2024 Edition

AGGREGATE TECHNICIAN

PART TWO

Aggregate Technician - Part 2

2024 – Updates

- **New: Aggregate is now divided into two parts, see the COURSE CONTENT PAGE for the division.**
    - **NOTE: Must have both parts to receive certification in Aggregate Technician.**
- No major changes in the methods.

2023 – Updates

- **<u>AASHTO T85</u>:**
    - **T85 Oven**: The thermometer for measuring the oven temperature shall meet the requirements of M339M/M339 with a range of at least 90 to 130°C (194 to 266°F) and an accuracy of ± 1.25°C (± 2.25°F) (see note 1),
        - NOTE 1: Thermometer types to use include:
            - ASTM E1 Mercury Thermometer
            - ASTM 2877 digital metal stem thermometer
            - ASTM E230/E230M thermocouple thermometer, Type J or K, Special Class, Type T any Class
            - IEC 60584 thermocouple thermometer, Type T, Class 1
            - Dial gauge metal stem (Bi-metal) thermometer

    - **T85 Water Bath**: The thermometer for measuring the temperature of the water bath shall meet the requirements of M339M/M339 with a temperature range of at least 16 to 27°C (60 to 80°F) and an accuracy of ±0.5°C (±0.9°F) (see note 2),
        - NOTE 2: Thermometer types to use include:
            - ASTM E1 Mercury Thermometer
            - ASTM E2877 digital metal stem thermometer
            - ASTM E230/E230M thermocouple thermometer, Type T, Special
            - IEC 60584: thermocouple thermometer, Type T, Class 1

- **AASHTO T84**:
  - **T84 Oven**: The thermometer for measuring the oven temperature shall meet the requirements of M339M/M339 with a range of at least 90 to 130°C (194 to 266°F) and an accuracy of ± 1.25°C (± 2.25°F) (see note 1),
    - NOTE 1: Thermometer types to use include:
      - ASTM E1 Mercury Thermometer
      - ASTM 2877 digital metal stem thermometer
      - ASTM E230/E230M thermocouple thermometer, Type J or K, Special Class, Type T any Class
      - IEC 60584 thermocouple thermometer, Type J or K, Special class 1, Type T any Class
      - IEC 60584 thermocouple thermometer, Type j or K, Class1, Type T any Class
      - Dial gauge metal stem (Bi-metal) thermometer

  - **T84 Water Bath**: The thermometer for measuring the temperature of the water bath shall meet the requirements of M339M/M339 with a temperature range of at least 16 to 27°C (60 to 80°F) and an accuracy of ±0.5°C (±0.9°F) (see note 2),
    - NOTE 2: Thermometer types to use include:
      - ASTM E1 Mercury Thermometer
      - ASTM E2877 digital metal stem thermometer
      - ASTM E230/E230M thermocouple thermometer, Type T, Special
      - IEC 60584: thermocouple thermometer, Type T, Class 1
      - Dial gauge metal stem (Bi-metal) thermometer

2022 – Updates

- **Removed** Absorption T85
- **Added** Aggregate Specific Gravity T84, T85, and Core-Lok information.
- **AASHTO T85** – Added AASHTO T255 and 122°F for cooling sample.

2021 – Updates

- **AASHTO T11** - Mechanical Washing: Do not wash the sample in a mechanical washer for more than 10 min.
- **Added AASHTO T85-Abs** – Absorption of coarse aggregate.

COURSE CONTENT

AGGREGATE TECHNICIAN

PART TWO

MoDOT TM 71	Deleterious Content of Aggregate
ASTM D 4791	Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
AASHTO T 84 ASTM C128	Specific Gravity and Absorption of Fine Aggregate
AASHTO T 85 ASTM C127	Specific Gravity and Absorption of Coarse Aggregate
MoDOT TM81	Specific Gravity & Absorption of Aggregate Using Automatic Vacuum Sealing Method. **(Information Only)**
Appendix	
Glossary	

PART TWO

MoDOT TM 71

DELETERIOUS CONTENT

Of

AGGREGATE

MoDOT TM 71

MoDOT EPG

Deleterious Content of Aggregate

Rev. 12/06/2019

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SCOPE

- This test method covers the determination of the percentages of various types of deleterious in a sample of aggregate by examining each piece and separating them into the various types of deleterious groups as described in the MoDOT EPG Section 106.
- **NOTE**: MoDOT TM 71 also covers the procedure for Determining the Deleterious of Fine Aggregate which is tested in accordance with AASHTO T 113 this will **NOT** be covered in this certification.

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SIGNIFICANCE

Deleterious material can have a detrimental effect on the durability and life-span of concrete and asphalt mixtures. Most deleterious substances have tendencies to deteriorate or cause degradation in concrete or asphalt mixtures.

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Some issues caused by deleterious:

- Clay, mud balls and other foreign material will breakdown quickly and cause pitting and excessive air void pockets.
- Hard chert has non-cohesive properties that will cause it to "pop out" of concrete.

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Quality:

- The quality of an aggregate depends on the application of its intended use and can be found in the following MoDOT EPG specifications:

  - 1002, Asphaltic Concrete
  - 1003, Seal Coats
  - 1004, Bituminous Surface
  - 1005, Concrete
  - 1006, Surfacing
  - 1007, Bases

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Deleterious groups:

- Shale
- Other Foreign Material (OFM)
- Extremely Soft Rock (Deleterious)
- Soft Chert
- Hard Chert
  - Samples can vary in the types and quantity of deleterious from one to the other depending on the product type and location.

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EQUIPMENT

- Containers –size and shape to contain the sample.
- Sieve – #4 (4.75 mm) sieve to divide the sample.
- Water – to wet sample for observation
- Scale – accurate to within 0.5 percent of the weight of the sample.
- Lamp or a good light source.

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MoDOT EPG TM 71

Maximum Size inches (mm)	Minimum Sample Size of Plus 4 material
2" (50)	10,000 grams
1 ½" (37.5)	9,000 grams
1" (25.0)	5,000 grams
¾" (19.0)	3,000 grams
½" (12.5)	2,000 grams
⅜" (9.5)	1,000 grams

TM 71: Maximum size is defined as the smallest sieve through which 100 % of the material will pass.

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PROCEDURE

1. Material shall be tested in an "as received" condition. (May be dried in an oven at 140°F if needed)
2. Reduce the sample according to the maximum size of aggregate, with a surplus for sieving.
3. Sieve the reduced sample over a #4 sieve and discard the passing material.
4. Check the plus #4 sample weight to see if there is at least the minimum amount for testing using the MoDOT TM 71 Table.

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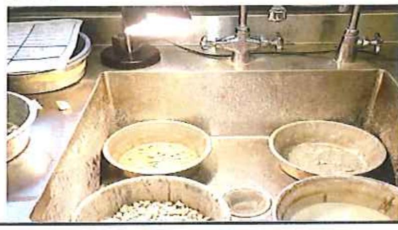
5. Record the weight of the plus #4 material to the nearest whole gram. (Original Mass)
   Plus #4 material = material retained on the #4 sieve
6. Set up a work station with a good light source, plenty of pans to work with, and a pan or spray bottle of water.



Procedure 10

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7. Obtain a handful of the sample and **briefly** wet the material. Do Not let the entire sample soak in water, some deleterious particles will dissolve!
8. Visually examine each piece for deleterious particles and separate into specific groups according to specifications: OFM, Hard Chert, Soft Chert, Shale, etc.

Procedure 11

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9. After the sample has been completely examined, weigh each deleterious group separately to the nearest whole gram. Discard the non-deleterious.
10. Calculate the percentage of each group and record the results.

Procedure 12

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CALCULATIONS

- % Deleterious Substances = $\dfrac{C}{W} \times 100$
- **C** = Actual weight (mass) of deleterious substance.
- **W** = Weight (Mass) of test sample for the portion retained on the #4 sieve.
- Report % Deleterious to the nearest **0.1%**

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NOTES

- For 1002 Asphaltic Concrete: The Soft Chert is used in the calculation of the Deleterious Content and the Total Chert Content.
- The number of groups vary by product type.
- MoDOT TM 71 gives specific description based on product type.

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EXAMPLE PROLEM 1A

Sample: 1002 Material (Asphalt) ID NO.___ Date: ___

	Mass, grams		Percent	
Original Mass +4	3000			
Deleterious Rock (Very soft rock)	55			
Shale	7	=		% Shale
OFM	3	=		% OFM
Soft Chert	15			
Hard Chert	114			

			Percent	
Deleterious Rock + Soft Chert =		=		% Total Deleterious Rock
Deleterious Rock + Soft Chert + Shale + OFM =		=		% Total Deleterious Material
Hard Chert + Soft Chert =		=		% Total Chert

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EXAMPLE PROLEM 1A

Sample: 1002 Material (Asphalt) ID NO.___ Date: ___

	Mass, grams		Percent	
Original Mass +4	3000			
Deleterious Rock (Very soft rock)	55			
Shale	7	=	0.2	% Shale
OFM	3	=	0.1	% OFM
Soft Chert	15			
Hard Chert	114			
			Percent	
Deleterious Rock + Soft Chert =	70	=	2.3	% Total Deleterious Rock
Deleterious Rock + Soft Chert + Shale + OFM =	80	=	2.7	% Total Deleterious Material
Hard Chert + Soft Chert =	129	=	4.3	% Total Chert

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EXAMPLE PROLEM 1B

Sample: 1002 Material (Asphalt) ID NO.___ Date: ___

	Mass, grams		Percent	
Original Mass +4	3000			
Deleterious Rock (Very soft rock)	60			
Shale	9	=		% Shale
OFM	1	=		% OFM
Soft Chert	15			
Hard Chert	125			
			Percent	
Deleterious Rock + Soft Chert =		=		% Total Deleterious Rock
Deleterious Rock + Soft Chert + Shale + OFM =		=		% Total Deleterious Material
Hard Chert + Soft Chert =		=		% Total Chert

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EXAMPLE PROLEM 1B

Sample: 1002 Material ID NO.___ Date: ___

	Mass, grams		Percent	
Original Mass +4	3000			
Deleterious Rock (Very soft rock)	60			
Shale	9	=	0.3	% Shale
OFM	1	=	0.0	% OFM
Soft Chert	15			
Hard Chert	125			
			Percent	
Deleterious Rock + Soft Chert =	75	=	2.5	% Total Deleterious Rock
Deleterious Rock + Soft Chert + Shale + OFM =	85	=	2.8	% Total Deleterious Material
Hard Chert + Soft Chert =	140	=	4.7	% Total Chert

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Summary:

- Quality must be determined according to specification requirements for various aggregates.
- Only material retained on #4 sieve is considered for deleterious determination.
- Any particle considered soft by means of chipping or spalling with the finger or fingernail is considered deleterious.
- Any substance that will reduce the effectiveness of the product will be considered detrimental, including material considered as Other Foreign Material (OFM).

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Descriptions of Specific Deleterious Groups and Tips on How to Determine Deleterious

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Shale: A dull looking grayish, green, or brownish rock made of clay or mud. Shale leaves a black mark on a non-glazed ceramic bowl.

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Other Foreign Material: Mud-balls, sticks, shell, lignite, and other miscellaneous items.

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- **Extremely Soft and or Porous Rock (Deleterious)**: Has a dull appearance, which can be easily spalled or chipped off with the finger nail.

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- **Soft Chert**: Will groove.

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Hard Chert: Has sharp edges, vary in color from white to black. Chert in lime-stone must be at least 50% chert to qualify as chert. Hard chert is hard enough to mark with a metal screwdriver. Has a non cohesive property that will cause it to pop-out of concrete

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Example Problem

1A

Sample: 1002 Material (Asphalt) ID NO.____ Date: ____

	Mass, grams		Percent	
Original Mass +4	3000			
Deleterious Rock (Very soft rock)	55			
Shale	7	=		% Shale
OFM	3	=		% OFM
Soft Chert	15			
Hard Chert	114			

			Percent	
Deleterious Rock + Soft Chert =		=		% Total Deleterious Rock
Deleterious Rock + Soft Chert + Shale + OFM =		=		% Total Deleterious Material
Hard Chert + Soft Chert =		=		% Total Chert

Example Problem

1A

Sample: 1002 Material (Asphalt) ID NO.____ Date: ____

	Mass, grams		Percent	
Original Mass +4	3000			
Deleterious Rock (Very soft rock)	55			
Shale	7	=	0.2	% Shale
OFM	3	=	0.1	% OFM
Soft Chert	15			
Hard Chert	114			

			Percent	
Deleterious Rock + Soft Chert =	70	=	2.3	% Total Deleterious Rock
Deleterious Rock + Soft Chert + Shale + OFM =	80	=	2.7	% Total Deleterious Material
Hard Chert + Soft Chert =	129	=	4.3	% Total Chert

Example Problem

1B

Sample: 1002 Material (Asphalt) ID NO.___ Date: ___

	Mass, grams		Percent	
Original Mass +4	3000			
Deleterious Rock (Very soft rock)	60			
Shale	9	=		% Shale
OFM	1	=		% OFM
Soft Chert	15			
Hard Chert	125			

			Percent	
Deleterious Rock + Soft Chert =		=		% Total Deleterious Rock
Deleterious Rock + Soft Chert + Shale + OFM =		=		% Total Deleterious Material
Hard Chert + Soft Chert =		=		% Total Chert

Example Problem Answers

1B

Sample: 1002 Material ID NO.___ Date: ___

	Mass, grams		Percent	
Original Mass +4	3000			
Deleterious Rock (Very soft rock)	60			
Shale	9	=	0.3	% Shale
OFM	1	=	0.0	% OFM
Soft Chert	15			
Hard Chert	125			

			Percent	
Deleterious Rock + Soft Chert =	75	=	2.5	% Total Deleterious Rock
Deleterious Rock + Soft Chert + Shale + OFM =	85	=	2.8	% Total Deleterious Material
Hard Chert + Soft Chert =	140	=	4.7	% Total Chert

106.3.2.71 TM-71, Deleterious Content of Aggregate

This test method determines the deleterious content of fine and coarse aggregates.

106.3.2.71.1 Apparatus

1) Containers of such a size and shape to contain the sample.

2) Sieves - No. 4 (4.75 mm) and No. 16 (1.18 mm).

3) Water to wet particles for observation.

4) Balance sensitive to within 0.5 percent of the weight (mass) of sample to be weighed.

106.3.2.71.2 Procedure for Coarse Aggregate Deleterious

106.3.2.71.2.1 Preparation

The sample shall be tested in an "as obtained" condition. The obtained sample shall be sieved over a No. 4 (4.75 mm) sieve, discarding the material passing the sieve. The material retained shall be the test sample used to determine the deleterious content.

106.3.2.71.2.2 Sample Size

Recommended minimum test sample sizes of plus No. 4 (4.75 mm) material are as follows:

Maximum Size[1], in. (mm)	**Sample Size, g**
2 (50)	10,000
1 ½ (37.5)	9,000
1 (25.0)	5,000
3/4 (19.0)	3,000
1/2 (12.5)	2,000
3/8 (9.5)	1,000
[1] Maximum size is defined as the smallest sieve through which 100 percent of the material will pass.	

106.3.2.71.2.3 Test

Each individual particle comprising the sample shall be examined piece-by-piece and separated into the various constituents as required by the specifications and in accordance with the descriptions shown in

EPG 106.3.2.71.6, Deleterious Definitions. The sample may be rinsed at the time of examination but shall not be soaked in water. Material not considered deleterious may be discarded except as needed for review. Each deleterious constituent shall be weighed, and the weight recorded. In some instances when required by the specification, the constituents are to be combined prior to weighing.

106.3.2.71.3 Procedure for Fine Aggregate Deleterious

106.3.2.71.3.1 Lightweight (Low Mass Density) Particle Content including Coal and Lignite

The test shall be in accordance with AASHTO T 113, however lightweight (low mass density) sand particles are not considered deleterious lightweight (low mass density) particles.

106.3.2.71.3.2 Percent Other Deleterious Substances, Clay Lumps and Shale in Fine Aggregate

106.3.2.71.3.2.1 Preparation

Recommended test sample size is approximately 200 grams, before sample is sieved over the No. 16 sieve.

106.3.2.71.3.2.2 Sample Size

The sample shall be tested in a dry condition (dried to a constant weight). Sample shall be sieved over a No. 16 sieve, discarding material passing the sieve. The material retained shall be the test sample used to determine the clay lumps and shale.

106.3.2.71.3.2.3 Procedure

The test sample shall be visually examined for shale, clay lumps and other deleterious substances. Particles may be lightly rinsed at the time of examination, but shall not be soaked in water. The deleterious substances shall be separated out into the constituents required by specification.

Shale is determined by using a non-glazed ceramic bowl (Plastic Index bowl). If particles leave a black mark on the bowl when pressure is applied to the material while moving it across the bottom of the bowl, this material is considered shale.

