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Soils

Testing Technician

Course Overview

Refresher Info
- **Conversions**
- **Terminology**

ARDOT Specifications

Soil Classification

Sampling / Preparation

Moisture Content

Atterberg Limits
- **LL, PL, PI**

Proctors
- **Standard & Modified**

% Compaction
- **Nuclear Density Gauge**

Introduction 4

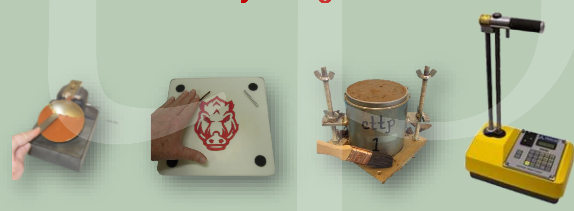
Test Day

Written Exam

- ≈ 60 Questions
- Closed Book Exam
  - ~ 2 Hour Time Limit
  - ~ 70 % Overall Required to Pass

Performance Exam

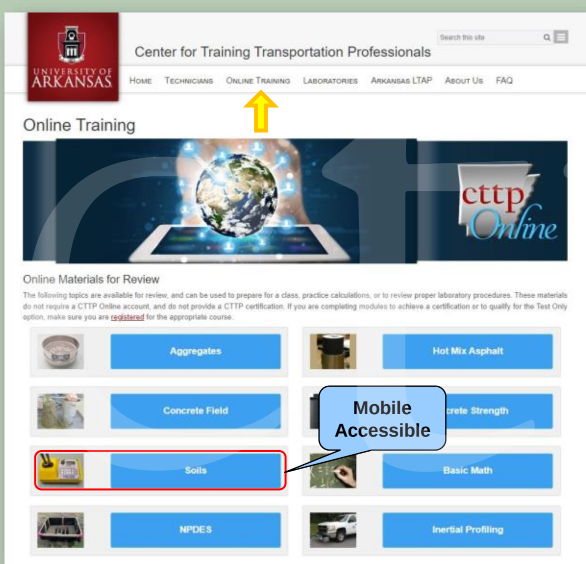
- 3 Exam Stations
  - ~ Liquid & Plastic Limit
  - ~ Proctor
  - ~ Density Gauge



Results

- www.cttp.org
- Letter & Certification
- 5 Year Certification

Introduction 5



Help?

If you need help with mathematical calculations, just ask. Your instructor will be happy to assist you.

If you need further practice or assistance, please see our website www.cttp.org for online training.

Introduction 6

Unit Conversions

Weight / Mass

- 1 ton 2000 lb
- 1 lb 453.6 g
- 1 kg 1000 g

Convert 15.235 lb to grams

$$15.235 \text{ lb} \times \frac{453.6 \text{ g}}{1 \text{ lb}} = 6910.6 \text{ g}$$

Convert 6910.6 g to lb

$$6910.6 \text{ g} \times \frac{1 \text{ lb}}{453.6 \text{ g}} = 15.235 \text{ lb}$$

Terminology

Soil

- Naturally occurring unconsolidated rock particles, organic matter, water, and air

Behavior influenced by:

- Individual components
- Grain size
- Particle shape
- Particle strength

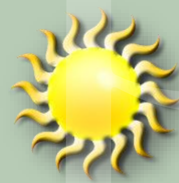
Terminology

Oven Dried

- Dried to a constant mass at a temperature of 230 ± 9 °F (110 ± 5 °C)
  - ~ No moisture is present in the soil sample
  - ~ Moisture Content = 0

Air Dried

- Dried at ≤ 140°F (60°C)
  - ~ Chemically bound moisture is still present in the soil
  - ~ Moisture Content ≠ 0



New Specification

AASHTO M 339 – 22

Thermometers Used in the Testing of Construction Materials

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This specification will impact testing procedures that entails the control of temperatures. It requires specifications to list the range and accuracy of each thermometer required.

Please review each specification to ensure that your lab is in compliance!

Sampling Soils

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Apparatus

Backhoe, auger, post hole digger, shovel

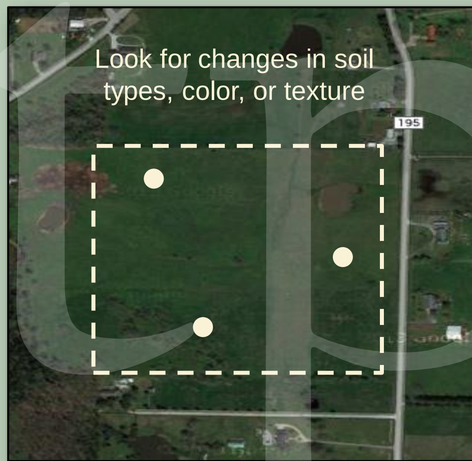
Sample containers should prevent the loss of fines and moisture

- **Sealable plastic containers**
- **Heavy doubled paper bags**
- **Unlined cloth or open weave bags should not be used**

Sampling

Sample Numbers

- Areas must be enclosed by at least three samples
  - ~ Risk factor of failure
  - ~ Uniformity of soil
- Typical Spacing
  - ~ Highway: 200’ – 2000’
  - ~ Borrow Pits: 100’ – 400’
  - ~ Earth Dams: 50’ – 150’



Sampling

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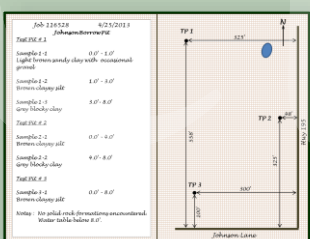
Documentation

Sample Location

- Reference landmarks
  - ~ Fence Posts
  - ~ Buildings / Roads
- Sketch



Soil Samples

- Test Pit or Boring #
- Material Classification
  - ~ Type of material
  - ~ Color and classification
- Layer Depths
  - ~ Start and end depth of each layer
- Comments
  - ~ Water table levels
  - ~ Rock outcrops

Sampling

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Test Pit

Boring

Roadway Samples

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Dry Preparation of Disturbed Soil… Samples for Test

AASHTO R 58

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Dry Preparation

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Apparatus

Drying Apparatus
- Fan, heat lamp, oven

Sieves
- 2”, ¾”, # 4, # 10, # 40
- Additional sizes as needed by specific test

Pulverizing Apparatus
- Mortar & rubber - covered pestle

- Power equipment with rubber - covered rollers

Individual grain sizes may not be reduced in size!

Procedure

Air dry material
- ≤ 140 °F

Reduce sample
- Split or Quarter

Select appropriate sieve according to test procedure to be performed

Process soil over specified sieve

Pulverize material retained on screen
- Rescreen the material
- Repeat until all soil particles are separated

Combine and mix all material passing the specified screen

Use AASHTO R 74 (Wet-Prep) for hard-to-process soils, or soils which need to maintain their natural moisture contents

ARDOT Field Testing for Moisture Content

ARDOT Specifications
- Oven Drying
  - ~ Most Accurate
  - ~ Slow Results
- Speedy Moisture
  - ~ Limited to finer grained soils
  - ~ Quick Results
  - ~ No license required
- Nuclear Density Gauge
  - ~ Accuracy may fluctuate based on surrounding conditions
  - ~ Quick Results
  - ~ Nuclear license required

Moisture Content of Soils

AASHTO T 265

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Equipment

Scales

- Must be readable to 0.1 % of the sample wt. or better
  - ~ 10 g → 0.01 g
  - ~ 100 g → 0.1 g
  - ~ 500 g → 0.5 g

Oven

- 230 ± 9 °F

Moisture Tins

- Corrosion Resistant
- Close-fitting Lids

Max. Particle Size	Min. Weight of Sample
2"	1000 g
1"	500 g
1/2"	300 g
# 4	100 g
# 40	10 g

Procedure

Record tin number and tare weight of empty tin

Place wet soil into tin

- Cover with lid

Record "Tare + Wet" weight

Dry sample at 230 °F to a constant mass

- Remove lid

Remove tin from oven and cool

- Cover with lid

Record "Tare + Dry" weight

Calculation

$$MC = \frac{(W - D)}{D} \times 100$$

W = wet weight of soil
D = dry weight of soil

Report moisture content to the nearest 0.1 %

Moisture Content

Determine the moisture content of the soil

Tare Weight	**18.76 g**
Tare + Wet	**30.62 g**
Tare + Dry	**29.55 g**

$$MC = \frac{(W - D)}{D} \times 100$$

Wet Soil = 30.62 – 18.76 = 11.86
Dry Soil = 29.55 – 18.76 = 10.79

$$MC = \frac{(11.86 - 10.79)}{10.79} \times 100 = \frac{1.07}{10.79} \times 100 = 9.92$$

9.9 %

Moisture Content

Determine the moisture content of the soil

Tare Weight	13.00 g
Tare + Wet	44.75 g
Tare + Dry	40.33 g

$$MC = \frac{(W - D)}{D} \times 100$$

Special Cases

Soil containing minerals which have loosely bound water from hydration

- Gypsum

Soil containing significant amounts of organic materials

Solutions

- Oven dry at ≈ 140°F
- Use vacuum desiccation at ≈ 10 mm Hg at a temperature of ≥ 73°F

Sieve Analysis of Soils

AASHTO T 11
AASHTO T 27

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Sieve Analysis of Soils

Determines the grain size distribution of soils

Used for:

- **Soil Classification**
- **Compliance**
  - ~ **ARDOT Specifications**
    - ~ Embankment
    - ~ Plating Materials
    - ~ Select Materials

Differences

- **Soil Sieve Sizes**
  - ~ **2", 1½", 1", ¾", 3/8", #4, #10, #40, #200**
- **Washing**
  - ~ **Use wetting agent if necessary**
  - ~ **Allow extra soak time**

Atterberg Limits

Liquid State
- Flows and changes shape easily

Plastic State
- Moldable and retains shape

Solid State
- Breaks rather than change shape

- Liquid Limit

Plasticity Index

- Plastic Limit

Atterberg limits characterize how a soil will behave with changes in moisture contents
- Liquid Limit
- Plastic Limit
- Plasticity Index

Plastic Limit of Soils

AASHTO T 90

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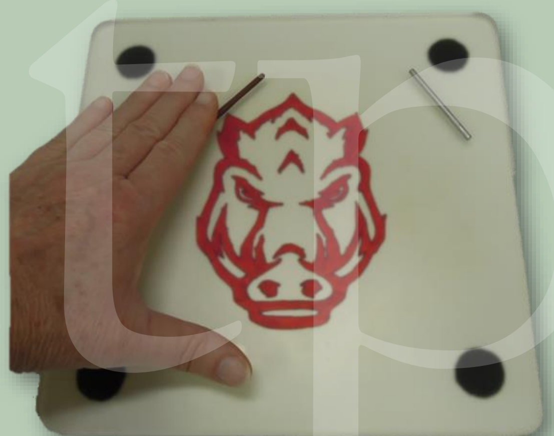

Introduction

Plastic limit is the lowest moisture content at which the soil remains plastic

A soil is at its plastic limit when it begins to crumble when rolled to a 3 mm diameter

Equipment

Scale (0.01 g)

Oven 110 ± 5 °C (230 ± 9 °F)

Rolling Surface

- **Ground Glass Plate**
- **Unglazed Paper**
- **Rolling Device**

Porcelain Dish

Moisture Tin

Spatula

Referee Test – Hand Roll
Use distilled, demineralized, or de-ionized water only

Soil Preparation

Air dry the soil
- **Process soil over # 40 sieve**

Add water to soil until moldable
- **Mix thoroughly**
- **Allow to season**

Remove ≈ 10 g
- **Form soil into a ball**

Plastic Limit

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Procedure

Record empty tin # and tare weight

Pinch off a small "pea" sized piece of soil and form an ellipsoidal shape

≈ 10 g ≈ 1.5 – 2 g

Roll specimen into a thread of 3 mm (≈ ⅛") uniform diameter
- **Roll on ground side of glass plate at 80-90 strokes per minute**
- **If thread crumbles before reaching 3 mm (1st rolling), add water and remix**

Plastic Limit

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Procedure

When thread reaches 3 mm in diameter, re-form soil into an ellipsoidal shape

- Do not roll past 3 mm

Repeat rolling process until soil crumbles before reaching or just as it reaches 3 mm

Place crumbled soil into tin

- Cover tin with lid

Select another "pea" and repeat process until entire 10 g sample is tested

Procedure

Weigh tin and record the "Tare + Wet" weight

Place tin in oven to dry

Cool sample to room temperature

Weigh tin and record the "Tare + Dry" weight

Calculate moisture content (MC)

Round moisture content to the nearest whole number

Report plastic limit to the nearest whole number

Plastic Limit

Determine the plastic limit of the soil

Tare + Wet	26.63 g	
Tare + Dry	24.14 g	
Tare Weight	13.20 g	

$\left.\begin{matrix}24.14\text{ g}\\13.20\text{ g}\end{matrix}\right\}$ 10.94 g Dry

$\left.\begin{matrix}26.63\text{ g}\\13.20\text{ g}\end{matrix}\right\}$ 13.43 g Wet

$$MC = \frac{(13.43 - 10.94)}{10.94} \times 100 = 22.76 = 22.8$$

PL = 23

Plastic Limit

Determine the plastic limit of the soil

Tare + Wet	31.25 g
Tare + Dry	30.10 g
Tare Weight	18.70 g

Liquid Limit of Soils

AASHTO T 89

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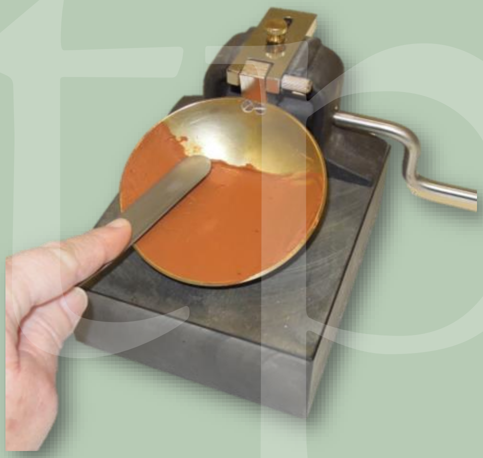
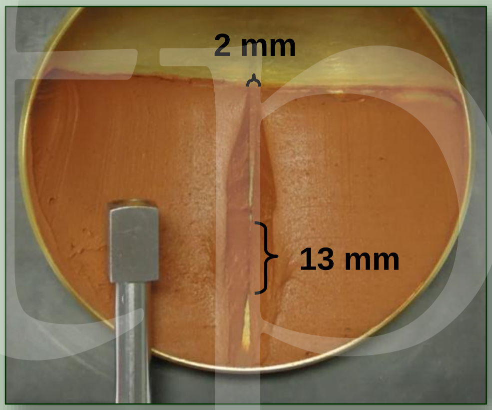


Introduction

The liquid limit of a soil is the moisture content necessary to close a 2 mm wide groove, for a length of 13 mm with 25 blows of the liquid limit machine



25 Blows

Equipment

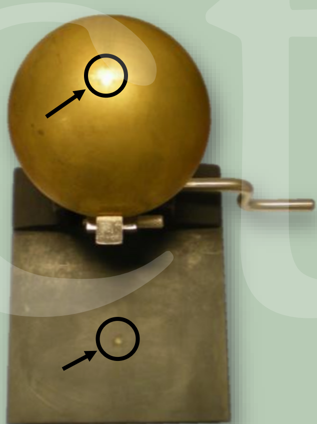
Scale (0.01 g)
Oven 110 ± 5 °C (230 ± 9 °F)
Liquid Limit Machine
Grooving Tool
- **AASHTO – Curved**
- **ASTM – Flat**

Gauge
- **10.0 ± 0.2 mm**

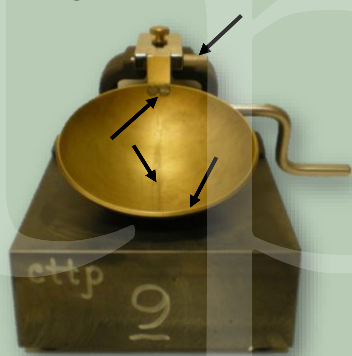
Mixing Dish / Spatula

LL Machine Check

Points of contact



Wear areas
Pin Play / Screws



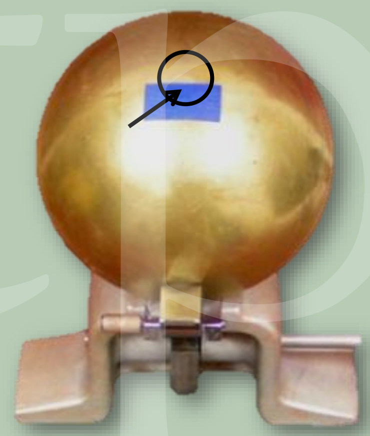
Calibrating Cup Drop (Daily Check)

Dissect the point of contact with smooth side of tape

Lower cup so that it is resting on the base

Insert gauge block until the edge is in contact with the tape

- **Hold gauge block so that it lies flat against the base**



Calibrating Cup Drop

Check drop height

- **Turn crank**
  - **Cup should make a clicking sound without lifting from gauge block**

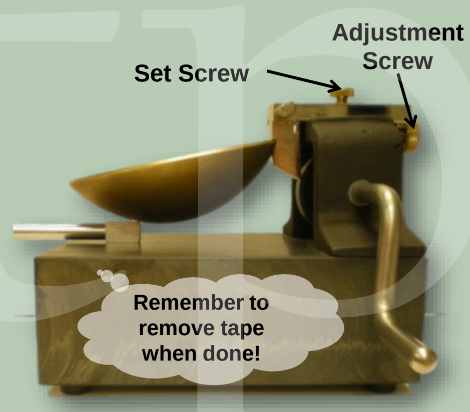
To adjust drop height

- **Loosen set screw**
- **Turn adjustment screw**
- **Tighten set screw**

Re-check drop height

- **Reset gauge block**
- **Check drop height**

Drop Height = 10 mm



Soil Preparation

Air dry soil

Dry or wet prep soil using # 40 sieve

Add water and mix until soil obtains a stiff consistency

- **Add water in small increments**
  - **Adding water too rapidly may produce a "false" liquid limit value**

If soil becomes too wet, <u>do not</u> add dry soil

- **Use natural evaporation**

Procedure Method B (1 Point)

Record empty tin #

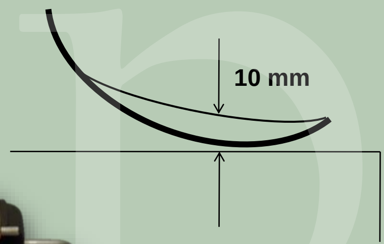
Record tare weight

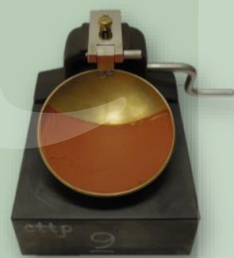
- **Include lid**

Procedure
Method B (1 Point)

Mix soil

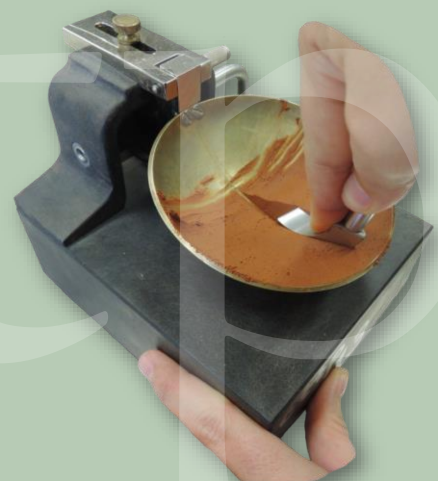
Place soil in cup
- **Depth of 10 mm**
- **Avoid entrapment of air bubbles within the soil**
- **Cover unused soil to retain moisture**





Procedure
Method B (1 Point)

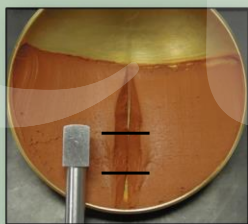
Divide the soil in the cup with the grooving tool
- **Cut groove along centerline of cup**
  - ~ **Up to 6 strokes allowed to reach bottom of cup**
  - ~ **No more cuts after touching the bottom of the cup**
- **Groove must be 2 ± 0.1 mm wide**



Procedure
Method B (1 Point)

Turn crank at 2 revolutions / sec
- Count # blows
- Stop at 13 mm closure
- Do not hold device

Blow Range 22 - 28



 # Blows outside 22 - 28
- Adjust moisture & retry

 # Blows 22 – 28
- Immediately verify test

Verification Test
- Redo test
  - ~ Do not adjust moisture
- ± 2 blows of previous test
- 22 – 28 blows

Procedure
Method B (1 Point)

Record blow count of verification test

Obtain MC sample
- Take sample perpendicular to groove and include the “closed” portion
- Sample weight ≥ 10 g

Record “Tare + Wet” weight
Dry sample to constant mass
Cool sample
Record “Tare + Dry” weight

Procedure
Method B (1 Point)

$LL = (k_N)(MC)$

Calculate moisture content

Correct moisture content to 25 Blows

- **"k" factor**

Round corrected moisture content

Report liquid limit to the nearest whole number

# of Blows (N)	"k" Factor
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014

Liquid Limit
Method B (1 Point)

Determine the liquid limit of the soil

$LL = (k_N)(MC)$

Tare + Wet	31.60 g	
Tare + Dry	27.14 g	27 blows
Tare Weight	14.50 g	k_{27}= 1.009

$$MC = \frac{(17.10 - 12.64)}{12.64} \times 100 = 35.28 = 35.3$$

$$LL = (1.009)(35.3) = 35.6177 = 36$$

LL = 36

Liquid Limit
Method B (1 Point)

Determine the liquid limit of the soil

$$LL = (k_N)(MC)$$

Tare + Wet	**30.71 g**	
Tare + Dry	**28.32 g**	**23 blows**
Tare Weight	**13.88 g**	

Procedure
Method A (3 Point)

Record three tin #'s and tare weights

Obtain a proper closure in each range
- **(1) 25 – 35 Blows**
- **(2) 20 – 30 Blows**
- **(3) 15 – 25 Blows**

$\underbrace{\text{(1), (2), (3)}}_{\geq 10}$

Record blow counts
- **No verification**

Obtain a MC sample and record weights for each closure recorded

Add additional water to adjust MC between closures and mix well

Check blow count difference
- **≥ 10**

Procedure
Method A (3 Point)

Calculate moisture contents

Plot data

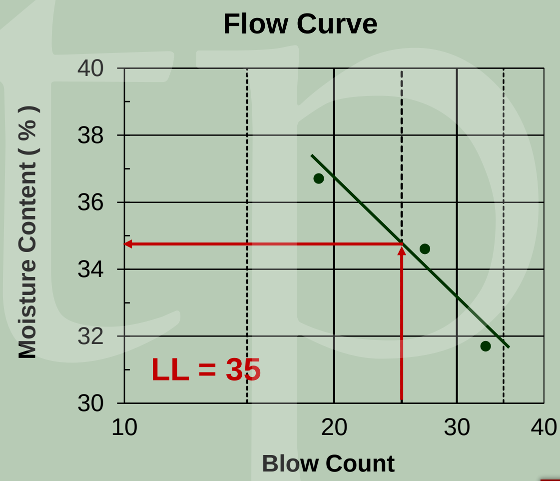
- **Blow count – log scale**
- **½ way is ≈ 3/5**

Draw "best fit" line

Find MC at 25 blows

Round MC

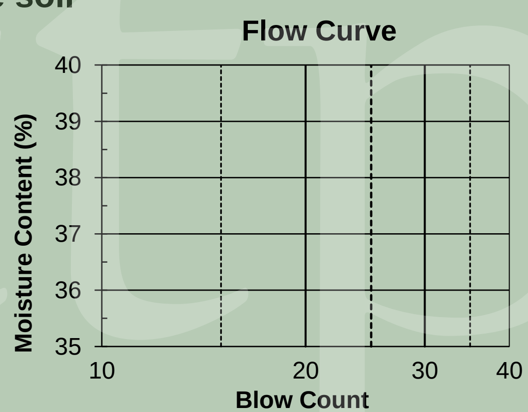
Report liquid limit to the nearest whole number



Calculation
Method A (3 Point)

Determine the liquid limit of the soil

# Blows	MC
17	39.1
24	38.5
30	36.2



Referee Tests

Method A (3 point)

Curved grooving tool

Use distilled or demineralized water only

Times

Mixing	**5-10 min.**
Seasoning	**30 min.**
Remixing	**1 min.**
Testing	**3 min.**
Adjusting	**3 min.**

