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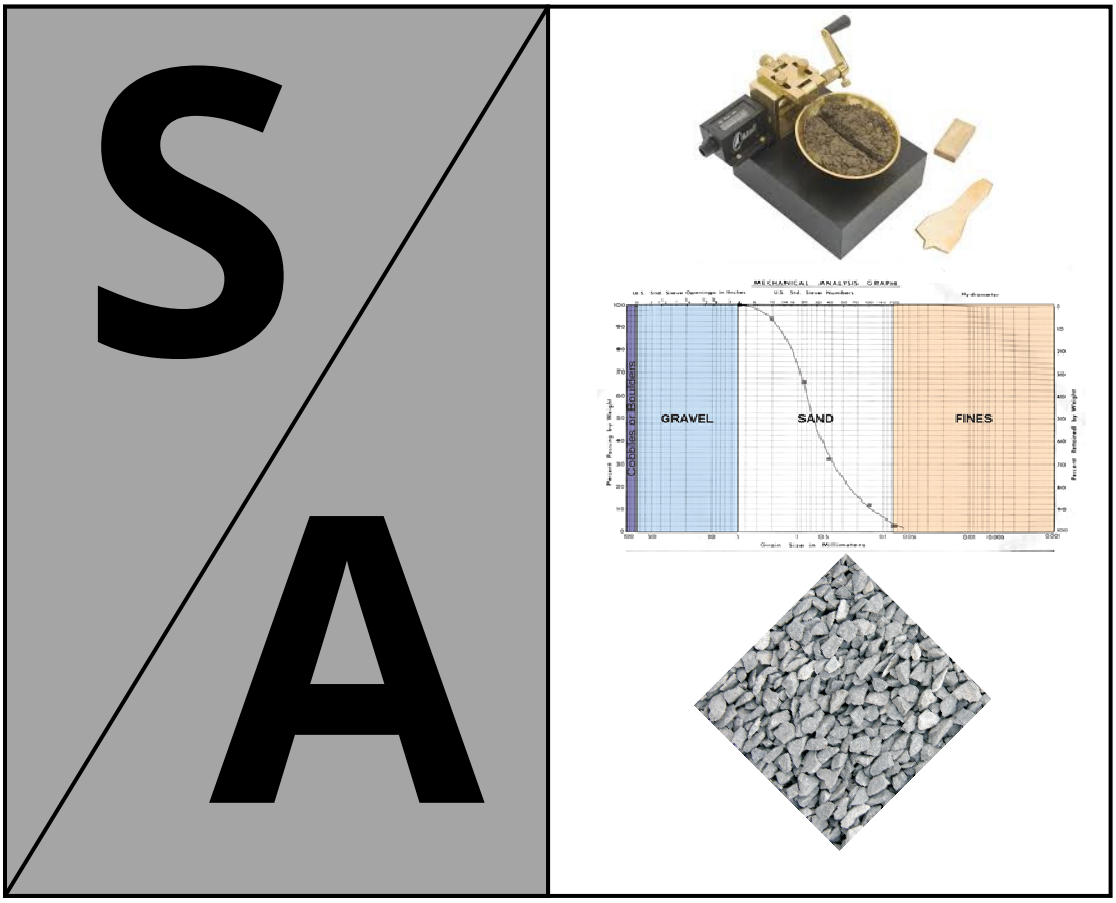
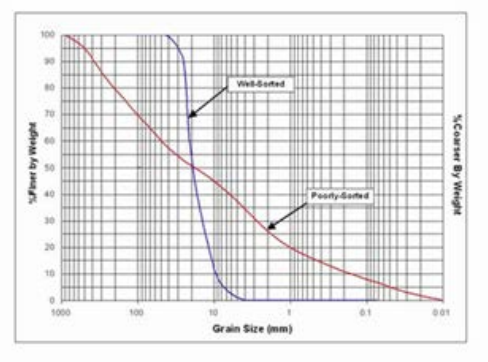


Soils and Aggregate Technician Course

Tennessee Department of Transportation

Volume 3.2



Soils and Aggregate Technician Course

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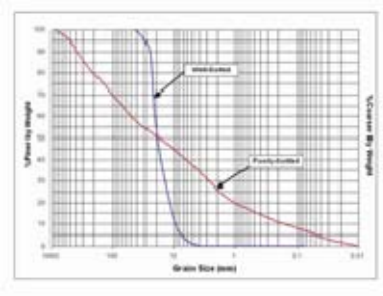

Soils & Aggregate Technician Course

Volume 3.2

Class Schedule

Day 1

1. Registration
2. Introduction to the Course
3. Sampling Aggregates
4. Reducing Samples of Aggregates to Testing Size
5. Total Evaporable Moisture Content of Aggregate by Drying
6. Break
7. Material Finer Than the No. 200 (75μm)
8. Sieve Analysis of Fine and Coarse Aggregate
9. LUNCH
10. Embankments and Embankment Materials
11. Compaction and Density Concepts
12. Break
13. Embankment Placement
14. Quality Acceptance Testing

Day 2

Exam Review/Questions

Exam

Welcome!

Soils and Aggregate Technician Certification

TN TDOT Department of Transportation

Introduction

- Technician Certification Program
- Purpose
- Who's Who
- Course Highlights
- Written Examination
- Results/Certification
- Resources/Contacts
- Summary/Questions

TN TDOT Department of Transportation

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S & A Technician Certification

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Technician Certification Program

- Asphalt Roadway Inspector
- Asphalt Plant Inspector
- Asphalt Mix Design
- Concrete Field Testing
- Concrete Plant Quality Control
- Concrete Mix Design
- Soils and Aggregate
- Nuclear Gauge Safety (TDOT Employees Only)

S & A Technician Certification

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Purpose of Certification

- To ensure proper performance of tests
- To improve reliability of results
- For quality control
- To comply with federal requirements

S & A Technician Certification

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Course Highlights

- Course schedule
  - Slide presentations
    - Introduction to Soils and Aggregates
    - 5 Test methods for Aggregate
    - Soil Testing and Properties
    - TDOT Specifications
  - Written exam
  - Results
  - Certification
- Recertification
  - every 5 years

S & A Technician Certification

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Written Examination

- Consists of:
  - 50 questions
  - Open-book
  - Two hours to complete
- To Pass:
  - Must get 70% overall
  - 35 of 50 questions correct

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Results

- Available within one week of completion
- Contact the Headquarters Materials & Tests Training Coordinator, Kim Whitby
  - kimberly.whitby@tn.gov
  - 615-350-4158

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Resources

- Course materials
  - Course textbook
  - Presentation slides and videos
  - Handouts
- TDOT
  - Standard Specifications, January 1, 2015
  - Special Provisions
- Contacts
  - Regional Materials Supervisors

S & A Technician Certification

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Resources

- Tennessee Department of Transportation
  - http://www.tdot.state.tn.us/
- American Road & Transportation Builders Association
  - http://www.artba.org/
- Tennessee Road Builders Association
  - http://www.trba.org/
- Tennessee Ready Mixed Concrete Association
  - http://www.trmca.org/
- American Association of State Highway Transportation Officials
  - http://www.aashto.org/
- American Society of Testing Materials
  - http://www.astm.org/
- American Concrete Institute
  - http://www.aci-int.org/
- Construction Materials Engineering Council
  - http://www.cmec.org/
- Portland Cement Association
  - http://www.portcement.org/

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Questions

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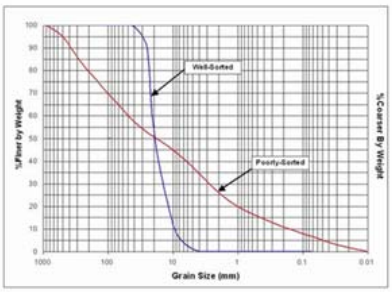

Soils & Aggregate Technician Course

Volume 3.2

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1

Sampling of Aggregates

AASHTO T 2

ASTM D 75

TDOT Standard Method of Test for

Sampling of Aggregates

References

TDOT Standard Specifications
AASHTO T 2
ASTM D 75

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Apparatus

- **Shovel**
- **Scoops**
- **Brushes**
- **Sampling tubes**
- **Sample containers**
- **Tags**

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Purpose

- **Preliminary investigation of the potential source of supply**
  - **Sample at source**
  - **Complete quality testing (dependent upon application)**
- **Control of the product at the source**
- **Control of the operations at the site of use**
  - **Project site**
  - **Concrete plant**
- **Acceptance or rejection of the materials**
  - **TDOT Standard Specifications**

Size of Aggregate

- **<u>Nominal maximum size</u> of aggregate is the first sieve upon which any material is retained**
- **<u>Maximum size</u> of aggregate is the sieve size above the nominal maximum size**

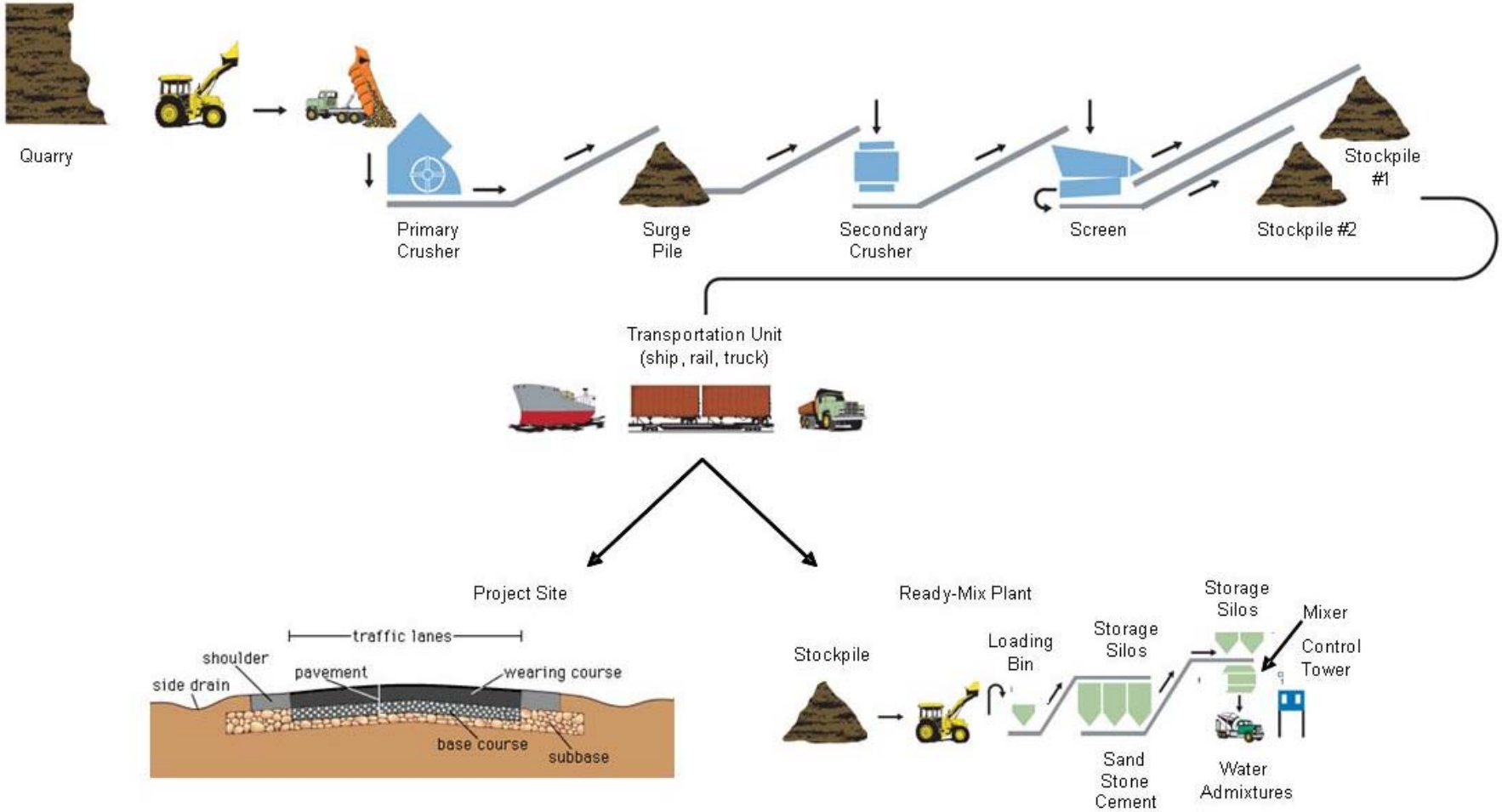
Field Sample Size

D75/D75M – 13

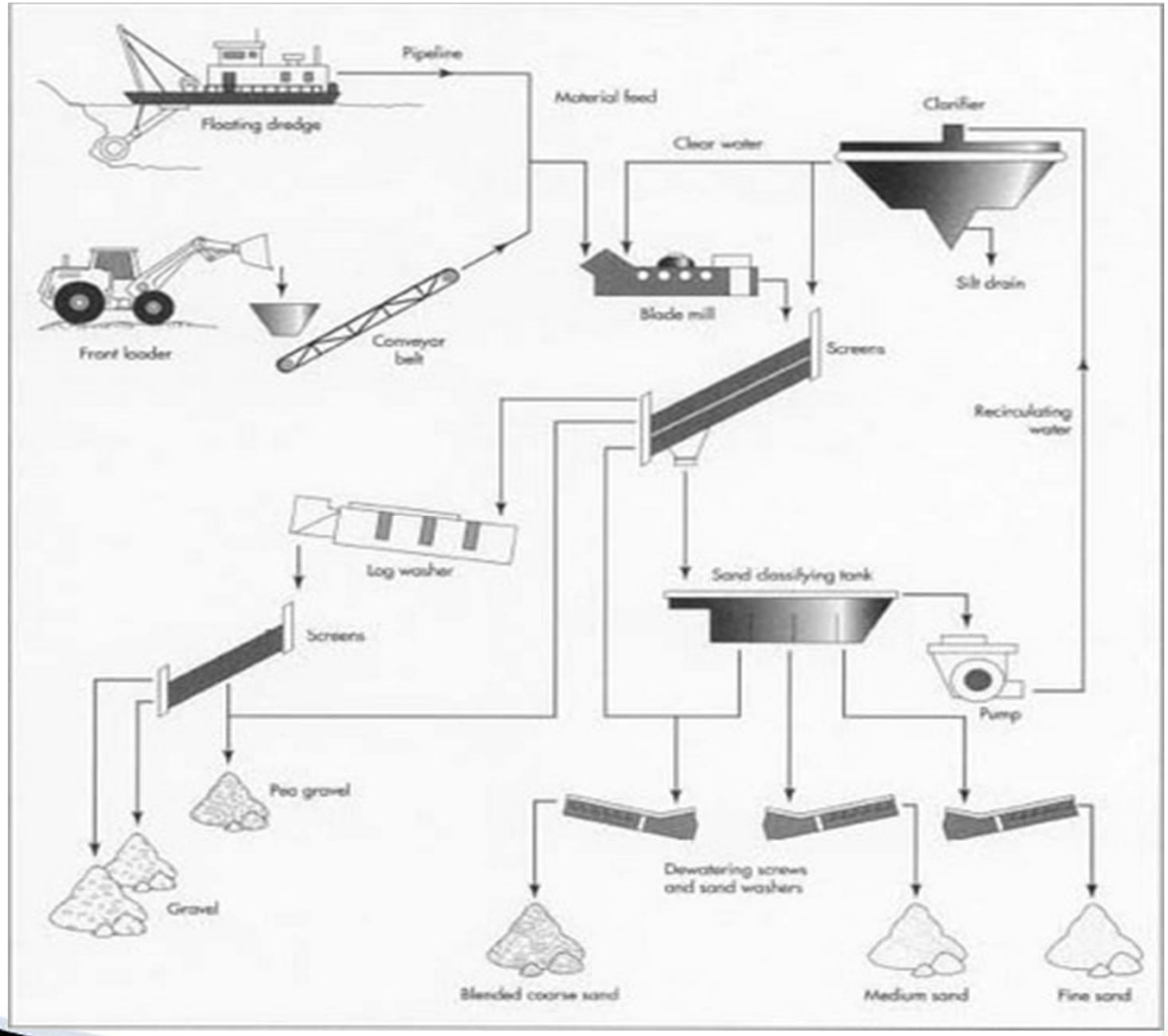
TABLE 1 Minimum Size of Field Samples

Aggregate Size[A]	Field Sample Mass, min, kg[B] [lb]	Field Sample Volume, min, L [gal]
Fine Aggregate		
2.36 mm [No. 8]	10 [22]	8 [2]
4.75 mm [No. 4]	10 [22]	8 [2]
Coarse Aggregate		
9.5 mm [⅜ in.]	10 [22]	8 [2]
12.5 mm [½ in.]	15 [35]	12 [3]
19.0 mm [¾ in.]	25 [55]	20 [5]
25.0 mm [1 in.]	50 [110]	40 [10]
37.5 mm [1½ in.]	75 [165]	60 [15]
50 mm [2 in.]	100 [220]	80 [21]
63 mm [2½ in.]	125 [275]	100 [26]
75 mm [3 in.]	150 [330]	120 [32]
90 mm [3½ in.]	175 [385]	140 [37]

Aggregate Production and Use



Aggregate Production and Use



Methods of Sampling

- Flowing aggregate stream
- Conveyor belt
- Stockpiles
  - with power equipment
  - without power equipment
- Roadways
- Transportation units

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Flowing Aggregate Stream

- From bins, for example
- <u>Three</u> increments
- Each increment obtained using a suitable sampling device
- Device must be capable of interrupting the entire flow of material as it passes off the belt

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Conveyor Belts

- Three increments
- Production suspended while sampling
- Designated sampling area
- Templates useful for defining sampling area
- All material within sampling area is removed including fines (with a brush)

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Stockpiles

- Stockpile must be checked for segregation and noted in log
- Segregation is the separation of varying sizes of aggregate
- Power equipment is recommended
- Portions collected at various locations around the main stockpile

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With Power Equipment

- **Loader bucket digs straight into pile level to ground**
- **Loader bucket is raised (perpendicular to the ground) through the entire height of the pile**

With Power Equipment

- **Portion is dropped onto a clear spot away from the main pile**
- **The loader is then used to blend and backblade the smaller stockpile**

With Power Equipment

- **The new stockpile can now be sampled at even intervals**
- **Material is obtained from each location with a shovel by digging into the pile**
- **The <u>three</u> increments are then combined to comprise the final field sample**

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Without Power Equipment

If power equipment is not available:

- **The stockpile is checked for segregation (and noted in log)**
- **The pile is visually divided into three even sections**
- **Portions are obtained from each section at least 12" below the surface by removing the outer layer of material**
- **The <u>three</u> increments are then combined to comprise the final field sample**

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Without Power Equipment

In lieu of shoveling:

- **The stockpile is checked for segregation (and noted in log)**
- **Sampling tubes may be used**
- **Sampling tubes may <u>not be</u> used on stockpiles containing coarse aggregate**
- **A minimum of <u>five</u> increments must be collected**
- **The <u>five</u> increments are then combined to comprise the final field sample**

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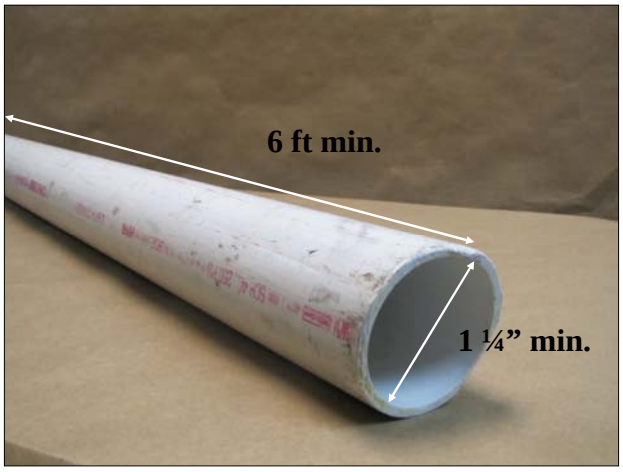
Without Power Equipment
(Sampling Tube)



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Roadways

- <u>Three</u> increments
- Sample obtained from uncompacted or loosely-compacted base or sub base material
- Predetermined random locations
- Full depth of layer must be sampled
- Avoid contamination from underlying material

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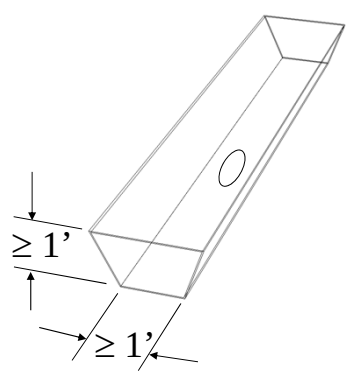
Transportation Units

- Railroad cars, barges, trucks
- Power equipment is recommended
- Various levels and random locations
- <u>Three</u> or more trenches



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Sample Containers

- Durable
- Strong
- Able to be carried

  [≤ 50 lbs. (23 kg)]
- Portion the sample, if necessary
- Appropriate container for test to be performed

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Tagging the Sample

Project Number: 55001-3231-18

Date Sampled: 11 Mar 02 Submitted: 12 Mar 02

Sampled by: F. Flintstone

Submitted by: F. Flintstone

Producer: Stone Materials, Inc.

Pit Number: 185 Sampled from: Stockpile

County: Davidson Region: 3

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Questions

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2

Reducing Samples of Aggregate to Testing Size

AASHTO T 248

ASTM C 702

TDOT Standard Method of Test for

Reducing Samples of Aggregate to Testing Size

References

TDOT Standard Specifications
AASHTO T 248
ASTM C 702

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Methods of Reduction

- **Method A - Mechanical Splitter**
- **Method B - Cone and Quarter**
- **Method C - Miniature Stockpile**

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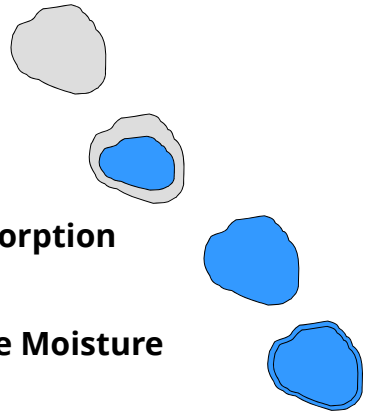
To Determine Method

- **Moisture condition of the aggregate**
  - **Dry**
  - **Moist**
  - **SSD/Absorption**
  - **Wet/Free Moisture**



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To Determine Method

- **Size of aggregate**
  - **Coarse**
  - **Fine**
  - **Combined**

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Determine Method

Moisture \ Aggregate Size	Coarse	Combined	Fine
Drier than saturated-surface-dry and SSD	A, B	A, B	A
Free moisture on surface	A, B	A, B	B, C

Splitting Method

- Method A - Mechanical Splitter
- Method B - Cone and Quarter
- Method C - Miniature Stockpile

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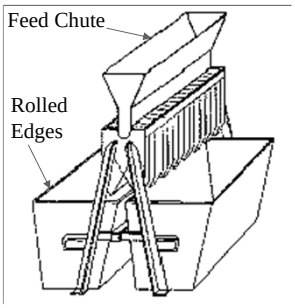
Mechanical Splitter / Method A

For Coarse and Combined Aggregate

- Even number of chutes
- Chutes of equal width
- At least 8 chutes
- Individual chutes about 50% larger than largest particles



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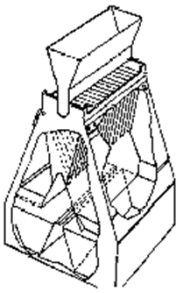
Mechanical Splitter / Method A

For Fine Aggregate

- Even number of chutes
- Chutes of equal width
- At least 12 chutes
- Individual chutes about 50% larger than largest particles (3/4" max.)



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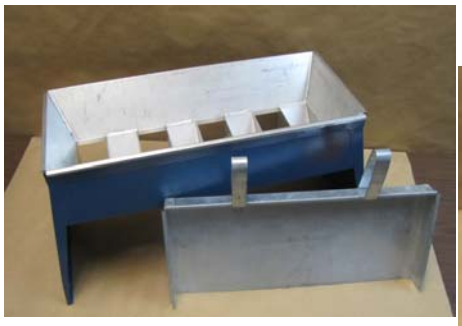
Mechanical Splitter / Method A



COARSE or COMBINED AGGREGATE

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Mechanical Splitter / Method A

FINE AGGREGATE

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Cone and Quarter / Method B

Cone the sample on a hard, clean, level surface.

Mix. Form a new cone.

Flatten the cone to a uniform thickness.

Diameter = 4 x thickness to 8 x thickness

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Cone and Quarter / Method B

Divide the flattened cone.

After dividing, remove two diagonal quarters (including fines).

Mix and quarter the remaining material until sample is adequately reduced.

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Cone and Quarter / Method B

Turn material over 3 times and place into a cone

Flatten to uniform thickness D=4t to 8t

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Cone and Quarter / Method B

Use scoop to separate into four quarters

Collect diagonal quadrants as the sample

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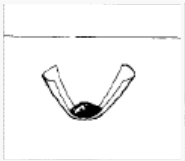
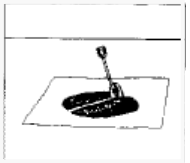
Quartering Alternative / Method B

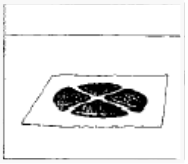
Mix with a shovel or with the canvas blanket



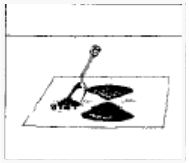
Form the material into a cone



After flattening the cone, use a shovel to divide



Quarter the material



Remove diagonal quarters (including fines)

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Quartering Alternative/Method B

Mix on canvas cloth by rolling aggregate on cloth.

Flatten aggregate pile to constant thickness with shovel.

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Quartering Alternative/Method B

Using a stick, divide the aggregate into four separate quarters

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Quartering Alternative/Method B

Collect fines using brush to include with the sample.

Remove diagonal quarters to use including the fines.

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Miniature Stockpile / Method C

- **Place sample on hard, clean, level surface**
- **Mix thoroughly by turning over three times**
- **Form a cone with the last turning**
- **Flatten, if desired, to a uniform thickness**
- **Select at least five increments at random locations using a shovel, scoop, or spoon**

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Miniature Stockpile / Method C

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3

Total Evaporable Moisture Content of Aggregate by Drying

AASHTO T 255

ASTM C 566

TDOT Standard Method of Test for

Total Evaporable Moisture Content of Aggregate by Drying

References

TDOT Standard Specifications
AASHTO T 255
ASTM C566

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Apparatus

- **Balance**
- **Heat Source**
- **Sample Container**
- **Stirring Spoon**

and Aggregate Technician Certification

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Sample Size

TABLE 1 Sample Size for Aggregate

Nominal Maximum Size of Aggregate, mm (in.)[A]	Mass of Normal Weight Aggregate Sample, min, kg[B]
4.75 (0.187) (No. 4)	0.5
9.5 (⅜)	1.5
12.5 (½)	2
19.0 (¾)	3
25.0 (1)	4
37.5 (1½)	6
50 (2)	8
63 (2½)	10
75 (3)	13
90 (3½)	16
100 (4)	25
150 (6)	50

[A] Based on sieves meeting Specification E11.
[B] Determine the minimum sample mass for lightweight aggregate by multiplying the value listed by the dry-loose unit mass of the aggregate in kg/m^3 (determined using Test Method C29/C29M) and dividing by 1600.

Samples

Determine Sample Mass

- **Weigh the sample to the nearest 0.1 of a unit of the original sample mass**

Dry the Sample

- **Dry the aggregate to a constant mass in an oven at 110 ± 5°C (230 ± 9°F)**
- **Allow the material to cool**

Reweigh the Sample

- **Weigh the sample to the nearest 0.1 of a unit of the original sample mass**

Calculations

$$P_{Moisture,Total} = \frac{M_{Original} - M_{Dry}}{M_{Dry}} \times 100$$

$$P = \frac{W - D}{D} \times 100$$

$$P = \frac{6285.6 - 6163.8}{6163.8} \times 100 = 1.98\% \approx \underline{2.0\%}$$

Problem

Given:

- **Weight of the original sample (W) = 1092.4 g**
- **Weight of sample after drying (D) = 1080.5 g**

Determine:

Total percent (P) moisture content of the aggregate.

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Solution

$$P = \frac{W - D}{D} \times 100$$

$$P = \frac{1092.4 - 1080.5}{1080.5} \times 100 = 1.101 \approx \underline{1.1\%}$$

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Practice

Sample Number	Original Weight	Dry Weight	Moisture Content
1	588.3	570.9	
2	1556.8	1540.9	
3	1225	1220.1	
4	1665.2	1650.5	

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Solutions

Sample Number	Original Weight	Dry Weight	Moisture Content
1	588.3	570.9	3.04782
2	1556.8	1540.9	1.03186
3	1225.0	1220.1	0.40161
4	1665.2	1650.5	0.89064

$$p_1 = \frac{588.3 - 570.9}{570.9} \times 100 = 3.048 \sim 3.0\%$$

$$p_2 = \frac{1556.8 - 1540.9}{1540.9} \times 100 = 1.032 \sim 1.0\%$$

$$p_3 = \frac{1225.0 - 1220.1}{1220.1} \times 100 = 0.402 \sim 0.4\%$$

$$p_4 = \frac{1665.2 - 1650.5}{1650.5} \times 100 = 0.891 \sim 0.9\%$$

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Determine the percent moisture content in the wet condition:

Determine the percent moisture of the aggregate at SSD (Absorption):

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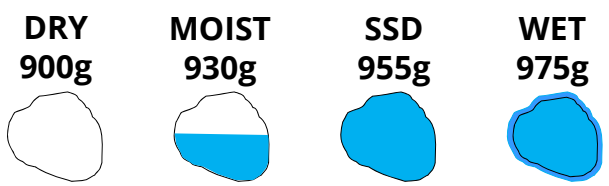

Determine the percent of free moisture on the sample:

Determine the amount of water the aggregate has in the wet condition:

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4

Materials Finer Than 75-µm (No.200) Sieve

In Mineral Aggregates by Washing

AASHTO T 11

ASTM C 117

TDOT Standard Method of Test for

Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

References

TDOT Standard Specifications
AASHTO T 11
ASTM C 117

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Apparatus

- **Balance**
- **Sieves**
- **Container**
- **Oven**
- **Wetting Agent**

and Aggregate Technician Certification

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Sample Size

Nominal Maximum Size[A]	Minimum Mass, g
4.75 mm (No. 4) or smaller	300
Greater than 4.75 mm (No. 4) to 9.5 mm (⅜ in.)	1000
Greater than 9.5 mm (⅜ in.) to 19.0 mm (¾ in.)	2500
Greater than 19.0 mm (¾ in.)	5000

[A] Based on sieve sizes meeting Specification E11.

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Minus 200 Material

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Dry the Material

- Dry the aggregate to a constant mass in an oven at 110 ± 5°C (230 ± 9°F)
- Allow the material to cool

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Determine the Sample Mass

- Weigh the sample to the nearest 0.1 of a unit of the original sample mass

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Two Procedures

Procedure A - Washing with plain water

- **Dust of Fracture**

Procedure B - Washing using a wetting agent

- **Clay Particles**

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Procedure

- **Place the sample in the container**
- **Add water to cover the sample**
- **Add wetting agent if performing Procedure B**

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Procedure

- Agitate the sample
- Use a spoon to stir, if desired
- Ensure complete separation of particles

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Procedure

- Pour the wash water with suspended solids over the nested sieves

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Procedure

- Repeat the washing with plain water
- Repeat until wash water is clear
- Use wetting agent first wash only

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Dry the Material

- Dry the aggregate to a constant mass in an oven at 110 ± 5°C (230 ± 9°F)
- Allow the material to cool

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Determine the Sample Mass

- **Weigh the sample to the nearest 0.1 of a unit of the original sample mass**

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Calculations

$$P_{\leq 75\,\mu m} = \frac{M_{Dry,Before} - M_{Dry,After}}{M_{Dry,Before}} \times 100$$

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

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Results

- **If the amount of material finer than 75-μm is <u>less than 10%</u> then report the results to the nearest 0.1.**
- **If the amount of material finer than 75- μm is <u>greater than 10%</u> then report the results to the nearest whole number.**

Problem

Given:

- **Original mass of the sample = 595.6 g**
- **Mass of the sample after washing = 579.3 g**

Determine:

- **The percent (P) of material finer than the No. 200 sieve in the sample.**

Solution

$$P_{\leq 75\,\mu m} = \frac{595.6 - 579.3}{595.6} \times 100 = 2.737 \approx \underline{2.7\%}$$

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Practice

Given:

- **Original mass of the sample = 6895.5 g**
- **Mass of the sample after washing = 6045.0 g**

Determine:

- **The percent (P) of material finer than the No. 200 sieve in the sample**

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Solution

$$P_{\leq 75\,\mu m} = \frac{6895.5 - 6045.0}{6895.5} \times 100 = 12.33 \approx \underline{12\%}$$

5

Sieve Analysis of Fine and Coarse Aggregates

AASHTO T 27

ASTM C 136

TDOT Standard Method of Test for

Sieve Analysis of Fine and Coarse Aggregates

References

TDOT Standard Specifications
AASHTO T 27
ASTM C 136

TN TDOT Department of Transportation

Apparatus

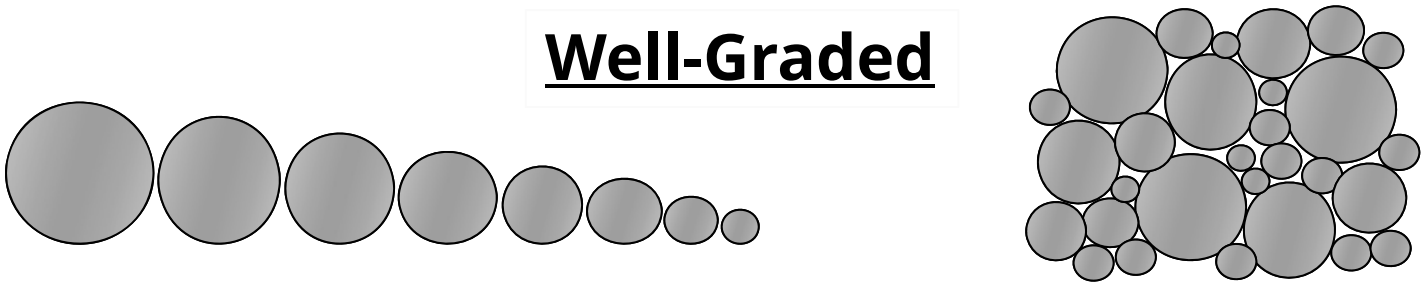
- **Balance**
- **Oven**
- **Sieves**
- **Mechanical Shaker**

and Aggregate Technician Certification

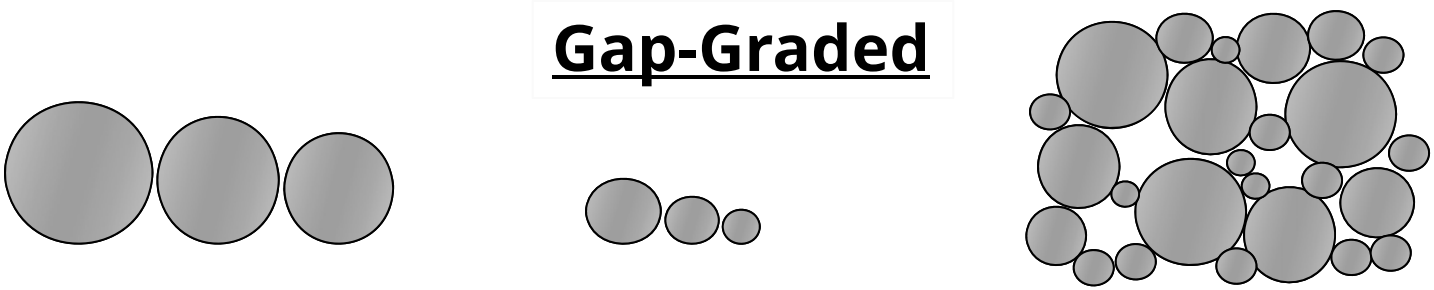
TN TDOT Department of Transportation

Aggregate Gradation

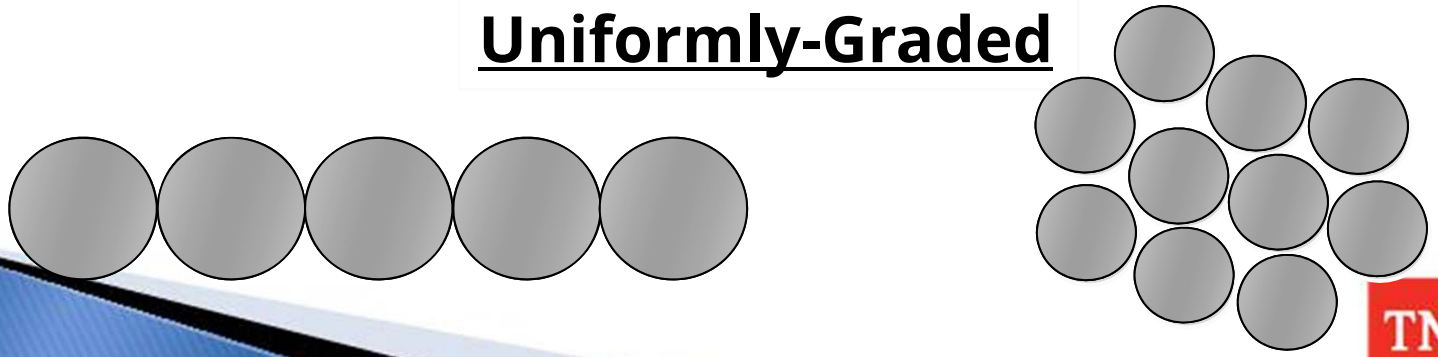
Well-Graded



Gap-Graded



Uniformly-Graded



Field Sample Size

D75/D75M – 13

TABLE 1 Minimum Size of Field Samples

Aggregate Size[A]	Field Sample Mass, min, kg[B] [lb]	Field Sample Volume, min, L [gal]
	Fine Aggregate	
2.36 mm [No. 8]	10 [22]	8 [2]
4.75 mm [No. 4]	10 [22]	8 [2]
	Coarse Aggregate	
9.5 mm [⅜ in.]	10 [22]	8 [2]
12.5 mm [½ in.]	15 [35]	12 [3]
19.0 mm [¾ in.]	25 [55]	20 [5]
25.0 mm [1 in.]	50 [110]	40 [10]
37.5 mm [1½ in.]	75 [165]	60 [15]
50 mm [2 in.]	100 [220]	80 [21]
63 mm [2½ in.]	125 [275]	100 [26]
75 mm [3 in.]	150 [330]	120 [32]
90 mm [3½ in.]	175 [385]	140 [37]

