# Grading & Base Tester
# Lab Performance Exam (Revised 10-16-2023)

**STUDENT NAME: _____ Tech. I.D. _____**

**CLASS NUMBER: GBTC-_____**

**_____Moisture-Density Test Method (Proctor) (G&B 5-692.222) p. 5**

**_____ Moisture Calculation (for Proctor) p. 5 Burner Method**

**_____Proctor – Data Entry and Graph (Form G&B-303) (G&B 5-692.222) pp. 5, 6**

**_____Calibration of Sand Cone & Plate (G&B 5-692.231) p. 9**

**_____Calibration of Standard Sand (G&B 5-692.232) p. 12**

**_____Field Density Test: Sand Cone Method (G&B 5-692.246) p. 16**

**_____Dynamic Cone Penetrometer (DCP) (G&B 5-692.255) p. 21**

**_____Soil Identification (G&B 5-692.601) p. 23**

**_____Speedy Moisture Meter (G&B 5-692.245) p. 26**

**Laboratory Instructor: _____**

**Location: _____**

**Date: _____**

***STUDENT: Please complete Name, Tech. I.D. and Class Number above. Lab Instructor fills out the remainder of this page.***

***THIS PAGE MUST BE FULLY COMPLETED, SIGNED AND DATED BY LAB INSTRUCTORS!***

**GRADING & BASE 1**
**Moisture-Density Test Method (Proctor)**

**See the entire Moisture-Density Test procedure in the MnDOT Grading & Base Manual, Section 5-692.222**

## Multi-Point Proctor (Standard Method)

STEP 1: Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately 4 percentage points below optimum moisture content.

*NOTE: To estimate the starting point for granular soils (less than 20% passing the #200 sieve), moisten and mix the soil until it can be squeezed into a ball or "cast". The cast should crumble easily when touched. Soils with more than 20% passing the #200 sieve usually have higher optimum moisture than granular soils and the cast is less easily crumbled at the starting point*

.

STEP 2: Determine the weight of the Proctor mold and base plate to the nearest 0.1 gram **(DO NOT INCLUDE THE COLLAR)** and record the weight on line **(B)** of the worksheet on page 5 of this packet: "Wt. Mold + Base Plate"

STEP 3: Place the assembled mold, including collar, on the concrete compaction base.

STEP 4: Place enough of the sample into the mold for one layer.

*NOTE: The mold is filled with three equal layers of compacted material. After compaction,* ***the final layer should be about 1/2" above the top of the mold when the collar is removed.***

STEP 5: Compact the loose material by 25 uniformly distributed blows from the rammer dropping freely from a height of 12" above the soil.

STEP 6: Repeat steps 4 & 5 until the three layers are placed and compacted.

STEP 7: Remove the collar and carefully trim the compacted soil with a knife until it is even with the top of the mold (check with a straight edge). Remove any stones dislodged by trimming and fill the holes by carefully pressing finer material into place. Trim around any stones that are at least half buried and solidly seated.

STEP 8: **Clean all the loose material from the mold and base plate** and weigh it on the electronic scale to the nearest 0.1 gram. Record the weight on line **(A)** of the worksheet on page 5 of this packet: “Wt. Wet Soil + Mold”.

STEP 9: Remove the mold from the base plate and loosen the locking devices so that the compacted material can be removed from the mold.

STEP 10: Quarter the compacted material by slicing twice vertically through the compacted soil. Select one of the quarters and weigh immediately. Determine the moisture content according to the procedures listed in MnDOT Grading & Base Manual, Section 5-692.245 Moisture Test (Burner Method).

*NOTE:* *A representative sample must consist of nearly equal portions of material from all three layers.*

*When the “Speedy” method is used, take the sample the same way as the burner method and use a representative portion for the moisture determination.*

STEP 11: Thoroughly break up the remaining portion of the compacted specimen and remix with the sample being tested.

STEP 12: Add enough water to increase the moisture content about two percentage points.

*NOTE:* *90 cc, ml or grams of water will increase the moisture content of 10 lb. of material about two percentage points. Additional water may be needed to replace moisture lost by evaporation during mixing.*

90 cc, ml or grams of water will increase the moisture content of 10 lbs. of material two percentage points.

**(90g $H_2O$ ÷ 4536 g) x 100 = 2%**

STEP 13: Repeat Steps 4 thru 12 until the “Wt. Wet Soil + Mold” determined in Step 8 either decreases or fails to increase. At this point the compacted material should be soft and spongy; granular material may not be very spongy but will be extremely wet. *The spongy condition indicates that the moisture content of the sample exceeds optimum.*

## EXAMPLE CALCULATIONS: (also see Form G&B-303 on pg. 5)

**1. Wet Density**

**A = Wt. Wet Soil + Mold + Base Plate must use grams for Excel Proctor Program ****
**B = Wt. Mold + Base Plate**
**C = Wt. Wet Soil (A-B)**
**D = Wet Density, lb. per cu. ft. (C x 0.06614) or (C x 30*)**

**Note: 30 = Proctor mold represents 1/30 cu. ft.***

**Example when recording weights in grams:**

**A = 7457.1 g ****
**B = 5629.1 g**
**C = 7457.1 – 5,629.1 = 1,828.0 g**
**D = 1,828.0 x 0.06614 = 120.9 lbs./ft$^3$**

*Same calculations in pounds:*

*A = 16.44 lb.*
*B = 12.41 lb.*
*C = 16.44 – 12.41 = 4.03 lb.*
*D = 4.03 x 30 =* **120.9 lbs./ft$^3$**

**2. Percent Moisture (Burner Method)**

**E = Wt. Wet Soil + Pan grams**
**F = Wt. Dry Soil + Pan grams**
**G = Wt. Moisture (E-F)**
**H = Wt. pan, grams**
**I = Wt. Dry Soil (F-H)**
**K = % Moisture, Dry Wt. = (G/I) x 100**

**Given: K = 14.0% and D = 120.9, calculate the dry density below:**

**4. Calculating Dry Density**

**To calculate dry density for letter "L" on the worksheet, use the following formula:**

**L = Dry Density, lb/ft$^3$ = [Wet Density / (100 + %Moisture)] x 100**
***OR L =*** *(Wet Density x 100) ÷ (%Moisture + 100)*

**L = [120.9 / (100 + 14.0)] x 100 = [120.9 / 114.0] x 100 = 106.1 lb/ft$^3$**

DEPARTMENT OF TRANSPORTATION

## Office of Materials and Road Research

**Calculation for Moisture - Density Relationships in Subgrade Soils and Aggregate Base and Shoulders, English & Metric, 4" (standard) and 6" (Modified) Mold**

Proctor Mold Density Units: 4-in English

| **Sample No:** | **Curve No:** | **Date:** |
|---|---|---|
| | | **S. P. No:** |