No dry soil may be added to the seasoned soil being tested

Plasticity Index of Soils

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Plasticity Index (PI) is the range of moisture contents where the soil exhibits plastic properties

- **Higher PI Values (≥ 11)**
  - ~ **Clayey soils**
- **Lower PI Values (≤ 10)**
  - ~ **Aggregates**
  - ~ **Sands**
  - ~ **Silts**

Plasticity Index

PI = LL − PL

PI = Plasticity Index
LL = Liquid Limit
PL = Plastic Limit

Determine the plasticity index of the soil

LL = 37 **PL = 23**

PI = 37 − 23 = 14

PI = 14

Report PI to the nearest whole number

Plasticity Index

Determine the plasticity index of the soil

LL = 32 **PL = 15**

Special Reporting

Report PL

- "Cannot be Determined"
  - ~ If specimen cannot be rolled to 3 mm

Report LL

- "Cannot be Determined"
  - ~ If soil "slides" in the cup at blow counts less than 25

Report PI

- "Non–Plastic (NP)" if any of the following are true
  - ~ LL could not be determined
  - ~ PL could not be determined
  - ~ PL is ≥ LL

Plasticity Index 72

Classification of Soils… for Highway Construction Purposes

AASHTO M 145

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Soil Classification 74

AASHTO Soil Classification

Table 1

	Granular Materials (35 Percent or Less Passing 75 µm)			Silt – Clay Materials (More Than 35 Percent Passing 75 µm)			
Group Classification	A - 1	A – 3[a]	A - 2	A - 4	A - 5	A - 6	A - 7
Sieve analysis, % passing:							
2.00 mm (No. 10)	---	---	---	---	---	---	---
0.425 mm (No. 40)	50 max	51 min	---	---	---	---	---
75 µm (No. 200)	25 max	10 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing 0.425 mm (No. 40)							
Liquid Limit	---			40 max	41 min	40 max	41 min
Plasticity Index	6 max	Nonplastic (NP)	[b]	10 max	10 max	11 min	11 min
General rating as subgrade	Excellent to Good			Fair to Poor			

Soil Classification

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AASHTO Soil Classification

Granular Materials
≤ 35% Passing # 200

- **Boulder: ≥ 12”**
- **Cobble: 12”- 3”**
- **Gravel: 3” - #10**
- **Sand: #200 - #10**

Silt / Clay Materials
> 35% Passing # 200

- **Silt: #200 - .002mm**

PI ≤ 10

- **Clay: < .002mm**

PI ≥ 11

Soil Classification

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AASHTO Soil Classification

Classify the following soil as a granular, silt, or clay material and determine the group number of the soil

Sieve	% Passing
2”	100
3/4”	100
# 4	95
# 10	85
# 40	60
# 200	42

Test	Value
LL	45
PL	37
PI	8

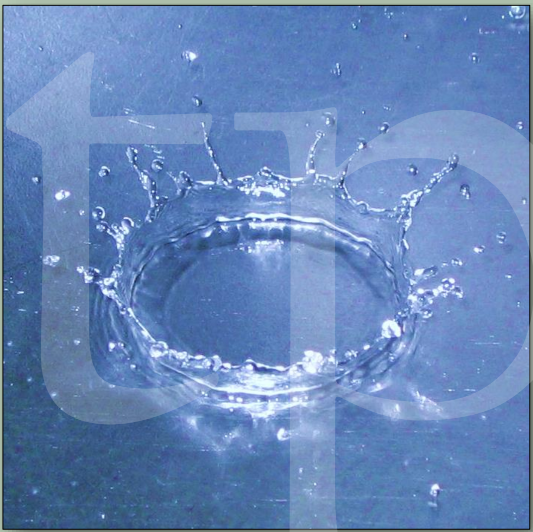
> 35% Passing # 200
= Silt or Clay
= A4, A5, A6, or A7

PI ≤ 10 = Silt = A4 or A5

LL ≥ 41 = A5

Silt - Group A5

Water



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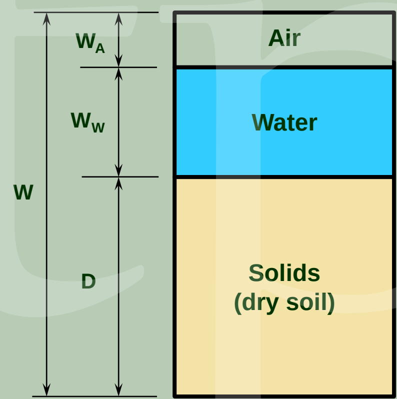
Water Calculation

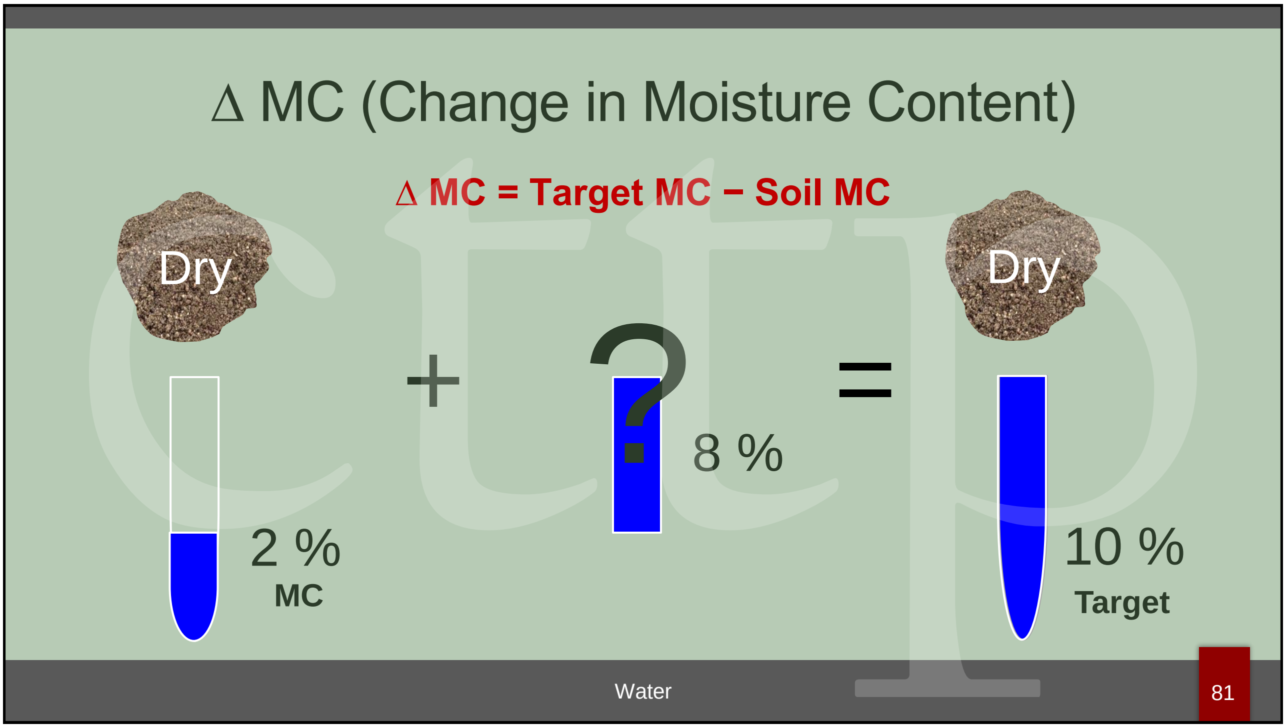
$$MC = \frac{(W - D)}{D} \times 100$$

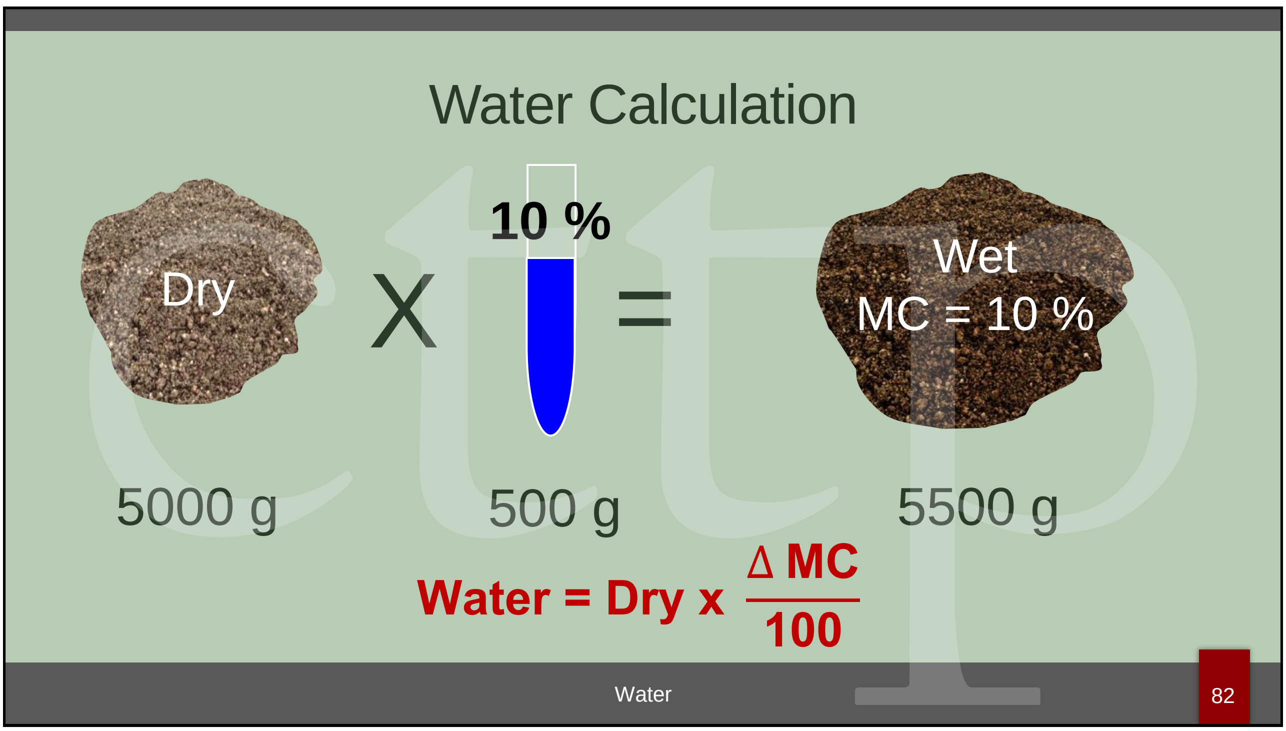
W – wet weight of soil
D – dry weight of soil

$$D = \frac{W}{\left(1 + \frac{MC}{100}\right)}$$



Wet Soil


Δ MC (Change in Moisture Content)
Δ MC = Target MC − Soil MC
Dry
+
?
8 %
=
Dry
2 %
MC
10 %
Target
Water
81


Water Calculation
Dry
X
10 %
=
Wet
MC = 10 %
5000 g
500 g
5500 g
Water = Dry x Δ MC / 100
Water
82

Water

Determine how much water is needed for the soil to contain 3 % moisture if the dry weight is 2000 g

$$\text{Water} = D \times \frac{\Delta\ MC}{100}$$

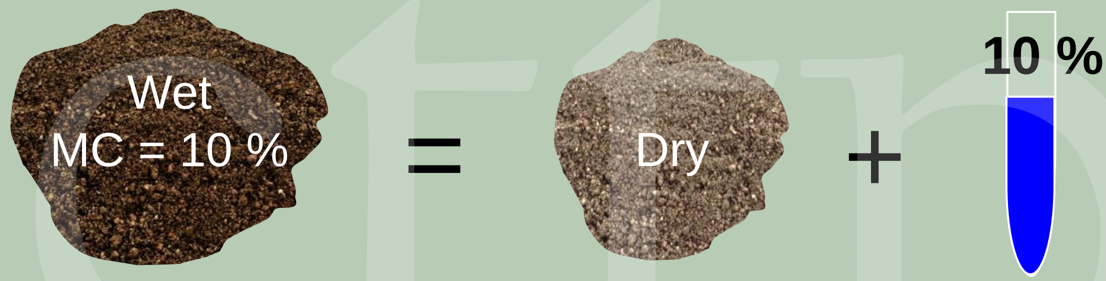
$$\text{Water} = 2000 \times \frac{3}{100} = (2000)(0.03) = 60$$

60 g or 60 mL

Water

Determine how much water is needed for the soil to contain 10.2 % moisture if the dry weight is 2500 g

$$\text{Water} = D \times \frac{\Delta\ MC}{100}$$



5500 g | 5000 g | 500 g

$$\text{Dry} = \frac{\text{Wet}}{\left(1 + \frac{\text{MC}}{100}\right)}$$

Water

Determine how much water is needed to bring a 2630 g soil sample with a moisture content of 3.4 % to a moisture content of 12.0 %

1. $\text{Dry} = \dfrac{\text{Wet}}{\left(1 + \frac{\text{MC}}{100}\right)} = \dfrac{2630}{\left(1 + \frac{3.4}{100}\right)} = \dfrac{2630}{1.034} = 2543.5$

2. $\Delta\text{MC} = \text{Target MC} - \text{MC} = 12.0 - 3.4 = 8.6$

3. $\text{Water} = \text{Dry} \times \dfrac{\Delta\text{MC}}{100} = 2543.5 \times \dfrac{8.6}{100} = 219$

219 mL

Water

Determine how much water is needed to bring a 5500 g soil sample with a moisture content of 1.3 % to a moisture content of 6.2 %

Determining Moisture Content by Speedy Moisture Tester

ArDOT 347

cttp
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Introduction / Equipment

Alternative method to oven drying for fine grained soils
- Not quite as accurate
- Quicker test
- No license to operate

Calcium carbide reacts with the water in the soil
- Produces acetylene gas

Gas pressure inside the meter is measured and converted to a moisture content based on the wet mass of the soil
- Must use conversion chart to convert to a moisture content based on the dry mass of soil

Procedure

Procedure is written for a standard sample size of 20 g

Clean tester chamber and cap prior to use

Tilt chamber on side and roll (2) steel balls into chamber
- Avoid dropping balls directly onto pressure port

Procedure

Place 3 scoops (≈ 24 g) of calcium carbide into chamber

Prepare soil sample
- **Pulverize or break into small pieces**

Procedure

Weigh out 20 g of soil
- **Check your individual tester specifications**

Place soil into cap

Keep chamber on its side and secure the cap
- **Prevents soil mixing with reagent**

Procedure

Raise tester to a vertical position
- **Soil must mix with reagent to produce gas**

Shake horizontally with a circular rotating motion for approximately 1 to 2 minutes

Procedure

Read dial
- **Dial Decreasing – Leak**
  - ~ **Invalid Test – Redo**

Repeat shaking until gauge dial stabilizes
- **Obtain 3 consecutive identical readings**

Record final dial reading (0.1 %)

What does this dial read?

11.7 %

Procedure

Remove cap

- **Point cap in a safe direction**

Examine contents and repeat test if sample is not completely pulverized

Convert dial reading to moisture content

- **ArDOT Conversion chart**

Report moisture content to the nearest 0.1 %

Speedy Moisture Content

Determine the moisture content of the soil

Sample Weight	**20 g**
Dial Reading	**9.3 %**

- **If the standard sample weight was used, read the moisture content directly from the ArDOT correction chart**

Speedy Moisture Tester Conversion Chart

%	0	.1	.2	.3	.4
5	5.4	5.5	5.6	5.7	5.8
6	6.5	6.6	6.7	6.8	6.9
7	7.6	7.7	7.8	7.9	8.0
8	8.7	8.8	8.9	9.0	9.1
9	9.8	9.9	10.0	10.1	10.3
10	11.0	11.1	11.3	11.4	11.6
11	12.3	12.4	12.6	12.7	12.9
12	13.6	13.7	13.8	14.0	14.1

Special Cases

Very low moistures

- **Double the sample size**
  - ~ **Use 40 g of soil instead of 20 g**
- **Divide dial reading by 2 before going to the conversion chart**

Very high moistures

- **Cut the sample size in half**
  - ~ **Use 10 g of soil instead of 20 g**
- **Multiply dial reading by 2 before going to the conversion chart**

Special Cases

Determine the moisture content of the soil

Sample Weight	**10 g**
Dial Reading	**11.5 %**

- **Sample weight cut in half**
- **Multiply dial reading by 2 before going to the chart**

11.5 x 2 = 23.0

%	0	.1	.2
21	26.5	26.7	26.9
22	28.2	28.4	28.5
23	29.8	30.0	30.2
24	31.5	31.7	31.9

Special Cases

Determine the moisture content of the soil

Sample Weight	**40 g**
Dial Reading	**7.6 %**

- **Sample weight doubled**
- **Divide dial reading by 2 before going to the chart**

7.6 / 2 = 3.8

%	.7	.8	.9
2	2.9	3.0	3.1
3	4.0	4.1	4.2
4	5.1	5.2	5.3
5	6.2	6.3	6.4

Speedy Moisture Content

Determine the moisture content of the soil

Sample Weight	Dial Reading	Chart	Moisture Content
20 g	15.3 %		
10 g	13.6 %		
40 g	4.6 %		

Moisture Density Relations of Soils

AASHTO T 99
AASHTO T 180

Center for Training Transportation Professionals

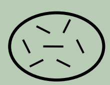
Compaction

Compaction
- **Densification of a soil by applying a load to the soil**
  - ~ **Reduces settlement**
  - ~ **Increases shear resistance**
  - ~ **Reduces permeability**

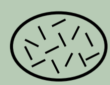
Moisture affects compaction
- **Compaction at the optimum water content results in the greatest density for a specified compactive effort**

Compaction

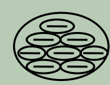
Below Opt. MC
- Soil particles pack loosely
- Weak, permeable soil structure
- Compaction is more difficult
- Stable soil structure is questionable



Optimum MC
- Soil particles pack closely
- Interlocking soil structure
- Compacts moderately easy
- Stable soil structure



Above Opt. MC
- Soil particles pack in layers (shear planes)
- Non-interlocking soil structure
- Compacts easily
- Non-stable soil structure typical



Proctor

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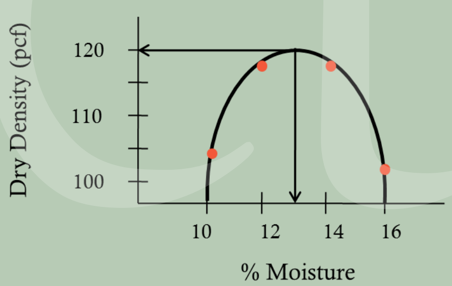
Proctor Curves

The relationship between moisture and density establishes the proctor curve of a soil



Proctor curves serve as the basis for field compaction

- **Maximum Dry Density**
  - ~ **Used in the field to determine the % compaction of the soil**
- **Optimum Moisture**
  - ~ **Used in the field as a target to help achieve the desired degree of compaction and prevent instability of the soil structure**

Proctor

113

Equipment

Sieves
- 3/4 in. or # 4

Scales
- Readable to 1 g (proctor)
- Readable to 0.1 g (MC)

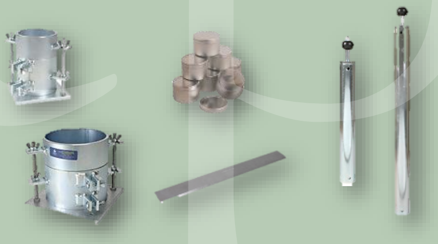
Oven (230 ± 9 °F)

Mold Assembly
- 4” or 6” I.D.
- Solid or split side

Beveled Straight Edge

Moisture Tins

Rammer
- 5.5 lb – 12” drop
- 10.0 lb – 18” drop



AASHTO Proctor Specifications

T 99 (Standard)

Method A	Method C
3 Lifts	3 Lifts
25 Blows	25 Blows
4” Mold	4” Mold
Minus # 4 Mat’l	Minus 3/4” Mat’l
Method B	**Method D**
3 Lifts	3 Lifts
56 Blows	56 Blows
6” Mold	6” Mold
Minus # 4 Mat’l	Minus 3/4” Mat’l

T 180 (Modified)

Method A	Method C
5 Lifts	5 Lifts
25 Blows	25 Blows
4” Mold	4” Mold
Minus # 4 Mat’l	Minus 3/4” Mat’l
Method B	**Method D**
5 Lifts	5 Lifts
56 Blows	56 Blows
6” Mold	6” Mold
Minus # 4 Mat’l	Minus 3/4” Mat’l

AASHTO Proctor Specifications

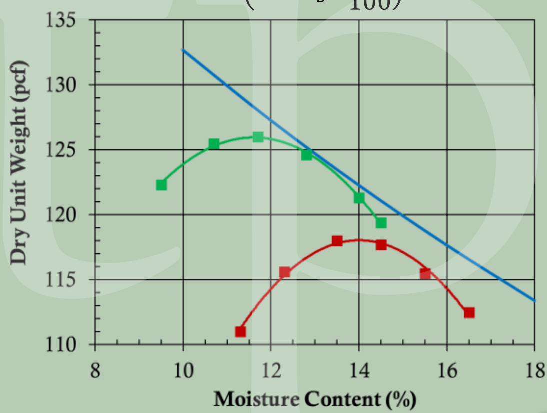
Modified Proctor :
56,000 ft-lb/ft³

Standard Proctor :
12,400 ft-lb/ft³

Compactive Effort
- **Hammer Weight**
- **Drop Height**
- **Number of Lifts**

ArDOT Limit :
≈ 105 % Compaction

$$\gamma_{ZAV} = \frac{G_s \cdot \gamma_w}{\left(1 + G_s \cdot \frac{w}{100}\right)}$$



ARDOT Specifications

Proctor method is based on the gradation of the field soil
- **Section 210.10 – Compacted Embankment**

% Retained # 4	Proctor
10 % Maximum	AASHTO T 99 A
11 % - 30 %	AASHTO T 99 C
31 % Minimum	AASHTO T 180 D

% Retained = 100 - % Passing

Procedure

Soil Preparation

- Determine the gradation of the field soil
  - ~ 2”, 3/4”, # 4 sieves
- Select the appropriate procedure and method based on the gradation of the soil or other specifications
- Air dry sample until the desired starting moisture content is obtained
- Process sample over the appropriate sieve
  - ~ # 4 or 3/4”

Procedure

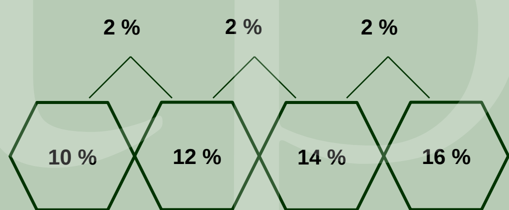
Reduce processed sample and obtain a representative portion(s)

- Rocky soils or heavy clays require individual portions
  - ~ 4” Mold ≈ 2500 g
  - ~ 6” Mold ≈ 6000 g

Bring the first point to the desired moisture content

Increase the moisture in the next point and the following points by the same amount

- Usually 1 – 2 %



Procedure

Determine the amount of water to be added

Mix water into soil to achieve a uniform moisture content

Procedure

Place soil into sealable containers

Allow soil to "season" if necessary

- **Heavy clays must "season" for a minimum of 12 hours prior to compaction**

Procedure

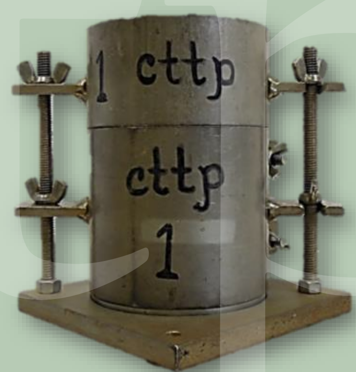
Tighten joint on split molds to maintain constant volume

Attach mold firmly to base

Procedure

Record weight of mold assembly (mold + base)

Attach collar to mold

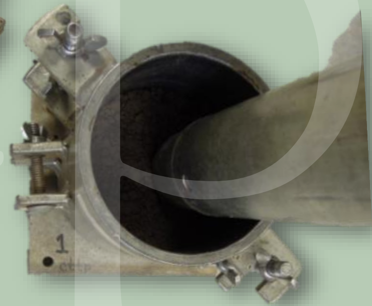


Procedure

Add soil for 1 lift into mold
- Evenly distribute soil in mold

Gently tamp soil surface
- Eliminates loose state

Place on compaction surface
- 200 lb concrete block
- Sound concrete floor



Procedure

Compact lift evenly using the appropriate number of blows

Trim soil around mold edges and distributed evenly across the surface

Repeat process for remaining lifts

Procedure

Remove collar

Trim excess soil with a beveled straightedge so that the soil surface is even with the top of the mold

- **Check for hammer marks**
  - **Re-compact point if hammer marks are seen**
- **Patch holes or tears caused by trimming**

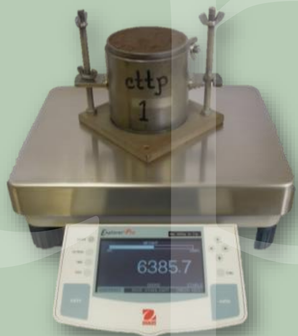
Height of soil above mold ≈ ¼ - ½ inch

Procedure

Clean outside of mold

- **Check under base**

Record weight of filled mold assembly



Procedure

Extrude specimen

AASHTO T 265

Passing # 4
100 g min.

Passing ¾"
500 g min.

Obtain a moisture content specimen

- **Use full slice**

Record MC weights

Proctor 130

Procedure

Repeat compaction process for all points

Compact points until:

- **There is no increase in the wet mass of soil, and then perform one more determination**
- **There are at least 2 points over optimum**
- **Points increase in mass and then decrease in mass**

After which point could you stop compacting points?

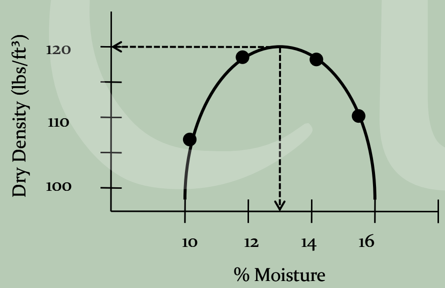
Target	Wet Mass
10 %	4300 g
12 %	4380 g
14 %	4400 g
16 %	4360 g
18 %	4310 g

Stop !

Proctor 131

Proctor Curve

Plot Proctor Points
- X - axis : % Moisture
- Y - axis : Dry Density

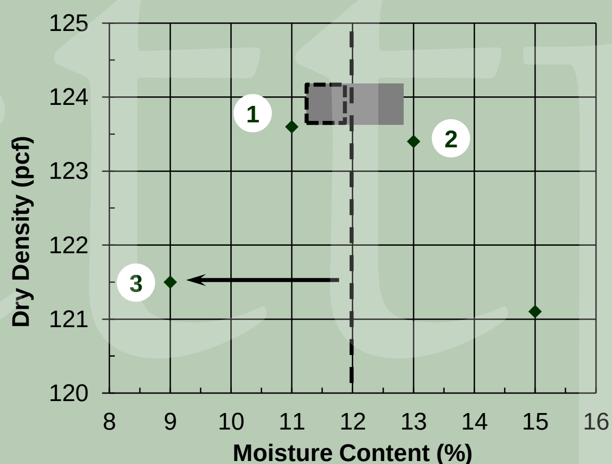


Draw Proctor Curve
- Decide ≈ peak location
- Draw smooth parabola

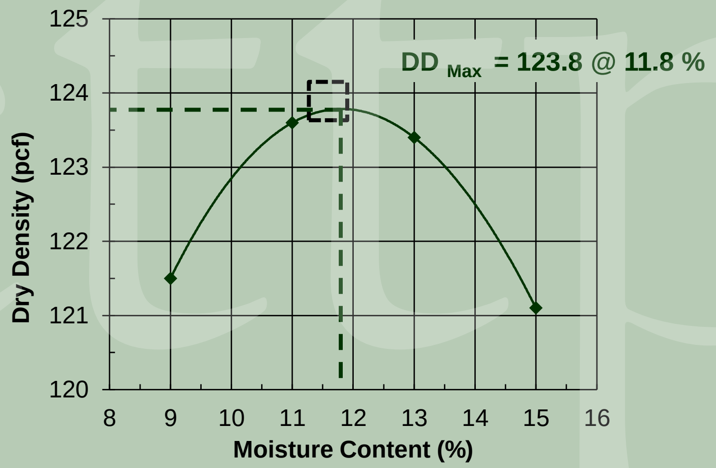
Record Peak Values
- Maximum Dry Density
- Optimum Moisture Content

Report Density & MC
- Max DD: nearest 0.1 lb/ft³
- Opt. MC: nearest 0.1%

Peak Location



Peak Location



Proctor

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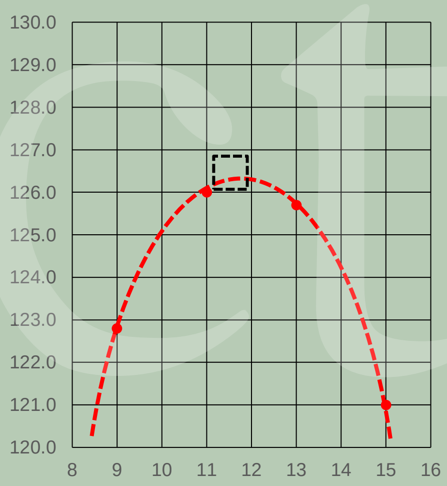
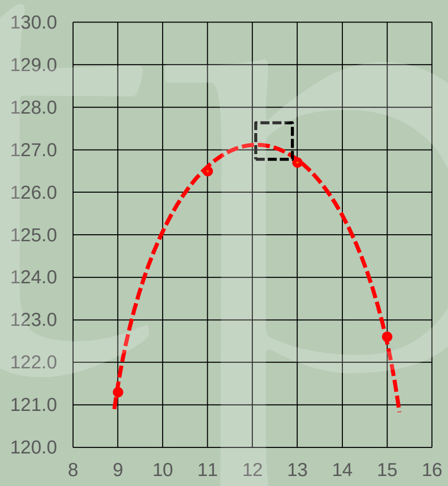
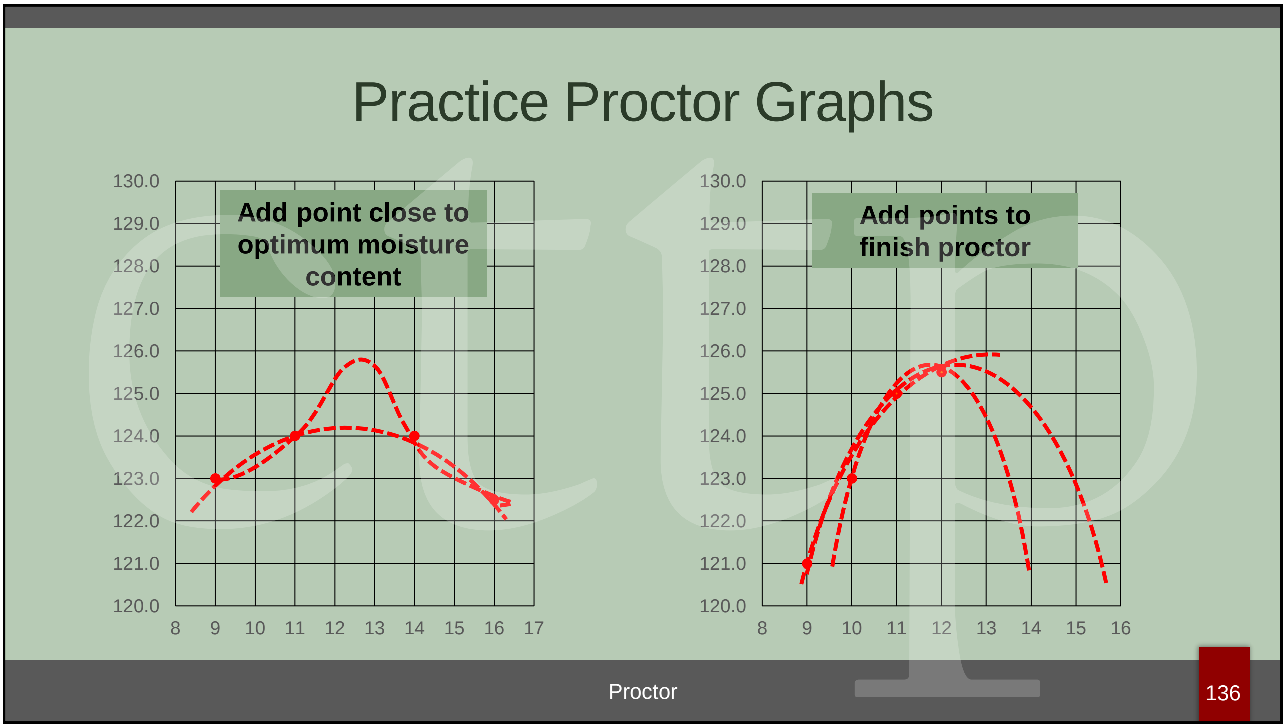
Practice Proctor Graphs

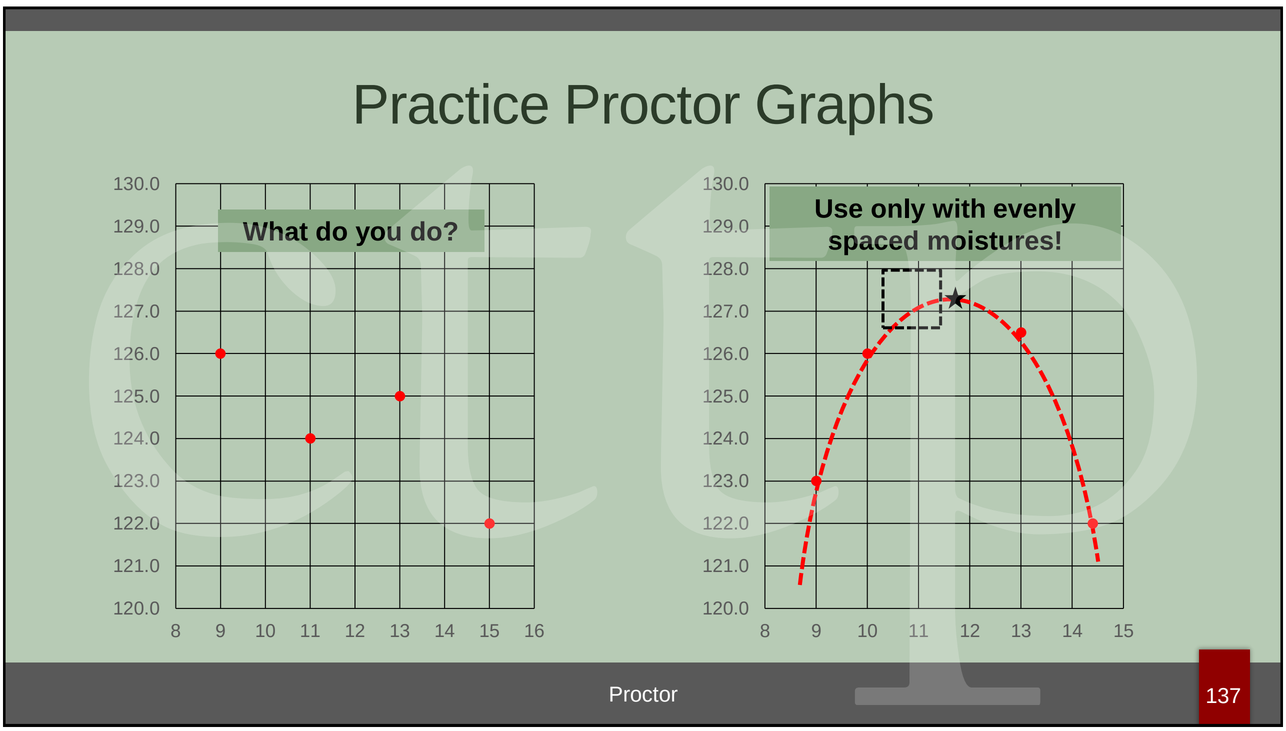




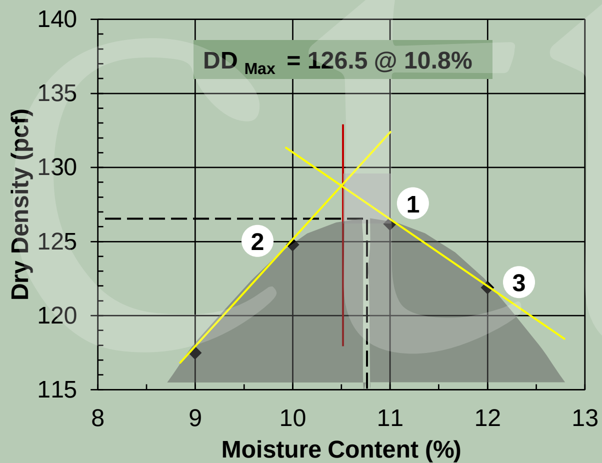
Proctor

135


Practice Proctor Graphs
Add point close to optimum moisture content
130.0
129.0
128.0
127.0
126.0
125.0
124.0
123.0
122.0
121.0
120.0
8 9 10 11 12 13 14 15 16 17
Add points to finish proctor
130.0
129.0
128.0
127.0
126.0
125.0
124.0
123.0
122.0
121.0
120.0
8 9 10 11 12 13 14 15 16
Proctor
136


Practice Proctor Graphs
What do you do?
130.0
129.0
128.0
127.0
126.0
125.0
124.0
123.0
122.0
121.0
120.0
8 9 10 11 12 13 14 15 16
Use only with evenly spaced moistures!
130.0
129.0
128.0
127.0
126.0
125.0
124.0
123.0
122.0
121.0
120.0
8 9 10 11 12 13 14 15
Proctor
137

Peak Location



Remember, you must have evenly spaced moisture contents for this method !

Never use straight lines through data points to establish peak!

Peak values obtained by using straight lines are too high for maximum density.

Axis Scales

X - Axis	Y - Axis
8.0	122.0
10.0	127.0
12.0	126.5
14.0	120.5

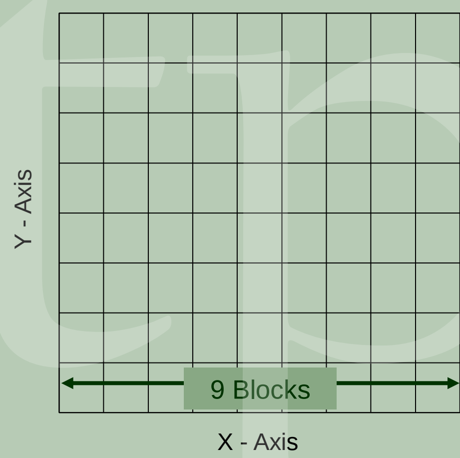
High 14
Low 8

14.0 – 8.0 = 6.0

6.0 / 9 blocks = 0.67 (min)

0.67 x 2 = 1.33 (max)

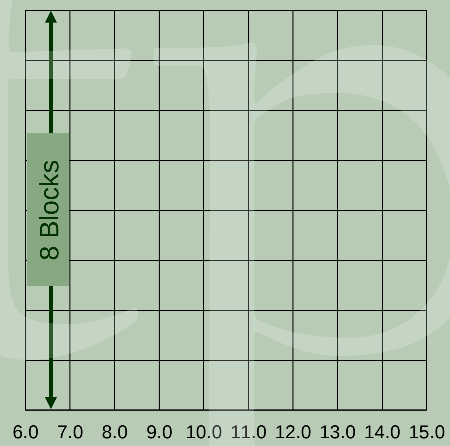
Choose an increment of 1



Axis Scales

X - Axis	Y - Axis
8.0	122.0
10.0	127.0
12.0	126.5
14.0	120.5

High 127
Low 120



127.0 – 120.0 = 7.0

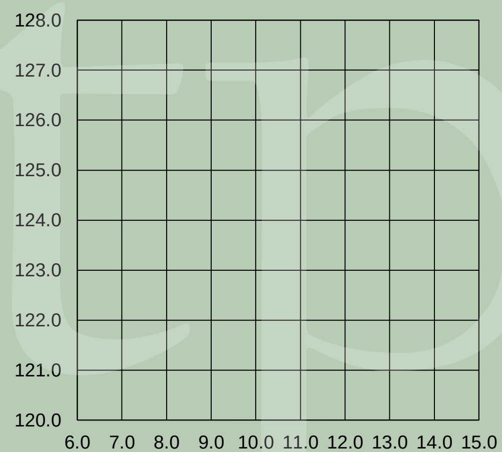
7.0 / 8 blocks = 0.875 (min)

0.875 x 2 = 1.75 (max)

Choose an increment of 1

Axis Scales

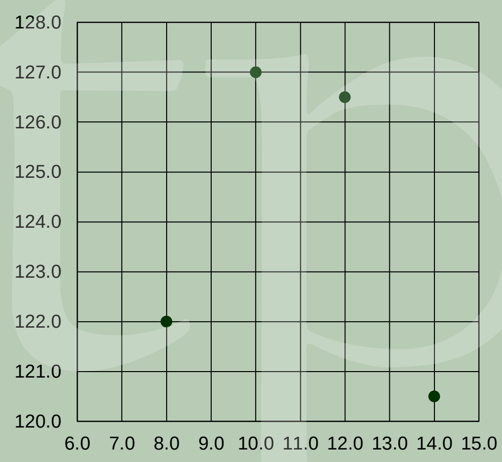
X - Axis	Y - Axis
8.0	122.0
10.0	127.0
12.0	126.5
14.0	120.5



Plot the data

Proctor Graph

X - Axis	Y - Axis
8.0	122.0
10.0	127.0
12.0	126.5
14.0	120.5

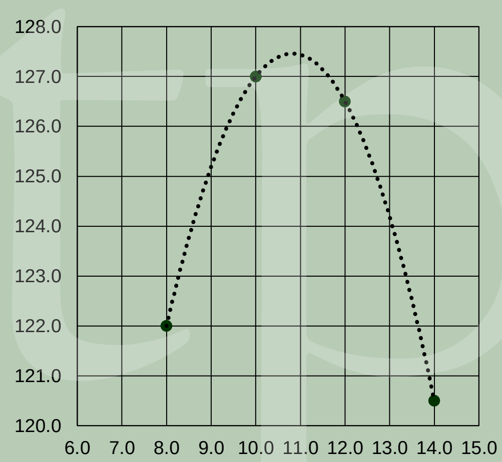


Draw the proctor curve

Proctor 142

Proctor Graph

X - Axis	Y - Axis
8.0	122.0
10.0	127.0
12.0	126.5
14.0	120.5



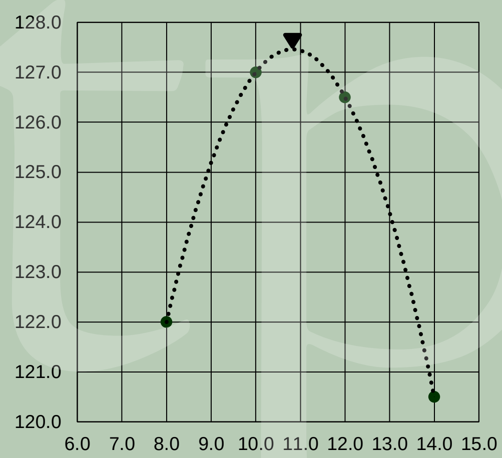
Record peak values

Proctor 143

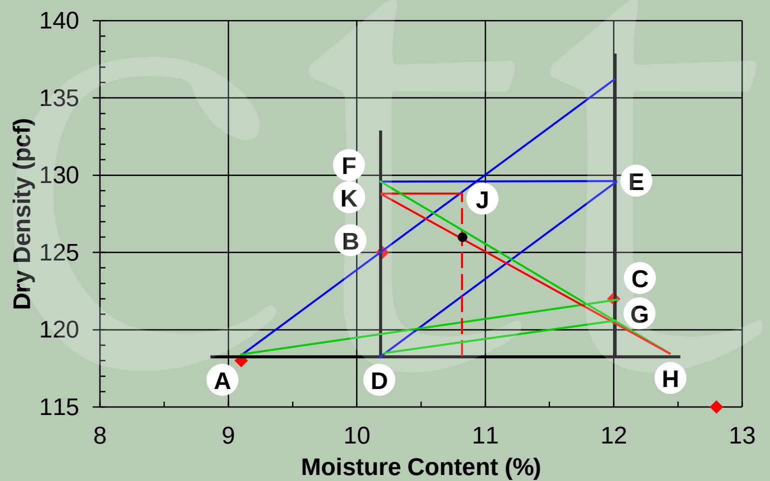
Proctor Graph

X - Axis	Y - Axis
8.0	122.0
10.0	127.0
12.0	126.5
14.0	120.5

127.5 @ 10.8 %



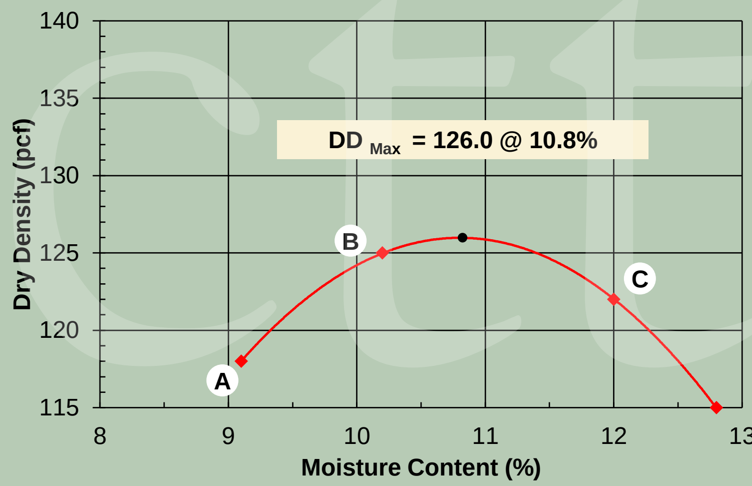
Graphical Parabola Method



Optimum MC is halfway between point A & H

$$\mathbf{MC = \frac{9.1 + 12.5}{2} = 10.8\ \%}$$

Graphical Parabola Method



Calibration of Measure

AASHTO T 19

Section 8

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Procedure

Clean and dry mold and base plate

Place a thin layer of grease on upper and lower mold rims

Assemble mold and base plate

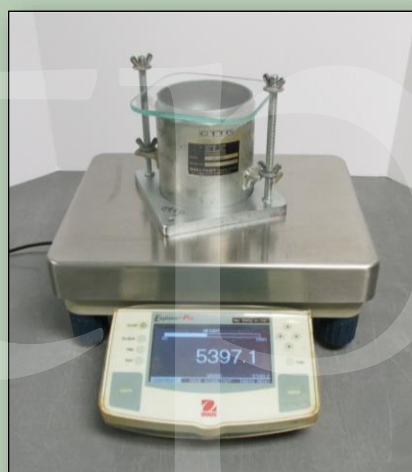
Record weight of glass plate and mold assembly

Procedure

Fill mold with water and cover with glass plate

- Eliminate bubbles and excess water
- Dry mold assembly and glass plate

Record weight of mold, water and glass plate



Procedure

Measure temperature of water to nearest 1° F

Determine the density of the water at the measured temperature

- AASHTO Table 3
  - Interpolate

Calculate the volume of the mold

° F	lb/ft³
65	62.336
66	62.329
67	62.322
68	62.315
69	62.308
70	62.301
71	62.293
72	62.285
73	62.277

° F	lb/ft³
74	62.269
75	62.261
76	62.252
77	62.243
78	62.234
79	62.225
80	62.216
81	62.206
82	62.196

Calculation

$$V = \frac{\text{Weight of Water}}{\text{Density of Water}}$$

Report volume of mold to the nearest 0.0001 ft³

Mold Volume

Determine the volume of the mold

$$V = \frac{\text{Weight of Water}}{\text{Density of Water}}$$

Mold + Plate	2.426 lb
Mold + Water + Plate	4.500 lb
Temperature	76 °F

Density of Water @ 76°
62.252 lb/ft³

$$V = \frac{(4.500 - 2.426)}{62.252} = \frac{2.074}{62.252} = 0.033316 = 0.0333$$

$$V = 0.0333\ ft^3$$

Mold Volume

Determine the volume of the mold

$$V = \frac{\text{Weight of Water}}{\text{Density of Water}}$$

Mold + Plate	15.248 lb
Mold + Water + Plate	19.928 lb
Temperature	68 °F

Mold Volumes

4" Mold
- **0.0333 (Tolerance of ± 0.0005 ft³)**

6" Mold
- **0.0750 (Tolerance of ± 0.0009 ft³)**

Molds shall be recalibrated at least once a year or whenever there is a reason to question the accuracy of calibration

Use the mold volume determined by AASHTO T 19 for density calculations

Density Calculations

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{WD} = \frac{\text{Wet Mass}}{\text{Volume}}$$

$$\text{DD} = \frac{\text{Dry Mass}}{\text{Volume}} = \left(\frac{1}{V}\right)\left(\frac{\text{Wet Mass}}{1 + \frac{\text{MC}}{100}}\right) = \frac{\text{WD}}{\left(1 + \frac{\text{MC}}{100}\right)}$$

WD = wet density *DD = Dry density* *MC = moisture content (%)*

Wet Density Calculation

Determine the wet density (lb/ft³) of the soil compacted in a mold with a volume of 0.0336 ft³

$$WD = \frac{\text{Wet Soil Wt}}{\text{Volume}}$$

Mold Weight	**4454.0 g**
Mold + Soil	**6398.6 g**

1) **Find the wet weight of soil**

$$\begin{array}{r} 6398.6\ \text{g} \\ -\ 4454.0\ \text{g} \\ \hline 1944.6\ \text{g} \end{array}$$

2) **Convert to pounds**

$$\frac{1944.6}{453.6} = 4.287\ \text{lb}$$

3) **Divide by volume**

$$\frac{4.287}{0.0336} = 127.589\ \text{lb/ft}^3$$

Proctor Calculations 160

Dry Density Calculation

Determine the dry density (lb/ft³) of the soil having a wet density of 127.589 lb/ft³ and a MC of the soil cut from the compacted specimen of 12.2 %

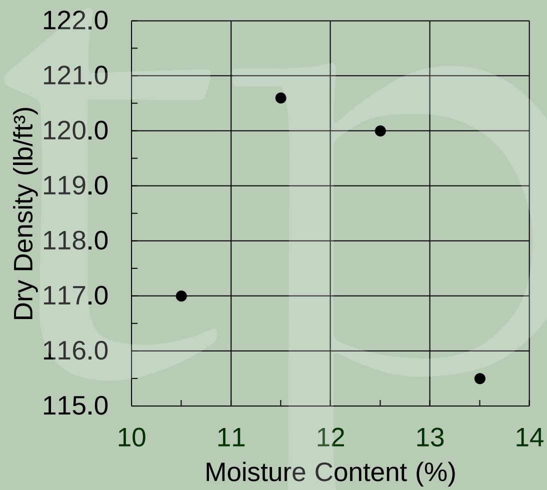
$$DD = \frac{WD}{\left(1 + \frac{MC}{100}\right)}$$

$$DD = \frac{127.589}{\left(1 + \frac{12.2}{100}\right)} = \frac{127.589}{1.122} = 113.716 = 113.7\ {}^{lb}/_{ft^3}$$

Proctor Calculations 161

Sample Proctor Plot

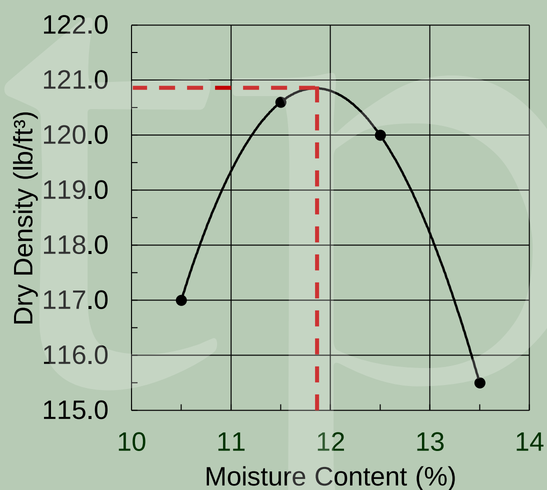
Moisture Content (%)	Dry Density (lb/ft³)
10.5	117.0
11.5	120.6
12.5	120.0
13.5	115.5



Sample Proctor Curve

Moisture Content (%)	Dry Density (lb/ft³)
10.5	117.0
11.5	120.6
12.5	120.0
13.5	115.5

Max DD 120.9
Opt. MC 11.9 %



Proctor Adjustments

An increase or decrease in the amount of rock in the field will change the maximum dry density and optimum moisture content of the soil

Adjustments are <u>only</u> made when the change would not require a different proctor method to be run

Field Indicators for Adjustments :

- **High density tests (continuously without reason)**
- **Low density tests (continuously without reason)**
- **Visual noticeable change in soil gradation**

Proctor Adjustments

Adjusts the maximum dry density and optimum moisture content of a soil to account for the coarse particles (rock) found in field conditions

- **ArDOT Material Replacement Method (ArDOT)**
  - ~ **Alters the way the proctor is run by substituting smaller rock which is allowed in the mold, for larger rock not allowed in the mold by the AASHTO method**
- **AASHTO Correction of Maximum Dry Density and Optimum Moisture for Oversized Particles (AASHTO COP)**
  - ~ **Mathematically corrects the established AASHTO proctor by using actual material properties and the percentages of soil and rock found in the field**

Proctor Adjustments

AASHTO T 99 A Proctors

- If more than 5 % is retained on the # 4 sieve, run the AASHTO proctor and apply the AASHTO correction for oversized particles on # 4 sieve

AASHTO T 99 C or T 180 D Proctors

- If material is retained on the ¾" sieve, use the ArDOT material replacement method when running the AASHTO proctor

% Retained # 4	Proctor	Adjustment	When
10 % Maximum	AASHTO T 99 A	AASHTO	More than 5 % is retained on the # 4 sieve
11 % - 30 %	AASHTO T 99 C	ArDOT	If material is retained on the 3/4" sieve
31 % Minimum	AASHTO T 180 D		

Proctor Adjustments

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Proctor Adjustments

Determine what proctor and correction is needed for soil with the following gradation

Sieve	% Passing
2"	100
3/4"	100
# 4	96
# 200	15

AASHTO T 99 A
No Correction

Determine what proctor and correction is needed for soil with the following gradation

Sieve	% Passing
2"	100
3/4"	100
# 4	64
# 200	8.7

AASHTO T 180 D
No Correction

Proctor Adjustments

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Proctor Adjustments

Determine what proctor and correction is needed for soil with the following gradation

Sieve	% Passing
2”	100
3/4”	100
# 4	93
# 200	13

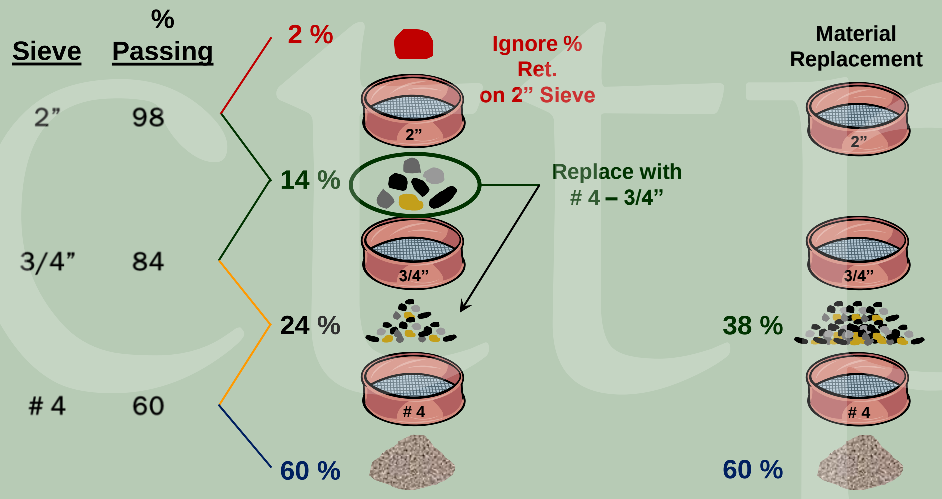
AASHTO T 99 A
with AASHTO COP

Determine what proctor and correction is needed for soil with the following gradation

Sieve	% Passing
2”	100
3/4”	92
# 4	77
# 200	10

AASHTO T 99 C
with ARDOT

ARDOT Material Replacement



ARDOT Material Replacement

Batching 5500 g / Point

- 98 % of material passes 2" sieve $\frac{5500}{0.98} = 5612$
- 38 % of (3/4" - # 4) Rock is needed for each point (5612)(0.38) = 2133
- 60 % of (minus # 4) Soil is needed for each point (5612)(0.60) = 3367

2133 Rock
+ 3367 Soil
5500 Point

AASHTO Correction for Oversized Particles

Sieve	% Passing	% Retained
2"	100	0
3/4"	100	0
# 4	92.6	7.4
# 200	25.0	75.0

Proctor

- AASHTO T 99 A
  - AASHTO COP
- Max. DD = 116.6 pcf
- Opt. MC = 14.2 %

Run Bulk Specific Gravity (G_{sb}) of Rock

- G_{sb}= 2.588

Calculate corrected proctor value and optimum moisture content

- Worksheet

AASHTO Correction for Oversized Particles

(P_c)	% Coarse Material (0.1)	(field)	7.4
(P_F)	% Fine Material (0.1)	100 – (PC)	92.6
(MC_C)	Moisture Content of Coarse Material	(assume 2 %)	2.0
(MC_F)	Moisture Content of Fine Material	(proctor)	14.2
(MC_T)	Corrected Total Moisture Content	$\frac{(MC_F \times P_F) + (MC_C \times P_C)}{100}$	
(D_F)	Dry Density of Fine Material	(proctor)	116.6
(Gsb)	Bulk Specific Gravity of Coarse Material	(lab test)	2.588
(k)	Unit Weight of Coarse Material	Gsb x 62.4 = 2.588 x 62.4	161.491
(Dd)	Corrected Total Dry Density	$\frac{100 \times D_F \times k}{(D_F \times P_C) + (k \times P_F)}$	

Proctor Adjustments

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In-Place Density and Moisture Content of Soil by Nuclear Methods

AASHTO T 310

cttp
Center for Training Transportation Professionals

Density Gauge

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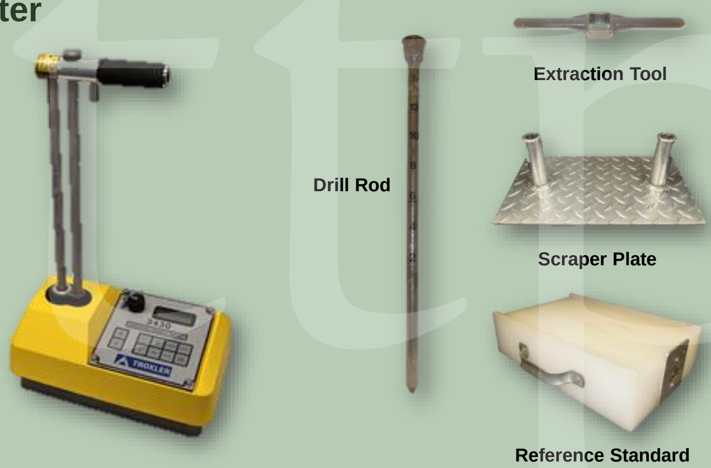
Apparatus

Nuclear Densometer



Measurements

Direct Measurements

- **Wet Density**
- **Moisture Content**

Calculated Values

- **Dry Density**

$$DD = \frac{WD}{\left(1 + \frac{MC}{100\ \%}\right)}$$

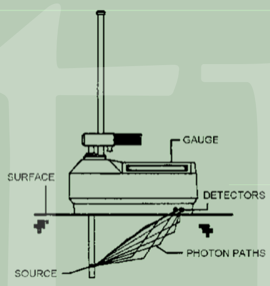
- **% Compaction**

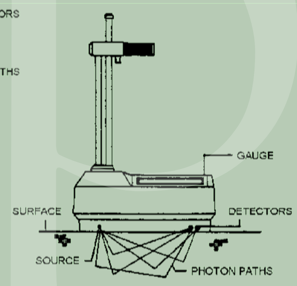
$$\%\ PR = \frac{\text{Gauge DD}}{\text{Proctor DD}} \times 100\ \%$$

Modes of Operation

Direct Transmission
- Measures the density of the material between the source and the surface

Backscatter
- Measures the density of the material close to the surface (80% in top 2")



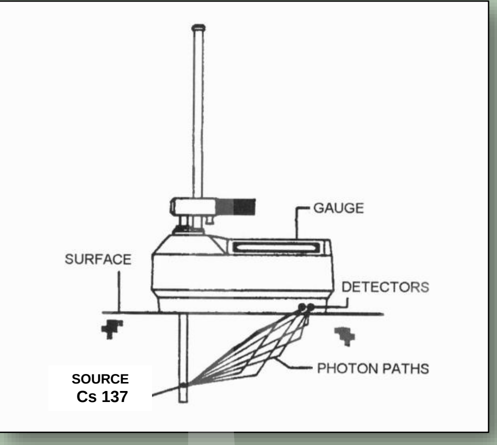


Wet Density

Source - Cesium 137
- Gamma Photons

Detectors
- Geiger – Mueller

Measurement
- The higher the density of a material, the lower the count values

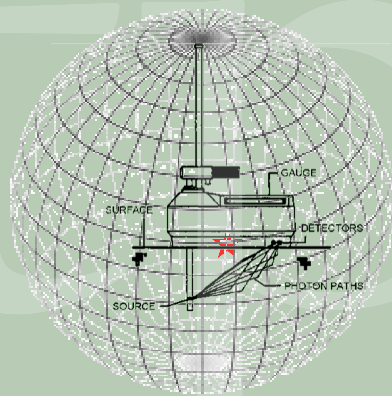


Moisture

Source – Am 241: BE 9
- Neutrons

Detectors
- Helium – 3

Measurement
- Neutrons are slowed by collisions with hydrogen
- Measurement depth is a function of the moisture content (unknown)



Density Gauge

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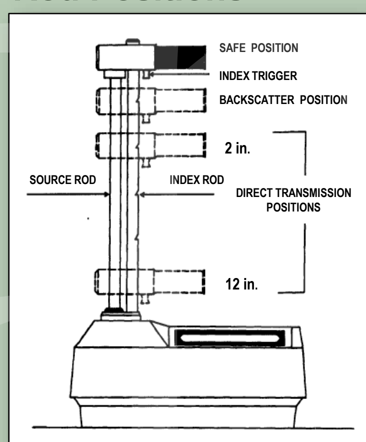
Calibration

Radioactive Sources
- Aging changes the relationship between count rates and gauge outputs

Calibration
- Initially
- 24 months
  - Or yearly verification

Source Rod Positions



Density Gauge

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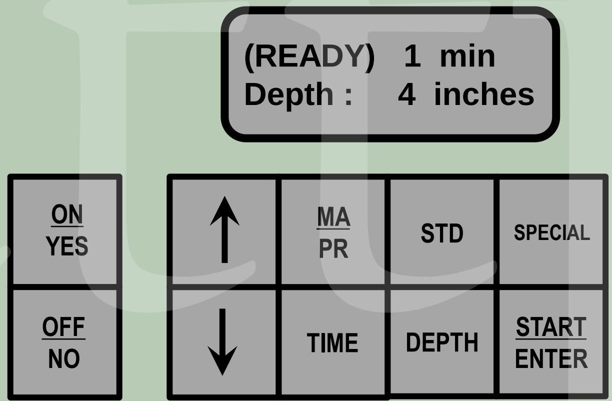
Troxler 3430

Keypad

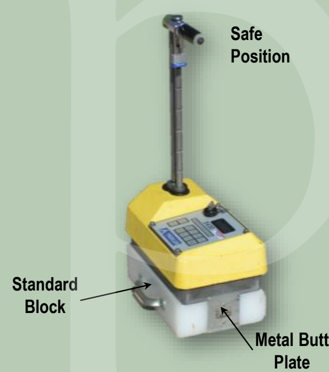


Standard Count

Adjusts for source decay and background radiation
- Used daily to determine the proper functioning of gauge

Site Selection
- Concrete or Asphalt
- ≥ 10' from large objects
- ≥ 30' from any other radioactive sources

Run Standard Count
- Place gauge on Standard Block
- Rod in "Safe" position
- Press <Standard>



Standard Count Compliance

Use procedure recommended by the gauge manufacturer

- **If none given by manufacturer, use**

$$Ns = No \pm 1.96\sqrt{No / F}$$

- ~ **Ns = new standard count**
- ~ **No = average of last 4 standard counts**
- ~ **F = pre-scale factor**

Troxler, Humbolt, InstroTek, & CPN Gauges require :

- **± 1 % Density**
- **± 2 % Moisture**
- **From the average of the last 4 standard counts taken**

Determining Compliance – Ratio Method

Average last 4 counts

Date	DS	MS
May 5th	2251	650
May 6th	2260	642
May 7th	2258	645
May 8th	2262	648
Average	2258	646

Take new standard

New Counts	2240	630

Determine Ratios

- **Density (± 1 %)**

Ratio Range = 0.99 – 1.01

P

- ~ **2240 / 2258 = 0.9920…**
- ~ **2258 / 2240 = 1.0080…**

- **Moisture (± 2 %)**

Ratio Range = 0.98 – 1.02

F

- ~ **630 / 646 = 0.9752…**
- ~ **646 / 630 = 1.0253…**

Determining Compliance – Range Method

Average last 4 counts

Date	DS	MS
May 5th	2251	650
May 6th	2260	642
May 7th	2258	645
May 8th	2262	648
Average	2258	646

Take new standard

New Counts 2240 630

Determine Ranges

- **Density (± 1 %)**
  2258 x 0.01 = ± 22
  P ~ 2258 – 2240 = 18
- **Moisture (± 2 %)**
  646 x 0.02 = ± 12
  F ~ 646 – 630 = 16

Density Gauge 193

Determining Compliance

Determine if the standard counts pass or fail

Date	DS	MS
May 10th	2275	588
May 12th	2260	551
May 13th	2265	565
May 15th	2262	556
Average		

New Counts 2246 575

Density Gauge 194

Failing Standard Counts

1. **Re-run standard count**
   - ~ **Check set-up**
2. **Establish a new average**
   - ~ **Run 4 new standard counts**
     - ~ Gauge Drift Best Practice
       - ~ Max. Deviation DS = 25
       - ~ Max Deviation MS = 12
   - ~ **Run new standard count and compare to new average**

Pass – Proceed to testing **Fail – Repair gauge**

Density Gauge

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Passing Standard Counts

Proceed to testing

Density Gauge

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Procedure

Prepare Surface

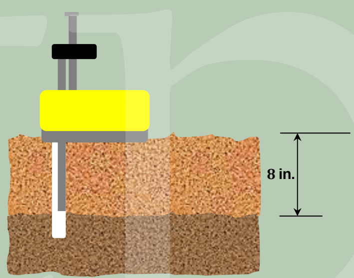
- Remove any dry or loose materials
- Smooth and level soil surface
- Fill any voids with native fines or sand
  - ~ No more than 10% of footprint should be filled
  - ~ Filler pad thickness should not exceed 1/8" in depth

Density Gauge 198

Procedure

Test depth should be equal to the lift thickness

- Test Depth is entered into gauge
- Test Depth is the depth the source rod should be extended to
- Test depth should never exceed lift thickness



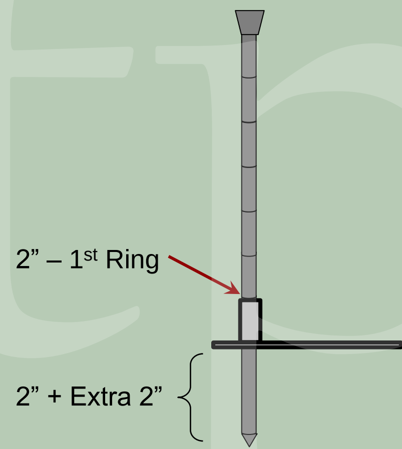
Test Depth = 8 inches

Density Gauge 199

Procedure

Hole

- **Hole should be at least 2 inches deeper than test depth**
- **Pin markings include the extra 2" required**



Procedure

Drill Hole

- **Place scraper plate on prepared test site**
- **Attach extraction tool and insert drill rod**
- **Step firmly on center of plate and hammer drill rod at least 2" deeper than test depth**
  - ~ **Perpendicular to surface**

Procedure

Remove drill rod with an upward, twisting motion

Mark plate footprint and hole location

Remove tools from area

- ≈ 3 ft away

Procedure

Check gauge parameters

- Time (1 minute)
- Depth (lift thickness)
- Max. Density (proctor)

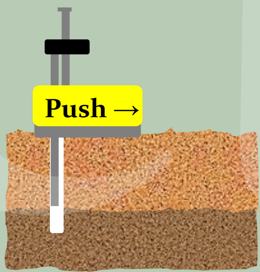
Place gauge in footprint

- Align rod with hole marks

Lower rod to test depth

Procedure

Snug gauge back against hole
- Check contact with soil



Start Test

Move away from gauge
- ≈ 3 feet

Procedure

Safe Rod

Record Data

- Wet Density
- Dry Density
- % Compaction
- % Moisture
- Location

Error Sources!
- Source rod not "clicked into position"
- Depth set incorrectly
- Gaps under gauge after rod insertion
- External causes
  - ~ Ground Vibration
  - ~ Drainage structures
  - ~ Power lines

What’s wrong?

Density Gauge 206

What’s wrong?

Density Gauge 207

% Compaction Calculation

If the correct proctor value was active in the gauge at the time of testing and a true moisture content is returned by the gauge:

% Compaction = % PR from Gauge

If the proctor value was not available at the time of testing:

$$\% \text{ PR} = \% \text{ Compaction} = \frac{\text{Gauge DD}}{\text{Proctor DD}} \times 100$$

% Compaction

Determine the % compaction

Gauge DD	113.0 lb/ft³ @ 12.4 %
Proctor	115.9 lb/ft³ @ 14.0 %

$$\% \text{ PR} = \frac{\text{Gauge DD}}{\text{Proctor DD}} \times 100$$

$$\% \text{ PR} = \frac{113.0}{115.9} \times 100 = 97.498 = 97.5$$

% PR = 97.5 %

% Compaction

Determine the % compaction

Gauge DD	**135.6 lb/ft³ @ 6.3 %**
Proctor	**138.0 lb/ft³ @ 6.5 %**

$$\% PR = \frac{\text{Gauge DD}}{\text{Proctor DD}} \times 100$$

% Compaction

Determine the % compaction

Test	DD	MC
Gauge (8 % Coarse)	114.0 pcf	12.5 %
Proctor (0 % Coarse)	116.0 pcf	14.0 %
Proctor (8 % Coarse)	119.3 pcf	13.0 %

$$\% PR = \frac{\text{Gauge DD}}{\text{Proctor DD}} \times 100$$

$$\% PR = \frac{114.0}{119.3} \times 100 = 95.557 = 95.6$$

% PR = 95.6 %

Moisture Offset

Corrects the gauge's inaccurate moisture content readings due to substances found in the soil

- Cement, Gypsum, Coal, Lime (- correction)
  - ~ High Hydrogen Forms
- Boron, Cadmium, Chlorine (+ correction)
  - ~ Neutron Absorbing

Take gauge MC readings at 5 different locations

Collect moisture samples from center of footprint at each location

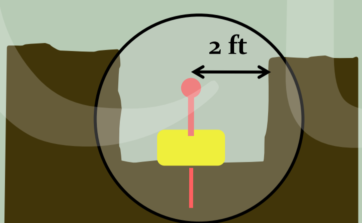
- Run oven dry moisture contents

Compute moisture offset according to the gauge manufacturer's recommendations

Trench Offset

Corrects moisture and shallow density readings

Use anytime gauge is within 2 feet of a vertical soil structure



Take a normal standard count outside trench

Put gauge on standard block inside trench

- Take a four minute reading with the rod in the "safe" position

Record trench counts

Offset = Trench - Standard

ARDOT Specifications

ARDOT specification limits are considered absolute limits !

- Observed or calculated values are not rounded for determination of compliance
  - ~ Compared directly with the limit
  - ~ Average values are rounded to the same # of significant digits
- Any deviation outside limits is non-compliance
  - ~ Failing test

ARDOT Specifications

Density Specifications

- Embankment ≥ 95 % Compaction
- Subgrade ≥ 95 % Compaction
- Base Aggregate ≥ 98 % Compaction

Moisture Specification

- ARDOT Moisture "At or near opt. moisture"

ARDOT Specifications

Base Aggregate
- Test Quantities
  - ~ Contractor - 1000 tons
  - ~ ARDOT - 4000 tons
- Tests for QC
  - ~ Gradation
  - ~ Density & Moisture
  - ~ Plasticity Index
  - ~ Thickness if Specified
    - ~ Sounding

Compacted Embankment
- Test Quantity
  - ~ 3000 yd³ / 1 per lift min.
- Tests for QC
  - ~ Density & Moisture

Granular Borrow
- Additional Tests for QC
  - ~ Gradation
  - ~ Plasticity Index

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