong enough to assure that (1) the pavement will perform; (2) the highway can carry a certain number of traffic loads; (3) the unnecessary cost and construction delay due to failure are minimized. Just as when a person is building a dream home, he or she does not want to see a tilted floor and cracks all over the walls. It is certainly not desirable to have too many bumps and cracks on the highways. Unfortunately, the soils formation is seldom uniform. There are many different layers and kinds of soil a person would have to deal with during a grading project. One may have to ask many questions during a grading project:

- How can a person recognize what soil he or she is dealing with?
- Why do these soils have different colors but are still the same classification?
- Where should a certain soil be used?
- Should it be right under the mainline or should it be out on the slope?
- Should a sheepsfoot roller be used to compact this soil or should it be something else?
- How can a person tell if adequate compaction is achieved or overcompaction has happened?

## *Course Objective*

An inspector may have many questions in regard to the earthwork. There is nothing wrong with asking questions. There is only one “stupid” question, which is the one that could not be answered because it was never asked. The intent of the training is to provide the inspector (1) a chance to ask questions; (2) a chance to learn, understand, and be ready; (3) an opportunity to make work more enjoyable. Please do not hesitate to express concerns or comments.

## *II. Preparation*

There are things that should be reviewed before the grading work begins. The inspector should get familiar with the project. Following are some items the inspector should be looking at:

### 1. Plan Review

The plans are the instruction and direction on what work is to be done. The plans are loaded with information. It is extremely important the inspector review and understand the plans. The Department has an excellent plan reading course available to the inspector. Thus, no attempt will be made here to duplicate this course.

The index sheet on the front will list by page number the description of the work. The individual plan sheets will give the exact location of the work. Please study the general notes, standard road plans, and typicals.

Tabulations will give information on size and location of different items such as pipe, silt fence, silt basin, subgrade treatment, etc.

Grading plans will also include soil information sheets that show various types of soil and rock formations found in a soil survey. This information is very important to the grade inspector. The main hope of this training is to provide the inspector with the knowledge to recognize what may be coming before the work actually begins. Please keep in mind the site condition may have changed. Therefore, use these soils sheets for information.

The inspector should also have cross-sections. These cross-sections will give additional information on design, estimates, and survey. Therefore, please study the cross-sections.

**NOTES:**

## 2. Proposal Review

When the contract is ready to be let, the Department sends the proposal form to various contractors who plan to submit bids. Contractors use this form for estimating and determining their final bid price. On the letting date the contractor with the lowest bid generally is awarded the contract.

The proposal form shows the project number, type of work, and location. Information on starting date, working days, liquidated damages, site completion dates etc. is included in this proposal.

Each proposal lists supplemental specifications and special provisions that apply to the contract. Special notes are included. This information gives the contractor the guidelines for acceptable construction procedures.

**NOTES:**

## 3. Right of Way (ROW) Contract Review

The ROW contract is the agreement between the State and the property owner. The inspector on the project and the survey party chief each should have a copy of this document. This contract gives specific information describing land acquired by the State. Items such as driveways and field entrances are shown on a plat in the back and must be constructed as stated.
The office copy of this contract includes a tabulation (a red breakdown) of what was included in the total amount paid. This can be very useful in dealing with the property owner on what was included and what may have to be preserved.

Property owners should be contacted to discuss construction staging and effects on temporary access. These visits may eliminate many complaints during the project.

It is important to compare the ROW contracts with the plans for the type and location of entrances.

**NOTES:**

## 4. Preconstruction Meeting

The preconstruction meeting may be the most important meeting to having a successful and enjoyable project. The main purpose of the preconstruction meeting is to evaluate the contractor's schedule and discuss potential problems that may occur on the project. It is very important that all the involved parties have a chance to present any questions or concerns on staging, weekly meeting, communications, etc. It must be made clear what is expected of the contractor, subcontractors, utility companies, etc. Everyone should be aware of the sequences so that no unnecessary delay will occur. Minutes of the meeting and the attendance list and phone numbers are available for information.

The topics that need to be discussed are listed in Chapter 2 of the Construction Manual.

**NOTES:**

## 5. Utility Companies

For a grading project, there are many utility companies existing within the project boundaries. These companies are notified of the preconstruction meeting. However, it must be understood that it is the contractor's responsibility to notify the utility company when working near any type of utility that may be damaged due to the construction.

There may also be Utility Relocation Agreements. These are for the areas where the utility was located on private property prior to the highway construction. There is information on documenting these agreements in Chapter 12 of the Construction Manual.

**NOTES:**

## *III. Pre-Construction*

There are many details that must be addressed before the actual soils moving operation can begin. Following are some of the "things" that must be done:

### 1. Asbestos Inspection and Removal

Make sure that asbestos inspection and removal are done before building demolition work.

Asbestos inspection is normally done by the Central Materials staff prior to letting. Once the inspection is done, the information is forwarded to the Environmental Section in the Office of Location and Environment. If asbestos is present, the Environmental Section will contact one of the three asbestos removal contractors under contract to remove the asbestos removed before demolition. The Resident Office is expected to get the "Notice of Completion" from the asbestos removal contractor, sign off, and send the paperwork to the Environmental Section so payment can be initiated. Tracking reports on the status of asbestos inspections and demolitions can be found at http:/dotnet/environment/regulated (Reference: Construction Manual 10.62).

**NOTES:**

### 2. Demolition /Underground Tank Removal/Contaminated Soil/Land Farming

a. Demolition

Before the demolition can begin, the Environmental Section needs to send "Demolition Notice" to the Iowa Department of Natural Resources and the U.S. EPA. This notification must be postmarked at least 14 calendar days in advance of commencing work. It will take some time to prepare the notice. Thus, do not wait until the last minute to fill out the request for "Demolition Notice". The specification requires a 25-day notice to the RCE. Check with the project engineer more than 2 weeks before the demolition starts. (Reference: C.M. 10.61)

The Demolition Notice is parcel specific. If an extra work order is created for another parcel or parcels, another notice must be requested.

The Demolition Notice is required for demolition of structures and structural components, i.e., house, garage, barn, sheds, etc. The contractor is allowed to start removing non-structural items such as sidewalks, driveways, fences, etc.

Demolition by burning is not allowed by specification.

If the local Fire Department would like to use the building for training purposes, please contact the Office of Construction.

b. Underground Storage Tank Removal

Underground Storage Tank (UST) is defined as a tank and associated piping with 10% or more of its volume below the ground which has stored or is storing a regulated substance.

Before the tank can be removed, a "Notification of Tank Closure or Change-in-Service" must be initiated. Please contact the Environmental Section for assistance.

It is important to check the registration of the tank. If none is found, please contact the Environmental Section for assistance. ***Do not remove nonregistered tanks.***

All the liquids in the tank must be removed and disposed of in accordance with the Iowa DNR regulations. ***Do not release the liquids on the ground.***

Soil and water samples must be taken by a "certified" ground water professional (GWP). For information on whether or not the contractor is certified, please contact Office of Construction or the Environmental Section. Also, a "Certification of Destruction" must be completed.

c. Contaminated Soil/Land Farming

If the site is contaminated, the contaminated soil must be excavated and treated or disposed of properly. It is the certified GWP's job to assist the RCE in determining the limits of excavation and quantifying the soil which must be treated. However, it is costly to take the contaminated soil to a landfill. Thus, the removed soil normally is spread out on the surface so the liquids can be evaporated. This method is called "Land Application" or "Land Farming".
Please call the Environmental Section for more information and assistance.

More information on the above subjects is available in Chapter 10 of the Construction Manual.

**NOTES:**

### 3. Stormwater Permit

A stormwater permit is required for projects in which more than 1 acre of land are being disturbed. The paperwork normally is started before the letting. Two newspaper notices are published near the location of the project. Also, a form and fee are sent to the Iowa Department of Natural Resources to get the permit. All the prime contractors of all the projects within the project boundaries are required to sign as the co-permittee of the permit at the time the contract is signed. The permit and signed co-permittee certification will be sent to the Resident office as soon as they are available. Please make sure that all the prime contractors have signed the co-permittee certification. If anyone has not done so, please contact Office of Construction. Also, all the subcontractors must sign the co-permittee certification statements. The signed certification should be kept in the file at the resident office.

This permit will be active until 70% of permanent vegetation is established.

More information on stormwater is available in Chapter 10 of the Construction Manual.

**NOTES:**

## 4. Erosion and Sediment Control

Erosion and sediment control is the vital requirement for stormwater regulations. Prior to beginning the grading or clearing and grubbing operations, silt fences must be installed. Silt fence must be placed along the perimeter of the area to be disturbed at locations where the runoff can move off site. Vegetation in areas not needed for construction shall be preserved.

Extra attention should be given to areas near a waterway. This includes the disturbed areas at the ends of a culvert or a ditch before the water gets to the creek or drainage way. Silt fences, silt basins, or rock checks should be installed at these locations to prevent siltation from getting into the water. Areas with a steep slope may need to be protected with rock flumes. The typicals for these devices are included in the appendix.

Contractors should not be allowed to disturb several areas without trying to do some finishing work, i.e., seeding or mulching. If cooperation is not obtained from the contractor, a letter of warning should be sent. Withholding payment and shutting down the project are the next steps.

Inspection of the erosion control devices will be made every seven calendar days and after each rain event of half an inch or greater. The inspection and the findings will be documented as the record for IDNR inspection and compliance with the storm water permit requirements.

The silt fences that have lost 50% of their capacity will be cleaned or replaced.

Maintenance of the erosion control devices is required throughout the contract period.

The inspector should work closely with the contractor to make sure that the appropriate actions in regard to erosion control devices are done as soon as possible.

More information on erosion and sediment control is available in Chapters 6, 7, and 10 of the Construction Manual.

**NOTES:**

## 5. Clearing and Grubbing/Tree Disposal

Clearing and grubbing are terms used to describe the removal and disposal of unwanted tree stumps, downed timber, hedge, brush, growing corn, vegetation, rubbish, and field fence within the need lines or right of way.

There are many ways to dispose of the clearing and grubbing waste. Following are the allowable ones:

- Open Burning

Iowa Administrative Code 567-23.2 allows open burning of the clearing and grubbing waste, unless prohibited by local ordinances or regulations. The Administrative Code prohibits burning in Cedar Rapids, Marion, Hiawatha, Council Bluffs, Carter Lake, Des Moines, West Des Moines, Clive, Windsor Heights, Urbandale, and Pleasant Hill. In locations where burning is allowed, the burning of the waste must be located at least one quarter mile away from any inhabited building. Rubber tires shall not be used to ignite the wastes.

Wind direction and ash pollution should be kept in mind so that complaints from the public are avoided.

- Chipping

Where feasible, brush should be chipped for subsequent use as mulch.

- Firewood

Where feasible, the logs should be salvaged for firewood.

- Landfill

The waste can be disposed at a “yard waste” landfill.

- Burial on Project

The stumps can be buried within the State of Iowa Right-of-Way at locations approved by the RCE.

More information on clearing and grubbing is available in Chapter 6 of the Construction Manual.

**NOTES:**

## 6. Traffic Control

Traffic control shall be checked and documented at least once a day and should be done twice; once in the morning and once in the afternoon. This is an important contract item, which requires constant monitoring. Traffic control will be shown on the plans and referenced to standards and typicals. Many times, modifications have to be made because of sight distance or unforeseen hazards. Before modifications are made, check with the Resident Engineer for approval.

More information on traffic control is available in Chapter 5 of the Construction Manual.

**NOTES:**

## 7. Survey

There are some basic points the inspector should know about the survey during the grading project. The following survey checklist should be kept in mind:

a. Reset control points on centerline to include:

* Mainline
* Interchanges
* Sideroads

b. Set all Right of Way pins with markers.

c. Establish a permanent bench mark list. This list should include a bench mark in every bridge and concrete box culvert.

d. Temporary references should be set on all control points as required in Item (a).

Also, there are two very important fundamentals in construction survey that relate to grading.

*1. Elevation:* Elevation is determined by using an established elevation point, which is called a bench mark. A rod reading is taken to determine how high the instrument is above the bench mark. The reading, added to the elevation of the bench mark, gives the elevation of the hair line. This elevation is called the height of instrument (H.I.). Any ground reading, subtracted from the H.I., gives the ground elevation at the place where the reading was taken.

*2. Horizontal Distance:* Horizontal distance is obtained by measuring from the base line to the point where a ground reading is taken.

Some common stakings that the inspector should be aware of are:

*Slope Stakes for Fills:* Slope stakes for fills are the means by which the information from the plans is transferred to the ground for the contractor to do the cut excavation and embankment construction. Slope stakes for the fill section are the stakes set at the toe of the slope to show the height of the fill, measured from the shoulder grade to the ground where the stake is driven. These stakes are set for grades and width of road bed as shown on plans.

*Slope Stakes for Cuts:* Slope stakes for cuts are the stakes set at the top of the backslope to show the depth of cut from a point on the ground where the stake is driven to grade at the bottom of the side ditch or, if no side ditches are planned, to the point where the floor of the proposed cut meets the plane of the backslope.

*Blue Tops:* Blue tops are finish stakes set on centerline and shoulder line. These are a distinct help in securing neat lines and smooth grades, and are needed on all grading projects regardless of the type of surface.

*Roadway Pipe:* One important thing to remember about roadway pipe is the inlet and outlet elevations. The direction of the flow must be recognized before the installation of the pipe. The elevations of the inlet and outlet must be checked so proper flow is achieved. Also, pipe elevation for the inlet and outlet should be checked against the existing ground elevations, as conditions often change between design and construction. Pipe alignment should be checked so flow will fit existing water ways.

The grade inspector should have good communication with the survey party (private or DOT) to make sure the method of staking is understood.

More information on survey is available in Chapter 4 of the Construction Manual and the Construction Surveying Handbook.

**NOTES:**

## 8. Tile Exploration

The best procedure for locating tile is to go through and find all existing lines shown on the plans. It is also a good idea to look near cut areas where a draw is located outside the ROW or to talk to the land owners in the area. Trench a minimum of five feet deep inside the ROW line, perpendicular to the tile. Watch closely for evidence of tile lines and record the following: location, depth, size, whether it is dry or running, and direction of flow. Make a rough drawing, in the field, as soon as possible. Make sure the lines are properly spliced to keep them working until they can be replaced. Tiles shown on the plans and not found by trenching may require deeper excavation.

After the tiles are found in an area, a plan for running the lines under the new highway should be made. This may require extra prospecting and elevation shots. Approval shall be made with the project inspector for any work not listed in the plans. Grades should be established for new tile lines when possible. Check the surface for possible intakes and outlets not listed on the plans. Locations and dimensions of subdrains on the plans do not necessarily have to be followed. However, any changes made in the plans should be for a good reason. The best and least expensive methods of keeping the water flowing should be the main consideration.

**NOTES:**

## 9. Documentation

There is no doubt that documentation should be the first priority. For a grading project, there may be more than one diary for documentation. These could include:

* *Project Diary* which the project inspector is responsible for. This diary may include: summary of contractors' work; conversations with RCE, contractors' superintendents, local property owners, visitors; changes to plans or specifications, documentation of traffic control; work on contract items, etc. In this diary, please indicate the date, time started, time stopped, and whether there was a work day charged. The weather and the average temperature of the day should be recorded

* *Spread Diary* which the grade inspector is responsible for. This diary may include: activity of one or more grading spreads. This diary should consist of superintendent's name, crew number, location of all work done each day. It also should contain the list of each separate contract item the crew is working on. The estimated quantities of contract items for each day should be recorded. In addition, conversations with a foreman, property owners, RCE, project inspector, visitors should be recorded. An equipment log should certainly be a part of this diary.

* *Pipe Diary* which the pipe inspector is responsible for. Similar information as the spread diary should be recorded.

The point of the daily diary is to provide accurate records of daily activities. In many cases, this record has provided the Department with enough information to resolve disputes. A log of equipment used by the contractor can show if a contractor is making a serious effort to complete the project. The inspector is required to keep track of all contract items. Daily quantity of each item should be recorded for payment purposes.

**NOTES:**

## 10. Preservation of Cultural Resources

Cultural resources are archaeological and historic/architectural resources in an area. A common cultural resource site is a burial ground. If unusual things such as bones, pottery, etc. are found, work should be stopped immediately. Please contact the Office of Construction and the Office of Location and Environment for assistance.

**NOTES:**

## *IV. Embankment Construction*

In order to achieve a quality embankment, it is very important to understand the soils behavior and their best uses for the project. There is a lot of preliminary work before the grading project actually starts. Soil boring and testing are the typical requirements. This section will provide some information on the soil classification, behavior, and compaction.

### 1. Soils Classifications

There are several systems of soil classification. In order to simplify this training, only two systems, the American Association of State Highway and Transportation Officials (AASHTO) and the U.S. Department of Agriculture (USDA) textural classifications the Iowa DOT uses will be presented.

#### a. AASHTO Classification

This system requires information on sieve analysis, liquid limit, and plasticity index. Before a soil can be classified, these properties must be determined first. Table 1 shows the AASHTO classifications.

**Sieve Analysis:** A mechanical sieve analysis is used for the sand and gravel fractions. A gradation is done with a hydrometer for the finer particles in which the settling velocity of the particles (spheres) in liquid is determined by distance of the hydrometer in the liquid and time. Particles with larger diameters will settle more quickly than those with smaller ones. From this settling velocity, the particle diameter is calculated. Please see Figure 1.

*Definitions:*
Gravel: Material passing sieve with 3-in square openings and retained on the No. 10 sieve.

Coarse sand: Material passing the No. 10 sieve and retained on the No. 40 sieve.

Fine sand: Material passing the No. 40 sieve and retained on the No. 200 sieve.

Silt-clay: Material passing No. 200 sieve.

**Liquid Limit:** Liquid limit (LL) is the moisture content above which a soil readily becomes a liquid. In general, the higher the liquid limit, the more compressible the soil may be and the more volume changes may occur. To run this test a small amount (250 grams) of soil passing the Number 40 sieve is mixed with water to a paste consistency. It is then placed in a round-bottomed brass cup and the surface is struck off with a spatula so that the maximum thickness is 10 mm. The soil is next divided into two segments by means of a grooving tool.

**TABLE 1 Classification[a] of Soils and Soil-Aggregate Mixtures (with Suggested Subgroups)**

| General Classification | Granular Materials (35% or less passing No. 200) | | | | | | | Silt-Clay Materials (More than 35% passing No. 200) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A-1 | | | A-2 | | | | | | | A-7 |
| Group Classification | A-1-a | A-1-b | A-3 | A-2-4 | A-2-5 | A-2-6 | A-2-7 | A-4 | A-5 | A-6 | A-7-5<br>A-7-6 |
| Sieve analysis, percent passing: | | | | | | | | | | | |
| No. 10 | 50 max. | | | | | | | | | | |
| No. 40 | 30 max. | 50 max. | 51 min. | | | | | | | | |
| No. 200 | 15 max. | 25 max. | 10 max. | 35 max. | 35 max. | 35 max. | 35 max. | 36 min. | 36 min. | 36 min. | 36 min. |
| Characteristics of fraction passing No. 40: | | | | | | | | | | | |
| Liquid limit | | | | 40 max. | 41 min. | 40 max. | 41 min. | 40 max. | 41 min. | 40 max. | 41 min.[b] |
| Plasticity index | 6 max. | | NP | 10 max. | 10 max. | 11 min. | 11 min. | 10 max. | 10 max. | 11 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 | | | |

[a] Classification procedure: With required test data available, proceed from left to right on above chart and correct group will be found by the process of elimination. The first group from the left into which the test data will fit is the correct classification.

[b] 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 (see Fig. 14.1).

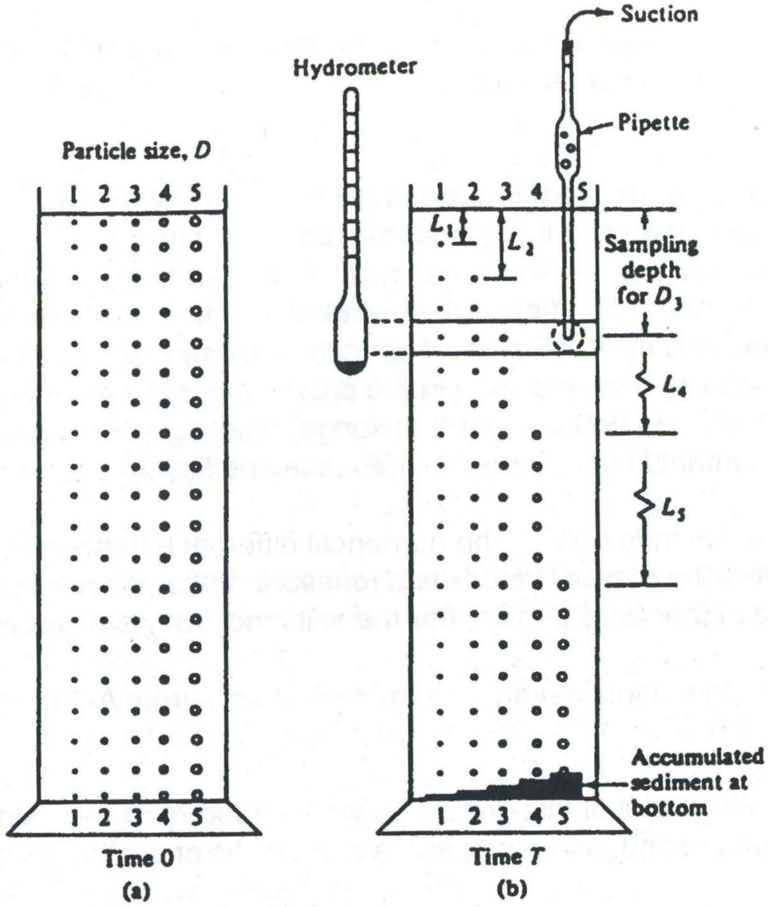



Figure 1 Schematic representation of sedimentation of different particle sizes, and sampling for particle size analysis.