Optimum Moisture ($M_t$) _____ %

Maximum Density (Dt) _____ ($lb/ft^3$)

| | | | | | |
|---|---|---|---|---|---|
| A: Wt. Wet Soil + Mold (g) | | | | | |
| B: Wt. Mold (g) | | | | | |
| C: Wt. Wet Soil (g) **(A-B)** | | | | | |
| D: Wet Density ($lb/ft^3$) | | | | | |
| **Burner Method - (Pan #)** | | | | | |
| E: Wt. Wet Soil + Pan (g) | | | | | |
| F: Wt. Dry Soil + Pan (g) | | | | | |
| G: Wt Moisture (g) **(E-F)** | | | | | |
| H: Wt Pan (g) | | | | | |
| I: Wt. Dry Soil (g) **(F-H)** | | | | | |
| **Speedy Method -** | | | | | |
| **Sample Size** [Note that input for % Wet Moisture (for Row J directly below) is dependant upon the sample size and the Speedy Dial Reading, see procedure in G&B Manual section 5-692.245] | | | | | |
| J: % Moisture - Wet Wt. | | | | | |
| K: % Moisture - Dry Wt. | | | | | |
| L: Dry Density ($lb/ft^3$) | | | | | |

Calculations: C= A-B
D= (0.06614)C for 4" Mold
G=E-F; I=F-H
K=(G/I)x100 L=(Dx100)/(100+K)

Soil Class _____

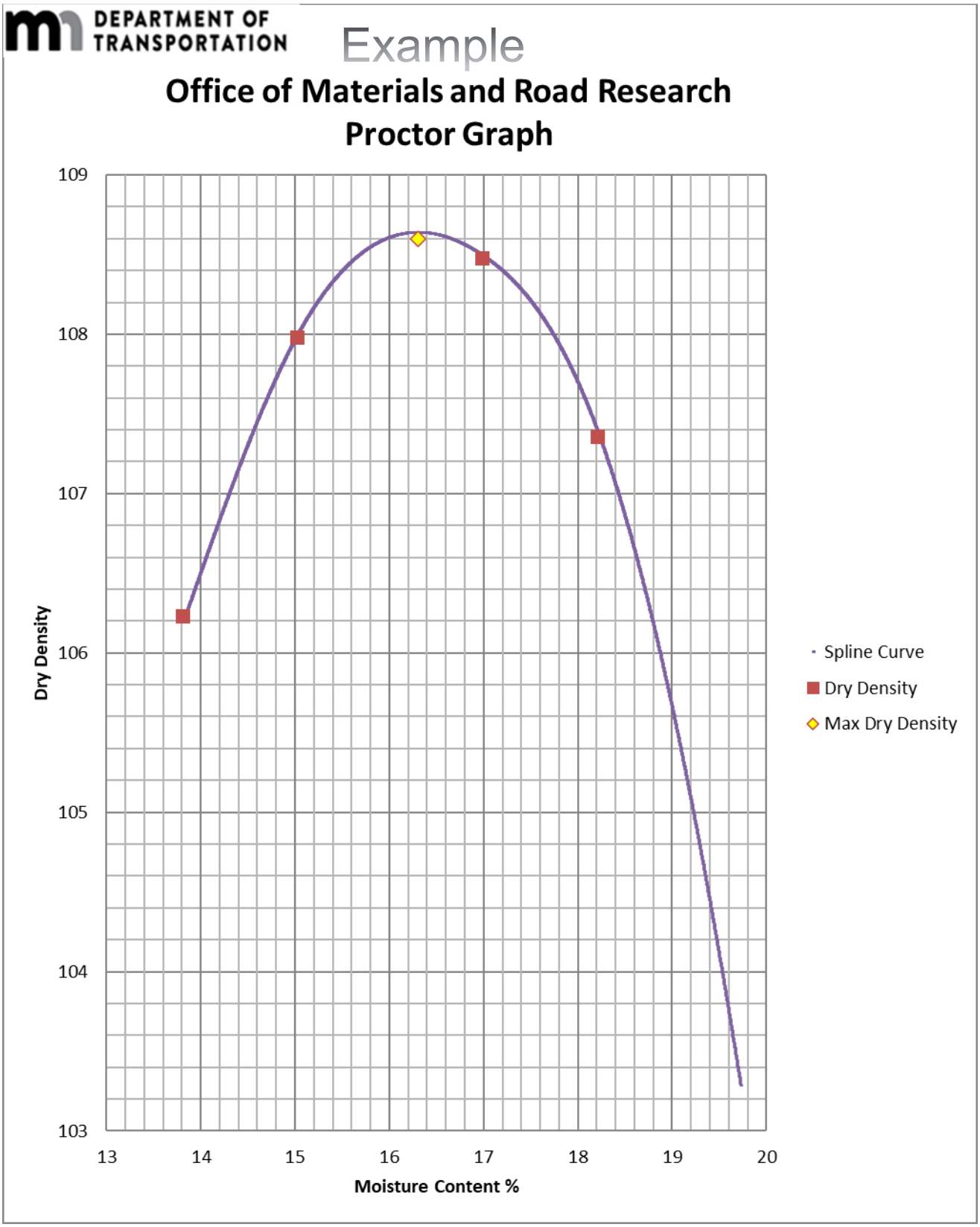
Tester _____

Moisture calculations: Calculate and record lines G, I and K (below)

Constant weight means no loss in weight greater than 0.5 gram in 15 min. of drying

DEPARTMENT OF TRANSPORTATION

Example



**GRADING & BASE 1**
**Calibration of Sand Cone and Plate**
**(Grading & Base Manual 5-692.231)**

STEP 1: Place the density plate on a piece of paper on a level, solid, vibration free table or bench.

STEP 2: Put about 2500 grams of Standard Sand, to be used in the field density test, into the jar and attach the sand cone device.

STEP 3: Weigh the jar, sand and sand cone and record to the nearest gram.

STEP 4: Close the valve in the sand cone and invert the jar and cone over the plate.

***NOTE:*** ***Make match marks on the sand cone and plate so that each time the sand cone is used it may be placed in exactly the same position on the plate.***

STEP 5: Carefully open the valve so that the sand flows freely into the plate and cone.

STEP 6: When the sand stops flowing, close the valve sharply and remove the jar and sand cone.

STEP 7: Reweigh the jar, sand cone and sand remaining in the jar to the nearest gram and subtract this weight from the weight recorded in STEP 3. The difference is the weight of sand required to fill the plate and cone.

STEP 8: Repeat Steps 1 through 7 at least three times and calculate the average weight of the sand in grams required to fill the plate and cone. Round off the average weight to the nearest gram and record. The weight of the sand in the cone and plate should not vary more than 5 grams from the other trials.