Test Sample Size

7.4 *Coarse Aggregate*—The size of the test sample of coarse aggregate shall conform with the following:

Nominal Maximum Size, Square Openings, mm (in.)	Test Sample Size, min, kg (lb)
9.5 (3/8)	1 (2)
12.5 (1/2)	2 (4)
19.0 (3/4)	5 (11)
25.0 (1)	10 (22)
37.5 (1 1/2)	15 (33)
50 (2)	20 (44)
63 (2 1/2)	35 (77)
75 (3)	60 (130)
90 (3 1/2)	100 (220)

Dry the Material

- Dry the aggregate to a constant mass in an oven at 110 ± 5°C (230 ± 9°F)
- Allow the material to cool

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Determine the Sample Mass

- Weigh the sample to the nearest 0.1 of a unit of the original sample mass

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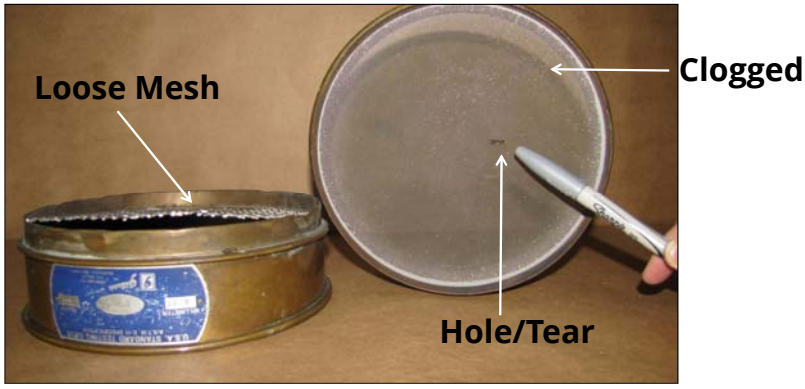
Sieves



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Mechanical Shaker

- **Use a mechanical shaker to agitate the sieves**

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Weighing

- **Weigh the sample to the nearest 0.1 of a unit of the original sample mass**

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Overloaded Sieve

Options for Overloading

- **Use larger sieve**
- **Portion the sample**
- **Place another sieve in the nest**

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Maximum Loading of Sieves

TABLE 1 Maximum Allowable Quantity of Material Retained on a Sieve, kg

Sieve Opening Size, mm	Nominal Dimensions of Sieve[A]				
	203.2-mm dia[B]	254-mm dia[B]	304.8-mm dia[B]	350 by 350 mm	372 by 580 mm
	Sieving Area, m^2				
	0.0285	0.0457	0.0670	0.1225	0.2158
125	C	C	C	C	67.4
100	C	C	C	30.6	53.9
90	C	C	15.1	27.6	48.5
75	C	8.6	12.6	23.0	40.5
63	C	7.2	10.6	19.3	34.0
50	3.6	5.7	8.4	15.3	27.0
37.5	2.7	4.3	6.3	11.5	20.2
25.0	1.8	2.9	4.2	7.7	13.5
19.0	1.4	2.2	3.2	5.8	10.2
12.5	0.89	1.4	2.1	3.8	6.7
9.5	0.67	1.1	1.6	2.9	5.1
4.75	0.33	0.54	0.80	1.5	2.6

[A] Sieve frame dimensions in inch units: 8.0-in. diameter; 10.0-in. diameter, 12.0-in. diameter; 13.8 by 13.8 in. (14 by 14 in. nominal); 14.6 by 22.8 in. (16 by 24 in. nominal).

[B] The sieve area for round sieve frames is based on an effective diameter 12.7 mm (½ in.) less than the nominal frame diameter, because Specification E11 permits the sealer between the sieve cloth and the frame to extend 6.35 mm (¼ in.) over the sieve cloth. Thus the effective sieving diameter for a 203.2-mm (8.0-in.) diameter sieve frame is 190.5 mm (7.5 in.). Sieves produced by some manufacturers do not infringe on the sieve cloth by the full 6.35 mm (¼ in.).

[C] Sieves indicated have less than five full openings and should not be used for sieve testing except as provided in 8.6.

Sample Problem #1

Original Sample Mass (g)		507.8
Sieve Size or Designation		Individual Weight Retained (g)
4.75 mm	No. 4	0.0
2.36 mm	No. 8	51.0
1.18 mm	No. 16	98.0
600 um	No. 30	106.0
300 um	No. 50	117.0
150 um	No. 100	95.0
75 um	No. 200	29.0
< 75 um	< No. 200	11.0
Total		

Sample Problem #1

Original Sample Mass (g)		507.8
Sieve Size or Designation		Individual Weight Retained (g)
4.75 mm	No. 4	0.0
2.36 mm	No. 8	51.0
1.18 mm	No. 16	98.0
600 um	No. 30	106.0
300 um	No. 50	117.0
150 um	No. 100	95.0
75 um	No. 200	29.0
< 75 um	< No. 200	11.0
Total		507.0

$$\text{AASHTO Loss} = \frac{\text{Original Sample Mass} - \text{Sum of Individual Wt.}}{\text{Original Sample Mass}} \times 100$$

$$\text{AASHTO Loss} = \frac{507.8 - 507.0}{507.8} \times 100$$

✓ AASHTO Loss = 0.16% ≤ 0.3%

Sample Problem # 1

Original Sample	507.8

Sieve Size or Designation		Individual Weight Retained (g)	Individual Percent Retained	Cumulative Percent Retained	Cumulative Percent Passing
4.75 mm	No. 4	0.0			
2.36 mm	No. 8	51.0			
1.18 mm	No. 16	98.0			
600 um	No. 30	106.0			
300 um	No. 50	117.0			
150 um	No. 100	95.0			
75 um	No. 200	29.0			
< 75 um	< No. 200	11.0			

Sample Problem # 1

Original Sample	507.8

Sieve Size or Designation		Individual Weight Retained (g)	Individual Percent Retained	Cumulative Percent Retained	Cumulative Percent Passing
4.75 mm	No. 4	0.0	0.0	0.0	100.0
2.36 mm	No. 8	51.0	10.0	10.0	90.0
1.18 mm	No. 16	98.0	19.3	29.3	70.7
600 um	No. 30	106.0	20.9	50.2	49.8
300 um	No. 50	117.0	23.0	73.3	26.7
150 um	No. 100	95.0	18.7	92.0	8.0
75 um	No. 200	29.0	5.7	97.7	2.3
< 75 um	< No. 200	11.0	2.2	99.8	0.2

Fineness Modulus

Sieve	Cumulative Percent Retained
3 in	
1 1/2 in	
3/4 in	
3/8 in	
No. 4	
No. 8	
No. 16	
No. 30	
No. 50	
No. 100	
Total	
FM	

Fineness Modulus

Sieve	Cumulative Percent Retained
3 in	0.0
1 1/2 in	0.0
3/4 in	0.0
3/8 in	0.0
No. 4	0.0
No. 8	10.0
No. 16	29.3
No. 30	50.2
No. 50	73.3
No. 100	92.0
Total	254.82
FM	2.55

Sample Problem #2

Original Sample Mass (g)		91.2
Sieve Size or Designation		Individual Weight Retained (g)
75 mm	3 in	0.0
50 mm	2 in	0.0
37.5 mm	1 1/2 in	6.0
25 mm	1 in	20.0
19 mm	3/4 in	16.0
12.5 mm	1/2 in	13.0
9.5 mm	3/8 in	28.0
4.75 mm	No. 4	8.0
< 4.75 mm	< No. 4	0.0
Total		

Sample Problem #2

Original Sample Mass (g)		91.2
Sieve Size or Designation		Individual Weight Retained (g)
75 mm	3 in	0.0
50 mm	2 in	0.0
37.5 mm	1 1/2 in	6.0
25 mm	1 in	20.0
19 mm	3/4 in	16.0
12.5 mm	1/2 in	13.0
9.5 mm	3/8 in	28.0
4.75 mm	No. 4	8.0
< 4.75 mm	< No. 4	0.0
Total		91.0

$$\text{AASHTO Loss} = \frac{\text{Original Sample Mass} - \text{Sum of Individual Weights}}{\text{Original Sample Mass}} \times 100$$

$$\text{AASHTO Loss} = \frac{91.2 - 91.0}{91.2} \times 100$$

✓ $\text{AASHTO Loss} = 0.22\% \leq 0.3\%$

Sample Problem # 2

Original Sample	91.2

Sieve Size or Designation		Individual Weight Retained	Individual Percent Retained	Cumulative Percent Retained	Cumulative Percent Passing
75 mm	3 in	0.0	0.0	0.0	100.0
50 mm	2 in	0.0	0.0	0.0	100.0
37.5 mm	1 1/2 in	6.0			
25 mm	1 in	20.0			
19 mm	3/4 in	16.0			
12.5 mm	1/2 in	13.0			
9.5 mm	3/8 in	28.0			
4.75 mm	No. 4	8.0			
< 4.75 mm	< No. 4	0.0			

Sample Problem # 2

Original Sample	91.2

Sieve Size or Designation		Individual Weight Retained	Individual Percent Retained	Cumulative Percent Retained	Cumulative Percent Passing
75 mm	3 in	0.0	0.0	0.0	100.0
50 mm	2 in	0.0	0.0	0.0	100.0
37.5 mm	1 1/2 in	6.0	6.6	6.6	93.4
25 mm	1 in	20.0	21.9	28.5	71.5
19 mm	3/4 in	16.0	17.5	46.0	54.0
12.5 mm	1/2 in	13.0	14.3	60.3	39.7
9.5 mm	3/8 in	28.0	30.7	91.0	9.0
4.75 mm	No. 4	8.0	8.8	99.8	0.2
< 4.75 mm	< No. 4	0.0	0.0	99.8	0.2

Fineness Modulus

Sieve	Cumulative Percent Retained
3 in	
1 1/2 in	
3/4 in	
3/8 in	
No. 4	
No. 8	
No. 16	
No. 30	
No. 50	
No. 100	
Total	
FM	

Fineness Modulus

Sieve	Cumulative Percent Retained
3 in	0.0
1 1/2 in	6.6
3/4 in	46.0
3/8 in	91.0
No. 4	99.8
No. 8	99.8
No. 16	99.8
No. 30	99.8
No. 50	99.8
No. 100	99.8
Total	742.34
FM	7.42

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6

Embankments and Embankment Materials

Embankments and Embankment Materials

References

TDOT Standard Specifications
(Section 205)
DT - Forms

TN TDOT Department of Transportation

Preparation of Embankment Areas Inspection Checklist

- Clearing and grubbing (removal of vegetation) satisfactorily performed
- Depressions or holes below the original ground are filled and compacted with suitable material before lifts are placed
- Where the original ground surface is less than three feet below the subgrade
  - all sod and vegetation is removed
  - unsuitable material is replaced with suitable material
  - the cleared surface is broken up to a depth of six inches and re-compacted
  - Cultivated sod not required to be removed before constructing the embankment
  - Compacted road surface containing granular materials lies within 3 feet of subgrade, scarify at least 6 inches and re-compact the scarified material
- Compacted road surfaces containing granular materials within 3 feet of the subgrade are scarified to a depth of 6 inches and re-compacted
- Concrete pavements and bases are removed and broken
- Embankment material must be placed in lifts
- Lifts are not placed on surfaces which are frozen or contain snow, mud or ice

and Aggregate Technician Certification

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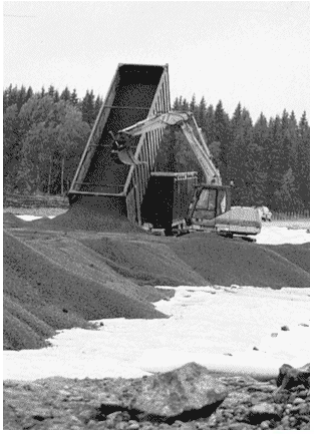
Major Embankment Materials

- Rock fragments
- Gravel
- Sand
- Silt
- Clay



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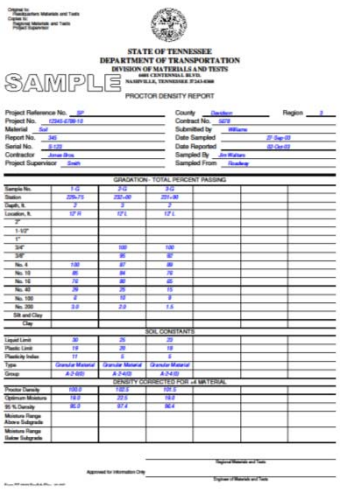
Form DT-0332 Proctor Density Report



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STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS
6601 CENTENNIAL BLVD.
NASHVILLE, TENNESSEE 37243-0360

SAMPLE

PROCTOR DENSITY REPORT

Project Reference No.	SP	County	Davidson
Project No.	13041-0708-13	Contract No.	5219
Material	Soil	Submitted by	Williams
Report No.	340	Date Sampled	27-Sep-03
Serial No.	S-123	Date Reported	02-Oct-03
Contractor	Jones Bros.	Sampled By	Jim Watson
Project Supervisor	Smith	Sampled From	Roadway

Region 3

GRADATION- TOTAL PERCENT PASSING

Sample No.	T-12	T-13	T-14			
Station	229+75	232+00	231+50			
Depth, ft.	2	3	2			
Location, ft.	12' R	12' L	12' L			
3"						
1 1/2"						
1"						
3/4"		100	100			
3/8"		95	92			
No. 4	100	87	89			
No. 10	85	84	74			
No. 16	74	80	65			
No. 40	29	25	15			
No. 100	8	10	9			
No. 200	3.5	2.3	1.5			
Silt and Clay						
Clay						

SOIL CONSTANTS

Liquid Limit	32	25	23			
Plastic Limit	19	20	18			
Plasticity Index	11	5	5			
Type	Granular Material	Granular Material	Granular Material			
Group	A-2-6(0)	A-3 (0)	A-3 (0)			

DENSITY CORRECTED FOR +4 MATERIAL

Proctor Density	108.0	110.5	105.3			
Optimum Moisture	19.0	20.0	18.0			
95 % Density	96.0	97.4	96.4			
Moisture Range Above Subgrade						
Moisture Range Below Subgrade						

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DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS

SAMPLE

6601 CENTENNIAL BLVD.
NASHVILLE, TENNESSEE 37243-0360

PROCTOR DENSITY REPORT

Project Reference No.	SP	County	Davidson	Region	3
Project No.	12345-6789-10	Contract No.	5678		
Material	Soil	Submitted by	Williams		
Report No.	345	Date Sampled	27-Sep-03		
Serial No.	S-123	Date Reported	02-Oct-03		
Contractor	Jones Bros.	Sampled By	Jim Walters		
Project Supervisor	Smith	Sampled From	Roadway		

GRADATION - TOTAL PERCENT PASSING						
Sample No.	1-G	2-G	3-G			
Station	229+75	232+00	231+90			
Depth, ft.	2	3	2			
Location, ft.	12' R	12' L	12' L			
2"						
1-1/2"						
1"						
3/4"		100	100			
3/8"		95	92			
No. 4	100	87	89			
No. 10	85	84	76			
No. 16	76	80	65			
No. 40	29	25	15			
No. 100	6	10	9			
No. 200	3.0	2.0	1.5			
Silt and Clay						
Clay						
SOIL CONSTANTS						
Liquid Limit	30	25	23			
Plastic Limit	19	20	18			
Plasticity Index	11	5	5			
Type	Granular Material	Granular Material	Granular Material			
Group	A-2-6(0)	A-2-4(0)	A-2-4(0)			
DENSITY CORRECTED FOR +4 MATERIAL						
Proctor Density	100.0	102.5	101.5			
Optimum Moisture	19.0	22.5	19.0			
95 % Density	95.0	97.4	96.4			
Moisture Range Above Subgrade						
Moisture Range Below Subgrade						

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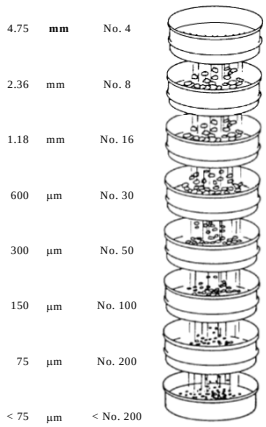
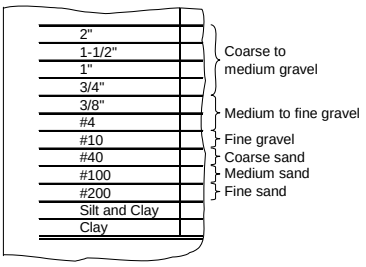
Form DT-0332 English (Rev. 10-03)

Gradation





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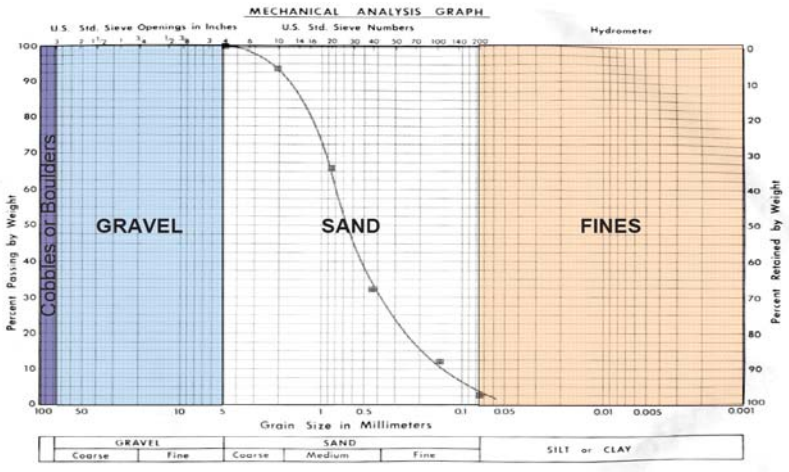
Gradation

(Grain Size Distribution)



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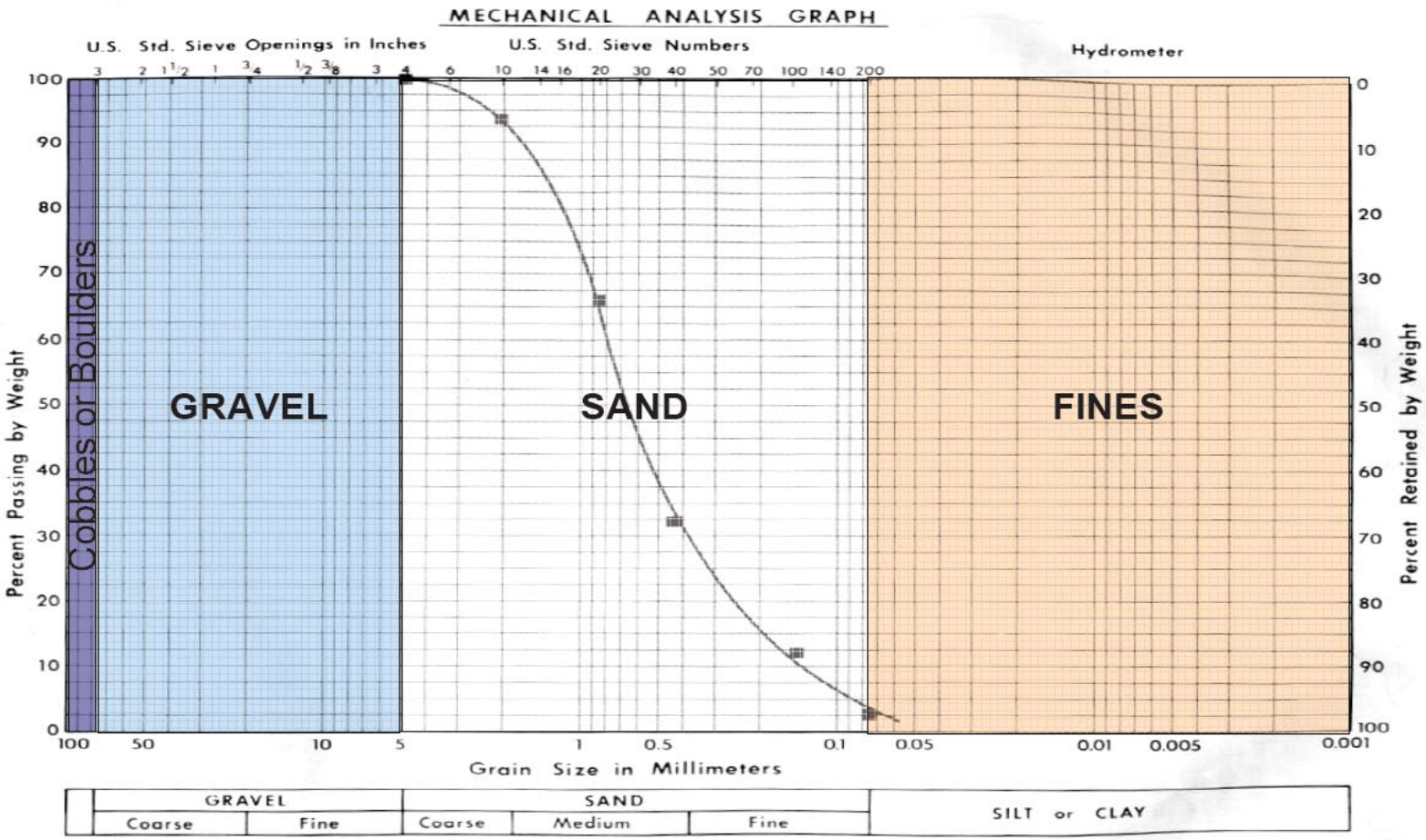
Gradation

(Grain Size Distribution)



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Gradation Example

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6601 CENTENNIAL BLVD.
NASHVILLE, TENNESSEE 37243-0360

PROCTOR DENSITY REPORT

Project Reference No. _____ County *MCMINN* Region *2*
Project No. *54000-1500-04* Contract No. _____
Material *Soil* Project Supervisor _____
Report No. _____ Date Sampled *04-Jan-03*
Serial No. *S-3* Date Reported *09-Jan-03*
Contractor _____ Sampled By _____
Producer _____ Sampled From _____

GRADATION - TOTAL PERCENT PASSING

Sample No.	1-A	2-A	3-A	4-A	5-A	6-A
Station	21+50	27+00	27+00	27+00	23+00	32+00
Depth, ft.	0'---5'	0'---8'	8'---17'	0'---3'	0'---13'	0'---8'
Location, ft.	C/L	60' Lt. C/L	60' Lt. C/L	C/L	30' Lt. C/L	C/L
2"						
1-1/2"						
1"						
3/4"		100	100			100
3/8"		98	93	100	100	97
No. 4	100	93	84	96	97	88
No. 10	99	86	76	94	91	83
No. 16	99	82	55	89	82	71
No. 40	98	77	48	86	78	63
No. 100	98	74	45	86	76	63
No. 200	98.0	74.0	45.0	86	76	60
Silt and Clay	98	74	45	86	76	60
Clay	74	39	18	54	45	26

Soil Constants

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6601 CENTENNIAL BLVD.
NASHVILLE, TENNESSEE 37243-0360

PROCTOR DENSITY REPORT

Project Reference No. _____ County *MCMINN* Region *2*
Project No. *54000-1500-04* Contract No. _____
Material *Soil* Project Supervisor _____
Report No. _____ Date Sampled *04-Jan-03*

SOIL CONSTANTS

Liquid Limit	60	51	28	54	50	34
Plastic Limit	40	24	17	25	29	22
Plasticity Index	20	27	11	29	21	12
Calculated PI	20	22	6	26	17	9
Type	A-7-5	A-7-6	A-6	A-7-6	A-7-6	A-6
Group	27	20	2	27	17	5
DENSITY CORRECTED FOR +4 MATERIAL						
Proctor Density	85.5	98.5	117.5	97.5	97.0	105.0
Optimum Moisture	33.0	22.5	12.5	22.0	23.0	17.5
95 % Density	81.2	93.6	111.6	92.6	92.2	99.8
Moisture Range Above Subgrade	30-37.5	19.5-25.5	10-15.5	20-24.5	19-25	15.5-20.5
Moisture Range Below Subgrade						

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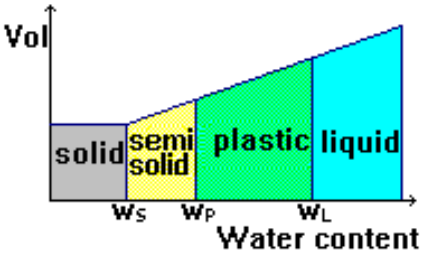
Form DT-0332 English (Rev. 10-02)

Consistency

- Atterberg limits are measures of moisture content at which the soil changes physical states
  - shrinkage limit
  - plastic limit
  - liquid limit
  - plasticity index
- Soil constants indicate the load-carrying capacity of the embankment material
- They are based on the water-holding capacity of soils under various conditions and are expressed as a moisture percentage



$$w = \frac{(\text{wet soil weight}) - (\text{oven - dry soil weight})}{(\text{oven - dry soil weight})} \times 100$$

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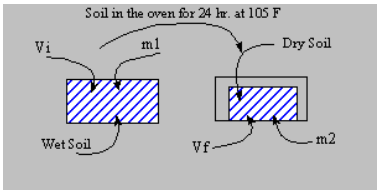
Shrinkage Limit

- Shrinkage limit is the moisture content below which a soil will no longer change volume



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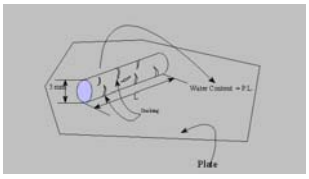
Plastic Limit

- Plastic limit is the moisture content at which a soil passes from a semisolid to a plastic state
- Plastic limit is influenced by the clay content of a soil
- Sand is a nonplastic material
- Reduction of moisture content below the P.L. leads to a rapid increase in load-carrying capacity
- Increased moisture content above the P.L. leads to a rapid decrease in load-carrying capacity



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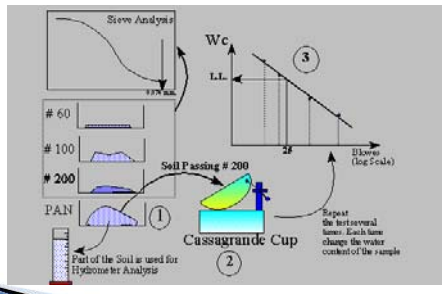
Liquid Limit

- Liquid limit is the moisture content at which a soil passes from a plastic to a liquid state
- High liquid limits indicate soils of high clay content and low load-carrying capacity



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Plasticity Index

- Plasticity index is the moisture content range at which a soil is in a plastic state
- The plasticity index is the numerical difference between the liquid limit and the plastic limit

  Given: LL = 56, PL = 37

  PI = 56-37 → PI = 19
- Low P.I. Values (<10) indicate that a soil will go from its P.L. to its L.L. with small additions of water
- High P.I. Values (>20) indicate that a considerable amount of water can be added to a soil before it will go from its P.L. to its L.L.
- If L.L.< P.L., the material is considered nonplastic (N.P.)

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Calculated Plasticity Index

- The calculated P.I. is significant when the material contains large amounts of granular particles
- It relates the P.I. to the total sample rather than just the < 40 material
- The calculated P.I. is determined as follows:

$$P.I._{calculated} = \frac{P.I._{actual} \times \text{material passing \#40 sieve}}{100}$$

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AASHTO Soil Classification

AASHTO Recommended Practice for
Classification of Soils and Soil-Aggregate Mixtures

General Classification	Granular materials (≤ 35 percent of total sample passing No. 200)							Silt-clay materials (> 35 percent of total sample passing No. 200)				
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7	
Subgroup	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5	A-7-6
Sieve Analysis, percent passing												
No. 10	≤ 50											
No. 40	≤ 30	≤ 50	≥ 51									
No. 200, F	≤ 15	≤ 25	≤ 10									
Characteristics of fraction passing 0.425 mm (No. 40)												
Liquid Limit, LL				≤ 40	≥ 41	≤ 40	≥ 41	≤ 40	≥ 41	≤ 40	≥ 41	≥ 41
Plasticity Index, PI	≤ 6		NP	≤ 10	≤ 10	≥ 11	≥ 11	≤ 10	≤ 10	≥ 11	≤ (LL-30)	> (LL-30)
Group Index, GI	0		0	0		≤ 4		≤ 8	≤ 12	≤ 16	≤ 20	

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Subgroup	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5	A-7-6
Sieve Analysis, percent passing												
No. 10	≤ 50											
No. 40	≥ 30	≤ 50	≥ 51									
No. 200, F	≤ 15	≤ 25	≤ 10									
Characteristics of fraction passing 0.425 mm (No. 40)												
Liquid Limit, LL				≤ 40	≥ 41	≤ 40	≥ 41	≤ 40	≥ 41	≤ 40	≥ 41	≥ 41
Plasticity Index, PI	≤ 6		NP	≤ 10	≤ 10	≥ 11	≥ 11	≤ 10	≤ 10	≥ 11	≤ (LL-30)	> (LL-30)
Group Index, GI	0		0	0		≤ 4		≤ 8	≤ 12	≤ 16	≤ 20	

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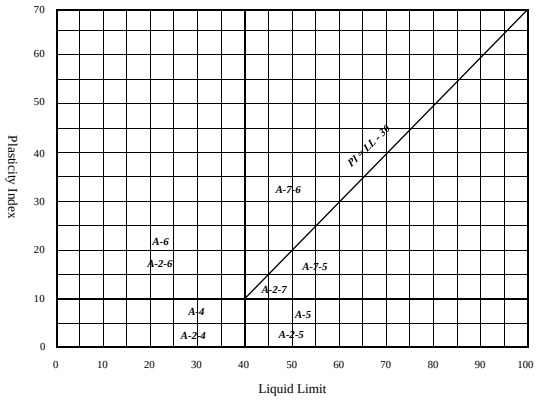
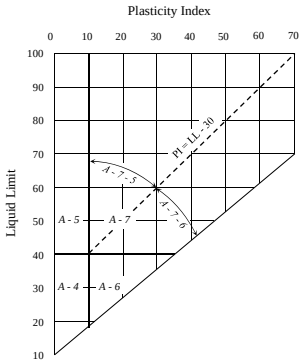
AASHTO Soil Classification





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Group A-1

- Usually well-graded mixture of coarse to fine particles.
- They may have soil binders.
- Soils in Group A-1 are the best embankment material.
- They have stable load-carrying capacities regardless of their moisture contents.
  - Subgroup A-1-a is predominantly stone fragments or gravel
  - Subgroup A-1-b is predominantly coarse sand

Group A-2

- Includes a variety of granular materials which are borderline between Groups A-1 and A-3, and silt-clay materials.
- These materials are stable when dry but may be subject to frost damage.
- Soils in Group A-2 can generally be used for blanketing plastic subgrades of some silty or clayey materials to prevent moisture (capillary water) from creeping to the pavement course.
  - Subgroups A-2-4 and A-2-5 are satisfactory base course materials when properly compacted; they are usually granular materials with silty or loamy soil-binder characteristics of Groups 4 and 5.
  - Subgroups A-2-6 and A-2-7 are usually granular materials with clay or loamy soil-binder characteristics of Groups 6 and 7. These soils may lose their stability under capillary action or from lack of proper drainage.

Group A-3

- Consists of sands with limited coarse materials or soil binders.
- Examples of this group are fine desert sand, fine beach sand and stream-deposited sand.
- These soils make suitable subgrades when confined and damp, but are subject to erosion.
- They can be compacted by vibratory, pneumatic-tire and steel-wheel rollers, but not with sheepsfoot rollers.

Group A-4

- Consists of common silty soils with textures varying from sandy loams to silty and clayey loams.
- These soils have an affinity for water and will swell and lose considerable stability unless properly compacted and drained.
- Silty loams are often difficult to compact--pneumatic rollers usually are needed for proper compaction.
- Careful field control of moisture content is required.

Group A-5

- Similar to A-4 but the soils are more elastic with higher liquid limit.

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Group A-6

- Consist of soils which usually have high volume changes between wet and dry states.
- If moisture content is properly controlled, they will compact readily under a sheepsfoot roller or a pneumatic-tired roller.
- These soils will compress when wet and shrink and swell with changes in moisture content.
- A-6 soils do not drain readily.

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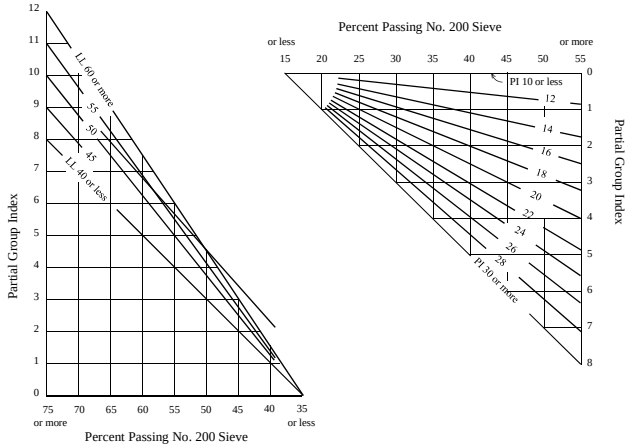
Group A-7

- Similar to A-6, except that the soils may be elastic as well as subject to considerable volume changes.
- Soils in Group A-7 are not preferred as embankment materials.
  - Subgroup A-7-5 soils usually have moderate P.I.s in relation to their L.L.s. These soils are highly elastic and subject to high volume changes.
  - Subgroup A-7-6 soils have high P.I.s in relation to their L.L.s. These soils are highly elastic and subject to higher volume changes than A-7-5 soils.

Group Index

- Group refers to the Group Index rating.
- It is based on gradation, liquid limit, and plasticity index of the material.
- It allows a within-group evaluation of the clayey granular materials and the silt-clay materials in the AASHTO classification.
- If the group index is known, the material can be rated within the AASHTO groups.
- The lower value of the index indicates better grades of material within the same group.