106.3.2.71.4 Calculations for Deleterious Content

The percentage of a deleterious substance shall be calculated as follows:

P = 100 x C / W

Where:

P = Percentage of each deleterious substance component.

C = Actual weight (mass) of deleterious substance for that component.

Quick Test for Per Cent of Deleterious Material

Report, 2009

See also: Innovation Library

W = Weight (mass) of test sample for the portion retained on the No. 4 sieve

106.3.2.71.5 Reports

Report the percent deleterious obtained for each constituent required by specification, to the nearest tenth (0.1).

106.3.2.71.6 Definitions of Deleterious Materials

The definition of deleterious material varies with the intended use and the anticipated affect on the final product.

106.3.2.71.6.1 Coarse Aggregate for Portland Cement Concrete

For coarse aggregate for portland cement concrete (Sec 1005), the following definitions apply:

106.3.2.71.6.1.1 Deleterious Rock

Deleterious rock includes the following material:

(1) Shaly rock. A rock that is generally contaminated with shale to a high degree. Color may vary but the rock usually has a dull gray appearance and is reasonably uniform in appearance. Also may occur in the form of numerous shale lines or seams closely spaced throughout the particle, thus giving a laminated or streaked appearance.

(2) Cap plus 20 percent. A rock particle with a line of demarcation of a layer or "cap" of shale or shaly rock which usually occurs on one face, but may be found on two faces; in either case, the summation of the percent of "caps" exceeds 20 percent of the volume of the rock particle.

(3) Extremely soft and/or porous rock. A rock which can be readily broken with the fingers. In some cases, due to the size or shape of the rock it cannot be broken, however, small areas can be spalled or chipped off with the fingers. Porosity or high absorption may be detected by rapid disappearance of surface water or by breaking rock in half and observing the depth of penetration of moisture.

106.3.2.71.6.1.2 Shale

A fine-grained rock formed by the consolidation of clay, mud, or silt; generally having a finely stratified or laminated structure.

106.3.2.71.6.1.3 Chert in Limestone

A fine-grained rock consisting of silica minerals, sharp-edged and may be highly absorptive. May occur in the form of nodules, lenses, or layers in limestone formations; and may vary in color from white to black. Quartz-type material is excluded. Any particle that contains more than 50% chert will be entirely classified as chert.

106.3.2.71.6.1.4 Other Foreign Material

Clay lumps, mud balls, lignite, coal, roots, sticks and other foreign material not related to the inherent material being inspected.

106.3.2.71.6.1.5 Material Passing No. 200 [75 µm] Sieve

The portion of material passing a No. 200 (75 µm) sieve as determined by a washed analysis.

106.3.2.71.6.1.6 Thin or Elongated Pieces

Rock particles that have a length greater than five times the maximum thickness. In case two sizes of coarse material are required to be combined into coarse aggregate, the limitation on "thin or elongated pieces" shall apply only to the coarser size so combined and shall only apply to particles retained on the 3/4 in. (19.0 mm) sieve. In the case of coarse aggregate produced without combining two sizes, the limitation on "thin or elongated pieces" shall apply only to particles retained on a 3/4 in. (19.0 mm) sieve.

106.3.2.71.6.2 Coarse Aggregate for Asphaltic Concrete, Plant Mix Bituminous Pavement, Plant Mix Bituminous and Seal Coats

For coarse aggregate for asphaltic concrete, plant mix bituminous pavement, plant mix bituminous leveling and seal coats (Sec 1002 and Sec 1003), the following definitions apply

106.3.2.71.6.2.1 Deleterious Rock

Deleterious rock includes the following materials:

(1) Shaly rock. A rock that is generally contaminated with shale to a high degree. Color may vary but the rock usually has a dull gray appearance and is reasonably uniform in appearance. Also may occur in the form of numerous shale lines or seams closely spaced throughout the particle, thus giving a laminated or streaked appearance.

(2) Cap plus 20 percent. A rock particle with a line of demarcation of a layer or "cap" of shale or shaly rock which usually occurs on one face, but may be found on two faces; in either case the summation of percent of "caps" exceeds 20 percent of the volume of the rock particle.

(3) Extremely soft rock. A rock that can be readily broken with the fingers. In some cases, due to size or shape of the rock it cannot be broken, however, small areas can be spalled or chipped off with the fingers.

(4) Chert. Chert which is soft and highly absorptive is considered deleterious.

106.3.2.71.6.2.2 Shale

A fine-grained rock formed by the consolidation of clay, mud, or silt; generally having a finely stratified or laminated structure.

106.3.2.71.6.2.3 Other Foreign Material

Clay lumps, mud balls, lignite, coal, roots, sticks, and other foreign material not related to the inherent material being inspected.

106.3.2.71.6.3 Coarse Aggregate for Bituminous Surface and Plant Mix Bituminous Base

For coarse aggregate for bituminous surface and plant mix bituminous base (Sec 1004), the following definitions apply:

106.3.2.71.6.3.1 Deleterious Rock

Deleterious rock includes the following materials:

(1) Shaly rock. A rock that is generally contaminated with shale to a high degree. Color may vary, but the rock usually has a dull gray appearance and is reasonably uniform in appearance. Pieces of rock having shaly seams, skin shale, and pieces of rock, which are not predominantly shaly, are not to be considered as deleterious.

(2) Extremely soft rock. A rock that can be readily broken with fingers, or from which small areas can be spalled or chipped off readily with the fingers or fingernail.

106.3.2.71.6.3.2 Shale

A fine-grained rock formed by the consolidation of clay, mud or silt; generally having a finely stratified or laminated structure.

106.3.2.71.6.3.3 Mud balls

Balls of mud.

106.3.2.71.6.3.4 Clay

A clay material that is more or less uniformly dispersed throughout the produced product.

106.3.2.71.6.3.5 Other Foreign Material

Any material not related to the inherent material being inspected.

106.3.2.71.6.4 Coarse Aggregate for Surfacing

For coarse aggregate for surfacing (Sec 1006), the following definitions apply:

106.3.2.71.6.4.1 Deleterious Rock

Deleterious rock includes extremely soft rock; a rock that can be readily broken or spalled with the fingers or fingernail.

106.3.2.71.6.4.2 Shale

A fine-grained rock formed by the consolidation of clay, mud, or silt; generally having a finely stratified or laminated structure.

106.3.2.71.6.4.3 Mud Balls

Balls of mud.

106.3.2.71.6.4.4 Other Foreign Material

Any material not related to the inherent material being inspected.

106.3.2.71.6.5 Coarse Aggregate for Base

For coarse aggregate for base (Sec 1007), the following definitions apply:

106.3.2.71.6.5.1 Deleterious Rock

Deleterious rock includes extremely soft rock; a rock that can be readily broken or spalled with the fingers or fingernail.

106.3.2.71.6.5.2 Shale

A fine-grained rock formed by the consolidated of clay, mud or silt; generally having a finely stratified or laminated structure.

106.3.2.71.6.5.3 Mud Balls

Balls of mud.

TM71: Deleterious Content of Aggregate
PROFICIENCY CHECKLIST

Applicant____

Employer____

Trial #	1	2
1. Material tested in an as received condition (may be dried at 140ºF)		
2. Reduced the sample according to the Maximum Size aggregate using the TM71 table below: Note: Surplus this amount for sieving		

Maximum Size Inches (mm)	Minimum Sample Size of +4 material
2 (50)	10,000 grams
1½ (37.5)	9,000 grams
1 (25.0)	5,000 grams
¾ (19.0)	3,000 grams
½ (12.5)	2,000 grams
⅜ (9.5)	1,000 grams
Maximum size is defined as the smallest sieve through which 100% of the material will pass.	

Trial #	1	2
3. Sieved the reduced sample over a #4 sieve and discarded the passing material		
4. Reweighed the plus 4 material to see if the sample meets the minimum size needed from the table.		
5. Recorded the weight of the plus #4 material as the Original Mass		
6. Set-up a workstation with a good light, a pan or spray bottle of water and several sorting pans		
7. Obtained a handful, briefly wet a few particles and visually examined each particle **(Do not soak the particles in water)**		
8. Examined each piece and separated the deleterious particles into specific groups according to specifications: (OFM, Hard Chert, Soft chert, Shale, etc.)		
9. Recorded the weight of each group of deleterious found in the sample to the nearest whole gram		
NOTES: ❖ Groups are defined in the test method and will vary based on product type as well as the presence of any given group ❖ For 1002 material, keep soft chert separate as it will be included in both deleterious and hard chert		
10. Calculate the percentage of each group identified, report to nearest 0.1% for each category $P = \frac{C}{W} x\ 100$ Where: P = Percentage of each deleterious component C = Actual weight (mass) of deleterious for each group W = Weight (mass) of test sample for the portion retained on the #4 sieve		
	PASS	PASS
	FAIL	FAIL

Examiner: ______________________________ Date: ______________

Aggregate Technician

ASTM D 4791

Flat Particles, Elongated Particles,

Or Flat and Elongated Particles

In Coarse Aggregate

ASTM D4791

Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

Rev. 12/15/2019

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SCOPE

- This test method covers the determination of the percentages of flat particles, elongated particles, or flat and elongated particles in coarse aggregates.
- Two procedures, Method A and Method B, are presented in ASTM D4791.
- <u>Method A</u> uses 4 groups of F&E:

1. Flat particles,
2. Elongated particles
3. Particles that meet the criteria of both groups
4. Neither flat nor elongated.

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- <u>Method A</u> is a reflection of the original procedure as developed prior to Superpave and is intended for all non-Superpave applications *and will <u>NOT</u> be covered in this certification. For more information on Method A, see the Appendix.*
- **<u>Method B</u> is a comparison of the maximum particle dimension to the minimum particle dimension and is intended for use with Superpave specifications.**

Scope

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SIGNIFICANCE AND USE

- The particle shape of course aggregate influences the properties of some construction materials and may affect their placement and consolidation.
- This test method provides a means for checking compliance with specifications that limit such particles or to determine the relative shape characteristics of coarse aggregate.

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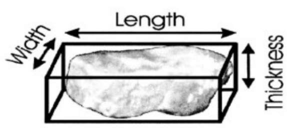
4

Definitions



- **Flat and Elongated Particles** (F&E) - Those particles having a ratio of length to thickness greater than a specified value
- **Length** - The longest dimension
- **Thickness** - The smallest dimension
- **Width** – Intermediate dimension of the particle that is greater than or equal to the thickness

5

5

Detrimental affects when used in mixtures:

- Interferes with placement and consolidation.
- Fractures or breaks more easily.
- When an aggregate particle breaks, it creates a face that is not coated with binder, increasing the potential of the mix to strip or ravel.
- When the coarse aggregate fractures the gradation will likely change, which may be detrimental to the mix.

6

6

Material Tested:

ASTM

- Material larger than ¾" (19mm) or #4 (4.75mm) as determined by specification requirements.

MoDOT

- See Engineering Policy Guide (EPG)
- 106.7.71 TM 71, Deleterious Content of Aggregate (106.7.71.6.1.6)

7

7

MoDOT Materials Tested:

1002

- Test all sieves with more than 10% retained (on #4 sieve and above)
- Test only 5:1 comparison
- Do a weighted average calculation and report this result

SMA (Stone Mastic Aggregate)

- Test all sieves with more than 10% retained on #4 sieve and above
- Test both 3:1 and 5:1 comparison
- Do a weighted average calculation and report this result

8

8

1005

- Test all sieves with more than 10% retained on **¾"** sieve and above.
- Test only 5:1 comparison
  - Do NOT do a weighted average calculation

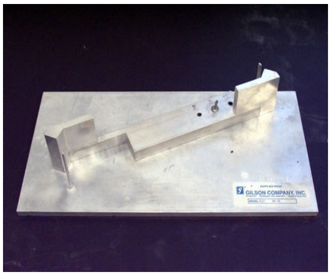
MoDOT Materials Tested

9

9

EQUIPMENT

- Proportional Caliper Device
- Scale, accurate to 0.5% of the sample mass
- Oven or hot plate



10

10

SAMPLING

- Sample the coarse aggregate in accordance with Practice AASHTO R 90 (ASTM D75).
- Thoroughly mix the sample and reduce it to an amount suitable for testing using the applicable procedures described in practice AASHTO R 76. The sample for testing shall be approximately the mass desired when dry and shall be the end result of the reduction. Reduction to an exact predetermined mass shall not be permitted.

11

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ASTM D4791 Sample Size

Maximum Retained Sieve Size in.(mm)	Minimum Amounts lb. (Mass in grams)
⅜ " (9.5)	2 (1000)
½ " (12.5)	4 (2000)
¾ " (19.0)	11 (5000)
1" (25.0)	22 (10,000)
1 ½" (37.5)	33 (15,000)

12

12

By particle count:

- Does not need to be oven dried.
- Perform AASHTO T27
- Reduce each fraction that has a minimum of 10% retained until approximately 100 particles remain
- Approximately 100 particles needed for testing

By mass/weight:

- Oven dry @ 230 ± 9°F (110 ± 5°C)
- Perform AASHTO T27
- Test all sieves with more than 10% retained on the #4 sieve and above as required by MoDOT specifications.

13

13

SUPERPAVE PROCEDURE; METHOD B

Acquire the amounts to be tested by count or mass.

1. Each particle in each size fraction tested and placed into one of two groups:

   Flat & Elongated OR Not Flat & Elongated

2. Proportional caliper device positioned at proper ratio? 3:1, 5:1, etc.
3. Test each particle in the caliper by setting the larger opening to the particle length.

14

14

4. Place the particle through the opposite side of the caliper for thickness, if it slips through the smaller measure, the particle is flat and elongated.
5. Weigh the amount of F&E of each fraction and record each to the nearest whole gram on the report.

NOTE: Particle is flat and elongated if the thickness can be passed through the smaller opening.

Method B

15

15

Evaluating Aggregates

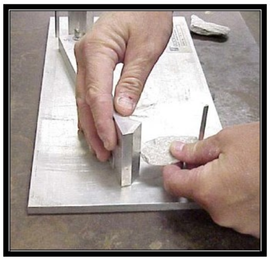


Figure 1
Checking Elongation

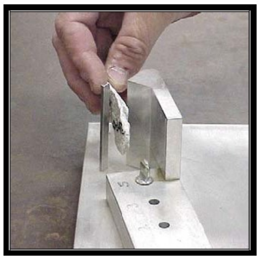


Figure 2
Checking Flatness

16

16

CALCULATIONS & REPORTING

- Report each group to nearest 1%. Test all sieves with more than 10% retained on #4 sieve and above as required by MoDOT Specifications.

  NOTE: If a sieve size has less than 10% retained, see example calculation sheet item for guidance.

- Report each F&E group to nearest whole number.
- When required, the weighted average percentages based on the actual or assumed proportions of the various sieve sizes tested.

17

17

A = Weight retained on each particular sieve

$B = \boxed{\dfrac{(A)}{\text{Original mass of sample}} \times 100}$ Report to nearest 0.1%

C = Weight of mass tested (Approximately 100 pieces)

D = Weight of flat and elongated particles

$E = \boxed{\dfrac{D}{C} \times 100}$ Report to nearest 1%

$F = \boxed{\dfrac{B}{TPR}}$ Report to nearest 0.001

$G = \boxed{E \times F}$ Report to nearest 1%

Calculations & Reporting

18

18

Common testing errors:

- Not obtaining a representative sample
- Not reducing the sample properly
- Not sieving to completion
- Improper positioning in the machine

19

19

Class Room
F&E
Problems

There are enlarged copies at the end of this module.

20

20

Flat and Elongated by Mass

Problem 1A

Original Mass of Sample 6301 grams Ratio 5 to 1 .

Report to:	0 g	0.0	0	0	0	0.000	0
Sieve Sizes	Mass Retained T27 (A)	Percent Retained % (B)	Number or Mass Tested (C)	Number or Mass F & E (D)	Percent F & E (E)	Sieve Fraction Retained Factor (F)	Percent F&E Weighted Ave. (G)
37.5mm 1 ½"	0						
25.0mm 1"	0						
19.0mm ¾"	2644		1973	8			
12.5mm ½"	3232		1632	44			
9.5mm ⅜"	69		0	0			
4.75mm #4	119		0	0			
Total % Retained (TPR)			(TPR)				
						Total	

21

21

Original Mass of Sample 6301 grams Ratio 5 to 1 **Answers 1A**

Report to:	0 g	0.0	0	0	0	0.000	0
Sieve Sizes	Mass Retained (A)	Percent Retained (B)	Number or Mass Tested (C)	Number or Mass F & E (D)	Percent F & E (E)	Sieve Fraction Retained Factor (F)	Percent F&E Weighted Ave. (G)
37.5mm 1 ½”	0						
25.0mm 1”	0						
19.0mm ¾”	2644	42.0	1973	8	0	.436	0
12.5mm ½”	3232	51.3	1632	44	3	.533	2
9.5mm ⅜”	69	1.1<10%	0	0	3	0.011	0
4.75mm #4	119	1.9<10%	0	0	3	.020	0
Total % Retained		96.3	(TPR)			1.000	
						Total	2%

22

22

Flat and Elongated by Mass

Problem 2B

Original Mass of Sample 7300 Ratio 5 to 1 .