**Use the worksheet on page 9 of this packet to record your results.**

**EXAMPLE & CALCULATIONS:**

| Trials | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Wt. of jar, cone & sand before (g) | 3384 | 3393 | 3392 | | |
| Wt. of jar, cone & sand after (g) | 2753 | 2763 | 2763 | | |
| Wt. of sand in cone & plate (g) | 631 | 630 | 629 | | |

*NOTE:* *The weight of sand in the Cone & Plate should not vary by more than 5 grams.* ***Get at least 3 weights within 5 grams of each other.***

$$\text{Average Weight of Sand in Cone and Plate} = \frac{(631 + 630 + 629)}{3} = 630 \textit{ grams}$$

# CALIBRATION OF SAND CONE AND PLATE

## Grading & Base Manual 5-692.231

| Project No: | Tester Name or Certification No: | Date: |
|---|---|---|
| Test No: | | |

**Cone & Plate Calibration**

| Trial No: | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| (A) Wt. Of Jar, Cone & Sand Before (gm) (Record to nearest whole gm) | | | | | |
| (B) Wt. Of Jar, Cone & Sand After (gm) (Record to nearest whole gm) | | | | | |
| (C) Weight of Sand in Cone & Plate (gm) **(A-B)** | | | | | |

Note: The Weight of Sand in Cone & Plate should not vary by more than 5 grams. Get at least 3 weights within 5 grams of each other.

(D) AVERAGE WEIGHT OF SAND IN CONE AND PLATE = $\frac{(\_\_\_\_ + \_\_\_\_ + \_\_\_\_)}{3}$ = _____ **gm**

**Calibration of the Standard Sand**
**(Grading & Base Manual 5-692.232 Field Method No. 2)**

STEP 1: Fill the density jar with a known weight of standard sand, usually about 2,500 grams. (See worksheet on pg. 12)

STEP 2: On a clean, level surface place a Proctor mold (1/30 cubic foot) with its' collar removed.

STEP 3: Place the density plate on the top edge of the Proctor mold, being careful to line up the inside edge of the plate with the inside of the mold.

STEP 4: Place the density cone, with jar and sand, on the density plate. Use the same method as calibrating the cone and plate.

STEP 5: Carefully open the valve on the cone. When the sand stops flowing, close the valve.

STEP 6: Weigh the sand remaining in the jar and record to the nearest gram.

STEP 7: Repeat Steps 1 through 6 at least three times. The weight of the sand should not vary more than 5 grams.

**EXAMPLE:**

| **Trials** | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| **Final wt. of sand in jar (grams)** | **548** | **550** | **561** | **552** |

***Average weight of sand =*** $\frac{548 + 550 + 552}{3}$ **= 550 grams**

***NOTE:*** ***Trial 3 was not used because it varied more than 5 grams from at least one other.***

STEP 8: **Subtract** the average weight of sand remaining in the jar and the weight of the sand in cone and plate from the original weight of sand to determine the weight of sand in the mold.

***NOTE:*** ***In order to do this procedure, you have to calibrate the sand cone and plate first.***

STEP 9: Calculate and record the grams of sand in the mold by dividing the average weight (g) of sand in mold by 453.6 grams/lb.

STEP 10: Calculate and record the unit weight (lbs./ft$^3$) of sand by multiplying the weight (g) of sand in mold by 30.

**EXAMPLE:**

**Original weight of sand = A = 2500 g**
**Average final weight of sand = B = 550 g**
**Weight of sand in cone & plate = C = 450 g**

**A-B-C = D**

**Weight of sand in the mold (grams) = D = 1500 g**

**Weight of sand in the mold (convert grams to pounds) = E = 1500g ÷ 453.6 grams/lb = 3.307 lb**

**Unit weight of sand (lb/ft$^3$) = F = E x 30 = (3.307 lb. x 30) = <u>99.2 lb/ft$^3$</u>**

(09/06)

# CALIBRATION OF STANDARD SAND

## (Field Method No. 2)

## Grading & Base Manual 5-692.232

| Project No: | Tester Name or Certification No: | Date: |
|---|---|---|
| Test No: | | |

**Standard Sand Calibration**

| TRIAL No: | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| (A) Wt. Of Jar, Cone & Sand Before (gm) (Record to nearest whole gm) | | | | | |
| (B) Wt. Of Jar, Cone & Sand After (gm) (Record to nearest whole gm) | | | | | |
| (C) Wt. Of Sand in Cone, Plate and Mold (gm) **(A-B)** | | | | | |
| (D) Wt. Of Sand in Cone & Plate from Calibration (gm) (Record to nearest whole gm) | | | | | |
| (E) Wt. Of Sand in Mold **(C-D)** | | | | | |

Note: The Weight Of Sand in Mold should not vary by more than 5 grams.
Get at least 3 weights within 5 grams of each other.

**Standard Sand Density Determination**

(H) Average Weight of Sand in Mold **(** _____ **+** _____ **+** _____ **) =** _____ **=** _____ **lbs**
**3** **453.6 g/lb**

(I) UNIT WEIGHT OF SAND (English) = Average Weight in pounds of Sand in Mold x 30 = _____ **lbs/ft$^3$**

## Field Density Test: Sand Cone Method
## (Grading & Base Manual 5-692.246; 247 and 248)

STEP 1: Select the location of the test (Section "5-692.247, Sampling and Inspection") and remove any loose material. (Worksheet on pg. 16)

STEP 2: **Smooth and level the surface of the area** until the plate can be evenly seated. Secure with nails driven through the pre-drilled holes on the opposite sides of the plate into the soil.

STEP 3: **Dig the test hole the size of the inside diameter of the plate** being very careful to avoid disturbing the soil that will bound the hole. Granular soils require extreme care.

Cut the sides of the hole vertical and smooth out rough spots that may develop when small stones are loosened. If stones larger than 2" are loosened, remove them but do not include them with the finer material in the sample container.

**Dig the hole as deep as necessary to test the layer compacted. Place all loosened soil in a clean container being careful to avoid losing any material**.

**NOTE:** Density tests on grading construction usually represents layers 8" or 12" in thickness (loose measurement). The test hole for grading construction **should be at least 4-1/2" deep** and yield from 1,200 grams of dry material for fine grained soils to 1800 grams for gravelly soils.
The standard sand cone density testing device with an approximate cone diameter of 4 1/2" is recommended; a 6 1/2" diameter cone may also be used.

STEP 4: Weigh and record a quantity of sand plus container. Place the sand in the two-quart jar and attach the sand cone.

**NOTE:** The amount of sand needed depends on the size of the test hole. When the standard 4-1/2" diameter sand cone test device is used, 2,500 grams is usually enough for a 4-1/2" deep test hole.

STEP 5: Invert the jar and sand cone and place it on the plate. **Use the match marks on the plate and cone to make sure they are in the same position as when the device was calibrated.**

**NOTE:** Do not allow construction equipment to operate within 30' of the test site while testing is in progress.

STEP 6: Open the valve and allow the sand to fill the hole and the sand cone.

**NOTE:** If stones larger than 2" were removed from the hole in Step 3, open the valve and let a small amount of sand flow into the hole; close the valve, remove the sand cone and place the rocks on the sand bedding in the hole; replace the jar and sand cone, reopen the valve and complete STEP 6.