Group Index



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7

Compaction and Density Concepts

Compaction and Density Concepts

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Compaction - Definition

- Compaction is the process of mechanically densifying a soil.
- Densification is accomplished by pressing the soil particles together into a close state of contact with air being expelled from the soil mass in the process.

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Compaction - Definition (cont'd)

- Compaction, as used here, implies dynamic compaction or densification by the application of moving loads to the soil mass.
- In relation to compaction, the density of a soil is normally expressed in terms of ***dry density or dry unit weight***. Occasionally, the wet density or wet unit weight is used.
- These values are typically described in a number of pounds per cubic foot (lb/ft^3)

Soil Properties Affected by Compaction

- Settlement
- Shearing resistance
- Movement of water
- Volume change

Settlement

- Consolidation is minimized by compaction
- Closer arrangement of soil particles

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Shearing Resistance

- Compaction increases shearing resistance which may allow
  - a thinner pavement structure
  - steeper side slopes

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Movement of Water

- Compaction reduces
  - number of voids
  - size of void spaces
  - permeability
  - seepage of water
  - Movement of capillary water

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Volume Change

- Compaction minimizes
  - shrinkage
  - swelling

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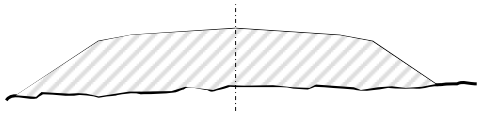
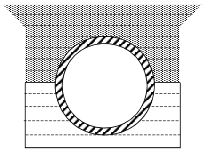
Earthwork Requiring Moisture-Density Tests

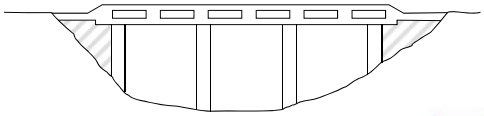
Embankments



Pipe backfill



Structure backfill



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Moisture-Density Tests

- TDOT uses the Proctor density test to determine the densities to which a soil can be compacted with various moisture contents
- The highest density obtained is called the <u>maximum density</u> (Proctor density) and the corresponding moisture content is called the <u>optimum moisture</u>

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Density Ranges

- High maximum densities will range from 125 to 145 pounds per cubic foot, oven-dry weight
- Low maximum densities will range from 85 to 100 pounds per cubic foot, oven-dry weight

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Moisture Ranges

- A low optimum moisture corresponds to a high maximum density and will be around 8 percent
- A high optimum moisture corresponds to a low maximum density and will be around 30 percent

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AASHTO T99 & T180

- AASHTO T99 Standard Proctor Test
- AASHTO T180 Modified Proctor Test
  - prescribes a compacting force and procedure that closely approximates densities that can be obtained on soils in the field with tamping rollers

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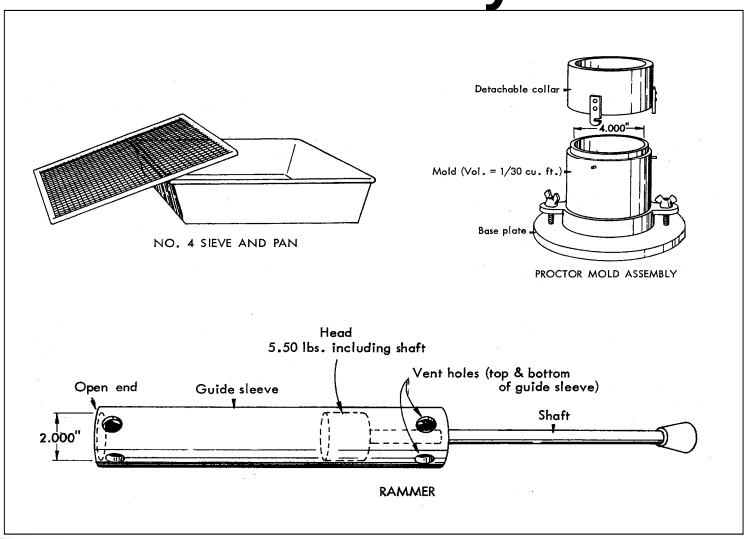
Proctor Density Test



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Proctor Density Test

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Proctor Density Test

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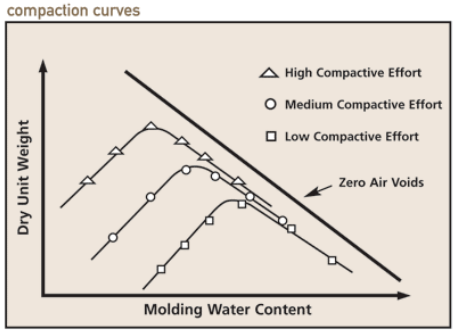
Compaction Theory

- When dry densities of the sample are determined and plotted as a function of moisture content, the curve is called a compaction curve.
- The peak of the curve represents the maximum dry density at the optimum moisture content

Figure 1. Typical moisture density relationships or compaction curves



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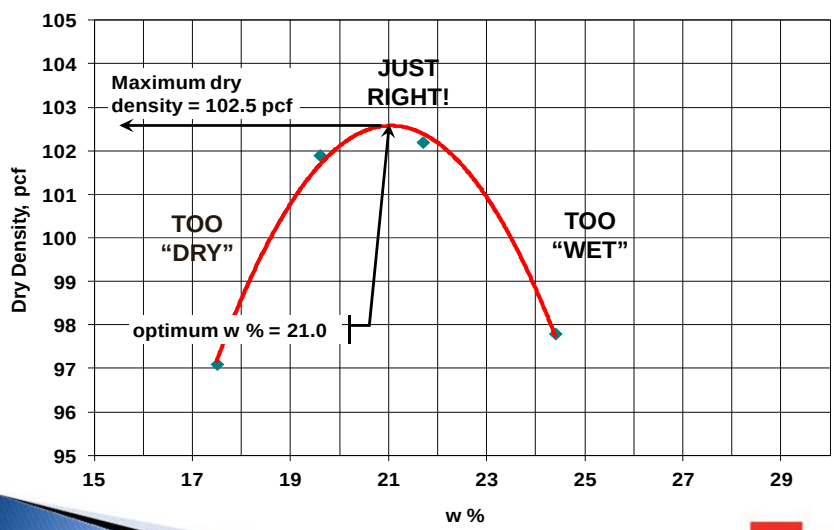
Moisture-Density Curve



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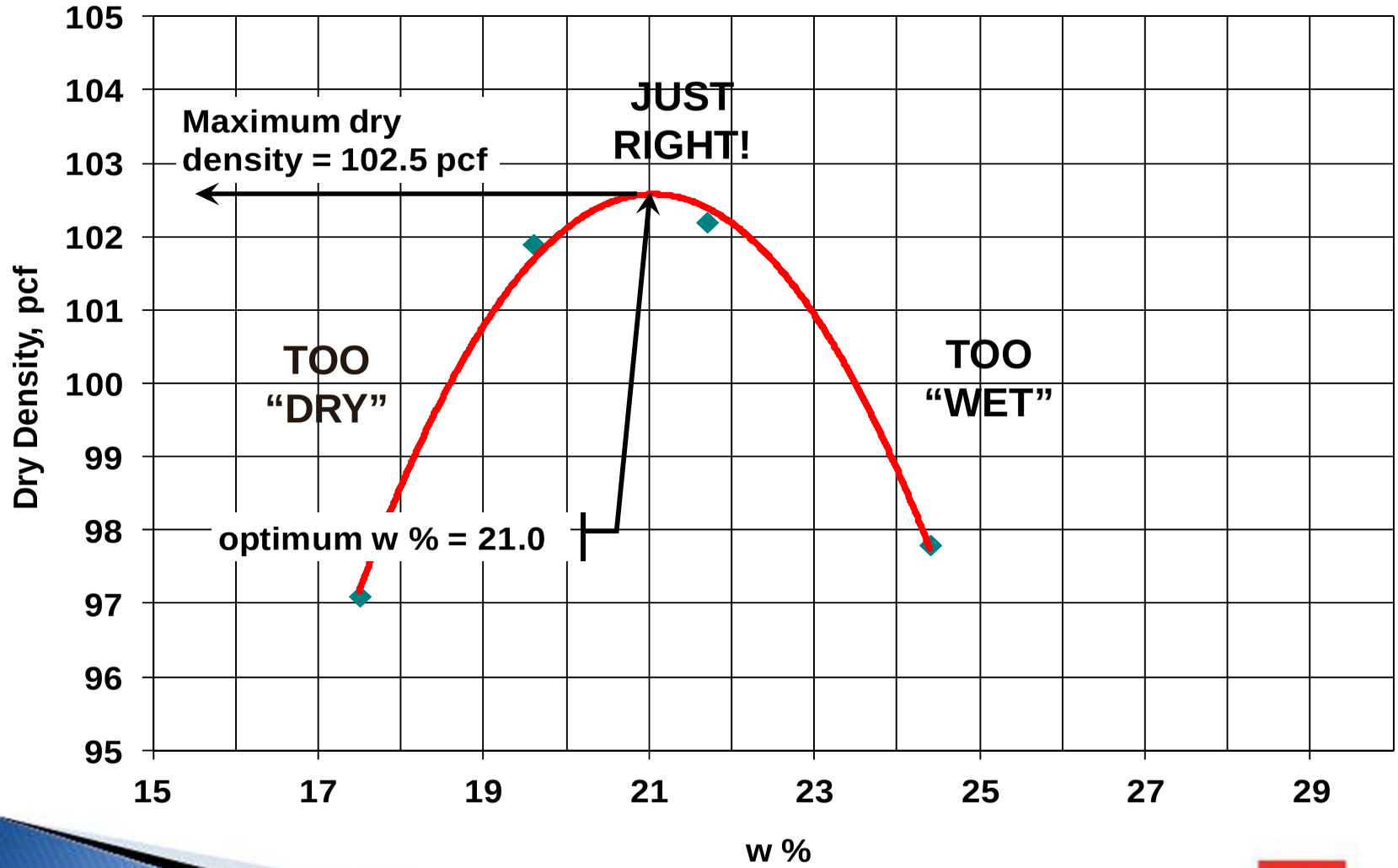
Moisture-Density Curve



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8

Embankment Placement

Embankment Placement

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Organic Materials

- Topsoil or other organic material should never be used as embankment material

WHY?

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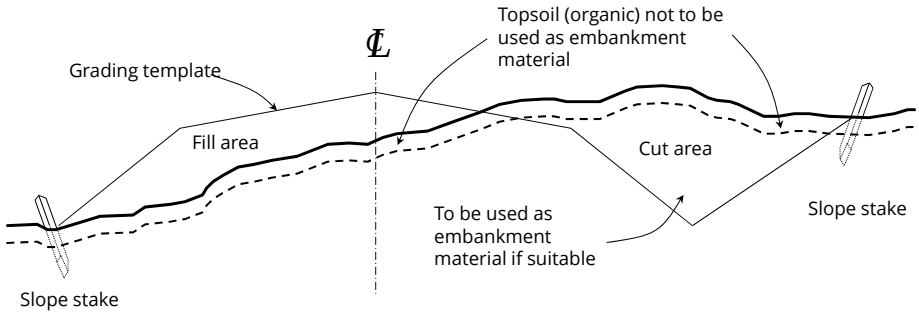
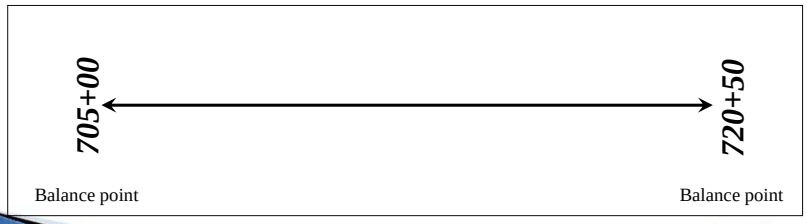
Sources of Embankment Materials



Earthwork Balances

- Embankments are typically designed to achieve earthwork balances at intervals along the project
- The contractor is expected to haul within the balances shown on the plans or as adjusted by the project supervisor



Equipment for Placement

- The embankment is placed on natural ground usually by scrapers used for excavation or by trucks if the haul distance is long
- It is spread and leveled in specified lifts

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Placement Equipment and Procedures

- The equipment and procedures involved in the dumping and spreading of the embankment material will depend on:
  - the type of equipment available
  - the type of material used
- Embankments must be built up in uniform, well-mixed layers for the full width of the roadway
- The contractor must have enough equipment and use procedures that will enable proper moisture and compaction requirements to be met

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Placement Inspection Checklist

- Perishable materials, such as stumps and brush, are not buried in the embankment
- Crowns are maintained
- Individual lifts do not exceed 10 inches before compaction
  - When excavated material consists predominantly of rock fragments that are too large to place in 10-inch lifts, the material may be placed in the embankment in layers not exceeding 3 feet
  - All rock to be placed in the embankment is broken into sizes not exceeding 2 feet in the maximum dimension and each of these rock lifts is leveled and smoothed with finer material
- The embankment is built up evenly and uniformly
- Embankments are constructed with similar materials

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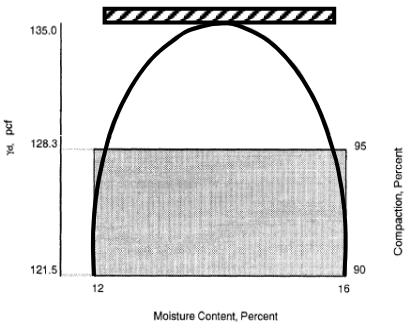
Compaction of Embankments

Standard Specifications Section 205.04

- Embankments that consist of predominantly fine-grained soil must be placed in horizontal lifts not thicker than 10 inches before compaction
- Each layer, excluding the top 6 inches of the roadbed must be compacted to a density not less than 95 percent of maximum density



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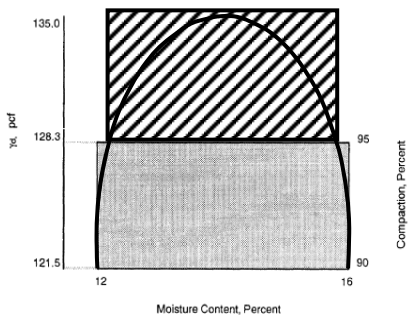
Compaction of Embankments

Standard Specifications Section 205.04

- When a minimum of 95 percent maximum density is required, the moisture content of the material must be within the range of values at which this density can be obtained



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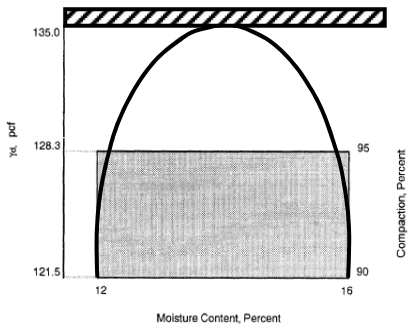
Compaction of Embankments

Standard Specifications Section 205.04

- When a 100 percent maximum density is required, the moisture content of the material must not vary from optimum moisture by more than 3 percentage points



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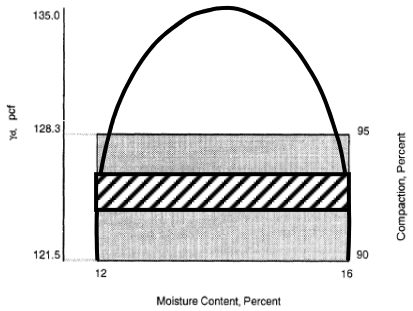
Compaction of Embankments

Standard Specifications Section 205.04

- The contractor is required to aerate the material or distribute and incorporate water uniformly to control moisture content within appropriate limits
- If the moisture is within the appropriate limits but the density is not, additional compaction is necessary



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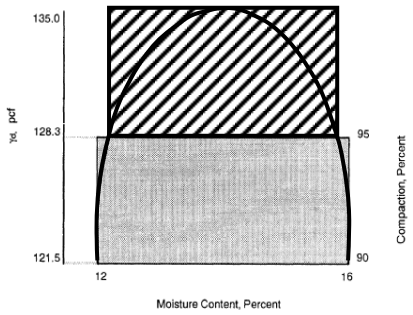
Top Six Inches Specifications

Standard Specifications Subsection 205.04

- In both cut and fill sections, the top six inches of roadbed must be compacted to 100 percent of maximum density



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Base Compaction

- Thickness of layers must be within limits that allow proper compaction
- In general, the limit is 4 to 8 inches, depending on
  - material
  - method of construction
- Smooth-wheeled or vibratory rollers are recommended for compacting hard, angular materials with limited fines
- Pneumatic-tired rollers are recommended for softer materials that may degrade under a steel roller

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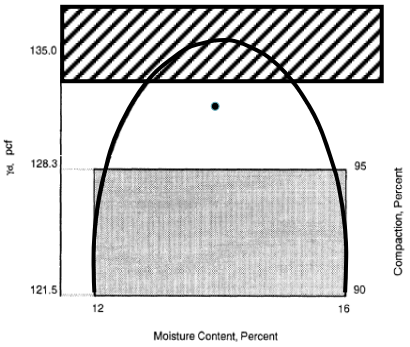
Type A Base Specifications

Standard Specifications Subsection 303.10

- An average of 100 percent of maximum density is specified
- No individual test less than 97 percent of maximum density
- A 3 percent range (from optimum moisture content) is specified for moisture



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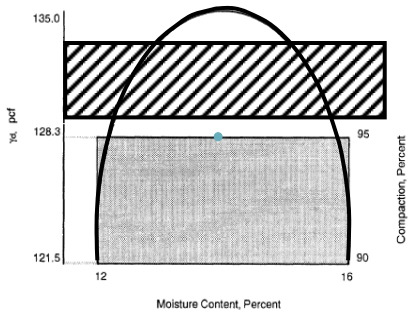
Type B Base Specifications

Standard Specifications Subsection 303.10

- An average of 97 percent of maximum density is specified
- No individual test less than 95 percent of maximum density
- A 3 percent range (from optimum moisture content) is specified for moisture



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Compaction of Embankments

- Rollers are used to obtain the required densities and should be operated continuously while embankment materials are being placed

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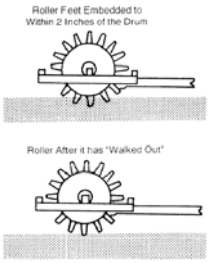
Sheepsfoot Roller

- Compacts all fine-grained materials
- Will not compact cohesionless granular materials
- Compacts from the bottom up and is used especially for plastic materials
- The lift thickness for sheepsfoot rollers is limited to 6 inches in compacted depth
- If the required densities are not being obtained, it is often necessary to change to a thinner lift to ensure that the specified density is obtained



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Tamping-Foot Roller

- A tamping-foot roller is a modification of the sheepsfoot roller
- The tamping feet are trapezoidal pads attached to a drum
- Tamping-foot rollers are normally self-propelled, and the drum may be capable of vibrating
- The tamping-foot roller is suitable for use with a wide range of soil types

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Steel-Wheeled Roller

- The steel-wheeled roller is much less versatile than the pneumatic roller
- Although extensively used, it is normally operated in conjunction with one of the other types of compaction rollers
- It is used for compacting granular materials in thin lifts
- Probably its most effective use in subgrade work is in the final finish of a surface, following immediately behind the blade, forming a dense and watertight surface

Self-Propelled, Smooth-Drum Vibratory Roller

- Compacts with a vibratory action that rearranges the soil particles into a denser mass
- The best results are obtained on cohesionless sands and gravels
- Compaction efficiency is impacted by the ground speed of the roller and the frequency and amplitude of the vibrating drum

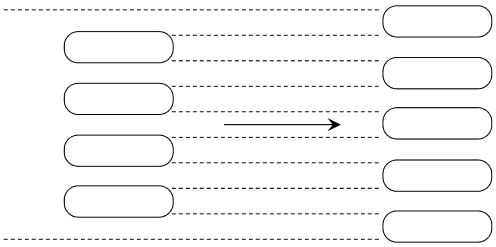
Pneumatic Rollers

- Variants include
  - pneumatic-tired roller
  - self-propelled pneumatic-tired roller

- Suitable for granular materials; however, it is not recommended for fine-grained clay soils except as necessary for sealing the surface after a sheepsfoot roller has "walked out"
- It compacts from the top down and is used for finishing all types of materials, following immediately behind the blade and water truck

Pneumatic Rollers

- Pneumatic rollers have an uneven number of wheels and should never have fewer than 7 wheels. The tires are arranged so that the gaps between the tires of one axle will be covered by the tires of the other.



Corrective Actions

- Overcompaction
- Undercompaction
- Too Wet
- Too Dry

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Overcompaction

- Occurs when material is densified in excess of specified range
- The material may be stronger than required, which indicates
  - wasted construction effort
  - sheared material

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Undercompaction

- Undercompaction may indicate
  - A missed roller pass
  - Insufficient roller weight
  - A change in operating frequency or amplitude (if vibratory rollers are in use)
  - A defective roller drum
  - The use of an improper type of compaction equipment
  - A change in soil type

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Too Wet

- Soils that are too wet when compacted are susceptible to shearing and strength loss
- Corrective action for a soil compacted too wet is to:
  - Scarify
  - Aerate
  - Retest the moisture content
  - Recompact, if moisture content is within the specified range
  - Retest for both moisture and density

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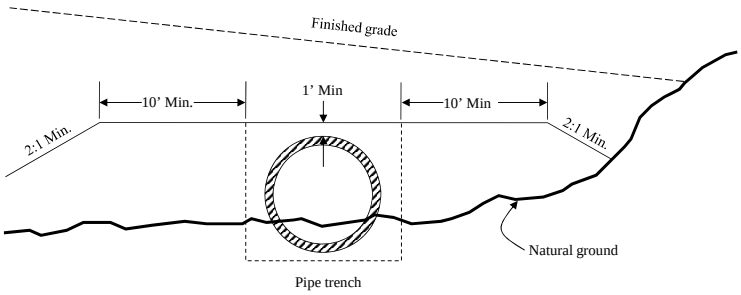
Too Dry

- Soils that are too dry when compacted do not achieve the specified degree of densification as do properly moistened soils
- Corrective action for a soil compacted too dry is to:
  - Scarify
  - Add water
  - Mix thoroughly
  - Retest the moisture content
  - Recompact, if moisture content is within the specified range
  - Retest for both moisture and density

TN TDOT Department of Transportation

Pipes in Fill Sections

- Where pipes must be placed in fill sections, it is not necessary that the entire embankment be constructed before cutting the trench but the embankment must be built up in the immediate vicinity of the pipe



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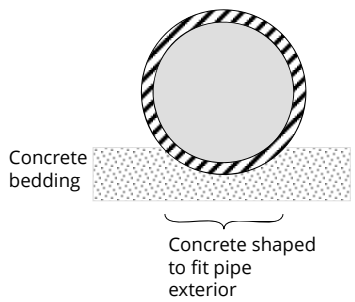
Class A Culvert Bedding

- The bedding consists of a continuous concrete cradle for the pipe



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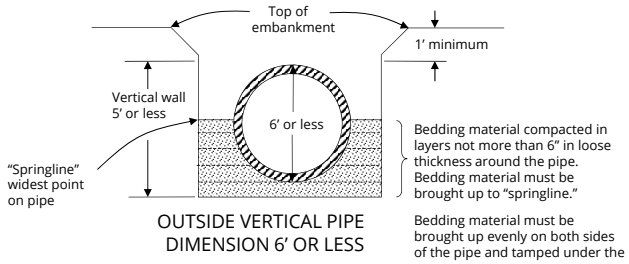
Class B Culvert Bedding

- The embankment is built up to at least one foot above the top of the proposed pipe before digging the trench
- The trench is then excavated to a depth which will allow the placement of six inches of bedding material below the pipe
- Additional bedding material is added so that it can be shaped by a template to fit the lower part of the pipe exterior for at least 10 percent of its overall height



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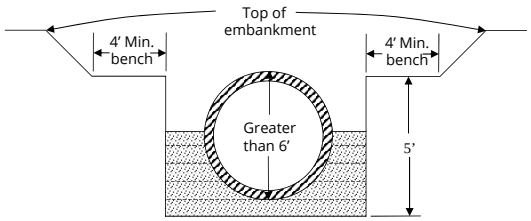
Class B Culvert Bedding

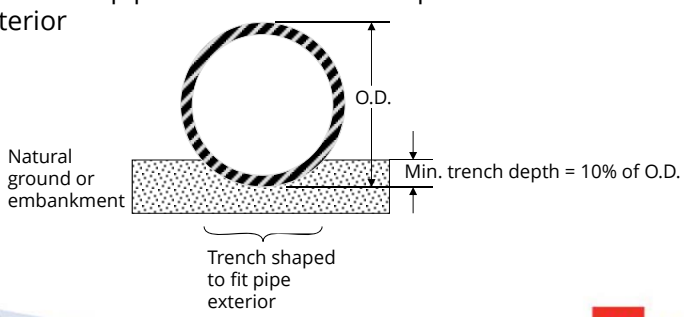
- Safety points:
  - Vertical walls must never exceed 5 feet
  - Where trenches must be deeper than 5 feet, the safety treatment depends on the outside vertical dimension of the pipe; the safety measures include sloping, benching, or both



OUTSIDE VERTICAL PIPE DIMENSION GREATER THAN 6'

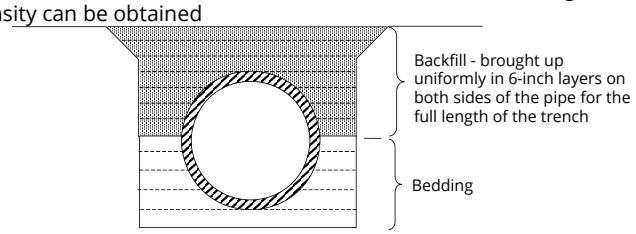
Class C Culvert Bedding

- The pipe is bedded in a shallow trench cut in the natural ground or the compacted embankment
- The trench must be cut to a depth not less than 10% of the outside vertical pipe dimension and shaped to fit the lower pipe exterior



Backfill Requirements

- After the pipe is properly bedded, backfill material must be placed in 6-inch loose layers and each layer compacted as the backfill is brought up to the top of the trench
- Each layer must be mechanically tamped to 100 percent of maximum density and the backfill material must be within the moisture range at which this density can be obtained



- Backfill material must consist of bedding material or fine, compactible soil selected from excavation or borrow as indicated on the plans

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9

Quality Acceptance Testing

Quality Acceptance Testing

References

SOP 7-1 (Nuclear Density Testing)

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Quality Acceptance Testing

- Generally, a quality-acceptance plan consists of breaking the total job down into lots
- A lot is accepted or rejected depending on the test results obtained through random sampling that represent the lot
- By handling the acceptance procedure in this way, the project engineer is able to determine the quality of the job on a lot-by-lot basis
- This benefits the construction unit and project engineer by identifying the lots that will be accepted and the lots that will be rejected
- As this type of information is accumulated from lot to lot, a better picture of the quality of the entire project is obtained

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Quality Acceptance Testing: Best Practices

- Use a “test strip” to determine the approximate number of passes needed to attain proper densities
- Test every lift as soon as compaction is completed
- Test every roller lane
- Test obvious weak spots
- Test roads and runways every 250 linear feet, staggering tests about the centerline
- Test parking lots and storage areas every 250 square yards
- Test trenches every 50 linear feet
- Remove all oversized materials
- Remove any pockets of organic or unsuitable soil material
- Increase the distance between tests as construction progresses, if initial checks are satisfactory

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Quality Acceptance Testing: Procedure

- Identify Density/Moisture Requirements
  - Based on type of material being placed
  - Target values are determined by Materials and Tests and submitted to Project Supervisor.
- Determine Required Lot Size/Number of Tests
- Determine Test Locations
- Perform Test(s)
- Report Results

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Identify Density/Moisture Requirements

- Acceptance criteria are different for Embankment, Aggregate Base, Etc. (as discussed in the last presentation)
- This information can be found in the corresponding section in the TDOT specs.
- The target values are determined by TDOT Materials and Tests personnel and will be made available by the TDOT Project Supervisor. *These values may change during the course of the project, so be sure to make sure you have the most current numbers.

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Determine Required: Lot Size/Number of Tests/Test Locations

- S.O.P. 1-1: Sampling and Testing Guide
  - Describes the testing frequency for all materials
  - Lists the person responsible for either obtaining the sample of performing the test.
  - Available in PDF format at:

http://www.tdot.state.tn.us/materials/fieldops/sop/default.htm

(see example in Part Five of S.O.P. 1-1)

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TDOT Sampling Procedure
(base stone example)

- SOP 1-1
  - 5 moisture/density tests are required for every 10,000-square-yard (SY) lot of material installed.
  - Tests are to be performed immediately before placing pavement structure
  - Specific test/sample locations are to be determined RANDOMLY

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Random Sampling

- Any portion of the population has equal chance of being selected
- Bias is introduced when judgment is used
- Use random number tables

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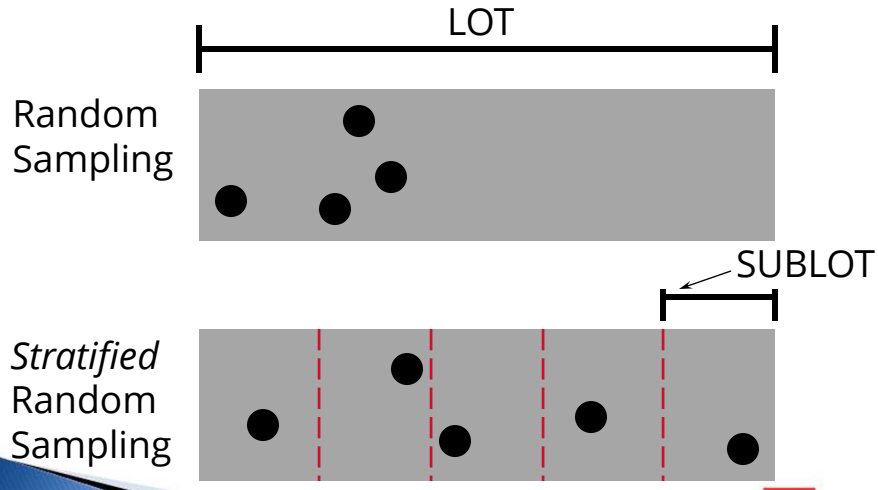
Why must we divide lots into sublots?



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TDOT Sampling Procedure
(base stone example)

- 5 tests per LOT with each LOT divided into 5 sublots (1 test per sublot)
- The location longitudinally shall be taken randomly (using a number table)
- The lateral location should also be determined by a random number.

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Random Number Table
(example)

.20	.68	.98	.30	.27	.84	.54	.31	.05	.88
.61	.17	.38	.62	.55	.59	.67	.73	.43	.23
.27	.38	.84	.99	.72	.51	.48	.81	.77	.76
.24	.38	.40	.34	.76	.87	.60	.75	.49	.56
.88	.52	.25	.51	.79	.41	.33	.08	.32	.47
.62	.36	.97	.61	.28	.50	.81	.29	.75	.82
.94	.83	.35	.66	.42	.70	.44	.30	.54	.45

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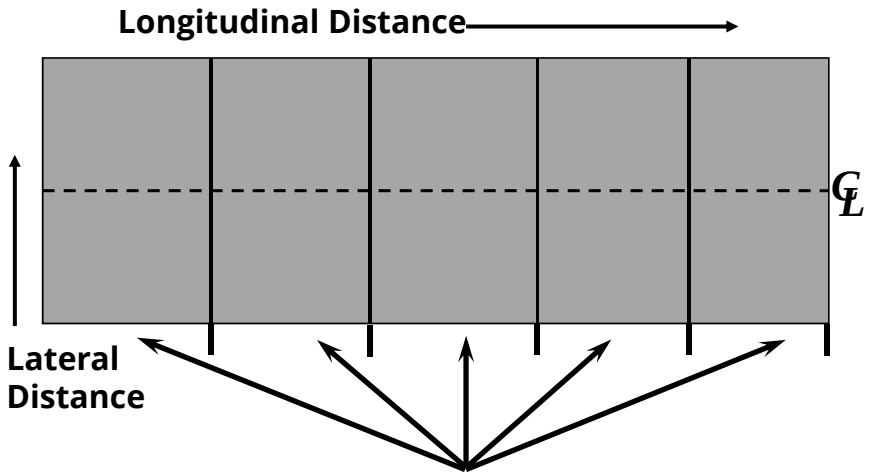
LOT



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Testing Locations

- STEP 1-
  - Determine LOT size, and with known lane width, determine LOT and sub-lot lengths
- STEP 2-
  - With known beginning station, determine beginning sub-lot stations
- STEP 3-
  - Using random number table, or calculator, select 5 numbers

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Testing Locations

- STEP 4-
  - Multiply random number by Sub- Lot Length, and add to beginning Sub-lot stations to determine longitudinal testing locations
- STEP 5-
  - Multiply random number by either lane or cross-sectional width to determine lateral testing location within each sublot

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Example Problem

Situation

- Placing Type A Base Material
- Typical base stone cross-section is 30 Feet
- Beginning Station 100+00

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A Bit About Station Numbers

- One “station” is equal to 100 linear feet.
- Locations between stations are described as a station number “+ XX” in additional feet.
- For example: If station “1 + 00” is the number that describes the first 100 feet of the project, then station “1 + 25” would be 25 feet past the first station.
- How many feet into the project would station number 100 + 00 be?

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A Bit More About Station Numbers

- To get from one station to another, simply drop the "+", add/subtract the numbers, and put the "+" back in the same place.
- Example: What would the final station be if we began at station number 100 + 00, and went forward 750 feet?