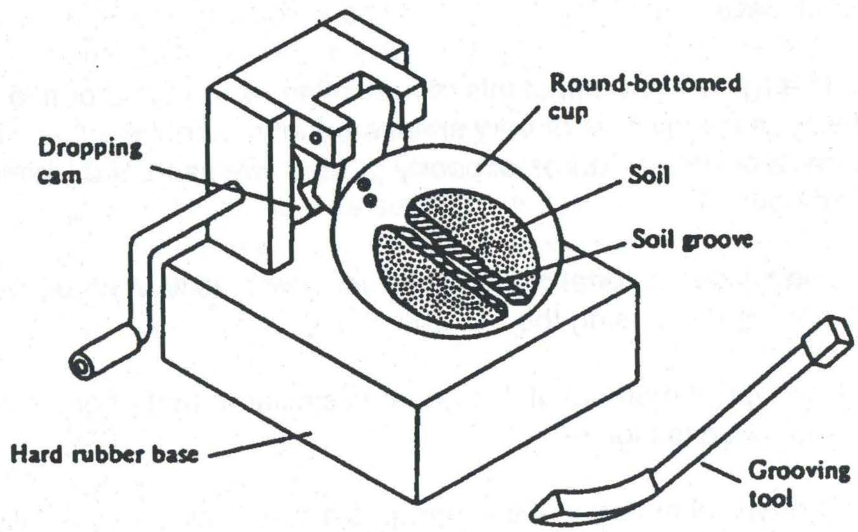



Figure 2 Liquid limit device; ASTM D423-66.

The cup is then raised and dropped onto a hard rubber block causing the divided soil to flow together. The moisture content at which it takes 25 blows to close the groove is the liquid limit. Please see Figure 2.

**Plastic Limit:** In order to determine the plasticity index, the plastic limit (PL) must be obtained. Plastic limit is the minimum moisture content at which the soil acts as a plastic solid. To run this test, a small soil-water mixture (soil particles passing No. 40) is rolled out with the palm of the hand on a glass plate until a thread of soil is formed. When the thread is rolled to a diameter of ⅛ of an inch, it is balled up and rolled out again. The mixture gradually loses moisture in the process. Finally the sample dries out to an extent that it becomes brittle and will no longer hold together in a continuous thread. This moisture content is the plastic limit. Please see Figure 3.

**Plasticity Index:** Plasticity index (PI) is the numerical difference between the liquid limit and the plastic limit. The plasticity index is a measure of the cohesive property of the soil. In general, the higher the PI, the softer the soil tends to get in wet weather.

From the above information, seven main groups of soils from A-1 to A-7 are classified.

***Group A-1:*** The typical material of this group is a well-graded mixture of stone fragments or gravel, coarse sand, fine sand, and a non plastic or slightly plastic soil binder.

***Group A-2:*** This group includes a wide variety of granular materials which are at the borderline between materials falling in groups A-1 and A-3 and silt-clay materials of groups A-4 through A-7. This group contains the materials with 35 percent or less passing No. 200 sieve.

***Group A-3:*** The typical material of this group is fine beach sand or fine desert blown sand without silty or clayey fine, or very small amount of nonplastic silt. The group also includes stream-deposited mixtures of poorly graded fine sand and limited amounts of coarse sand and gravel.

***Group A-4:*** The typical material of this group is a nonplastic or moderately plastic silty soil having 75% or more passing the No. 200 sieve.

***Group A-5:*** The typical material of this group is similar to that of group A-4 except the liquid limit for this group is higher.

***Group A-6:*** The typical material of this group is a plastic clay soil usually having 75 percent or more passing the No. 200 sieve. This group also includes mixtures of fine clayey soils and up to 64% of sand and gravel retained on the No. 200 sieve.

***Group A-7:*** The typical material of this group is similar to that of group A-6 except the liquid limit is higher.

The original classification had an A-8 group. This A-8 group is mainly a peat or muck soil. It is characterized by low density, high water content, high organic matter, and high compressibility. It is very unstable material.

In addition to the group classification, one important property that the inspector should know is the group index (GI). The group index is the number in parentheses. The IDOT has been using the 1949 AASHTO method. With this method the maximum value for GI is 20. The group index chart to determine the GI is attached for information. The higher the GI, the less desirable the soil is. With this method, when the GI is 19 or 20, the soil is unsuitable.

The Department recently adopted the 1991 AASHTO method and is using it on most metric projects. There is no limit for GI with the 1991 method. The following equation is used to calculate the group index:

$$\text{Group Index} = GI = (F-35)[0.2 + 0.005(LL - 40)] + 0.01(F - 15)(PI - 10)$$

Where:

F: Percentage passing No. 200 sieve
LL: Liquid limit
PI: Plasticity index

According to the Metric Specification Book, when the group index determined by the 1991 method is 30 or higher, the soil is considered unsuitable. However, the Soils Design Section is currently evaluating the universality of this criterion, and is finding instances where the break between suitable and unsuitable soil should be below or above 30. Additionally, Soils Design does make project-specific exceptions to this general rule(typically raising it above 30). Thus, Soils Design sheets may show soils with a GI above 30 that is still marked as suitable, and feasibly soils with a GI below that are marked unsuitable. The evaluation of the universality of this criterion is not yet finished, but when complete may lead to re-adoption of the 1949 criteria.

**NOTES:**

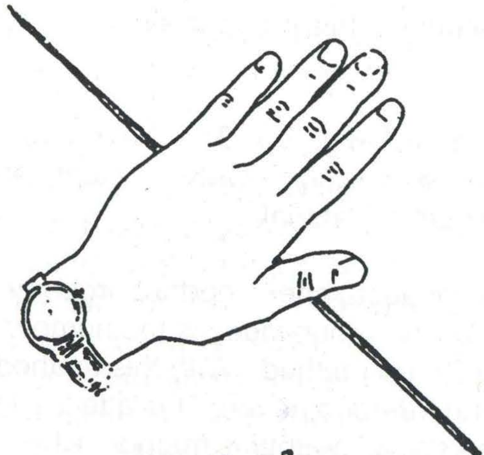


Fig. 3

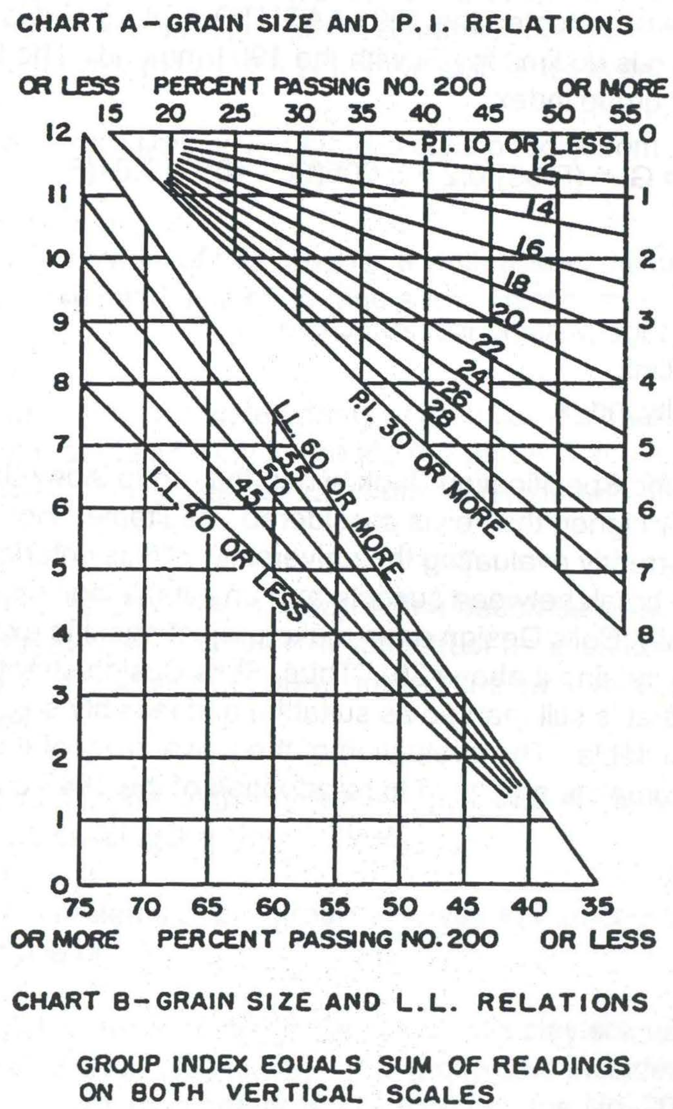



Figure 4. Group Index Chart

b. Textural Classification

Another classification that the IDOT uses is the USDA textural classification. From this method, the soil will be described as loam, silty loam, clay loam, etc. These descriptions are frequently abbreviated on the soil sheets as L, S. L., C.L., etc. For a grading project, the soils are classified in 12 common textural classes. The gradation of the soil is first determined. From the gradation, different classes are defined. This method does not consider the gravel portion or content. Thus, the sand, silt, and clay contents are prorated so the sum is 100 percent. In addition, if the gravel content is 10% or more, the term "gravelly" will be put in front.

*Example:* The gradation analysis shows the gravel, sand, silt, and clay contents are 4, 31, 44, and 21 respectively. What is the textural class of this soil?

Since the gravel content is not considered in this method, the sand, silt, and clay contents must be prorated. The prorated contents are:

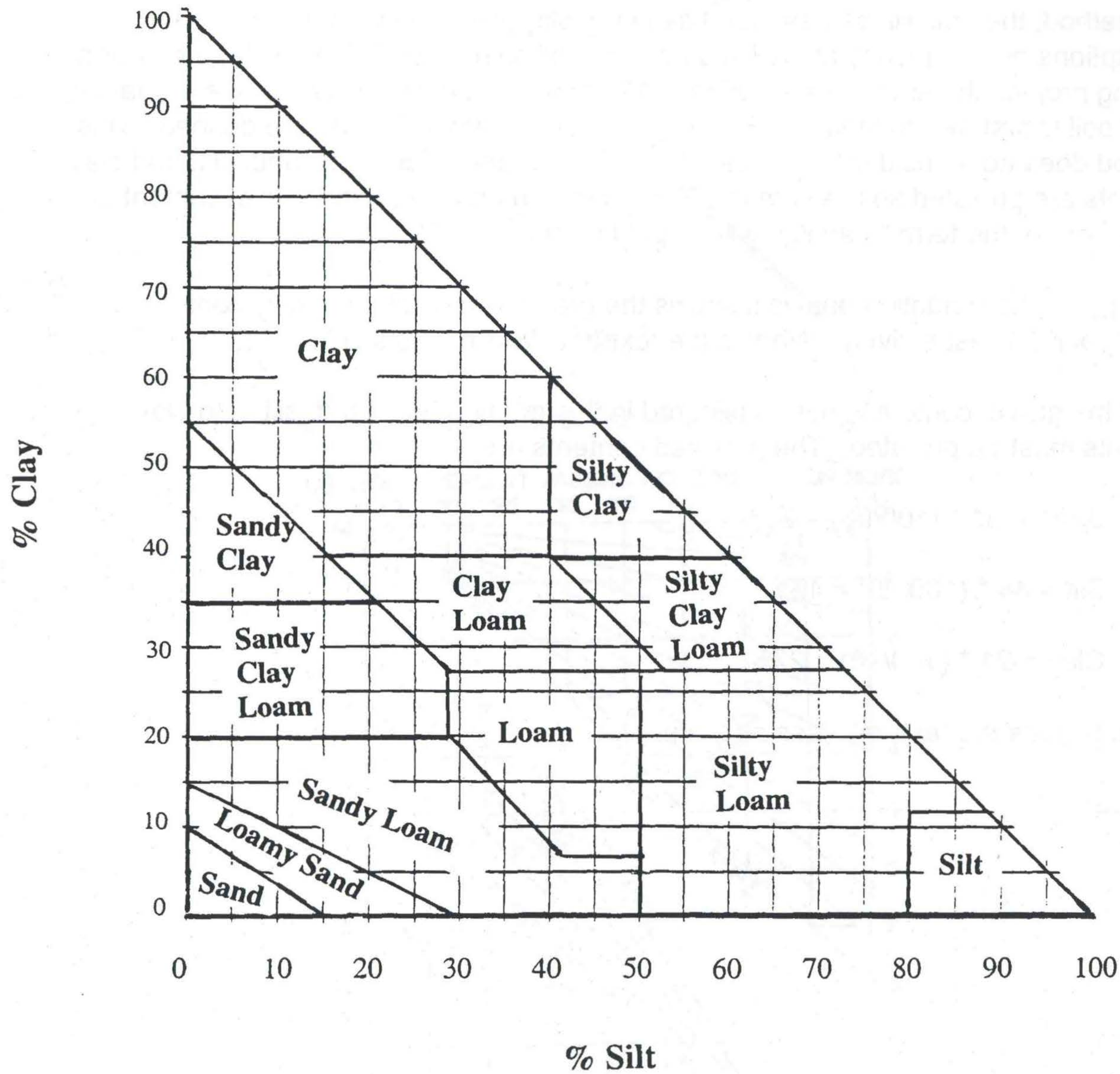
Sand = 31 * (100/96) = 32%

Silt = 44 * (100/96) = 46%

Clay = 21 * (100/96) = 22%

Figure 5 gives the textural class as loam.

**NOTES:**



% Clay
% Silt
0
10
20
30
40
50
60
70
80
90
100
Clay
Silty Clay
Sandy Clay
Clay Loam
Silty Clay Loam
Sandy Clay Loam
Loam
Silty Loam
Sandy Loam
Loamy Sand
Sand
Silt

## 2. Engineering Properties of Soils

The small particles of the available soils throughout the project may be structured differently. This difference includes composition, texture, shape, size, structure, etc. One should know the differences and the engineering properties of each type. Following is the discussion of some materials that are encountered during a grading project:

### a. Granular Soils (Sands and Gravels)

Granular soils are those containing high percentages of sand, gravel, cobbles, or mixtures of them. Fine sand is an exception because its engineering properties are on the borderline between the granular and the fine-grained soils. A granular soil has the following significant engineering properties:

- It is generally excellent foundation material for supporting structures and roads. The bearing capacity is large and the settlement is small. Settlement occurs quickly.
- It is the best material for embankment, because it has high shear strength. It is easy to compact and it is not susceptible to frost action.
- It is the best backfill material for retaining walls due to good drainage and low lateral pressure.
- It is very permeable.

### b. Cohesive Soils (Silts, Clays, and Loess)

*Clay* is the soil that has a particle size of less than 2 microns. Its shear strength is largely or entirely derived from cohesion. A clayey soil may have the following significant engineering properties:

- It often possesses low shear strength.
- It is often plastic and compressible.
- It loses part of its shear strength upon wetting or disturbance.
- It is very impervious.

*Silt* is the material with grain size between the No. 200 sieve and 2 microns in size. It possesses little cohesion and plasticity. Because it is so fine, silt may have the following undesirable properties:

* It may be very difficult to compact.
* It has a high capillary potential.
* It is susceptible to frost action.
* It possesses low shear strength.
* It is highly erodible.

*Loess* is a silt material but is differentiated because it is the wind-blown deposited material with grain size of silt. Loess may have the following properties:

* It has a relatively low unit weight.
* It does contain some cementitious material if undisturbed in its natural condition. Thus, it may be capable of standing nearly on a vertical cut bank in some instances, but not in an embankment fill. However, the Iowa DOT currently does not allow or design for vertical cuts in loess.
* It may subside upon saturation due to loss of cementation.

c. Organic Soils

Any soil that contains a sufficient amount of organic matter to influence the engineering properties is called organic soil. The organic soil has the following properties:

* It may have a low shear strength.
* It may be highly compressible.
* It can be very difficult to compact.

**NOTES:**

### 3. Shear Strength

Shear strength has been mentioned several times in the previous section. What is the shear strength of a soil? It is mainly the ability of a soil to resist shear failure along a certain rupture plane or zone. The shear strength of a soil comes from the cohesion, friction, or combination of both. There are two groups of factors that would affect the shear strength of a given soil. The first group includes the void ratio of the soil and the confining stresses. The second group includes the size, the shape, and the gradation of the particles making up the soils. Sand and gravel have no real cohesion. A cohesive soil, on the other hand, obtains the shear strength mainly from cohesion. In some instances when a new embankment is constructed, part of the "load" will be carried by the water held within a saturated soil. However, as time goes by, the water escapes from the soil which means that the friction between the particles is more effective. Thus, the shear strength can increase with time.

The shear strength of a soil may be expressed by the following equation:

$$s = c + \sigma' \tan\phi$$

Where:

- s: Shear strength
- c: Cohesion
- σ': Effective stress
- φ: Angle of internal friction of the soil.

Because the effective stress is the difference between the total pressure and the pore pressure, the effective stress decreases as the pore pressure increases. Water has no cohesion or internal friction angle, and water possesses no shear strength. Hence, when the soil is saturated with water and part of the load is carried by this water, the actual benefit of friction in the soil is lower. In other words, the beneficial effects of friction cannot be fully utilized until the pore pressures dissipate. Thus, it is very important to keep the water table as low as possible to prevent loss of shear strength. Figure 6 illustrates the shear strength of different soils.

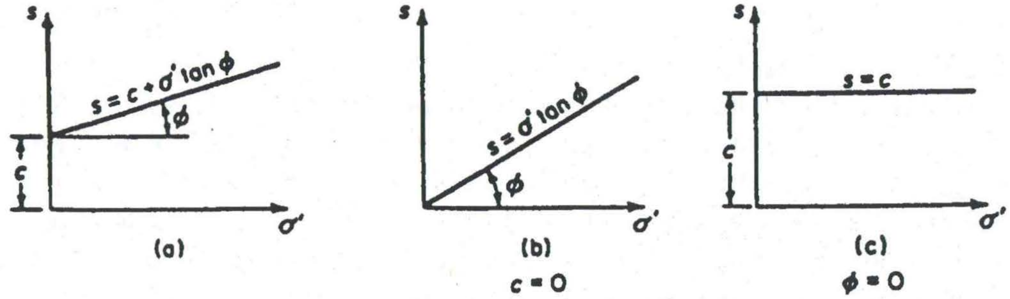



**Fig. 6 Shear strength of soils.**

*Example 1:* This example does not have anything to do with grading. This example is actually used to illustrate how friction works. Let's imagine a little pickup in winter. The roads are icy. Without the additional load on the back of the pickup or the effective stress, the pickup slides everywhere. This light pickup does not have the weight on top to obtain the friction against sliding.

*Example 2:* Suppose a stone key at the toe may be normally required to provide the friction to an unstable slope. However, in order for this stone key to work, several feet of soil must be on top of the stone. The weight of the soil puts more "pressure" on the stone key, and thus the shearing resistance of the key improves dramatically since shearing resistance is basically friction angle times burial depth.

*Example 3:* Let's look at an example on effective stress. For now the cohesion is ignored. Imagine a little box of soil in the embankment with 10 feet of fill on top at 100 pcf. The effective stress on top of this little box is 1,000 pcf (10 ft x 100 pcf = 1,000 psf). Due to heavy rain in the Spring of 1993, the total embankment was under water. The embankment was totally saturated. Since the embankment is saturated, the unit weight of the soil goes up to 122 pcf. Nevertheless since the pore pressure lowers the effective stress, the calculated effective stress is now at 596 psf [(122 - 62.4)pcf x 10 ft] = 596 psf.

**NOTES:**

## 4. Soil Sheets

The soil sheets are very important to a grading inspector. These sheets should provide the key to building a quality project. There is a lot of information on the soil sheet. Please see the three attached Q-sheets. The typical information includes cut moisture, cut density, plastic limit, Shelby tube core data, AASHTO classification and group index, color and textural classification, the abbreviated color and description, proctor density and optimum moisture content, water table, etc. The following are some general descriptions and discussions of each term:

_Cut Moisture:_ Moisture of in-place soil at location indicated for "core" in the boring. This information should be compared to the proctor density information so that the inspector would have some idea how wet the soil is and how much discing would need to be done. It may provide some information on whether or not a backslope subdrain is needed at the cut area.