STEP 7: When the sand stops flowing, close the valve and remove the jar and sand cone.

STEP 8: Weigh and record the sand remaining plus container.

STEP 9: Weigh the wet material removed from the hole.

STEP 10: Determine the moisture content of a representative portion of the material from the hole by the burner method or Speedy moisture meter.

**CALCULATIONS:**

Calculate and record the weight of the sand used in the test by subtracting the weight of the container and sand remaining **after** performing the test from the weight of the container and sand **before** performing the test (STEP 4).

Calculate and record the weight of the sand required to fill the hole by subtracting the calibrated weight of the sand required to fill the plate and cone (see pg. 11) from the weight of the sand used in the test.

Determine the dry weight of the material by calculating the weight of the moisture and subtracting it from the wet weight of the material from the hole.

**Example:**

Wet wt. of material = 1528.3 g
Moisture content = 10.7%

Weight of moisture = wet wt. x (%moisture/100) = 1528.3 x 0.107 = 163.5 grams
Dry weight = Wet wt. – wt. of moisture = 1528.3 – 163.5 = 1364.8 g

**NOTE:** An alternate method of obtaining the dry weight is to dry all the material removed from the test hole (minus 2" size) and weigh it to the nearest gram. Record this weight as the dry weight of the material from the hole.

Calculate the dry density of the in-place material using the formula:

Dry Density = (dry wt. of material from hole ÷ wt. of sand to fill hole) X unit weight of sand

**EXAMPLE CALCULATIONS: (SEE EXAMPLE ON WORKSHEET, PAGE 16)**

1. Wt. of sand before test – Wt. of sand after test = (2500.0 g – 625.4) = **1874.6 g**
2. Wt. of sand after test – Cone & plate calibration = (**1874.6 g** – 631.0) = **1243.6 g**
3. Wt. of sand it took to fill the hole = **1243.6 g**
4. Unit weight of sand from calibration ***(See 5-692.232 Field Method 2, page 12)***

   Unit wt. of sand = 99.2 lb/ft$^3$

**Wet weight of material from hole = 1528.3 g**

**Moisture content = 10.7%** (burner method used)

**CALCULATE DRY DENSITY:**

**Wt. of Moisture = Wet Wt. X $\frac{\text{\% Moisture}}{100}$ = (1528.3 g x 0.107) = 163.5 g**

**Dry Wt. = Wet Wt. – Wt. of Moisture = (1528.3 g – 163.5 g) = 1364.8 g**

$$\text{Dry Density} = \frac{\text{Dry Wt. of Material (g)}}{\text{Wt. of Sand in Hole (g)}} \times \text{Unit Wt. of Sand in Hole (lb/ft}^3\text{)}$$

$$\frac{1364.8\text{ g}}{1243.6\text{ g}} \times 99.2\text{ lb/ft}^3 = \textbf{108.9 lb/ft}^{\mathbf{3}}\textbf{ Dry Density}$$

**Minnesota Department of Transportation**

**Office of Materials and Road Research**

# RELATIVE DENSITY TEST
# GRADING & BASE CONSTRUCTION

**Grading & Base Manual 5-692.248**

| SP 6913-11 | T.H.: 194 | Page No: 1 |
|---|---|---|

**EXAMPLE** **Use this column for calculations**

| | | | | | |
|---|---|---|---|---|---|
| Date | 6/9/22 | | | | |
| Tester Initials or Certification No. | C.B. | | | | |
| Test No. | 1 | | | | |
| Material Type | CL** | | | | |
| Station | 524+00 | | | | |
| Roadway Lane and Offset from Center Line | SBL CL | | | | |
| Depth from Grading Grade | -6' | | | | |

**Volume Determination (Sand Cone)**

| | | | | | |
|---|---|---|---|---|---|
| A. Wt. Sand & Container Before | 2500.0 | | | | |
| B. Wt. Sand & Container After | 625.4 | | | | |
| C. Wt. Sand in Funnel & Hole **A-B** | **1874.6** | | | | |
| D. Wt. Sand in Funnel (from Calib) | **631.0** | | | | |
| E. Wt. Sand in in Hole **C-D** | **1243.6** | | | | |

**Inplace Dry Density Determination (Field Density Test)**

| | | | | | |
|---|---|---|---|---|---|
| Percent Moisture Determination | | | | | |
| - Burner Method - 5-692.231 | | | | | |
| F. Pan ID | D | | | | |
| G. Wt. Wet Material + Pan | 1735.5 | | | | |
| H. Wt. Dry Material + Pan | 1572.0 | | | | |
| I. Wt Moisture **G-H** | **163.5** | | | | |
| J. Wt Pan | 207.2 | | | | |
| K. Wt. Wet Soil **G-J** | **1528.3** | | | | |
| - Speedy Method - 5-692.232 | | | | | |
| L. Dial Reading | XXXX | | | | |
| M. Sample Size Factor | XXXX | | | | |
| Moisture Content | | | | | |
| N. % Moisture - Wet Wt. **(I/K) x 100** | **10.7** | | | | |
| Dry Density Determination | **Container Weight =** | | | **Container + Material =** | |
| O. Total Wt. Wet Material From Hole | 1528.3 | | | | |
| P. Wt. Moist. in Mat.from Hole **O x (N/100)** | **163.5** | | | | |
| Q. Dry Wt.of Material from Hole **O-P** | **1364.8** | | | | |
| R. Unit Wt. of Sand (lb/ft$^3$) | **99.2** | | | | |
| S. Dry Density (lb/ft$^3$) **(Q/E) x R** | **108.9** | | | | |
| Relative Density Determination | | | | | |
| T. Maximum Density (lb/ft$^3$) | 110.8 | | | | |
| U. Spec. Requirements | **95** | | | | |
| V. Relative Density % **(S/T) x 100** | **98** | | | | |
| W. Curve No. | 5 | | | | |

****CLAY LOAM**

## 5-692.255 DYNAMIC CONE PENETROMETER TEST (DCP)

**USE EXTREME CAUTION WHEN USING THE DCP TO AVOID INJURY TO HANDS OR FINGERS**

**Test Procedure (for Aggregate Base, Spec. 2211)** ***USE WORKSHEET ON PG. 21***

STEP 1a: Record the gradation (% passing values) that represent the area to be tested on the attached Penetration Index form G&B-204 (pg. 21) or Excel spreadsheet. Using the attached form, calculate the Grading Number (GN) by using the formula on the form. If using the spreadsheet, the computer calculates this information.

STEP 1: Locate a level and undisturbed area (test site) that is representative of the material to be tested.

STEP 2: Record the Test #, Date, Station, Offset, and Test Layer Depth in the "DCP Data" area on the bottom of the Penetration Index form, or spreadsheet,

STEP 3: Place the DCP device on the aggregate base test site. **Record the initial reading** using the graduated rule on the DCP. The measurement is taken to the nearest mm. (Place this information on the attached Penetration Index form or spreadsheet, in the DCP Data table, under **Initial Reading** column.)