100 + 00 → 10000
+ 750
10750 → 107 + 50

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Example Problem
(Continued)

- STEP 1- (Per SOP 1-1)
  - 10,000 SY LOT
  - LOT Length: 10,000 yd^2 x 9 = 90,000 ft^2
    90,000 ft^2 / 30 ft = 3000 ft length
  - SUB-LOT Length: 3000 ft / 5 = 600 ft

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Example Problem
(Continued)

- STEP 2- (Beginning Station 100+00)

• 100+00	+600= 106+00
• 106+00	+600=112+00
• 112+00	+600=118+00
• 118+00	+600=124+00
• 124+00	+600=130+00

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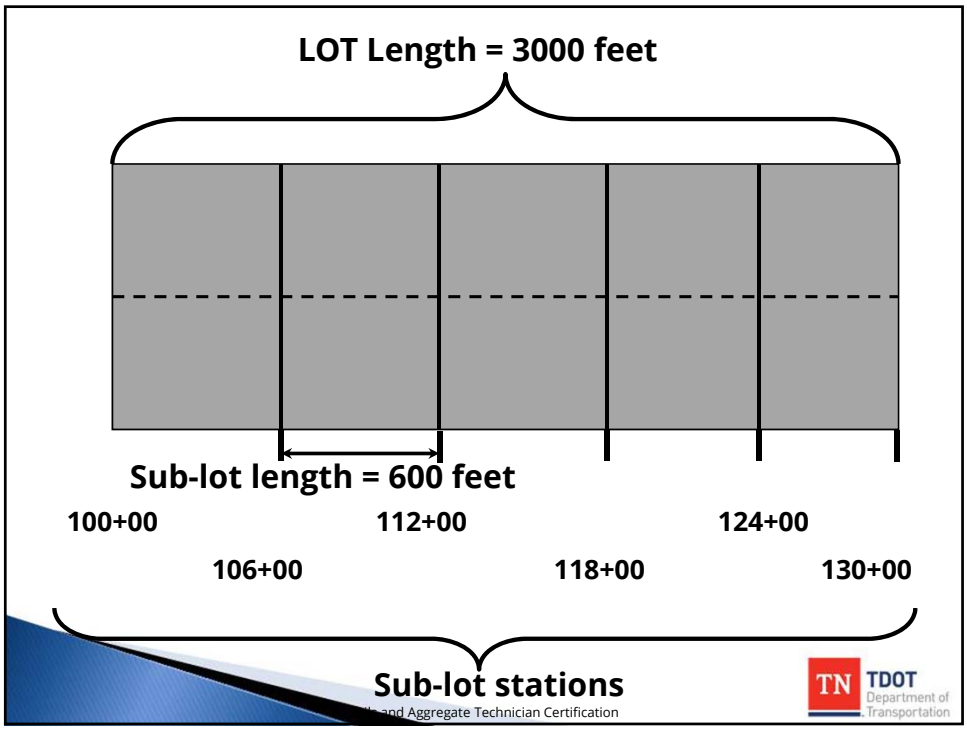

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Example Problem
(Continued)

- STEP 3-
  - Using a random number table, select 5 numbers

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Random Number Table

.20	.68	.98	.30	.27	.84	.54	.31	.05	.88
.61	.17	.38	.62	.59	.67	.73			.23
.27	.38	.84	.99	.72	.51	.48	.81	.77	.76
	.38	.40	.34	.76	.87	.60	.75	.49	.56
.88	.52	.25	.51	.79		.33	.08	.32	.47
.62	.36	.97	.61	.28	.50	.81	.29	.75	.82
.94	.83	.35	.66	.42	.70	.44		.54	.45

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Example Problem
(Continued)

- Step 4 -
- Use
  - Sub-lot Length from Step 1
  - Sub-lot Stations from Step 2
  - Random Numbers from Step 3

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Example Problem
(Continued)

- STEP 4 -
  - 0.41 x 600′ = 246′
    - 2+46 + 100+00 = <u>102+46</u>
  - 0.30 x 600′ = 180′
    - 1+80 + 106+00 = <u>107+80</u>
  - 0.43 x 600′ = 258′
    - 2+58 + 112+00 = <u>114+58</u>
  - 0.55 x 600′ = 330′
    - 3+30 + 118+00 = <u>121+30</u>
  - 0.24 x 600′ = 144′
    - 1+44 + 124+00 = <u>125+44</u>

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Example Problem
(Continued)

- STEP 5-
  - Randomly select the transverse location for testing

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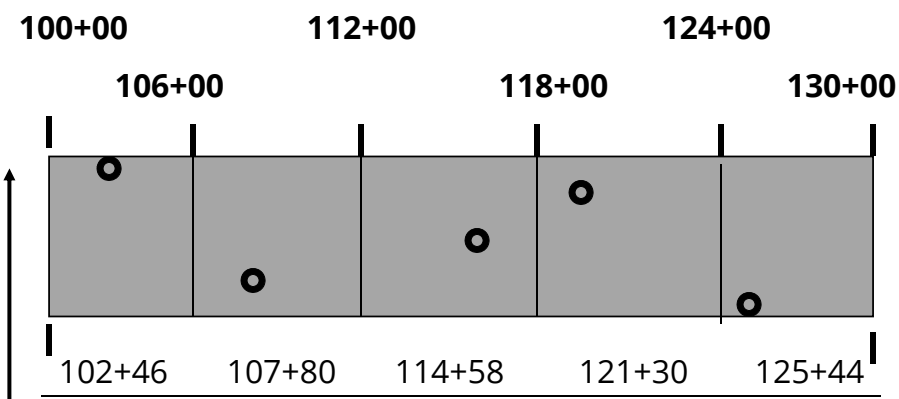

Lateral Distance is determined by multiplying random numbers by road width.

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Nuclear Density/Moisture Testing

- You must have attended a Radiation Safety course prior to using a Nuclear Gauge!

(click for example)

- TDOT references AASHTO T-310 as the standard test method.
- **SAFETY FIRST**!!!!

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Nuclear Density/Moisture Testing

- Never handle a nuclear gauge without wearing your own personal radiation dosimeter.
- Never leave a nuclear gauge unattended on a job site.

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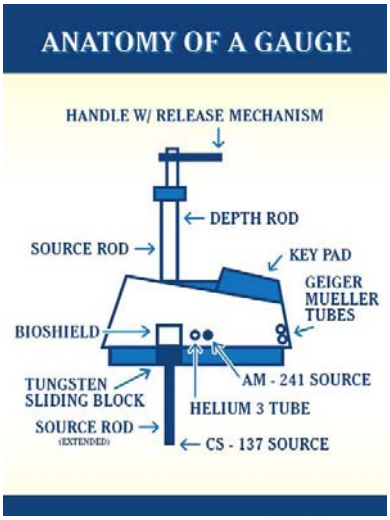
Nuclear Density/Moisture Testing

- Regardless of gauge manufacturer (Troxler, Humbolt, Instrotek, etc.), all gauges utilize the same basic components.
- All tests performed on soil and aggregate will be using the *Direct Transmission* method.



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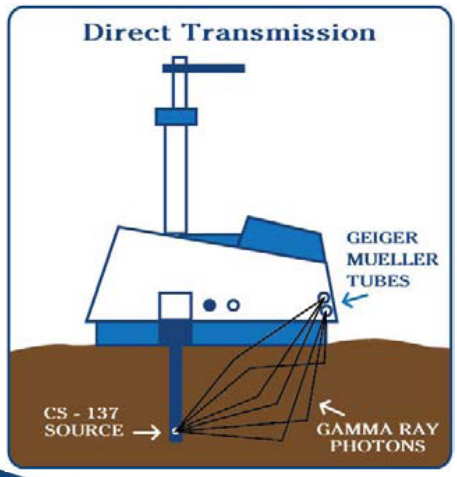
Nuclear Density/Moisture Testing

TN TDOT Department of Transportation

Nuclear Density/Moisture Testing



When taking a test the gauge measures the amount of radiation detected over a predetermined timeframe, such as one minute. The detector tubes count the radiation that is able to pass through the material between the bottom of the source rod and the detector tubes. The denser the material, the lower the amount of radiation that is able to reach the detector tubes to be counted.

Standard Counts

- Standard counts measure the number of counts received from the density and moisture sources and provide a quick reference check to ensure that the gauge is operating correctly.
- A standard count should be taken <u>daily</u> and the results should be very close to previous standard counts, typically 1% for density and 2% for moisture.

Standard Counts (Continued)

- If the last count has been longer than 60 days a new standard count average may need to be established. This can be done by taking three more tests and averaging these most recent results to establish a new count.
- If the gauge still does not match it's standard count values, it must ***not*** be used.
- Check the gauge manual and AASHTO T-310 for additional information.

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Nuclear Density/Moisture Testing

Enter the predetermined proctor density and moisture content for the material you will be testing. This will enable the gauge to calculate the dry density and determine the percent compaction.

Where does this information come from?

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Nuclear Density/Moisture Testing

When testing on soils always prepare the ground by using the scraper plate to smooth out any obstacles or fill in any voids.

This will reduce the chance that open pockets or protruding objects impact the reading.

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Nuclear Density/Moisture Testing

When using the drill rod to make a hole in the compacted material for testing, always make sure to first place the drill rod removal device – this is a mistake that will probably be made only once.

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Nuclear Density/Moisture Testing

Etch around the base of the scraper plate before picking it up, then place the gauge down inside of this etched area. The opening for the source rod will be positioned over the hole that was drilled.

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Nuclear Density/Moisture Testing

- Pull or depress the gauge trigger and drop the rod into the hole.
- Before taking a test push the gauge towards the side of the hole with the detector tubes. This ensures that there is no air gap between the source rod and the side of the hole.
- Make sure that the source rod is well seated in the depth position notch. Any misalignment will impact the results.

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Nuclear Density/Moisture Testing

IMPORTANT: Do not extend the source rod to guide it into the hole! This exposes you and others to an unnecessary exposure of radiation.

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Nuclear Density/Moisture Testing

- Secure and record one or more 1-minute readings.
- The gauge may be rotated about the axis of the probe to obtain additional readings.
- Do not stand right next to the gauge while running a test.
- Never run a test within 30 ft of another gauge.

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Nuclear Density/Moisture Testing

- Report test results on TDOT Form no. DT-0314
- All forms are available at:

http://www.tn.gov/tdot/article/transportation-materials-tests-division-field-operations-forms

How do we know if the results are acceptable?

If they're not, what should we do?

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION
DIVISION OF MATERIALS AND TESTS
6601 CENTENNIAL BLVD.
NASHVILLE, TENNESSEE 37243-0360

SAMPLE

DENSITY WORKSHEET - NUCLEAR METHOD

Project Reference No. SP
Project No. STATE-PTRX-W
Nuclear gauge no. 450
County Montgomery
Contract No. N/A
Date 01-Jan-07
Region 2

Lot No.	#				
Test No.	1	2	3	4	5
Station	40+77	39+50	40+77	39+50	40+77
Offset (ft.)	12'R	24'R	12'R	24'L	0'L
Feet Below Grade	8	10	8	8	7
Moisture Standard Count	500	500	500	500	500
Moisture Count Ratio	—	—	—	—	—
Probe Depth	6"	6"	6"	6"	6"
Density Standard Count	2709	2709	2709	2709	2709
Density Count	2460	2297	2842	2991	2490
Density Count Ratio	—	—	—	—	—
Unit Weight Wet (pcf)	123.0	124.1	131.4	131.4	122.3
Moisture (pcf)	23.7	23.8	27.3	27.8	24.2
Unit Weight Dry (pcf)	99.3	100.1	104.1	103.6	98.2
Percent Moisture	23.8	23.8	26.2	26.3	27.2
Cut Station	43+00	43+00	43+00	43+00	43+00
Sample Number	99	99	99	99	99
Proctor Density	98.2	98.2	98.2	98.2	98.2
Optimum Moisture	22.3	22.3	22.3	22.3	22.3
Percent +4	26.3	26.3	26.3	26.3	26.3
Corrected Proctor Density					
Corrected Optimum Moisture					
Percent Compaction	101.2	104.1	107.8	107.8	96.7

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Nuclear Gauge Contacts

Headquarters Radiation Safety Officer (RSO):
Chris Smith (615) 906-1628
(615) 476-8799 (cell)

Regional RSOs

Region 1: Scott Ault	(865) 748-6040
Region 2: Dennis Beaty	(423) 208-4386
Region 3: Mark Hand	(615) 389-5217
Region 4: Marc Turner	(731) 234-6048

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Nuclear Density/Moisture Testing

- Always return the gauge to its case after use.
- Make sure the case is secured properly before transporting to another test location.
- Do not store the gauge in your basement.

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10

AASHTO

Test Methods

Standard Method of Test for

Sampling of Aggregates

AASHTO Designation: T 2-91 (2010)
ASTM Designation: D 75-03

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Standard Method of Test for

Sampling of Aggregates

AASHTO Designation: T 2-91 (2010)
ASTM Designation: D 75-03

AASHTO T 2-91 (2010) is identical to ASTM D 75-03 except that all references to ASTM C 702 contained in ASTM D 75-03 shall be replaced with T 248 in T 2.

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Standard Method of Test for

Reducing Samples of Aggregate to Testing Size

AASHTO Designation: T 248-14[1]
ASTM Designation: C 702/C 702M-11

AASHTO
THE VOICE OF TRANSPORTATION

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Standard Method of Test for

Reducing Samples of Aggregate to Testing Size

AASHTO Designation: T 248-14[1]
ASTM Designation: C 702/C 702M-11

1. SCOPE

1.1. These methods cover the reduction of large samples of aggregate to the appropriate size for testing, employing techniques that are intended to minimize variations in measured characteristics between the test samples so selected and the large sample.

1.2. The values stated in SI units are to be regarded as the standard.

1.3. *This standard does not purport to address the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- T 2, Sampling of Aggregates
- T 84, Specific Gravity and Absorption of Fine Aggregate

2.2. *ASTM Standard*:

- C 125, Standard Terminology Relating to Concrete and Concrete Aggregates

3. TERMINOLOGY

3.1. *definitions*—the terms used in this standard are defined in ASTM C 125.

4. SIGNIFICANCE AND USE

4.1. Specifications for aggregates require sampling portions of the material for testing. Other factors being equal, larger samples will tend to be more representative of the total supply. The methods described in this standard provide for reducing the large sample obtained in the field or produced in the laboratory to a convenient size for conducting a number of tests to describe the material and measure its quality. These methods are conducted in such a manner that the smaller test sample portion will be representative of the larger sample and, thus, of the total supply. The individual test methods provide for minimum masses of material to be tested.

4.2. Under certain circumstances, reduction in size of the large sample prior to testing is not recommended. Substantial differences between the selected test samples sometimes cannot be avoided, as for example, in the case of an aggregate having relatively few large-sized particles in

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the sample. The laws of chance dictate that these few particles may be unequally distributed among the reduced-size test samples. Similarly, if the test sample is being examined for certain contaminants occurring as a few discrete fragments in only small percentages, caution should be used in interpreting results from the reduced-size test sample. Chance inclusion or exclusion of only one or two particles in the selected test sample may importantly influence interpretation of the characteristics of the original sample. In these cases, the entire original sample should be tested.

4.3. Failure to carefully follow the procedures in these methods could result in providing a nonrepresentative sample to be used in subsequent testing.

5. SELECTION OF METHOD

5.1. *Fine Aggregate*—Samples of fine aggregate that are drier than the saturated surface-dry condition (Note 1) shall be reduced in size by a mechanical splitter according to Method A. Samples having free moisture on the particle surfaces may be reduced in size by quartering according to Method B, or by treating as a miniature stockpile as described in Method C.

5.1.1. If the use of Method B or Method C is desired, and the sample does not have free moisture on the particle surfaces, the sample may be moistened to achieve this condition, thoroughly mixed, and then the sample reduction performed.

Note 1—The method of determining the saturated surface-dry condition is described in T 84. As a quick approximation, if the fine aggregate will retain its shape when molded in the hand, it may be considered to be wetter than saturated surface-dry.

5.1.2. If use of Method A is desired and the sample has free moisture on the particle surfaces, the entire sample may be dried to at least the surface-dry condition, using temperatures that do not exceed those specified for any of the tests contemplated, and then the sample reduction performed. Alternatively, if the moist sample is very large, a preliminary split may be made using a mechanical splitter having wide chute openings 38 mm ($1^1/_2$ in.) or more to reduce the sample to not less than 5000 g. The portion so obtained is then dried, and reduction to test sample size is completed using Method A.

5.2. *Coarse Aggregates*—Reduce the sample using a mechanical splitter in accordance with Method A (preferred method) or by quartering in accordance with Method B. The miniature stockpile Method C is not permitted for coarse aggregates or mixtures of coarse and fine aggregates.

5.3. *Combined Coarse and Fine Aggregate*—Samples that are in a dry condition may be reduced in size by either Method A or Method B. Samples having free moisture on the particle surfaces may be reduced in size by quartering according to Method B. When Method A is desired and the sample is damp or shows free water, dry the sample until it appears dry or until clumps can be easily broken by hand (Note 2). Dry the entire sample to this condition, using temperatures that do not exceed those specified for any of the tests contemplated, and then reduce the sample. The miniature stockpile Method C is not permitted for combined aggregates.

Note 2—The "dryness" of the sample can be tested by tightly squeezing a small portion of the sample in the palm of the hand. If the cast crumbles readily, the correct moisture range has been obtained.

6. SAMPLING

6.1. The samples of aggregate obtained in the field shall be taken in accordance with T 2, or as required by individual test methods. When tests for sieve analysis only are contemplated, the size of field sample listed in T 2 is usually adequate. When additional tests are to be conducted, the

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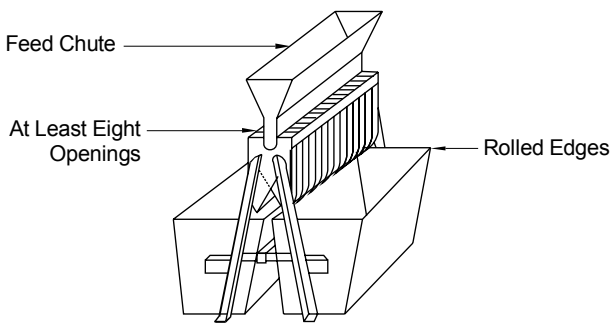
user shall determine that the initial size of the field sample is adequate to accomplish all intended tests. Similar procedures shall be used for aggregate produced in the laboratory.

METHOD A—MECHANICAL SPLITTER

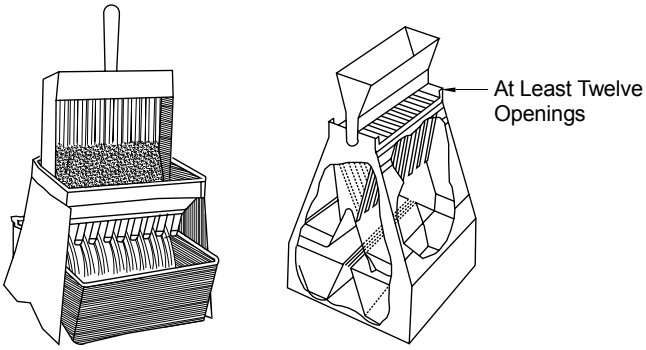
7. APPARATUS

7.1. *Sample Splitter*—Sample splitters shall have an even number of equal width chutes, but not less than a total of eight for coarse aggregate, or 12 for fine aggregate, which discharge alternatively to each side of the splitter. For coarse aggregate and mixed aggregate, the minimum width of the individual chutes shall be approximately 50 percent larger than the largest particles in the sample to be split (Note 3). For dry fine aggregate in which the entire sample will pass the 9.5-mm ($^3/_8$-in.) sieve, the minimum width of the individual chutes shall be at least 50 percent larger than the largest particles in the sample and the maximum width shall be 19 mm ($^3/_4$ in.). The splitter shall be equipped with two receptacles to hold the two halves of the sample following splitting. It shall also be equipped with a hopper or straightedged pan, which has a width equal to or slightly less than the overall width of the assembly of chutes, by which the sample may be fed at a controlled rate to the chutes. The splitter and accessory equipment shall be so designed that the sample will flow smoothly without restriction or loss of material (see Figure 1).



Riffle Sample Splitter

(a) Large Sample Splitter for Coarse Aggregate



(b) Small Sample Splitters for Fine Aggregate

Note: (a) may be constructed as either closed or open type. Closed type is preferred.

Figure 1—Sample Splitters (Riffles)

Note 3—Mechanical splitters are commonly available in sizes adequate for coarse aggregate having the largest particle not over 37.5 mm ($1^1/_2$ in.).

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8. PROCEDURE

8.1. Place the original sample in the hopper or pan and uniformly distribute it from edge to edge, so that when it is introduced into the chutes, approximately equal amounts will flow through each chute. The rate at which the sample is introduced shall be such as to allow free flowing through the chutes into the receptacles below.

8.2. Reintroduce the portion of the sample in one of the receptacles into the splitter as many times as necessary to reduce the sample to the size specified for the intended test. The portion of the material collected in the other receptacle may be reserved for reduction in size for other tests.

METHOD B—QUARTERING

9. APPARATUS

9.1. Apparatus shall consist of a straightedge; straightedged scoop, shovel or trowel; a broom or brush; and a canvas blanket or tear-resistant tarp approximately 2 by 2.5 m (6 by 8 ft).

10. PROCEDURE

10.1. Use either the procedure described in Section 10.1.1 or 10.1.2, or a combination of both.

10.1.1. Place the original sample on a hard, clean, level surface where there will be neither loss of material nor the accidental addition of foreign material. Mix the material by turning the entire sample over at least three times until the material is thoroughly mixed. With the last turning, form the entire sample into a conical pile by depositing individual lifts on top of the preceding lift. Carefully flatten the conical pile to a uniform thickness and diameter by pressing down the apex with a shovel or trowel so that each quarter sector of the resulting pile will contain the material originally in it. The diameter should be approximately four to eight times the thickness. Divide the flattened mass into four equal quarters with a shovel or trowel and remove two diagonally opposite quarters, including all fine material, and brush the cleared spaces clean. The two unused quarters may be set aside for later use or testing, if desired. Successively mix and quarter the remaining material until the sample is reduced to the desired size (see Figure 2).

10.1.2. As an alternative to the procedure in Section 10.1.1 or when the floor surface is uneven, the field sample may be placed on a canvas blanket or tear-resistant tarp and mixed with a shovel or trowel as described in Section 10.1.1, leaving the sample in a conical pile. As an alternative to mixing with the shovel or trowel, lift each corner of the blanket or tarp and pull it over the sample toward the diagonally opposite corner, causing the material to be rolled. After the material has been rolled a sufficient number of times (a minimum of four times), so that it is thoroughly mixed, pull each corner of the blanket or tarp toward the center of the pile so the material will be left in a conical pile. Flatten the pile as described in Section 10.1.1. Divide the sample as described in Section 10.1.1, or insert a stick or pipe beneath the blanket or tarp and under the center of the pile, then lift both ends of the stick, dividing the sample into two equal parts. Remove the stick, leaving a fold of the blanket between the divided portions. Insert the stick under the center of the pile at right angles to the first division and again lift both ends of the stick, dividing the sample into four equal parts. Remove two diagonally opposite quarters, being careful to clean the fines from the blanket or tarp. The two unused quarters may be set aside for later use or testing, if desired. Successively mix and quarter the remaining material until the sample is reduced to the desired size (see Figure 3).

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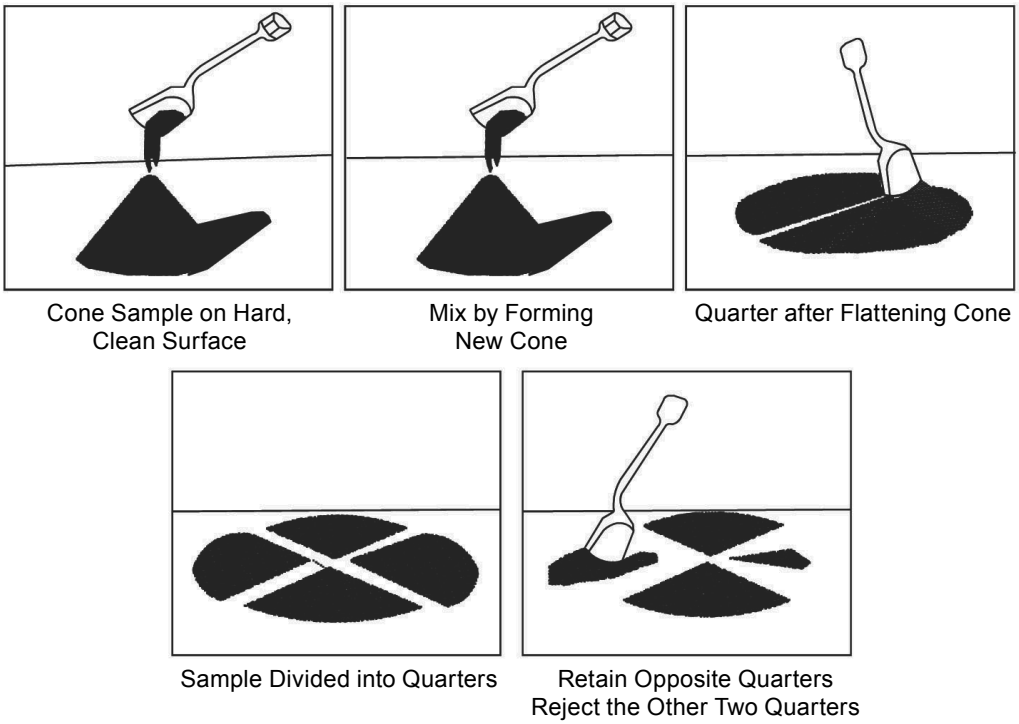

Figure 2—Quartering on a Hard, Clean, Level Surface

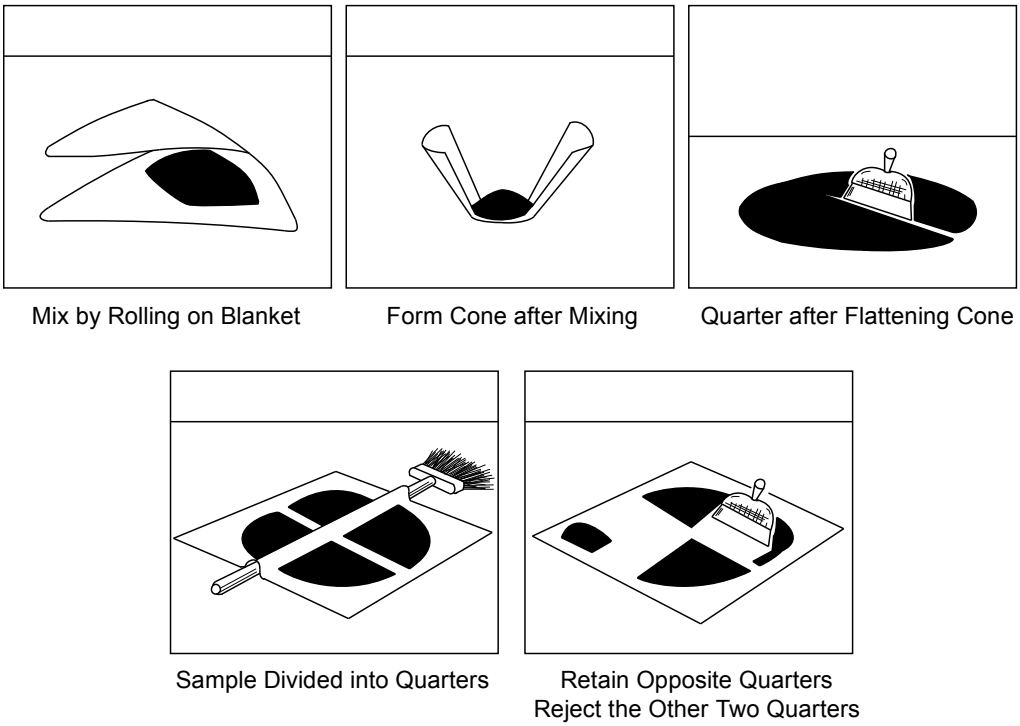

Figure 3—Quartering on a Canvas Blanket or Tear-Resistant Tarp

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METHOD C—MINIATURE STOCKPILE SAMPLING (DAMP FINE AGGREGATE ONLY)

11. APPARATUS

11.1. Apparatus shall consist of a straightedge; straightedged scoop, shovel, or trowel for mixing the aggregate; and either a small sampling thief, small scoop, or spoon for sampling.

12. PROCEDURE

12.1. Place the original sample of damp fine aggregate on a hard, clean, level surface where there will be neither loss of material nor the accidental addition of foreign material. Mix the material by turning the entire sample over at least three times until the material is thoroughly mixed. With the last turning, form the entire sample into a conical pile by depositing individual lifts on top of the preceding lift. If desired, the conical pile may be flattened to a uniform thickness and diameter by pressing the apex with a shovel or trowel so that each quarter sector of the resulting pile will contain the material originally in it. Obtain a sample for each test by selecting at least five increments of material at random locations from the miniature stockpile, using any of the sampling devices described in Section 11.1.

[1] Technically equivalent but not identical to ASTM C 702/C 702M-11.

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Standard Method of Test for

Total Evaporable Moisture Content of Aggregate by Drying

AASHTO Designation: T 255-00 (2012)[1]
ASTM Designation: C 566-97 (2004)

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Standard Method of Test for

Total Evaporable Moisture Content of Aggregate by Drying

AASHTO Designation: T 255-00 (2012)[1]
ASTM Designation: C 566-97 (2004)

1. SCOPE

1.1. This test method covers the determination of the percentage of evaporable moisture in a sample of aggregate by drying both surface moisture and moisture in the pores of the aggregate. Some aggregate may contain water that is chemically combined with the minerals in the aggregate. Such water is not evaporable and is not included in the percentage determined by this test method.

1.2. The values stated in SI units are to be regarded as the standard. The values stated in parentheses are provided for information only.

1.3. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use*. For specific precautionary statements, see Sections 5.3.1, 7.2.1, and 7.3.1.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 92, Wire-Cloth Sieves for Testing Purposes
- M 231, Weighing Devices Used in the Testing of Materials
- T 2, Sampling of Aggregates
- T 19M/T 19, Bulk Density ("Unit Weight") and Voids in Aggregate
- T 84, Specific Gravity and Absorption of Fine Aggregate
- T 85, Specific Gravity and Absorption of Coarse Aggregate

2.2. *ASTM Standards*:

- C 125, Standard Terminology Relating to Concrete and Concrete Aggregates
- C 670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. TERMINOLOGY

3.1. *Definitions*:

3.1.1. For definitions of terms used in this test method, refer to ASTM C 125.

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4. SIGNIFICANCE AND USE

4.1. This test method is sufficiently accurate for usual purposes such as adjusting batch quantities of ingredients for concrete. It will generally measure the moisture in the test sample more reliably than the sample can be made to represent the aggregate supply. In rare cases where aggregate itself is altered by heat, or where more refined measurement is required, the test should be conducted using a ventilated, controlled-temperature oven.

4.2. Large particles of coarse aggregate, especially those larger than 50 mm (2 in.), will require greater time for the moisture to travel from the interior of the particle to the surface. The user of this test method should determine by trial if rapid drying methods provide sufficient accuracy for the intended use when drying large-size particles.

5. APPARATUS

5.1. *Balance*—The balance shall have sufficient capacity, be readable to 0.1 percent of the sample mass, or better, and conform to the requirements of M 231.

5.2. *Source of Heat*—A ventilated oven capable of maintaining the temperature surrounding the sample at 110 ± 5°C (230 ± 9°F). Where close control of the temperature is not required (see Section 4.1), other suitable sources of heat may be used, such as an electric or gas hot plate, electric heat lamps, or a ventilated microwave oven.

5.3. *Sample Container*—A container not affected by the heat, and of sufficient volume to contain the sample without danger of spilling, and of such shape that the depth of sample will not exceed one-fifth of the least lateral dimension.

5.3.1. **Precaution**—When a microwave oven is used, the container shall be nonmetallic.

Note 1—Except for testing large samples, an ordinary frying pan is suitable for use with a hot plate, or any shallow flat-bottomed metal pan with heat lamps or oven. Note precaution in Section 5.3.1.

5.4. *Stirrer*—A metal spoon or spatula of convenient size.

6. SAMPLE

6.1. Sampling shall generally be accomplished in accordance with T 2, except the sample size may be as stated in Table 1.

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Table 1—Sample Size for Aggregate

Nominal Maximum Size of Aggregate, mm (in.)[a]	Mass of Normal Weight Aggregate Sample, Min., kg[b]
4.75 (0.187) (No. 4)	0.5
9.5 ($^3/_8$)	1.5
12.5 ($^1/_2$)	2
19.0 ($^3/_4$)	3
25.0 (1)	4
37.5 ($1^1/_2$)	6
50 (2)	8
63 ($2^1/_2$)	10
75 (3)	13
90 ($3^1/_2$)	16
100 (4)	25
150 (6)	50

[a] Based on sieves meeting M 92.

[b] Determine the minimum sample mass for lightweight aggregate by multiplying the value listed by the dry-loose unit mass of the aggregate in kg/m3 (determined using T 19M/T 19) and dividing by 1600.

6.2. Secure a sample of the aggregate representative of the moisture content in the supply being tested and having a mass not less than the amount listed in Table 1. Protect the sample against loss of moisture prior to determining the mass.

7. PROCEDURE

7.1. Determine the mass of the sample to the nearest 0.1 percent.

7.2. Dry the sample thoroughly in the sample container by means of the selected source of heat, exercising care to avoid loss of any particles. Very rapid heating may cause some particles to explode, resulting in loss of particles. Use a controlled temperature oven when excessive heat may alter the character of the aggregate, or where more precise measurement is required. If a source of heat other than the controlled temperature oven is used, stir the sample during drying to accelerate the operation and avoid localized overheating. When using a microwave oven, stirring of the sample is optional.

7.2.1. **Caution**—When using a microwave oven, occasionally minerals are present in aggregates that may cause the material to overheat and explode. If this occurs, it can damage the microwave oven.

7.3. When a hot plate is used, drying can be expedited by the following procedure. Add sufficient anhydrous denatured alcohol to cover the moist sample. Stir and allow suspended material to settle. Decant as much of the alcohol as possible without losing any of the sample. Ignite the remaining alcohol and allow it to burn off during drying over the hot plate.

7.3.1. **Warning**—Exercise care to control the ignition operation to prevent injury or damage from the burning alcohol.

7.4. The sample is thoroughly dry when further heating causes, or would cause, less than 0.1 percent additional loss in mass.

7.5. Determine the mass of the dried sample to the nearest 0.1 percent after it has cooled sufficiently not to damage the balance.

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8. CALCULATION

8.1. Calculate total evaporable moisture content as follows:

$$p = 100\left(W - D\right)/D \qquad (1)$$

where:

p = total evaporable moisture content of sample, percent;

W = mass of original sample, g; and

D = mass of dried sample, g.

8.2. Surface moisture content is equal to the difference between the total evaporable moisture content and the absorption, with all values based on the mass of a dry sample. Absorption may be determined in accordance with T 85, Test for Specific Gravity and Absorption of Coarse Aggregate, or T 84, Test for Specific Gravity and Absorption of Fine Aggregate.

9. PRECISION AND BIAS

9.1. *Precision*:

9.1.1. The within-laboratory single operator standard deviation for moisture content of aggregates has been found to be 0.28 percent (Note 2). Therefore, results of two properly conducted tests by the same operator in the same laboratory on the same type of aggregate sample should not differ by more than 0.79 percent (Note 2) from each other.

9.1.2. The between-laboratory standard deviation for moisture content of aggregates has been found to be 0.28 percent (Note 2). Therefore, results of properly conducted tests from two laboratories on the same aggregate sample should not differ by more than 0.79 percent (Note 2) from each other.

9.1.3. Test data used to derive the above precision indices were obtained from samples dried to a constant mass in a drying oven maintained at 110 ± 5°C. When other drying procedures are used, the precision of the results may be significantly different than that indicated above.

Note 2—These numbers represent, respectively, the 1s and d2s limits as described in ASTM C 670.

9.2. *Bias*:

9.2.1. When experimental results are compared with known values from accurately compounded specimens, the following has been derived.

9.2.1.1. The bias of moisture tests on one aggregate material has been found to have a mean of +0.06 percent. The bias of individual test values from the same aggregate material has been found with 95 percent confidence to lie between –0.07 percent and +0.20 percent.

9.2.1.2. The bias of moisture tests on a second aggregate material has been found to have a mean of less than +0.01 percent. The bias of individual test values from the same aggregate material has been found with 95 percent confidence to lie between –0.14 percent and +0.14 percent.

9.2.1.3. The bias of moisture tests overall on both aggregate materials has been found to have a mean of +0.03 percent. The bias of individual test values overall from both aggregate materials has been found with 95 percent confidence to lie between –0.12 percent and +0.18 percent.

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9.2.2. Test data used to derive the above bias statement were obtained from samples dried to a constant mass in a drying oven maintained at 110 ± 5°C. When other drying procedures are used, the bias of the results may be significantly different than that indicated above.

Note 3—These precision and bias statements were derived from aggregate moisture data provided by 17 laboratories participating in the SHRP Soil Moisture Proficiency Sample Program, which is fully described in the National Research Council Report SHRP-P-619. The samples tested that relate to these statements were well-graded mixtures of fine and coarse aggregate with moisture contents ranging from air dry to saturated surface-dry.

10. KEYWORDS

10.1. Aggregate; drying; moisture content.

[1] This method is technically equivalent with ASTM C 566-97 (2004), except for the balance statement in Section 5.1.

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Standard Method of Test for

Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

AASHTO Designation: T 11-05 (2013)[1]
ASTM Designation: C 117-13

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Standard Method of Test for

Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

AASHTO Designation: T 11-05 (2013)[1]
ASTM Designation: C 117-13

1. SCOPE

1.1. This test method covers determination of the amount of material finer than a 75-µm (No. 200) sieve in aggregate by washing. Clay particles and other aggregate particles that are dispersed by the wash water, as well as water-soluble materials, will be removed from the aggregate during the test.

1.2. Two procedures are included, one using only water for the washing operation, and the other including a wetting agent to assist the loosening of the material finer than the 75-µm (No. 200) sieve from the coarser material. Unless otherwise specified, Procedure A (water only) shall be used.

1.3. The values stated in SI units are to be regarded as the standard.

1.4. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 92, Wire-Cloth Sieves for Testing Purposes
- M 231, Weighing Devices Used in the Testing of Materials
- T 2, Sampling of Aggregates
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 248, Reducing Samples of Aggregate to Testing Size

2.2. *ASTM Standards*:

- C 117, Standard Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
- C 670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. SUMMARY OF METHOD

3.1. A sample of the aggregate is washed in a prescribed manner, using either plain water or water containing a wetting agent, as specified. The decanted wash water, containing suspended and

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dissolved material, is passed through a 75-µm (No. 200) sieve. The loss in mass resulting from the wash treatment is calculated as mass percent of the original sample and is reported as the percentage of material finer than a 75-µm (No. 200) sieve by washing.