_Cut Density:_ Density of in-place soil at location indicated for "core" in the boring. Similar to the cut moisture, the cut density may provide some information on shrinkage. For example, the cut density is 95 pcf and the Proctor density is 105 pcf. Thus, there should be at least 10% shrinkage if compacted to 100% Proctor. However, the current practice without any actual testing, this guide is not applicable.

_Plastic Limit:_ This term was defined earlier on Page 18.

_Shelby Tube Core Data:_ This is an undisturbed Shelby Tube sample. It is usually taken in an area where a fill is proposed or the soil investigation indicates that there may be a soft layer that may experience some settlement upon loading. A triaxial test is run on this sample to determine the cohesion, internal friction angle, consolidation coefficient, etc. The results are used for slope stability analysis, settlement prediction, etc. which will determine whether berms, blankets, core-outs, etc. are necessary.

_AASHTO and Group Index:_ These terms were also defined earlier on Page 19.

_Color and Textural Classification:_ The color and textural description are the preliminary remarks described by the soil crew during the drilling. Sometimes they are not the same as the abbreviated textural classification.

_Abbreviated Color and Textural Classification:_ The textural classification was defined earlier. However, the color of the soil was not discussed. Soil color is a function of surface coatings which constitute only a small percentage of the soil. For example, an intense rusty red-brown signifies iron oxide coating. On the other hand, a white crusty appearance indicates calcium carbonate coating. The water table and air have a lot to do with the color of the soils. Dark gray or green or blue hues indicate conditions or greying, which occurs below a permanent water table. Once, they are exposed to the air, the color will change.

*Proctor Density and Optimum Moisture Content:* These two terms will be defined in more detail later in "Soil Compaction" section. Proctor density is the maximum density that a given soil can be compacted at the proper or optimum moisture content. This moisture content provides important information on what moisture content the soil should be during compaction to obtain adequate compaction.

*Water Table:* The water table is indicated as the little dash-line with the symbol $H_2O$. This is what was found during the soil investigation. This water table should give some good indication on how wet the soil is and whether or not a backslope subdrain is needed.

*Subgrade Treatment:* Subgrade treatments are used to provide the best possible support for the subbase (if needed) and the pavement. The type of subgrade treatment used depends on the type and quality and quantity of natural soils available on the project.

## How to "Read" a Soil Sheet.

Start at the bottom of the sheet. The first numbers are the station numbers (i.e., 119,120, 121, and 122 etc.). The next number is the distance the boring was from centerline (i.e., Rt. 44'). The next number is the "Boring" number. All DOT soils crews have a letter prefix (A, D, F or whatever) assigned them. This crew's borings start with No. 1 and go thru 9999. Then start at No. 1 again. Next is a bar graph with the word subgrade treatment number which are the limits of the proposed treatment and the treatment depth, such as sta. 110+00 to 140+00 and 2.0' in depth. Next is another bar graph showing unsuitable topsoil C-3 and the phrase "see standard RL-1". This bar also shows the limits of the unsuitable soil at sta. 105+50 to sta. 149+00 (see the cross sections for actual removal).

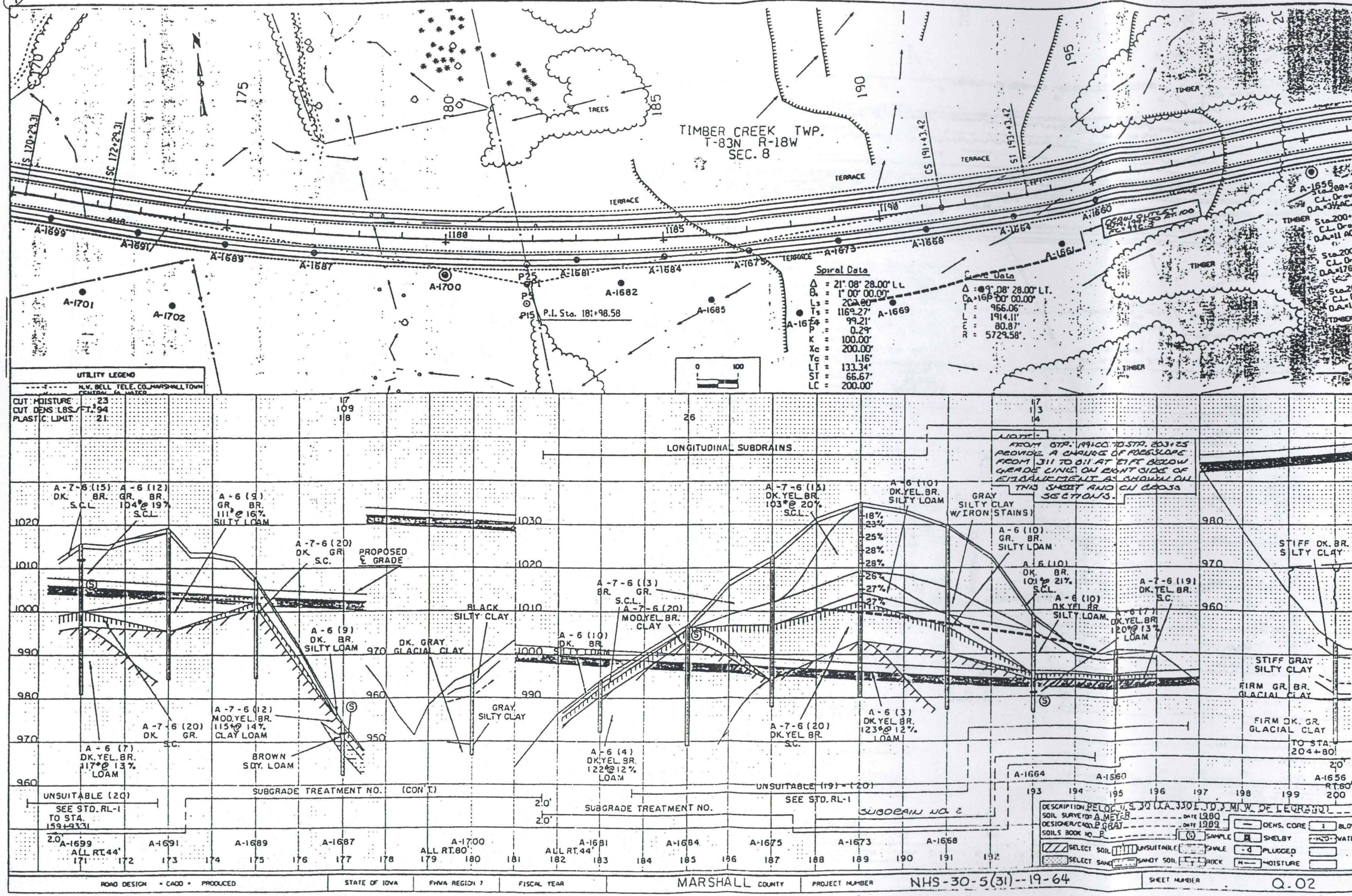
The ground profile with the borings is in the middle of the sheet. Boring No. D-7974 shows 3 bag samples were taken, and one in place density core. The bag samples are represented by the letter "S", and the core is a black bar across the boring. The sample data comes from the soil lab data sheets. The dash---line is the water level in the boring. Note the texturing designation of the soils as unsuitable and select (please see box in bottom right-hand corner). Any soil that is not marked as select or unsuitable will be Class 10 soil. Not all samples have proctors run on them.

The proposed pavement grade is shown by a properly-labeled line. Under that line is a shaded area showing the proposed subgrade treatment.

Next is a series of short bar graphs showing the limits of the proposed longitudinal subdrains. On each end of the bar is a small "flag" representing the proposed outlet location and "direction." All should compare directly to a long subdrain tab. The longitudinal subdrains, however, usually will not be installed until the paving is done. Next comes the core data showing moisture content. In-place density: Density of in-place soil at location indicated for “core” in the boring.

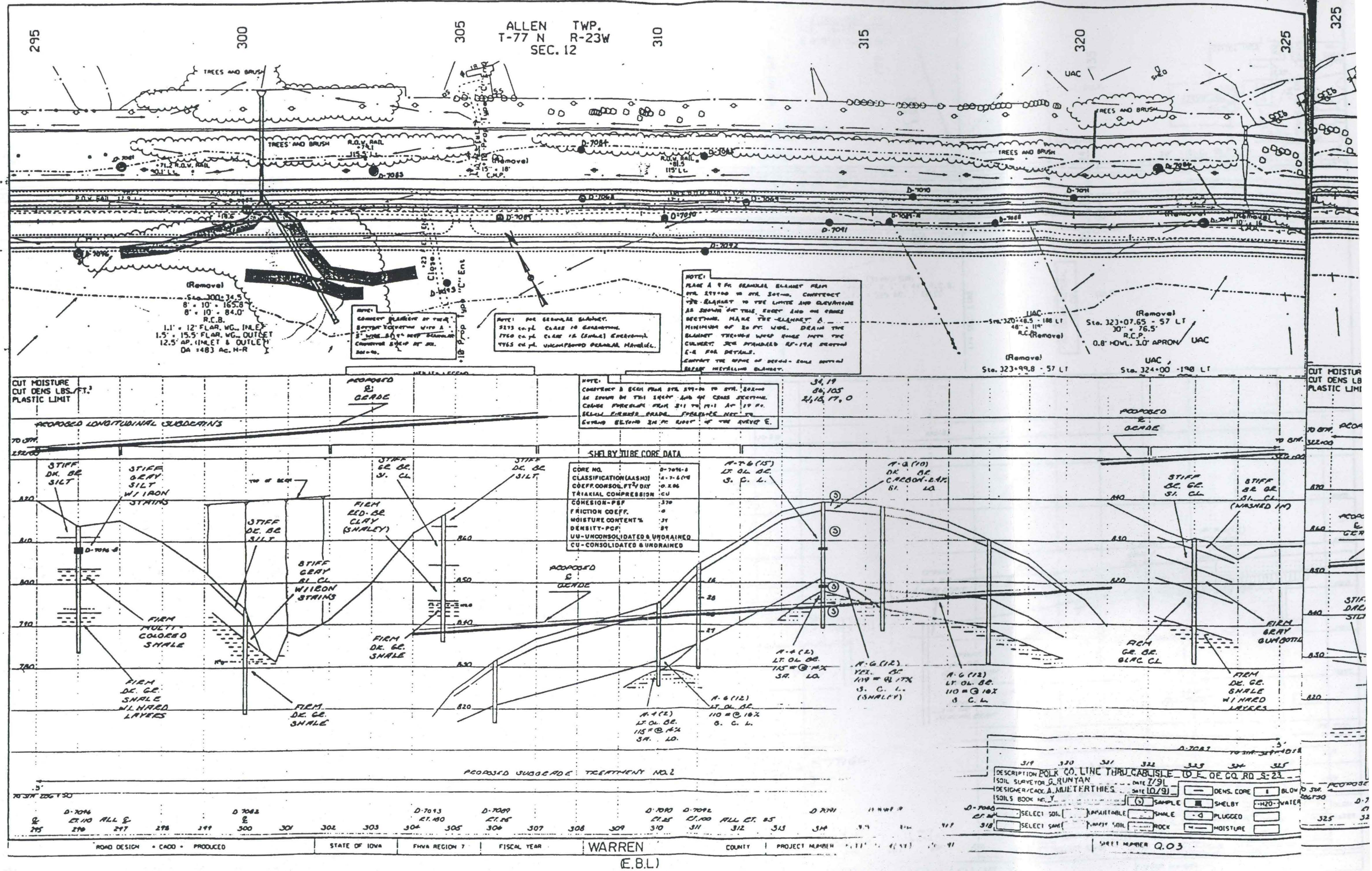
The “Top” part of the soil sheet is just a plan view of the soil profile sheet. But, it also will show the location of the other borings that were not plotted on the soils profile sheets. These borings are plotted on the cross-sections.

**NOTES:**

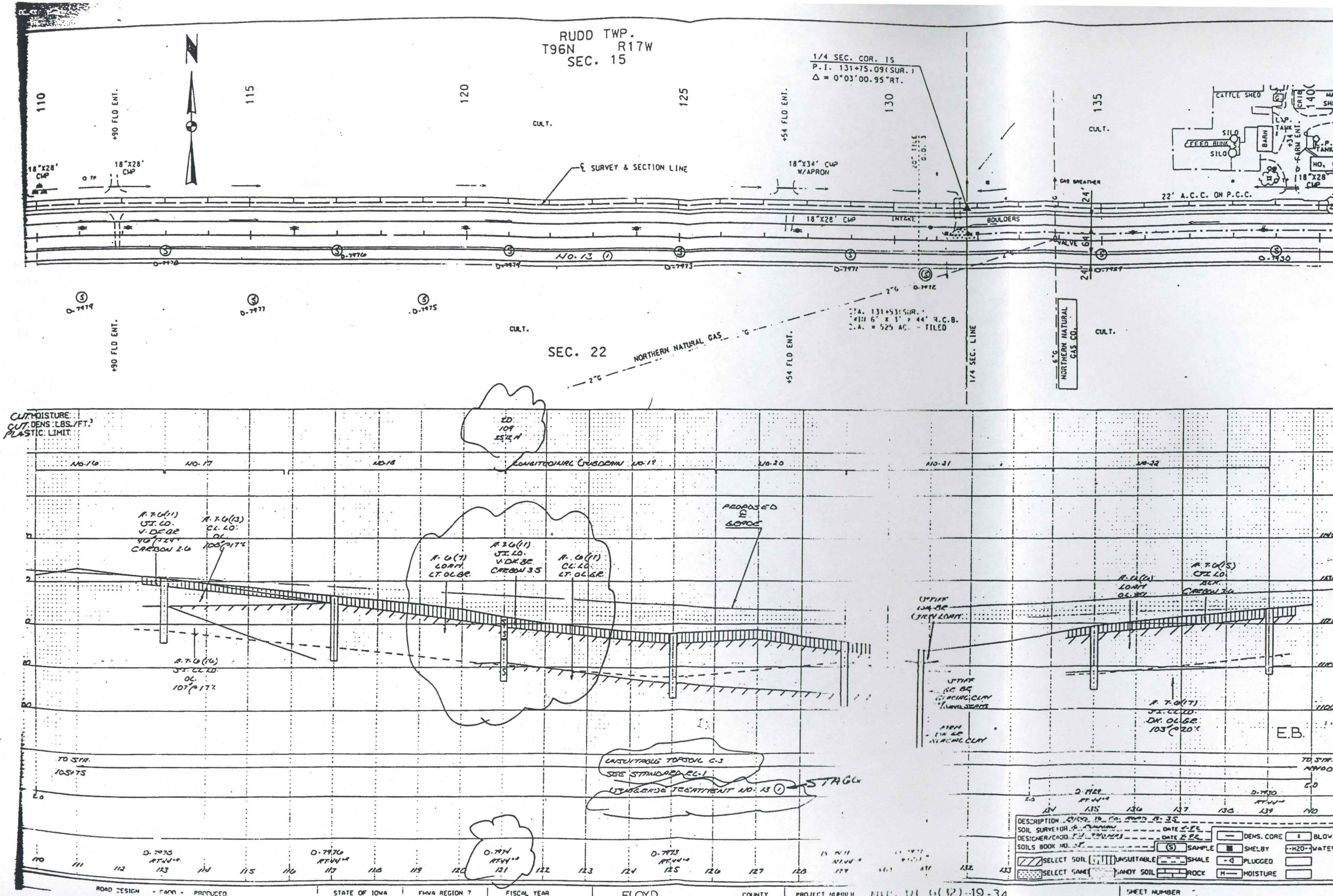


TIMBER CREEK TWP.
T-83N R-18W
SEC. 8
TREES
TERRACE
TIMBER
Spiral Data
Δ = 21° 08' 28.00" LL
Curve Data
Δ = 9° 08' 28.00" LT.
T = 966.06'
L = 1914.11'
E = 80.87'
R = 5729.58'
P.I. Sta. 181+98.58
UTILITY LEGEND
N.W. BELL TELE. CO. MARSHALLTOWN
CUT MOISTURE 23
CUT DENS LBS./FT.³ 94
PLASTIC LIMIT 21
LONGITUDINAL SUBDRAINS
NOTE: FROM STA. 199+00 TO STA. 203+25 PROVIDE A CHANGE OF FORESLOPE FROM 3:1 TO 6:1 AT 8 FT. BELOW GRADE LINE ON RIGHT SIDE OF EMBANKMENT AS SHOWN ON THIS SHEET AND ON CROSS SECTIONS.
PROPOSED ℄ GRADE
BLACK SILTY CLAY
DK. GRAY GLACIAL CLAY
GRAY SILTY CLAY
BROWN SDY. LOAM
GRAY SILTY CLAY W/IRON STAINS
STIFF DK. BR. SILTY CLAY
STIFF GRAY SILTY CLAY
FIRM GR. BR. GLACIAL CLAY
FIRM DK. GR. GLACIAL CLAY
TO STA. 204+80
UNSUITABLE (20)
SEE STD. RL-1
TO STA. 159+93.31
SUBGRADE TREATMENT NO. (CON'T.)
SUBGRADE TREATMENT NO.
UNSUITABLE (19) - (20)
SEE STD. RL-1
SUBDRAIN NO. 2
ALL RT. 44'
ALL RT. 80'
ALL RT. 44'
DESCRIPTION RELOC. U.S. 30 (1A. 330 E. TO 3 MI. W. OF LE GRAND)
SOIL SURVEY FOR A. MEYER DATE 1980
DESIGNER/CADD P. GRAY DATE 1989
SELECT SOIL
UNSUITABLE
SHALE
SELECT SAND
SANDY SOIL
ROCK
SAMPLE
SHELBY
PLUGGED
DENS. CORE
BLOW
WATER
MOISTURE
ROAD DESIGN • CADD • PRODUCED
STATE OF IOWA
FHWA REGION 7
FISCAL YEAR
MARSHALL COUNTY
PROJECT NUMBER NHS-30-5(31)--19-64
SHEET NUMBER Q.02

2



ALLEN TWP.
T-77 N R-23W
SEC. 12
295
300
305
310
315
320
325
TREES AND BRUSH
(Remove)
R.C.B.
UAC
CUT MOISTURE
CUT DENS LBS./FT.³
PLASTIC LIMIT
PROPOSED LONGITUDINAL SUBDRAINS
SHELBY TUBE CORE DATA
CORE NO.
CLASSIFICATION(AASHO)
COEFF. CONSOL. FT.²/DAY
TRIAXIAL COMPRESSION
COHESION-PSF
FRICTION COEFF.
MOISTURE CONTENT %
DENSITY-PCF
UU-UNCONSOLIDATED & UNDRAINED
CU-CONSOLIDATED & UNDRAINED
PROPOSED SUBGRADE TREATMENT NO.2
DESCRIPTION POLK CO. LINE THRU CARLISLE
SOIL SURVEYOR G. RUNYAN
DESIGNER/CADD A. MUETERTHIES
SOILS BOOK NO.
ROAD DESIGN • CADD • PRODUCED
STATE OF IOWA
FHWA REGION 7
FISCAL YEAR
WARREN
COUNTY
PROJECT NUMBER
SHEET NUMBER Q.03
(E.B.L.)



RUDD TWP.
T96N R17W
SEC. 15
1/4 SEC. COR. 15
P.I. 131+75.09(SUR.)
Δ = 0°03'00.95"RT.
CULT.
+90 FLD ENT.
+54 FLD ENT.
18"X28' CMP
18"X34' CMP W/APRON
℄ SURVEY & SECTION LINE
22' A.C.C. ON P.C.C.
BOULDERS
INTAKE
VALVE
CATTLE SHED
FEED BUNK
SILO
BARN
CRIB
MA. SHED
FARM ENT.
NO. 13
SEC. 22
NORTHERN NATURAL GAS
NORTHERN NATURAL GAS CO.
1/4 SEC. LINE
CUT MOISTURE
CUT DENS. LBS./FT.³
PLASTIC LIMIT
LONGITUDINAL SUBDRAIN
PROPOSED ℄ GRADE
UNSUITABLE TOPSOIL C-3
SEE STANDARD RL-1
SUBGRADE TREATMENT NO. 13
E.B.
TO STA. 105+75
DESCRIPTION
SOIL SURVEYOR
DESIGNER/CADD
SOILS BOOK NO.
DATE
DENS. CORE
BLOW
SAMPLE
SHELBY
WATER
PLUGGED
SELECT SOIL
UNSUITABLE
SHALE
SELECT SAND
SANDY SOIL
ROCK
MOISTURE
ROAD DESIGN
STATE OF IOWA
FHWA REGION 7
FISCAL YEAR
FLOYD
COUNTY
PROJECT NUMBER
SHEET NUMBER

## 5. Soil Testing Results

The information on the soil sheets is a visual presentation of the soils present along the general centerline of the proposed roads as well as the Soil Design features that apply to the construction of the road. The report on the soil testing from the Central Laboratory provides further information. The inspector should get this report as soon as possible. Please contact the Office of Construction for a copy of this report. Samples of these reports are attached.