STEP 4: **To properly seat the DCP (cone tip), two hammer blows are required.** Therefore, carefully raise the sliding weighted hammer until it meets the handle, and then release the hammer under its own weight. Repeat this process one more time for a **total of two complete blows.**

STEP 5: **Record the penetration measurement after seating** using the graduated rule on the DCP. The measurement is taken to the nearest mm. (Place this information on the attached Penetration Index form or spreadsheet, in the DCP Data table, under **Reading after seating (2 blows).**

**NOTE:** **No seating** requirement is used for **granular materials** (See Specification 2106); **however, seat the DCP using two blows before the DPI is calculated. See example worksheet on pg.**

STEP 6: **Carefully raise the hammer until it meets the handle, and then release the hammer under its own weight. Repeat this process two more times for a total of three times.**

STEP 7: Record the final penetration measurement using the graduated rule on the DCP. The measurement is taken to the nearest mm. (Place this information on the attached Penetration Index form or spreadsheet, in the DCP Data table, under **Reading after test (3 blows)** column.

STEP 8: Subtract the measurement in step 3 from the measurement in step 5 and then divide the difference of the measurements by the number of blows (3) required for testing. If necessary, follow the formula on the test form to convert from inches to mm. Round off all test results to the nearest mm or one tenth of an inch, see section, “5-692.705 “Procedures for “Rounding Off”.

STEP 9: After using the DCP, obtain a sample of material and determine the moisture content of the aggregate base by using the pan drying method or a Super Speedy. **Record the moisture content on the Penetration Index form or spread sheet, in the DCP Data table, under MC (%) column.**

**NOTE:** No moisture test required if the toughest penetration requirement is met.

STEP 10: If using the Penetration Index form, fill in the **Maximum Allowable SEAT** & **Maximum Allowable DPI** columns; this information is in the Penetration Requirements table by using the recorded **GN** & **MC**. Next calculate the **SEAT** by using the following formula:

**SEAT** = **Reading after seating (2 blows) - Initial Reading**

Compare the calculated **SEAT** and compare it to the **Maximum Allowable SEAT column**, if **SEAT** is larger than the **Maximum Allowable SEAT**, the **SEAT** fails. If the **SEAT** is smaller than the **Maximum Allowable SEAT**, the **SEAT** passes.

Next calculate the **DPI** by using the following formula:

$$\textbf{DPI} = \frac{\{\textbf{Reading after test (3 blows) - Reading after seating (2 blows)}\}}{\textbf{3}}$$

Compare the calculated **DPI** and compare it to the **Maximum Allowable DPI** column. If the **DPI** is larger than the **Maximum Allowable DPI**, the **DPI** fails. If the **DPI** is smaller than the **Maximum Allowable DPI**, the **DPI** passes.

Next determine the **Adequate Layer** by using the following formula:

To determine whether the **Test Passes or Fails**, check the
**Seat Pass or Fail**,
**DPI Pass or Fail**,

► If either of the two columns has **Fail** or **No**, the **Test** Fails.

► If **both columns** have **Pass** or **Yes**, the **Test** Passes.

If using the Penetration Index spreadsheet, all the above information is calculated by the computer. To determine whether the test passes or fails look in the "**Test: Pass or Fail"** column for the answer.

STEP 11: For test purposes, the approximate test layer in compacted thickness, is located in the Penetration Index chart.

NOTE: MnDOT uses three different Excel spreadsheets for recording and calculating DCP test results.

Page 20 – Use this form when testing Granular Embankment (Specification 2106)
Page 21 – Use this form when testing Aggregate Base (Specification 2211)
Page 22 – Use this form when testing FDR or if Bit. Content ≥ 2.5%

All forms are available on the MnDOT Grading & Base Website:
http://www.dot.state.mn.us/materials/gbforms.html

# (Table 2105-6, 2106-6) DCP Penetration Index Method GRANULAR G&B-203 (04/30/2019)

SP 4013-41 Highway TH 169 Engineer L.VanPelt Inspector C.Brown
Material Granular B./Embankment Date 06/21/18 Notes

## Procedure

• Enter Project info and Gradation Data. Calculate the Grading Number **(GN)** (electronic version calculated automatically)

**Granular materials - NO SEATING (DPI) required (Two blows still reqired to seat the cone) - Aggregate Base Use Form G&B-204**

DPI = Initial Reading - Reading after 3 Blows / 3

Electronic Version
- Determine the test location and conduct the DCP test.
- Measure the moisture content (***MC***) at the DCP test location.
- Enter the Test Information and DCP Data in table.
- The test results will be determined automatically.

Hard Copy
- Determine the test location and conduct the DCP test.
- Measure the moisture content (***MC***) at the DCP test location.
- Enter the Test Information and DCP Data in table.
- Establish the allowable values for ***DPI*** based on ***GN*** and ***MC***.
- Compute ***DPI*** test results.
- Compare ***DPI*** to Maximum Requirements.
- * **No requirement for seating for 2014/2016/2018 spec. book**

**No moisture test is required when DPI requirements are met for a given GN. E.G., if GN is 4.8 & DPI is 14, no moisture test is required.**

## Gradation Data (use **% passing** in formulas)

$$GN = \frac{1" + \frac{3}{4}" + \frac{3}{8}" + \#4 + \#10 + \#40 + \#200}{100}$$

| Sieve | % Passing |
|---|---|
| 1 Inch | 100 |
| 3/4 Inch | 95 |
| 3/8 Inch | 87 |
| # 4 | 66 |
| # 10 | 52 |
| # 40 | 40 |
| # 200 | 15.3 |
| **GN =** | **4.6** |

## Penetration Requirements

| Grading Number | MC (% Dry) | Maximum Allowable DPI (mm/blow) | Grading Number | MC (% Dry) | Maximum Allowable DPI (mm/blow) |
|---|---|---|---|---|---|
| < 3.1 | 0 – >8.0 | 10 | | < 5.0 | 15 |
| | < 5.0 | 10 | 4.6 – 5.0 | 5.0 – 8.0 | 19 |
| 3.1 – 3.5 | 5.0 – 8.0 | 12 | | > 8.0 | 23 |
| | > 8.0 | 16 | | < 5.0 | 17 |
| | < 5.0 | 10 | 5.1 – 5.5 | 5.0 – 8.0 | 21 |
| 3.6 – 4.0 | 5.0 – 8.0 | 15 | | > 8.0 | 25 |
| | > 8.0 | 19 | | < 5.0 | 19 |
| | < 5.0 | 13 | 5.6 – 6.0 | 5.0 – 8.0 | 24 |
| 4.1 – 4.5 | 5.0 – 8.0 | 17 | | > 8.0 | 28 |
| | > 8.0 | 21 | | | |