Sieve Sizes	Mass Retained (A)	Percent Retained (B)	Number or Mass Tested (C)	Number or Mass F & E (D)	Percent F & E (E)	Sieve Fraction Retained Factor (F)	Percent F&E Weighted Ave. (G)
37.5mm 1 ½”							
25.0mm 1”	0		0	0			
19.0mm ¾”	2710		1840	13			
12.5mm ½”	3252		1588	51			
9.5mm ⅜”	70		0	0			
4.75mm #4	1252		825	33			
Total % Retained			(TPR)				
						Total	

23

23

Flat and Elongated by Mass

Problem 2B

Original Mass of Sample 7300 Ratio 5 to 1 .

Sieve Sizes	Mass Retained (A)	Percent Retained (B)	Number or Mass Tested (C)	Number or Mass F & E (D)	Percent F & E (E)	Sieve Fraction Retained Factor (F)	Percent F&E Weighted Ave. (G)
37.5mm 1 ½”							
25.0mm 1”	0		0	0			
19.0mm ¾”	2710	37.1	1840	13	1		
12.5mm ½”	3252	44.5	1588	51	3		
9.5mm ⅜”	70	1.0 <10%	0	0	4		
4.75mm #4	1252	17.2	825	33	4		
Total % Retained		99.8	(TPR)				
For column E where zero is : 3+4 =7 (7 ÷ 2) = 3.5 = 4 Using the number above and below the zero, add, divide by 2 =4						Total	

24

24

Flat and Elongated by Mass

Answers 2B

Original Mass of Sample 7300 Ratio 5 to 1.

Sieve Sizes	Mass Retained (A)	Percent Retained (B)	Number or Mass Tested (C)	Number or Mass F & E (D)	Percent F & E (E)	Sieve Fraction Retained Factor (F)	Percent F&E Weighted Ave. (G)
37.5mm 1 ½"							
25.0mm 1"	0		0	0			
19.0mm ¾"	2710	37.1	1840	13	1	0.372	0
12.5mm ½"	3252	44.5	1588	51	3	0.446	1
9.5mm ⅜"	70	1.0 <10%	0	0	4	0.010	0
4.75mm #4	1252	17.2	825	33	4	0.172	1
Total % Retained		99.8	(TPR)			1.000	
For column E where zero is : 3+4 =7 (7 ÷ 2) = 3.5 = 4 Using the number above and below the zero, add, divide by 2 =4						Total	2%

25

25

Flat and Elongated by Count

Problem 3C

Original Mass of Sample COUNT Ratio 5 to 1.

Report to:	0	0.0	0	0	0	0.000	0
Sieve Sizes	Mass Retained T27 (A)	Percent Retained % (B)	Number or Mass Tested (C)	Number or Mass F & E (D)	Percent F & E (E)	Sieve Fraction Retained Factor (F)	Percent F&E Weighted Ave. (G)
37.5mm 1 ½"							
25.0mm 1"							
19.0mm ¾"							
12.5mm ½"		10.2	102	4			
9.5mm ⅜"		10.5	104	1			
4.75mm #4		35.8	109	3			
Total % Retained (TPR)		56.5	(TPR)				
						Total	

26

26

Flat and Elongated by Count

Answer 3C

Original Mass of Sample COUNT Ratio 5 to 1.

Report to:	0	0.0	0	0	0	0.000	0
Sieve Sizes	Mass Retained T27 (A)	Percent Retained % (B)	Number or Mass Tested (C)	Number or Mass F & E (D)	Percent F & E (E)	Sieve Fraction Retained Factor (F)	Percent F&E Weighted Ave. (G)
37.5mm 1 ½"							
25.0mm 1"							
19.0mm ¾"							
12.5mm ½"		10.2	102	4	4	0.181	1
9.5mm ⅜"		10.5	104	1	1	0.186	0
4.75mm #4		35.8	109	3	3	0.634	2
Total % Retained (TPR)		56.5	(TPR)				
						Total	3

27

27

FLAT AND ELONGATED PARTICLES (ASTM D 4791) Problem 1A

Project: J8P0633 **Mix Design:** SP250 05-43 **Date:** 7/25/08 .
Material/Stockpile ID 1" Fraction **Technician:** Bob Poteet

Original Mass of Sample 6301 **Ratio** 5 to 1 .

Report to:	0	0.0	0	0	0	0.000	0
Sieve Sizes	Mass Retained (A)	Percent Retained (B)	Number or Mass Tested (C)	Number or Mass F & E (D)	Percent F & E (E)	Sieve Fraction Retained Factor (F)	Percent F&E Weighted Ave. (G)
37.5mm 1 ½"	0						
25.0mm 1"	0		0	0			
19.0mm ¾"	2644		1973	8			
12.5mm ½"	3232		1632	44			
9.5mm ⅜"	69		0	0			
4.75mm #4	119		0	0			
Total % Retained			(TPR)				
						Total	

A = Weight retained on each particular sieve

$$B = \frac{(A)}{\text{original mass of sample}} \times 100$$

C = Weight of mass tested (Approximately 100 pieces)

D = Weight of Flat and Elongated particles

$$E = \frac{D}{C} \times 100$$

$$F = \frac{B}{TPR}$$

$$G = E \times F$$

(9.1) (E&G) Calculated to nearest 1%

(9.2) When a weighted average for a sample is required, assume that the sieve sizes not tested (those representing less than 10% of the sample) have the same percentage of F&E particles as the next smaller or next larger size, or use the average for the next smaller and next large sizes, if both are present.

FLAT AND ELONGATED PARTICLES (ASTM D 4791)

Answer 1A

Project: J8P0633 **Mix Design:** SP250 05-43 **Date:** 7/25/08 .
Material/Stockpile ID 1" Fraction **Technician: Bob Poteet**

Original Mass of Sample 6301 **Ratio** 5 to 1 .

Report to:	0	0.0	0	0	0	0.000	0
Sieve Sizes	Mass Retained (A)	Percent Retained (B)	Number or Mass Tested (C)	Number or Mass F & E (D)	Percent F & E (E)	Sieve Fraction Retained Factor (F)	Percent F&E Weighted Ave. (G)
37.5mm 1 ½"	0						
25.0mm 1"	0		0	0			
19.0mm ¾"	2644	42.0	1973	8	0	0.436	0
12.5mm ½"	3232	51.3	1632	44	3	0.533	2
9.5mm ⅜"	69	1.1<10%	0	0	3	0.011	0
4.75mm #4	119	1.9<10%	0	0	3	0.020	0
Total % Retained		96.3	(TPR)			1.000	
						Total	2%

A = Weight retained on each particular sieve

$$B = \frac{(A)}{\text{original mass of sample}} X\ 100$$

C = Weight of mass tested (Approximately 100 pieces)

D = Weight of Flat and Elongated particles

$$E = \frac{D}{C} X\ 100$$

$$F = \frac{B}{TPR}$$

G = E x F

(9.1) (E&G) Calculated to nearest 1%

(9.2) When a weighted average for a sample is required, assume that the sieve sizes not tested (those representing less than 10% of the sample) have the same percentage of F&E particles as the next smaller or next larger size, or use the average for the next smaller and next large sizes, if both are present.

FLAT AND ELONGATED PARTICLES (ASTM D 4791) **Problem 2B**

Project:__________**Mix Design:**________________**Date:** 2017 .
Material/Stockpile ID __________________ **Technician**

Original Mass of Sample 7300 **Ratio** 5 **to** 1 .

Sieve Sizes	Mass Retained (A)	Percent Retained (B)	Number or Mass Tested (C)	Number or Mass F & E (D)	Percent F & E (E)	Sieve Fraction Retained Factor (F)	Percent F&E Weighted Ave. (G)
37.5mm 1 ½"							
25.0mm 1"	0		0	0			
19.0mm ¾"	2710		1840	13			
12.5mm ½"	3252		1588	51			
9.5mm ⅜"	70		0	0			
4.75mm #4	1252		825	33			
Total % Retained			(TPR)				
						Total	

A = Weight retained on each particular sieve

$$B = \frac{(A)}{\text{original mass of sample}} \text{ X } 100$$

C = Weight of mass tested (Approximately 100 pieces)

D = Weight of Flat and Elongated particles

$$E = \frac{D}{C} \text{ X } 100$$

$$F = \frac{B}{TPR}$$

$$G = E \text{ x } F$$

(9.1) (E&G) Calculated to nearest 1%

(9.2) When a weighted average for a sample is required, assume that the sieve sizes not tested (those representing less than 10% of the sample) have the same percentage of F&E particles as the next smaller or next larger size, or use the average for the next smaller and next large sizes, if both are present.

FLAT AND ELONGATED PARTICLES (ASTM D 4791) **Answer 2B**

Project:___________Mix Design:___________________Date:__2017________.
Material/Stockpile ID ____________________ Technician

Original Mass of Sample __7300______ Ratio __5__ to __1____.

Sieve Sizes	Mass Retained (A)	Percent Retained (B)	Number or Mass Tested (C)	Number or Mass F & E (D)	Percent F & E (E)	Sieve Fraction Retained Factor (F)	Percent F&E Weighted Ave. (G)
37.5mm 1 ½"							
25.0mm 1"	0		0	0			
19.0mm ¾"	2710	37.1	1840	13	1	0.372	0
12.5mm ½"	3252	44.5	1588	51	3	0.446	1
9.5mm ⅜"	70	1.0 <10%	0	0	4	0.010	0
4.75mm #4	1252	17.2	825	33	4	0.172	1
Total % Retained		99.8	(TPR)			1.000	
For column E where zero is : 3+4 =7 (7 ÷ 2) = 3.5 = 4 Using the number above and below the zero, add, divide by 2 =4						Total	2%

A = Weight retained on each particular sieve

$$\mathbf{B} = \frac{(A)}{\text{original mass of sample}} \text{ X } 100$$

C = Weight of mass tested (Approximately 100 pieces)

D = Weight of Flat and Elongated particles

$$\mathbf{E} = \frac{D}{C} \text{ X } 100$$

$$\mathbf{F} = \frac{B}{TPR}$$

(9.1) (E&G) Calculated to nearest 1%

G = E x F

(9.2) When a weighted average for a sample is required, assume that the sieve sizes not tested (those representing less than 10% of the sample) have the same percentage of F&E particles as the next smaller or next larger size, or use the average for the next smaller and next large sizes, if both are present.

FLAT AND ELONGATED PARTICLES (ASTM D 4791) — Problem 3C

Project: J8P0633 **Mix Design:** SP250 05-43 **Date:** 7/25/08 .
Material/Stockpile ID ¾" Fraction **Technician:** Bob Poteet

Original Mass of Sample Count **Ratio** 5 to 1 .

Sieve Sizes	Mass Retained (A)	Percent Retained (B)	Number or Mass Tested (C)	Number or Mass F & E (D)	Percent F & E (E)	Sieve Fraction Retained Factor (F)	Percent F&E Weighted Ave. (G)
37.5mm 1 ½"							
25.0mm 1"			0	0			
19.0mm ¾"			0	0			
12.5mm ½"		10.2	102	4			
9.5mm ⅜"		10.5	104	1			
4.75mm #4		35.8	109	3			
Total % Retained		56.5	(TPR)				
						Total	

A = Weight retained on each particular sieve

$$\mathbf{B} = \frac{(A)}{\text{original mass of sample}} \text{ X } 100$$

C = Weight of mass tested (Approximately 100 pieces)

D = Weight of Flat and Elongated particles

$$\mathbf{E} = \frac{D}{C} \text{ X } 100$$

$$\mathbf{F} = \frac{B}{TPR}$$

G = E x F

(9.1) (E&G) Calculated to nearest 1%

(9.2) When a weighted average for a sample is required, assume that the sieve sizes not tested (those representing less than 10% of the sample) have the same percentage of F&E particles as the next smaller or next larger size, or use the average for the next smaller and next large sizes, if both are present.

FLAT AND ELONGATED PARTICLES (ASTM D 4791) **Answer 3C**

Project: J8P0633 **Mix Design:** SP250 05-43 **Date:** 7/25/08 .
Material/Stockpile ID ¾" Fraction **Technician: Bob Poteet**

Original Mass of Sample Count **Ratio** 5 **to** 1 .

Sieve Sizes	Mass Retained (A)	Percent Retained (B)	Number or Mass Tested (C)	Number or Mass F & E (D)	Percent F & E (E)	Sieve Fraction Retained Factor (F)	Percent F&E Weighted Ave. (G)
37.5mm 1 ½"							
25.0mm 1"			0	0			
19.0mm ¾"			0	0			
12.5mm ½"		10.2	102	4	4	0.181	1
9.5mm ⅜"		10.5	104	1	1	0.186	0
4.75mm #4		35.8	109	3	3	0.634	2
Total % Retained		56.5	(TPR)			1.001	
						Total	3

A = Weight retained on each particular sieve

$$B = \frac{(A)}{\text{original mass of sample}} \text{ X } 100$$

C = Weight of mass tested (Approximately 100 pieces)

D = Weight of Flat and Elongated particles

$$E = \frac{D}{C} \text{ X } 100$$

$$F = \frac{B}{TPR}$$

$$G = E \text{ x } F$$

(9.1) (E&G) Calculated to nearest 1%

(9.2) When a weighted average for a sample is required, assume that the sieve sizes not tested (those representing less than 10% of the sample) have the same percentage of F&E particles as the next smaller or next larger size, or use the average for the next smaller and next large sizes, if both are present.

MODOT - EPG

106.3.2.71.6.1.6 Flat or Elongated Pieces

Rock particles that have a length greater than five times the maximum thickness. In case two sizes of coarse material are required to be combined into coarse aggregate, the limitation on "thin or elongated pieces" shall apply only to the coarser size so combined and shall only apply to particles retained on the 3/4 in. (19.0 mm) sieve. In the case of coarse aggregate produced without combining two sizes, the limitation on "thin or elongated pieces" shall apply only to particles retained on a 3/4 in. (19.0 mm) sieve.

ASTM D4791: Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
PROFICIENCY CHECKLIST

Applicant: ______________________________

Employer: ______________________________

Sample Preparation **Trial #**	1	2
1. Sampled in accordance with AASHTO R 90		
2. Determined the Nominal Maximum size of the aggregate sample		
3. Reduced the sample using AASHTO R 76 to the testing size using the Table below		
4. Determined to test either by Count or Mass		
5. For Mass, sample oven-dried to constant mass at 230 ± 9°F (110 ± 5°C) For Count, sample is tested in an as is condition		
6. Sieve analysis completed according to AASHTO T 27, recorded the mass retained of each fraction in column A of the report		
7. Obtained the fractions needed to test per Count or Mass: **By Particle Count**: From the Sieve Analysis each fraction from the #4 or 3/4" sieve and above as required by specification, with a minimum of 10% retained will be reduced to approximately 100 particles **By Mass:** Use the material retained on the #4 or 3/4" sieve and above as required by MoDOT EPG specifications 1002, 1005, etc.		
Procedure: Method B - Flat and Elongated Particle Test		
1. Sorted each particle in each size fraction into one of two groups: (1) Flat and elongated OR (2) Not flat and elongated		
2. Proportional caliper device positioned at the proper ratio 5:1 or 3:1		
3. Tested each particle in the caliper by setting the larger opening to the particle length		
4. Placed the particle through the opposite side of the caliper for thickness, if it slips through the smaller measure, the particle is flat and elongated		
5. Weighed the amount of F&E of each fraction and recorded each to the nearest whole number on the report		
Calculations		
Percentage of flat and elongated particles calculated to nearest 1% for each sieve size as required		
	PASS FAIL	PASS FAIL

Table for item 3:

Nominal Maximum Size in. (mm)	**Minimum Mass lb. (g,)**
⅜ (9.5)	2 (1000)
½ (12.5)	4 (2000)
¾ (19.0)	11 (5000)
1 (25.0)	22 (10,000)
1 ½ (37.5)	33 (15,000)
2 (50)	44 (20,000)

Examiner: ______________________________ Date: ______________

AASHTO T84

ASTM C128

Specific Gravity and

Absorption
of
Fine Aggregate

AASHTO T 84

Test for Specific Gravity and Absorption of Fine Aggregate

Rev 12/16/2019

1

SCOPE

- This method covers the determination of bulk, and apparent specific gravity, at 73.4ºF (23ºC), and the absorption of fine aggregate after 15-19 hours of soaking in water.

2

2

SIGNIFICANCE AND USE

- Bulk specific gravity is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures containing aggregate including Portland cement concrete, bituminous concrete, and other mixtures that are proportioned or analyzed on an absolute volume basis.

3

3

- Bulk specific gravity is also used in the computation of voids in aggregate in AASHTO T19M/T19 Unit Weight.
- Bulk specific gravity determined on the SSD basis is used if the aggregate is wet; that is, if its absorption has been satisfied.
- Apparent specific gravity pertains to the relative density of the solid material making up the primary particles not including the pore space within the particles that is accessible to water. This value is not widely used in construction aggregate technology.

Significance and Use

4

4

- Absorption values are used to calculate the change in the mass of an aggregate due to water absorbed in the pore spaces within the particles, compared to the dry condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the absorption potential. The laboratory standard for absorption is that obtained after soaking dry aggregate in water.

Significance and Use

5

5

TERMINOLOGY

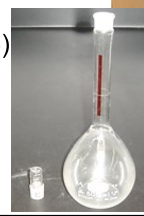
- **Oven Dried**: Dried to a constant mass at a temperature of 230±9°F (110±5°C).
- **Air Dried**: Dried at a temperature ≤ 140 °F (60 °C).
- **Constant Mass:** The mass at which additional drying of the sample would result in less than an additional 0.1% loss in mass.
- **Saturated Surface Dry (SSD):** When the aggregate is saturated on the inside, but the surface is dry.

6

6

EQUIPMENT

- Balance readable to 0.1 grams
- 500 ml Pycnometer (flask)
- Conical mold
- Tamper
- Oven capable of 230 ± 9°F (110 ± 5°C)
- No. 4 Sieve



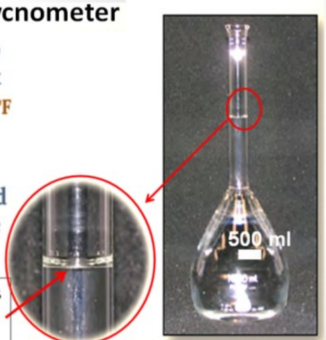
7

7

Calibrate the Pycnometer

Calibration

- Fill with water to calibration mark
  - Water @ 73.4 ± 3°F
- Read bottom of meniscus
- Weigh and record the weight of the "Pyc + Water"



Bottom of Meniscus touches the line for full capacity.

Weigh to the nearest 0.1 grams

And record this is "**B**" in the equation.

8

8

SAMPLE PREPARATION

- Obtain a representative field sample (ASHTO R90).
- Mix and reduce (AASHTO R76).
- Sieve over a **#4 sieve**, collect approximately **1,000 grams of minus #4** material.
- Oven dry the minus #4 material in a pan to a constant weight at **230 ± 9°F (110 ± 5°C).**

9

9

Sample Preparation

- Allow the sample to cool to comfortable handling temperature.
- Cover the sample with water for **15-19**

(or add at least 6%moisture, 0.06 x test weight)

10

10

PROCEDURE

- Set up a calibrated pycnometer partially filled with water and a funnel near a scale and ready to go.
- After the 15 -19 hour soak, decant excess water from the sample with care to avoid loss of fines.

11

11

Procedure

- After soaking, spread the sample on a flat, nonabsorbent surface.
- Uniformly dry the sample with a gentle current of warm air, stir frequently.

Note: It may be necessary to work the sample with your hands in a rubbing motion to break up any lumps that develop.

- Keep stirring, until the sample approaches a free-flowing condition.

Note: Sample must be on the wet side of SSD when beginning the cone test.

12

12

Things to know before starting the cone test: If the sample falls flat, on the first cone test, or before the SSD state, it has been dried past the SSD condition.

Procedure

What to do. . .

- Mix in a few milliliters of water
- Cover
- Let stand for 30 minutes.
- Return to nonabsorbent surface, stirring and continuing with cone testing till SSD is reached.

Too Dry!

13

13

Cone Test:

Procedure

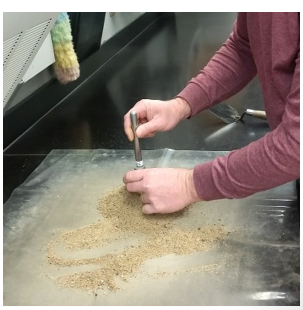
- Place the mold on a flat, nonabsorbent surface, with the large diameter down.
- Fill the mold to overflowing.

14

14

- Tamp 25 times with **5mm** drops (0.2 in).
- Allow the tamper to fall freely.

Procedure



15

15

Procedure

- Remove the material from around the base of the mold, then lift cone vertically.

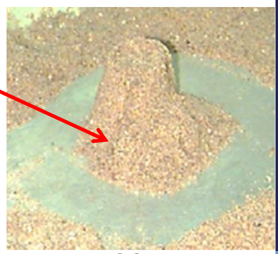
A good first trial = Retains the shape of the cone!

16

16

Procedure

- Continue drying and doing cone tests until the sample slumps slightly = SSD condition.



- The closer testing gets to the SSD state, increase the number of cone tests.

17

17

Procedure

After the SSD condition is reached:

- Immediately weigh 500 ± 10 grams of SSD material and add it to the pycnometer.

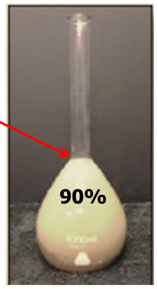
- Record the SSD weight to the nearest **0.1g**, this is "**S**" in the equation.

18

18

Procedure

- Fill Pycnometer with additional Water to approximately 90% capacity.
- Usually, 90% is just into or slightly below the neck of the flask.

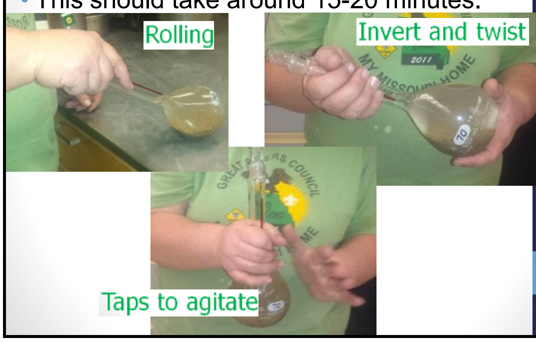


19

19

Procedure

- Roll, invert, and agitate the pycnometer to remove all the air bubbles.
- This should take around 15-20 minutes.



20

20

Procedure

- After removing air from the sample, adjust the water level in the pycnometer to its calibrated capacity.

NOTES:

The etched line at top of neck on the flask is the calibrated capacity.

If foam developed on the water surface, use a paper towel or isopropyl alcohol to reduce this.

21

21

Procedure

- Place the pycnometer in a bath 73.4 ± 3°F (23.0 ± 1.7°C). After 30-45 minutes check the water inside the pycnometer with a thermometer to verify that the temperature is at 73.4 ± 3°F (23.0 ± 1.7°C).
- If at temperature move on to the next step. Otherwise give the flask more time in the bath and check again later.

22

22

Procedure

- Determine total mass of the pycnometer, sample, and water. Weigh to 0.1 gram = "**C**" in the equation.
- Remove the sample from pycnometer into a small pre-weighed pan.
- Weigh to the nearest 0.1 grams.
- Oven dry sample to constant weight at 230 ± 9° (110 ± 5°C).

23

23

Procedure

- Cool sample in air at room temperature for 1.0 ± 0.5 hour(s), weigh the dry sample to the nearest 0.1g. Report as "A" in the equation.

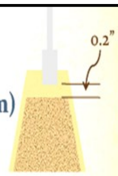
Note: All weights determined to 0.1 gram.

24

24

Cone Test Summary

- Fill cone to overflowing
- Tamp 25 times from a height of 0.2" (5mm)
- Clean aggregate from base of cone
- Lift cone vertically



Wet	Dry	SSD
Aggregate Maintains Shape	NO Shape	Aggregate Slumps Slightly

Procedure

25

25

CALCULATIONS

Bulk Specific Gravity

$$Bulk\ Specific\ Gravity = \frac{A}{(B+S-C)}$$

A = mass of oven-dry sample in air (g)
B = mass of pycnometer filled with water (g)
S = mass of saturated surface-dry sample (g)
C = mass of pycnometer with sample and water to calibrated mark (g)

26

26

Bulk Specific Gravity (SSD)

- **S**aturated **S**urface **D**ry Basis

$$SSD = \frac{S}{(B+S-C)}$$

S = mass of the saturated surface-dry sample (g)
B = mass of pycnometer filled with water (g)
C = mass of pycnometer with sample and water to calibration mark (g)

Calculations

27

27

Apparent Specific Gravity

$$App\ Sp.Gr. = \frac{A}{(B + A - C)}$$

A = mass of oven dry sample in air

B = mass of pycnometer filled with water

C = mass of pycnometer with sample and water to the calibration mark

Calculations

28

28

Absorption Percent

$$Abs.\% = \left[\frac{(S - A)}{A}\right] x100$$

A = mass of oven dry sample in air

B = mass of pycnometer filled with water

S = mass of the saturated surface dry sample

C = mass of pycnometer with sample and water to the calibration mark

Calculations

29

29

REPORTING

- Report the Specific Gravities
  - to the hundredth, **0.01**, for **1005** Concrete
  - to the thousandth, **0.001**, for **1002** Asphalt
- Report the Absorption to the tenth, **0.1%**
- Alternative: For, naturally moist condition report the source of the sample and the procedures used to prevent drying prior to testing.

30

30

Reporting for AASHTO M6:

For AASHTO **M6:** Fine aggregate for Hydraulic Cement Concrete.

Report specific gravity results to the nearest 0.01 and absorption to the nearest 0.1%.

Reporting

31

31

Notes:

T84 for Aggregate Maintained in A Naturally Moist Condition

- As an alternative, where the absorption and specific gravity values are to be used in their naturally moist condition, the requirement for initial drying to constant mass may be eliminated and, if the surfaces of the particles have been kept wet, the required soaking may also be eliminated.

Sample Preparation

32

32

Notes:

- **Definitions:** Are in the glossary.
- **Tests for materials that do not readily slump:**

1. Provisional Cone Test
2. Provisional Surface Test
3. Colorimetric procedures
4. SSD on single-size material

See the appendix for more information

Special Notes

33

33

Practice Calculations

Asphalt (1002) Sample		
499.9 g	Mass of oven-dry sample in air	A
683.7g	Mass of pycnometer filled with water	B
503.3g	Mass of saturated-surface-dry sample	S
990.1g	Mass of pyc., water, and sample	C

Using the information above, Find;

- Bulk Specific Gravity,
- SSD,
- Apparent Specific Gravity,
- Absorption Percent.

Use regular rounding.

34

34

Answers:

This slide is enlarged

ASPHALT SAMPLE

Bulk Sp. Gr. (O.D. basis) $= \dfrac{A}{B + S - C} = \dfrac{(\ 499.9\ )}{(\ 683.7\ ) + (\ 503.3\ ) - (\ 990.1\ )} = 2.539$ (2.538852)

Bulk Sp. Gr. (SSD basis) $= \dfrac{S}{B + S - C} = \dfrac{(\ 503.3\ )}{(\ 683.7\ ) + (\ 503.3\ ) - (\ 990.1\ )} = 2.556$ (2.556120)

Apparent Sp. Gr. $= \dfrac{A}{B + A - C} = \dfrac{(\ 499.9\ )}{(\ 683.7\ ) + (\ 499.9\ ) - (\ 990.1\ )} = 2.583$ (2.583463)

Absorption, percent $= \dfrac{S - A}{A} \times 100 = \dfrac{(\ 503.3\ ) - (\ 499.9\ )}{(\ 499.9\ )} \times 100 = 0.7\%$ (0.680136)

35

35

____

ASG Enlarged slide for T84

EXAMPLE OF CALCULATIONS FOR FINE SPECIFIC GRAVITY

ASPHALT SAMPLE

Bulk Sp. Gr. (O.D. basis)

$$= \frac{A}{B + S - C} \qquad \frac{(\ 499.9\ )}{(\ 683.7\ ) + (\ 503.3\ ) - (\ 990.1\ )} = \frac{2.539}{2.538852}$$

Where: **A** = mass of oven-dry sample in air, g.
B = mass of pycnometer filled with water, g.
C = mass of pycnometer with sample and water to calibration mark, g.
S = mass of saturated-surface-dry sample, g.

499.9
683.7
990.1
503.3

Bulk Sp. Gr. (SSD basis) =

$$= \frac{S}{B + S - C} \qquad \frac{(\ 503.3\ )}{(\ 683.7\ ) + (\ 503.3\ ) - (\ 990.1\ )} = \frac{2.556}{2.556120}$$

Apparent Sp. Gr.

$$= \frac{A}{B + A - C} \qquad \frac{(\ 499.9\ )}{(\ 683.7\ ) + (\ 499.9\ ) - (\ 990.1\ )} = \frac{2.583}{2.583463}$$

Absorption, percent

$$= \frac{S - A}{A} \times 100 \qquad \frac{(\ 503.3\ ) - (\ 499.9\ )}{(\ 499.9\ )} \times 100 = \frac{0.\ 7}{0.680136}\ \%$$

AASHTO T 84: Specific Gravity for Fine Aggregate
PROFICIENCY CHECKLIST
(rev 12/16/2019)

Applicant: ____

Employer: ____

. Trial #	1	2
Sample Preparation		
1. Obtain a representative sample. (AASHTO R90)		
2 Mix and Reduce. (AASHTO R76)		
3. Sieved over #4 sieve , keep minus 4 material (approximately 1,000 g)		
4. Dried to constant mass at 230 ± 9°F (110 ± 5°C) **Note:** Oven drying not necessary if naturally moist condition is desired **Note:** See Provisional Tests 1-4 for materials that do not readily slump found in appendix		
5. Sample is covered with water, allowed to stand 15-19 hours		
6. Pycnometer calibrated at 73.4 ± 3ºF record this weight to nearest 0.1g (This is "**B**" in the equation)		
7. After 15-19hrs, decant the excess water off the sample without loss of fines		
8. Calibrated pycnometer partially filled with water, set by the scale		
STEPS 9-15 is the CONE TEST		
9. Sample spread on a flat nonabsorbent surface		
10. Sample uniformly dried by a current of warm air		
11. Mold placed on flat nonabsorbent surface and filled to overflowing		
12. Tamped 25 times with 5 mm drop, and allowed to fall freely		
13. Sample removed from around base and mold lifted vertically		
14. Sample should retain the shape of the cone on first trial. <u>If slumps on the first trial, water added, sample covered and allowed to stand for 30min….then back to cone testing.</u>		
15. Drying continued, and slump test repeated at frequent intervals until sample slumps slightly = SSD Condition		
16. Immediately weighed 500±10g of the SSD sample to the partially filled pycnometer. (Report the mass to nearest 0.1 this is "**S**" in the equation)		
17. Pycnometer filled to 90% of total capacity and agitated to eliminate air bubbles. **Note:** Paper towel or isopropyl alcohol may be used to disperse foam on the water surface		
18. Pycnometer filled with water to the calibrated capacity line.		
19. When temperature of contents reach 73.4 ± 3°F (23.0 ± 1.7°C), towel dried the outside of the pycnometer and determined the total mass of the pycnometer, sample, and water to the nearest 0.1g (Report this as "**C**" in the equation)		
20. Sample removed from the pycnometer, placed in a pre-weighed pan and dried to constant mass at 230 ± 9°F (110 ± 5°C)		
21. Sample cooled in air at room temperature for 1.0 ± 0.5 hr. and dry mass determined to the nearest 0.1g, this is "**A**" in the equation.		
22. Calculations completed as needed: **Report:** Specific Gravity for Asphalt (1002) to the nearest: **0.001** Specific Gravity for Concrete (1005) and M6 to the nearest: **0.01** And Absorptions Report to the nearest: **0.1%**		

PASS PASS

FAIL FAIL

Examiner: ____ Date: _________________

AASHTO T85

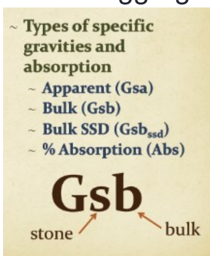
(ASTM C127)

Specific Gravity and

Absorption
of
COARSE Aggregate

AASHTO T85

Specific Gravity and Absorption of Coarse Aggregate



Rev 09/21/2021

1

SCOPE

- This method covers the determination of specific gravity and absorption of coarse aggregate.
- The specific gravity may be expressed as bulk specific gravity, bulk specific gravity (saturated surface-dry (SSD)), or apparent specific gravity.
- The bulk specific gravity (SSD) and absorption are based on aggregate after 15-19 hours of soaking in water.
- This method is not intended to be used with lightweight aggregates.
- NOTE: Definitions are in the glossary.

2

SIGNIFICANCE AND USE

- **Bulk specific gravity** is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures containing aggregate, including Portland cement concrete, bituminous concrete, and other mixtures that are proportioned or analyzed on an absolute volume basis.

3

Significance and Use

- Apparent specific gravity pertains to the relative density of the solid material making up the constituent particles not including the pore space within the particles that is accessible to water.
- Absorption values are used to calculate the change in the mass of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the absorption potential.

4

EQUIPMENT

- Scale M231, Class G5
- Sieves #4 or #8
- Basket mesh [No.6 or (No.10 or smaller)]
- Towels
- Oven capable of maintaining 230 ± 9°F (110 ± 5°C)
- Water Tank - Watertight with an overflow outlet for maintaining a constant water level.
- Suspended Apparatus - A wire of smallest practical size.

5

SAMPLING

- Obtain a representative field sample using AASHTO R 90
- Mix and reduce the sample according to AASHTO R 76 and Chart A
- Dry sieve over a #4 sieve
  - Exceptions to using a #4 sieve:
    - Use a #8 sieve as indicated by specification.
    - Use a #8 sieve if the coarse aggregate contains a large quantity of material finer than the #4 sieve.   Keep the minus No.8 material and test per AASHTO T84 for fine aggregate.

6

Sample Size – Chart A

Sampling

Nominal Maximum Size	Minimum Mass of Sample needed For testing
½" (12.5mm) or less	2000 grams
¾" (19.0mm)	3000 grams
1" (25.0mm)	4000 grams
1 ½" (37.5mm)	5000 grams

7

Sampling

- Reject all aggregate passing the #4 sieve.
- Keep all the retained #4 aggregate, this is the plus 4 material.
  - Plus 4 aggregate = +4 aggregate
- Wash the +4 aggregate to remove dust or other coatings.

NOTE: All of these mean the same. . .

- Aggregate retained on # 4 sieve
- Plus 4 aggregate
- +4 aggregate
- Sometimes the aggregate may contain foreign material like shells and pieces of glass because of this sometimes aggregate is called +4 material.

8

PROCEDURE

- Dry the +4 aggregate to a constant mass at 230 ± 9°F (110 ± 5°C), according to AASHTO T255.
- Cool the aggregate at room temperature for 1-3 hours.

(The sample should be comfortable to handle ~ 122°F (50°C).

9

Procedure

- Place the +4 aggregate sample in a plastic container and cover it with water for 15-19 hours.

10

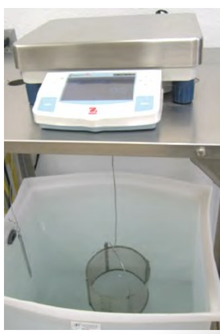
Procedure

NEXT DAY

Prepare the water bath:

- Overflow the water outlet.

Adjust the temperature to **73.4 ± °F (23.0 ± 1.7°C)**



11

Procedure

- Drain excess water from the +4 aggregate sample and place it onto a large absorbent cloth.

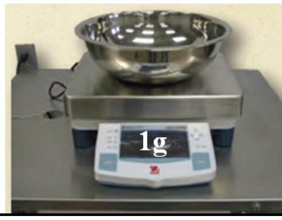
- Dry the aggregate surfaces with an absorbent cloth until all visible surface water is gone.
- Wipe the larger particles individually.

12

NOTE: Throughout the procedure, avoid evaporation of water from the aggregate pores.

Procedure

- Tare the scale.
- Weigh the sample and write the SSD mass as "**B**" in the calculations.
  - SSD = **S**aturated **S**urface **D**ry
- Determine the mass to the nearest 1gram or 0.1%.

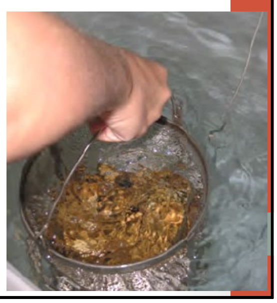


13

Procedure

- Immediately place sample in the wire basket.
- Shake the basket while immersed to remove entrapped air.
- Weigh the sample in water to the nearest **1g**.

(This weight is "**C**" in the calculations).



14

Procedure

- Place the sample in a pan for the oven.
  - Remove all particles from the basket
- Dry to a constant weight at 230 ± 9°F (110 ± 5°C).
- Cool sample for 1-3 hours or when comfortably handle 122°F (~ 50° C).
- Determine the dry mass
  - Record to the nearest 1g,
  - use this as "**A**" in the calculations.

15

Calculations

$$Bulk\ Specific\ Gravity = \frac{A}{(B-C)}$$

- Mass of Dry Sample (**A**) =________
- Mass Surface Dry Sample (**B**) =______
- Mass of Sample in Water (**C**) = _______

16

Calculations

Calculations

$$Apparent\ Specific\ Gravity = \frac{A}{(A-C)}$$

- Mass of Dry Sample (**A**) =________
- Mass Surface Dry Sample (**B**) =______
- Mass of Sample in Water (**C**) = _______

17

Calculations

Calculations

$$SSD\ Specific\ Gravity = \frac{B}{(B-C)}$$

- Mass of Dry Sample (**A**) =________
- Mass Surface Dry Sample (**B**) =______
- Mass of Sample in Water (**C**) = _______

18

Calculations

$$Absorption\ Percent = \frac{(B - A)}{A} x100$$

- Mass of Dry Sample (**A**) =________
- Mass Surface Dry Sample (**B**) =______
- Mass of Sample in Water (**C**) = _______

19

Reporting

- Report the Specific Gravities
  - 0.01, for **1005 (Concrete)**
  - 0.01 for **M80 (Hydraulic Cement Concrete)**
  - 0.001, for **1002 (Asphalt).**
- Report the Absorption to the tenth, **0.1%**
- ***Use regular rounding***

Note: If the specific gravity and absorption values were tested in an as received condition, note this in the report.

20

- **NOTE:** Where the absorption and specific gravity values are to be used in proportioning concrete mixtures in which the aggregates will be in their **naturally moist condition**, the requirement for initial drying to constant mass may be eliminated, and, if the surfaces of the particles in the sample have been kept continuously wet until test, the required soaking may also be eliminated.

21

AASHTO T 85: Specific Gravity and Absorption Of Coarse Aggregate

PROFICIENCY CHECKLIST

Revised on: 09/21/2021

Applicant: ____

Employer: ____

Trial#	1	2
Procedure		
1. Sample obtained by ASHTO R90, and Reduced per AASHTO R76		
2. Screened on No. 4 sieve (4.75mm) or No. 8 (2.36mm) sieve		
3. Sample mass as follows: ½ in. or less – 2 kg; ¾ in. – 3 kg; 1 in. – 4 kg; 1 ½ in. – 5kg		
4. Washed to clean surfaces of particles		
5. Dried to constant mass at 230 ± 9°F (110 ± 5°C) and cooled to room temperature for 1 to 3 hours (for up to 1 ½ in. nominal maximum size, longer for larger sizes) According to AASHTO T255.		
6. Covered with water for 15 to 19 hours		
7. Prepared bath, overflowed the water for level, and adjusted temperature to 73.4 ± 3°F (23.0 ± 1.7°C)		
8. Rolled in cloth to remove visible films of water		
9. Larger particles wiped individually		
10. Evaporation avoided		
11. Weigh the SSD sample and Record all masses determined to the nearest 1g or 0.1% of sample mass.		
12. Sample immediately placed in the wire basket		
13. Entrapped air removed before weighing by shaking the wire basket while immersed.		
14. Mass determined in water at 73.4 ± 3°F (23.0 ± 1.7°C)		
15. Dried to constant mass at 230 ± 9°F (110 ± 5°C) and cooled to room temperature for 1 to 3 hours [or until aggregate has cooled to comfortable handling temperature, approximately 122°F (50°C)]		
16. Weigh the dry sample and record the mass		
17. Calculated the Bulk Specific Gravity and Absorption. **Report:** Specific Gravity for Asphalt (1002) to the nearest: **0.001** Concrete (1005) and M80 to the nearest: **0.01** And Absorption to the nearest: **0.1%**		

PASS PASS

FAIL FAIL

Examiner: ___________________________________Date:___________________

MoDOT TM-81

"Core-Lok"

"INFOMATIONAL ONLY"

MODOT TM – 81 "CORELOK"

Specific Gravity and Absorption of Aggregate Using Automatic Vacuum Sealing Method

1

Summary of Method

- The known volume of the vessel with water only, mass of dry aggregate and mass of sample in vessel with water, are used to calculate the **bulk** specific gravity oven dry (OD)
- The dry mass and submerged mass are used to calculate **apparent** specific gravity

2

2

Summary of Method

- Dry aggregate to a constant mass
- For each test-
  - Two representative samples of the same material tested (Bulk Specific Gravity)
  - One sample is vacuum saturated and weighed under water (Apparent Specific Gravity)
- The sample is weighed in water in a vessel of known volume

3

3

Summary of Method

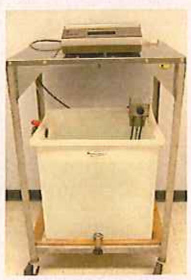
- The results from the two (bulk and apparent) are then used to calculate absorption and bulk specific gravity saturated surface dry (SSD)
- This test can be used for rapid determination of aggregate properties in construction testing laboratories

4

4

Equipment

- Balance – readable to 0.1%
- Water Bath – 24 x 18 x 18in. Min., capable of maintaining water temperature of 25±1°C (77±2° F)



5

5

Equipment

- Sample holder – for displacement

- Vacuum Chamber – for placing aggregate in vacuum and sealing in a bag in one operation

6

6

Equipment

- A Vacuum Measurement Gauge – independent of the vacuum sealing device, capable of reading down to 3mm Hg ± 1 mm Hg
- Plastic bags - two sizes are required with minimums specified for dimensions, opening and thickness

7

7

Equipment

- Pycnometer – two sizes, the smaller equipped with fixture to hold the lid in place during test

8

8

Equipment

- Accessories – timer, knife or scissors, spray bottle of isopropyl alcohol, bucket, syringe, small paint brush
- Rubber sheets

9

9

Verification & Calibration

- Verify the vacuum system annually, when relocated or after major repairs

- Calibrate pycnometer daily – calibration is achieved by repeating the procedure until three masses are within
  - 0.5 gram for fine aggregates (small pyc)
  - 1 gram for coarse aggregates (large pyc)

10

10

Verification & Calibration

- Condition the pycnometer by submerging in water maintained at 25 ± 1°C.

11

11

Verification & Calibration

- Fill pycnometer with water and weigh in the same manner as you will with a sample.
  - Small pycnometer is weighed using the clamping device.

12

Sampling

- Sample in accordance with AASHTO T 2
- For fine aggregate, thoroughly mix sample and reduce it to one sample, 1000 ± 10 grams for the apparent SpGr, and two samples, 500 ± 3 grams for the bulk SpGr.
  - Use AASHTO T 248 to reduce material.

13

13

Sampling

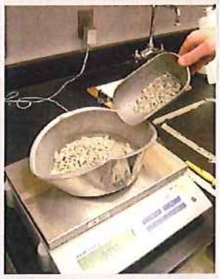
- For Coarse or Combined aggregates, thoroughly mix sample and reduce it to one sample, 2000 ± 10 grams for the apparent SpGr, and two samples, 1000 ± 10 grams for the bulk SpGr.
  - Use AASHTO T 248 to reduce material.
- When coarse aggregates of large size are encountered, it may be easier to perform the test using two or more sub-samples.

14

14

Test Procedure
Bulk Specific Gravity

- Dry samples to a constant mass.
- Allow to cool to room temperature.
- Weigh a 1000 ± 10 grams sample and record.



15

15

Test Procedure
Bulk Specific Gravity

- Fill the <u>conditioned</u> pycnometer half full with water at test temperature (25 ± 1°C)

16

16

Test Procedure
Bulk Specific Gravity

<u>The following steps shall be completed in less than 2 min.</u>

- Slowly and evenly pour the sample into the pycnometer, ensuring that no material is lost in the process

17

17

Test Procedure
Bulk Specific Gravity

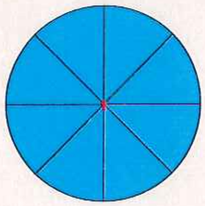
- Insert a metal spatula along the inside of the pycnometer until it reaches the bottom.

18

18

Test Procedure
Bulk Specific Gravity

- Slowly drag the spatula to the center
- Repeat 7 more times moving 45° along the wall

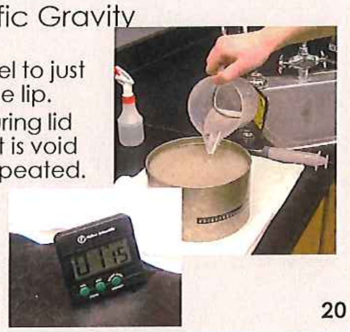


19

19

Test Procedure
Bulk Specific Gravity

- Top off water level to just below (10mm) the lip.
  - If water spills during lid placement, test is void and must be repeated.



20

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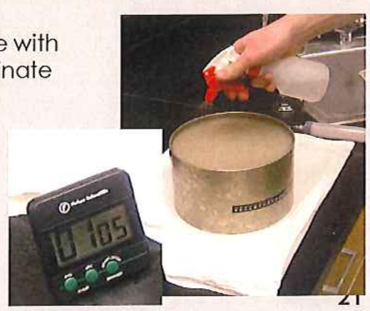
Test Procedure
Bulk Specific Gravity

- Use spray bottle with alcohol to eliminate bubbles

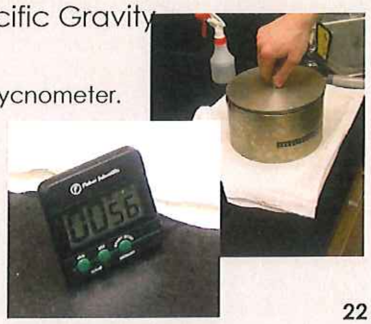


21

21

Test Procedure
Bulk Specific Gravity

- Place lid on pycnometer.

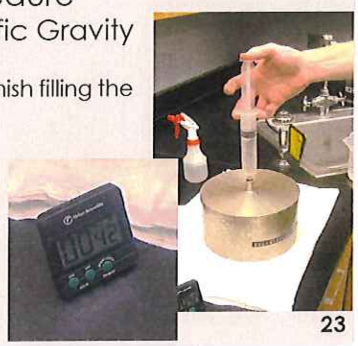


22

22

Test Procedure
Bulk Specific Gravity

- Use syringe to finish filling the pycnometer

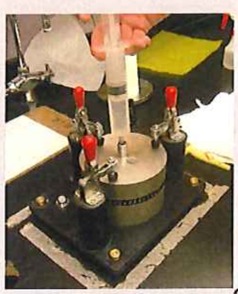


23

23

Test Procedure
Bulk Specific Gravity

- For fine aggregates, the clamping device must be installed prior to injection



24

24

Test Procedure
Bulk Specific Gravity

- Fill pycnometer until water just comes out of hole on the surface of the lid.

25

25

Test Procedure
Bulk Specific Gravity

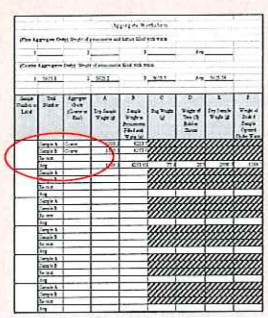
- Dry water from around hole on surface
- **<u>"Times up!"</u>**
- Place pycnometer on scale
- Record mass

26

26

Test Procedure
Bulk Specific Gravity

- Repeat procedure for a second sample.
- Record average



27

Test Procedure
Apparent Specific Gravity

- Set vacuum device according to manufactures recommendation

28

28

Test Procedure
Apparent Specific Gravity

- Before using, check condition of plastic bags, discard if flaw is discovered
- Weigh both bags and record

29

29

Test Procedure
Apparent Specific Gravity

- Weigh rubber sheets
- Record

30

30

Test Procedure
Apparent Specific Gravity

- Weigh 2000 ± 10 grams of aggregate
- Record

31

31

Test Procedure
Apparent Specific Gravity

- Place sample in small bag
  - Use caution to prevent damaging the bag

32

32

Test Procedure
Apparent Specific Gravity

- Place large bag into vacuum chamber

33

33

Test Procedure
Apparent Specific Gravity

- Place first rubber sheet into large bag
- Push all the way to the back of the large bag

34

34

Test Procedure
Apparent Specific Gravity

- Place the small bag containing the sample into the large bag
- Center it on top of the rubber sheet

35

35

Test Procedure
Apparent Specific Gravity

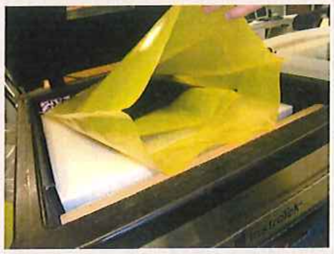
- Manually spread the sample inside the small bag
  - Lightly spray mist samples that contain high amounts of minus No. 200 material

36

36

Test Procedure
Apparent Specific Gravity

- Place the second rubber sheet on top of the small bag



37

37

Test Procedure
Apparent Specific Gravity

- Place the open end of the large external bag over the seal bar
  - Bag should extend over the bar a minimum of ½"

Position of seal bar

Ensure that rubber pads are not over seal bar

38

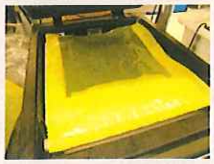
38

Test Procedure
Apparent Specific Gravity

- With bag assembly in the proper position, close lid of vacuum device
- Machine will begin vacuum cycle & bag seal automatically

39

Test Procedure
Apparent Specific Gravity



- After vacuum cycle is finished, chamber will open automatically
- Remove sample pack and immediately submerge in water

40

40

Test Procedure
Apparent Specific Gravity

- While keeping completely submerged, cut one corner of the bag 3-4" to allow water into the bag

  - Note: make slit in bag large enough to get your hand into the bag

41

41

Test Procedure
Apparent Specific Gravity

- Open the cut portion with your hand to allow water to flow freely into the bag

(25 seconds)

- Allow any small air bubbles to escape

42

42

Test Procedure
Apparent Specific Gravity

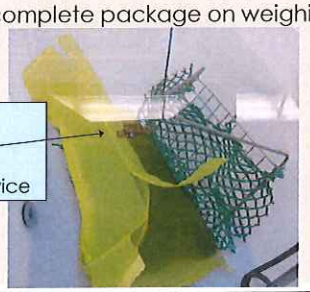
- After water is filled in, cut the other corner similar to the first
- Do not completely remove any cut portion as this needs weighed as a complete package

43

43

Test Procedure
Apparent Specific Gravity

- Place complete package on weighing device



Clip aids in stability of package on weighing device

44

44

Test Procedure
Apparent Specific Gravity

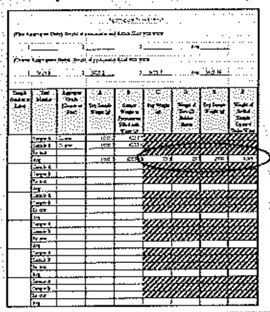
- Ensure that no part of the package is touching the bottom or sides of the water bath
- Allow sample to remain in the water bath for a minimum of 20 minutes
- Record mass

45

45

Test Procedure
Apparent Specific Gravity

- Recorded weights



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Calculations

- Results may be obtained using software developed by the equipment manufacturer. Alternatively, users can develop their own software and correlations for calculation of the results with the equations given in section 10.0 of the test method

47

47

Aggregate Worksheet

(Fine Aggregate Only) Weight of pycnometer and fixture filled with water.

1. ________ 2. ________ 3. ________ Avg. ________

(Coarse Aggregates Only) Weight of pycnometer filled with water.

1. 5625.8 2. 5625.2 3. 5625.7 Avg. 5625.56

Sample Number or Label	Trial Number	Aggregate Grade (Coarse or Fine)	A. Dry Sample Weight (g)	B. Sample Weight in Pycnometer Filled with Water (g)	C. Bag Weight (g)	D. Weight of Two (2) Rubber Sheets	E. Dry Sample Weight (g)	F. Weight of Sealed Sample Opened Under Water
	Sample A	Coarse	1000.2	6253.7				
	Sample B	Coarse	1000.2	6253.6				
	Re-test							
	Avg		1000.2	6253.65	77.6	207	2000.7	1289.7
	Sample A							
	Sample B							
	Re-test							
	Avg							
	Sample A							
	Sample B							
	Re-test							
	Avg							
	Sample A							
	Sample B							
	Re-test							
	Avg							
	Sample A							
	Sample B							
	Re-test							
	Avg							
	Sample A							
	Sample B							
	Re-test							
	Avg							

Updated 12/15/2006

Enter Rubber Sheet Density 1.305
Enter Plastic Bag Density 0.903

* Use AASHTO T 84 when no coarse fraction is available; blank will produce an approximate value.

Sample ID	Dry Sample 1 Weight (g)	Sample 1 weight in container filled with water (g)	Volumeter Calib. (g)	Bag weight (g)	Rubber sheet weight (g)	Dry Sample 2 weight (g)	Weight of sealed Sample 2 opened in water (g)	P1 **CorGsb** g/cm3	Input initial absorption estimate AASHTO T 85* **ABS**	Preliminary Absorption **CorABS**	Apparent Specific Gravity **CorGsa** (g/cm3)	**Gsa**$_{pred}$ CoreLok Apparent	**Gsb**$_{pred}$ CoreLok Bulk	**ABS**$_{pred}$ Corelok Absorption

Sample ID	Dry Sample 1 Weight (g)	Sample 1 weight in container filled with water (g)	Volumeter Calib. (g)	Bag weight (g)	Rubber sheet weight (g)	Dry Sample 2 weight (g)	Weight of sealed Sample 2 opened in water (g)	P1 **CorGsb** g/cm3	Input initial absorption estimate AASHTO T 85* **ABS**	Preliminary Absorption **CorABS**	Apparent Specific Gravity **CorGsa** (g/cm3)	**Gsapred** CoreLok Apparent	**Gsbpred** CoreLok Bulk	**ABSpred** Corelok Absorption

Sample ID	Dry Sample 1 Weight (g)	Sample 1 weight in container filled with water (g)	Volumeter Calib. (g)	Bag weight (g)	Rubber sheet weight (g)	Dry Sample 2 weight (g)	Weight of sealed Sample 2 opened in water (g)	P1 **CorGsb** g/cm3	Input initial absorption estimate AASHTO T 85* **ABS**	Preliminary Absorption **CorABS**	Apparent Specific Gravity **CorGsa** (g/cm3)	**Gsapred** CoreLok Apparent	**Gsbpred** CoreLok Bulk	**ABSpred** Corelok Absorption

Sample ID	Dry Sample 1 Weight (g)	Sample 1 weight in container filled with water (g)	Volumeter Calib. (g)	Bag weight (g)	Rubber sheet weight (g)	Dry Sample 2 weight (g)	Weight of sealed Sample 2 opened in water (g)	P1 CorGsb g/cm3	Input initial absorption estimate AASHTO T 85* ABS	Preliminary Absorption CorABS	Apparent Specific Gravity CorGsa (g/cm3)	Gsa_{pred} CoreLok Apparent	Gsb_{pred} CoreLok Bulk	ABS_{pred} Corelok Absorption

Standard Method of Test for

Specific Gravity and Absorption of Aggregate Using Automatic Vacuum Sealing Method

AASHTO Format MoDOT TM-81

1. SCOPE

1.1 This standard covers the determination of specific gravity and absorption of fine aggregates by Method A and coarse and blended aggregates by Method B.

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

1.3 A multi-laboratory precision and bias statement for coarse and combined aggregate tests in this standard has not been developed at this time. Therefore, this standard should not be used for acceptance or rejection of coarse and combined aggregate materials for purchasing purposes.

1.4 *This standard may involve hazardous materials, operations and equipment. This standard does not purport to address all of the safety problems 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 limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1 *AASHTO Standards:*

- M43, Sizes of Aggregate for Road and Bridge Construction
- M 29, Wire-Cloth Sieves for Testing Purposes
- M 132, Terms Relating to Density and Specific Gravity of Solids, Liquids and Gases
- M 231, Weighing Devices Used in the Testing of Materials
- T 2, Standard Practice for Sampling of aggregates
- T 19, Standard Test Method for Bulk Density (Unit Weight) and Voids in Aggregate
- T 27, Test Method for Sieve Analysis of Fine and Coarse Aggregates
- T 85, Standard Test method for Specific Gravity and Absorption of Coarse Aggregate
- T 84, Standard Test Method for Specific Gravity and Absorption of Fine Aggregate
- T 248, Standard Practice for Reducing Samples of Aggregate to Testing Size

2.2 *ASTM Standards:*

- D4753, Standard Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Testing Soil, Rock and Related Construction Materials
- C 670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

- C 691, Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
- C29/ C29 M, Standard Test Method for Bulk Density (Unit Weight) and Voids in Aggregate
- C 127, Standard Test method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate
- C128, Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate
- C 125, Terminology Relating to Concrete and Concrete Aggregates
- C 702, Standard Practice for Reducing Samples of Aggregate to Testing Size
- D 75, Standard Practice for Sampling of Aggregates
- D 136, Test Method for Sieve Analysis of Fine and Coarse Aggregates

2.3 *Other Standards:*

- CoreLok Operational Instructions (InstroTek, Inc.)

3. TERMINOLOGY

3.1 *Definitions*:

3.1.1 *absorption*—the increase in the mass of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass. The aggregate is considered "dry" when it has been maintained at a temperature of 110 ± 5°C for sufficient time to remove all uncombined water.

3.1.2 *specific gravity*—the ratio of the mass (or weight in air) of a unit volume of a material to the mass of the same volume of water at stated temperatures. Values are dimensionless.

3.1.2.1 *apparent specific gravity*—the ratio of the weight in air of a unit volume of the impermeable portion of aggregate at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

3.1.2.2 *bulk specific gravity*—the ratio of the weight in air of a unit volume of aggregate (including the permeable and impermeable voids in the particles, but not including the voids between particles) at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

3.1.2.3 *bulk specific gravity (SSD)*—the ratio of the mass in air of a unit volume of aggregate, including the mass of water within the voids filled to the extent achieved by vacuum saturating (but not including the voids between particles) at a stated temperature, compared to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

4. SUMMARY OF METHOD

4.1 Sufficient aggregate sample is dried to constant mass. For each test, two representative dry aggregate samples of the same material are selected for testing. One sample is evacuated in a vacuum chamber inside a plastic bag and opened under water for rapid saturation of the aggregate. The dry mass and submerged mass of the sample is used for calculation of apparent specific gravity. The second sample of the same aggregate is tested in a known volume metal pycnometer. The known mass of the pycnometer with water, mass of the dry aggregate, and mass of the aggregate and pycnometer filled with water is used for calculation of bulk specific gravity oven dry (OD.) The results from the two samples tested are then used to calculate absorption, and bulk specific gravity saturated-surface-dry (SSD.)

4.2 This test can be completed in less than 30 minutes and can be used for rapid determination of aggregate properties in construction testing laboratories.

4.3 This test can be performed on fine, coarse and blended (combined) aggregates by using appropriate plastic bag and pycnometer sizes.

5. SIGNIFICANCE AND USE

5.1 Bulk specific gravity is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures containing aggregate, including Portland cement concrete, hot mix asphalt, and other mixtures that are proportioned or analyzed on an absolute volume basis. Bulk specific gravity is also used in the computation of voids in aggregate in test T 19. Bulk specific gravity SSD is used if the aggregate is wet, that is, if its absorption has been satisfied. Conversely, the bulk specific gravity OD is used for computations when the aggregate is dry or assumed to be dry.

5.2 Apparent specific gravity pertains to the solid material making up the constituent particles not including the pore space within the particles which is accessible to water.

5.3 Absorption values are used to calculate the change in the mass of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the absorption potential. The laboratory standard for absorption is that obtained after submerging dry aggregate for a prescribed period of time.

6. APPARATUS

6.1 *Balance*—A balance that conforms to M 231. The balance shall be sensitive, readable and accurate to 0.1% of the test sample mass. The balance shall be equipped with suitable apparatus for suspending the sample in water.

6.2 *Water Bath*—A container with minimum dimensions (Length × Width × Depth) of 610 × 460 × 460 mm (24 × 18 × 18 in.) or a large cylindrical container with a minimum diameter of 460 mm and depth of 460 mm (18 × 18 in), for completely submerging the sample in water while suspended, equipped with an overflow outlet for maintaining a constant water level. Temperature controls may be used to maintain the water temperature at 25 ± 1° C (77 ± 2 °F).

Note 1—It is preferable to keep the water temperature constant by using a temperature controlled heater. Also, to reduce the chance for the bag to touch the sides of the water tank, it is preferable to elevate the water tank to a level at which the sample can be placed on the weighing mechanism while the operator is standing up (waist height), and the placement of the sample and the bag in the water tank can easily be inspected.

6.3 Sample *holder* for water displacement of the sample, having no sharp edges.

6.4 *Vacuum Chamber*—with a pump capable of evacuating a sealed and enclosed chamber to a pressure of 6 mm Hg, when at sea level. The device shall automatically seal the plastic bag and exhaust air back into the chamber in a controlled manner to ensure proper conformance of the plastic to the specimen. The air exhaust and vacuum operation time shall be set at the factory so that the chamber is brought to atmospheric pressure in 80 to 125 seconds, after the completion of the vacuum operations.

6.5 *A Vacuum Measurement Gauge*, independent of the vacuum sealing device, that could be placed directly inside the chamber to verify vacuum performance and the chamber door sealing condition of the unit. The gauge shall be capable of reading down to 3 mm Hg and readable to ± 1 mm Hg.

6.6 *Plastic Bags*, used with the vacuum device, shall be one of the two following sizes: The smaller bags shall have a minimum opening of 235 mm (9.25 in.) and maximum opening of 260 mm (10.25 in.) and the larger bags shall have a minimum opening of 375 mm (14.75 in.) and a maximum opening of 394 mm (15.5 in.). The bags shall be of plastic material, shall be puncture resistant, and shall be impermeable to water. The bags shall have a minimum thickness of 0.127mm (0.005 in.). The manufacturer shall provide the apparent specific gravity for the bags.

6.7 Small metal pycnometer with 137 ± 0.13 mm (5.375 ± 0.005 in.) inside diameter (ID) and 89 ± 0.41 mm (3.5 ± 0.016 in.) height, for testing fine aggregates. The pycnometer shall be machined to be smooth on all surfaces. The inside of the lid shall be machined at a 5° angle to create an inverted conical surface. The pycnometer shall be equipped with a temperature strip to allow the user to monitor temperature during testing.

6.8 Large metal pycnometer with 198 ± 0.13 mm (7.776 ± 0.005 in.) ID and 114 ± 0.8 mm (4.5 ± 0.03 in.) height, for testing coarse and blended aggregate. The pycnometer shall be machined to be smooth on all surfaces. The inside of the lid shall be machined at a 5° angle to create an inverted conical surface. The pycnometer shall be equipped with a temperature strip to allow the user to monitor temperature during testing.

6.9 Fine aggregate fixture to hold and secure the lid on the small metal pycnometer from lifting during fine aggregate tests. The fixture shall be provided with a level indicator.

6.10 *Accessories*— A bag cutting knife or scissors, spray bottle filled with isopropyl alcohol, a bucket large enough to allow the pycnometer to be fully submerged in water, water containers to dispense water into pycnometer during testing, syringe with a needle no larger in diameter than 3 mm (0.125 in.), small paint brush and 25 mm (1 in.) wide aluminum spatula.

6.11 Rubber sheets, for protecting the plastic bags against punctures caused by sharp edges on coarse and blended aggregate samples. The manufacturer shall provide the apparent specific gravity for the rubber sheets.

7. VERIFICATION

7.1 *System Verification:*

7.1.1 The vacuum settings of the vacuum chamber shall be verified once every 12 months and after major repairs and after each shipment or relocation.

7.1.2 Place the gauge inside the vacuum chamber and record the setting, while the vacuum unit is operating. The gauge should indicate a pressure of 6 mm Hg (6 TORR) or less. The unit shall not be used if the gauge reading is above 6 mm Hg (6 TORR).

7.1.3 Vacuum gauge used for verification shall be verified for accuracy once every three years.

Note 2— In line vacuum gauges, while capable of indicating vacuum performance of the pump, are not suitable for use in enclosed vacuum chambers and cannot accurately measure vacuum levels.

7.2 *Calibration of the Small Pycnometer:*

7.2.1 Prior to testing, condition the pycnometer to 25 ± 1°C (77 ± 2°F) by placing it inside a bucket of water that is maintained at 25 ± 1°C (77 ± 2°F). Place the fine aggregate fixture on a level surface. Use a level indicator or the provided level to level the fixture.

7.2.2 Remove the pycnometer from the water bucket and dry it with a towel. Place the pycnometer in the fixture and push it back until it makes contact with the stops.

7.2.3 Fill the pycnometer with 25 ± 1°C (77 ± 2°F) water to approximately 10 mm (0.375 in.) from the top. Using the alcohol spray bottle, spray the surface of the water to remove bubbles.

7.2.4 Gently place the lid on the pycnometer and close the clamps on the fixture.

7.2.5 Using a syringe filled with 25 ± 1°C (77 ± 2°F) water, slowly fill the pycnometer through the large fill hole on the lid post. Make sure the syringe tip is far enough in the pycnometer to be below the water level. Gentle application in this step prevents formation of air bubbles inside the pycnometer.

7.2.6 Fill the pycnometer until water comes out the 3 mm (1/8-in.) hole on the surface of the lid.

7.2.7 Wipe any remaining water from the top of the lid with a towel.

7.2.8 Place the entire fixture with the pycnometer on the scale and record the mass. Record the mass in the top portion of the Aggregate Worksheet. (See Appendix X.1)

7.2.9 Clean the pycnometer and repeat steps 7.2.1 to 7.2.8 two more times and average the calibration masses obtained in 7.2.8.

7.2.10 If the range for the 3 calibration masses is larger than 0.5 grams, then the test is not being run correctly. Check to see if the fixture is level. Make certain the water injection with the syringe is done below the pycnometer water surface and is applied gently. Check the water temperature. Check the pycnometer temperature. Repeat the above procedure until you have three masses that are within ± 0.5 gram.

7.2.11 Re-calibrate the pycnometer daily.

7.3 *Calibration of the Large Pycnometer:*

7.3.1 Prior to testing, condition the pycnometer to 25 ± 1°C (77 ± 2°F) by placing it inside a bucket of water that is maintained at 25 ± 1°C (77 ± 2°F).

7.3.2 Remove the pycnometer from the water bucket and dry it with a towel. Set the pycnometer on a level surface.

7.3.3 Fill the pycnometer with 25 ± 1°C (77 ± 2°F) water to approximately 10 mm (0.375 in.) from the top. Using the alcohol spray bottle, spray the surface of the water to remove any air bubbles.

7.3.4 Gently place the lid on the pycnometer. Using a syringe filled with 25 ± 1°C (77 ± 2°F) water, slowly fill the pycnometer through the large fill hole on the lid post. Make sure the syringe tip is far enough in the pycnometer to be below the water level. Gentle application in this step prevents formation of air bubbles inside the pycnometer. Fill the pycnometer until water comes out the 3 mm (1/8-in.) hole on the surface of the lid.

7.3.5 Wipe any remaining water from the top of the lid and sides with a towel. Place the pycnometer on the scale and record the mass. Record the mass in the top portion of the Aggregate Worksheet.

7.3.6 Clean the pycnometer and repeat steps 7.3.2 to 7.3.5 two more times and average the calibration masses obtained in 7.3.5.

7.3.7 If the range for the 3 calibration masses is larger than 1 gram, then the test is not being run correctly. Check to see if the fixture is level. Make certain the water injection with the syringe is done below the pycnometer water surface and is applied gently. Check the water temperature. Check the pycnometer temperature. Repeat the above procedure until you have three masses that are within 1 gram range.

7.3.8 Re-calibrate the pycnometer daily.

8. SAMPLING

8.1 *Fine aggregate samples (Method A):*

8.1.1 Sampling shall be done in accordance with T 2. For fine aggregate testing thoroughly mix the sample and reduce it to obtain one 1000 ± 10 gram sample for apparent specific gravity and two 500 ± 3 gram samples for bulk specific gravity determination. For aggregate reduction use the appropriate procedures described in T 248.

8.2 *Coarse aggregate samples (Method B):*

8.2.1 Sample the aggregate in accordance with T 2.

8.2.2 Dry the aggregate to constant mass and thoroughly mix the sample of aggregate and reduce it to one 2000 ± 10 gram sample for determination of apparent specific gravity and two 1000 ± 10 gram samples for determination of bulk specific gravity. For reduction of the aggregate samples, use the appropriate procedures in T 248.

8.2.3 If the sample is tested in two or more size fractions, determine the grading of the sample in accordance with test T 27, including the sieves used for separating the size fractions for the determinations in this method.

Note 3— When testing coarse aggregate of large nominal maximum size requiring large test samples, it may be more convenient to perform the test on two or more sub samples, and the values obtained combined for the computations.

9. PROCEDURES

9.1 *Method A, Fine Aggregate Test:*

9.1.1 Make certain water temperature used for this test remains at 25 ± 1°C (77 ± 2°F).

9.1.2 Prior to testing, condition the pycnometer to 25 ± 1°C (77 ± 2°F) by placing it inside a bucket of water that is maintained at 25 ± 1°C (77 ± 2°F).

9.1.3 *Determine Bulk Specific Gravity:*

9.1.3.1 Make certain the samples are dried to constant mass.

9.1.3.2 For a single test select and separate two 500 ± 3 gram samples (samples A and B) for the test in the pycnometer and one 1000 ± 10 gram sample for vacuum saturation test.

9.1.3.3 Allow the sample to cool to room temperature.

9.1.3.4 Place the empty pycnometer in the fixture and push it back until it makes contact with the stops.

9.1.3.5 Weigh a 500 ± 3 gram dry sample that is at 25 ± 1°C (77 ± 2°F) and record in column A of the worksheet.

9.1.3.6 Steps 9.1.3.8 to 9.1.3.15 shall be completed in less than 2 minutes.

9.1.3.7 Place approximately 500 ml (halfway full) of 25 ± 1°C (77 ± 2°F) water in the pycnometer.

9.1.3.8 Slowly and evenly pour the sample into the pycnometer. Make certain aggregate is not lost in the process of filling the pycnometer. Use a brush if necessary to sweep any remaining fines into the pycnometer. If any aggregate is lost during the process of filling the pycnometer, start the test over.

9.1.3.9 Use a metal spatula and push it to the bottom of the pycnometer against the inside circumference. Slowly and gently drag the spatula to the center of the pycnometer, removing the spatula after reaching the center. Repeat this procedure 7 more times so that the entire circumference is covered in 8 equal angles, i.e. every 45 degrees until the starting point is reached. If necessary, use a squeeze water bottle to rinse any sample residue off the spatula into the pycnometer.

9.1.3.10 Fill the pycnometer with 25 ± 1°C (77 ± 2 °F) water to approximately 10 mm (0.375 in.) of the pycnometer rim. It is important that the water level is kept at or below the 10 mm line to avoid spills during lid placement.

9.1.3.11 Use the spray bottle filled with isopropyl alcohol and spray the top of the water to remove air bubbles.

9.1.3.12 Gently place the lid on the pycnometer and lock the clamps. Using the syringe, slowly fill the pycnometer through the center hole on top of the lid post. Make sure the syringe tip is far enough in the pycnometer to be below the water level. Gentle application in this step will prevent formation of air bubbles inside the pycnometer.

9.1.3.13 Fill the pycnometer until water just comes out the 3 mm (1/8-in.) hole on the surface of the lid.

9.1.3.14 Wipe any remaining water from around the 3 mm (1/8-in.) hole with a towel.

9.1.3.15 Weigh the sample, pycnometer and the fixture. Record this mass in column B of the worksheet.

9.1.3.16 Repeat steps 9.1.3.6 to 9.1.4.15 for the second 500 ± 3 gram sample, Sample B.

9.1.3.17 Average the mass in each column of the worksheet for sample A and sample B.

9.1.3.18 Record the average weight of the pycnometer from section 7.2.9 in column C.

9.1.4 *Determine Apparent Specific Gravity:*

9.1.4.1 Set the vacuum device according to manufacturer's recommendation.

9.1.4.2 Use a small plastic bag and inspect the bag to make sure there are no holes, stress points or side seal discontinuities in the bag. If any of the above conditions are noticed, use another bag.

9.1.4.3 Weigh the bag and record in column D of the worksheet.

Note 4—Always handle the bag with care to avoid creating weak points and punctures.

9.1.4.4 Weigh 1000 ± 10 grams of oven dry aggregate and record the mass in column F.

9.1.4.5 Place the sample in the bag. Support the bottom of the bag on a smooth tabletop when pouring the aggregate to protect against punctures and impact points.

9.1.4.6 Place the bag containing the sample inside the vacuum chamber.

9.1.4.7 Grab the two sides of the bag and spread the sample flat by gently shaking the bag side to side. Do not press down or spread the sample from outside the bag. Pressing down on the sample from outside the bag will cause the bag to puncture and will negatively impact the results. Lightly spray mist aggregates with high minus 75-µm (No. 200) sieve material to hold down dust prior to sealing.

9.1.4.8 Place the open end of the bag over the seal bar and close the chamber door. The unit will draw a vacuum and seal the bag, before the chamber door opens.

9.1.4.9 Gently remove the sample from the chamber and immediately submerge the sample in a large water tank equipped with a balance for water displacement analysis. It is extremely important that the bag be removed from the vacuum chamber and immediately placed in the water bath. Leaving the bag in the vacuum chamber or on a bench top after sealing can cause air to slowly enter the bag and can result in low apparent specific gravity results.

9.1.4.10 Cut one corner of the bag, approximately 25 to 50 mm (1 to 2 in.) from the side while the top of the bag is at least 2-inch below the surface of the water. Make sure the bag is completely submerged before cutting. Introducing air into the bag will produce inaccurate results.

9.1.4.11 Open the cut portion of the bag and hold open for 45 seconds. Allow the water to freely flow into the bag. Allow any small residual air bubbles to escape. Do not shake or squeeze the sample, as these actions will cause the fines to escape from the bag.

9.1.4.12 After water has filled in, cut the other corner of the bag approximately 25 to 50 mm (1 to 2 in.). Squeeze any residual air bubbles on top portion of the bag through the cut corners by running your fingers across the top of the bag. Do not completely remove corners from bag nor allow any portion of the bag to reach the surface of the water.

9.1.4.13 Place the bag containing the aggregate on the weighing basket in the water to obtain the under water mass. The bag may be folded before placing it on the basket. However, once on the basket under water, unfold the bag and allow water to freely flow into the bag. Keep the sample and bag under water at all times. Make certain the bag or the sample are not touching the bottom, the sides, or floating out of the water tank. If the bag contacts the tank it will negatively impact the results of this test.

9.1.4.14 Allow the sample to stay in the water bath for a minimum of fifteen (15) minutes.

9.1.4.15 Record the submerged mass in column G of the worksheet.

9.1.4.16 Results may be obtained using software developed by the equipment manufacturer. Alternatively, users can develop their own software and correlations for calculation of the results with equations given in section 10.0.

9.2 *Method B, Coarse and Combined Aggregate Test:*

9.2.1 Make certain water temperature used for this test remains at 25 ± 1°C (77 ± 2°F)

9.2.2 Prior to testing, condition the pycnometer to 25 ± 1°C (77 ± 2°F) by placing it inside a bucket of water that is maintained at 25 ± 1°C (77 ± 2°F).

9.2.3 *Determine Bulk Specific Gravity:*

9.2.3.1 Make certain the samples are dried to constant mass.

9.2.3.2 Allow the sample to cool to room temperature.

9.2.3.3 For a single test select and separate two 1000 ± 10 gram samples (samples A and B) for the test in the pycnometer and one 2000 ± 10 gram sample for vacuum saturation test.

9.2.3.4 Make certain the pycnometer is set on a level surface.

9.2.3.5 Weigh a 1000 ± 10 gram dry sample (sample A) that is at 25 ± 1°C (77 ± 2°F) and record in column A of the worksheet.

9.2.3.6 Steps 9.2.3.8 to 9.2.3.15 shall be completed in less than 2 minutes.

9.2.3.7 Place approximately 1000 ml (halfway full) of 25 ± 1°C (77 ± 2°F) water in the pycnometer.

9.2.3.8 Slowly and evenly pour the sample into the pycnometer. Make certain aggregate is not lost in the process of filling the pycnometer. Use appropriate pouring techniques to help in transferring the aggregate into the pycnometer. If any aggregate is lost during the process of filling the pycnometer, start the test over.

9.2.3.9 Use a metal spatula and push it to the bottom of the pycnometer against the inside circumference. Slowly and gently drag the spatula to the center of the pycnometer, removing the spatula after reaching the center. Repeat this procedure 7 more times so that the entire circumference is covered in 8 equal angles, i.e. every 45 degrees until the starting point is reached. If necessary, use a squeeze water bottle to rinse any sample residue off the spatula into the pycnometer.

9.2.3.10 Fill the pycnometer with 25 ± 1°C (77 ± 2°F) water to approximately 10 mm (0.375 in.) of the pycnometer rim. It is important that the water level is kept at or below the 10 mm line in order to avoid spills during lid placement

9.2.3.11 Use the spray bottle filled with isopropyl alcohol and spray the top of the water to remove air bubbles.

9.2.3.12 Gently place the lid on the pycnometer. Using the syringe, slowly fill the pycnometer through the center hole on top of the lid post. Make sure the syringe tip is far enough in the pycnometer to be below the water level. Gentle application in this step will prevent formation of air bubbles inside the pycnometer.

9.2.3.13 Fill the pycnometer until you see water coming out the 3 mm (1/8-in.) hole on the surface of the lid.

9.2.3.14 Wipe any remaining water from around the 3 mm (1/8-in.) hole with a towel.

9.2.3.15 Weigh the pycnometer and the fixture. Record this mass in column B of the worksheet.

9.2.3.16 Repeat steps 9.2.3.6 to 9.2.3.15 for the second 1000 ± 10 gram sample, Sample B.

9.2.3.17 Average the mass in each column of the worksheet, for Sample A and Sample B.

9.2.3.18 Record the average weight of the pycnometer from section 7.3.6 in column C.

9.2.4 *Determine Apparent Specific Gravity:*

9.2.4.1 Set the vacuum device according to manufacturers recommendation.

9.2.4.2 Use one small and one large plastic bag. Inspect both bags to make sure there are no holes, stress points or side seal discontinuities in the bag. If any of the above conditions are noticed, use another bag.

9.2.4.3 Weigh both bags and record the mass in column D of the worksheet.

Note 5—Always handle the bag with care to avoid creating weak points and punctures.

9.2.4.4 Weigh the two rubber sheets and record the mass in column E.

9.2.4.5 Weigh 2000 ± 10 grams of aggregate and record the mass in column F.

9.2.4.6 Place the sample in the small bag. When filling, support the bottom of the bag on a smooth tabletop to protect against puncture and impact points.

9.2.4.7 Place the large bag into the vacuum chamber, then place one of the rubber sheets inside the large bag. The rubber sheet should be flat, centered, and pushed all the way to the back of the large bag.

9.2.4.8 Place the small bag containing the sample into the large bag centered on top of the rubber sheet. Manually spread the sample inside the small bag. Be sure the area taken up by the sample inside the small bag remains completely contained within the area of the rubber sheets. Lightly spray mist aggregates with high minus 75-μm (No. 200) sieve material to hold down dust prior to sealing.

9.2.4.9 Place the other rubber sheet on top of the small bag, inside the large bag. The small bag should be between the two rubber sheets.

9.2.4.10 Place the open end of the large external bag over the seal bar and close the chamber door. Make certain the rubber sheets are not over the seal bar.

9.2.4.11 After the chamber door opens, gently remove the sample from the chamber. Immediately place the sample in the water, for water displacement analysis.

9.2.4.12 Cut one corner of the bag, approximately 70 to 100 mm (3 to 4 in.) from the side. Make sure the bag is completely submerged before cutting. Introducing air into the bag will produce inaccurate results.

9.2.4.13 Open the cut portion of the large bag and the small bag with your fingers and hold open for 25 seconds. Allow water to freely flow into the bags. Allow any small residual air bubbles to escape from the bags.

9.2.4.14 After water has filled in, cut the other corner of the bag approximately 70 to 100 mm (3 to 4 in.). Squeeze any residual air bubbles out of the cut corners by running your fingers across the top of the bag. Do not completely remove corners from bag nor allow any portion of the bag to reach the surface of the water.

9.2.4.15 Place the bags containing the rubber sheets and the aggregate on the provided weighing basket under water. You may fold the bag to place it on the basket. However, once on the basket under water, unfold the bag and allow water to freely flow into the bag.

9.2.4.16 Make certain the bag or the sample are not touching the bottom, the sides, or floating out of the water tank. If the bag contacts the tank during mass measurement, it will negatively impact the results of this test. Allow the sample to stay in the water bath for a minimum of twenty (20) minutes.

9.2.4.17 Record the submerged mass in column G of the worksheet.

9.2.4.18 Results may be obtained using software developed by the equipment manufacturer. Alternatively, users can develop their own software and correlations for calculation of the results with equations given in section 10.0.

10. CALCULATIONS

10.1 *Initial Specific Gravity:*

10.1.1 *Initial Bulk Specific Gravity*—Calculate the bulk specific gravity, 25°C (77°F) as follows:

$$\text{Cor G}_{\text{sb}} = \frac{A}{C-(B-A)} \qquad (1)$$

where:

A = Mass of oven-dry sample 1 in air, g
B = Mass of pycnometer and oven-dry sample in water, g
C = Mass of plastic bag(s), g
D = Mass of 2 rubber sheets, g
E = Mass of oven-dry sample 2 in air, g
F = Mass of saturated sample 2 in water, g
ρ_{bag} = Density of plastic bag(s)
ρ_{rbr} = Density of rubber sheets

10.1.2 *Initial Apparent Specific Gravity*—Calculate the bulk specific gravity, 25°C (77°F) as follows:

$$\text{Cor G}_{\text{sa}} = \frac{F}{(D+E+F-G)-(D/\rho_{bag} - E/\rho_{rbr})} \qquad (2)$$

10.1.3 *Initial Absorption*—Calculate the absorption, percent, as follows:

$$\text{Cor Abs} = \frac{CorG_{sa} - CorG_{sb}}{CorG_{sa} \times CorG_{sb}} \times 100 \qquad (3)$$

10.1.4 *Initial Bulk Specific Gravity (Saturated-Surface-Dry)*—Calculate the bulk specific gravity, 25°C (77°F) on the basis of saturated-surface-dry aggregate as follows:

$$\text{Cor G}_{\text{sb}}\text{(SSD)} = (1 + CorAbs/100) \times CorGsb \qquad (4)$$

10.2 Predicted properties account for the effects of absorption during the measurement of the dry aggregate volume by correlating the results to those obtained by T 85 using absorption. When an aggregate does not contain a coarse fraction, e.g. natural sand, T 84 absorption may be used. The result of equations 1 and 2 are used to calculate the following:

Note 6—Development of regression equations for correlation of properties may be found in Missouri Department of Transportation Report OR06.016. These equations may be substituted for correlation to local aggregates.

10.2.1 *Predicted Bulk Specific Gravity—*

$$G_{sb} = 0.342355 + 0.8751137 CorG_{sb} - 0.051843 Abs_{T85} \quad (5)$$

where:

Abs_{T85} = Absorption from T 85

10.2.2 *Predicted Apparent Specific Gravity—*

$$G_{sa} = 0.24680896 + 0.90993947 CorG_{sa} - 0.02031058 Abs_{T85} \quad (6)$$

10.2.3 *Predicted Absorption—*

$$\text{Abs} = \frac{G_{sa} - G_{sb}}{G_{sa} \times G_{sb}} \times 100 \quad (7)$$

10.2.4 *Predicted Bulk Specific Gravity (Saturated-Surface-Dry)—*

$$G_{sb}\,(\text{SSD}) = (1 + Abs/100) \times G_{sb} \quad (8)$$

10.3 *Average Specific Gravity Values*—When the sample is tested in separate size fractions, the average value for bulk specific gravity, bulk specific gravity (SSD), or apparent specific gravity can be computed as the weighted average of the values as computed in accordance with Section 9.1 using the following equation:

$$G = \frac{1}{\dfrac{P_1}{100\,G_1} + \dfrac{P_2}{100\,G_2} + \cdots \dfrac{P_n}{100\,G_n}} \quad (9)$$

where:

G = average specific gravity (All forms of expression of specific gravity can be averaged in this manner.);

$G_1, G_2 \ldots G_n$ = appropriate specific gravity values for each size fraction depending on the type of specific gravity being averaged; and

$P_1, P_2 \ldots P_n$ = mass percentages of each size fraction present in the original sample.

Note 7—Some users of this method may wish to express the results in terms of density. Density may be determined by multiplying the bulk specific gravity, bulk specific gravity (SSD), or apparent specific gravity by the density of water (997.5 kg/m^3 or 0.9975 Mg/m^3 or 62.27 lb/ft^3 at 23°C). Some authorities recommend using the density of water at 4°C (1000 kg/m^3 or 1.000 Mg/m^3 or 62.43 lb/ft^3) as being sufficiently accurate. Results should be expressed to three significant figures. The density terminology corresponding to bulk specific gravity, bulk specific gravity (SSD), and apparent specific gravity has not been standardized.

10.4 *Average Absorption*—Calculate the percentage of absorption, as follows:

$$\text{Absorption, percent} = [(B - A)/A] \times 100 \quad (10)$$

10.5 *Average Absorption Value*—When the sample is tested in separate size fractions, the average absorption value is the average of the values as computed in Section 9.3, weighted in proportion to the mass percentages of the size fractions in the original sample as follows:

$$A = (P_1 A_1/100) + (P_2 A_2/100) + \cdots (P_n A_n/100) \qquad (11)$$

where:

A	=	average absorption, percent;
$A_1, A_2 \ldots A_n$	=	absorption percentages for each size fraction; and
$P_1, P_2 \ldots P_n$	=	mass percentages of each size fraction present in the original sample.

11. REPORT

11.1 Report predicted specific gravity results to the nearest 0.001, and indicate the type of specific gravity, whether bulk, bulk (SSD), or apparent.

11.2 Report the predicted absorption result to the nearest 0.1 percent.

X1. WORKSHEET

(Fine Aggregate Only) Mass of pycnometer and fixture filled with water.

1.________ 2. __________ 3. __________ Avg. __________

(Coarse Aggregates Only) Mass of pycnometer filled with water.

1. ________ 2. __________ 3. __________ Avg. __________

Sample Number or Label	Trial Number	Aggregate Grade (Coarse or Fine)	A Dry Sample Mass (g)	B Sample Mass in Pycnometer Filled with Water (g)	C Mass of Pycnometer Filled with Water-Avg. (g)	D Bag Mass (g)	E Mass of Two (2) Rubber Sheets (g)	F Dry Sample Mass (g)	G Mass of Sealed Sample Opened Under Water
	Sample A								
	Sample B								
	Re-test								
	Avg								
	Sample A								
	Sample B								
	Re-test								
	Avg								
	Sample A								
	Sample B								
	Re-test								
	Avg								
	Sample A								
	Sample B								
	Re-test								
	Avg								

Appendix

Aggregate Technician

FLAT AND ELONGATED PARTICLES (ASTM D4791)

8.3 Method A

Test each of the particles in each size fraction, and place in one of four groups:
(1) Flat particles,
(2) Elongated particles,
(3) Particles that meet the criteria of both groups 1 and 2,
(4) Neither flat nor elongated particles that do not meet the criteria of either group 1 or group 2.

Each particle shall be subjected to the Flat Particle Test and Elongated Particle Test. If the particle is determined to be flat but not elongated, the particle is placed in the “flat” group. If it is determined that the particle is not flat, but is elongated, the particle is placed in the “elongated” group. In some cases it may be possible for a particle to meet the criteria of both a flat particle and an elongated particle. In this case the particle is placed in the “particles that meet the criteria of both groups 1 and 2. If the particle is not flat and is not elongated, it is placed in the “particles that do not meet the criteria of either group 1 or group2.

8.3.1 Use the proportional caliper device, positioned at the proper ratio see Figure 4 below:

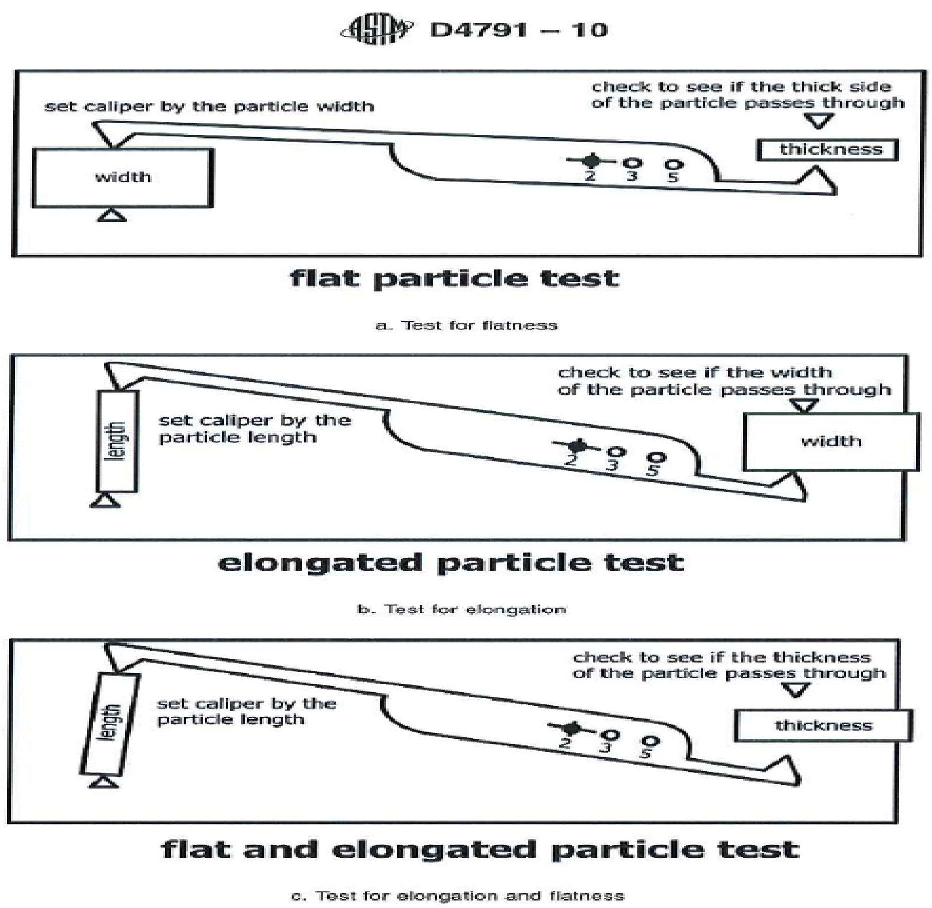

FIG. 4 Use of Proportional Caliper

8.3.1.1 Flat Particle Test – Set the larger opening equal to the maximum particle width. The particle is flat if the maximum thickness can be placed through the smaller opening.

8.3.1.2 Elongated Particle Test – Set the larger opening equal to the maximum particle length. The particle is elongated if the maximum width can be placed through the smaller opening.

8.3.2 After each of the particles have been classified into one of the groups described in 8.3, determine the proportion of the sample in each group by either count or by mas, as required.

2023 – THERMOMETERS

- **AASHTO T85**:
  - **T85 Oven**: The thermometer for measuring the oven temperature shall meet the requirements of M339M/M339 with a range of at least 90 to 130°C (194 to 266°F) and an accuracy of ± 1.25°C (± 2.25°F) (see note 1),
    - NOTE 1: Thermometer types to use include:
      - ASTM E1 Mercury Thermometer
      - ASTM 2877 digital metal stem thermometer
      - ASTM E230/E230M thermocouple thermometer, Type J or K, Special Class, Type T any Class
      - IEC 60584 thermocouple thermometer, Type T, Class 1
      - Dial gauge metal stem (Bi-metal) thermometer

  - **T85 Water Bath**: The thermometer for measuring the temperature of the water bath shall meet the requirements of M339M/M339 with a temperature range of at least 16 to 27°C (60 to 80°F) and an accuracy of ±0.5°C (±0.9°F) (see note 2),
    - NOTE 2: Thermometer types to use include:
      - ASTM E1 Mercury Thermometer
      - ASTM E2877 digital metal stem thermometer
      - ASTM E230/E230M thermocouple thermometer, Type T, Special
      - IEC 60584: thermocouple thermometer, Type T, Class 1

2023 – THERMOMETERS CONTINUED . . .

- **AASHTO T84**:
  - **T84 Oven**: The thermometer for measuring the oven temperature shall meet the requirements of M339M/M339 with a range of at least 90 to 130°C (194 to 266°F) and an accuracy of ± 1.25°C (± 2.25°F) (see note 1),
    - NOTE 1: Thermometer types to use include:
      - ASTM E1 Mercury Thermometer
      - ASTM 2877 digital metal stem thermometer
      - ASTM E230/E230M thermocouple thermometer, Type J or K, Special Class, Type T any Class
      - IEC 60584 thermocouple thermometer, Type J or K, Special class 1, Type T any Class
      - IEC 60584 thermocouple thermometer, Type j or K, Class1, Type T any Class
      - Dial gauge metal stem (Bi-metal) thermometer

  - **T84 Water Bath**: The thermometer for measuring the temperature of the water bath shall meet the requirements of M339M/M339 with a temperature range of at least 16 to 27°C (60 to 80°F) and an accuracy of ±0.5°C (±0.9°F) (see note 2),
    - NOTE 2: Thermometer types to use include:
      - ASTM E1 Mercury Thermometer
      - ASTM E2877 digital metal stem thermometer
      - ASTM E230/E230M thermocouple thermometer, Type T, Special
      - IEC 60584: thermocouple thermometer, Type T, Class 1
      - Dial gauge metal stem (Bi-metal) thermometer

The following have been used on materials that do not readily slump:

1. **Provisional Cone Test** - Fill the cone mold as described in the presentation for T84, except only use 10 drops of the tamper. Add more fine aggregate and use 10 drops of the tamper again. Then add material two more times using three and two drops of the tamper, respectively. Level off the material even with the top of the mold, remove loose material from the base, and lift the mold vertically.

2. **Provisional Surface Test** – If airborne fines are noted when the fine aggregate is such that it will not slump when it is at a moisture condition, add more moisture to the sand, and at the onset of the surface-dry condition, with the hand lightly pat approximately 100g of the material on a flat, dry, clean, dark, or dull nonabsorbent surface such as a sheet of rubber, a worn oxidized, galvanized, or steel surface, or a black-painted metal surface. After 1 to 3 seconds, remove the fine aggregate. If noticeable moisture shows on the test surface for more than 1 to 2 seconds, then surface moisture is considered to be present on the fine aggregate.

3. **Colorimetric** procedures described by Kandhal and Lee, Highway Research Record No. 307, page 44.

4. For reaching the SSD condition on a **single-size material** that slumps when wet, hard-finish paper towels can be used to surface-dry the material until the point is just reached where the paper towel does not appear to be picking up moisture from the surfaces of the fine aggregate particles.

Glossary

Revised: 09/17/2019

Aggregate Glossary of Terms

Absorption – The increase in mass (weight) due to water contained in the pores of the material.

Air Dry Aggregate – Aggregate that is dry at the particle surface but containing some internal moisture.

Coarse Aggregate – Aggregate which is predominately larger than the #4 (4.75mm) sieve.

Combined Aggregate – Aggregate that is a blend of both coarse and fine particles.

Field Sample – A quantity of the material of sufficient size to provide an acceptable estimate of the average quality of a unit.

Fine Aggregate – Aggregate which has a nominal maximum size of the #4 (4.75mm) sieve or smaller.

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).

Maximum Aggregate Size-(*Superpave*) One size larger than the nominal maximum aggregate size.

Maximum size of Aggregate/particle – *(in specifications for aggregate)* the smallest sieve opening through which the entire amount of aggregate is required to pass.

Nominal Maximum Size – Nominal Maximum is defined as the smallest sieve which 100% of sample passes.

Oven Dry Aggregate – Aggregate that has no internal or external moisture.

Saturated Surface Dry – An ideal condition in which the aggregate can neither absorb nor contribute water. In this condition, the interior has absorbed all the moisture it can hold, but the surface is dry = No Free Moisture.

Sieve Analysis – Determination of particle size distribution (gradation) using a series of progressively finer sieves.

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.

Sieving to Completion – Having no more than 0.5 % of aggregate particles retained on any sieve after shaking which should have passed through that sieve. Percent is calculated by mass of material retained divided by the original mass.

Tare – The mass (weight) of a pan or container. Normally the balance is adjusted to a "zero" reading by moving the scale counterbalance, or in the case of electronic scales, by tapping the tare button after the pan is placed on the scale to get a zero reading.

Unit- A batch or finite subdivision of a lot of bulk material (for example, a truck load or a specific area covered).

Wet Aggregate – Aggregate containing moisture on the particle surface.

Absorption: The increase in the mass of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass. The aggregate is considered "dry" when it has been maintained at a temperature of 110 ± 5ºC for sufficient time to remove all uncombined water by reaching a constant mass.

Bulk Specific Gravity (also known as Bulk Dry Specific Gravity): The ratio of the weight in air of a unit volume of aggregate (including the permeable and impermeable voids in the particles, but not including the voids between particles) at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

Bulk Specific Gravity (SSD): The ratio of the mass in air of a unit volume of aggregate, including the mass of water within the voids filled to the extent achieved by submerging in water for 15 to 19 hours (but not including the voids between particles) at a stated temperature, compared to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

Apparent Specific Gravity: The ratio of the weight in air of a unit volume of the impermeable portion of aggregate at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

SSD – Saturated Surface Dry: The condition in which the aggregate has been soaked in water and has absorbed water into its pore spaces. The excess, free surface moisture has been removed so that the particles are still saturated, but the surface of the particle is essentially dry.

Specific Gravity – The ratio of the mass (or weight in air) of a unit volume of a material to the mass of the same volume of gas-free distilled water at stated temperatures. Values are dimensionless.