4. SIGNIFICANCE AND USE

4.1. Material finer than the 75-µm (No. 200) sieve can be separated from larger particles much more efficiently and completely by wet sieving than through the use of dry sieving. Therefore, when accurate determinations of material finer than 75 µm in fine or coarse aggregate are desired, this test method is used on the sample prior to dry sieving in accordance with T 27. The results of this test method are included in the calculation in T 27, and the total amount of material finer than 75 µm by washing, plus that obtained by dry sieving the same sample, is reported with the results of T 27. Usually the additional amount of material finer than 75 µm obtained in the dry-sieving process is a small amount. If it is large, the efficiency of the washing operation should be checked. A large amount of material could also be an indication of the degradation of the aggregate.

4.2. Plain water is adequate to separate the material finer than 75 µm from the coarser material with most aggregates. In some cases, the finer material is adhering to the larger particles, such as some clay coatings and coatings on aggregates that have been extracted from bituminous mixtures. In these cases, the fine material will be separated more readily with a wetting agent in the water.

5. APPARATUS AND MATERIALS

5.1. *Balance*—The balance shall have sufficient capacity, be readable to 0.1 percent of the sample mass, or better, and conform to the requirements of M 231.

5.2. *Sieves*—A nest of two sieves, the lower being a 75-µm (No. 200) sieve and the upper being a sieve with openings in the range of 2.36 mm (No. 8) to 1.18 mm (No. 16), both conforming to the requirement of M 92.

5.3. *Container*—A pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water.

5.4. *Oven*—An oven of sufficient size, capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F).

5.5. *Wetting Agent*—Any dispersing agent, such as liquid dishwashing detergents, that will promote separation of the fine materials.

Note 1—The use of a mechanical apparatus to perform the washing operation is not precluded, provided the results are consistent with those obtained using manual operations. The use of some mechanical washing equipment with some samples may cause degradation of the sample.

6. SAMPLING

6.1. Sample the aggregate in accordance with T 2. If the same test sample is to be tested for sieve analysis according to T 27, comply with the applicable requirements of that method.

6.2. Thoroughly mix the sample of aggregate to be tested and reduce the quantity to an amount suitable for testing using the applicable methods described in T 248. If the same test sample is to be tested according to T 27, the minimum mass shall be as described in the applicable sections of that method. Otherwise, the mass of the test sample, after drying, shall conform with the following:

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Nominal Maximum Size	Minimum Mass, g
4.75 mm (No. 4) or smaller	300
9.5 mm ($^3/_8$ in.)	1000
19.0 mm ($^3/_4$ in.)	2500
37.5 mm ($1^1/_2$ in.) or larger	5000

The test sample shall be the end result of the reduction. Reduction to an exact predetermined mass shall not be permitted. If the nominal maximum size of the aggregate to be tested is not listed above, the next larger size listed shall be used to determine sample size.

7. SELECTION OF PROCEDURE

7.1. Procedure A shall be used, unless otherwise specified by the specification with which the test results are to be compared, or when directed by the agency for which the work is performed.

8. PROCEDURE A—WASHING WITH PLAIN WATER

8.1. Dry the test sample to constant mass at a temperature of 110 ± 5°C (230 ± 9°F). Determine the mass to the nearest 0.1 percent of the mass of the test sample.

8.2. If the applicable specification requires that the amount passing the 75-µm (No. 200) sieve shall be determined on a portion of the sample passing a sieve smaller than the nominal maximum size of the aggregate, separate the sample on the designated sieve and determine the mass of the material passing the designated sieve to 0.1 percent of the mass of this portion of the test sample. Use this mass as the original dry mass of the test sample in Section 10.1.

Note 2—Some specifications for aggregates with a nominal maximum size of 50 mm or greater, for example, provide a limit for material passing the 75-µm (No. 200) sieve determined on that portion of the sample passing the 25.0-mm sieve. Such procedures are necessary because it is impractical to wash samples of the size required when the same test sample is to be used for sieve analysis by T 27.

8.3. After drying and determining the mass, place the test sample in the container and add sufficient water to cover it. No detergent, dispersing agent, or other substance shall be added to the water. Agitate the sample with sufficient vigor to result in complete separation of all particles finer than the 75-µm (No. 200) sieve from the coarser particles, and to bring the fine material into suspension. The use of a large spoon or other similar tool to stir and agitate the aggregate in the wash water has been found satisfactory. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, arranged with the coarser sieve on top. Take care to avoid, as much as feasible, the decantation of coarser particles of the sample.

8.4. Add a second charge of water to the sample in the container, agitate, and decant as before. Repeat this operation until the wash water is clear.

Note 3—If mechanical washing equipment is used, the charging of water, agitating, and decanting may be a continuous operation.

Note 4—A spray nozzle or a piece of rubber tubing attached to a water faucet may be used to rinse any of the material that may have fallen onto the sieves. The velocity of water, which may be increased by pinching the tubing or by use of a nozzle, should not be sufficient to cause any splashing of the sample over the sides of the sieve.

8.5. Return all material retained on the nested sieves by flushing to the washed sample. Dry the washed aggregate to constant mass at a temperature of 110 ± 5°C (230 ± 9°F) and determine the mass to the nearest 0.1 percent of the original mass of the sample.

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Note 5—Following the washing of the sample and flushing any materials retained on the 75-µm (No. 200) sieve back into the container, no water should be decanted from the container except through the 75-µm sieve, to avoid loss of material. Excess water from flushing should be evaporated from the sample in the drying process.

9. PROCEDURE B—WASHING USING A WETTING AGENT

9.1. Prepare the sample in the same manner as for Procedure A.

9.2. After drying and determining the mass, place the test sample in the container. Add sufficient water to cover the sample, and add wetting agent to the water (Note 6). Agitate the sample with sufficient vigor to result in complete separation of all particles finer than the 75-µm (No. 200) sieve from the coarser particles, and to bring the fine material into suspension. The use of a large spoon or other similar tool to stir and agitate the aggregate in the wash water has been found satisfactory. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, arranged with the coarser sieve on top. Take care to avoid, as much as feasible, the decantation of coarser particles of the sample.

Note 6—There should be enough wetting agent to produce a small amount of suds when the sample is agitated. The quantity will depend on the hardness of the water and the quality of the detergent. Excessive suds may overflow the sieves and carry some material with them.

9.3. Add a second charge of water (without wetting agent) to the sample in the container, agitate, and decant as before. Repeat this operation until the wash water is clear.

9.4. Complete the test as for Procedure A.

10. CALCULATION

10.1. Calculate the amount of material passing a 75-µm (No. 200) sieve by washing as follows:

$$A = \left[\left(B - C \right) / B \right] \times 100 \qquad (1)$$

where:

A = percentage of material finer than a 75-µm (No. 200) sieve by washing;

B = original dry mass of sample, g; and

C = dry mass of sample after washing, g.

11. REPORT

11.1. Report the percentage of material finer than the 75-µm (No. 200) sieve by washing to the nearest 0.1 percent, except if the result is 10 percent or more, report the percentage to the nearest whole number.

11.2. Include a statement as to which procedure was used.

12. PRECISION AND BIAS

12.1. *Precision*—The estimates of precision of this test method listed in Table 1 are based on results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by this test method and ASTM C 117. The significant differences between the methods at the time the data were acquired is that T 11 required, and ASTM C 117 prohibited, the use of a

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wetting agent. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

Table 1—Precision

	Standard Deviation (1s),[a] %	Acceptable Range of Two Results (d2s),[a] %
Coarse aggregate:[b]		
Single-operator precision	0.10	0.28
Multilaboratory precision	0.22	0.62
Fine aggregate:[c]		
Single-operator precision	0.15	0.43
Multilaboratory precision	0.29	0.82

[a] These numbers represent the (1s) and (d2s) limits as described in ASTM C 670.

[b] Precision estimates are based on aggregates having a nominal maximum size of 19.0 mm ($^3/_4$ in.) with less than 1.5 percent finer than the 75-µm (No. 200) sieve.

[c] Precision estimates are based on fine aggregates having 1.0 to 3.0 percent finer than the 75-µm (No. 200) sieve.

12.1.1. The precision values for fine aggregate in Table 1 are based on nominal 500-g test samples. Revision of this test method in 1996 permits the fine aggregate test sample size to 300-g minimum. Analysis of results of testing of 300-g and 500-g test samples from Aggregate Proficiency Test Samples 99 and 100 (Samples 99 and 100 were essentially identical) produced the precision values in Table 2, which indicates only minor differences due to test sample size.

Table 2—Precision Data for 300-g and 500-g Test Samples

Fine Aggregate Proficiency Sample				Within Laboratory		Between Laboratory	
Test Result	Sample Size	No. Labs	Avg	1s	d2s	1s	d2s
AASHTO T 11/ASTM C 117 (Total material passing the	500 g	270	1.23	0.08	0.24	0.23	0.66
No. 200 sieve by washing, %)	300 g	264	1.20	0.10	0.29	0.24	0.68

Note 7—The values for fine aggregate in Table 1 will be revised to reflect the 300-g test sample size when a sufficient number of Aggregate Proficiency Tests have been conducted using that sample size to provide reliable data.

12.2. *Bias*—Because there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is made.

13. KEYWORDS

13.1. Aggregate; size analysis; wash loss; 75-µm (No. 200) sieve.

[1] Except for Sections 5.1 and 6.2, and Note 4, this test method is identical with ASTM C 117-13.

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Standard Method of Test for

Sieve Analysis of Fine and Coarse Aggregates

AASHTO Designation: T 27-14[1]
ASTM Designation: C 136-06

American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

Standard Method of Test for

Sieve Analysis of Fine and Coarse Aggregates

AASHTO Designation: T 27-14[1]
ASTM Designation: C 136-06

1. SCOPE

1.1. This method covers the determination of the particle size distribution of fine and coarse aggregates by sieving.

1.2. Some specifications for aggregates, which reference this method, contain grading requirements including both coarse and fine fractions. Instructions are included for sieve analysis of such aggregates.

1.3. The values stated in SI units are to be regarded as the standard. The values in parentheses are provided for information purposes only.

1.4. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory regulations prior to use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 92, Wire-Cloth Sieves for Testing Purposes
- M 231, Weighing Devices Used in the Testing of Materials
- T 2, Sampling of Aggregates
- T 11, Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
- T 248, Reducing Samples of Aggregate to Testing Size

2.2. *ASTM Standards*:

- C 125, Standard Terminology Relating to Concrete and Concrete Aggregates
- C 670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

2.3. *IEEE/ASTM Standard*:

- SI 10, American National Standard for Metric Practice

3. TERMINOLOGY

3.1. *Definitions*—For definitions of terms used in this standard, refer to ASTM C 125.

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4. SUMMARY OF METHOD

4.1. A sample of dry aggregate of known mass is separated through a series of sieves of progressively smaller openings for determination of particle size distribution.

5. SIGNIFICANCE AND USE

5.1. This method is used primarily to determine the grading of materials proposed for use as aggregates or being used as aggregates. The results are used to determine compliance of the particle size distribution with applicable specification requirements and to provide necessary data for control of the production of various aggregate products and mixtures containing aggregates. The data may also be useful in developing relationships concerning porosity and packing.

5.2. Accurate determination of material finer than the 75-µm (No. 200) sieve cannot be achieved by use of this method alone. Test Method T 11 for material finer than the 75-µm (No. 200) sieve by washing should be employed.

6. APPARATUS

6.1. *Balance*—The balance shall have sufficient capacity, be readable to 0.1 percent of the sample mass, or better, and conform to the requirements of M 231.

6.2. *Sieves*—The sieve cloth shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. The sieve cloth and standard sieve frames shall conform to the requirements of M 92. Nonstandard sieve frames shall conform to the requirements of M 92 as applicable.

Note 1—It is recommended that sieves mounted in frames larger than standard 203.2 mm (8 in.) diameter be used for testing coarse aggregate to reduce the possibility of overloading the sieves. See Section 8.3.

6.3. *Mechanical Sieve Shaker*—A mechanical sieving device, if used, shall create motion of the sieves to cause the particles to bounce, tumble, or otherwise turn so as to present different orientations to the sieving surface. The sieving action shall be such that the criterion for adequacy of sieving described in Section 8.4 is met in a reasonable time period.

Note 2—Use of a mechanical sieve shaker is recommended when the size of the sample is 20 kg (44 lb) or greater, and may be used for smaller samples, including fine aggregate. Excessive time (more than approximately 10 min) to achieve adequate sieving may result in degradation of the sample. The same mechanical sieve shaker may not be practical for all sizes of samples because the large sieving area needed for practical sieving of a large nominal size coarse aggregate very likely could result in loss of a portion of the sample if used for a smaller sample of coarse aggregate or fine aggregate.

6.4. *Oven*—An oven of appropriate size capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F).

7. SAMPLING

7.1. Sample the aggregate in accordance with T 2. The mass of the field sample shall be the mass shown in T 2 or four times the mass required in Sections 7.4 and 7.5 (except as modified in Section 7.6), whichever is greater.

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7.2. Thoroughly mix the sample and reduce it to an amount suitable for testing using the applicable procedures described in T 248. The sample for test shall be the approximate mass desired when dry and shall be the end result of the reduction. Reduction to an exact predetermined mass shall not be permitted.

Note 3—Where sieve analysis, including determination of material finer than the 75-µm (No. 200) sieve, is the only testing proposed, the size of the sample may be reduced in the field to avoid shipping excessive quantities of extra material to the laboratory.

7.3. *Fine Aggregate*—The size of the test sample of aggregate, after drying, shall be 300 g minimum.

7.4. *Coarse Aggregate*—The mass of the test sample of coarse aggregate shall conform with the following:

Nominal Maximum Size Square Openings, mm (in.)	Minimum Mass of Test Sample, kg (lb)
9.5 ($^3/_8$)	1 (2)
12.5 ($^1/_2$)	2 (4)
19.0 ($^3/_4$)	5 (11)
25.0 (1)	10 (22)
37.5 ($1^1/_2$)	15 (33)
50 (2)	20 (44)
63 ($2^1/_2$)	35 (77)
75 (3)	60 (130)
90 ($3^1/_2$)	100 (220)
100 (4)	150 (330)
125 (5)	300 (660)

7.5. *Coarse and Fine Aggregates Mixtures*—The mass of the test sample of coarse and fine aggregate mixtures shall be the same as for coarse aggregate in Section 7.4.

7.6. *Samples of Large-Size Coarse Aggregate*—The size of sample required for aggregate with 50-mm (2-in.) nominal maximum size or larger is such as to preclude convenient sample reduction and testing as a unit except with large mechanical splitters and sieve shakers. As an option when such equipment is not available, instead of combining and mixing sample increments and then reducing the field sample to testing size, conduct the sieve analysis on a number of approximately equal sample increments such that the total mass tested conforms to the requirements of Section 7.4.

7.7. In the event that the amount of material finer than the 75-µm (No. 200) sieve is to be determined by T 11, use the procedure described in Section 7.7.1 or 7.7.2, whichever is applicable.

7.7.1. For aggregates with a nominal maximum size of 12.5 mm ($^1/_2$ in.) or less, use the same test sample for testing by T 11 and this method. First test the sample in accordance with T 11 through the final drying operation, then dry sieve the sample as stipulated in Sections 8.2 through 8.6 of this method.

7.7.2. For aggregates with a nominal maximum size greater than 12.5 mm ($^1/_2$ in.), a single test sample may be used as described in Section 7.7.1 or separate test samples may be used for T 11 and this method.

7.7.3. Where the specification requires determination of the total amount of material finer than the 75-µm (No. 200) sieve by washing and dry sieving, use the procedure described in Section 7.7.1.

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8. PROCEDURE

8.1. If the test sample has not been subjected to testing by T 11, dry it to constant mass at a temperature of 110 ± 5°C (230 ± 9°F). Determine and record the mass of material that will be placed on the sieves to the accuracy of the balance as defined in Section 6.1.

Note 4—For control purposes, particularly where rapid results are desired, it is generally not necessary to dry coarse aggregate for the sieve analysis test. The results are little affected by the moisture content unless (1) the nominal maximum size is smaller than about 12.5 mm ($^1/_2$ in.), (2) the coarse aggregate contains appreciable material finer than 4.75 mm (No. 4), or (3) the coarse aggregate is highly absorptive (a lightweight aggregate, for example). Also, samples may be dried at the higher temperature associated with the use of hot plates without affecting results, provided steam escapes without generating pressures sufficient to fracture the particles, and temperatures are not so great as to cause chemical breakdown of the aggregate.

8.2. Select sieves with suitable openings to furnish the information required by the specifications covering the material to be tested. Use additional sieves as desired or necessary to provide other information, such as fineness modulus, or to regulate the amount of material on a sieve. Nest the sieves in order of decreasing size of opening from top to bottom and place the sample, or portion of the sample if it is to be sieved in more than one increment, on the top sieve. Agitate the sieves by hand or by mechanical apparatus for a sufficient period, established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy of sieving described in Section 8.4.

8.3. Limit the quantity of material on a given sieve so that all particles have opportunity to reach sieve openings a number of times during the sieving operation. For sieves with openings smaller than 4.75-mm (No. 4), the quantity retained on any sieve at the completion of the sieving operation shall not exceed 7 kg/m^2 (4 g/in.^{2}) of sieving surface area (Note 5). For sieves with openings 4.75 mm (No. 4) and larger, the quantity retained in kg shall not exceed the product of 2.5 × (sieve opening, mm × (effective sieving area, m^2)). This quantity is shown in Table 1 for five sieve-frame dimensions in common use. In no case shall the quantity retained be so great as to cause permanent deformation of the sieve cloth.

8.3.1. Prevent an overload of material on an individual sieve by one or a combination of the following methods:

8.3.1.1. Insert an additional sieve with opening size intermediate between the sieve that may be overloaded and the sieve immediately above that sieve in the original set of sieves.

8.3.1.2. Split the sample into two or more portions, sieving each portion individually. Combine the masses of the several portions retained on a specific sieve before calculating the percentage of the sample on the sieve.

8.3.1.3. Use sieves having a larger frame size and providing greater sieving area.

Note 5—The 7 kg/m^2 amounts to 200 g for the usual 203.2-mm (8-in.) diameter sieve (with effective sieving surface diameter of 190.5 mm (7.5 in.)).

8.3.1.4. In the case of coarse and fine aggregate mixtures, the portion of the sample finer than the 4.75-mm (No. 4) sieve may be distributed among two or more sets of sieves to prevent overloading of individual sieves.

8.3.1.5. Alternatively, the portion finer than the 4.75-mm (No. 4) sieve may be reduced in size using a mechanical splitter according to T 248. If this procedure is followed, compute the mass of each size increment of the original sample as follows:

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$$A = \frac{W_1}{W_2} \times B \qquad (1)$$

where:

A = mass of size increment on total sample basis,

W_1 = mass of fraction finer than 4.75-mm (No. 4) sieve in total sample,

W_2 = mass of reduced portion of material finer than 4.75-mm (No. 4) sieve actually sieved, and

B = mass of size increment in reduced portion sieved.

Table 1—Maximum Allowable Quantity of Material Retained on a Sieve, kg

Sieve Opening Size	Nominal Dimensions of Sieve[a]				
	203.2-mm, dia[b]	254-mm, dia[b]	304.8-mm, dia[b]	350 by 350, mm	372 by 580, mm
	Sieving Area, m^2				
	0.0285	0.0457	0.0670	0.1225	0.2158
125 mm (5 in.)	[c]	[c]	[c]	[c]	67.4
100 mm (4 in.)	[c]	[c]	[c]	30.6	53.9
90 mm (3 $^1/_2$ in.)	[c]	[c]	15.1	27.6	48.5
75 mm (3 in.)	[c]	8.6	12.6	23.0	40.5
63 mm (2 $^1/_2$ in.)	[c]	7.2	10.6	19.3	34.0
50 mm (2 in.)	3.6	5.7	8.4	15.3	27.0
37.5 mm (1 $^1/_2$ in.)	2.7	4.3	6.3	11.5	20.2
25.0 mm (1 in.)	1.8	2.9	4.2	7.7	13.5
19.0 mm ($^3/_4$ in.)	1.4	2.2	3.2	5.8	10.2
12.5 mm ($^1/_2$ in.)	0.89	1.4	2.1	3.8	6.7
9.5 mm ($^3/_8$ in.)	0.67	1.1	1.6	2.9	5.1
4.75 mm (No. 4)	0.33	0.54	0.80	1.5	2.6

[a] Sieve frame dimensions in inch units: 8.0-in. diameter; 10.0-in. diameter; 12.0-in. diameter; 13.8 by 13.8 in. (14 by 14 in. nominal); 14.6 by 22.8 in. (16 by 24 in. nominal).

[b] The sieve area for round sieves is based on an effective diameter 12.7 mm ($^1/_2$ in.) less than the nominal frame diameter, because M 92 permits the sealer between the sieve cloth and the frame to extend 6.35 mm ($^1/_4$ in.) over the sieve cloth. Thus the effective sieving diameter for a 203.2-mm (8.0-in.) diameter sieve frame is 190.5 mm (7.5 in.). Sieves produced by some manufacturers do not infringe on the sieve cloth by the full 6.35 mm ($^1/_4$ in.).

[c] Sieves indicated have less than five full openings and should not be used for sieve testing.

8.4. Continue sieving for a sufficient period and in such manner that, after completion, not more than 0.5 percent by mass of the total sample passes any sieve during 1 min of continuous hand sieving performed as follows: Hold the individual sieve, provided with a snug-fitting pan and cover, in a slightly inclined position in one hand. Strike the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turn the sieve about one sixth of a revolution at intervals of about 25 strokes. In determining sufficiency of sieving for sizes larger than the 4.75-mm (No. 4) sieve, limit the material on the sieve to a single layer of particles. If the size of the mounted testing sieves makes the described sieving motion impractical, use 203.2-mm (8-in.) diameter sieves to verify the sufficiency of sieving.

8.5. Unless a mechanical sieve shaker is used, hand sieve particles obtained on the 75 mm (3 in.) by determining the smallest sieve opening through which each particle will pass by rotating the particles, if necessary, in order to determine whether they will pass through a particular opening; however, do not force particles to pass through an opening.

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8.6. Determine the mass of each size increment on a scale or balance conforming to the requirements specified in Section 6.1 to the nearest 0.1 percent of the total original dry sample mass. The total mass of the material after sieving should check closely with the total original dry mass of the sample placed on the sieves. If the two amounts differ by more than 0.3 percent, based on the total original dry sample mass, the results should not be used for acceptance purposes.

9. CALCULATION

9.1. Calculate percentages passing, total percentages retained, or percentages in various size fractions to the nearest 0.1 percent on the basis of the total mass of the initial dry sample. If the same test sample was first tested by T 11, include the mass of material finer than 75-µm (No. 200) sieve by washing in the sieve analysis calculation; and use the total dry sample mass prior to washing in T 11 as the basis for calculating all the percentages.

9.1.1. When sample increments are tested as provided in Section 7.6, total the masses of the portion of the increments retained on each sieve, and use these masses to calculate the percentage as in Section 9.1.

9.2. Calculate the fineness modulus, when required, by adding the total percentages of material in the sample that is coarser than each of the following sieves (cumulative percentages retained), and dividing the sum by 100; 150 µm (No. 100), 300 µm (No. 50), 600 µm (No. 30), 1.18 mm (No. 16), 2.36 mm (No. 8), 4.75 mm (No. 4), 9.5 mm ($^3/_8$ in.), 19.0 mm ($^3/_4$ in.), 37.5 mm ($1^1/_2$ in.), and larger, increasing the ratio of 2 to 1.

10. REPORT

10.1. Depending upon the form of the specifications for use of the material under test, the report shall include one of the following:

10.1.1. Total percentage of material passing each sieve, or

10.1.2. Total percentage of material retained on each sieve, or

10.1.3. Percentage of material retained between consecutive sieves.

10.2. Report percentages to the nearest whole number, except if the percentage passing the 75-µm (No. 200) sieve is less than 10 percent, it shall be reported to the nearest 0.1 percent.

10.3. Report the fineness modulus, when required, to the nearest 0.01.

11. PRECISION AND BIAS

11.1. *Precision*—The estimates of precision for this test method are listed in Table 2. The estimates are based on the results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by T 27 and ASTM C 136. The data are based on the analyses of the test results from 65 to 233 laboratories that tested 18 pairs of coarse aggregate proficiency test samples and test results from 74 to 222 laboratories that tested 17 pairs of fine aggregate proficiency test samples (Samples No. 21 through 90). The values in the table are given for different ranges of total percentage of aggregate passing a sieve.

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Table 2—Estimates of Precision

	Total Percentage of Material Passing		Standard Deviation (1s), %[a]	Acceptable Range of Two Results (d2s), %[a]
Coarse Aggregate:[b]	100	≥95	0.32	0.9
Single-operator precision	<95	≥85	0.81	2.3
	<85	≥80	1.34	3.8
	<80	≥60	2.25	6.4
	<60	≥20	1.32	3.7
	<20	≥15	0.95	2.7
	<15	≥10	1.00	2.8
	<10	≥5	0.75	2.1
	<5	≥2	0.53	1.5
	<2	0	0.27	0.8
Multilaboratory precision	100	≥95	0.35	1.0
	<95	≥85	1.37	3.9
	<85	≥80	1.92	5.4
	<80	≥60	2.82	8.0
	<60	≥20	1.97	5.6
	<20	≥15	1.60	4.5
	<15	≥10	1.48	4.2
	<10	≥5	1.22	3.4
	<5	≥2	1.04	3.0
	<2	0	0.45	1.3
Fine Aggregate:				
Single-operator precision	100	≥95	0.26	0.7
	<95	≥60	0.55	1.6
	<60	≥20	0.83	2.4
	<20	≥15	0.54	1.5
	<15	≥10	0.36	1.0
	<10	≥2	0.37	1.1
	<2	0	0.14	0.4
Multilaboratory precision	100	≥95	0.23	0.6
	<95	≥60	0.77	2.2
	<60	≥20	1.41	4.0
	<20	≥15	1.10	3.1
	<15	≥10	0.73	2.1
	<10	≥2	0.65	1.8
	<2	0	0.31	0.9

[a] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C 670.

[b] The precision estimates are based on aggregates with nominal maximum size of 19.0 mm ($^3/_4$ in.).

11.1.1. The precision values for Fine Aggregate in Table 2 are based on nominal 500-g test samples. Revision of ASTM C 136 in 1994 permitted the fine aggregate test sample size to be 300 g minimum. Analysis of results of testing of 300-g and 500-g test samples from Aggregate Proficiency Test Samples 99 and 100 (Samples 99 and 100 were essentially identical) produced the precision values in Table 3, which indicate only minor differences due to test sample size.

Note 6—The values for Fine Aggregate in Table 2 will be revised to reflect the 300-g test sample size when a sufficient number of Aggregate Proficiency Tests have been conducted using that sample size to provide reliable data.

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Table 3—Precision Data for 300-g and 500-g Fine Aggregate Test Samples

Fine Aggregate Proficiency Sample				Within Laboratory		Among Laboratories	
Test Result	Sample Size	Number of Labs	Average	1s	d2s	1s	d2s
AASHTO T 27/ASTM C 136:							
Total material passing the 4.75-mm (No. 4) sieve (%)	500 g	285	99.992	0.027	0.066	0.037	0.104
	300 g	276	99.990	0.021	0.060	0.042	0.117
Total material passing the 2.36-mm (No. 8) sieve (%)	500 g	281	84.10	0.43	1.21	0.63	1.76
	300 g	274	84.32	0.39	1.09	0.69	1.92
Total material passing the 1.18-mm (No. 16) sieve (%)	500 g	286	70.11	0.53	1.49	0.75	2.10
	300 g	272	70.00	0.62	1.74	0.76	2.12
Total material passing the 600-µm (No. 30) sieve (%)	500 g	287	48.54	0.75	2.10	1.33	3.73
	300 g	276	48.44	0.87	2.44	1.36	3.79
Total material passing the 300-µm (No. 50) sieve (%)	500 g	286	13.52	0.42	1.17	0.98	2.73
	300 g	275	13.51	0.45	1.25	0.99	2.76
Total material passing the 150-µm (No. 100) sieve (%)	500 g	287	2.55	0.15	0.42	0.37	1.03
	300 g	270	2.52	0.18	0.52	0.32	0.89
Total material passing the 75-µm (No. 200) sieve (%)	500 g	278	1.32	0.11	0.32	0.31	0.85
	300 g	266	1.30	0.14	0.39	0.31	0.85

11.2. *Bias*—Because there is no accepted reference material suitable for determining the bias in this test method, no statement on bias is made.

[1] Similar but not identical to ASTM C 136-06.

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Standard Method of Test for

In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

AASHTO Designation: T 310-13

AASHTO
THE VOICE OF TRANSPORTATION

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Standard Method of Test for

In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

AASHTO Designation: T 310-13

1. SCOPE

1.1. This test method describes the procedure for determining the in-place density and moisture of soil and soil-aggregate by use of nuclear gauge. The density of the material may be determined by either Direct Transmission, Backscatter, or Backscatter/Air-Gap Ratio Method. The moisture of the material is determined only from measurements taken at the surface of the soil (i.e., backscatter).

1.2. *Density*—The total or wet density of soil and soil-rock mixtures is determined by the attenuation of gamma radiation where the source or detector is placed at a known depth up to 300 mm (12 in.) while the detector(s) or source remains on the surface (Direct Transmission Method) or the source and detector(s) remain on the surface (Backscatter Method).

1.2.1. The density in mass per unit volume of the material under test is determined by comparing the detected rate of gamma radiation with previously established calibration data.

1.3. *Moisture*—The moisture content of the soil and soil-rock mixtures is determined by thermalization or slowing of fast neutrons where the neutron source and the thermal neutron detector both remain at the surface.

1.3.1. The water content in mass per unit volume of the material under test is determined by comparing the detection rate of thermalized or slow neutrons with previously established calibration data.

1.4. *SI Units*—The values stated in SI units are to be regarded as the standard. The inch-pound equivalents may be approximate. It is common practice in the engineering profession to concurrently use pounds to represent both a unit of mass (lbm) and of force (lbf). This implicitly combines two systems of units, that is, the absolute system and the gravitational system.

1.4.1. This standard has been written using the absolute system for water content (kilograms per cubic meter) in SI units. Conversion to the gravitational system of unit weight in lbf/ft^3 may be made. The recording of water content in pound-force per cubic foot should not be regarded as nonconformance with this standard, although the use is scientifically incorrect.

1.4.2. In the U.S. Customary units system, the pound (lbf) represents a unit of force (weight). However, the use of balances or scales recording pounds of mass (lbm) or recording of density (lbm/ft^3) should not be regarded as nonconformance with this standard.

1.5. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use*.
See Section 6, Hazards.

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2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- T 99, Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop
- T 180, Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in.) Drop
- T 191, Density of Soil In-Place by the Sand-Cone Method
- T 217, Determination of Moisture in Soils by Means of a Calcium Carbide Gas Pressure Moisture Tester
- T 224, Correction for Coarse Particles in the Soil Compaction Test
- T 255, Total Evaporable Moisture Content of Aggregate by Drying
- T 265, Laboratory Determination of Moisture Content of Soils
- T 272, Family of Curves—One-Point Method

2.2. *ASTM Standards*:

- D 2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
- D 2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)
- D 4253, Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table
- D 4254, Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density
- D 7013/D 7013M, Standard Guide for Calibration Facility Setup for Nuclear Surface Gauges

3. SIGNIFICANCE

3.1. The test method described is useful as a rapid, nondestructive technique for the in-place determination of the wet density and water content of soil and soil-aggregate.

3.2. The test method is used for quality control and acceptance testing of compacted soil and rock for construction and for research and development. The nondestructive nature allows for repetitive measurements at a single test location and statistical analysis of the results.

3.3. *Density*—The fundamental assumptions inherent in the methods are that Compton scattering is the dominant interaction and that the material under test is homogeneous.

3.4. *Moisture*—The fundamental assumptions inherent in the test method are that the hydrogen present is in the form of water as defined by T 265 and that the material under test is homogeneous.

3.5. Test results may be affected by chemical composition, sample heterogeneity, and to a lesser degree, material density and the surface texture of the material being tested. The technique also exhibits spatial bias in that the gauge is more sensitive to water contained in the material in close proximity to the surface and less sensitive to water at deeper levels.

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4. INTERFERENCES

4.1. *In-Place Density Interferences*:

4.1.1. The chemical composition of the sample may affect the measurement, and adjustments may be necessary.

4.1.2. The gauge is more sensitive to the density of the material in close proximity to the surface in the Backscatter Method.

Note 1—The nuclear gauge density measurements are somewhat biased to the surface layers of the soil being tested. This bias has largely been corrected out of the Direct Transmission Method, and any remaining bias is insignificant. The Backscatter Method is still more sensitive to the material within the first several inches from the surface. Density measurements with direct transmission is the preferred method.

4.1.3. Oversize rocks or large voids in the source-detector path may cause higher or lower density determination, respectively. Where lack of uniformity in the soil due to layering, rock, or voids is suspected, the test site should be excavated and visually examined to determine if the test material is representative of the full material in general, and if rock correction is required.

4.1.4. The sample volume is approximately 0.0028 m^3 (0.10 ft^3) for the Backscatter Method and 0.0057 m^3 (0.20 ft^3) for the Direct Transmission Method when the test depth is 150 mm (6 in.). The actual sample volume is indeterminate and varies with the gauge and the density of the material. In general, the higher the density, the smaller the volume.

4.1.5. Other radioactive sources must not be within 10 m (30 ft) of the gauge in operation.

4.2. *In-Place Moisture Content Interferences*:

4.2.1. The chemical composition of the sample may dramatically affect the measurement and adjustments may be necessary. Hydrogen in forms other than water will cause measurements in excess of the true value. Some chemical elements, such as boron, chlorine, and minute quantities of cadmium, will cause measurements lower than the true value.

4.2.2. The water content determined by this test method is not necessarily the average water within the volume of the sample involved in the measurement. The measurement is heavily influenced by the water content of the material closest to the surface. The volume of soil and rock represented in the measurement is indeterminate and will vary with the water content of the material. In general, the greater the water content of the material, the smaller the volume involved in the measurement. At 160 kg/m^3 (10 lb/ft^3), approximately 50 percent of the typical measurement results from the water content of the upper 50 to 75 mm (2 to 3 in.).

4.2.3. Other neutron sources must not be within 10 m (30 ft) of the gauge in operation.

5. APPARATUS

5.1. *Nuclear Density/Moisture Gauge*—Although exact details of construction of the gauge may vary, the system shall consist of:

5.1.1. A sealed source of high-energy gamma radiation, such as cesium or radium.

5.2. *Gamma Detector*—Any type of gamma detector, such as a Geiger-Mueller tube(s).

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5.3. *Fast Neutron Source*—A sealed mixture of a radioactive material, such as americium, radium, or californium-252, and a target material such as beryllium.

5.4. *Slow Neutron Detector*—Any type of slow neutron detector, such as boron trifluoride or helium-3 proportional counter.

5.5. *Reference Standard*—A block of material used for checking gauge operation, correction of source decay, and to establish conditions for a reproducible reference count rate.

5.6. *Site Preparation Device*—A plate, straightedge, or other suitable leveling tool that may be used for planing the test site to the required smoothness, and in the Direct Transmission Method, guiding the drive pin to prepare a perpendicular hole.

5.7. *Drive Pin*—A pin not to exceed the diameter of the rod in the Direct Transmission gauge by more than 6 mm ($^1/_4$ in.), or as recommended by the gauge manufacturer, used to prepare a hole in the material under test for inserting the rod.

5.7.1. A slide hammer, with a drive pin attached, may also be used both to prepare a hole in the material to be tested and to extract the pin without distortion to the hole.

5.8. *Drive Pin Extractor*—A tool that may be used to remove the drive pin in a vertical direction so that the pin will not distort the hole in the extraction process.

6. HAZARDS

6.1. The gauge utilizes radioactive materials that may be hazardous to the health of the users unless proper precautions are taken. Users of the gauge must become familiar with applicable safety procedures and government regulations.