## DCP Data - GRANULAR ONLY

| Test Information | | | | | | | Requirements | DCP Data (**mm**) | | Test Results | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Test # | Date | Station | Offset (ft) | R or L of CL | GN | MC (%) | Maximum Allowable DPI (mm/blow) | Initial Reading (after seating cone) | Reading after 3 Blows | DPI (mm/blow) | Test: Pass or Fail |
| 1 | 6/21/18 | 25+33 | 4 | R | 4.6 | 8.6 | 23 | 11 | 61 | 17 | Pass |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

* **Seating required for 2005 spec. book only use form G&B 204.**

EXAMPLE Worksheet for Embankment

# (Table 2211-3) DCP Penetration Index Method

G&B-204 (04/30/2019)

SP | Highway | Engineer | Inspector

Material | Date | Notes

## Procedure

- Enter Project info and Gradation Data. Calculate the Grading Number **(GN)** (electronic version calculated automatically)
- When bitumen content is ≥ 2.5%, compact to achieve a penetration index value of 10mm ans a seat value of 40mm.

$$Seating = Reading\ after\ 2\ blows - Initial\ Reading$$

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

Electronic Version

- Determine the test location and conduct the DCP test.
- Measure the moisture content (***MC***) at the DCP test location.
- Enter the Test Information and DCP Data in table.
- The test results will be determined automatically.

Hard Copy

- Determine the test location and conduct the DCP test.
- Measure the moisture content (***MC***) at the DCP test location.
- Enter the Test Information and DCP Data in table.
- Establish the allowable values for ***SEAT*** and ***DPI*** based on ***GN*** and ***MC***.
- Compute ***SEAT*** and ***DPI*** test results.
- Compare ***SEAT*** and ***DPI*** to Maximum Requirements. *Both must pass to accept test*.

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

## Gradation Data (use **% passing** in formulas)

$$GN = \frac{1" + \frac{3}{4}" + \frac{3}{8}" + \#4 + \#10 + \#40 + \#200}{100}$$

| Sieve | % Passing |
|---|---|
| 1 Inch | |
| 3/4 Inch | |
| 3/8 Inch | |
| # 4 | |
| # 10 | |
| # 40 | |
| # 200 | |
| **GN =** | |

## Penetration Requirements

| Grading Number | MC (% dry) | Maximum Allowable Seat (mm) | Maximum Allowable DPI (mm/blow) | Approx. Test Layer (inch) |
|---|---|---|---|---|
| < 3.1 | 0 - > 8.0 | 40 | 10 | 4 - 6 |
| 3.1 - 3.5 | < 5.0 | 40 | 10 | 4 - 6 |
| | 5.0 - 8.0 | 40 | 12 | |
| | > 8.0 | 40 | 16 | |
| 3.6 - 4.0 | < 5.0 | 40 | 10 | 4 - 6 |
| | 5.0 - 8.0 | 45 | 15 | |
| | > 8.0 | 55 | 19 | |
| 4.1 - 4.5 | < 5.0 | 50 | 13 | 5 - 6 |
| | 5.0 - 8.0 | 60 | 17 | |
| | > 8.0 | 70 | 21 | |
| 4.6 - 5.0 | < 5.0 | 65 | 15 | 6 - 12 |
| | 5.0 - 8.0 | 75 | 19 | |
| | > 8.0 | 85 | 23 | |
| 5.1 - 5.5 | < 5.0 | 85 | 17 | 7 - 12 |
| | 5.0 - 8.0 | 95 | 21 | |
| | > 8.0 | 105 | 25 | |
| 5.6 - 6.0 | < 5.0 | 100 | 19 | 8 - 12 |
| | 5.0 - 8.0 | 115 | 24 | |
| | > 8.0 | 125 | 28 | |

## DCP Data

| Test Information | | | | | | | Requirements | | DCP Data (**mm**) | | | Test Results | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test # | Date | Station | Offset | Test Layer Depth (mm) | GN | MC (%) | Maximum Allowable SEAT (mm) | Maximum Allowable DPI (mm/blow) | Initial Reading | Reading after seating (2 Blows) | Reading after 5 blows | SEAT (mm) | SEAT: Pass or Fail | DPI (mm/blow) | DPI: Pass or Fail | (1) Adequate Layer? | **TEST**: Pass or Fail |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |

(1) [Reading after test (3 blows) - Initial Reading]< Test Layer Depth = Adequate Layer

G&B-205 (06/07/17)

# For Full Depth Reclamation or Bit Content ≥ 2.5%
## SHEAR STRENGTH METHOD
## DYNAMIC CONE PENETROMETER
**Grading & Base Manual 5-692.XXX**

| | | | |
|---|---|---|---|
| Project No. | | Page No. | |

| | |
|---|---|
| Date | |
| Test No. | |
| Tester Initials or Certification No. | |
| **LOCATION** | |
| Station (or X-Coordinate) | |
| Roadway Lane and Offset (or Y-Coordinate) | |
| (A) Lift Thickness mm | |

| | |
|---|---|
| Gradation Test No. | |

| Thickness | No. of Blows |
|---|---|
| 0 to 5" | 5 |
| > 5 to 6" | 8 |
| > 6 to 7" | 11 |
| > 7 to 8" | 14 |
| > 8 to 9" | 17 |
| > 9" | 20 |

### DYNAMIC CONE PENETROMETER

*Test the entire lift. See chart above for number of required blows per thickness of FDR or Base.*

| | Blow Count | Reading (mm) | Seating (mm) | Formula | Pass / Fail | Passing Criteria |
|---|---|---|---|---|---|---|
| (B) | 0 | | | | | |
| (C) | 2 | | | (C - B) | | Seating ≤ 40 mm |
| | | | DPI (mm/blow) | Formula | | |
| (D) | 5 | | | (D - C) / 3 | | DPI ≤ 10 mm/blow |
| (E) | 8 | | | (E - D) / 3 | | |
| (F) | 11 | | | (F - E) / 3 | | |
| (G) | 14 | | | (G - F) / 3 | | |
| (H) | 17 | | | (H - G) / 3 | | |
| (I) | 20 | | | (I - H) / 3 | | |
| (J) | 23 | | | (J - I) / 3 | | |
| (K) | 26 | | | (K - J) / 3 | | |
| (L) | 29 | | | (L - K) / 3 | | |
| (M) | 32 | | | (M - L) / 3 | | |
| (N) | 35 | | | (N - M,) / 3 | | |
| (O) | 38 | | | (O - N) / 3 | | |
| (P) | 41 | | | (P - O) / 3 | | |
| (Q) | 44 | | | (Q - P) / 3 | | |
| (R) | 47 | | | (R - Q) / 3 | | |
| (S) | 50 | | | (S - R) / 3 | | |
| (T) | 53 | | | (T - S) / 3 | | |
| (U) | 56 | | | (U - T) / 3 | | |
| (V) | 59 | | | (V - U) / 3 | | |
| (W) | 62 | | | (W - V) / 3 | | |
| (X) | 65 | | | (X - W) / 3 | | |
| (Y) | 68 | | | (Y - X) / 3 | | |
| (Z) | 71 | | | (Z - Y) / 3 | | |
| (AA) | 74 | | | (AA - Z) / 3 | | |
| (AB) | 77 | | | (AB-AA) / 3 | | |
| (AC) | 80 | | | (AC-AB) / 3 | | |

| | | | | |
|---|---|---|---|---|
| (AD) | Estimated DCP Reading at Bottom of Lift | (A+B) | mm | |
| (AE) | Last DCP Reading | | mm | |
| (AF) | Thickness of Layer Tested | (AE - B) | mm | |