The report includes the station, location from the centerline, depth of the sample, liquid limit, plastic limit, plasticity index, gravel content, sand content, silt content, clay content, Proctor density, optimum moisture content, carbon content, textural classification, AASHTO and USDA classifications, color, and sieve analysis.

Even though the distance between the samples could be two or three hundred feet, the testing information is very useful. The following are some typical examples that the inspector can use:

*Example 1:* Due to the additional cost for hauling, a contractor approaches the inspector to use the Class 10 with the following information for select. AASHTO classification is A-7-6; the unit weight is 110 pcf. According to Specification 2102.06, it appears this material would meet the requirement for select material. Does it? No, it does not. The information on the soil sheet does not mention the silt content of the soil. When the inspector looks it up in the report, the silt content is 50%. This is Class 10 soil, not select because the silt content limit for select is 45% according to the specification.

A similar example could be used with plasticity index.

*Example 2:* From looking at the test report, the inspector may recognize there is a close relationship between the optimum moisture content and plastic limit. Most of the time the optimum moisture content is a few percentage points lower than the plastic limit. Thus, the inspector should be able to tell whether the moisture content is good for compaction or whether some discing is needed by running the plastic limit at the site.

The plastic limit was discussed earlier. For a quick and easy method in the field, the following brief discussion may be useful:

Since the optimum moisture content is lower than the plastic limit, rolling a soil thread would give some information on moisture content. Thus, obtain a small piece of the soil. Roll the soil in the palms until a thread of soil is formed. When the thread is rolled to a diameter of ⅛ inch and not broken, the moisture content is too high. The inspector should work with the contractor to get some discing done.

Some other information that the inspector could use would be liquid limit, plasticity index, and silt content, etc. to determine whether the soil is select soil or Class 10. In addition, the information may provide some good indication about the soils' behavior. For example, the soil with high liquid limit indicates that the soil can take in a lot of water. It also means that the soil may be compressible or the soil can experience volume changes. A high plasticity index indicates the soil could get very soft when it is wet and volume change may happen.

The soil testing report will not indicate whether shale is encountered. From experience, it appears when the clay content is in the 30's or 40's but the plasticity index is in the 10's or low 20's, it is a good indication the soil is shale. The numerical difference between the two values is more than 20. For example, the clay content is 43 but the plasticity index is only 15. When it comes to shale, the inspector should look at the soil profile and compare it with the site condition.

For more information on soils uses and classes, please see the appendix and specification.

**NOTES:**

SOIL SURVEY METRIC FINAL REPORT

COUNTY-WARREN PROJECT STP-5-4(30)2C-91 ROAD 5 JOB 2C910054030 

| STATION | DIST. | LAYER | LAB NO. | SENDER NO. | PLASTIC LL | PL | PI | GR | SA | SI | CL | PROCTOR DEN | M | CARBON | TEXTURE CLASS | AASHTO CLASS A | COLOR | *SIEVE ANALYSIS(% PASSING)* 3/4 | 3/8 | 4 | 10 | 40 | 100 | 200 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4029 +0 | C 0 | 0.00M0.54 | 5-1144 | D0905A | 45 | 24 | 21 | 7 | 24 | 49 | 20 | | | 3.2 | SI LO | 7-6(12) | V DK GR | 100 | 97 | 95 | 93 | 84 | 72 | 69 |
| 4029 +0 | C 0 | 0.54M5.00 | 5-1145 | D0905B | 58 | 16 | 42 | 0 | 18 | 37 | 45 | 1730 | 17 | | CL | 7-6(20) | LT O BR | | | | 100 | 97 | 87 | 82 |
| 4029 +0 | C 0 | 5.00M6.00 | 5-1146 | D0905C | 52 | 14 | 38 | 1 | 21 | 39 | 39 | 1760 | 16 | | CL LO | 7-6(18) | LT Y BR | | | 100 | 99 | 97 | 85 | 78 |
| 4029 +0 | R 50 | 0.00M0.78 | 5-1149 | D0913A | 46 | 18 | 28 | 0 | 1 | 68 | 31 | 1700 | 18 | | SI CL LO | 7-6(16) | LT O BR | | | | | | 100 | 99 |
| 4029 +0 | R 50 | 0.78M3.00 | 5-1150 | D0913B | 65 | 18 | 47 | 1 | 15 | 31 | 53 | | | | CL | 7-6(20) | Y BR | | 100 | 99 | 99 | 99 | 89 | 84 |
| 4029 +0 | R 50 | 3.00M4.60 | 5-1151 | D0913C | 54 | 15 | 39 | 1 | 17 | 43 | 39 | 1670 | 19 | | SI CL LO | 7-6(19) | LT Y BR | | | 100 | 99 | 98 | 87 | 82 |
| 4029 +50 | C 0 | 3.80M4.79 | 5-1147 | D0906C | 30 | 12 | 18 | 0 | 60 | 19 | 21 | | | | SA CL LO | 6(3) | LT O BR | | | | 100 | 87 | 47 | 40 |
| 4029 +50 | C 0 | 3.80M4.79 | *** WARNING *** ALL SELECT SOIL CRITERIA MET EXCEPT THE PROCTOR DENSITY IS BLANK | | | | | | | | | | | | | | | | | | | | | |
| 4029 +50 | C 0 | 4.79M6.00 | 5-1148 | D0906D | 0 | NP | 0 | 0 | 85 | 7 | 8 | | | | LO SA | 2-4(0) | LT O BR | | | | 100 | 85 | 20 | 15 |
| 4029 +50 | C 0 | 4.79M6.00 | *** WARNING *** ALL SELECT SOIL CRITERIA MET EXCEPT THE PROCTOR DENSITY IS BLANK | | | | | | | | | | | | | | | | | | | | | |
| 4032 +0 | C 0 | 0.00M0.48 | 5-1264 | D0937A | 36 | 21 | 15 | 0 | 2 | 71 | 27 | | | 1.5 | SI LO | 6(10) | DARK BROWN | | | | | 100 | 99 | 98 |
| 4032 +0 | C 0 | 0.48M2.83 | 5-1265 | D0937B | 47 | 18 | 29 | 0 | 0 | 69 | 31 | | | | SI CL LO | 7-6(17) | Y BR | | | | | | | 100 |
| 4032 +0 | C 0 | 2.83M5.00 | 5-1266 | D0937C | 36 | 18 | 18 | 0 | 0 | 75 | 25 | | | | SI LO | 6(11) | LT O BR | | | | | | | 100 |
| 4032 +0 | C 0 | 5.00M7.50 | 5-1267 | D0937D | 41 | 17 | 24 | 0 | 5 | 60 | 35 | | | | SI CL LO | 7-6(14) | Y BR | | | | 100 | 99 | 97 | 95 |
| 4032 +50 | R 100 | 0.00M0.43 | 5-1268 | D0943A | 40 | 23 | 17 | 0 | 1 | 68 | 31 | | | 1.9 | SI CL LO | 6(11) | DARK BROWN | | | | | 100 | 99 | 99 |
| 4032 +50 | R 100 | 0.43M2.40 | 5-1269 | D0943B | 49 | 18 | 31 | 0 | 0 | 66 | 34 | 1630 | 20 | | SI CL LO | 7-6(18) | LT O BR | | | | | | | 100 |
| 4032 +50 | R 100 | 2.40M5.20 | 5-1270 | D0943C | 37 | 19 | 18 | 0 | 1 | 75 | 24 | 1750 | 17 | | SI LO | 6(11) | LT O BR | | | | | | 100 | 99 |
| 4032 +50 | R 100 | 5.20M6.10 | 5-1271 | D0943D | 49 | 19 | 30 | 0 | 4 | 47 | 49 | 1730 | 17 | | SI CL | 7-6(18) | Y BR | | | | | 100 | 98 | 96 |
| 6048 +35 | C 0 | 0.00M2.10 | 5-476 | D0730A | 41 | 21 | 20 | 0 | 2 | 70 | 28 | 1630 | 20 | 1.1 | SI CL LO | 7-6(12) | V DK GR BR | | | | 100 | 99 | 99 | 98 |
| 6048 +35 | C 0 | 2.10M4.60 | 5-477 | D0730B | 43 | 18 | 25 | 0 | 1 | 68 | 31 | 1680 | 19 | | SI CL LO | 7-6(15) | O BR | | | | | | 100 | 99 |
| 6051 +0 | L 15 | 0.00M0.59 | 5-472 | D0728A | 34 | 21 | 13 | 0 | 2 | 75 | 23 | | | 1.4 | SI LO | 6(9) | V DK GR BR | | | | 100 | 99 | 99 | 98 |
| 6051 +0 | L 15 | 0.59M3.73 | 5-473 | D0728B | 47 | 20 | 27 | 0 | 1 | 67 | 32 | | | | SI CL LO | 7-6(16) | DK GR BR | | | | | 100 | 99 | 99 |
| 6051 +0 | L 15 | 3.73M5.75 | 5-474 | D0728C | 37 | 20 | 17 | 0 | 1 | 75 | 24 | | | | SI LO | 6(11) | LT O BR | | | | | | 100 | 99 |
| 6051 +0 | L 15 | 5.75M7.50 | 5-475 | D0728D | 43 | 19 | 24 | 0 | 10 | 53 | 37 | | | | SI CL LO | 7-6(14) | DK GR BR | | | | 100 | 98 | 93 | 90 |
| 9059 +0 | L 30 | 0.00M1.53 | 5-431 | D0711A | 45 | 20 | 25 | 0 | 0 | 67 | 33 | | | | SI CL LO | 7-6(15) | O BR | | | | | | | 100 |
| 9059 +0 | L 30 | 1.53M2.80 | 5-432 | D0711B | 38 | 19 | 19 | 0 | 0 | 75 | 25 | | | | SI LO | 6(12) | LT O BR | | | | | | | 100 |
| 9059 +0 | L 30 | 2.80M5.45 | 5-433 | D0711C | 52 | 16 | 36 | 0 | 22 | 38 | 40 | | | | CL | 7-6(18) | LT O BR | | | | 100 | 97 | 85 | 78 |
| 9059 +0 | L 30 | 2.80M5.45 | *** WARNING *** ALL SELECT SOIL CRITERIA MET EXCEPT THE PROCTOR DENSITY IS BLANK | | | | | | | | | | | | | | | | | | | | | |
| 9059 +0 | L 30 | 5.45M7.50 | 5-434 | D0711D | 44 | 15 | 29 | 1 | 20 | 41 | 38 | | | | CL LO | 7-6(16) | LT O BR | | | 100 | 99 | 98 | 86 | 79 |
| 9059 +0 | L 30 | 5.45M7.50 | *** WARNING *** ALL SELECT SOIL CRITERIA MET EXCEPT THE PROCTOR DENSITY IS BLANK | | | | | | | | | | | | | | | | | | | | | |
| 9059 +50 | R 5 | 2.55M4.60 | 5-478 | D0731C | 53 | 15 | 38 | 0 | 23 | 34 | 43 | | | | CL | 7-6(19) | LT O BR | | | | 100 | 98 | 84 | 77 |
| 15114+0 | C 0 | 8.40M10.1 | 5-1128 | A5393D | 36 | 13 | 23 | 0 | 35 | 38 | 27 | 1910 | 13 | | CL LO | 6(11) | LT O BR | | | | 100 | 97 | 77 | 65 |
| 15114+50 | C 0 | 0.00M0.50 | 5-1124 | A5392A | 37 | 26 | 11 | 0 | 3 | 78 | 19 | 1510 | 24 | | SI LO | 6(8) | V DK GR BR | | | | | 100 | 98 | 97 |
| 15114+50 | C 0 | 0.50M5.50 | 5-1125 | A5392B | 50 | 21 | 29 | 0 | 0 | 67 | 33 | 1650 | 20 | | SI CL LO | 7-6(18) | GRAY | | | | | | | 100 |
| 15114+50 | C 0 | 5.50M8.20 | 5-1126 | A5392C | 79 | 20 | 59 | 0 | 3 | 35 | 62 | 1600 | 23 | | CL | 7-6(20) | LT Y BR | | | | 100 | 99 | 97 | 97 |
| 15114+50 | C 0 | 8.20M10.1 | 5-1127 | A5392D | 38 | 14 | 24 | 0 | 24 | 46 | 30 | 1830 | 15 | | CL LO | 6(14) | LT O BR | | | | 100 | 98 | 85 | 76 |
| 15116+0 | C 0 | 2.30M2.70 | 5-1130 | A5397B | 46 | 17 | 29 | 0 | 0 | 66 | 34 | 1620 | 21 | | SI CL LO | 7-6(17) | LT O BR | | | | | | | 100 |
| 15116+0 | C 0 | 2.70M3.60 | 5-1131 | A5397C | 56 | 15 | 41 | 0 | 13 | 42 | 45 | 1620 | 21 | | SI CL | 7-6(19) | GR BR | | | | 100 | 99 | 92 | 87 |
| 15116+0 | C 0 | 3.60M4.60 | 5-1132 | A5397D | 43 | 13 | 30 | 0 | 30 | 37 | 33 | 1810 | 15 | | CL LO | 7-6(16) | LT Y BR | | | | 100 | 97 | 79 | 70 |
| 15116+50 | L 4 | 0.00M3.00 | 5-1129 | A5396A | 43 | 19 | 24 | 0 | 4 | 64 | 32 | 1730 | 17 | | SI CL LO | 7-6(14) | OLIVE GRAY | | | | 100 | 98 | 97 | 96 |
| 16115+50 | L 55 | 0.00M0.30 | 5-1135 | A5400A | 41 | 22 | 19 | 0 | 3 | 70 | 27 | 1630 | 20 | | SI LO | 7-6(12) | DK O BR | | | | 100 | 99 | 98 | 97 |
| 16115+50 | L 55 | 0.30M5.50 | 5-1139 | A5400B | 45 | 18 | 27 | 0 | 0 | 71 | 29 | | | | SI CL LO | 7-6(16) | LT O BR | | | | | | | 100 |
| 16115+50 | L 55 | 5.50M7.00 | 5-1136 | A5400C | 61 | 16 | 45 | 0 | 7 | 43 | 50 | | | | SI CL | 7-6(20) | LT O BR | | | | 100 | 99 | 95 | 93 |
| 16117+50 | L 3 | 0.00M1.40 | 5-1133 | A5398A | 44 | 19 | 25 | 0 | 1 | 65 | 34 | 1730 | 17 | | SI CL LO | 7-6(15) | BROWN | | | | | 100 | 99 | 99 |
| 16117+50 | L 3 | 1.40M3.80 | 5-1134 | A5398B | 45 | 17 | 28 | 0 | 0 | 69 | 31 | 1710 | 18 | | SI CL LO | 7-6(16) | LT O BR | | | | | | | 100 |
| STATION | DIST. | LAYER | L NO. | S NO. | LL | PL | PI | GR | SA | SI | CL | DEN | M | CARB | TEXTURE | CLASS A | COLOR | 3/4 | 3/8 | 4 | 10 | 40 | 100 | 200 |

SOIL SURVEY FINAL REPORT

COUNTY-DUBUQUE PROJECT STP-52-2(17)2J-31 ROAD 52 JOB 2J310522017 

| STATION | DIST. | LAYER | LAB NO. | SENDER NO. | PLASTIC LL | PL | PI | *********** GR | SA | SI | CL | PROCTOR DEN | M | CARBON | TEXTURE CLASS | AASHTO CLASS A | COLOR | *SIEVE ANALYSIS(% PASSING)* 3/4 | 3/8 | 4 | 10 | 40 | 100 | 200 | CL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 628 +0 | R 430 | 0.0-2.3 | 6-1753 | D1551A | 37 | 22 | 15 | 0 | 2 | 75 | 23 | | | | SI LO | 6(10) | BROWN | | | | 100 | 99 | 99 | 98 | 23 |
| 628 +0 | R 430 | 2.3-9.5 | 6-1754 | D1551B | 44 | 17 | 27 | 0 | 0 | 70 | 30 | 104 | 19 | | SI CL LO | 7-6(16) | DK Y BR | | | | | | | 100 | 30 |
| 628 +0 | R 430 | 9.5-15.0 | 6-1755 | D1551C | 30 | 20 | 10 | 0 | 0 | 84 | 16 | 109 | 17 | | SI LO | 4(8) | LT O BR | | | | | | | 100 | 16 |
| 628 +0 | R 430 | 15.0-18.0 | 6-1756 | D1551D | 32 | 17 | 15 | 3 | 2 | 52 | 43 | | | | SI CL | 6(10) | LT O GR | 100 | 97 | 97 | 97 | 97 | 96 | 95 | 43 |
| 631 +0 | R 530 | 0.0-1.4 | 6-1749 | D1549A | 39 | 24 | 15 | 0 | 1 | 79 | 20 | 98 | 23 | 1.6 | SI LO | 6(10) | BROWN | | | | | 100 | 99 | 99 | 20 |
| 631 +0 | R 530 | 1.4-9.2 | 6-1750 | D1549B | 43 | 18 | 25 | 0 | 0 | 68 | 32 | 105 | 19 | | SI CL LO | 7-6(15) | Y BR | | | | | | | 100 | 32 |
| 631 +0 | R 530 | 9.2-12.3 | 6-1751 | D1549C | 33 | 17 | 16 | 0 | 4 | 55 | 41 | | | | SI CL | 6(10) | PALE Y | | | | | 100 | 99 | 96 | 41 |
| 631 +0 | R 530 | 12.3-18.0 | 6-1752 | D1549D | 33 | 18 | 15 | 0 | 1 | 58 | 41 | | | | SI CL | 6(10) | GRAY | | | | | | 100 | 99 | 41 |
| STATION | DIST. | LAYER | L NO. | S NO. | LL | PL | PI | GR | SA | SI | CL | DEN | M | CARB | TEXTURE | CLASS A | COLOR | 3/4 | 3/8 | 4 | 10 | 40 | 100 | 200 | CL |

☒ English
☐ Metric

Form 820468
6-96

# SOIL TEST RECORD

County Dubuque Senders No. D-1551-D AAD 6-1756
Project STP-52-2(17)2J-31 Road No. IA #52 Layer Depth 15.0-18.0
Location STA. 628+00 Rt 430' Shelby Depth
Interchange Ramp or Side Road Conn. Location Water Level
Date Sampled 10/23/96 Date Reported Sampled By G. Runyan
Report To
Circle The Desired Tests: Proctor Triaxial Consolidation
Remarks: Weathered Shale & Silt w/ L.S. Pieces

| | |
|---|---|
| | Gm. = + No. 4 Sieve Analysis Wt. |
| | Gm. Retd. On No. 4 |
| | Gm. ( % Total) Passing No. 4 |
| 377.1 | Gm. = + No. 40 Sieve Analysis Wt. |
| 10.3 | Gm. ( % Total) Retd. on No. 40 |
| 366.8 | Gm. ( % Total) Passing No. 40 |

**SIEVE ANALYSIS**

| Sieve | Grams Retained | % of Total Retained | % of Total Passing Exact | % of Total Passing Report | Sieve |
|---|---|---|---|---|---|
| 2" | | | | | 2" |
| 1½" | | | | | 1½" |
| 1" | | | | | 1" |
| ¾" | | | | * | ¾" |
| ½" | 9.9 | | | | ½" |
| ⅜" | — | | | * | ⅜" |
| No. 4 | 0.3 | | | * | No. 4 |
| +No. 4 | | | | | |
| No. 8 | — | | | | No. 8 |
| No. 10 | — | | | * | No. 10 |
| No. 20 | | | | | No. 20 |
| No. 30 | | | | | No. 30 |
| No. 40 | 0.1 | | | * | No. 40 |
| +No. 40 | | | | | |
| No. 50 | | | | | No. 50 |
| No. 60 | | | | | No. 60 |
| No. 100 | 0.7 | | | * | No. 100 |
| No. 200 | 0.7 | | | * | No. 200 |
| +No. 200 | | | | | |

| | |
|---|---|
| 58.6 | Gm. = + No. 200 Sieve Analysis Wt. |
| 1.4 | Gm. Retd. On No. 200 |
| 57.2 | Gm. ( % Total) Passing No. 200 |

**BOUYOUCOS HYDROMETER ANALYSIS**

| B/N | 450 Min. Reading | -Corr. ( ) | Percent Clay Exact | Percent Clay Report | Particle Dia. |
|---|---|---|---|---|---|
| | 32.0 | | | * | .002 mm. |

| Liquid Limit | | Plastic Limit | |
|---|---|---|---|
| Blow Count | 21 | Tested by | Cathy |
| Pan No. | 307 | Pan No. | 308 |
| A) Wet Wt. | 7571 | A) Wet Wt. | 3401 |
| B) Dry Wt. | 7003 | B) Dry Wt. | 3242 |
| C) Empty Wt. | | C) Empty Wt. | |
| D) A-B | | D) A-B | |
| E) B-C | | E) B-C | |
| LL=D/E | | PL=D/E | |

| | |
|---|---|
| 32 | Liquid Limit (%) |
| 17 | Plastic Limit (%) |
| 15 | Plasticity Index (%) |
| | Gravel (%) |
| | Sand (%) |
| | Silt (%) |
| | Clay (%) |
| | Proctor Density (LB/FT³) |
| | Proctor Moisture (%) |
| | Carbon Content (%) |
| | Class Name |
| | AASHTO Class |
| 32 | Color |

## 6. Soil Compaction

Compaction is the act of densifying the soil by pressing soil particles together into close contact. As a result, the air and water are removed from the soil body. This increases the strength of the soil and reduces the permeability. In the "shear strength" section, it was said void ratio affects the shear strength. This, once again, indicates the importance of proper compaction of the soil. The three most important factors when it comes to soil compaction are:

* Soil type
* Moisture content
* Equipment

In order to determine the soil type, the soil classification is done. This topic and the soil properties were discussed earlier.

_Moisture Content and Proctor Density_

For moisture content information, a Proctor density relationship should be established. R. R. Proctor, the Los Angeles County Engineer, discovered an important relationship between soil density and moisture content. Proctor found that by molding a series of specimens with different moisture contents, using the same compactive effort for each specimen, the density on a dry-weight basis would peak out as shown in Figure 7. A Proctor density curve or test should be done when there are some questions about the soil. The method of running a proctor density is in the appendix.

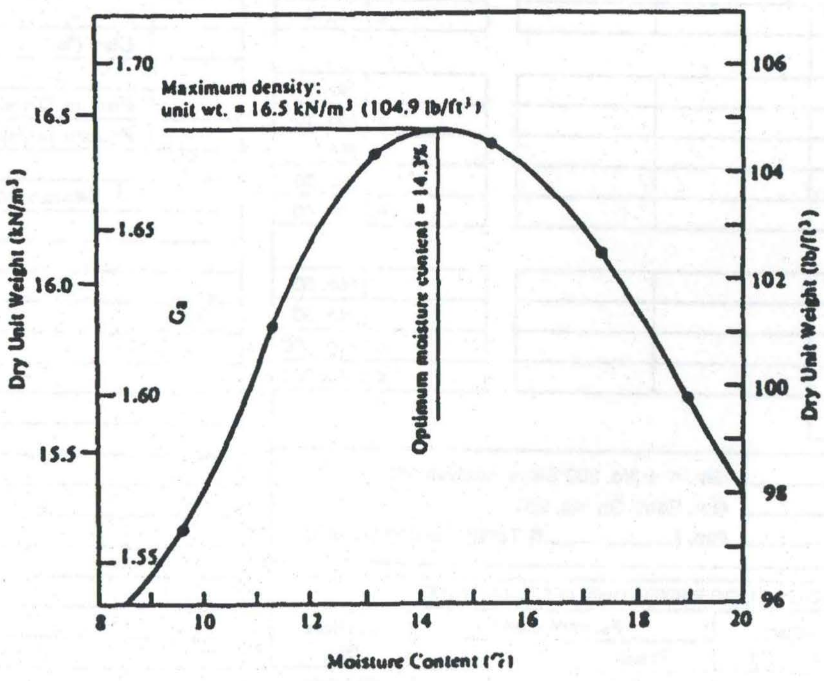



Figure 7. Proctor density curve.

The theory behind this relationship is that during compaction, moisture or water is needed to provide the lubrication between soil particles and hence improve compaction. However, it is not good to compact soil too far away from the optimum moisture content. When the moisture is too low, soil particles are prevented from sliding. Thus, good compaction would be hard to obtain. On the other hand, when moisture is too high, soil particles cannot come in contact with each other. Unlike gases, water is an incompressible material. Consequently the compactive effort will rework the soil, shearing it, and reducing its strength.

Over-compaction is a condition which occurs when a large compactive effort is put into soil which is too wet for proper compaction. The compactive effort causes the wet soil particles to slide over/across each other into such a configuration where they have a “preferred orientation”, which in turn produces “weak zones” which, along with low density, produce a soft, weak, unstable embankment. For this reason, the hauling pattern must be considered. If it is possible, the trucks should be running on the shoulder. If it is not possible, the wheel tracks should spread out across the grade instead of one location, i.e., not driving in the same wheelpath. When the top of the grade is used for traffic hauling for a while, it is highly recommended that the top layer be scarified and recompacted. This will remove the overcompacted layer with shearing zone.

At the present time, the moisture-density requirement is seldom specified during grading projects. Moisture content limits are specified for shale compaction. Also, there are some limits on moisture content ( from -2.5% to no upper limit) for select material. Special compaction sometimes is required under the detour. For special compaction, the moisture shall not be drier than 6 percentage points below optimum and the density will be 95% or more of maximum density. For high fills, there is usually a moisture control during compaction for the lower portion of the fills (8 meters or 25 feet from the top). This is to ensure good compaction for the foundation.

*Equipment*

Compaction can be obtained by rollers or devices with different forces. These forces are pressure, impact, vibration, and manipulation.

Pressure is mainly the downward force applied by the roller. Impact and vibration are from series of blows. Manipulation is the kneading action within the soil.

The specification requires the pressure of the roller be not less than 200 psi. It is important to check the pressure of the roller.

*Compaction*

Type A compaction is normally required. This means the lift thickness before compaction should be 8 inches or less and there will be at least one rolling per inch depth of each lift. The rolling will be done until the tamping feet penetrate not more than 3 inches into the 8 inch lift. This is the roller walkout requirement.

Once again, since there is no moisture requirement for compaction and the different soils behave differently, it could be very misleading to require the same pattern and the same equipment for all soils. With the proper moisture content, the compactive effort to get good density should be lower. It would be best if the rolling pattern, the lift thickness, and the approximate moisture content could be determined for the roller being used with a specific soil. This means that some density be taken at the beginning using methods such as nuclear density, kerosene density, etc. The test procedure and IM for the density testing are included in the appendix. Some information to keep in mind is the lift thickness should not be more than two inches thicker than the length of the tamping feet.

For cohesive soils, a sheepsfoot roller should be used. However, for granular soils, a sheepsfoot is not appropriate and a vibratory roller is the preferred equipment.

Section 6.41 of the Construction Manual has more detailed information on equipment and how to determine the roller pressure.

**NOTES:**

## 7. Stability Analysis

In the shear strength section, it was mentioned for soils with an internal friction angle the shear strength is affected by the confining stress. An equation illustrated the higher the effective stress, the higher the shear strength. The first concept is easy to understand. The second one, however, is confusing. If the stress is high, wouldn't it be a problem with slope failure? Hopefully this section will clear up some of the "unclear" discussions.

There is a relationship between horizontal stress to vertical stress. The ratio between these two is called the conjugate ratio and is defined as:

$$K = \text{horizontal stress/ vertical stress} = (1 - \sin\phi)/(1 + \sin\phi)$$

The internal friction angle values, $\phi$, indicate clay and silt will have a higher value for the conjugate ratio. The horizontal stress from these soils is higher compared to sand and gravel. Because the horizontal stress is high, the confining stress or resistance should be high. The conjugate ratio is critical to retaining walls. In embankment construction, it is not used for stability analysis.

Stresses are very important in slope stability analysis. In order to analyze the slope stability, different methods could be used. The main point is to calculate the factor of safety (F.S.) for the certain slope with certain height. The factor of safety is defined as:

$$\text{F. S.} = \text{resisting force/shearing force.}$$

Some of the general components contributing to shear resistance are cohesion, weight of the soil, angle of the slope, and internal friction angle.

Some of the general components contributing to shearing force are weight of the soil and angle of the slope.

Other factors such as water level, ground topography, foundation, etc. are considered in the analysis.

The above discussion indicates the importance of internal friction angle and cohesion of the soil. Once again, these two properties are greatly influenced by degree of compaction and moisture content.

*For Embankment Fill with Cohesive Soils*

A cohesion of 600 psf and friction coefficient of 0.2 or 11.3 degrees (the $\tan\phi$ in the shear strength equation) are assumed for a clay fill. A 3:1 slope fill with this material could be as high as 53 feet and still gives a factor of safety of 1.3. The height for a 2½:1 slope with the same value for cohesion and friction coefficient is feasibly as high as 46 feet.

For a silty clay fill, a cohesion of 700 psf and friction coefficient of 0.1 are assumed.

For a loess fill, a cohesion of 600 psf and a friction coefficient of 0.4 are assumed.

A fill with a 3:1 slope over shale without any sand blanket or stone key could only be 27 feet.

Once again, as it was stated earlier, many other factors also drastically affect the slope stability. The prime example is the foundation under an embankment. Usually other factors are considered in slope stability analysis, and in most instances are the controlling factor.

*For Embankment Fill with Sand*

For a sand fill, a cohesion of 0 psf and friction coefficient of 0.6 or internal friction angle of 31 degrees are assumed for stability analysis.

**NOTES:**

## 8. Step/Bench Cutting Procedures

Sometimes the water table is high on the backslope. This could potentially cause backslope failure. Other times when wet material is used, foreslope failure may occur. This failure sometimes happens because the excess water in the fill material has prohibited proper compaction. When failure like this happens, some sort of drainage with porous backfill and/or a stone key is frequently recommended. If the problem is extreme, a toe berm is also sometimes added.

Please keep in mind since the slope is already failing, minor mistakes would cause severe problems. Following are some recommended procedures to follow:

*For Bench Cutting to Install a Subdrain*

Benches and drains are common on an unstable backslope. Keep in mind the slope is already failing. The only thing in this situation that would keep this slope from complete failure is the resistant weight at the toe. The higher the backslope, the more critical it would be. The best thing to do is to give the Office of Construction or Soils Design a call to let them know there is a problem. A field visit may be necessary.

If a backslope subdrain is proposed, this ***does not mean let's excavate the toe open for some time to see what would happen.*** Care must be taken to remove a small portion at the toe and install the subdrain before moving to the next portion. A stone key is not normally required. However, if one is called for, please ask for a specific design and procedure.

*For Bench Cutting to Install a Stone Key and an Additional Berm*

This procedure is normally done when the embankment experiences some failure on the foreslope. Reworking the foreslope by making some benches and adding a stone key at the toe usually are recommended. If the failure is significant, a toe berm may be needed. As previously mentioned, the slope is already in an unstable condition and the resistant weight at the toe or lower portion of the slope is very important. The best thing to do is to ask for help from Soils Design and Construction Office. In most cases, a specific design and procedure must be followed.

In some instances, the weight at the top may have to be moved down to the toe first. A portion of the berm may have to be built before installing the stone key or cutting any benches. The soil from the upper portion may be brought down to build the lowest bench. From there, a step by step procedure is followed for every bench. Once again, please follow the given design and procedure.

**NOTES:**

## 9. Settlement Plate

When a proposed fill is built over a layer of compressible soil, a settlement plate may be required if the time rate of settlement is critical for any reason. This plate is used to determine whether or not the predicted settlement has occurred. It is also used to determine whether or not the consolidated strength at a certain time is enough to allow the additional fill on top. Elevation of the settlement plate is normally taken every week during the construction. The elevation readings are forwarded to Soils Design for monitoring purpose. It would be very helpful to Soils Design to have the exact elevation of the plate on the report. A detail of the settlement plate is included in the appendix.

**NOTES:**

## 10. Pipe Bedding

Currently there are two classes of pipe bedding. Backfilling and compacting the soil around the pipe are not that easy. This leads to low stability and settlement problems. As a result, a bump or dip may show up after some time. Other types of backfill materials and methods of compaction are being considered.

**NOTES:**

## 11. Tabulation of Template Quantities

Balance and overhaul information could be found on the T-sheets. The following section will provide a brief description of columns.

| Column # | ***(Cut side of Tab 107-27A)*** | |
|---|---|---|
| 1 | Station: | Stationing should be in increments of 100 ft from Beginning of Project to End of Project. |
| 2 | Template Cut: (Total:everything) | The quantity shown here is a raw absolute quantity containing all materials contained within the design |
| 3 | Additional Quantity: (+C) | This column is used for entrance dikes, safety dikes, side borrows, etc. |
| 4 | Subgrade Treatment: (+C) | Used when working up subgrade treatments from Tab 103-3. This represents additional cut below the proposed subgrade (see Std Rd. Plans RL-2A). Note column 27 goes hand in hand with this column. |
| 5 | Moisture & Density: (+C) | This column is used when the Class 10 doesn't produce any Select soil material. When figuring M & D, let's say a 2' treatment (from Tabs 103-1 or 103-6) you only cut to a depth of 1.5' (see RL-2A). The last .5' is scarified and compacted in place. |
| 6&7 | The next 2 columns: (+C) | These are blank columns that can be used as +C columns for Bench Cut, Plowing & Shaping, Subdrain stair steps, etc. |
| 8 | Select Soil: (-C) | This column represents the select material from the roadway that has to be reserved for subgrade treatments. The total of select in this column should equal the amount of material and shrink as shown on Tab 103. |
| 9 | Pavement Removal: (-C) | If the template quantities have included the existing pavement, you will have to subtract the rate per station from the template cut. (No. 2) |
| 10 | Rock: (-C) | This material is usually labeled on the x-section as (limestone, shale, broken shale, etc. This material also has to be subtracted from the template cut. (No. 2) |

| | | |
|---|---|---|
| 11 | The next column: (-C) | This one is also blank and can be used for anything that has to be subtracted from the template cut. |
| 12 | Adjusted Earth Cut | This column is the sum of all the +C columns (2-7) minus all the -C columns (8-11). This column includes unsuitable C-3's and C-5's. |
| 13 | Unsuitable C-3: | Type 'C' placement as shown on RL-1B. This material cannot be used in the upper 3' of the proposed fill. Note: This material is included in Adjusted Earth Cut. (No. 12) |
| 14 | Unsuitable C-5: | Type 'B' placement as shown on RL-1B. This material cannot be used in the upper 5' of the proposed fill. Note: This material is included in Adjusted Earth Cut. (No. 12) |

Note: Unsuitable C-3 & C-5 can be used for entrances, dikes, wing dikes & foreslope dressing.

| | | |
|---|---|---|
| 15 | Rock Cut: | This number should be the same as shown in the Rock (-C) column. (No. 10) |
| 16 | Additional Rock Cut: (+C) | This quantity comes from rock that was present in the +C columns (Add. Cut, Subgrade Treatment, Moisture & Density and the two blank columns.) |
| 17 | The next column: | This column can be used to add the Rock Cut and the Additional Rock Cut. |
| 18 | Percent Swell: | The soils design puts the % of swell on Solid Rock only. There is no swell used on shale, sandstone, and broken limestone. |
| 19 | Adjusted Rock+ Swell: | This column is used to show the total amount of rock per station with and without swell. |

***(Fill side of Tab 107-27B)***

| | | |
|---|---|---|
| 20 | Template Fill: | The quantity shown here is the total design template fill. |
| 21 | Additional Fill: (+F) | This column is used for dikes, entrances, safety dikes, core & wedge (C & W), etc. |
| 22 | Moisture & Density: (+F) | This number is the same number as shown in the M & D column on the cut side (see column #5) When working with M & D, the cut has to be removed and then backfilled. The backfill material will require shrinkage. |

M & D Note: You cannot add up columns #5 or #22 to get the amount shown on Tab 103-1 or 103-6. The reason is that the bottom 6 inches was scarified and recompacted.

| | | |
|---|---|---|
| 23 | Pavement Removal: (+F) | The template fill quantity doesn't include pavement fill. This quantity is only where the pavement is to be removed. (Fill height from 0' to 4'). Pavement is then broken up and left in place (from 4' to 6'). At depth of 6 feet and over it is just left in place. Note: When ACC is present, then all of the ACC has to be removed. |
| 24 & 25 | The next 2 columns: (+F) | These are blank columns that can be used for Bench Fill, Plowing & Sloping, Subdrain, stair steps, etc. |
| 26 | Subtract Quantity: (-F) | This would be used when making an adjustment to the Template Fill. |
| 27 | Subgrade Treatment: (-F) | Used when working up subgrade treatment from Tab 103-3. This represents a correction to the fill quantity. (See Std Rd Plan RL-2A). |

Note: You can add up the Subgrade Treatment columns (#4 & #27) and they should equal the rate per station and the total amount of select without shrinkage.

| | | |
|---|---|---|
| 28 | Rock Fill: (-F) | The numbers in this column equal the Adjust Rock + Swell. The reason for this is that the Rock swell usually isn't the same % of shrink as the adjusted fill. |
| 29 | The next column: (-F) | This one is also blank and can be used for anything that has to be subtracted from the template fill. |

| | | |
|---|---|---|
| 30 | Adjusted Fill: | This column is the sum of all the +F columns (21-25) minus all of the minus -F columns (26-29). |
| 31 | Unsuitable Fill: | This column represents the unsuitable C-3 & C-5 used on the project divided by the percent of shrink. This column will not add up to equal the C-3 & C-5 on the cut side. |
| 32 | Percent of Shrink: | This number is given to Design by the Soils Section . It usually runs about 30% for most projects. |
| 33 | Adjusted Fill + Shrink: | This number is based upon the Adjusted Fill less Unsuitable Fill times the Percent of Shrink. (30-31)x32=33. |
| 34 | Unsuitable Fill + Shrink: | This number is based from the Unsuitable Fill times the Percent of Shrink. This number normally will add up to the total of unsuitable material (C-3 and C-5) from the cut side. We will waste unsuitable material before class 10 excavation. 31x32=34. |
| 35 | Mass Diagrams: | The suitable mass ordinate is based upon the Adjust Earth Cut minus Unsuitable C-3 and C-5 minus the Adjusted Fill + Shrink. 12-13-14-33=35. |
| 36 | Unsuitable Mass Diagrams: | We normally run two separate mass ordinates one for C-3 and one for C-5. The unsuitable mass is based upon the Unsuitable C-3 minus the Unsuitable Fill & Shrink for C-5. 13+14-34=36. |

**NOTES:**

## WORK SHEET FOR TABULATION OF TEMPLATE QUANTITIES AND ADJUSTMENTS (1 of 2)

Refer to Standard Plan RL-1

107-27A
01-09-90

| STATION | TEMPLATE CUT | ADDITIONAL QUANTITY +C | SUBGRADE TREATMENT +C | MOISTURE AND DENSITY +C | | | SELECT SOIL -C | PAVEMENT REMOVAL -C | ROCK -C | | ADJUSTED EARTH CUT | UNSUITABLE C - 3 | UNSUITABLE C - 5 | ROCK CUT | ADDITIONAL ROCK CUT +C | | PERCENT SWELL | ADJUSTED ROCK + SWELL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |

## WORK SHEET FOR TABULATION OF TEMPLATE QUANTITIES AND ADJUSTMENTS (2 of 2)

Refer to Standard Plan RL-1

107-27B
01-09-90

| TEMPLATE FILL | ADDITIONAL QUANTITY +F | MOISTURE AND DENSITY +F | PAVEMENT REMOVAL +F | | | SUBTRACT QUANTITY -F | SUBGRADE TREATMENT -F | ROCK FILL -F | | ADJUSTED FILL | UNSUITABLE FILL | PERCENT SHRINK | ADJUSTED FILL + SHRINK | UNSUITABLE FILL + SHRINK | MASS DIAGRAM ORDINATE SUITABLE | MASS DIAGRAM ORDINATE UNSUITABLE | BALANCE AND OVERHAUL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | |

## TABULATION OF TEMPLATE QUANTITIES AND ADJUSTMENTS

[illegible]

107-[illegible]

| STATION | [illegible] | [illegible] +C | [illegible] +C | [illegible] +C | | | [illegible] -C | [illegible] -C | [illegible] -C | | [illegible] | [illegible] C - 3 | [illegible] C - 5 | [illegible] | [illegible] +C | | [illegible] | [illegible] | [illegible] | [illegible] +F | [illegible] +F | [illegible] +F | | | [illegible] -F | [illegible] -F | [illegible] -F | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

## V. Drainage

Drainage is one of the most important issues to consider during a grading project and during the service life of a highway. Without proper drainage, there will be many problems. Some information the inspector should keep in mind when it comes to proper drainage is:

### 1. Water Table

The term "water table" was mentioned in the Shear Strength of Embankment Construction. It was said that the effective stress decreases as the pore pressure increases. In other words, when the water table goes up, the shear resistance or the stability support of the soil can go down. Hence, it is very important to keep the water table as low as possible. On the Q-sheets, the water table is marked as the little dash line. One thing to keep in mind is the information on the Q sheets may have been obtained several years before the project actually starts. The actual water table may have changed before or during the construction time. Modifications in backslope subdrain elevation, working sand blanket, etc. may have to be made. The following topics will discuss some of the key methods to deal with drainage.

**NOTES:**

### 2. Sand Blanket

A sand blanket could be specified for different reasons. They could be (a) working blanket, (b) drainage, (c) stability/settlement or (d) core-outs. The inspector needs to understand how each type works to make certain that the installation is done properly.

*a. Working Blanket*

The working blanket is specified to help the construction traffic and to provide better "foundation" in fill sections. It is usually called for at locations where the water table is high (close to the ground) or at a drainage way. If there is no drain with this blanket, then the blanket will usually be a working blanket. This blanket location may be adjusted during the construction due to a change in the drainage way or it may be deleted if the stability is enough to carry the construction traffic through. However, it the fill is more than 25 feet, the working blanket should not be deleted. Also, outlets should be installed if the fill is high.

*b. Drainage*

When a granular blanket is specified, there is typically also a drain with this blanket. This blanket must be there to provide drainage for the layer underneath. This drainage is required to allow the consolidation of the soft layer underneath so that the stability would increase or settlement rate would accelerate. The pressure release pipe from this blanket usually has a bend at some point. Thus, the level of the outlet is higher than that of the sand blanket, which is acceptable from a design standpoint. However, the outlet does not have to be that way. If modification can be made in the field to have the outlet at the same level with the sand blanket, please do so. If there is a culvert nearby, small weep holes should be made to allow the water to drain into the culvert.

*c. Stability Requirement*

When shale is encountered, a sand blanket or stone key may be used to provide the frictional resistance between the shale and the Class 10 fill. The inspector should recognize this if the soil sheets indicate there is shale underneath. It is very important to have this sand blanket in contact with or key into the shale. A visual check must be done to make sure that the excavation for this blanket is down to the shale layer. Remove as much soft shale as possible before placing the blanket.

*d. Core-Outs (for overexcavation and backfilling)*

Core-outs which are subsequently backfilled with sand are frequently used because of stability and/or settlement issues. The basic idea here is to remove the soft and compressible soils to a specified design depth and replace it with stronger, less compressible soils to alleviate the stability or settlement problem. It is feasible that some core-outs will not have drains, but this does not negate their need or function. When this layer is below the water table, an outlet or outlets may be necessary.

**NOTES:**

### 3. Trench Drains

Sometimes trench drains may be required to provide drainage and lower the water table at some locations. The function of the trench drain is similar to that of the sand blanket, that is, either for stability or settlement improvement. The trench drain, however, is installed much deeper. Since the area is unstable, the installation of the trench drain may be difficult. There are cases where the top layer had to be removed and replaced so the surface was adequate to support construction equipment. Other times the trench drains have been done with a "dig and push" operation. Trench drains may also be used to drain the water from sand pockets underneath the embankment to provide better stability. Clean and porous materials should be used in backfilling the trenches.

Trench drains must be installed at the designed depth and spacing so they will not change the design requirements. If trench drains cannot be installed at the specified depth and spacing, please contact the Construction Office and Soils Design.

**NOTES:**

### 4. Backslope Subdrain

This subdrain is to allow the water in the backslope to drain off. Again, a quick refresher on the water table, the shear strength, which is the resistance to shear failure, decreases as the pore pressure or water table goes up. Therefore, in order to prevent backslope failure, the backslope subdrain has to be installed. It is critical to install the subdrain at the proper elevation. The subdrain has to be on or somewhat in the layer of clay, shale, gumbotil, glacial clay, etc. The reason for this is clay is considered impervious. Thus, the water cannot drain through this layer. Hence, the subdrain has to be there to drain off the water. The backslope subdrain has to be installed as soon as possible after the cut is made. The longer the delay, the bigger the chance for problems.

In cases where different layers of shale are encountered in the backslope, the backslope subdrain must be placed below the shale layer that the water is running on.

Back slope subdrains should be added as needed.

**NOTES:**

## 5. Ditch Cut

It is very important to have the ditch cut to the proposed level as soon as possible. This should be done so that the storm water can drain properly. Also, since the ditch level is low, it would allow any water at the upper portion of the embankment to drain off. This, once again, will provide higher stability for the embankment.

**NOTES:**

## 6. Wick Drains

Wick drains can be best described as prefabricated vertical drains. Their primary ise is to accelerate consolidation of the deep, soft, saturated, and compressible soil layer(s). They decrease the settlement time. Thus, they accelerate the strength gaining of the soils.

**NOTES:**

## *VI. Stabilization Methods*

In this section the stabilization methods are referred to as subgrade treatment. The reason we have subgrade treatment is to provide the best possible support for the subbase (if needed) and the pavement. The type of subgrade treatment used depends on the type, the quality and quantity of natural soils available on the project. The subgrade treatment material is much stronger than the regular Class 10. It is to provide uniform and better support for the pavement. However, it is not there to cover up unstable locations. Thus, it is critical to make sure the subgrade is in reasonable condition before the subgrade treatment is placed because once it is placed, it may not be economical to remove it.

The Soils Design Section will always recommend using on-site soils or borrow for the subgrade treatment if available for no other reason than cost of these materials. On-site material may cost approximately $2.50 per cubic yard, while special backfill may cost $16.00 per ton. A one mile treatment of the above would be as follows. Soils: 2.0' thick=12,906 cubic yards @ $2.50=$32,265.00. Special backfill @ 1.0'=10,962 tons=$180,087.00.

The following are some of the typical materials used as subgrade treatment:

### 1. Select Soil

The normal materials for the select are clay loam, loam, or sand. From the textural classification table, it should be recognized that these classes contain either predominantly sand or a good mixture of sand, silt, and clay. Because of the composition, the density and the shear strength are much higher when they are properly compacted. At locations where modifications were done but stability is questionable, additional select should be considered. This is an economical way to improve stability.

**NOTES:**

### 2. Special Backfill

The special backfill is a uniform mixture of coarse and fine particles of crushed concrete, crushed limestone, composite pavement, or a mixture of gravel, sand, soil, or a mixture of crushed limestone, gravel, sand, and soil. In other words, the special backfill could be a variety of different materials. The requirement for this material is that it has to meet a certain gradation. Since the materials vary, different behaviors should be expected. For example, a piece of gravel is going to provide much less stability than a piece of crushed limestone. In order to get the best material, the inspector may need to work with the contractor to get the better material for each situation. The additional special backfill at the questionable locations will certainly improve stability.

**NOTES:**

### 3. Polymer Grid

A polymer grid is a high strength polymer material. It is used to provide additional support at unstable locations. The open grid structure material works better with aggregate base for the interlocking effect. A polymer grid is used by the Soils Design for subgrade strength when on-site materials are not of sufficient quality to use in the upper part of the subgrade. "Grid" will most likely be used with special backfill material and 1.0' of moisture control of the on-site soils. Grids work because the material has a very high tensile strength which allows wheel loads to be spread over a much larger area rather than having localized punching failure, ruts, etc.

A polymer gird should not be extended beyond the edge of the pavement so it will not interfere with the longitudinal subdrain installation.

A polymer grid should be utilized when there is an unstable location and other methods have been tried to rectify the situation but were not successful.

***Do not attempt to fix the polymer grid if the stability is not enough. The best thing to do is to add more special backfill on top.***

**NOTES:**

## *VII. Finishing Roadway and Slopes*

Finishing work should be done as soon as possible. This work should be done as the project progresses. Do not wait until the end of the grading project to do everything at once. In order to complete an area, finishing and seeding must be performed.

### 1. Finishing

Finishing work for grading must be precise and accurate. Surfaces and slopes must be smooth to provide good drainage. This is extremely important because the grade can get unstable before the paving starts. The finishing work is also important because the stormwater permit requires that any area where there is no construction for 21 days or more must be seeded or stabilized within 14 days. Therefore, do not delay the finishing work.

Ruts should be smoothed out when rain is likely to occur.

**NOTES:**

### 2. Seeding

Successful seeding cannot be obtained all year long. The germination and growth depend on temperature and moisture. This does not mean that seeding can only be done at certain time. Seeding must be done as soon as possible, when specifications permit. To be in compliance with the stormwater regulations, seeding or mulching will be needed on the project as finishing progresses. For more information about erosion control, please refer to erosion control section and Sections 7.40 and 7.41 of the Construction Manual.

**NOTES:**

## ***VIII. Before the Paving***

### 1. Proof Rolling

Specification Section 2301.10, Paragraph C, "Proof Rolling Requirements" requires that the subgrade be proof rolled no more than one week prior to trimming of the final grade. This proof rolling is very critical to make sure that the subgrade is strong enough to help support the pavement. Soft spots or unstable areas must be reworked to obtain adequate stability.

**NOTES:**

### 2. Trimming

The method of trimming is not specified. Thus, it is very difficult to ask a contractor to use a specific piece of equipment for trimming. It is obvious that an automated profile controller, i.e., CMI trimmer, is preferred. The contractor shall not be allowed to tear the subgrade or compacted special backfill/select for the trimming purposes.

**NOTES:**

### 3. Granular Subbase

The main purpose of the granular subbase material is to provide drainage under the pavement. Since this material has an open gradation, the maximum density is not very high. In addition, this material is compacted with a maximum of three passes of a self propelled, non-vibratory steel or pneumatic roller, the compacted density may be from 100 to 120 pcf. Thus, the percent voids could be as high as 40%. This is the reason why it is very permeable. Since it is there mainly for drainage, the structural support is also not very high. It is usually specified under Portland cement concrete (PCC) pavement which can provide the mat foundation or bridging support across the granular subbase layer.

No construction traffic is allowed on top of the granular subbase layer.

During the construction of the granular subbase, it is very important to check the permeability of this layer. One quick and easy way to do this is to fill one-gallon milk jug with water. Pour this gallon of water from waist level down at one spot. If the water drains away and no sign of any buildup after one minute, the granular subbase layer is considered permeable.

**NOTES:**

### 4. Modified Subbase

Modified subbase is used mainly for stability/support. It is normally specified under hot mix asphalt (HMA) pavement. A vibratory steel roller is normally used for compaction. This makes this layer very strong. Construction traffic is allowed to run on it.

Modified subbase is also used under PCC pavement when the access is limited such as urban reconstruction projects.

Modified subbase is generally less permeable than granular subbase, but more permeable than most Class 10 or select soil materials. As a general rule, it is considered permeable enough to require installation of continuous longitudinal subdrains when it is used.

**NOTES:**

## *IX. Summary*

It should be very obvious by now that in order to achieve a quality and successful project, there are several things the inspector needs to pay special attention to. They are:

*1. Erosion Control*

Erosion control devices have to be installed and maintained properly. Sometimes it is difficult to get the attention and cooperation from the contractor. There is no option in this issue. It must be done and done as quickly as possible.

*2. Compaction*

In order to get good strength/support and minimize the settlement and failure, adequate compaction must be achieved. There are three factors that need to be considered. They are soil type, moisture content, and equipment. The current specification does not provide the inspector much control over the contractor. It does mean, however, the inspector needs to recognize what is going on and should try to work with the contractor to get a better product. Sheepsfoot roller walkout condition, in general, works. Nevertheless, whether or not good compaction is achieved with this requirement is yet to be determined. The inspector should go beyond what is required to make sure that adequate compaction is obtained. If it is possible, please take some density and moisture tests to see what is there. At least, some information is available. Quality cannot be achieved without the solid data.

*3. Proper Drainage*

Water is very powerful and it is the worst enemy to soils work. Unstable subgrade and failure can happen if water is not drained away. The inspector should do whatever it takes to make sure that the water table is as low as possible.

*4. Documentation*

Documentation relates to the payment procedure and sometimes legal issues, it must be done as adequately as possible.

*5. Communication*

It would take more than just the inspector or any one person to get the job done. Do not be afraid to let someone know there are some questions, problems, etc. Help is always available.

## *X. References*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## ***Acknowledgements***

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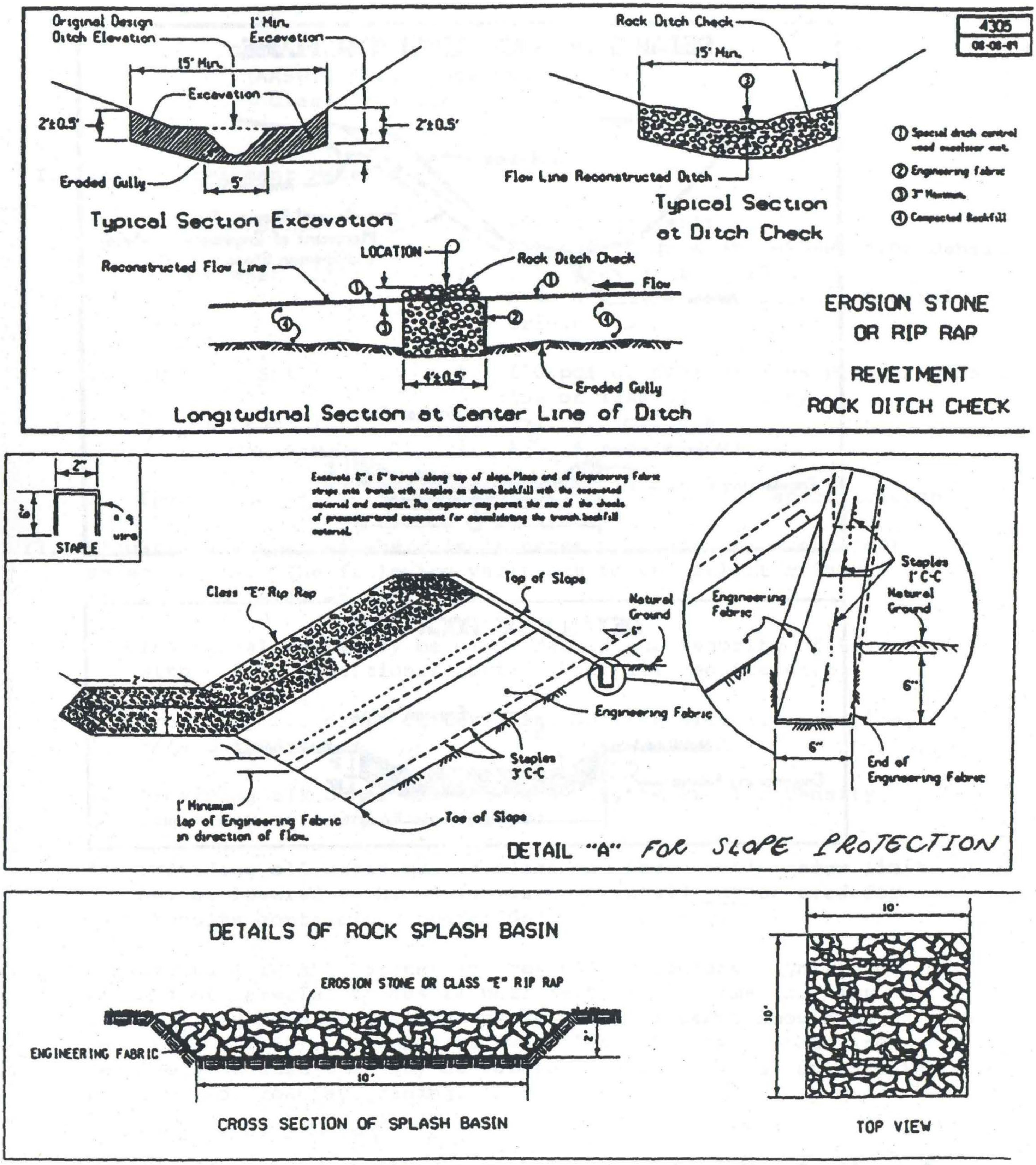
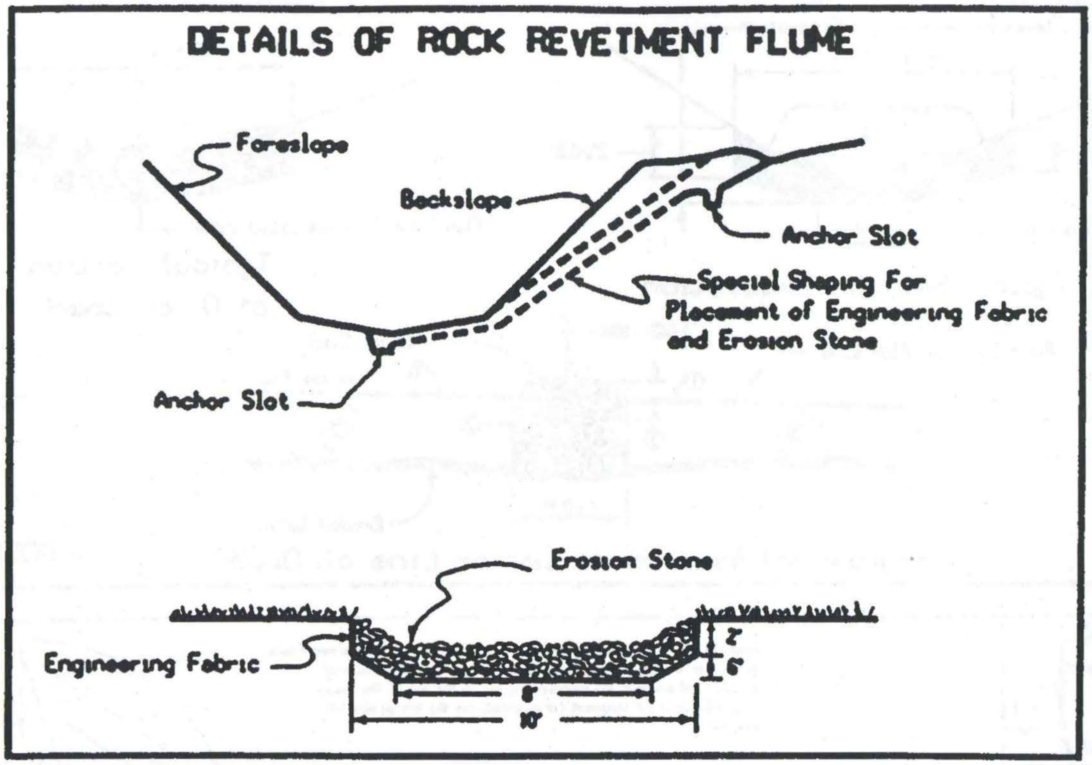
Thanks should also be extended to Bill Nelson (Design), Ron Otto and Mike Seymour (Ames Construction), Lee Hansen and Tommy Thomas (Soils Design) for the information in balances, survey, and soil sheets/soil design respectively.

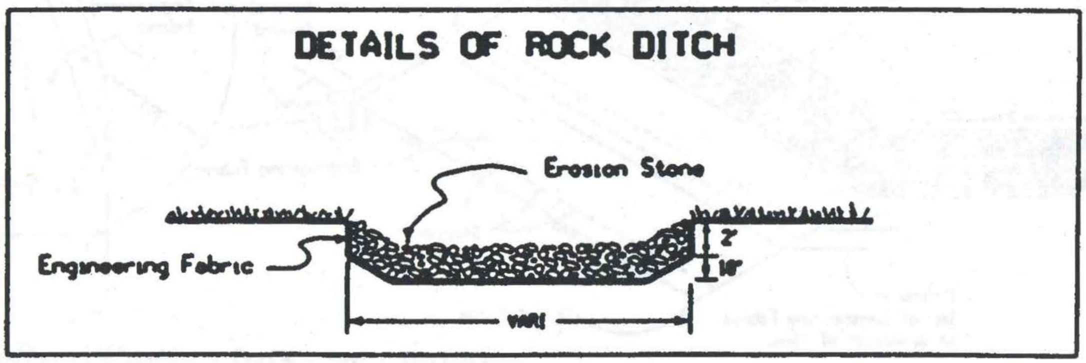
This reference guide was put together in a short period of time to answer most, if not all, of the questions that were submitted. Therefore, there is no doubt that this reference guide can continuously be improved. The writer would like to thank those who submitted the questions and the ones that will continue with input to make this reference guide better for the grading inspectors.

# Appendix




Appendix 1. Details of some Erosion Control Devices




Appendix 2. More Erosion Control Devices

Guidelines for Soil Use in Roadways
(AASHTO-Test Procedures, M-145-49
Classification-.002 mm clay)

I. Select Treatment Materials

| | |
|---|---|
| 1. Cohesive Soils (must meet all): | 1. 45% or less silt<br>2. 110 pcf or greater T-99-Proctor Densit<br>3. P.I. greater than 10<br>4. A-4, A-6 or A-7-6 Soils of Glacial Origin |
| 2. Granular Soils (must meet all): | 1. 110 pcf or greater T-99-Proctor Densit<br>2. 15% or less silt & clay<br>3. P.I. = 3 or less<br>4. A-1, A-2 or A-3(0) |
| 3. Special Backfill | 1. Article 4132 IA DOT specifications |

II. Situations may arise where it is necessary to utilize marginal select soils. The following variances to the select criteria may be considered as limiting.

1. Individual tests may be discarded if the majority of tests within the depositional horizon meet all requirements.

2. Providing all other criteria are met, the silt limit may be raised to 47%.

3. Providing all other criteria are met, the Proctor Density limit may be lowered to 108 pcf.

4. Providing all other criteria are met the Plastic Index limit may be lowered to 8. This variance should not be used for deposits containing interbedded sand or silt.

Designated Select Treatment sources should contain significant amounts of material to assure uniformity of treatments. The material may be hauled as necessary but an attempt should be made to limit this distance to two miles. Borrow sources are desirable because they may be worked independently of any staging required for roadway grading.

Appendix 3. Soil Uses

III. Unsuitable Soil

| | Definition |
|---|---|
| Use (Rl-1 Standard) slope dressing only: | 1. Peat or Muck<br>2. Soils with P.L. 35 or greater<br>3. A-7-5 or A-5 having less than 85 pcf T-99-Proctor Density |
| Type C Disposal-3' below subgrade in fills | 1. All soils other than A-7-5 or A-5 having a T-99-Proctor Density of 95 pcf or less.<br>2. All soils other than A-7-5 or A-5 containing 3.0% or more carbon. |
| Type B Disposal-5' below subgrade in fills | 1. A-7-6 (19-20)<br>2. Residual clays (overlaying bedrock) regardless of classification |
| Type A Disposal in fills | 1. Shale<br>2. A-7-5 or A-5 soils having a T-99-Proctor Density greater than 86 pcf but less than 95 pcf |

A. It is desirable to dispose of all unsuitable soils within a reasonable haul distance (±1.0 mile) and to utilize all materials found on the project. If disposal of excessive "unsuitable" soils becomes a problem, it may be necessary to make minor grade adjustments to minimize the unsuitable soil cut and require that suitable material be obtained from borrows.

B. Excess C-5 soils may be disposed of following the C-3 criteria if the C-5 disposal requirements cause the material to be wasted.

IV. Cut area subgrade situations requiring treatment.

1. When unsuitable soils are located within 2' of finished subgrade a minimum treatment of 2.0 select soil or 1.0' special backfill (section 4132) is required.

2. Nonuniform soils within 3.0' of subgrade top, particularly contact zones of major soil horizons and these soils containing pockets or interbedded layers of sand or silt indicate potential frost heave areas. Treatments and/or drainage must assure that protection from ice lensing extends a minimum of 3.0' below subgrade.

Appendix 4. More Information on Soil Uses

3. A-4 soils with an index of (7) or less have a high frost heave potential but area easily drainable. Treat as per #1 and assure that the upper 3' of subgrade is well drained.

4. Bedrock cuts shall be subcut and treated a minimum of 1.0'. Shale cuts should be treated full width with select cohesive soil. All rock cuts requiring blasting shall be treated with special backfill.

5. Drainage (subdrains or ditching) should assure that the ground water level is maintained at least 3.0' below finished subgrade. In areas where conditions are severe or where positive drainage cannot be assured a minimum 1.0' special backfill treatment should be used. In most cases continuous longitudinal subdrainage should be used.

6. In all urban designs, areas mentioned above shall be subcut and treated with 1.0' of Special backfill (4132). Those areas not requiring treatments shall have the upper 1.0' placed as per Article 2109.06 - Special Compaction of Subgrade.

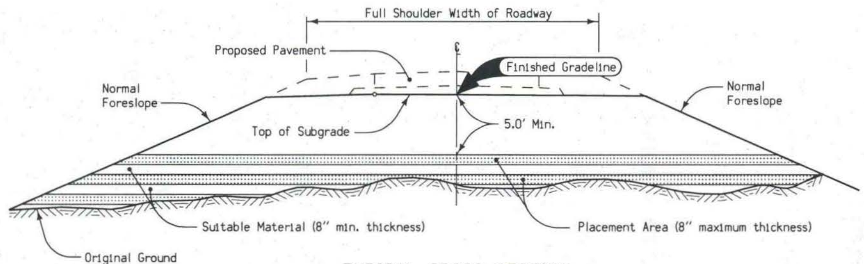
V. Other Surface Treatments

1. If available project materials are limited, it may be desirable to treat only areas meeting the above requirements. Moisture Density Control (Article 2107.08) may be used in areas not requiring 'treatment' as follows: In cuts the upper 2' of the subgrade shall be subcut and replaced with Moisture Density Control. All fill areas shall have the upper 3' placed with Moisture Density Control.

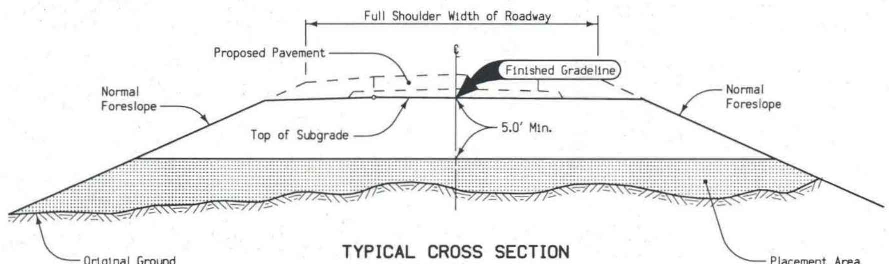
2. Treatments composed of materials meeting the criteria for granular soils shall have the upper 1.0' placed with Moisture Control (Article 2107.09).

**TABLE Textural Classification of Soil Based on Grading**

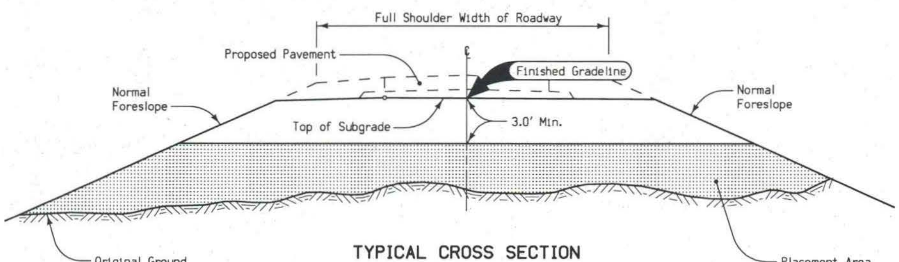
| Textural Class | Composition (%) Sand | Silt | Clay |
|---|---|---|---|
| Sand | 80–100 | 0–20 | 0–20 |
| Sandy loam | 50–80 | 0–50 | 0–20 |
| Loam | 30–50 | 30–50 | 0–20 |
| Silt loam | 0–50 | 50–100 | 0–20 |
| Sandy clay loam | 50–80 | 0–30 | 20–30 |
| Clay loam | 20–50 | 20–50 | 20–30 |
| Silty clay loam | 0–30 | 50–80 | 20–30 |
| Sandy clay | 55–70 | 0–15 | 30–45 |
| Silty clay | 0–15 | 55–70 | 30–45 |
| Clay | 0–55 | 0–55 | 30–100 |




**TYPICAL CROSS SECTION**
**TYPE "A" PLACEMENT**




**TYPICAL CROSS SECTION**
**TYPE "B" PLACEMENT**




**TYPICAL CROSS SECTION**
**TYPE "C" PLACEMENT**

GENERAL NOTES:

This plan illustrates the normal construction procedure for the placement of unsuitable materials.

Materials and methods of construction shall be in accordance with current Standard and Supplemental Specifications.

Materials listed as "unsuitable" in the project plans shall normally be placed as detailed for the particular type of soil described in "Roadway and Borrow Excavation" of the Specifications. Project plan details or specific directions of the Engineer may require placement of topsoil or other unsuitable soil by methods other than those shown. Refer also to plan cross sections and soil survey sheets for additional information.

Iowa Department of Transportation

**STANDARD ROAD PLAN**

REVISION 7 10-17-06

**RL-1B**

SHEET 1 of 1

REVISIONS: Do not allow placement of Type "C" under shoulders due to shoulder stability problems.

Deanna Maifield
APPROVED BY DESIGN METHODS ENGINEER

DETAILS OF EMBANKMENT
(ALLOWABLE PLACEMENT
OF UNSUITABLE MATERIAL)

# METHOD OF TEST FOR DENSITY OF UNDISTURBED SOIL CORES BY DISPLACEMENT

## SCOPE

This method of test is intended to determine the density of soils in their natural state by measuring the weight, volume and moisture content of undisturbed samples.

## PROCEDURE

### A. Apparatus

1. Overflow meter, which is a volume measuring device, consisting of a 9-1/2" high by 5-1/2" diameter brass tube and a 9-1/2" by 2" diameter brass tube connected near their base by a 1" diameter cross tube. The 2" diameter tube, acting as a surge tank, has an antisiphoning overflow outlet near its top.
2. 250 ml. tared plastic beaker.
3. 2 ¼ Quart plastic pitcher.
4. Trimming knife.
5. Carrier for soil specimens, consisting of brass wire with fish line bails.
6. Balance with a capacity of at least 1000 grams, accurate to 0.5 grams.
7. Oven, forced draft at 230 ± 9 degrees F.
8. Supply of kerosene (or diesel fuel).
9. Data sheets.
10. 250 ml volumetric.
11. Metal object for carrier calibration.

### B. Calibration

Whenever new kerosene is purchased and at least once a year, it is advisable to determine the weight of a known volume of kerosene and to indirectly calculate the weight of kerosene displaced by the carrier.

1. Place a clean, dry 250 ml volumetric on the balance, and tare the balance to read zero.
2. Fill with kerosene to the exact 250 ml line, and clean and dry the outside of the

volumetric.

3. Place the volumetric on the tared balance, and then record the weight of the 250 ml of kerosene. Record this weight as KX.

4. Prime the empty overflow meter to the cut-off point.

5. Place a combined metal object and carrier into the overflow meter. The metal object shall be large enough to induce the flow of kerosene into a tared beaker. Measure in grams the displaced kerosene and record as TMC.

6. Again prime the overflow meter, but this time with an empty carrier in it.

7. Remove the carrier from the overflow meter. Place the combined metal object and carrier back into the overflow meter. Measure in grams the displaced kerosene and record as TM.

8. The carrier displacement equals TMC -TM.

9. Repeat steps 4 through 8 for each carrier.

10. Record the carrier displacement CD as the average of the values calculated in Step 8. Use of an average carrier displacement is valid only if their individual displacements are nearly equal.

## C. Test Procedure

1. The core samples shall arrive from the field in tightly closed wide mouth Mason jars containing proper identification. Sort these samples according to sender's number, and enter on data sheets.

2. If the sample has a concave surface on either end, trim this end using the knife and place the specimen into the tared sample carrier.

3. Record the weight of the specimen and then lower the carrier with specimen into the gallon can containing sufficient kerosene to cover the entire specimen. (Care must be used on steps 3 through 6 to prevent loss of material).

4. When air bubbles cease to be displaced, remove specimen from the kerosene bath, allow to drain and lower into the overflow meter that has previously been filled and allowed to overflow to the cut-off point.

5. Catch the displaced kerosene in a tared 250 ml. beaker and weigh the overflow. Record this weight onto the data sheets. On completion of the overflow, the specimen must be fully immersed.

6. Remove the carrier from the bath. Allow the specimen to drain and aerate to

remove the kerosene. Place the specimen into a bread pan along with the corresponding shipping tag. Refill the overflow meter and allow the overflow to stop. Oven dry the bread pan with specimen at least overnight and then reweigh. (Outside vents should be open fully on the forced air oven).

## C. Calculations

1. $$M = \frac{WW - DW}{DW} \times 100$$

Where:

W W=Original weight of specimen (core)
DW= Dry weight of specimen (core)
M = Moisture content, in percent

2. $$DE = \frac{DWg \times \frac{0.00220462lb}{g}}{(DV - CD)\frac{250ml}{Kxg}\frac{1ft^3}{28{,}316.8466ml}}$$

Where:

DW = Dry weight of specimen (core)
DV = Displaced weight (grams) of kerosene for the core + carrier
CD = Carrier displacement (grams) of kerosene
KX = Weight (grams) of 250 ml of kerosene
DE = Dry core density, in pounds per cubic foot

3. $$DM = DE \times \frac{1kg/m^3}{0.062428lb/ft^3}$$

Where:

DE = Dry core density, in lbs. per cubic foot
DM = Dry core density, in kg per cubic meter

# DETERMINING MOISTURE CONTENT & DENSITY OF SOILS, BASES, & SUBBASES WITH A NUCLEAR GAUGE

## SCOPE

This test method describes the procedure used in determining the in-place density and moisture content of soils, cold-in-place recycled asphalt pavement, soil aggregate sub-base, soil lime sub-base, and cement treated granular base or sub-base by the use of nuclear method.

## OPERATOR QUALIFICATION

In addition to complying with IM 206, an operator, to determine the moisture content and density of soils, bases, and sub-bases with a nuclear gauge, must first demonstrate knowledge and proficiency in various related areas that may affect the test result. The specific areas will be determined by and demonstrated to the satisfaction of the District Materials Engineer or an authorized representative.

## PROCEDURE

A. Apparatus

1. A recognized nuclear moisture-density gauge containing a radioisotope, detectors and related circuitry. The gauge shall be capable of determining densities by either the backscatter or direct transmission methods.
2. A reference standard for the purpose of taking standard counts, and for checking equipment operation
3. Calibration curves or tables for the gauge
4. A drill rod and combination guide-scraper plate for preparing the testing site
5. Manufacturer Instructional Manual

B. Standard Counts

1. Place the reference standard in a position recommended by the manufacturer to obtain standard counts.
2. Allow the gauge to warm up as suggested by the manufacturer.
3. Take one automatic four-minute standard count per manufacturer instructions. This count should be within 1% of the latest standard count established for the gauge. In the event the standard count varies by more than 1%, take four additional automatic four-minute standard counts. Use the average of the five four-minute counts to establish a new standard count for the gauge.

4. If the day-to-day shift in the standard count varies more than 2% for moisture or 1% for density, reset the gauge on the standard and repeat the procedure in B3.

5. Keep a log of the gauge standard counts.

6. Standard counts should be taken twice a day to detect any shift during daily use.

C. Site Preparation

1. Select a location for test where the gauge will be a least 6 in. (150 mm) away from any vertical projection. Be sure the vehicle is at least 10 ft. (3 m) away from the test site.

2. Remove all loose and disturbed material, and remove additional material as necessary to reach the top of the compacted lift to be tested.

3. Prepare a horizontal area, sufficient in size to accommodate the gauge, using the scraper plate supplied with the gauge; by planing to a smooth condition so as to obtain maximum contact between the gauge and material being tested. Make sure the gauge sits solidly on the site without rocking.

4. The maximum depressions beneath the gauge shall not exceed 1/8 in. (3 mm). Use native fines or fine sand to fill voids and level the excess with the scraper plate. The total area thus filled with native fines or sand should not exceed ten percent of the bottom area of the gauge.

D. Moisture Determination

1. Prepare test site as described in C.

2. Obtain a one-minute moisture count.

3. Determine the moisture content form the calibration data supplied with the gauge.

4. The moisture measurement is based upon the thermalization of fast neutrons by hydrogen atoms. Because some materials may contain hydrogen other than free water or may contain thermalizing elements other than hydrogen, not less than ten moisture samples should be oven dried to correct the calibration data. If the gauge reading is higher than the values obtained by oven dry samples, the error is due to hydrogen containing materials, and the correction may be made by subtracting a constant value from the gauge reading. If the gauge reading is lower than that obtained by oven drying, the error is likely due to materials which absorb thermalized neutrons. In this case, the error is not a constant offset, but varies directly with the moisture content. The compensation is made by adding the full error at moisture contents used to obtain the error data and reducing the added value at lower moisture contents. At zero moisture, the error would be zero.

E. Density Determination - Direct Transmission

1. Place the guide plate on the site for the moisture determination and drive the drive pin through the guide to a depth at least 2 in. (50 mm) below the depth of material to be measured. Remove the drive pin by pulling straight up in order to avoid disturbing the access hole.

2. Place the gauge over the access hole and push the index handle down until the source has reached the desired depth.

3. With the source at the desired depth, pull the gauge so that the probe is in contact with the near side of the hole, take and record a one-minute density count.

4. Determine the wet density from the calibration data supplied with the gauge.

5. Generally no corrections for density need be made due to soil compositional error, however, if a soil has a mean atomic weight higher than limestone, the gauge may indicate a high density. If it is felt that the gauge is indicating an unrealistic high density, two undisturbed soil cores shall be obtained. These two cores should be sent to the Central Materials Laboratory and be tested for density using Iowa Test Method 102. A correction factor should be obtained based on the density measured by the Central Materials Laboratory. This factor should be applied to the field nuclear densities.

F. Calculations

1. When determining the moisture correction described in D4, use the oven dry percent of moisture and the gauge wet density to calculate the moisture content in kilograms per cubic meter (pounds per cubic foot) as follows:

$$\text{Moisture Content [kg/m}^3\text{ (lbs./cu. ft.)]} = \frac{\text{\% Moisture x Wet Density}}{\text{\% Moisture} + 100}$$

2. Calculate the dry density as follows:

$$\text{Dry Density = Wet Density - Moist. Content [kg/m}^3\text{ (lbs./cu. ft.)]}$$

3. Calculate the percent moisture as follows:

% Moisture = (Moisture Content x 100)/(Dry Density)

G. General Notes

1. Do not attempt to operate a nuclear gauge before thoroughly reading the Instruction Manual.

2. Do not attempt to operate a nuclear gauge before thoroughly reviewing the radiological safety precautions described in Office of Materials IM 206, "Nuclear Test Equipment."

# METHOD OF TEST FOR MOISTURE-DENSITY RELATION OF SOILS (STANDARD PROCTOR)

## SCOPE

This test method describes both the multiple-point and the one-point test procedures for determining the relation between the moisture content and density of soils.

## PROCEDURE

### A. Apparatus

1. Cylindrical metal molds, with detachable collar assemblies (approx. 2-1/2 inches in height), constructed so they can be fastened firmly to detachable metal plates. The molds shall have internal diameters of 4.000 ± 0.016", heights of 4.584 ± 0.005", and capacities of 1/30 cubic foot ± 0.0003 cubic feet. During compaction, the mold shall rest firmly on a dense, uniform, rigid, and stable foundation.

2. A mechanically operated metal rammer equipped to control the height of drop to a free fall of 12.00 ± 0.06 inches above the elevation of the soil and to uniformly distribute such drops to the soil surface. The rammer shall have a flat circular face 2.000 ± 0.005 inches in diameter. The mechanical rammer apparatus shall be calibrated periodically and adjusted, if necessary, to give the same moisture-density results obtained with a manually operated sleeve type rammer. The weight of the rammer will vary, and will be adjusted to give the same compaction as a 5.5 lb manually operated rammer using soil calibration procedure No. 4.

3. Sample extruder, consisting of a lever or jack arrangement.

4. A balance with at least 5000 gram capacity, accurate to 0.5 gram.

5. Forced draft drying ovens capable of maintaining a temperature of 230 ± 9° F.

6. A rigid steel straightedge longer than twice the mold diameter and have a beveled, plane, and sharpened edge.

7. Large stainless steel dish pan, large spoon, 500 cc. graduate, rubber mallet, and numbered tared pans.

8. A mechanical mixing device equivalent to a Lancaster mixer for pulverizing the soil and thoroughly mixing it with the initial increment of water.

### B. Multiple-Point Test Procedure

1. From the air-dried sample obtained as per Section 101-C, par. C3, thoroughly break up the aggregations in such a manner as to avoid reducing the natural particle sizes.

Replace the aggregate larger than 3/4" with an equal weight of No. 4 to 3/4" aggregate from the same source, or break up the material larger than 3/4" to pass the 3/4" sieve and return it to the sample.

2. Thoroughly pulverize and mix a selected representative sample of approximately 4000 to 5000 grams in the mixer muller until no soil lumps remain larger than No. 4 sieve size. Mix with sufficient water to uniformly dampen it to approximately 3 percentage points below the optimum moisture content.

3. Transfer the sample to a large dishpan for subsequent treatment. Form a specimen by compacting the prepared soil in the 4-inch diameter mold (with collar attached) in three approximately equal layers to give a total compacted depth in excess of the mold height by 0.1 to 0.4 inch. Compact each layer with 25 uniformly distributed blows from the rammer dropping from a height of 12 inches above the elevation of the soil. Do not allow soil to accumulate on the bottom of the rammer.

4. Following compaction, remove the extension collar and carefully trim the excess material even with the top of the mold with the straightedge. Patch small holes developed in the surface by compacting small-sized material into these voids. Again use a straightedge to trim the surface. Weigh to the nearest gram and record the weight of the mold and its compacted contents.

5. Extrude the material from the mold, and slice vertically through the center of the specimen. Place into a weighed pan at least a 500 gram moisture sample from one of the cut faces. Alternately, obtain a moisture sample from the dishpan while the mechanical machine is compacting the specimen. Immediately record the weight of this sample and pan. Place into the 230° F. oven to dry at least overnight. When the sample is dry, record the weight of the dry soil plus pan.

6. Thoroughly break up the remainder of the compacted specimen until, as nearly as is feasible, it will pass a No. 4 sieve and add this material to the remaining portion of the sample in the large dishpan. Add water, by sprinkling, in a sufficient amount to increase the moisture content of the soil sample by one to two percentage points, mix well with a large spoon, and repeat the above compaction procedure. Continue this process of compacting successively wetter specimens until the peak dry density has been bracketed by at least three data points. Use the mold plus compacted soil weights to estimate whether the peak dry density is included between the data points. These weights should successively increase until the peak is reached and then decrease. A final weight slightly higher (up to 30 grams) than the previous one may be sufficient to show a decreasing density. If there is any doubt that the peak has been reached, compact another specimen as above with one to two percent additional water.

C. **Calculations for Multiple-Point Test Procedure**

1. Calculate the moisture content and dry weight per cubic foot of the soil as compacted for each trial as follows:

$$P = \frac{A - B}{B - C} \times 100 = \text{Percent Moisture}$$

$$D = \frac{100\ (W-M)\ gm}{(1/30\ ft.^3)(453.6\ gm/lb)\ (P + 100)}$$

Where:

P = Percentage of moisture in the specimen, based on oven dry weight of soil.
A = Weight of moisture pan plus wet soil.
B = Weight of moisture plan plus dry soil.
C = Weight of moisture pan.
D = Dry density in pounds per cubic foot of compacted soil.
W = Wet weight in grams of specimen plus mold.
M = Mold weight in grams.

**D. Moisture-Density Relationship**

1. Using the calculated results from Section C, plot the dry densities of the soil as ordinates and the corresponding moisture contents as abscissas.

2. Connect the plotted points with a smooth curve. The peak of the curve will give the maximum density (for the compaction effort used) or Proctor density and the corresponding optimum moisture content.

**E. One-Point Test Procedure**

1. Any soil may be tested by using the above multiple-point procedure. However, the one-point procedure may be used to determine the optimum moisture content and maximum density for most soils. The one-point procedure will not give an accurate analysis for certain granular materials, black soils, or soils containing a considerable amount of aggregate. Care should be exercised in deciding whether to use the one-point procedure for a particular soil.

2. Follow the procedure outlined in paragraph B-1, and then thoroughly mix and pulverize a selected representative sample of approximately 3000 grams in the mixer muller until no soil lumps remain larger than No. 4 sieve size. Mix with sufficient water to uniformly dampen it to an estimated moisture content of zero to three percentage points below Proctor optimum moisture.

3. Follow the procedure outlined in paragraphs B-3 through B-5 to obtain moisture content and density data for a single compacted specimen.

F. **Calculations for One-Point Test Procedure**

1. Calculate the moisture content and wet weight per cubic foot of a one-point specimen as follows:

$$P = \frac{A - B}{B - C} \times 100 = \text{Percent Moisture}$$

$$D = (W - M)(0.06614) = \text{Wet Density (lb/ft}^3\text{)}$$

Where:

P = Percentage of moisture in the specimen, based on oven-dry weight of the soil.
A = Weight of moisture pan plus wet soil.
B = Weight of moisture pan plus dry soil.
C = Weight of moisture pan.
W = Wet weight, in grams, of specimen plus mold.
M = Mold weight.
D = Wet density in pounds per cubic foot of compacted specimen.

2. Plot the point of intersection of the above wet density and moisture content in the family of curves entitled "Moisture-Density Curves". If the plotted point falls outside the "Range of Confidence", recompact another specimen at an adjusted moisture content that will place the point within this range.

3. Using the number of the nearest curve, obtain the dry Proctor density and optimum moisture value in the adjoining table.

<u>Example</u>

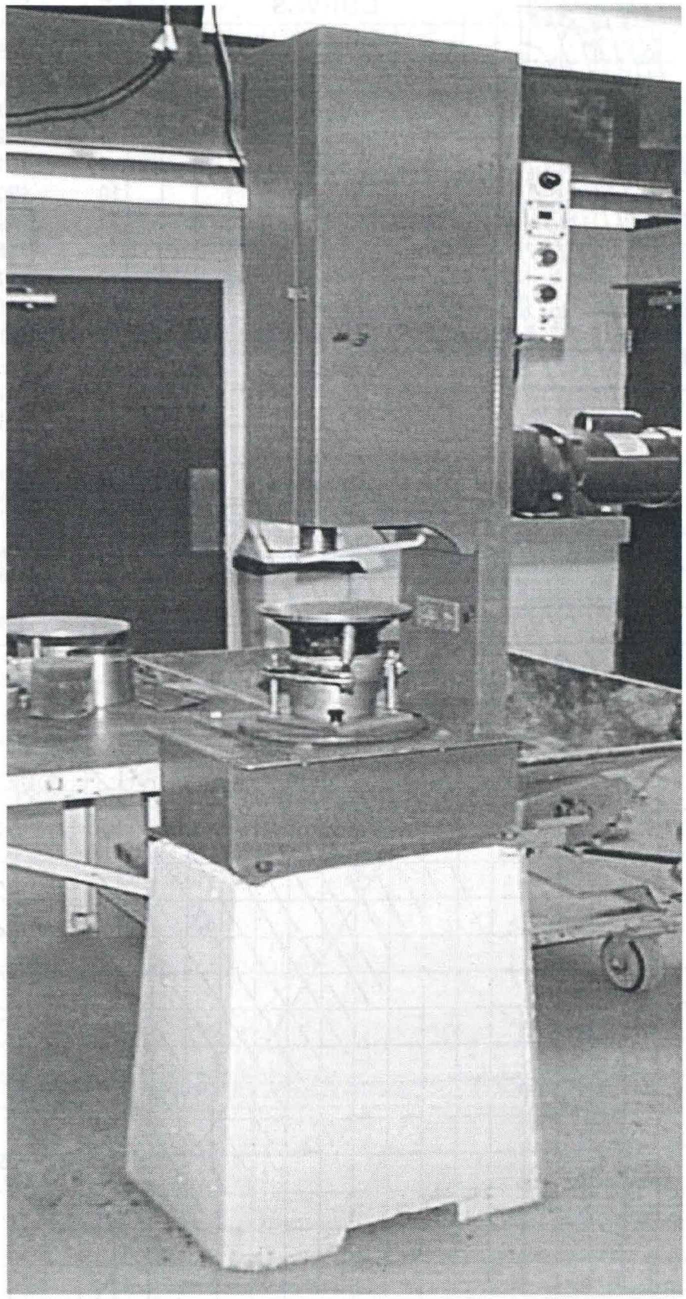
A = 700.0 gm
B = 630.0 gm
C = 144.5 gm
W = 3750.0 gm
H = 1879.0 gm

$$P = \frac{(700.0 - 630.0)}{(630.0 - 144.5)} \times 100 = 14.4\%$$

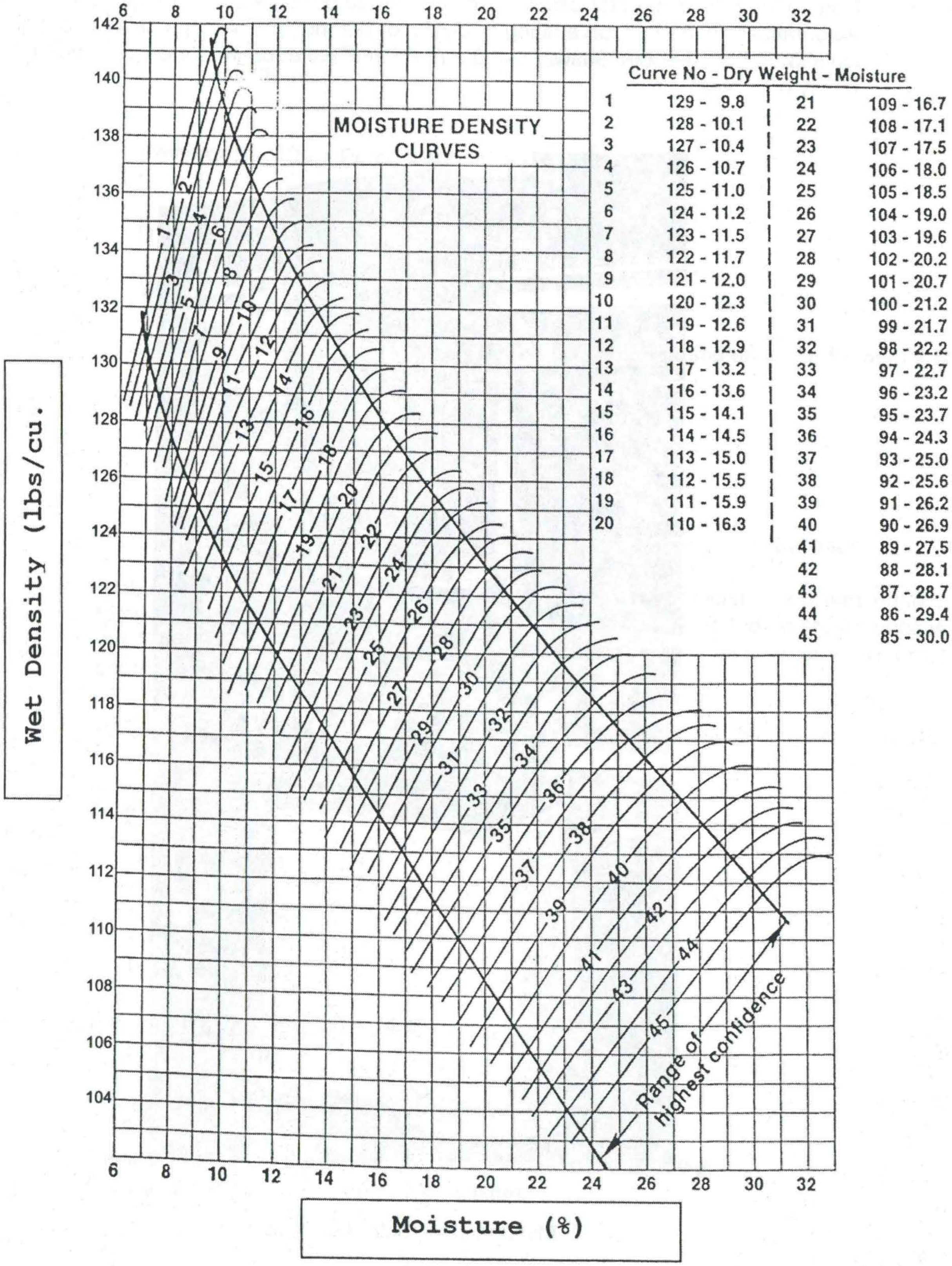
$$D = (3750.0 – 1879.0)(0.6614) = 123.7 \text{ pounds per cu. ft.}$$

Point of intersection is closest to curve No. 21 which is 109 lb./ft.$^3$ Proctor density at 16.7% optimum moisture.

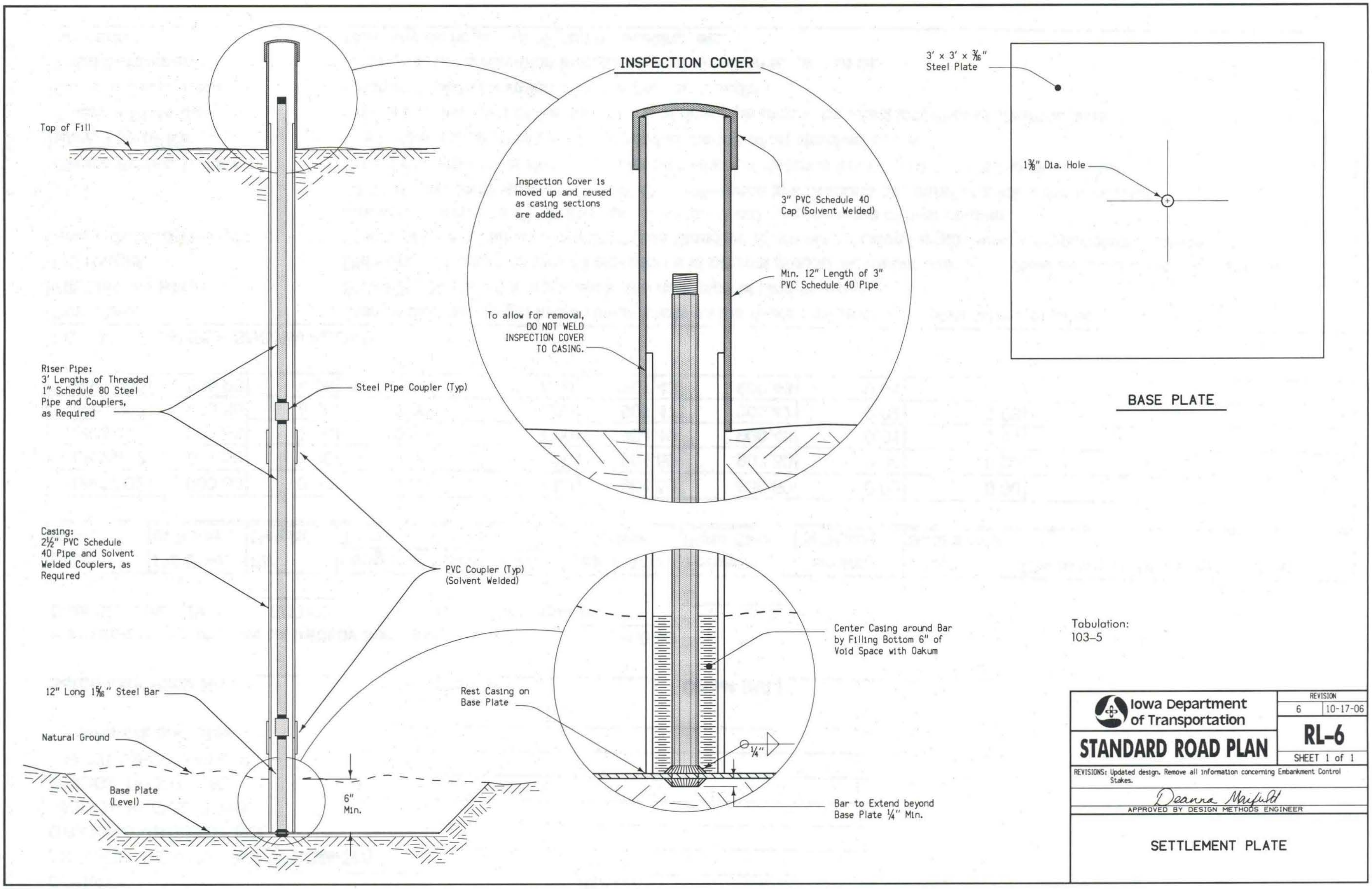
Note: Currently all proctor calculations are carried out on a computer which not only automatically does the curve fitting analysis for the multiple point procedure, but also calculates the one-point answer using a mathematical equation for each curve of the family of curves.



Mechanical Proctor Machine




| Curve No | Dry Weight - Moisture | Curve No | Dry Weight - Moisture |
|---|---|---|---|
| 1 | 129 - 9.8 | 21 | 109 - 16.7 |
| 2 | 128 - 10.1 | 22 | 108 - 17.1 |
| 3 | 127 - 10.4 | 23 | 107 - 17.5 |
| 4 | 126 - 10.7 | 24 | 106 - 18.0 |
| 5 | 125 - 11.0 | 25 | 105 - 18.5 |
| 6 | 124 - 11.2 | 26 | 104 - 19.0 |
| 7 | 123 - 11.5 | 27 | 103 - 19.6 |
| 8 | 122 - 11.7 | 28 | 102 - 20.2 |
| 9 | 121 - 12.0 | 29 | 101 - 20.7 |
| 10 | 120 - 12.3 | 30 | 100 - 21.2 |
| 11 | 119 - 12.6 | 31 | 99 - 21.7 |
| 12 | 118 - 12.9 | 32 | 98 - 22.2 |
| 13 | 117 - 13.2 | 33 | 97 - 22.7 |
| 14 | 116 - 13.6 | 34 | 96 - 23.2 |
| 15 | 115 - 14.1 | 35 | 95 - 23.7 |
| 16 | 114 - 14.5 | 36 | 94 - 24.3 |
| 17 | 113 - 15.0 | 37 | 93 - 25.0 |
| 18 | 112 - 15.5 | 38 | 92 - 25.6 |
| 19 | 111 - 15.9 | 39 | 91 - 26.2 |
| 20 | 110 - 16.3 | 40 | 90 - 26.9 |
| | | 41 | 89 - 27.5 |
| | | 42 | 88 - 28.1 |
| | | 43 | 87 - 28.7 |
| | | 44 | 86 - 29.4 |
| | | 45 | 85 - 30.0 |


INSPECTION COVER
Top of Fill
Inspection Cover is moved up and reused as casing sections are added.
3" PVC Schedule 40 Cap (Solvent Welded)
Min. 12" Length of 3" PVC Schedule 40 Pipe
To allow for removal, DO NOT WELD INSPECTION COVER TO CASING.
Riser Pipe: 3' Lengths of Threaded 1" Schedule 80 Steel Pipe and Couplers, as Required
Steel Pipe Coupler (Typ)
Casing: 2½" PVC Schedule 40 Pipe and Solvent Welded Couplers, as Required
PVC Coupler (Typ) (Solvent Welded)
Center Casing around Bar by Filling Bottom 6" of Void Space with Oakum
12" Long 1⅝" Steel Bar
Rest Casing on Base Plate
Natural Ground
Base Plate (Level)
6" Min.
¼"
Bar to Extend beyond Base Plate ¼" Min.
3' x 3' x ⅜" Steel Plate
1⅜" Dia. Hole
BASE PLATE
Tabulation: 103-5
Iowa Department of Transportation
REVISION
6 10-17-06
STANDARD ROAD PLAN
RL-6
SHEET 1 of 1
REVISIONS: Updated design. Remove all information concerning Embankment Control Stakes.
Deanna Maifield
APPROVED BY DESIGN METHODS ENGINEER
SETTLEMENT PLATE

## SETTLEMENT PLATE DATA

(See Standard Road Plan RL-6)

COUNTY ______________________ ROUTE ____________

PROJECT DESCRIPTION (FROM-TO) ______________________

GRADING PROJECT NO. ______________________

BRIDGE PROJECT NO. ______________________

BRIDGE DESIGN NO. ______________________

OTHER INFORMATION ______________________

Benchmark and Elev. ______________________

Settlement Plate No. ________ Station ____________ Offset (R/L) ____________

Elevation of top of plate as initially installed 900.50

Date plate installed 5/17/02 Date fill completed ________

| Date Read | Fill Elev. at Riser | Fill Height | Length of Risers Added | | Elev, Top of Riser | Today's Plate Elev. | Current Settlement | Total Settlement | Remarks or other information |
|---|---|---|---|---|---|---|---|---|---|
| | | | Today | To Date | | | | | |
| 05/17/02 | 900.50 | 0.00 | 4.00 | 4.00 | 904.50 | 900.50 | 0.00 | 0.00 | |
| 05/24/02 | 901.50 | 1.00 | 0.00 | 4.00 | 904.50 | 900.50 | 0.00 | 0.00 | |
| 05/31/02 | 902.50 | 2.00 | 0.00 | 4.00 | 904.49 | 900.49 | 0.01 | 0.01 | |
| 06/07/02 | 903.50 | 3.00 | 3.00 | 7.00 | 907.47 | 900.47 | 0.02 | 0.03 | |
| 06/14/02 | 905.00 | 4.50 | 0.00 | 7.00 | 907.43 | 900.43 | 0.04 | 0.07 | |

*FOR THE EXAMPLE SHOWN ABOVE:*

| | |
|---|---|
| **Date Read:** | Start at day zero to get initial survey shots on the risers attached to the plate when installed. |
| **Fill Elev. At Riser:** | Shoot the fill elevation adjacent to the riser pipe at time of reading. |
| **Fill Height:** | Difference between current fill elevation and original ground elevation; use top of plate as ground elev. if reasonable |
| **Risers Added Today:** | Standard pipe extensions are 3'-0" (see Standard RL-6) but installed length varies with couplers in place.<br>Measure length directly on the pipe, from top of old coupler to top of new coupler.<br>CHECK this length against a SAME-DAY difference in elevations before/after adding the new riser. |
| **Risers Added To Date:** | Sum the lengths of all riser pipes placed to date; = distance from top of plate to top of last riser. |
| **Elev, Top of Riser:** | It is recommended this always be read at the top of an attached coupler. |
| **Today's Plate Elev:** | This is the elevation of the current top of riser pipe minus the exact length of all risers to date. |
| **Current Settlement:** | Change in plate elevation from the previous reading. |
| **Total Settlement:** | Change in plate elevation from its original elevation at base of fill. |
| **Remarks:** | Note any damage, out-of-plumb, resetting, etc. |