6.2. Effective user instructions together with routine safety procedures, such as source leak tests, recording and evaluation of film badge data, etc., are a recommended part of the operation and storage of this gauge.

7. CALIBRATION

7.1. Calibration of the gauge will be in accordance with Annexes A1 and A2. (See also ASTM D 7013/D 7013M.)

8. STANDARDIZATION

8.1. All nuclear density/moisture gauges are subject to long-term aging of the radioactive sources, detectors, and electronic systems, which may change the relationship between count rates and the material density and water content. To offset this aging, gauges are calibrated as a ratio of the measurement count rate to a count rate made on a reference standard or to an air-gap count (for the backscatter/air-gap ratio method). The reference count rate should be in the same or higher order of magnitude than the range of measurement count rates over the useful range of the gauge.

8.2. Standardization of the gauge on the reference standard is required at the start of each day's use and a permanent record of these data shall be retained. The standardization shall be performed with the gauge at least 10 m (30 ft) away from other nuclear density/moisture gauges and clear of large masses of water or other items that may affect the reference count rates. Standard counts should be taken in the same environment as the actual measurement counts.

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8.2.1. Turn on the gauge and allow for stabilization according to the manufacturer's recommendations. If the gauge is to be used either continuously or intermittently during the day, it is best to leave it in the "power on" condition to prevent having to repeat the stabilization (refer to the manufacturer's recommendations). This will provide more stable, consistent results.

8.2.2. Using the reference standard, take at least four repetitive readings at the normal measurement period and obtain the mean. If available on the gauge, one measurement of four or more times the normal period is acceptable. This constitutes one standardization check.

Use the procedure recommended by the gauge manufacturer for determining compliance with the gauge calibration curves. Without specific recommendations for the gauge manufacturer, use the procedure in Section 8.2.3.

8.2.3. If the mean of the four repetitive readings is outside the limits set by Equation 1, repeat the standardization check. If the second standardization check satisfies Equation 1, the gauge is considered in satisfactory operating condition. If the second standardization check does not satisfy Equation 1, the gauge should be checked and verified according to Annexes A1 and A2, Sections A1.8 and A2.5. If the verification shows that there is no significant change in the calibration curve, a new reference standard count, N_o, should be established. If the verification check shows that there is a significant difference in the calibration curve, repair and recalibrate the gauge.

$$N_s = N_o \pm 1.96\sqrt{(N_o/F)} \qquad (1)$$

where:

N_s = value of current standardization count;

N_o = average of the past four values of Ns taken for prior usage; and

F = factory prescale factor (contact gauge manufacturer for the factor).

9. PROCEDURE

9.1. Select a test location where the gauge will be at least 150 mm (6 in.) away from any vertical mass. If closer than 600 mm (24 in.) to a vertical mass, such as in a trench, follow the gauge manufacturer's correction procedures.

9.2. *Prepare the test site in the following manner*:

9.2.1. Remove all loose and disturbed material and additional material, as necessary, to expose the top of the material to be tested.

Note 2—The spatial bias should be considered in determining the depth at which the gauge is to be seated.

9.2.2. Prepare a horizontal area sufficient in size to accommodate the gauge by planing the area to a smooth condition so as to obtain maximum contact between the gauge and material being tested.

9.2.3. The maximum void beneath the gauge shall not exceed 3 mm ($^1/_8$ in.). Use native fines or fine sand to fill the voids and smooth the surface with a rigid plate or other suitable tool. The depth of the filler should not exceed approximately 3 mm ($^1/_8$ in.).

Note 3—The placement of the gauge on the surface of the material to be tested is critical to the successful determination of density. The optimum condition is total contact between the bottom surface of the gauge and the surface of the material being tested. When optimal conditions are not present, correct surface irregularities by the use of sand or similar filler material. The total area filled should not exceed 10 percent of the bottom area of the gauge. Several trial seatings may be required to achieve these conditions.

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9.3. Turn on and allow the gauge to stabilize (warm up) according to the manufacturer's recommendations (see Section 8.2.1).

9.4. *Backscatter or Backscatter/Air-Gap Ratio Method of In-Place Nuclear Density and Moisture Content*:

9.4.1. Seat the gauge firmly.

9.4.2. Keep all other radioactive sources at least 10 m (30 ft) away from the gauge to avoid affecting the measurement.

9.4.3. Set the gauge into the Backscatter (BS) position (see Note 4).

9.4.4. Secure and record one or more 1-min readings (see Note 5). When using the backscatter/air-gap ratio method, follow the manufacturer's instructions regarding gauge setup. Take the same number of readings for the normal measurement period in the air-gap position as in the standard backscatter position. Determine the air-gap ratio by dividing the counts per minute obtained in the air-gap position by the counts per minute obtained in the standard position. Many gauges have built-in provisions for automatically calculating the air-gap ratio and wet density.

9.4.5. Determine the in-place wet density by use of the calibration curve previously established or read the gauge directly if so equipped.

9.5. *Direct Transmission Method of In-Place Nuclear Density and Moisture Content:*

9.5.1. Select a test location where the gauge in test position will be at least 150 mm (6 in.) away from any vertical projection.

9.5.2. Make a hole perpendicular to the prepared surface using the guide and the hole-forming device (Section 5). The hole shall be a minimum of 50 mm (2 in.) deeper than the desired measurement depth and of an alignment that insertion of the probe will not cause the gauge to tilt from the plane of the prepared area.

9.5.3. Mark the test area to allow the placement of the gauge over the test site and to allow the alignment of the source rod to the hole. Follow manufacturer recommendations, if applicable.

9.5.4. Remove the hole-forming device carefully to prevent the distortion of the hole, damage to the surface, or loose material to fall into the hole.

9.5.5. Place the gauge on the material to be tested, making sure of maximum surface contact as described above.

9.5.6. Lower the source rod into the hole to the desired test depth. Pull gently on the gauge in the direction that will bring the side of the probe to face the center of the gauge so that the probe is in intimate contact with the side of the hole in the gamma measurement path.

Note 4—As a safety precaution, do not extend a rod containing radioactive sources out of its shielded position prior to placing on the test site. Always align the gauge so as to allow placing the rod directly into the test hole from the shielded position.

9.5.7. Keep all other radioactive sources at least 10 m (30 ft) away from the gauge to avoid affecting the measurement.

9.5.8. If the gauge is so equipped, set the depth selector to the same depth as the probe before recording the automated (gauge computed densities, moisture contents, and weights) values.

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9.5.9. Secure and record one or more 1-min readings (see Note 5).

9.5.10. Determine the in-place wet density by use of the calibration curve previously established or read the gauge directly; if so equipped.

Note 5—The gauge may be rotated about the axis of the probe to obtain additional readings.

9.6. If representative samples of material are to be taken for purposes of water content and/or density determination, the sample shall be taken from directly underneath the gauge. For the Backscatter Method, remove the material to a depth of approximately 75 mm (3 in.). For the Direct Transmission Method, remove the material to the approximate depth of the measurement of the gauge.

10. CALCULATION OF RESULTS

10.1. If dry density is required, the in-place water content may be determined by using the nuclear methods described herein, gravimetric samples and laboratory determination, or other approved instrumentation.

10.1.1. If the water content is determined by nuclear methods, use the gauge readings directly, or subtract the kg/m^3 (lbm/ft^3) of moisture from the kg/m^3 (lbm/ft^3) of wet density, and obtain dry density in kg/m^3 (lbm/ft^3).

10.1.2. If the water content is determined by other methods, and is in the form of percent, proceed as follows:

$$d = \frac{100}{100 + w}(m) \qquad (2)$$

where:

d = dry density in kg/m^3 (lbm/ft^3);

m = wet density in kg/m^3 (lbm/ft^3); and

w = water as a percent of dry mass.

10.2. *Percent Density:*

10.2.1. It may be desired to express the in-place density as a percentage of some other reference density, for example, the laboratory densities determined in accordance with T 99, T 180, or T 272. This relation can be determined by dividing the in-place density by the laboratory reference density and multiplying by 100. Calculations for determining relative density are provided in ASTM D 4253 or D 4254. Corrections for oversize material, if required, should be performed in accordance with T 224.

11. REPORT

11.1. *The report shall include the following*:

11.1.1. Standardization and adjustment data for the date of the tests;

11.1.2. Make, model, and serial number of the test gauge;

11.1.3. Name of the operator(s);

11.1.4. Date of last instrument calibration or calibration verification;

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11.1.5. Test site identification;

11.1.6. Visual description of material tested;

11.1.7. Test mode (backscatter or direct transmission) and test depth (if applicable);

11.1.8. Wet and dry densities in kg/m^3 or unit weights in lb/ft^3;

11.1.9. Water content in percent of dry mass or dry unit weight; and

11.1.10. Any adjustments made in the reported values and reasons for adjustments (i.e., offset, oversize particles, etc.).

12. PRECISION AND BIAS

12.1. *Precision*:

12.1.1. *Wet Density*—Criteria for judging the acceptability of wet density test results obtained by this test method are given in Table 1. The figure in Column 3 represents the standard deviations that have been found to be appropriate for the materials tested in Column 1. The figures given in Column 4 are the limits that should not be exceeded by the difference between the results of two properly conducted tests. The figures given are based upon an interlaboratory study in which five test sites containing soils, with wet densities as shown in Column 2, were tested by eight different devices and operators. The wet density of each test site was determined three times by each device.

Table 1—Results of Statistical Analysis (Wet Density)[a]

	Soil Type (Column 1)	Average, lb/ft^3 (kg/m^3) (Column 2)	Standard Deviation (Column 3)	Acceptable Range of Two Results,[b] lb/ft^3 (kg/m^3) (Column 4)
Single-Operator Precision				
Direct Transmission:				
	CL	114.7 (1837.3)	0.34 (5.45)	0.94 (15.06)
	SP	120.9 (1936.6)	0.27 (4.32)	0.74 (11.85)
	ML	130.1 (2084.0)	0.46 (7.37)	1.28 (20.50)
Backscatter:				
	ML	124.6 (1995.9)	1.21 (19.38)	3.39 (54.30)
Multilaboratory Precision				
Direct Transmission:				
	CL	114.7 (1837.3)	0.66 (10.57)	1.86 (29.79)
	SP	120.9 (1936.6)	0.68 (10.89)	1.91 (30.59)
	ML	130.1 (2084.0)	0.77 (12.23)	2.15 (34.44)
Backscatter:				
	ML	124.6 (1995.9)	2.38 (38.12)	6.67 (106.84)

[a] The data used to establish the density and moisture content precision statements are contained in ASTM Research Report RR:D18-1004. Similar soil types using other classification systems should reflect similar precision values.

[b] Two separate readings at a singular site with constant gate orientation and settings.

12.1.2. *Moisture Content*—Criteria for judging the acceptability of the moisture content results obtained by this test method are given in Table 2. The value in Column 2 is in the units actually measured by the nuclear gauge. The figures in Column 3 represent the standard deviations that have been found to be appropriate for the materials tests in Column 1. The figures given in Column 4 are the limits that should not be exceeded by the difference between the results of two properly conducted tests. The figures given are based upon an interlaboratory study in which five test sites containing

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soils, with moisture content as shown in Column 2, were tested by eight different devices and operators. The moisture content of each test site was determined three times by each device.

Table 2—Results of Statistical Analysis (Moisture Content)

	Soil Type (Column 1)	Average, lb/ft^3 (kg/m^3) (Column 2)	Standard Deviation (Column 3)	Acceptable Range of Two Results,[a] lb/ft^3 (kg/m^3) (Column 4)
Single-Operator Precision				
	CL	12.1 (193.8)	0.35 (5.6)	0.97 (15.5)
	SP	18.7 (299.5)	0.46 (7.4)	1.29 (20.7)
	ML	19.6 (314.0)	0.35 (5.6)	0.99 (15.8)
Multilaboratory Precision				
	CL	12.1 (193.8)	0.52 (8.3)	1.44 (23.1)
	SP	18.7 (299.5)	0.75 (12.0)	2.10 (33.6)
	ML	19.6 (314.0)	0.58 (9.3)	1.63 (26.1)

[a] Two separate readings at a singular site with constant gauge orientation and settings.

12.2. *Bias*:

12.2.1. There are no accepted reference values for these test methods; therefore, bias cannot be determined.

13. KEYWORDS

13.1. Compaction test; construction control; density; moisture content; nuclear methods; quality control; water content.

ANNEXES

(Mandatory Information)

A1. WET DENSITY CALIBRATION AND VERIFICATION

A1.1. *Calibration*—Newly acquired gauges shall be calibrated initially. Existing gauges shall be calibrated after repairs that may affect the gauge geometry. Existing gauges shall be calibrated to reestablish calibration curves, tables, or equivalent coefficients if the gauge does not meet the specified tolerances in the verification process. If the owner does not establish a verification procedure, the gauge shall be calibrated at a minimum frequency of 24 months.

A1.2. *Verification*—Existing gauges shall be verified at a minimum frequency of 12 months. The verification process and resultant tolerances obtained over the depths that the gauge shall be formally recorded and documented. If the verification process indicates a variance beyond the specified tolerances, the gauge shall be calibrated.

A1.3. The calibration response of the gauge shall be within ±16 kg/m^3 (±1.0 lb/ft^3) on the blocks on which the gauge was calibrated. This calibration may be done by the manufacturer, the user, or an independent vendor. Nuclear gauge response is influenced by the chemical composition of measured materials. This response must be taken into account in establishing the assigned standard block density. The blocks used for calibration shall be capable of generating a general and reliable curve covering the entire density range of materials tested in the field. The density of these standard blocks shall be determined to an accuracy of ±0.2 percent.

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A1.3.1. Calibrate the density of the blocks used to verify the gauge calibrations any time the blocks are damaged, structurally altered in any way, and at a period not to exceed 5 years. The density of blocks composed of natural materials such as soil or rock shall be verified annually.

Note A1—Unless calibration blocks are damaged during transportation from one facility to another, they do not need to be re-verified for density. However, changes in the size and set up of the calibration bays, or environmental conditions such as temperature changes and different background radiation levels, may affect the blocks and the gauge response on the calibration blocks. To determine the effect of the changes, it is recommended that the gauge response be checked by one or more gauges recently calibrated at the original location.

A1.4. Sufficient data shall be taken on each density standard block to ensure a gauge count precision (see Annex A3) of at least one-half the gauge count precision required for field use, assuming field use measurement of 1-min duration and 4-min duration used for calibration, or an equivalent relationship. The data may be presented in the form of a graph, table, equation coefficients, or stored in the gauge, to allow converting the count rate data to density.

A1.5. The method and test procedures used in establishing the calibration count rate data shall be the same as those used for obtaining the field count rate data.

A1.6. The material type, actual density, or assigned standard block density of each calibration standard used to establish or verify the gauge calibration shall be stated as part of the calibration data for each measurement depth.

A1.7. The standards should be sufficient in size to not change the count rate if enlarged in any dimension.

Note A2—Minimum surface dimensions of approximately 610 mm by 430 mm (24 by 17 in.) have proven satisfactory. For the Backscatter Method, a minimum depth of 230 mm (9 in.) is adequate, whereas for the Direct Transmission Method the depth should be at least 50 mm (2 in.) deeper than the deepest rod penetration depth. A larger surface area should be considered for the backscatter air-gap method. For blocks with width and length smaller than the sizes specified, follow the block manufacturers' recommendations for proper installation and use.

A1.8. The most successful standards that have been established for calibration have been made of magnesium, aluminum, aluminum/magnesium, granite, and limestone. These standards have been used in combination with each other, with historical curve information, and with other prepared block(s) to produce accurate and reliable calibration.

A1.8.1. Standards of soil, rock, and concrete that have stable characteristics for reproducibility and uniformity are difficult to prepare. These standards may be of use for specialty verification or field calibration where local site material chemistry or background situation require special adaptation.

A1.9. Verify an existing calibration by taking a sufficient number of counts at each measurement depth on one or more blocks of established density to ensure the accuracy of the existing calibration within ±32 kg/m^3 (±2.0 lb/ft^3) at each measurement depth.

A1.9.1. Sufficient data shall be taken to ensure a gauge count precision of at least one-half the gauge count precision required for field use assuming field use measurement of 1-min duration and 4-min duration used for calibration, or an equivalent relationship.

A1.9.2. Calibration blocks, which are used for calibration of the gauge, or prepared block(s), which are capable of generating a general and reliable curve covering the range of densities of the materials to be tested in the field, can be used to verify the gauge calibration.

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A1.9.2.1. Blocks prepared of soil, rock, concrete, asphalt, and engineered blocks that have characteristics of reproducible uniformity may be used, but care must be taken to minimize changes in density and water content over time.

A1.9.2.2. Density values of prepared blocks shall be determined to an accuracy of ±0.5 percent at each measurement depth.

A1.9.3. The assigned block density for each calibration depth used to verify the gauge calibration shall be stated as part of the verification data.

A2. WATER CONTENT CALIBRATION AND VERIFICATION

A2.1. *Calibration*—Newly acquired gauges shall be calibrated initially. Existing gauges shall be calibrated after repairs that may affect the gauge geometry. Existing gauges shall be calibrated to reestablish calibration curves, tables, or equivalent coefficients if the gauge does not meet the specified tolerances in the verification process. If the owner does not establish a verification procedure, the gauge shall be calibrated at a minimum frequency of 24 months.

A2.2. *Verification*—Existing gauges shall be verified at a minimum frequency of 12 months. The verification process and resultant tolerances obtained over the depths the gauge shall be formally recorded and documented. If the verification process indicates a variance beyond the specified tolerances, the gauge shall be calibrated.

A2.3. The calibration response of the gauge shall be within ±16 kg/m^3 (±1.0 lb/ft^3) on the blocks on which the gauge was calibrated. This calibration may be done by the manufacturer, the user, or an independent vendor. The blocks used for calibration should be capable of generating a general curve covering the entire water content range of the materials to be tested in the field. The calibration curve can be established using counts and water contents of standard blocks, previous factory curve information, or historical data. Due to the effect of chemical composition, the calibration supplied by the manufacturer with the gauge will not be applicable to all materials. It shall be accurate for silica and water; therefore, the calibration must be verified and adjusted, if necessary, in accordance to Section A2.5.

A2.4. Calibration standards may be established using any of the following methods. Prepared containers or standards must be large enough to not change the observed count rate if made larger in any dimension.

Note A3—Dimensions of approximately 610 mm long by 460 mm wide by 360 mm deep (approximately 24 in. by 18 in. by 14 in.) have proven satisfactory. For blocks with width and length smaller than the sizes specified, follow block manufacturers' recommendations for proper installation and use.

A2.4.1. Prepare a homogeneous standard of hydrogenous materials having an equivalent water content determined by comparison (using a nuclear gauge) with a saturated silica sand standard prepared in accordance with Section A.2.4. Metallic blocks used for wet density calibration, such as magnesium or aluminum, are a convenient zero water content standard.

A2.4.2. Prepare containers of compacted material with a percent water content determined by oven-dry (T 265) and a wet density calculated from the mass of the material and the inside dimensions of the container. The water content may be calculated as follows:

$$M_m = \frac{\rho \times w}{100 + w} \qquad (A2.1)$$

where:

M_m = water content, kg/m^3 or lbm/ft^3;

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ρ = wet (total) density, kg/m^3 or lbm/ft^3; and

w = water content, percent of dry mass.

A2.4.3. Where neither of the previous calibration standards are available, the gauge may be calibrated by using a minimum of four selected test sites in an area of a compaction project where material has been placed at several different water contents. The test sites shall represent the range of water contents over which the calibration is to be used. At least four replicate nuclear measurements shall be made at each test site. The density at each site shall be measured by making four closely spaced determinations with calibrated equipment in accordance with T 191. The water content of each of the density tests shall be determined by T 265. Use the mean value of the replicate readings as the calibration point value for each site.

A2.5. *Calibration Adjustments*:

A2.5.1. The calibration of newly acquired or repaired gauges shall be verified and adjusted prior to use. Calibration curves shall be checked prior to performing tests on materials that are distinctly different from material types previously used in obtaining or adjusting the calibration. Sample materials may be selected by either Section A2.5.1.1 or Section A2.5.1.2. The amount of water shall be within ±2 percent of the water content established as optimum for compaction. Determine the water content in kg/m^3 or lb/ft^3 by Equation A2.1. A microwave oven or direct heater may be utilized for drying materials that are not sensitive to temperature, in addition to the methods listed in Section A2.4.3. A minimum of four comparisons is required and the mean of the observed differences used as the correction factor.

A2.5.1.1. Container(s) of compacted material taken from the test site may be prepared in accordance with Section A2.4.2.

A2.5.1.2. Test site(s) or the compacted material may be selected in accordance with Section A2.4.3.

A2.5.2. The method and test procedures used in obtaining the count rate to establish the error must be the same as those used for measuring the water content of the material to be tested.

A2.5.3. The mean value of the difference between the moisture content of the test samples as determined in Section A2.5.1.1 or Section A2.5.1.2 and the values measured with the gauge shall be used as a correction to measurements made in the field. Some gauges utilizing a microprocessor may have provision to input a correction factor that is established by the relative values of water content as a percentage of dry density, thus eliminating the need to determine the difference in mass units of water.

A2.6. Verify an existing calibration by taking sufficient number of counts on one or more blocks of established water content to ensure the accuracy of the existing calibration within ±16 kg/m^3 (±1 lb/ft^3). The water content block(s) should be prepared in accordance with Sections A2.4.1 and A2.4.2.

A2.6.1. Sufficient data shall be taken to ensure a gauge count precision (see Annex A3) of at least one-half the gauge count precision required for field use, assuming field use measurement of 1-min duration and 4-min duration used for calibration, or an equivalent relationship.

A2.6.2. Calibration blocks used to establish calibration parameters and prepared block(s) that are capable of generating a general and reliable curve covering the range of densities of the materials that are to be tested in the field can be used to verify calibration.

A2.6.3. Prepared block(s) that have characteristics of reproducible uniformity may be used, but care must be taken to minimize changes in density and water content over time.

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A2.6.4. The assigned water content of the block(s) used for verification of the gauge shall be stated as part of the verification data.

A3. GAUGE COUNT PRECISION

A3.1. Gauge count precision is defined as the change in density or water content that occurs corresponding to a one standard deviation change in the count due to the random decay of the radioactive source. The density of the material and time period of the count must be stated. It may be determined using calibration data (Equation A3.1) or Sections A3.2 and A3.3.

A3.2. Determine the gauge count precision of the system, P, from the slope of the calibration curve, S, and the standard deviation, σ, of the signals (detected gamma rays or detected neutrons) in counts per minute (cpm), as follows:

$$P = \sigma / S \qquad (A3.1)$$

where:

P = precision;

σ = standard deviation, cpm; and

S = slope, cpm/kg/m^3 (cpm/lb/ft^3).

Note A4—Displayed gauge counts may be scaled. Contact the manufacturer to obtain the appropriate prescale factor.

A3.3. *Density*—Determine the slope of the calibration curve at the 2000-kg/m^3 (125-lb/ft^3) point in counts per minute per kilogram per cubic meter (counts per minute per pound per cubic foot). Determine the standard deviation of a minimum of 20 per pound repetitive readings of 1 min each (gauge is not moved after seating for the first count) taken on material having a density of 2000 ± 80 kg/m^3 (125.0 ± 5.0 lb/ft^3). The value of P is typically less than 10 kg/m^3 (0.6 lb/ft^3) in the Backscatter Method and 5 kg/m^3 (0.3 lb/ft^3) in the Direct Transmission Method at 6-in. depth.

A3.4. *Moisture*—Where the slope of the calibration curve is determined at the 160-kg/m^3 (10-lb/ft^3) point and the standard deviation is determined from a minimum of 20 repetitive readings of 1 min each (the gauge is not moved after the first count) taken on material having a moisture content of 160 ± 10 kg/m^3 (10.0 ± 0.6 lb/ft^3), the value of P is typically less than 4.8 kg/m^3 (0.30 lb/ft^3).

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ASTM

Test Methods

Designation: D75/D75M – 14

American Association State
Highway and Transportation
Officials Standard
AASHTO No.: T2

Standard Practice for Sampling Aggregates[1]

This standard is issued under the fixed designation D75/D75M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers sampling of coarse and fine aggregates for the following purposes:

1.1.1 Preliminary investigation of the potential source of supply,

1.1.2 Control of the product at the source of supply,

1.1.3 Control of the operations at the site of use, and

1.1.4 Acceptance or rejection of the materials.

NOTE 1—Sampling plans and acceptance and control tests vary with the type of construction in which the material is used.

1.2 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 2—The quality of the results produced by this standard are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of Practice D3666 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3666 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of Practice D3666 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C125 Terminology Relating to Concrete and Concrete Aggregates

C702 Practice for Reducing Samples of Aggregate to Testing Size

D8 Terminology Relating to Materials for Roads and Pavements

D2234/D2234M Practice for Collection of a Gross Sample of Coal

D3665 Practice for Random Sampling of Construction Materials

D3666 Specification for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials

E105 Practice for Probability Sampling of Materials

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

E141 Practice for Acceptance of Evidence Based on the Results of Probability Sampling

3. Terminology

3.1 *Definitions:*

3.1.1 *maximum size of aggregate, n—in specifications for, or descriptions of aggregate*—the smallest sieve opening through which the entire amount of aggregate is required to pass.

3.1.2 *maximum aggregate size, (Superpave) n—in specifications for, or descriptions of aggregate*—one size larger than the nominal maximum aggregate size.

3.1.3 *nominal maximum aggregate size (of aggregate), n—in specifications for, or descriptions of aggregate*—the smallest sieve opening through which the entire amount of the aggregate is permitted to pass.

3.1.4 *nominal maximum aggregate size (Superpave), n—in specifications for, or descriptions of aggregate*—one size larger than the first sieve that retains more than 10 % aggregate.

[1] This practice is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.30 on Methods of Sampling.

Current edition approved June 1, 2014. Published June 2014. Originally approved in 1920. Last previous edition approved in 2009 as D75/D75M – 09. DOI: 10.1520/D0075_D0075M-14.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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3.1.4.1 *Discussion*—The definitions in 3.1.1 and 3.1.2 also appear in Terminologies C125 and D8. They are presented in this standard to illustrate the differences between the aggregate definitions and Superpave definitions of similar terms. The definitions in 3.1.2 and 3.1.4 apply to hot mix asphalt (HMA) mixtures designed using the Superpave system only.

3.1.4.2 *Discussion*—Specifications on aggregates usually stipulate a sieve opening through which all of the aggregate may, but not need to, pass so that a slated maximum portion of the aggregate may be retained on that sieve. A sieve opening so designed is the *nominal maximum size*.

4. Significance and Use

4.1 Sampling is equally as important as the testing, and the sampler shall use every precaution to obtain samples that will show the nature and condition of the materials which they represent.

4.2 Samples for preliminary investigation tests are obtained by the party responsible for development of the potential source (Note 3). Samples of materials for control of the production at the source or control of the work at the site of use are obtained by the manufacturer, contractor, or other parties responsible for accomplishing the work. Samples for tests to be used in acceptance or rejection decisions by the purchaser are obtained by the purchaser or his authorized representative.

NOTE 3—The preliminary investigation and sampling of potential aggregate sources and types occupies a very important place in determining the availability and suitability of the largest single constituent entering into the construction. It influences the type of construction from the standpoint of economics and governs the necessary material control to ensure durability of the resulting structure, from the aggregate standpoint. This investigation should be done only by a responsible trained and experienced person. For more comprehensive guidance, see the Appendix.

5. Securing Samples

5.1 *General*—Where practicable, samples to be tested for quality shall be obtained from the finished product. Samples from the finished product to be tested for abrasion loss shall not be subject to further crushing or manual reduction in particle size in preparation for the abrasion test unless the size of the finished product is such that it requires further reduction for testing purposes.

5.2 *Inspection*—The material to be sampled shall be visually inspected to determine discernible variations. If any discernible variations are noted, corrective action shall be taken to establish homogeneity in the material prior to sampling. If it is necessary to indicate the degree of variability existing within the main pile, separate samples shall be drawn from separate areas of the pile. The seller shall provide suitable equipment needed for proper inspection and sampling.

5.3 *Procedure:*

5.3.1 *Sampling from a Flowing Aggregate Stream (Bins or Belt Discharge)*—Select units to be sampled by a random method, such as Practice D3665, from the production. Obtain at least three approximately equal increments, selected at random from the unit being sampled, and combine to form a field sample whose mass equals or exceeds the minimum recommended in 5.4.2. Take each increment from the entire cross section of the material as it is being discharged. It is usually necessary to have a special device constructed for use at each particular plant. This device consists of a pan of sufficient size to intercept the entire cross section of the discharge stream and hold the required quantity of material without overflowing. A set of rails may be necessary to support the pan as it is passed under the discharge stream. Insofar as is possible, keep bins continuously full or nearly full to reduce segregation.

NOTE 4—Sampling the initial discharge or the final few tons from a bin or conveyor belt increases the chances of obtaining segregated material and should be avoided.

5.3.2 *Sampling from the Conveyor Belt*—Select units to be sampled by a random method, such as Practice D3665, from the production. Obtain at least three approximately equal increments, selected at random, from the unit being sampled and combine to form a field sample whose mass equals or exceeds the minimum recommended in 5.4.2. Stop the conveyor belt while the sample increments are being obtained. Insert two templates, the shape of which conforms to the shape of the belt in the aggregate stream on the belt, and space them such that the material contained between them will yield an increment of the required weight (see Fig. 1). Carefully scoop all material between the templates into a suitable container and collect the fines on the belt with a brush and dust pan and add to the container.

NOTE 5—Automatic belt samplers may be used as long as they are properly maintained, and regular inspection ensures all material is being removed from the belt (see Fig. 2).

5.3.3 *Sampling from Stockpiles*—Avoid sampling coarse aggregate or mixed coarse and fine aggregate from stockpiles whenever possible, particularly when the sampling is done for the purpose of determining aggregate properties that may be dependent upon the grading of the sample. If circumstances make it necessary to obtain samples from a stockpile of coarse aggregate or a stockpile of combined coarse and fine aggregate, design a sampling plan for the specific case under consideration to ensure that segregation does not introduce a bias in the results. This approach will allow the sampling agency to use a sampling plan that will give a confidence in results obtained therefrom that is agreed upon by all parties concerned to be

FIG. 1 Belt Sampling Template

FIG. 2 Automatic Belt Sampler

acceptable for the particular situation. The sampling plan shall define the number of samples necessary to represent lots and sublots of specific sizes. The sampling plan shall also define any specialized site-specific sampling techniques or procedures that are required to ensure unbiased samples for existing conditions. The owner and supplier shall agree upon the use of any specialized site-specific techniques or procedures. When site-specific techniques or procedures are developed for sampling a stockpile, those procedures shall supersede the procedures given in 5.3.3.1. (Note 6). General principles for sampling from stockpiles are applicable to sampling from trucks, rail cars, barges, or other transportation units.

NOTE 6—Specific site sampling plans may include the number of sampling increments (loader buckets) required to construct the sampling pad.

5.3.3.1 *Sampling from Stockpiles with Power Equipment (preferred)*—In sampling material from stockpiles it is very difficult to ensure unbiased samples due to the segregation which often occurs when material is stockpiled, with coarser particles rolling to the outside base of the pile. For coarse or mixed coarse and fine aggregate, every effort shall be made to enlist the services of power equipment to develop a separate small sampling pile.

(1) When obtaining a sample from a stockpile for acceptance testing, a loader shall enter the stockpile nearest the area representing material that is currently being shipped or loaded into a production facility, with the bucket approximately 150 mm [6 in.] above ground level, never allowing the front tires of the loader to ramp up on the pile. Without backing up, the loader shall lift the full bucket of material then tilt the bucket down to gently roll the material out of the bucket back onto the pile, thus re-blending any segregated material on the outside surface of the pile. If prior visual inspection noted discernible variation, or if the loader is not of sufficient size to cause a cascading effect down the face of the pile during this remixing process, several buckets of material shall either be remixed or removed and discarded to prevent use of potentially injurious material.

(2) After re-blending, the loader shall re-enter the stockpile, as before, and obtain a full loader bucket of the re-blended material, tilt back and lift the bucket only high enough to back up slightly.

(3) At the base of the main stockpile with the bucket only high enough to permit free-flow of the material from the bucket, the loader operator shall tilt the bucket forward to gently roll the material out of the bucket forming a small sampling pile. If the loader bucket is not of sufficient size to create a sample pad of representative size, multiple buckets shall be used, dumped on top of each other and back-dragged to form a single sample pad.

(4) At this point the loader operator shall raise the bucket, drive forward far enough to reach across the small pile with the loader bucket without allowing the loader tires to ramp up on the sampling pile, lower the bucket to about half the height of the small pile, and backup, therefore creating a flat surface for sampling (see Fig. 3). The loader shall only back-drag the small pile once. This flat surface provides a stable and safe area to obtain a representative sample.

(5) Place the sample bucket(s) near the center of the flat, oval-shaped sampling pad. The sample shall be obtained across the entire flat area, but avoid sampling within 0.3 m [1 ft] of the sample pad edge. Divide the sample pad into 4 quadrants and sample equal amounts of materials evenly across each quadrant. Fully insert the shovel as near vertical as possible then gently roll the shovel back and lift slowly to avoid coarse material rolling off the sides of the shovel (Note 7). Obtain additional shovelfuls from different quadrants of the sampling pad, and in areas that avoid previous "shovel holes."

NOTE 7—Square-tip shovels with the outer edges rolled up approximately 50 mm [2 in.] on each side works well in preventing material from rolling from the side. Spade-tip shovels are not recommended.

5.3.3.2 *Sampling from Stockpiles Without Power Equipment:*

NOTE 8—Sampling coarse aggregate and coarse and fine mixed aggregate stockpiles without the aid of power equipment is not advised.

(1) Where power equipment is not available, samples from stockpiles shall be made up of at least three increments taken from the top third, at the mid-point, and bottom third of the elevation of the stockpile.

(2) Shove a board vertically into the pile just above the sampling point to prevent coarser material from rolling down and further segregating the material and biasing the sample. The board shall be of ample size to prevent material from cascading down into the sampling area.

(3) With the board in place, scrape off the outer most surface of the pile with the shovel, then insert the shovel perpendicular to the angle of the pile, into the freshly exposed material to obtain the sample. Repeat this process across the face of the stockpile until the recommended minimum field sample size in 5.4.2 is obtained but no less than the three increments described in 5.3.3.2*(1)*.

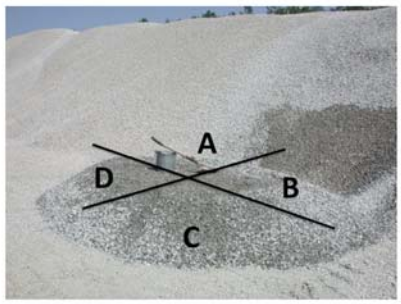
5.3.3.3 *Sampling Fine Aggregate from Stockpiles (Alternative Method for Fine Aggregate Only)*—When sampling fine aggregate from a stockpile, the outer layer, which easily becomes segregated by wind and rain during stockpile storage, shall be removed and the sample taken from the material beneath.

Step 1. Loader enters stockpile with bucket approximately 150mm [6 in.] above ground level

Step 2. Loader gently rolls the material out of the bucket to form a small pile

Step 3. Loader reaches across the small pile, lowers bucket, and back-drags small pile to form the sampling pad

Step 4. Sampling pad



Step 5. Draw sample portions from each quadrant

FIG. 3 Five-Step Photographic Sequence of Constructing Sampling Pad From Stockpile of Aggregate

(1) Sampling tubes approximately 30 mm [1.25 in.] minimum by 2 m [6 ft.] in length shall be inserted into the shipping face of the stockpile horizontally at random locations.

NOTE 9—A sampling tube can be constructed of aluminum, PVC, or other sturdy material. The tip being inserted into the pile can be cut at a 45° angle to ease insertion.

(2) Sample shall be taken at a minimum height of 3 ft from the surrounding grade.

(3) A minimum of five tube insertions randomly spaced across the face of the stockpile shall form a single field sample (see Fig. 4). Ensure that the minimum field sample size recommended in 5.4.2 is obtained.

5.3.4 *Sampling from Transportation Units*—Avoid sampling coarse aggregate or mixed coarse and fine aggregate from transportation units whenever possible, particularly when the sampling is done for the purpose of determining aggregate properties that may be dependent upon the grading of the sample. If circumstances make it necessary to obtain samples from a transportation unit, design a sampling plan for the specific case under consideration to ensure that segregation does not introduce a bias in the results. This approach will allow the sampling agency to use a sampling plan that will give a confidence in results obtained therefrom that is agreed upon by all parties concerned to be acceptable for the particular situation. The sampling plan shall define the number of samples necessary to represent lots and sublots of specific sizes. General principles for sampling from stockpiles are applicable to sampling from trucks, rail cars, barges, or other transportation units.

NOTE 10—Sampling from transportation units should be avoided if at all possible. In sampling material from transportation units it is very difficult to ensure unbiased samples, due to the segregation which often occurs when material is transported, with coarser particles rolling to the outside and finer particles settling.

5.3.4.1 In sampling coarse aggregates from railroad cars or barges, effort shall be made to enlist the services of power equipment capable of exposing the material at various levels and random locations.

5.3.4.2 Where power equipment is not available, a common procedure requires excavation of three or more trenches using a shovel across the unit at points that will, from visual appearance, give a reasonable estimate of the characteristics of the load. The trench bottom shall be approximately level, at least 0.3 m [1 ft] in width and in depth below the surface.

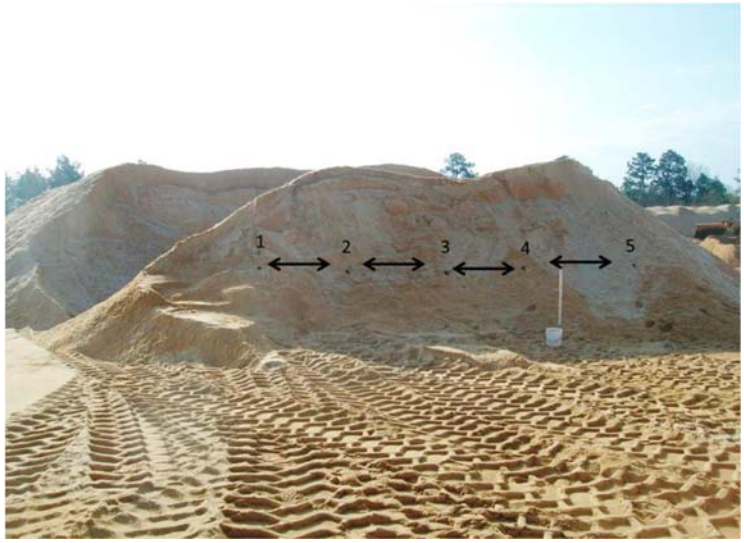


FIG. 4 Sampling Fine Aggregate from Stockpile Using Sampling Tube

5.3.4.3 A minimum of three increments from approximately equally spaced points along each trench shall be taken by pushing a shovel downward into the material.

5.3.4.4 Coarse aggregate in trucks shall be sampled in essentially the same manner as for rail cars or barges, except for adjusting the number of increments according to the size of the truck.

5.3.4.5 For fine aggregate in transportation units, sampling tubes as described in 5.3.3.3, except inserted vertically, may be used to extract an appropriate number of increments from the trenches to form the field sample.

5.3.5 *Sampling from Roadway (Bases and Subbases):*

5.3.5.1 Sample units selected by a random method, such as Practice D3665, from the construction.

5.3.5.2 Obtain at least three approximately equal increments, selected at random from the unit being sampled, after the material has been placed and prior to compaction, and combine to form a field sample whose mass equals or exceeds the minimum recommended in 5.4.2. Take all increments from the roadway for the full depth of the material, taking care to exclude any underlying material. Clearly mark the specific areas from which each sample increment is to be removed.

5.3.5.3 A metal template placed over the area will aid in securing approximately equal increment weights. Place the template on top of the material to be sampled. Sample material from the center of the template. As material is extracted from the center of the template, the template is continuously lowered to prevent the material outside of the template from falling into the sample hole. The template shall be composed of metal or other sturdy material, no less than 0.3 m [12 in.] in diameter and 0.25 m [9 in.] in height, providing a sampling area not less than 0.07 m^2 [110 $in.^2$] (see Fig. 5).

5.4 *Number and Masses of Field Samples:*

5.4.1 The number of field samples (obtained by one of the methods described in 5.3) required depends on the criticality of, and variation in, the properties to be measured. Designate each unit from which a field sample is to be obtained prior to sampling. The number of field samples from the production shall be sufficient to give the desired confidence in test results.

NOTE 11—Guidance for determining the number of samples required to obtain the desired level of confidence in test results may be found in Test Method D2234/D2234M, Practice E105, Practice E122, and Practice E141.

FIG. 5 Proper Use of Metal Template For Sampling Mixed Coarse and Fine Aggregate From Roadway Grade

TABLE 1 Minimum Size of Field Samples

Aggregate Size[A]	Field Sample Mass, min, kg[B] [lb]	Field Sample Volume, min, L [gal]
Fine Aggregate		
2.36 mm [No. 8]	10 [22]	8 [2]
4.75 mm [No. 4]	10 [22]	8 [2]
Coarse Aggregate		
9.5 mm [⅜ in.]	10 [22]	8 [2]
12.5 mm [½ in.]	15 [35]	12 [3]
19.0 mm [¾ in.]	25 [55]	20 [5]
25.0 mm [1 in.]	50 [110]	40 [10]
37.5 mm [1½ in.]	75 [165]	60 [15]
50 mm [2 in.]	100 [220]	80 [21]
63 mm [2½ in.]	125 [275]	100 [26]
75 mm [3 in.]	150 [330]	120 [32]
90 mm [3½ in.]	175 [385]	140 [37]

[A] For processed aggregates, use the nominal maximum size as indicated by the appropriate specification or description. If the specification or description does not indicate a nominal maximum size (for example, a sieve size indicating 90 to 100 % passing), use the maximum size (that sieve indicating 100 % passing).
[B] For combined coarse and fine aggregates (for example, base or subbase aggregate), the minimum weight shall be coarse aggregate minimum mass plus 10 kg.

5.4.2 The field sample masses cited are tentative. The masses must be predicated on the type and number of tests to which the material is to be subjected and sufficient material obtained to provide for the proper execution of these tests. Standard acceptance and control tests are covered by ASTM standards and specify the portion of the field sample required for each specific test. Generally speaking, the amounts specified in Table 1 will provide adequate material for routine grading and quality analysis. Extract test portions from the field sample according to Practice C702 or as required by other applicable test methods.

6. Shipping Samples

6.1 Transport aggregates in bags or other containers so constructed as to preclude loss or contamination of any part of the sample, or damage to the contents from mishandling during shipment.

6.2 Shipping containers for aggregate samples shall have suitable individual identification attached and enclosed so that field reporting, laboratory logging, and test reporting may be facilitated.

7. Keywords

7.1 aggregates; exploration of potential sources; number and sizes needed to estimate character; sampling

APPENDIXES

(Nonmandatory Information)

X1. EXPLORATION OF POTENTIAL AGGREGATE SOURCES

X1.1 Scope

X1.1.1 Sampling for evaluation of potential aggregate sources should be performed by a responsible trained and experienced person. Because of the wide variety of conditions under which sampling may have to be done it is not possible to describe detailed procedures applicable to all circumstances. This appendix is intended to provide general guidance and list more comprehensive references.

X1.2 Sampling Stone from Quarries or Ledges

X1.2.1 *Inspection*—The ledge or quarry face should be inspected to determine discernible variations or strata. Differences in color and structure should be recorded.

X1.2.2 *Sampling and Size of Sample*—Separate samples having a mass of at least 25 kg [55 lbs] should be obtained from each discernible stratum. The sample should not include material weathered to such an extent that it is no longer suitable for the purpose intended. One or more pieces in each sample should be at least 150 by 150 by 100 mm [6 in. by 6 in. by 4 in.] in size with the bedding plane plainly marked, and this piece should be free of seams or fractures.

X1.2.3 *Record*—In addition to the general information accompanying all samples the following information should accompany samples taken from ledges or quarry faces:

X1.2.3.1 Approximate quantity available. (If quantity is very large this may be recorded as practically unlimited.)

X1.2.3.2 Quantity and character of overburden.

X1.2.3.3 A detailed record showing boundaries and location of material represented by each sample.

NOTE X1.1—A sketch, plan, and elevation, showing the thickness and

location of the different layers is recommended for this purpose.

X1.3 Sampling Roadside or Bank Run Sand and Gravel Deposits

X1.3.1 *Inspection*—Potential sources of bank run sand and gravel may include previously worked pits from which there is an exposed face or potential deposits discovered through air-photo interpretation, geophysical exploration, or other types of terrain investigation.

X1.3.2 *Sampling*—Samples should be so chosen from each different stratum in the deposit discernible to the sampler. An estimate of the quantity of the different materials should be made. If the deposit is worked as an open-face bank or pit, samples should be taken by channeling the face vertically, bottom to top, so as to represent the materials proposed for use. Overburdened or disturbed material should not be included in the sample. Test holes should be excavated or drilled at numerous locations in the deposit to determine the quality of the material and the extent of the deposit beyond the exposed face, if any. The number and depth of test holes will depend upon the quantity of the material needed, topography of the area, nature of the deposit, character of the material, and potential value of the material in the deposit. If visual inspection indicates that there is considerable variation in the material, individual samples should be selected from the material in each well defined stratum. Each sample should be thoroughly mixed and quartered if necessary so that the field sample thus obtained will be at least 12 kg [25 lbs] for sand and 35 kg [75 lbs] if the deposit contains an appreciable amount of coarse aggregate.

X1.3.3 *Record*—In addition to the general information accompanying all samples the following information should accompany samples of bank run sand and gravel:

X1.3.3.1 Location of supply.

X1.3.3.2 Estimate of approximate quantity available.

X1.3.3.3 Quantity and character of overburden.

X1.3.3.4 Length of haul to proposed site of work.

X1.3.3.5 Character of haul (kind of road, maximum grades, and so forth)

X1.3.3.6 Details as to extent and location of material represented by each sample.

NOTE X1.2—A sketch of plans and elevations, showing the thickness and location of different layers, is recommended for this purpose.

X2. NUMBER AND SIZE OF INCREMENTS NEEDED TO ESTIMATE CHARACTER OF UNIT SAMPLED

X2.1 Scope

X2.1.1 This appendix presents the rationale used by the responsible committee in the development of this practice.

X2.2 Descriptions of Terms Specific to This Standard

X2.2.1 *field sample*—a quantity of the material of sufficient size to provide an acceptable estimate of the average quality of a unit.

X2.2.2 *lot*—a sizable isolated quantity of bulk material from a single source, assumed to have been produced by the same process (for example, a day's production or a specific mass or volume).

X2.2.3 *test portion*—a quantity of the material to be tested of sufficient size extracted from the larger field sample by a procedure designed to ensure accurate representation of the field sample, and thus of the unit sampled.

X2.2.4 *unit*—a batch or finite subdivision of a lot of bulk material (for example, a truck load or a specific area covered).

X2.3 Test Unit, Size, and Variability

X2.3.1 The unit to be represented by a single field sample should neither be so large as to mask the effects of significant variability within the unit nor be so small as to be affected by the inherent variability between small portions of any bulk material.

X2.3.2 A unit of bulk material composed of graded aggregate or aggregate mixtures might consist of a full truckload. If it were possible, the entire load might be tested; as a practical matter, a field sample is composed of three or more increments chosen at random from the material as it is loaded or unloaded from the truck. Research has shown that such a procedure permits an acceptable estimate to be made of the average gradation that might be measured from 15 or 20 increments from the truck.

X2.3.3 Significant variability with a lot of material, where it might exist, should be indicated by statistical measures, such as the standard deviation between units selected at random from within the lot.

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Designation: C702/C702M – 11

American Association State
Highway and Transportation
Officials Standard: T 248

Standard Practice for Reducing Samples of Aggregate to Testing Size[1]

This standard is issued under the fixed designation C702/C702M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This practice covers three methods for the reduction of large samples of aggregate to the appropriate size for testing employing techniques that are intended to minimize variations in measured characteristics between the test samples so selected and the large sample.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

NOTE 1—Sieve size is identified by its standard designation in Specification E11. The alternative designation given in parentheses is for information only and does not represent a different standard sieve size.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C125 Terminology Relating to Concrete and Concrete Aggregates

C128 Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate

D75 Practice for Sampling Aggregates

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Terminology

3.1 *Definitions*—The terms used in this practice are defined in Terminology C125.

4. Significance and Use

4.1 Specifications for aggregates require sampling portions of the material for testing. Other factors being equal, larger samples will tend to be more representative of the total supply. This practice provides procedures for reducing the large sample obtained in the field or produced in the laboratory to a convenient size for conducting a number of tests to describe the material and measure its quality in a manner that the smaller test sample portion is most likely to be a representation of the larger sample, and thus of the total supply. Failure to carefully follow the procedures in this practice could result in providing a nonrepresentative sample to be used in subsequent testing. The individual test methods provide for minimum amount of material to be tested.

4.2 Under certain circumstances, reduction in size of the large sample prior to testing is not recommended. Substantial differences between the selected test samples sometimes cannot be avoided, as for example, in the case of an aggregate having relatively few large size particles in the sample. The laws of chance dictate that these few particles may be unequally distributed among the reduced size test samples. Similarly, if the test sample is being examined for certain contaminants occurring as a few discrete fragments in only small percentages, caution should be used in interpreting results from the reduced size test sample. Chance inclusion or exclusion of only one or two particles in the selected test sample may importantly influence interpretation of the characteristics of the original sample. In these cases, the entire original sample should be tested.

5. Selection of Method

5.1 *Fine Aggregate*—Reduce the size of samples of fine aggregate that are drier than the saturated-surface-dry condition (Note 2) using a mechanical splitter according to Method A. Reduce the size of samples having free moisture on the particle surfaces by quartering according to Method B, or by treating as a miniature stockpile as described in Method C.

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregatesand is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

Current edition approved Aug. 1, 2011. Published September 2011. Originally approved in 1971. Last previous edition approved in 2003 as C702–98(2003). DOI: 10.1520/C0702_C0702M-11.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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5.1.1 If the use of Method B or Method C is desired, and the sample does not have free moisture on the particle surfaces, moisten the sample to obtain free moisture on the particle surfaces, mix thoroughly, and then reduce the sample size.

5.1.2 If use of Method A is desired and the sample has free moisture on the particle surfaces, dry the entire sample to at least the saturated-surface-dry condition, using temperatures that do not exceed those specified for any of the tests contemplated, and then reduce the sample size. Alternatively, if the moist sample is very large, make a preliminary split using a mechanical splitter having chute openings of 38 mm [1½ in.] or more in width to reduce the sample to not less than 5 kg [10 lb]. Dry the portion so obtained, and reduce it to test sample size using Method A.

NOTE 2—The method of determining the saturated-surface-dry condition is described in Test Method C128. As a quick approximation, if the fine aggregate will retain its shape when molded in the hand, it may be considered to be wetter than saturated-surface-dry.

5.2 *Coarse Aggregates and Mixtures of Coarse and Fine Aggregates*—Reduce the sample using a mechanical splitter in accordance with Method A (preferred method) or by quartering in accordance with Method B. The miniature stockpile Method C is not permitted for coarse aggregates or mixtures of coarse and fine aggregates.

6. Sampling

6.1 Obtain samples of aggregate in the field in accordance with Practice D75, or as required by individual test methods. When tests for sieve analysis only are contemplated, the size of the field sample listed in Practice D75 is usually adequate. When additional tests are to be conducted, the user shall be satisfied that the initial size of the field sample is adequate to accomplish all intended tests. Use similar procedures for aggregate produced in the laboratory.

METHOD A—MECHANICAL SPLITTER

7. Apparatus

7.1 *Sample Splitter*—Sample splitters shall have an even number of equal width chutes, but not less than a total of eight for coarse aggregate, or twelve for fine aggregate, which discharge alternately to each side of the splitter. For coarse aggregate and mixed aggregate, the minimum width of the individual chutes shall be approximately 50 % larger than the largest particles in the sample to be split (Note 3). For dry fine aggregate in which the entire sample will pass the 9.5-mm (⅜-in.) seive, a splitter having chutes 12.5 to 20 mm [½ to ¾ in.] wide shall be used. The splitter shall be equipped with two receptacles to hold the two halves of the sample following splitting. It shall also be equipped with a hopper or straightedged pan which has a width equal to or slightly less than the over-all width of the assembly of chutes, by which the sample may be fed at a controlled rate to the chutes. The splitter and accessory equipment shall be so designed that the sample will flow smoothly without restriction or loss of material (see Fig. 1 and Fig. 2).

NOTE 3—Mechanical splitters are commonly available in sizes adequate for coarse aggregate having the largest particle not over 37.5 mm [1½ in.].

8. Procedure

8.1 Place the original sample in the hopper or pan and uniformly distribute it from edge to edge, so that when it is introduced into the chutes, approximately equal amounts will flow through each chute. Introduce the sample at a rate so as to allow it to flow freely through the chutes and into the receptacles below. Reintroduce the portion of the sample in one of the receptacles into the splitter as many times as necessary to reduce the sample to the size specified for the intended test. Reserve the portion of material collected in the other receptacle for reduction in size for other tests, when required.

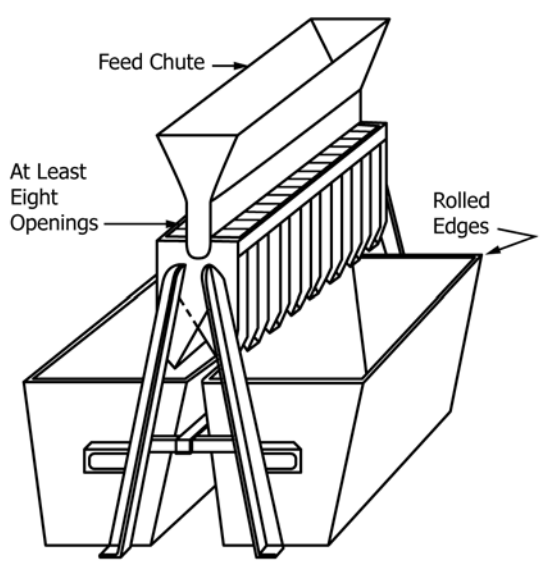
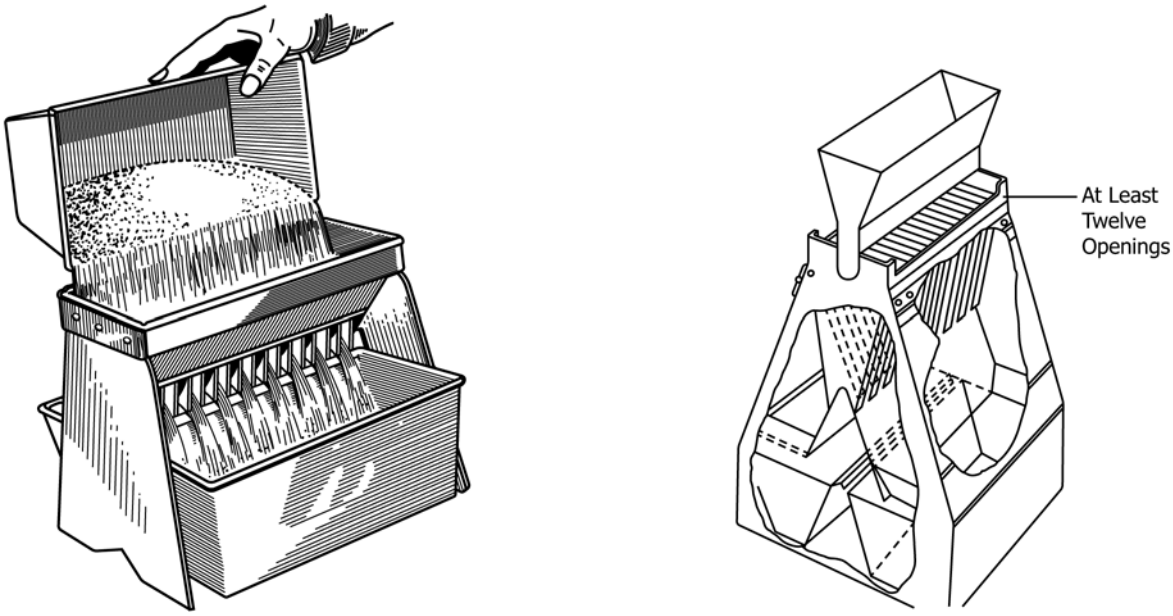


FIG. 1 Large Sample Splitter for Coarse Aggregate



NOTE 1— Small Sample Splitters for Fine Aggregate. May be constructed as either closed or open type. Closed type is preferred.

FIG. 2 Sample Splitters (Riffles)

METHOD B—QUARTERING

9. Apparatus

9.1 Apparatus shall consist of a straight-edged scoop, shovel, or trowel; a broom or brush; and a canvas blanket approximately 2 by 2.5 m [6 by 8 ft].

10. Procedure

10.1 Use either the procedure described in 10.1.1 or 10.1.2 or a combination of both.

10.1.1 Place the original sample on a hard, clean, level surface where there will be neither loss of material nor the accidental addition of foreign material. Mix the material thoroughly by turning the entire sample over three times. With the last turning, shovel the entire sample into a conical pile by depositing each shovelful on top of the preceding one. Carefully flatten the conical pile to a uniform thickness and diameter by pressing down the apex with a shovel so that each quarter sector of the resulting pile will contain the material originally in it. The diameter should be approximately four to eight times the thickness. Divide the flattened mass into four equal quarters with a shovel or trowel and remove two diagonally opposite quarters, including all fine material, and brush the cleared spaces clean. Successively mix and quarter the remaining material until the sample is reduced to the desired size (Fig. 3).

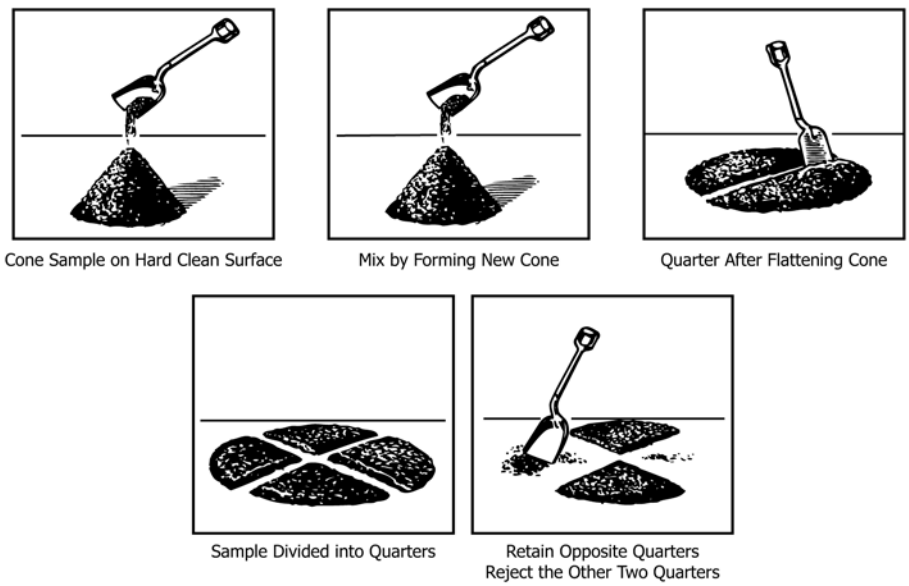


FIG. 3 Quartering on a Hard, Clean Level Surface

10.1.2 As an alternative to the procedure described in 10.1.1, when the floor surface is uneven, place the field sample on a canvas blanket and mix with a shovel as described in 10.1.1, or by alternately lifting each corner of the canvas and pulling it over the sample toward the diagonally opposite corner causing the material to be rolled. Flatten the pile as described in 10.1.1. Divide the sample as described in 10.1.1, or if the surface beneath the blanket is uneven, insert a stick or pipe beneath the blanket and under the center of the pile, then lift both ends of the stick, dividing the sample into two equal parts. Remove the stick leaving a fold of the blanket between the divided portions. Insert the stick under the center of the pile at right angles to the first division and again lift both ends of the stick, dividing the sample into four equal parts. Remove two diagonally opposite quarters, being careful to clean the fines from the blanket. Successively mix and quarter the remaining material until the sample is reduced to the desired size (Fig. 4).

METHOD C—MINIATURE STOCKPILE SAMPLING (DAMP FINE AGGREGATE ONLY)

11. Apparatus

11.1 Apparatus shall consist of a straight-edged scoop, shovel, or trowel for mixing the aggregate, and either a small sampling thief, small scoop, or spoon for sampling.

12. Procedure

12.1 Place the original sample of damp fine aggregate on a hard clean, level surface where there will be neither loss of material nor the accidental addition of foreign material. Mix the material thoroughly by turning the entire sample over three times. With the last turning, shovel the entire sample into a conical pile by depositing each shovelful on top of the preceding one. If desired, flatten the conical pile to a uniform thickness and diameter by pressing down the apex with a shovel so that each quarter sector of the resulting pile will contain the material originally in it. Obtain a sample for each test by selecting at least five increments of material at random locations from the miniature stockpile, using any of the sampling devices described in 11.1.

13. Keywords

13.1 aggregate; aggregate—coarse; aggregate—fine; field testing—aggregate; sampling—aggregates; sample reduction; specimen preparation

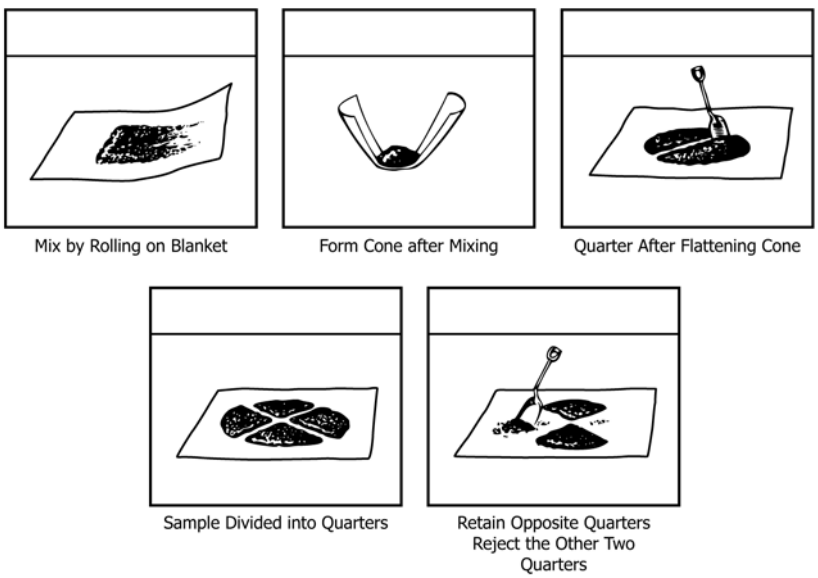


FIG. 4 Quartering on a Canvas Blanket

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Designation: C566 – 13

Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying[1]

This standard is issued under the fixed designation C566; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This test method covers the determination of the percentage of evaporable moisture in a sample of aggregate by drying both surface moisture and moisture in the pores of the aggregate. Some aggregate may contain water that is chemically combined with the minerals in the aggregate. Such water is not evaporable and is not included in the percentage determined by this test method.

1.2 The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard.

NOTE 1—Sieve size is identified by its standard designation in Specification E11. The alternative designation given in parentheses is for information only and does not represent a different standard sieve size.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements, see 5.3.1, 7.2.1, and 7.3.1.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C29/C29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C125 Terminology Relating to Concrete and Concrete Aggregates

C127 Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate

C128 Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

D75 Practice for Sampling Aggregates

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

2.2 *Other Document:*

National Research Council Report SHRP-P-619[3]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this test method, refer to Terminology C125.

4. Significance and Use

4.1 This test method is sufficiently accurate for usual purposes, such as adjusting batch quantities of ingredients for concrete. It will generally measure the moisture in the test sample more reliably than the sample can be made to represent the aggregate supply. In cases where the aggregate itself is altered by heat, or where more refined measurement is required, the test should be conducted using a ventilated, controlled temperature oven.

4.2 Large particles of coarse aggregate, especially those larger than 50 mm, will require greater time for the moisture to travel from the interior of the particle to the surface. The user of this test method should determine by trial if rapid drying methods provide sufficient accuracy for the intended use when drying large size particles.

5. Apparatus

5.1 *Balance*—A balance or scale accurate, readable, and sensitive to within 0.1 % of the test load at any point within the range of use. Within any interval equal to 10 % of the capacity of the balance or scale used to determine mass, the load indication shall be accurate within 0.1 % of the difference in masses.

5.2 *Source of Heat*—A ventilated oven capable of maintaining the temperature surrounding the sample at 110 ± 5°C. Where close control of the temperature is not required (see

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregatesand is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

Current edition approved Feb. 1, 2013. Published February 2013. Originally approved in 1965. Last previous edition approved in 2004 as C566 – 97 (2004). DOI: 10.1520/C0566-13.

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4.1), other suitable sources of heat may be used, such as an electric or gas hot plate, electric heat lamps, or a ventilated microwave oven.

5.3 *Sample Container*—A container not affected by the heat, of sufficient volume to contain the sample without danger of spilling, and of such shape that the depth of sample will not exceed one fifth of the least lateral dimension.

5.3.1 **Precaution**—When a microwave oven is used, the container shall be nonmetallic.

NOTE 2—Except for testing large samples, an ordinary frying pan is suitable for use with a hot plate, or any shallow flat-bottomed metal pan is suitable with heat lamps or oven. Note the precaution in 5.3.1.

5.4 *Stirrer*—A metal spoon or spatula of convenient size.

6. Sampling

6.1 Sample in accordance with Practice D75, except for the sample size.

6.2 Secure a sample of the aggregate representative of the moisture content in the supply being tested and having a mass not less than the amount listed in Table 1. Protect the sample against loss of moisture prior to determining the mass.

7. Procedure

7.1 Determine the mass of the sample to the nearest 0.1 %.

7.2 Dry the sample thoroughly in the sample container by means of the selected source of heat, exercising care to avoid loss of any particles. Very rapid heating may cause some particles to explode, resulting in loss of particles. Use a controlled temperature oven when excessive heat may alter the character of the aggregate, or where more precise measurement is required. If a source of heat other than the controlled temperature oven is used, stir the sample during drying to accelerate the operation and avoid localized overheating. When using a microwave oven, stirring of the sample is optional.

7.2.1 **Caution—**When using a microwave oven, occasionally minerals are present in aggregates that may cause the material to overheat and explode. If this occurs it can damage the microwave oven.

TABLE 1 Sample Size for Aggregate

Nominal Maximum Size of Aggregate, mm (in.)[A]	Mass of Normal Weight Aggregate Sample, min, kg[B]
4.75 (0.187) (No. 4)	0.5
9.5 (⅜)	1.5
12.5 (½)	2
19.0 (¾)	3
25.0 (1)	4
37.5 (1½)	6
50 (2)	8
63 (2½)	10
75 (3)	13
90 (3½)	16
100 (4)	25
150 (6)	50

[A] Based on sieves meeting Specification E11.
[B] Determine the minimum sample mass for lightweight aggregate by multiplying the value listed by the dry-loose unit mass of the aggregate in kg/m^3 (determined using Test Method C29/C29M) and dividing by 1600.

7.3 When a hot plate is used, drying can be expedited by the following procedure. Add sufficient anhydrous denatured alcohol to cover the moist sample. Stir and allow suspended material to settle. Decant as much of the alcohol as possible without losing any of the sample. Ignite the remaining alcohol and allow it to burn off during drying over the hot plate.

7.3.1 **Warning**—Exercise care to control the ignition operation to prevent injury or damage from the burning alcohol.

7.4 The sample is thoroughly dry when further heating causes, or would cause, less than 0.1 % additional loss in mass.

7.5 Determine the mass of the dried sample to the nearest 0.1 % after it has cooled sufficiently not to damage the balance.

8. Calculation

8.1 Calculate total evaporable moisture content as follows:

$$p = 100\,(W - D)/D \tag{1}$$

where:

p = total evaporable moisture content of sample, percent,
W = mass of original sample, g, and
D = mass of dried sample, g.

8.2 Surface moisture content is equal to the difference between the total evaporable moisture content and the absorption, with all values based on the mass of a dry sample. Absorption may be determined in accordance with Test Method C127 or Test Method C128.

9. Precision and Bias

9.1 *Precision:*

9.1.1 The within-laboratory single operator standard deviation for moisture content of aggregates has been found to be 0.28 % (Note 3). Therefore, results of two properly conducted tests by the same operator in the same laboratory on the same type of aggregate sample should not differ by more than 0.79 % (Note 3) from each other.

9.1.2 The between-laboratory standard deviation for moisture content of aggregates has been found to be 0.28 % (Note 3). Therefore, results of properly conducted tests from two laboratories on the same aggregate sample should not differ by more than 0.79 % (Note 3) from each other.

9.1.3 Test data used to derive the above precision indices were obtained from samples dried to a constant mass in a drying oven maintained at 110 ± 5°C. When other drying procedures are used, the precision of the results may be significantly different than that indicated above.

NOTE 3—These numbers represent, respectively, the 1s and 2s limits as described in Practice C670.

9.2 *Bias:*

9.2.1 When experimental results are compared with known values from accurately compounded specimens, the following has been derived.

9.2.1.1 The bias of moisture tests on one aggregate material has been found to have a mean of +0.06 %. The bias of individual test values from the same aggregate material has been found with 95 % confidence to lie between –0.07 % and +0.20 %.

9.2.1.2 The bias of moisture tests on a second aggregate material has been found to have a mean of < +0.01 %. The bias of individual test values from the same aggregate material has been found with 95 % confidence to lie between −0.14 % and +0.14 %.

9.2.1.3 The bias of moisture tests overall on both aggregate materials has been found to have a mean of +0.03 %. The bias of individual test values overall from both aggregate materials has been found with 95 % confidence to lie between −0.12 % and +0.18 %.

9.2.2 Test data used to derive the above bias statements were obtained from samples dried to a constant mass in a drying oven maintained at 110 ± 5°C. When other drying procedures are used, the bias of the results may be significantly different than that indicated above.

NOTE 4—These precision and bias statements were derived from aggregate moisture data provided by 17 laboratories participating in the SHRP Soil Moisture Proficiency Sample Program which is fully described in the National Research Council Report SHRP-P-619. The samples tested which relate to these statements were well-graded mixtures of fine and coarse aggregate with moisture contents ranging from air dry to saturated surface dry.

10. Keywords

10.1 aggregate; drying; moisture content

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Designation: C566 – 13

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This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This test method covers the determination of the percentage of evaporable moisture in a sample of aggregate by drying both surface moisture and moisture in the pores of the aggregate. Some aggregate may contain water that is chemically combined with the minerals in the aggregate. Such water is not evaporable and is not included in the percentage determined by this test method.

1.2 The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard.

NOTE 1—Sieve size is identified by its standard designation in Specification E11. The alternative designation given in parentheses is for information only and does not represent a different standard sieve size.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements, see 5.3.1, 7.2.1, and 7.3.1.

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C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

D75 Practice for Sampling Aggregates

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

2.2 *Other Document:*

National Research Council Report SHRP-P-619[3]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this test method, refer to Terminology C125.

4. Significance and Use

4.1 This test method is sufficiently accurate for usual purposes, such as adjusting batch quantities of ingredients for concrete. It will generally measure the moisture in the test sample more reliably than the sample can be made to represent the aggregate supply. In cases where the aggregate itself is altered by heat, or where more refined measurement is required, the test should be conducted using a ventilated, controlled temperature oven.

4.2 Large particles of coarse aggregate, especially those larger than 50 mm, will require greater time for the moisture to travel from the interior of the particle to the surface. The user of this test method should determine by trial if rapid drying methods provide sufficient accuracy for the intended use when drying large size particles.

5. Apparatus

5.1 *Balance*—A balance or scale accurate, readable, and sensitive to within 0.1 % of the test load at any point within the range of use. Within any interval equal to 10 % of the capacity of the balance or scale used to determine mass, the load indication shall be accurate within 0.1 % of the difference in masses.

5.2 *Source of Heat*—A ventilated oven capable of maintaining the temperature surrounding the sample at 110 ± 5°C. Where close control of the temperature is not required (see

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4.1), other suitable sources of heat may be used, such as an electric or gas hot plate, electric heat lamps, or a ventilated microwave oven.

5.3 *Sample Container*—A container not affected by the heat, of sufficient volume to contain the sample without danger of spilling, and of such shape that the depth of sample will not exceed one fifth of the least lateral dimension.

5.3.1 **Precaution**—When a microwave oven is used, the container shall be nonmetallic.

NOTE 2—Except for testing large samples, an ordinary frying pan is suitable for use with a hot plate, or any shallow flat-bottomed metal pan is suitable with heat lamps or oven. Note the precaution in 5.3.1.

5.4 *Stirrer*—A metal spoon or spatula of convenient size.

6. Sampling

6.1 Sample in accordance with Practice D75, except for the sample size.

6.2 Secure a sample of the aggregate representative of the moisture content in the supply being tested and having a mass not less than the amount listed in Table 1. Protect the sample against loss of moisture prior to determining the mass.

7. Procedure

7.1 Determine the mass of the sample to the nearest 0.1 %.

7.2 Dry the sample thoroughly in the sample container by means of the selected source of heat, exercising care to avoid loss of any particles. Very rapid heating may cause some particles to explode, resulting in loss of particles. Use a controlled temperature oven when excessive heat may alter the character of the aggregate, or where more precise measurement is required. If a source of heat other than the controlled temperature oven is used, stir the sample during drying to accelerate the operation and avoid localized overheating. When using a microwave oven, stirring of the sample is optional.

7.2.1 **Caution—**When using a microwave oven, occasionally minerals are present in aggregates that may cause the material to overheat and explode. If this occurs it can damage the microwave oven.

TABLE 1 Sample Size for Aggregate

Nominal Maximum Size of Aggregate, mm (in.)[A]	Mass of Normal Weight Aggregate Sample, min, kg[B]
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50 (2)	8
63 (2½)	10
75 (3)	13
90 (3½)	16
100 (4)	25
150 (6)	50

[A] Based on sieves meeting Specification E11.
[B] Determine the minimum sample mass for lightweight aggregate by multiplying the value listed by the dry-loose unit mass of the aggregate in kg/m^3 (determined using Test Method C29/C29M) and dividing by 1600.

7.3 When a hot plate is used, drying can be expedited by the following procedure. Add sufficient anhydrous denatured alcohol to cover the moist sample. Stir and allow suspended material to settle. Decant as much of the alcohol as possible without losing any of the sample. Ignite the remaining alcohol and allow it to burn off during drying over the hot plate.

7.3.1 **Warning**—Exercise care to control the ignition operation to prevent injury or damage from the burning alcohol.

7.4 The sample is thoroughly dry when further heating causes, or would cause, less than 0.1 % additional loss in mass.

7.5 Determine the mass of the dried sample to the nearest 0.1 % after it has cooled sufficiently not to damage the balance.

8. Calculation

8.1 Calculate total evaporable moisture content as follows:

$$p = 100\,(W - D)/D \tag{1}$$

where:

p = total evaporable moisture content of sample, percent,
W = mass of original sample, g, and
D = mass of dried sample, g.

8.2 Surface moisture content is equal to the difference between the total evaporable moisture content and the absorption, with all values based on the mass of a dry sample. Absorption may be determined in accordance with Test Method C127 or Test Method C128.

9. Precision and Bias

9.1 *Precision:*

9.1.1 The within-laboratory single operator standard deviation for moisture content of aggregates has been found to be 0.28 % (Note 3). Therefore, results of two properly conducted tests by the same operator in the same laboratory on the same type of aggregate sample should not differ by more than 0.79 % (Note 3) from each other.

9.1.2 The between-laboratory standard deviation for moisture content of aggregates has been found to be 0.28 % (Note 3). Therefore, results of properly conducted tests from two laboratories on the same aggregate sample should not differ by more than 0.79 % (Note 3) from each other.

9.1.3 Test data used to derive the above precision indices were obtained from samples dried to a constant mass in a drying oven maintained at 110 ± 5°C. When other drying procedures are used, the precision of the results may be significantly different than that indicated above.

NOTE 3—These numbers represent, respectively, the 1s and 2s limits as described in Practice C670.

9.2 *Bias:*

9.2.1 When experimental results are compared with known values from accurately compounded specimens, the following has been derived.

9.2.1.1 The bias of moisture tests on one aggregate material has been found to have a mean of +0.06 %. The bias of individual test values from the same aggregate material has been found with 95 % confidence to lie between –0.07 % and +0.20 %.

9.2.1.2 The bias of moisture tests on a second aggregate material has been found to have a mean of < +0.01 %. The bias of individual test values from the same aggregate material has been found with 95 % confidence to lie between −0.14 % and +0.14 %.

9.2.1.3 The bias of moisture tests overall on both aggregate materials has been found to have a mean of +0.03 %. The bias of individual test values overall from both aggregate materials has been found with 95 % confidence to lie between −0.12 % and +0.18 %.

9.2.2 Test data used to derive the above bias statements were obtained from samples dried to a constant mass in a drying oven maintained at 110 ± 5°C. When other drying procedures are used, the bias of the results may be significantly different than that indicated above.

NOTE 4—These precision and bias statements were derived from aggregate moisture data provided by 17 laboratories participating in the SHRP Soil Moisture Proficiency Sample Program which is fully described in the National Research Council Report SHRP-P-619. The samples tested which relate to these statements were well-graded mixtures of fine and coarse aggregate with moisture contents ranging from air dry to saturated surface dry.

10. Keywords

10.1 aggregate; drying; moisture content

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Designation: C136/C136M – 14

Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates[1]

This standard is issued under the fixed designation C136/C136M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This test method covers the determination of the particle size distribution of fine and coarse aggregates by sieving.

1.2 Some specifications for aggregates which reference this test method contain grading requirements including both coarse and fine fractions. Instructions are included for sieve analysis of such aggregates.

1.3 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

NOTE 1—Sieve size is identified by its standard designation in Specification E11. The alternative designation given in parentheses is for information only and does not represent a different standard sieve size. Specification E11 cites the following with respect to SI units versus inch-pound units as standard. "The values stated in SI units shall be considered standard for the dimensions of the sieve cloth openings and the wire diameters used in the sieve cloth. The values stated in inch-pound units shall be considered standard with regard to the sieve frames, pans," and covers.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C117 Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

C125 Terminology Relating to Concrete and Concrete Aggregates

C637 Specification for Aggregates for Radiation-Shielding Concrete

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C702 Practice for Reducing Samples of Aggregate to Testing Size

D75 Practice for Sampling Aggregates

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

2.2 *AASHTO Standard:*

AASHTO No. T 27 Sieve Analysis of Fine and Coarse Aggregates[3]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this standard, refer to Terminology C125.

4. Summary of Test Method

4.1 A sample of dry aggregate of known mass is separated through a series of sieves of progressively smaller openings for determination of particle size distribution.

5. Significance and Use

5.1 This test method is used primarily to determine the grading of materials proposed for use as aggregates or being used as aggregates. The results are used to determine compliance of the particle size distribution with applicable specification requirements and to provide necessary data for control of the production of various aggregate products and mixtures containing aggregates. The data may also be useful in developing relationships concerning porosity and packing.

5.2 Accurate determination of material finer than the 75-µm (No. 200) sieve cannot be achieved by use of this test method alone. Test Method C117 for material finer than 75-µm sieve by washing should be employed.

5.3 Refer to methods of sampling and testing in Specification C637 for heavyweight aggregates.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

Current edition approved Dec. 1, 2014. Published February 2015. Originally approved in 1938. Last previous edition approved in 2006 as C136 – 06. DOI: 10.1520/C0136_C0136M-14.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Association of State Highway and Transportation Officials, 444 North Capitol St. N.W., Suite 225, Washington, DC 20001.

***A Summary of Changes section appears at the end of this standard**

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6. Apparatus

6.1 *Balances*—Balances or scales used in testing fine and coarse aggregate shall have readability and accuracy as follows:

6.1.1 For fine aggregate, readable to 0.1 g and accurate to 0.1 g or 0.1 % of the test load, whichever is greater, at any point within the range of use.

6.1.2 For coarse aggregate, or mixtures of fine and coarse aggregate, readable and accurate to 0.5 g or 0.1 % of the test load, whichever is greater, at any point within the range of use.

6.2 *Sieves*—The sieve cloth shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. The sieve cloth and standard sieve frames shall conform to the requirements of Specification E11. Nonstandard sieve frames shall conform to the requirements of Specification E11 as applicable.

NOTE 2—It is recommended that sieves mounted in frames larger than standard 203.2-mm [8 in.] diameter be used for testing coarse aggregate to reduce the possibility of overloading the sieves. See 8.3.

6.3 *Mechanical Sieve Shaker*—A mechanical sieving device, if used, shall create motion of the sieves to cause the particles to bounce, tumble, or otherwise turn so as to present different orientations to the sieving surface. The sieving action shall be such that the criterion for adequacy of sieving described in 8.4 is met in a reasonable time period.

NOTE 3—Use of a mechanical sieve shaker is recommended when the size of the sample is 20 kg or greater, and may be used for smaller samples, including fine aggregate. Excessive time (more than approximately 10 min) to achieve adequate sieving may result in degradation of the sample. The same mechanical sieve shaker may not be practical for all sizes of samples, since the large sieving area needed for practical sieving of a large nominal size coarse aggregate very likely could result in loss of a portion of the sample if used for a small sample of coarse aggregate or fine aggregate.

6.4 *Oven*—An oven of appropriate size capable of maintaining a uniform temperature of 110 ± 5 °C [230 ± 10 °F].

7. Sampling

7.1 Sample the aggregate in accordance with Practice D75. The size of the field sample shall be the quantity shown in Practice D75 or four times the quantity required in 7.4 and 7.5 (except as modified in 7.6), whichever is greater.

7.2 Thoroughly mix the sample and reduce it to an amount suitable for testing using the applicable procedures described in Practice C702. The sample for test shall be approximately the quantity desired when dry and shall be the end result of the reduction. Reduction to an exact predetermined quantity shall not be permitted.

NOTE 4—Where sieve analysis, including determination of material finer than the 75-µm sieve, is the only testing proposed, the size of the sample may be reduced in the field to avoid shipping excessive quantities of extra material to the laboratory.

7.3 *Fine Aggregate*—The size of the test sample, after drying, shall be 300 g minimum.

7.4 *Coarse Aggregate*—The size of the test sample of coarse aggregate shall conform with the following:

Nominal Maximum Size, Square Openings, mm (in.)	Test Sample Size, min, kg [lb]
9.5 (⅜)	1 [2]
12.5 (½)	2 [4]
19.0 (¾)	5 [11]
25.0 (1)	10 [22]
37.5 (1½)	15 [33]
50 (2)	20 [44]
63 (2½)	35 [77]
75 (3)	60 [130]
90 (3½)	100 [220]
100 (4)	150 [330]
125 (5)	300 [660]

7.5 *Coarse and Fine Aggregate Mixtures*—The size of the test sample of coarse and fine aggregate mixtures shall be the same as for coarse aggregate in 7.4.

7.6 *Samples of Large Size Coarse Aggregate*—The size of sample required for aggregate with 50-mm [2-in.] nominal maximum size or larger is such as to preclude convenient sample reduction and testing as a unit except with large mechanical splitters and sieve shakers. As an option when such equipment is not available, instead of combining and mixing sample increments and then reducing the field sample to testing size, conduct the sieve analysis on a number of approximately equal sample increments such that the total mass tested conforms to the requirement of 7.4.

7.7 In the event that the amount of material finer than the 75-µm (No. 200) sieve is to be determined by Test Method C117, proceed as follows:

7.7.1 For aggregates with a nominal maximum size of 12.5 mm [½ in.] or less, use the same test sample for testing by Test Method C117 and this test method. First test the sample in accordance with Test Method C117 through the final drying operation, then dry sieve the sample as stipulated in 8.2 – 8.7 of this test method.

7.7.2 For aggregates with a nominal maximum size greater than 12.5 mm [½ in.], use a single test sample as described in 7.7.1, or optionally use separate test samples for Test Method C117 and this test method.

7.7.3 Where the specifications require determination of the total amount of material finer than the 75-µm sieve by washing and dry sieving, use the procedure described in 7.7.1.

8. Procedure

8.1 Dry the sample to constant mass at a temperature of 110 ± 5 °C [230 ± 10 °F].

NOTE 5—For control purposes, particularly where rapid results are desired, it is generally not necessary to dry coarse aggregate for the sieve analysis test. The results are little affected by the moisture content unless: (*1*) the nominal maximum size is smaller than about 12.5 mm (½ in.); (*2*) the coarse aggregate contains appreciable material finer than 4.75 mm (No. 4); or (*3*) the coarse aggregate is highly absorptive (a lightweight aggregate, for example). Also, samples may be dried at the higher temperatures associated with the use of hot plates without affecting results, provided steam escapes without generating pressures sufficient to fracture the particles, and temperatures are not so great as to cause chemical breakdown of the aggregate.

8.2 Select sieves with suitable openings to furnish the information required by the specifications covering the material to be tested. Use additional sieves as desired or necessary to provide other information, such as fineness modulus, or to regulate the amount of material on a sieve. Nest the sieves in

order of decreasing size of opening from top to bottom and place the sample on the top sieve. Agitate the sieves by hand or by mechanical apparatus for a sufficient period, established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy or sieving described in 8.4.

8.3 Limit the quantity of material on a given sieve so that all particles have opportunity to reach sieve openings a number of times during the sieving operation. For sieves with openings smaller than 4.75-mm (No. 4), the quantity retained on any sieve at the completion of the sieving operation shall not exceed 7 kg/m^2 of sieving surface area (Note 6). For sieves with openings 4.75 mm (No. 4) and larger, the quantity retained in kg shall not exceed the product of 2.5 × (sieve opening, mm × (effective sieving area, m^2)). This quantity is shown in Table 1 for five sieve-frame dimensions in common use. In no case shall the quantity retained be so great as to cause permanent deformation of the sieve cloth.

8.3.1 Prevent an overload of material on an individual sieve by one of the following methods:

8.3.1.1 Insert an additional sieve with opening size intermediate between the sieve that may be overloaded and the sieve immediately above that sieve in the original set of sieves.

8.3.1.2 Split the sample into two or more portions, sieving each portion individually. Combine the masses of the several portions retained on a specific sieve before calculating the percentage of the sample on the sieve.

8.3.1.3 Use sieves having a larger frame size and providing greater sieving area.

NOTE 6—The 7 kg/m^2 amounts to 200 g for the usual 203-mm [8-in.] diameter sieve (with effective sieving surface diameter of 190.5 mm [7.5 in.].

8.4 Continue sieving for a sufficient period and in such manner that, after completion, not more than 1 % by mass of the material retained on any individual sieve will pass that sieve during 1 min of continuous hand sieving performed as follows: Hold the individual sieve, provided with a snug-fitting pan and cover, in a slightly inclined position in one hand. Strike the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turn the sieve about one sixth of a revolution at intervals of about 25 strokes. In determining sufficiency of sieving for sizes larger than the 4.75-mm (No. 4) sieve, limit the material on the sieve to a single layer of particles. If the size of the mounted testing sieves makes the described sieving motion impractical, use 203-mm [8 in.] diameter sieves to verify the sufficiency of sieving.

8.5 In the case of coarse and fine aggregate mixtures, refer to 8.3.1 to prevent overloading of individual sieves.

8.5.1 Optionally, reduce the portion finer than the 4.75-mm (No. 4) sieve using a mechanical splitter according to Practice C702. If this procedure is followed, compute the mass of each size increment of the original sample as follows:

$$A = \frac{W_1}{W_2} \times B \tag{1}$$

where:

A = mass of size increment on total sample basis,
W_1 = mass of fraction finer than 4.75-mm (No. 4) sieve in total sample,
W_2 = mass of reduced portion of material finer than 4.75-mm (No. 4) sieve actually sieved, and
B = mass of size increment in reduced portion sieved.

8.6 Unless a mechanical sieve shaker is used, hand sieve particles larger than 75 mm [3 in.] by determining the smallest sieve opening through which each particle will pass. Start the test on the smallest sieve to be used. Rotate the particles, if necessary, in order to determine whether they will pass through a particular opening; however, do not force particles to pass through an opening.

8.7 Determine the mass of each size increment on a scale or balance conforming to the requirements specified in 5.1 to the nearest 0.1 % of the total original dry sample mass. The total mass of the material after sieving should check closely with original mass of sample placed on the sieves. If the amounts

TABLE 1 Maximum Allowable Quantity of Material Retained on a Sieve, kg [lb]

Sieve Opening Size, mm	Nominal Dimensions of Sieve[A]				
	[8-in.] diameter[B]	[10-in.] diameter[B]	[12-in.] diameter[B]	[14-in. by 14-in.]	[14.5-in. by 23-in.]
	Sieving Area, m^2 [ft^2]				
	0.0285 [0.3]	0.0457 [0.5]	0.0670 [0.7]	0.1225 [1.3]	0.2158 [2.3]
125	C	C	C	C	67.4 [148½]
100	C	C	C	30.6 [67½]	53.9 [118¾]
90	C	C	15.1 [33¼]	27.6 [60¾]	48.5 [106¾]
75	C	8.6 [19]	12.6 [27¾]	23.0 [50¾]	40.5 [89¼]
63	C	7.2 [15¾]	10.6 [23¼]	19.3 [42½]	34.0 [75]
50	3.6 [8]	5.7 [13]	8.4 [18½]	15.3 [33¾]	27.0 [59½]
37.5	2.7 [6]	4.3 [9½]	6.3 [13¾]	11.5 [25¼]	20.2 [44½]
25.0	1.8 [4]	2.9 [6½]	4.2 [9¼]	7.7 [17]	13.5 [29¾]
19.0	1.4 [3½]	2.2 [4¾]	3.2 [7½]	5.8 [12¾]	10.2 [22½]
12.5	0.89 [2]	1.4 [3]	2.1 [4¾]	3.8 [8¼]	6.7 [14¾]
9.5	0.67 [1½]	1.1 [2½]	1.6 [3½]	2.9 [6¼]	5.1 [11¼]
4.75	0.33 [¾]	0.54 [1¼]	0.80 [1¾]	1.5 [3¼]	2.6 [5¾]

[A] Sieve frame dimensions in inch units: 8.0-in. diameter; 10.0-in. diameter, 12.0-in. diameter; 13.8 by 13.8 in. (14 by 14 in. nominal); 14.6 by 22.8 in. (16 by 24 in. nominal).
[B] The sieve area for round sieve frames is based on an effective diameter 12.5 mm [½ in.] less than the nominal frame diameter, because Specification E11 permits the sealer between the sieve cloth and the frame to extend 6.5 mm [¼ in.] over the sieve cloth. Thus the effective sieving diameter for a 203-mm [8.0-in.] diameter sieve frame is 190.5 mm [7.5 in.]. Sieves produced by some manufacturers do not infringe on the sieve cloth by the full 6.5 mm [¼ in.].
[C] Sieves indicated have less than five full openings and should not be used for sieve testing except as provided in 8.6.

differ by more than 0.3 %, based on the original dry sample mass, the results should not be used for acceptance purposes.

8.8 If the sample has previously been tested by Test Method C117, add the mass finer than the 75-µm (No. 200) sieve determined by that test method to the mass passing the 75-µm (No. 200) sieve by dry sieving of the same sample in this test method.

9. Calculation

9.1 Calculate percentages passing, total percentages retained, or percentages in various size fractions to the nearest 0.1 % on the basis of the total mass of the initial dry sample. If the same test sample was first tested by Test Method C117, include the mass of material finer than the 75-µm (No. 200) size by washing in the sieve analysis calculation; and use the total dry sample mass prior to washing in Test Method C117 as the basis for calculating all the percentages.

9.1.1 When sample increments are tested as provided in 7.6, total the masses of the portion of the increments retained on each sieve, and use these masses to calculate the percentages as in 9.1.

9.2 Calculate the fineness modulus, when required, by adding the total percentages of material in the sample that is coarser than each of the following sieves (cumulative percentages retained), and dividing the sum by 100: 150-µm (No. 100), 300-µm (No. 50), 600-µm (No. 30), 1.18-mm (No. 16), 2.36-mm (No. 8), 4.75-mm (No. 4), 9.5-mm (⅜-in.), 19.0-mm (¾-in.), 37.5-mm (1½-in.), and larger, increasing in the ratio of 2 to 1.

10. Report

10.1 Depending upon the form of the specifications for use of the material under test, the report shall include the following:

10.1.1 Total percentage of material passing each sieve, or

10.1.2 Total percentage of material retained on each sieve, or

10.1.3 Percentage of material retained between consecutive sieves.

10.2 Report percentages to the nearest whole number, except if the percentage passing the 75-µm (No. 200) sieve is less than 10 %, it shall be reported to the nearest 0.1 %.

10.3 Report the fineness modulus, when required, to the nearest 0.01.

11. Precision and Bias

11.1 *Precision*—The estimates of precision for this test method are listed in Table 2. The estimates are based on the results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by Test Method C136 and AASHTO No. T 27. The data are based on the analyses of the test results from 65 to 233 laboratories that tested 18 pairs of coarse aggregate proficiency test samples and test results from 74 to 222 laboratories that tested 17 pairs of fine aggregate proficiency test samples (Samples No. 21 through 90). The values in the table are given for different ranges of total percentage of aggregate passing a sieve.

TABLE 2 Precision

	Total Percentage of Material Passing		Standard Deviation (1s), %[A]	Acceptable Range of Two Results (d2s), %[A]
Coarse Aggregate:[B]				
Single-operator precision	<100	≥95	0.32	0.9
	<95	≥85	0.81	2.3
	<85	≥80	1.34	3.8
	<80	≥60	2.25	6.4
	<60	≥20	1.32	3.7
	<20	≥15	0.96	2.7
	<15	≥10	1.00	2.8
	<10	≥5	0.75	2.1
	<5	≥2	0.53	1.5
	<2	>0	0.27	0.8
Multilaboratory precision	<100	≥95	0.35	1.0
	<95	≥85	1.37	3.9
	<85	≥80	1.92	5.4
	<80	≥60	2.82	8.0
	<60	≥20	1.97	5.6
	<20	≥15	1.60	4.5
	<15	≥10	1.48	4.2
	<10	≥5	1.22	3.4
	<5	≥2	1.04	3.0
	<2	>0	0.45	1.3
Fine Aggregate:				
Single-operator precision	<100	≥95	0.26	0.7
	<95	≥60	0.55	1.6
	<60	≥20	0.83	2.4
	<20	≥15	0.54	1.5
	<15	≥10	0.36	1.0
	<10	≥2	0.37	1.1
	<2	>0	0.14	0.4
Multilaboratory precision	<100	≥95	0.23	0.6
	<95	≥60	0.77	2.2
	<60	≥20	1.41	4.0
	<20	≥15	1.10	3.1
	<15	≥10	0.73	2.1
	<10	≥2	0.65	1.8
	<2	>0	0.31	0.9

[A] These numbers represent, respectively, the (1s) and (d2s) limits described in Practice C670.
[B] The precision estimates are based on aggregates with nominal maximum size of 19.0 mm (¾ in.).

11.1.1 The precision values for fine aggregate in Table 2 are based on nominal 500-g test samples. Revision of this test method in 1994 permits the fine aggregate test sample size to be 300 g minimum. Analysis of results of testing of 300-g and 500-g test samples from Aggregate Proficiency Test Samples 99 and 100 (Samples 99 and 100 were essentially identical) produced the precision values in Table 3, which indicate only minor differences due to test sample size.

NOTE 7—The values for fine aggregate in Table 2 will be revised to reflect the 300-g test sample size when a sufficient number of Aggregate Proficiency Tests have been conducted using that sample size to provide reliable data.

11.2 *Bias*—Since there is no accepted reference material suitable for determining the bias in this test method, no statement on bias is made.

12. Keywords

12.1 aggregate; coarse aggregate; fine aggregate; gradation; grading; sieve analysis; size analysis

TABLE 3 Precision Data for 300-g and 500-g Test Samples

Fine Aggregate Proficiency Sample				Within Laboratory		Between Laboratory	
Test Result	Sample Size	Number Labs	Average	1s	d2s	1s	d2s
Test Method C136/AASHTO No. T 27							
Total material passing the 4.75-mm No. 4 sieve (%)	500 g	285	99.992	0.027	0.066	0.037	0.104
	300 g	276	99.990	0.021	0.060	0.042	0.117
Total material passing the 2.36-mm No. 8 sieve (%)	500 g	281	84.10	0.43	1.21	0.63	1.76
	300 g	274	84.32	0.39	1.09	0.69	1.92
Total material passing the 1.18-mm No. 16 sieve (%)	500 g	286	70.11	0.53	1.49	0.75	2.10
	300 g	272	70.00	0.62	1.74	0.76	2.12
Total material passing the 600 µm No. 30 sieve (%)	500 g	287	48.54	0.75	2.10	1.33	3.73
	300 g	276	48.44	0.87	2.44	1.36	3.79
Total material passing the 300 µm No. 50 sieve (%)	500 g	286	13.52	0.42	1.17	0.98	2.73
	300 g	275	13.51	0.45	1.25	0.99	2.76
Total material passing the 150 µm No. 100 sieve (%)	500 g	287	2.55	0.15	0.42	0.37	1.03
	300 g	270	2.52	0.18	0.52	0.32	0.89
Total material passing the 75 µm No. 200 sieve (%)	500 g	278	1.32	0.11	0.32	0.31	0.85
	300 g	266	1.30	0.14	0.39	0.31	0.85

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C136 – 06, that may impact the use of this test method. (Approved Dec. 1, 2014)

(1) Revised (with designation change) from SI-only to combined SI/inch-pound standard, where values stated in either SI or inch-pound units are regarded separately as standard.

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Test No.					
Station					
Offset (ft.)					
Feet Below Grade					
Moisture Standard Count					
Moisture Count					
Moisture Count Ratio					
Probe Depth					
Density Standard Count					
Density Count					
Density Count Ratio					
Unit Weight Wet (pcf)					
Moisture (pcf)					
Unit Weight Dry (pcf)					
Percent Moisture					
Cut Station					
Sample Number					
Proctor Density (pcf)					
Optimum Moisture, %					
Dry Weight of +4 Material					
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DIVISION OF MATERIALS AND TESTS
6601 CENTENNIAL BLVD.
NASHVILLE, TENNESSEE 37243-0360

PROCTOR DENSITY REPORT

Project Reference No. _____ County _____ Region _____
Project No. _____ Contract No. _____
Material _____ Project Supervisor _____
Report No. _____ Date Sampled _____
Serial No. _____ Date Reported _____
Contractor _____ Sampled By _____
Producer _____ Sampled From _____

GRADATION - TOTAL PERCENT PASSING						
Sample No.						
Station						
Depth, ft.						
Location, ft.						
2"						
1-1/2"						
1"						
3/4"						
3/8"						
No. 4						
No. 10						
No. 16						
No. 40						
No. 100						
No. 200						
Silt and Clay						
Clay						
SOIL CONSTANTS						
Liquid Limit						
Plastic Limit						
Plasticity Index						
Calculated PI						
Type						
Group						
DENSITY CORRECTED FOR +4 MATERIAL						
Proctor Density						
Optimum Moisture						
95 % Density						
Moisture Range Above Subgrade						
Moisture Range Below Subgrade						

_____
Regional Materials and Tests

Approved for Information Only _____
Engineer of Materials and Tests

Form DT-0332 English (Rev. 10-02)

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Standard Operating Procedures (SOP) 7-1

Tennessee Department of Transportation
Division of Materials and Tests

Nuclear Density Testing (SOP 7-1)

Purpose: The purpose of this document is to provide guidance for conducting nuclear density tests on hot mix asphalt, backfill, soil, aggregate base, embankments, and other materials requiring density tests in accordance with SOP 1-1.

Discussion: Many compacted materials on TDOT projects are accepted by means of testing with nuclear density gauges. This document intends to provide guidance and define best practices for operation of these gauges to unify testing operations statewide. Testing details of common concern include proper setup of gauge information, depth of test probes, time length of tests, and recording of data.

Basic Procedure: All test procedures shall be in accordance with AASHTO T310, "*In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)"* and ASTM D2950, "*Standard Test Method for Density of Bituminous Concrete In-Place by Nuclear Methods"* except as revised herein.

Specific instructions on conducting standard counts, entering maximum specific gravity values, offsets, correction factors, and proctor information can be found in the users' manuals corresponding to the make and model of the gauge in use.

PART ONE – ACCEPTANCE TESTING

Hot Mix Asphalt

Mixtures: 307-A, 307-B, 307-BM, 307-BM2, 307-C, 307-CW, 411-D, 411-Es

Step 1: Conduct Standard Count

Step 2: Enter maximum specific gravity (Gmm) value from asphalt mix design.

Step 3: Enter gauge correction factor from test strip. See Part Two for determining correction factors.

Step 4: Set gauge setting to Backscatter.

Step 5: Place gauge in location to be tested.

Footnote 1: For guidance on testing frequencies, random numbers, and selecting test locations, see SOP 1-1.

Step 6: Activate a test. When collecting a density test, the following approach shall be used:

- *"Four Nineties" Test:* Four tests may be conducted at a single location, rotating around the test location 90 degrees at a time, as shown in Figure 1. The four test results will then be averaged to obtain a single test value for that location. Test counts for this approach should be 15 seconds or longer.

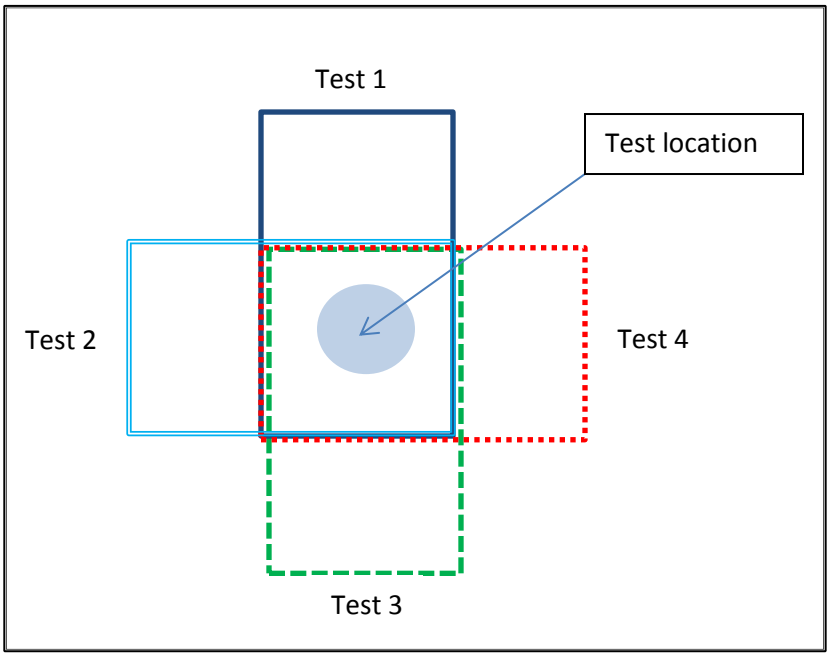

Figure 1. Testing at four 90° locations

Step 7: Record the test value into the appropriate paperwork.

- DT-0315, Daily Asphalt Density Report

Soil and Aggregate Materials

Materials: Backfill (Earth retaining structures), Select granular backfill (Earth retaining structures), Embankments, Subgrade preparation, Lime-treated subgrade, Soil-Cement Base, Mineral Aggregate Base and Surface, Aggregate for Underdrains, Aggregate-Cement base course, Aggregate Lime fly ash base course, & Conditioned mineral aggregate base.

Step 1: Conduct Standard Count

Step 2: Enter maximum dry density and optimum moisture content from Proctor Density report.

Step 3: Select Test location. Create a test hole using the scraper plate and drill rod provided with the gauge.

Footnote 2: For guidance on selecting test locations, see SOP 1-1.

Step 4: Set gauge setting to Direct Transmission at a depth reasonably close to one half the depth of the compacted lift.

Step 5: Place gauge in location to be tested and insert test probe into test hole at a depth reasonably close to one half the depth of the compacted lift. Pull gauge back to ensure probe makes contact with material being tested.

Step 6: Activate a test. When collecting a density test, the following approach shall be used:

Single Count Test: A single test may be conducted at any test location, given that the test count is greater than or equal to 60 seconds.

Step 7: Record the test value into the appropriate paperwork.

- DT-0298, Daily Report on Soil and Aggregate Stabilization
- DT-0304, Daily Report on Embankment
- DT-0307, Daily Report on Mineral Aggregate Base
- DT-0314, Density Worksheet – Nuclear Method (Aggregate, Soil)

PART TWO – DETERMINATION OF ASPHALT CALIBRATION FACTORS

- Conduct test strips in accordance with most current version of TDOT Standard specifications, subsection 407.15
- Test strips are required for the following mixtures:
  307-A, 307-B, 307-BM, 307-BM2, 307-C, 307-CW, 411-D, 411-Es
- The minimum size of a single test strip is 400 yd^2, but a larger area is recommended. The following roadway lengths provide an area of 400 yd^2 :
  - 9' wide= 400' long
  - 10' wide= 360' long
  - 11' wide= 330' long
  - 12' wide= 300' long
- Compaction of the test strip shall commence immediately after placement of the bituminous mixture.
- TDOT form DT-0316, Density and Roller Pattern Test Strip

Step 1: After a single pass of the breakdown roller, conduct a density test in accordance with Part One, above. Record the uncorrected test value in lbs/ft^3.

Step 2: After a second pass of the breakdown roller, conduct a second density test and record the uncorrected test value in lbs/ft^3.

Step 3: Repeat the roller pass/testing process until a value is obtained that does not increase from the previous pass more than 1 lb/ft^3. This number of passes or the pass before it shall be the target number of passes for the breakdown roller.

Step 4: After compacting an additional area with the breakdown roller at the correct target number of passes, repeat steps 1-3 for the intermediate roller.

Step 5: After compacting an additional area with the breakdown and intermediate rollers at the correct target number of passes, repeat steps 1-3 for the finish roller. Often times, the resulting target number of passes will only be 1 or 2 passes for finish rollers.

Step 6: Compact test strip area with all three rollers at the correct target number of passes.

Step 7: Layout test strip test locations and conduct and record ten uncorrected density tests on the compacted test strip area and record test information

Step 8: Cores should be cut at same locations as nuclear density tests and tested by TDOT Plant Technician for laboratory density in accordance with AASHTO T166.

Footnote 3: Only Method A of T166 shall apply when testing test strip cores for density. Cores shall be COMPLETELY DRY before testing. Accelerated drying in accordance with ASTM D 7227 (core drying device) is permitted.

Step 9: The nuclear gauge correction factor shall be the difference between the average of ten nuclear gauge readings and the average of ten core density values.

Additional notes on test strips and correction factors:

- Nuclear gauges are specific to an individual gauge, mix, and project. It is poor practice to develop a correction factor with a different gauge unit than the one to be used during mainline acceptance testing.
- Developing correction factors based on cores that were not allowed to dry completely will influence results in a manner that can mislead test results into appearing as if they are higher than they actually are. In other words, wet cores appear heavier or denser than they actually are.
- In accordance with TDOT Specifications, a new test strip is required when:
    - There is a change in job mix formulas
    - A change in the source of materials occurs
    - A change in the material from the same source is observed
    - There is reason to believe that the test strip density is not representative of the mixture being placed. For example, test results are consistently above 100% density or test results have been consistent for a steady number of days and had suddenly changed significantly.
    - A change in paving or compaction equipment occurs.
- Test variables selected during test strips (i.e. - length of count, single test for 60 seconds, testing at "four 90's", backscatter, driving test holes, etc) must be consistent between what is chosen during development of correction factors and what is done during subsequent acceptance testing. *i.e. – If a correction factor is set up by testing 307A mix in backscatter, then all acceptance tests using that correction factor must be tested in backscatter*.
- When testing large aggregate mixtures such as 307-A mixture that have a large amount of surface texture, clean natural sand may be spread to fill surface voids prior to testing.