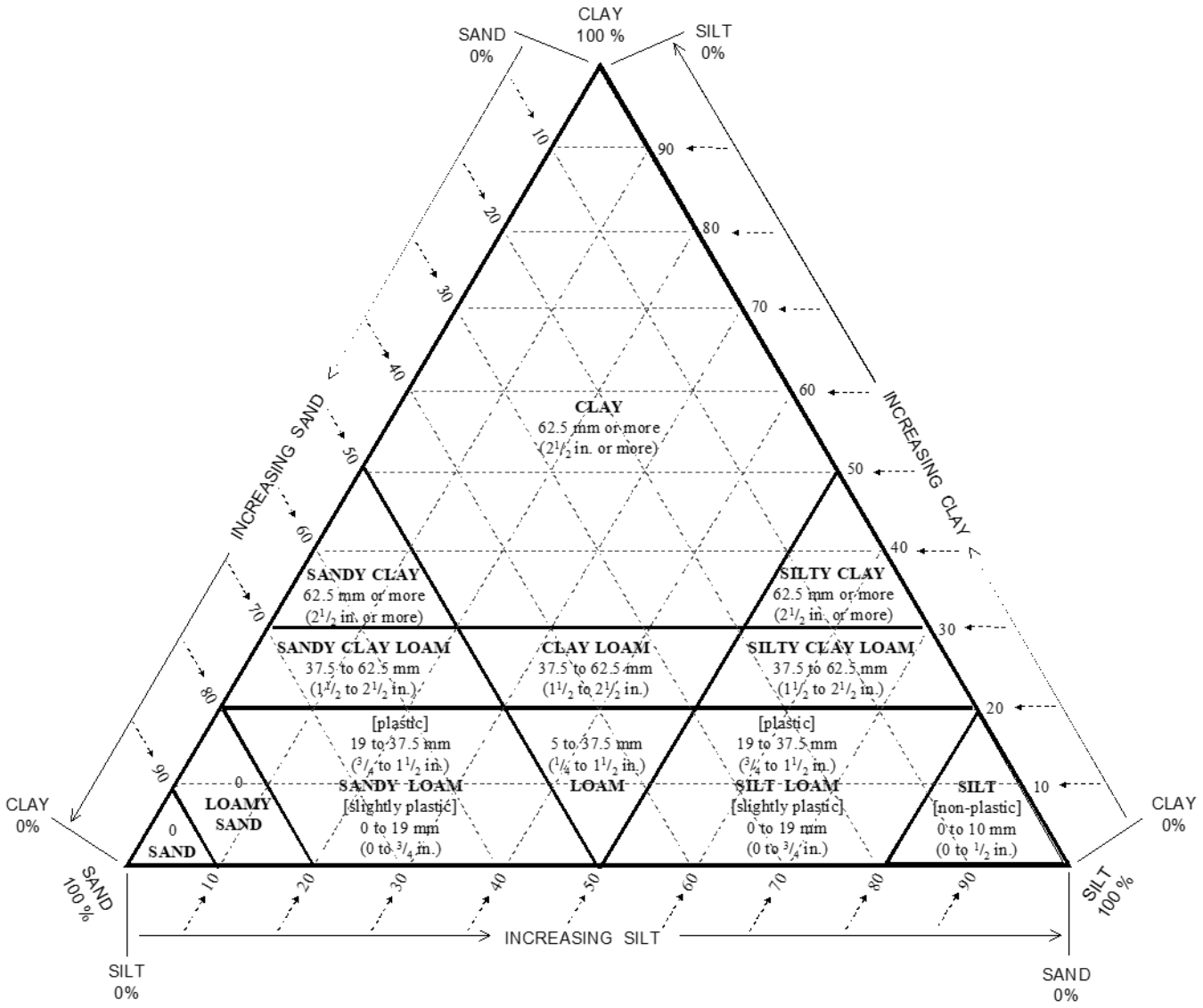
**Comments:**

**SOIL IDENTIFICATION**
**(Grading & Base Manual 5-692.601)**

| SAMPLE NO. | SAND | SILT | CLAY | | SOIL CLASS |
|---|---|---|---|---|---|
| #1 | | | | | |
| #2 | | | | | |
| #3 | | | | | |
| #4 | | | | | |
| #5 | | | | | |
| #6 | | | | | |
| #7 | | | | | |
| #8 | | | | | |

## THE TRIAXIAL CHART

MAIN SOIL CLASSES SHOWING LENGTH TO WHICH SOIL CAN BE RIBBONED AND THEIR PERCENTAGE COMPOSITION OF SAND, SILT, AND CLAY




GRAIN SIZE

**SAND** ---------- Particle Diameter from 2.0 mm (# 10 Sieve) to 0.075 mm (# 200 Sieve)

**SILT** ---------- Particle Diameter from 0.075 mm (# 200 Sieve) to 0.002 mm

**CLAY** ---------- Particle Diameter below 0.002 mm

**Feel and Appearance of Soil Mass**

**CLAY** – marked resistance to ribbon – roll to thin thread – shiny when smeared

SANDY CLAY – gritty – 50 to 70% sand – rarely encountered

SILTY CLAY – less resistance to ribbon than clay loam – slippery and soft

SANDY CLAY LOAM – gritty feel – sand particles easily seen and felt – uncommon

CLAY LOAM – fine texture – uniform in structure – moderate resistance to ribbon

SILTY CLAY LOAM – less resistance to ribbon than clay loam – slippery – smeary – dull when smeared

SANDY LOAM – slightly plastic to plastic – sand grains seen and felt

LOAM – mellow – somewhat gritty but smoother than sandy loam

SILT LOAM – smooth, slippery, or velvety – cloddy when dry – easily pulverized

**SILT** – smooth, powdery, velvety

LOAMY SAND – will form a cast when wet – will stand light jarring

**SAND** – will form a cast when wet – crumbles easily

**GRADING & BASE 1**
**Moisture Test (Speedy Method)**
**(Grading & Base Manual 5-692.245)**

The moisture test is a method of determining the moisture content of soils and aggregates by either **drying the sample**, **using a calcium carbide gas pressure (CCGP) moisture meter**, or **using a nuclear gauge**.

The calcium carbide gas pressure (CCGP) method may be used to determine the moisture content of ***untreated*** grading soils, subbase, and base aggregate. Either a 20 or 26 gram soil sample size "Speedy" or 200 gram soil sample size "Super Speedy" moisture meter is used. **Do not use a "Speedy" with recycled materials!**

In general, use a 20 or 26 gram "Speedy" meter for non-granular soils, with little no appreciable amount retained on the No. 4 sieve.

The CCGP method is as reliable and accurate as the burner method in these cases.

**Equipment:**

**20 or 26 gram "Speedy" Moisture Meter**
The "Speedy" moisture meter is furnished as a kit containing the CCGP meter, tared scale, two 1-1/4" steel balls, cleaning brush and cloth, and scoop for measuring calcium carbide reagent.

**Calcium carbide reagent**
Available in one pound cans. Use fresh calcium carbide. Date the can on its first use and discard after three months, or if it becomes contaminated before three months. Seal the can properly after each use.

**CAUTION:** Calcium carbide and water produces a dangerous, flammable gas. Keep the reagent can closed tightly, avoid breathing the fumes and use only in a well-ventilated area. Point the opening of the tester away while removing the cap. Tape the metal handle of the cleaning brush; otherwise, when the metal handle comes in contact with the chamber a spark could ignite gas trapped in the chamber. Keep the kit clean; do not allow the moisture meter to be mishandled.

**NOTE:** Calcium carbide may be transported under an exemption to the strict DOT shipping requirements for hazardous materials, **if all the following procedures are strictly followed**:

A. You are carrying no more than one pound (½ kilogram) in the original manufacturer's container.

B. The container is stored in a secured durable box.

C. The durable box is clearly labeled on all sides with:
   1. Calcium Carbide, 4, 3
   2. UN 1402, P G II
   3. Limited Quantity

D. The shipping manifest is within reach of the driver at all times.

E. The shipping manifest must include the following information:
   1. Calcium Carbide, 4, 3
   2. UN1402, Packing Group PG II
   3. Limited Quantity
   4. The weight or volume of material being carried
   5. The Emergency Response telephone number

**NOTE:** Citations and penalties for failure to comply with DOT shipping requirements for hazardous materials are the sole responsibility of the motor vehicle driver.

**PROCEDURE:**

1. Set the "Speedy" carrying case on level ground or a solid, level bench. The tared scale must be level to be reliable.

2. Select a representative soil sample and weigh out an exact amount on the tared scale.

NOTE: The tared scale weighs either a 26 (20 for 20 gram speedy) or 13 (10 for 20 gram speedy) gram sample. The pressure gage indicates up to 20 percent moisture in a 26 (20 for 20 gram speedy) gram sample or 40 percent moisture in a 13 (10 for 20 gram speedy) gram sample.

For base or subbase moisture testing, use material screened through a #4 sieve and use a 26 (20 for 20 gram speedy) gram sample. Additionally run at least one verification test to determine that the "speedy" is within 1.0% of a burn test.

3. Calculate and record the Sample Size Factor using the following formula:
Sample Size Factor = 26 (20 for 20 gram speedy)/weight of sample used.

4. Place the weighed soil sample in the cap of the meter. Be certain the cap is clean.

5. Place three full scoops of reagent and the two steel balls in the body of the meter.

6. Hold the body of the meter in an approximately horizontal position, insert the cap into the body, and seal the unit by positioning and tightening the clamp**. The calcium carbide should not come in contact with the soil until a complete seal is made.**

7. Tilt the meter so that the sample falls into the body and begins mixing with the reagent.

8. Return the Speedy to the horizontal position. Shake the tester to pulverize any soil lumps and to cause mixing so that the reaction between the calcium carbide and all free moisture is complete.

The meter should be shaken with a rotating motion so that the steel balls will not damage the gauge and soil particles will not become imbedded in the orifice leading to the pressure diaphragm.

Do not allow the balls to hit the gauge end of the meter. Attempt to roll the balls rather than rattle them. Up to four minutes of shaking may be required on heavy clay type soils. Allow time for the dissipation of heat generated by the chemical reaction.

9. Hold the meter horizontal at eye level with the dial facing you. When the needle comes to rest, read the dial to the nearest 0.1 percent and record the dial reading.

10. Calculate and record the percent moisture of the wet weight by multiplying the dial reading by the sample size factor.

11. Determine and record the percent moisture by dry weight by using the table (in your class Manual) or the following formula:

% moisture, dry wt. = (100 x % moisture, wet weight)/(100 - % moisture, wet weight)

EXAMPLE:

% moisture, wet wt. = **12.8%**
% moisture, dry wt. = (100 x **12.8**)/(100 – **12.8**) = 1280/87.2 = **14.7%**

See **G&B-105** (on pg. 29 of this packet)

12. Point the opening away from you, slowly release the pressure and remove the cap.

13. Dump the material from the meter and examine. The soil must be completely pulverized. Lumps indicate an inaccurate test that must be re-run, increasing the shaking time.

14. Brush out the body of the meter. Wipe out the cap and clean off the two steel balls with the special cleaning rag.

**NOTE**: Keep the Speedy kit clean at all times. Never leave the kit out in the rain or allow anyone to mishandle any part of it.

G&B-105

TP-21850

# MOISTURE TEST
# GRADING & BASE CONSTRUCTION

**Grading & Base Manual 5-692.230**

| Project No: | Date: | Page No: |
|---|---|---|
| | | |

**Test Identification Data**

| | | | | | |
|---|---|---|---|---|---|
| Date | | | | | |
| Tester Initials or Certification No. | | | | | |
| Test No. | | | | | |
| Material Type | | | | | |
| Station (X-Coordinate) | | | | | |
| Roadway Lane & Offset (Y-Coordinate) | | | | | |
| Depth Below Grading Grade (Z-Coordinate) | | | | | |

**Moisture Determination**

| | | | | | |
|---|---|---|---|---|---|
| - Burner Method - 5-692.231 | | | | | |
| (A) Pan Id. | | | | | |
| (B) Wt. Wet Material + Pan | | | | | |
| (C) Wt. Dry Material + Pan | | | | | |
| (D) Wt Moisture **B-C** | | | | | |
| (E) Wt Pan | | | | | |
| (F) Wt. Dry Material **C-E** | | | | | |
| - Speedy Method - 5-692.232 | | | | | |
| (G) Dial Reading | 12.8 | | | | |
| (H) Sample Size Factor | 1 | | | | |
| (I) % Moisture Wet Wt. **GxH** | 12.8 | | | | |

**Moisture Content 5-692.237**

| | | | | | | |
|---|---|---|---|---|---|---|
| (K) % Moisture Dry Wt. | **D/F x 100** (Burner)<br>**I /[1-(I/100)]** (Speedy) | 14.7 | | | | |

**Relative Moisture Determination 5-692.238**

| | | | | | |
|---|---|---|---|---|---|
| (L) Minimum Moisture Specification | | | | | |
| (M) Maximum Moisture Specification | | | | | |
| (N) Standard Optimum Moisture | | | | | |
| (O) Relative Moisture % **K/N x 100** | | | | | |
| (P) Curve No. | | | | | |

(N) and (P) From Form G&B-901 (TP-02430-03)

Notes: