

**2020 Edition**

**AGGREGATE**

**TECHNICIAN**





# Aggregate Technician

## 2020 – Updates

- **AUDIT NOTIFICATION SLIDE ADDED TO ALL MANUALS:** To all material testers, who work on Missouri Highways, this includes Consultants, Contractors, City, County, and MoDOT workers; you will be audited by **MoDOT IAS Inspectors** and sometimes **FHWA** personnel.
- **No Method Changes for 2020.**



# **COURSE CONTENT**

## **AGGREGATE TECHNICIAN**

<b>AASHTO R 90</b>	Sampling of Aggregate Products
<b>AASHTO R 76</b> ASTM C702	Reducing Samples of Aggregate to Testing Size
<b>AASHTO T 255</b> ASTM C566	Total Evaporable Moisture Content of Aggregate by Drying
<b>AASHTO T 11</b> ASTM C117	Materials Finer Than No. 200 Sieve in Mineral Aggregates by Washing
<b>AASHTO T 27</b> ASTM C136	Sieve Analysis of Fine and Coarse Aggregates
<b>MoDOT TM 71</b>	Deleterious Content of Aggregate
<b>ASTM D 4791</b>	Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
<b>Appendix</b>	
<b>Glossary</b>	





# **AASHTO R 90**

## **Sampling Aggregate Products**





### **Required Audits**

**All testers** on Federal-Aid Projects (MoDOT or Off-System) are required by the FHWA to be audited at least once per year.

**Reasons:**

- To ensure proper test procedures are being utilized.
- To ensure testing equipment is calibrated and operating properly.
- **Types of Audits;** procedure or comparison.
- **Be Proactive;** schedule your audit as early as possible with MoDOT Materials in district offices, do **NOT** wait till the end of the year.
- **Provide Proof;** when audited, present a MoDOT Certification Card, or a MoDOT Letter.

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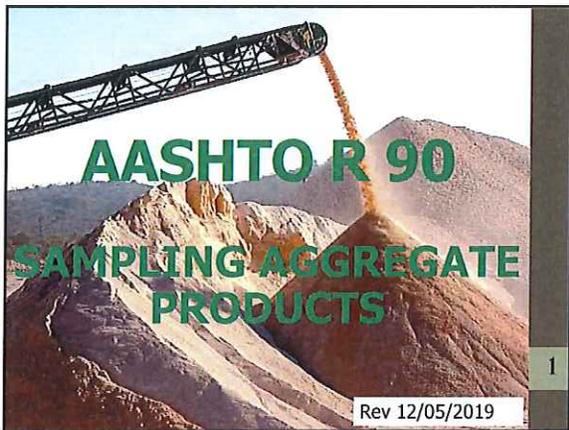
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### **SAFETY GEAR**

#### **Personal Protective Equipment (PPE)**

- Goggles or Safety Glasses
- Ear Plugs or Ear Muffs
- Steel-Toed Boots
- Hardhat
- Safety Vest
- Dust Mask



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**SCOPE**

- This practice covers the procedures for obtaining representative samples of Coarse Aggregate (CA), Fine Aggregate (FA), or combinations of Coarse and Fine Aggregate (CA/FA) products to determine compliance with requirements of the specifications under which the aggregate is furnished.
- This method includes sampling from conveyor belts, transport units, roadways, and stockpiles.

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**SIGNIFICANCE AND USE**

- Sampling is a critical step in determining the quality of the material being evaluated. Care shall be exercised to ensure that samples are representative of the material being evaluated.
- This practice is intended to provide standard requirements and procedures for sampling coarse, fine, and combination of coarse and fine aggregate products.

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**SECURING SAMPLES**

(All Methods)

- *General:* Where practicable, samples to be tested for quality shall be obtained from the finished product.
- *Inspection:* The material to be sampled shall be visually inspected to determine discernible variations, corrective action shall be taken to establish *homogeneity* in the material prior to sampling.

**Examples of variations:** *Segregation, clay pockets, varying seams, boulders.*

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**TERMINOLOGY**

- **Coarse Aggregate (CA)**
  - All the material retained on the #4 (4.75mm) sieve and above.
- **Fine Aggregate (FA)**
  - All the material passing the #4 (4.75mm) sieve.
- **Special Note**
  - MoDOT – Specific sample sizes are on the following chart. These sizes are different from AASHTO/ASTM specifications.

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**MoDOT AGGREGATE SAMPLE SIZES**

Nominal Maximum Size	Minimum Weight/Mass of Sample
2" (50 mm)	80 lb. (36kg)
1-1/2" (37.5 mm)	54 lb. (25kg)
1" (25.0 mm)	36 lb. (16kg)
3/4" (19.0 mm)	22 lb. (10kg)
1/2" (12.5 mm)	14 lb. (6kg)
3/8" (9.5 mm)	10 lb. (5kg)
Fines and Natural Sands	500g

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**Aggregate Sampling Procedures:**

- **Conveyor Belt**
  - Using a sampling device (belt discharge)
  - Using a template
- **Stockpiles**
  - Using a loader
  - Using a flat board
  - Using a sampling tube (fine aggregate)
- **Transport Units**
  - *Not recommended, therefore not covered*
- **Roadway**
  - In place (preferred)
  - Berm or windrow (*Not recommended, therefore not covered*)

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## CONVEYOR BELT SAMPLING

### Sampling Device Procedure Coarse Aggregate (CA) & Combined (CA/FA)



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### Conveyor Belt Equipment Sampling Device

- Safety Gear; PPE
- Sampling Device
- Proper Containers



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### Conveyor Belt - Sampling Device Procedure

1. Plant is operating at the usual rate.
2. Select a random sample from a conveyor belt discharge during production.
  - If sampling for quality control or acceptance, record the sampling time, date, and location.
  - Avoid the initial or end of an aggregate run.

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3. Pass the sampling device at a constant speed through the entire cross-section of the stream flow once in each direction without overflowing the sampling device.
4. Include all material from the sampling device when emptying into the container.
5. Obtain one or more equal increments as required for testing, and combine to form a field sample.

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**CONVEYOR BELT SAMPLING**  
**Template Procedure**  
 Coarse Aggregate (CA) & Combined (CA/FA)




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**Conveyor Belt Equipment**  
**Template**

- Safety gear; PPE
- Template
- Scoop or trowel
- Brush or broom
- Proper containers
- Tag out items




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### Conveyor Belt - Template Procedure

**NOTE:** Record sampling time or location, or both.

- 1. STOP** the conveyor belt.  
**Lock and Tag Out !**
- 2.** Select a random sample area from production.  
- Avoid sampling at the beginning or end of an aggregate run.
- 3.** Insert the sampling template on the belt to yield one increment.



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- 4.** Remove all material including the fines from inside the template with a scoop and a brush into a clean dry container.
- 5.** Obtain one or more equal increments to supply enough material for the required test(s).
- 6.** Combine the increments to form a field sample.

Conveyor Belt - Template

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### Conveyor Belt Automatic Sampling Device



- The Automatic Sampling Device is a permanently attached device that allows a sample container to pass perpendicularly through the entire stream of material or diverts the entire stream of material into the container by manual, hydraulic, or pneumatic operation.
- May be used if properly maintained and inspected.

Conveyor Belt - Automatic

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## STOCKPILES

Show Stockpile Video



Re-blend a segregated stockpile before sampling.



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## STOCKPILE SAMPLING

### Loader Procedure

Coarse Aggregate (CA) & Combined (CA/FA)



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## Stockpile Equipment

### Loader



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**Stockpile – Loader Procedure**  
 (Sampling from a flat surface created by a loader)

**NOTE:** Record sampling time or location, or both.

1. Re-blend segregated material with the loader.
2. Direct the loader operator to enter the stockpile with the bucket at least **1 foot** above the ground level to avoid contaminating the stockpile.
3. Discard the first bucketful.

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**Stockpile – Loader**

4. Have the loader re-enter the stockpile to obtain a full loader bucket of the material.
5. Tilt the bucket just high enough to permit free flow of the material to create a small pile to the side.  
(Repeat as necessary)
6. Create a flat surface by having the loader back drag the small pile.



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**Stockpile – Loader**

7. Collect a minimum of **three random** locations from the flat surface that are at least **one foot** from the sample pile edge.
8. Fully insert the shovel, exclude the underlying material, roll back the shovel, and without losing material place it in a clean dry container.
9. Combine the increments to form a field sample.

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**STOCKPILE SAMPLING**  
**Flat Board & Shovel Procedure**  
Coarse Aggregate (CA) & Combined (CA/FA)



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**Stockpile Equipment**  
**Board and Shovel**



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**Stockpile – Flat Board**

(Sampling from a horizontal surface on a stockpile face)

**NOTE:** Record sampling time or location, or both.

1. With a shovel, create a horizontal surface with a vertical face.
2. Insert a flat board against a vertical face behind sampling location to prevent sloughing.
3. Do not use sloughed material.
4. Obtain a sample from the horizontal surface near vertical face.

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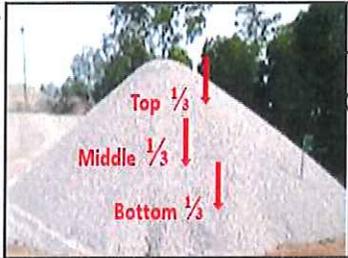
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5. Obtain at least one increment of equal size from the **top** third, **middle** third, and **bottom** third of the pile.
6. Combine the increments to form a field sample.




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**STOCKPILE SAMPLING**  
**Sampling Tube Procedure**  
**Fine Aggregate (FA) Only**




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**Stockpile Equipment**  
**Sampling Tube**

- Sampling tube with the dimensions:
  - 1 1/4" diameter x 6 feet in length, tip cut at a 45° angle




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**Stockpiles – Sampling Tube**

**NOTE:** Record sampling time or location, or both.

1. Remove the outer layer of the stockpile.
2. Using a sampling tube obtain a minimum of **5** samples from random locations on the stockpile.
3. Combine the increments in a clean dry sample container to form a field sample.



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**TRANSPORT UNITS**

Sampling aggregate from transport units is **NOT** a recommended procedure due to safety concerns and is not covered as part of this certification.

**NOT RECOMMENDED**



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**ROADWAY BASE IN-PLACE SAMPLING**

**Coarse Aggregate (CA) & Combined (CA/FA)**



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### Roadway Base In-Place Equipment



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### Roadway Base Sampling In-Place Procedure

**NOTE:** Record sampling time or location, or both.

1. Obtain a representative sample after spreading and before compaction using a random number set for a QC/QA sample.
2. If **not** a QC/QA sample, obtain at least **1** or more random increments before compaction.
3. Clearly mark the specific area from which materials will be removed with the template or square nosed shovel.

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4. Remove material from inside the marked area; the full depth of material, exclude any underlying material.
5. Combine the increments to form a field sample.



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Roadway Base -In-Place

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**STOCKPILES**  
**Roadway Base Sampling**

- Sampling from a berm or windrow
- **MoDOT does not sample from berms or windrows**

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**SHIPPING SAMPLES**

Proper Container

- Bags made for shipping aggregates, or other suitable containers that prevent contamination or loss during shipment.
- **NOTE: MoDOT prefers bags**



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**Proper Identification:**

- Shipping containers for aggregate samples shall have suitable individual identification that is clearly marked on the outside and enclosed.
- Include ID, location, date & time, material type, and quantity of material represented by the sample, if applicable.

Shipping Samples

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**Common Errors (All methods):**

- Using an improper sampling device.
- Sampling in segregated areas.
- Not obtaining enough increments.
- Not labeling the bags inside and out with proper identification.
- Allowing overflowing of a stream flow device.
- Not being safe. (example; Not performing lock out/tag out on a stopped conveyer belt.)

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1001.3 Sampling Procedures

Sampling procedures shall be in accordance with **AASHTO R90**. Portions shall be combined and reduced in accordance with **AASHTO R76**.

When sampling a stockpile, it is recommended that separate samples be taken from different parts of the pile, care being taken to avoid any segregated areas and bearing in mind that the material near the base of the pile is likely to be segregated and coarser than the average of the material in the stockpile.

**Table 1001.3 Size of Original Field Samples**

Maximum Size of Particle <sup>1</sup>	Minimum Weight (Mass) of Sample, lb. (kg) <sup>2</sup>
2" (50 mm)	80 (36)
1-1/2" (37.5 mm)	54 (25)
1" (25.0 mm)	36 (16)
3/4" (19.0 mm)	22 (10)
1/2" (12.5 mm)	14 (6)
3/8" (9.5 mm)	10 (5)
<sup>1</sup> Maximum size of particle is defined as the smallest sieve through which 100 percent of the material will pass.	
<sup>2</sup> The samples prepared for testing shall be obtained from the field sample in accordance with AASHTO T248	

1001.4 Types of Samples

**1001.4.1 Initial Evaluation**

Sampling for initial evaluation shall be done by, or under the supervision of the District Geologist.

**1001.4.1.1 Mines and Quarries**

Producers should be reminded that all quarries will be sampled initially on a "ledge" basis regardless of intended use. The initial sample will be obtained for Central Laboratory testing from each ledge of stone that varies from the adjacent material. Sampling shall be in compliance with all federal, state and local safety requirements. It is suggested that the sample be obtained from the pile after each ledge has been excavated.



# AASHTO R\_90: Sampling of Aggregates PROFICIENCY CHECKLIST

Applicant \_\_\_\_\_

Employer \_\_\_\_\_

For all QC/QA or Acceptance sampling, record the time or location or both.

<b>Conveyor Belt Sampling – Sampling Device – Coarse/Combined Aggregate</b>	Trial 1	Trial 2
NOTE: Automatic belt samplers may be used if properly maintained and inspected.		
1. Plant was operating at the usual rate.		
2. Random samples taken from a conveyor belt discharge taken from production. - Avoided sampling the beginning or end of a run.		
3. Sample taken from the entire cross-section of material once in each direction without overflowing the device.		
4. Included all material from the sampling device into a clean empty container.		
5. Obtained 1 or more increments to form a field sample.		
<b>Conveyor Belt Sampling – Template - Coarse/Combined Aggregate</b>		
1. Conveyor belt stopped, locked and tagged out.		
2. Random samples taken from production. - Avoided sampling at the beginning or end of a run.		
3. Template placed on the belt to yield one increment.		
4. All material inside the template scooped into a proper container including fines.		
5. Obtained 1 or more increments to combine for a field sample.		
<b>Stockpile Sampling – Flat Board – Coarse/Combined Aggregate</b>		
1. Created a horizontal surface with a vertical face.		
2. Inserted board vertically against a vertical face to prevent sloughing.		
3. Discarded sloughed material.		
4. Obtained a sample from the horizontal surface close to the vertical face.		
5. Obtained at least one increment from; the top third, the middle third, and the bottom third of the stockpile.		
6. Combined to form a field sample.		
<b>Stockpile Sampling - Sampling Tube - Fine Aggregate Only</b>		
1. The outer layer of the stockpile removed.		
2. Obtained a minimum of 5 random tube insertions on the stockpile.		
3. Combined to form a field sample.		
<b>Stockpile Sampling – Loader – Coarse/Combined Aggregate</b>		
1. Segregation avoided by re-blending the pile.		
2. Loader entered the pile with bucket at least 1 foot above the ground.		
3. Discarded first bucketful.		
4. Re-entered stockpile to obtain a full loader bucket of material		
5. Bucket tilted just enough for free flow, created small sampling pile. (Can go back for more).		
6. Back-dragged the small pile to form a sampling pad.		
7. Randomly collected a minimum of 3 increments with a shovel at least 1 foot from sample pile edge.		
8. Inserted the shovel, excluding underlying material, placed in a clean dry container.		
9. Combined increments to form a field sample.		
<b>Roadway Base Sampling – In-Place – Coarse/Combined Aggregate</b>		
1. Obtained at least 1 increment, using a random number set for a QC/QA sample before compaction.		
2. If not a QC/QA sample, obtained at least 1 or more random increments for a field sample.		
3. Used a square nose shovel and or a metal template to mark the area.		
4. Shoveled the full depth of the material excluding underlying material.		
5. Combined increments to form a field sample.		

Pass      Pass  
Fail      Fail

Examiner: \_\_\_\_\_ Date: \_\_\_\_\_



# **AASHTO R 76**

ASTM C702

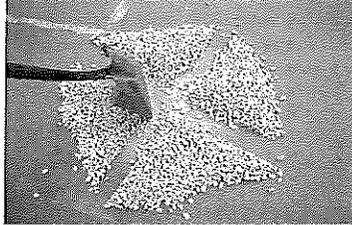
## **Reducing Samples of Aggregate**

### **To Testing Size**





# AASHTO R 76



## REDUCING SAMPLES OF AGGREGATE TO TESTING SIZE

Rev 09/09/2019

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## SIGNIFICANCE AND USE

- The significance for AASHTO R 76, is to reduce a large sample obtained in the field or produced in the laboratory to the proper size for conducting a number of tests to describe the material and measure its quality. These methods are conducted in such a manner that the smaller test sample portion will be representative of the larger sample and therefore the total supply.

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## SAMPLING

- The samples of aggregate obtained in the field shall be taken in accordance with AASHTO R 90 (ASTM D75), or as required by individual test methods and shall be reduced by AASHTO R 76 (ASTM C702).

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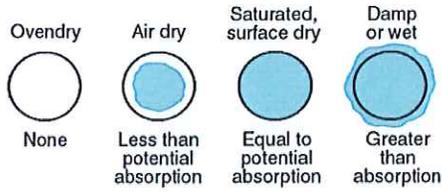
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**The moisture content of aggregate is defined in four states:**



**Total moisture**

Total Moisture = Free (surface) Moisture + Absorbed Moisture

**NOTE:** The Damp or Wet State #4 has free moisture on the particle surface.

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**METHODS**

- **Method A:** Mechanical Splitter
  - Riffle Splitter
- **Method B:** Quartering
  - Canvas
  - Hard, Clean, Level Surface
- **Method C:** Miniature Stockpile

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**Method Selection**

METHOD A Mechanical Splitter	METHOD B Quartering	METHOD C Miniature Stockpile
"Air Dry"	"Free Moisture"	"Free Moisture"
Fine Aggregate	Fine Aggregates	Fine Aggregates
Coarse Aggregates	Coarse Aggregates	
Combined/Mixed Aggregates	Combined/Mixed Aggregates	

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**Things to know before you begin:**

- Minimize the chance of variability during handling.
- The reduction method used depends upon the maximum aggregate size, the moisture condition, and the equipment available.
- A sample collected in two or more increments shall be thoroughly mixed before reducing.
- The mechanical splitter is the preferred method for reducing coarse aggregate.

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**METHOD A**  
MECHANICAL SPLITTER



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**APPARATUS**

Method A - Mechanical Splitter

- Shall have an even number of equal width chutes.
- At least **8 chutes** for coarse aggregate.
- At least **12 chutes** for fine aggregate.
- Must discharge alternately to each side of the splitter.
- Equipped with 2 receptacles to hold the two halves of the sample following splitting.

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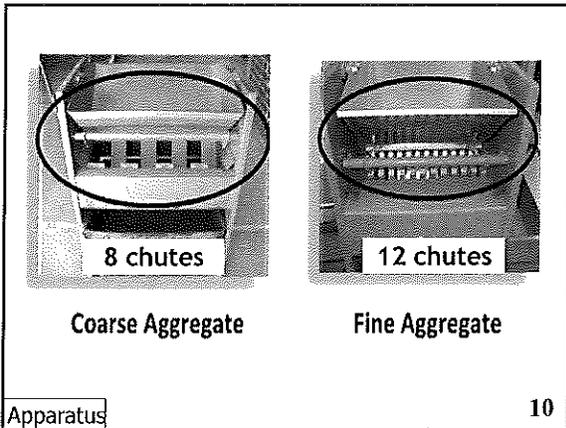
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Apparatus

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- Equipped with a hopper or straightedge pan, which has a width equal to or slightly less than the overall width of the assembly of chutes.
- Designed for smooth flow without restriction or loss of material.
- For coarse aggregate and mixed aggregate, the minimum width of the individual chutes shall be approximately 50% larger than the largest particles in the sample to be split.

Apparatus

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- For dry fine aggregate in which the entire sample will pass the  $\frac{3}{8}$ " (9.5mm) sieve, the minimum width of the individual chutes shall be at least 50% larger than the largest particles in the sample and the maximum width shall be  $\frac{3}{4}$ " (19mm).
- **NOTE:** A preliminary split may be made using a mechanical splitter for fine aggregate sample that is very large. Set the chute openings to  $1\frac{1}{2}$  inch or more to reduce the sample to not less than 5,000g. The portion so obtained is dried and reduced to test sample size using Method A.

Apparatus

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**SAMPLE PREPARATION**

Method A - Mechanical Splitter

- Sample should be air-dry.
- Clean the chutes before splitting and between splits.
- Large samples should be representative of the material.  
(Blending may be necessary)

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**PROCEDURE**

Method A - Mechanical Splitter

1. Material is in an air-dry condition.
2. Adjust the openings for the correct chute size.
3. Load the hopper uniformly, distributing the sample from edge to edge, avoiding segregation.
4. The rate at which the sample is introduced shall allow free flowing through the chutes into the receptacles below.

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5. Reintroduce the portion of the sample in one of the receptacles into the splitter as many times as necessary to reduce the sample to the size specified for the intended test.

**NOTE:** The portion of the material collected in the other receptacle may be reserved for reduction in size for the other tests.

Procedure

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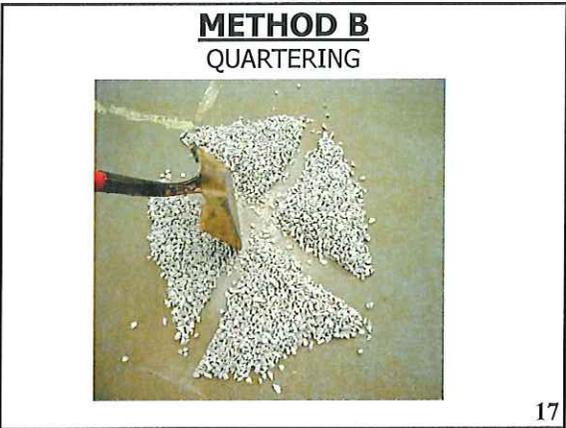
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- EQUIPMENT**  
Method B - Quartering
- Straight-edged scoop
  - Square-nosed shovel or trowel
  - Broom or brush
  - Canvas blanket for alternate method approximately 6' x 8'
  - Long stick
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**SAMPLE PREPARATION**

Method B - Quartering

- Fine, coarse, or combined aggregates must be in a moist condition.
- For fine aggregates, the sample should be wet enough to stand in a vertical face. If the sample does not have free moisture on the surfaces, the sample may be moistened to achieve this condition.

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**PROCEDURE**

Method B - Quartering

1. Place the sample on a clean, hard, level surface where there will be neither loss of material nor the accidental addition of foreign material.
2. Mix by turning the material over completely at least **THREE** times until thoroughly mixed.
3. Form a conical pile.

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4. Flatten evenly so the diameter is 4-8 times the thickness.
5. Divide this into 4 equal quarters with a shovel or trowel.
6. Remove two diagonally opposite quarters, including all fine material, brush the spaces clean and set the other two quarters aside for later use.

Procedure

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7. Take the remaining 2 quarters, mix and quarter until the sample is reduced to the desired size.

**NOTE:** Save the unused portion until testing is completed.

Procedure

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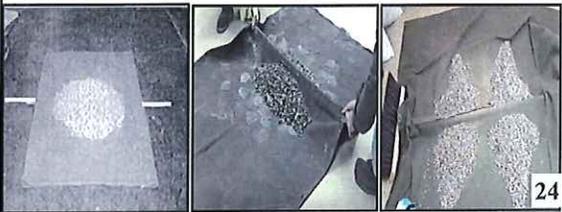
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**Method B - Alternate Quartering Method Using a Canvas and Broom Stick**

1. Place a canvas blanket on a clean, level surface.
2. Mix by lifting opposite corners towards each other causing the material to be rolled a minimum of four times.
3. Use a stick to quarter as shown below.




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4. Take opposite quarters to test or to further reduce.



Method B – Alternate Quartering

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**METHOD C**  
MINIATURE STOCKPILE



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**EQUIPMENT**

Method C - Miniature Stockpile

- Shovel or trowel (For mixing the aggregate)
- Straight-edged scoop
- Small sampling thief, small scoop, or spoon

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**PROCEDURE**

Method C - Miniature Stockpile

1. Place the original sample of damp fine aggregate on a hard clean, level surface.
2. Mix the material thoroughly by turning the entire sample over at least three times.
3. With the last turning, shovel the entire sample into a conical pile by depositing each shovel full on top of the preceding one.

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**Optional step:** The conical pile may be flattened to a uniform thickness and diameter by pressing the apex with a shovel or trowel so that each quarter sector of the resulting pile will contain the material originally in it.

4. Obtain a sample by selecting at least **FIVE** increments of material at random locations from the pile and combine them to attain the appropriate sample size.

Procedure

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**Common Errors:**

- Improper method for reduction based on moisture condition.
- Using wrong size chute openings.
- Failure to introduce sample to chutes evenly.
- Failure to use proper flow rate while splitting.

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**AASHTO R 76: Reducing Field Samples of Aggregate to Testing Size  
PROFICIENCY CHECKLIST**

Applicant \_\_\_\_\_

Employer \_\_\_\_\_

Trial #	1	2
<b>Method A – Splitting</b>		
<b>8 chutes for Coarse (CA), 12 chutes for Fine (FA)</b>		
1. Material in an air-dry condition.		
2. Adjusted the openings to be 50% larger than the largest particle.		
3. Material spread uniformly on feeder from edge to edge.		
4. Rate of feed slow enough so that sample flows freely through chutes.		
5. Material in one receptacle re-split until desired weight was obtained.		

<b>Method B - Quartering</b>		
1. Moist sample placed on clean, hard, level surface.		
2. Mixed by turning over completely at least 3 times with shovel.		
3. Conical pile formed.		
4. Pile flattened to uniform thickness and diameter of 4-8 times thickness.		
5. Divided into 4 equal portions with shovel or trowel.		
6. Removed two diagonally opposite quarters, including all fines.		
7. Remaining quarters, mixed and quartered until reduced to desired sample size.		
<b>NOTE:</b> The sample may be placed upon a canvas quartering cloth and a stick or pipe may be placed under the tarp to divide the pile into quarters.		

<b>Method C – Miniature Stockpile (Damp Fine Aggregate Only)</b>		
1. Moist fine aggregate sample placed on clean, hard, level surface.		
2. Material thoroughly mixed by turning over completely three times.		
3. Small stockpile formed.		
4. Obtain at least 5 samples taken at random with sampling thief, small scoop, or spoon, combined to attain appropriate sample size.		

Pass Pass

Fail Fail

Examiner: \_\_\_\_\_ Date: \_\_\_\_\_



# **AASHTO T 255**

ASTM C566

## **Total Evaporable Moisture Content**

**of**

## **Aggregate by Drying**





# AASHTO T 255

## Total Evaporable Moisture Content of Aggregate by Drying



Rev. 12/06/2019

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### SCOPE

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

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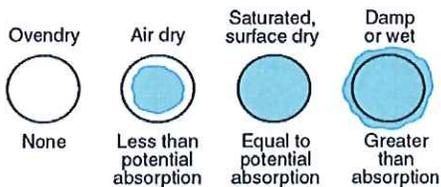
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The moisture content of aggregate is defined in four states:



#### Total moisture

$$\text{Total Moisture} = \text{Free (surface) Moisture} + \text{Absorbed Moisture}$$

**NOTE:** The Damp or Wet State #4 has FREE moisture on the particle surface.

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**SIGNIFICANCE AND USE**

- Used for adjusting batch quantities of ingredients for concrete.
- Measures the moisture in a test sample.
- Calculates the free moisture of aggregates to adjust for water-cement ratio.
- Affects the concrete plant report calculations.
- Affects the asphalt plant production rate and asphalt-cement content.
- NOTE: Larger particles will require greater time for the moisture to travel from the interior to the surface.

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**EQUIPMENT**

- Scale
  - Readable to 0.1 percent of the sample mass, or better
- Source of Heat
  - Ventilated oven  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ )
  - Hot plate
  - Ventilated microwave oven
  - Electric heat lamps



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Sample Container

- Air tight cans
  - Not affected by heat
  - Sufficient volume size

Other Items

- Gloves
- Metal Spoon
- Brush
- Pans

Shovel or Scoop

- for sampling



Equipment

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**SAMPLING**

- Obtain a sample in accordance with AASHTO R90/ASTM D75.
- Secure a sample of the aggregate representative of the moisture content in the supply being tested and having a mass not less than the amount listed in Table 1 using the *Nominal Maximum Size of Aggregate*. (See Glossary for definition)
- Protect the sample against moisture loss prior to determining the mass.

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**AASHTO Sample Size (TABLE 1)**

Nominal Maximum Size of Aggregate in. (mm)	Minimum Sample Mass Lbs. (g.)
#4 (4.75)	1.1 (500)
3/8" (9.5)	3.3 (1,500)
1/2" (12.5)	4.4 (2,000)
3/4" (19.0)	6.6 (3,000)
1" (25.0)	8.8 (4,000)
1 1/2" (37.5)	13.2 (6,000)

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**PROCEDURE**

1. Obtain representative sample in an air tight container.
  - It is advised to retrieve sample from interior of aggregate stockpile.
  - Cover immediately to prevent any moisture loss.
  - Protect the sample against moisture loss when transporting to a testing facility and prior to determining the mass.
2. Weigh and record the wet sample to the nearest 0.1% of the total mass, typically 0.1g.  
(From this point on do not lose material or overheat the sample.)

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**3. Dry the sample using one of the following; oven, hot plate, or microwave oven.**

– **Ventilated Oven:** (Preferred)

- Easily regulated at  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ).
- Good for sensitive aggregates.

– **Hot Plate:** (Fast) Exercise caution!

- Periodically stir to avoid overheating causing aggregate to fracture.
- If aggregate cannot be heated without fracture, use a ventilated oven.

Procedure

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– **Ventilated Microwave Oven:** Use a non-metal container, stirring is optional.

(If the material explodes you can not use the microwave, go to another method of drying.)

**NOTE:** Material used in the microwave cannot be used for any other test method.<sup>CC12</sup>

Procedure

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**4. Remove the sample from the heat source** when the sample is thoroughly dried to a *constant mass*.

**The sample is thoroughly dried to a constant mass when further heating causes, or would cause, less than 0.1 % additional loss in mass.**

**5. Allow to cool.**

**6. Weigh and record** the mass of the dried sample to the nearest **0.1 %** of the total mass.

Procedure

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### CALCULATIONS

- Determine the total evaporable moisture content

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

- $p$  = percent total evaporable moisture content
- $W$  = mass of original sample, (g)
- $D$  = mass of dried sample, (g)

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### **Class Practice**

Calculate the total evaporable moisture content:

- Mass of original sample = 3,523.0 g
- Mass of dried sample = 3,501.0 g
- Report your answer to the nearest 0.1%

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### **Answer**

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

$$\frac{3523.0 - 3501.0}{3501.0} \times 100 = \mathbf{0.6\% \textit{Moisture}}$$

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**REPORTING RESULTS**

- Record results in the bound field book to the nearest **0.1 %** total moisture.
- Notify plant operator of results.

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**Common Errors:**

- Overheating
- Insufficient sample size
- Loss of material when stirring
- Loss of moisture prior to testing
- Sample not dried to a constant mass

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# AASHTO T 255: Total Evaporable Moisture Content of Aggregate by Drying PROFICIENCY CHECKLIST

Applicant \_\_\_\_\_

Employer \_\_\_\_\_

	Trial #	1	2														
1. Representative test sample secured																	
2. Test sample mass conforms to following from the AASHTO T 255 Table:																	
<table border="1" style="margin: auto; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;">Nominal Maximum Size of Aggregate in. (mm)</th> <th style="text-align: center;">Minimum Sample Mass Lbs. (g.)</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">#4 (4.75)</td> <td style="text-align: center;">1.1 (500)</td> </tr> <tr> <td style="text-align: center;">3/8" (9.5)</td> <td style="text-align: center;">3.3 (1,500)</td> </tr> <tr> <td style="text-align: center;">1/2" (12.5)</td> <td style="text-align: center;">4.4 (2,000)</td> </tr> <tr> <td style="text-align: center;">3/4" (19.0)</td> <td style="text-align: center;">6.6 (3,000)</td> </tr> <tr> <td style="text-align: center;">1" (25.0)</td> <td style="text-align: center;">8.8 (4,000)</td> </tr> <tr> <td style="text-align: center;">1 1/2" (37.5)</td> <td style="text-align: center;">13.2 (6,000)</td> </tr> </tbody> </table>	Nominal Maximum Size of Aggregate in. (mm)	Minimum Sample Mass Lbs. (g.)	#4 (4.75)	1.1 (500)	3/8" (9.5)	3.3 (1,500)	1/2" (12.5)	4.4 (2,000)	3/4" (19.0)	6.6 (3,000)	1" (25.0)	8.8 (4,000)	1 1/2" (37.5)	13.2 (6,000)			
Nominal Maximum Size of Aggregate in. (mm)	Minimum Sample Mass Lbs. (g.)																
#4 (4.75)	1.1 (500)																
3/8" (9.5)	3.3 (1,500)																
1/2" (12.5)	4.4 (2,000)																
3/4" (19.0)	6.6 (3,000)																
1" (25.0)	8.8 (4,000)																
1 1/2" (37.5)	13.2 (6,000)																
3. Mass determined to the nearest 0.1% of the total mass																	
4. Loss of moisture avoided prior to determining the mass																	
5. Sample dried by a suitable heat source																	
6. If heated by means other than a controlled temperature oven, is sample stirred to avoid localized overheating																	
7. Sample dried to constant mass and mass determined to nearest 0.1% of the total mass																	
8. Moisture content calculated by:  $\% \text{ moisture} = \frac{\text{wet sample mass} - \text{dried sample mass}}{\text{dried sample mass}} \times 100$																	

PASS    PASS

FAIL    FAIL

Examiner: \_\_\_\_\_ Date: \_\_\_\_\_



# **AASHTO T 11**

ASTM C117

**Materials Finer Than**

**No. 200 Sieve in Mineral  
Aggregates**

**by Washing**





# AASHTO T 11



**MATERIALS FINER THAN  
No. 200 (75  $\mu$ m) SIEVE IN  
MINERAL AGGREGATES BY WASHING**

Rev 12/06/2019

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## SCOPE

- This test washes the fine particles through the #200 (75  $\mu$ m) sieve to give an accurate determination of the minus #200 portion in a sample.



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## SIGNIFICANCE AND USE

- Material finer than the # 200 (75- $\mu$ m) sieve can be separated from larger particles much more efficiently and completely by wet sieving than through the use of dry sieving. Therefore, when accurate determinations of material finer than #200 in fine or coarse aggregate is desired, this test method should be used on the sample prior to dry sieving in accordance with AASHTO T 27.

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**EQUIPMENT**

- Oven capable of 230 ± 9°F (110 ± 5°C)
- Scale, reads to 0.1% of the sample mass or better
- Sieve #200
  - Plus a
  - #8 sieve or a
  - #16 sieve
- Suitable container
- Wetting agent for "Method B"
- Water
- Spoon



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**SAMPLING**

- Sample the aggregate in accordance with AASHTO R 90 (ASTM D75).
- Thoroughly mix the sample of aggregate to be tested and reduce the quantity to an amount suitable for testing using the methods described in AASHTO R 76.
- The test specimen shall be a representative sample based on **AASHTO Table 1**.

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**AASHTO Table 1 – Sample Mass Requirements**

Nominal Maximum Size, in.(mm)	Minimum Weight of Sample, grams
#4 (4.75)	300
3/8" (9.5)	1000
3/4" (19.0)	2500
1 1/2" (37.5) or larger	5000

- Nominal Maximum is defined as the smallest sieve which 100% of sample passes.
- If the aggregate size is an in-between size just go to the next size on the chart for the amount ex: 1/2" you would go to 2500 grams.

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**SAMPLE PREPARATION**

**Method A**

- Dry the test sample to a constant mass at  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ) and determine the mass to the nearest 0.1 % of the mass of the test sample.
- Check the #200 sieve for damage before testing.  
(if damaged replace the sieve)

**NOTE:** Take care not to overload the #200 sieve during washing.

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**PROCEDURE**

**Method A**

1. Place the sample into a washing pan/vessel suitable for heating in the oven.
2. Add water to cover the aggregate.

**Optional Method B:**  
Add a small amount of wetting agent only once per sample during agitation.

3. Agitate the sample.  
(Use a spoon or similar tool to agitate the sample.)

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4. Immediately pour the wash water through the nest of sieves avoiding the decantation of the coarser particles.  
**Nest of sieves:** Protective sieve on top of the #200; either a #8 or #16.
5. Add another charge of water to the sample in the pan, agitate, decant the wash water through the nest of sieves as before. Repeat several times until the wash water is clear.

Procedure

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6. Material on sieves returned to washed sample.

**NOTES:**

- If mechanical washing equipment is used, the charging of water, agitating, and decanting will be a continuous operation.
- Do not decant any water from the pan except through a # 200 sieve to avoid loss of material.

Procedure

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7. Oven dry the sample to a constant mass at a temperature of 230 ± 9°F (110 ± 5°C), weigh to the nearest 0.1 % of the original mass of the sample. **(Typically 1 gram)**

8. Calculate the loss and report the results.

Procedure

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**CALCULATIONS**

Calculate the amount of material passing a # 200 sieve by washing as follows:

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

A = Total % passing #200 (75 µm) sieve

B = Original dry mass of sample (grams)

C = Dry mass of sample after washing and drying to constant mass (grams)

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**REPORTING**

Report the percentage of material finer than the #200 sieve by washing to the nearest **0.1 % if the loss is less than 10%.**

Report the result to the nearest **whole number if the loss is 10% or more.**

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

B = 532 grams

C = 521 grams

$$A = \frac{(532 - 521)}{532} \times 100$$

A = 2.1%

*Sample Calculations*

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**Classroom Exercise and Reporting Results**

Determine the percent of minus #200 material and report the answer to the nearest 0.1% if less than 10%, to the nearest 1% if 10% or more:

Original dry weight (B) = 3171 g

Washed dry weight (C) = 2729 g

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ANSWER

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

$$A = \frac{3171 - 2729}{3171} \times 100$$

Answer: A = 13.94  
Reported: A = **14%**

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**Common Errors:**

- Overloading #200 sieve
- Losing sample when transferring or washing
- Using a damaged #200 sieve

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# AASHTO T 11: Materials Finer Than No. 200 Sieve in Mineral Aggregates by Washing

## PROFICIENCY CHECKLIST

Applicant \_\_\_\_\_

Employer \_\_\_\_\_

	Trial #	1	2
1. Test sample dried to constant mass at 230 ± 9°F (110 ± 5°C).			
2. Test sample allowed to cool and mass determined to 0.1%.			
3. #200 sieve checked for damage. Cover the #200 with a #8 or #16 sieve.			
4. Sample placed in a container and covered with water.			
5. Wetting agent added. (optional)			
6. Sample and contents of container vigorously agitated.			
7. Wash water poured through the sieve nest.			
8. Wash water free of coarse particles.			
9. Operation continued until wash water is clear.			
10. Material on sieves returned to washed sample.			
11. Excess water decanted from washed sample only through the #200 sieve.			
12. Washed aggregate dried to constant mass at 230 ± 9°F (110 ± 5°C).			
13. Washed aggregate mass cooled and determined to 0.1%.			
14. Calculation: % less than #200 = $\frac{\text{Orig. dry mass} - \text{Final dry mass}}{\text{Orig. dry mass}} \times 100$			

PASS    PASS

FAIL    FAIL

Examiner: \_\_\_\_\_

Date: \_\_\_\_\_



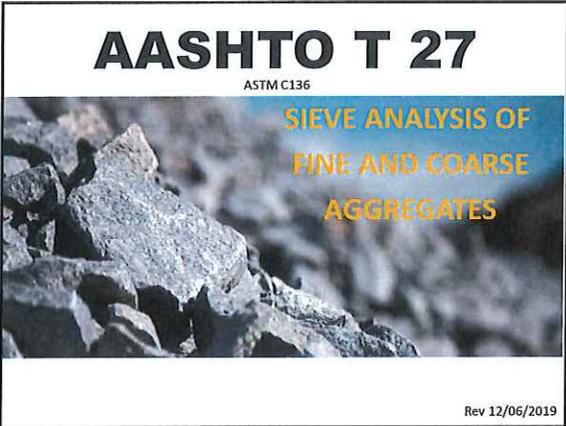
# **AASHTO T 27**

ASTM C136

## **Sieve Analysis of Fine and Coarse Aggregates**







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**SCOPE**

- Sieve analysis of aggregate is used to determine compliance with design, production control requirements, and verification of specifications.
- According to AASHTO, either Cumulative or Non-Cumulative methods may be used.

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**SIGNIFICANCE AND USE**

- This method is used primarily to determine the grading of materials proposed for use as aggregates or being used as aggregates. The results are used to determine compliance of the particle size distribution with applicable specification requirements and to provide necessary data for control of the production of various aggregate products. The data may also be useful in developing relationships concerning porosity and packing.
- Accurate determination of material finer than the #200 sieve cannot be achieved by use of this method alone. Therefore AASHTO T 11 for material finer than the #200 sieve by washing should be used.

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**EQUIPMENT**

- **Scale** – readable to 0.1% of the sample mass or better
- **Sieves**
- **Brushes** – soft and stiff brushes
- **Pans**
- **Oven**– Capable of maintaining  $230 \pm 9^{\circ}\text{F}$  ( $110 \pm 5^{\circ}\text{C}$ )  
–A **Hot Plate** may be used

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- **Mechanical Shaker**

- Check sieving thoroughness every **12 months** or **as needed** throughout the year.
  - The timer will be calibrated/verified during this process.
- A Record of this verification will be kept in the lab's Quality Manual System (QMS). See **AASHTO R 18**, located in Annex A1, Table A1.1.

Equipment

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- **Brushes**

- Vary to clean out sieves
  - ≥ #30 sieve use a wire brush or stiff brush
  - < #30 sieve use a soft bristle brush



Equipment

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**DEFINITIONS AND LANGUAGE**

• **Nominal Maximum Aggregate Size**

– For AASHTO T 27 this is defined as the smallest sieve that the specification for the material being tested allows for 100% of the material to pass.

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**Interchangeable Words**

- Sieve Analysis and Gradation
- Weight and Mass
- Minus (*sieve #*) Material and Material Passing through a (*sieve #*)
  - Example: -4 Material = Material Passing through #4 sieve
- Plus (*sieve #*) Material and Material Retained on a (*sieve #*)
  - Example: +4 Material = Material retained on a #4 sieve

Definitions and Language

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**THREE THINGS TO KNOW  
BEFORE  
SIEVE ANALYSIS**

1. Sieve Condition
2. Check Sieving Thoroughness
3. Sieve Overloading

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### 1. SIEVE CONDITION

- Check sieves for the following conditions prior to use.

- Large Holes
- Tears
- Unevenly spaced wires
- Cracks around rim
- Bowed screens
- Cleanliness
- Periodically examine finer mesh sieves against a backlight or white background for damaged openings or perimeter separations; use magnified viewing if needed.



- Wash finer sieves periodically per manufacturers instructions.
- Replace or repair any damaged sieves.

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### 2. CHECK SIEVING THOROUGHNESS

- Use a snug fitting pan and cover to prevent sample loss.
- Strike side of sieve with heel of hand at a rate of **150 times per minute**, turning about **1/6 turn every 25 strokes**.



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- There should not be more than **0.5 %** by mass of the total sample pass any sieve during **1 minute** of continuous hand sieving.
  - If **>0.5%** increase the time for sieving.



Sieving Thoroughness

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### 3. SIEVE OVERLOADING

- For sieves with openings **smaller than #4**, the quantity retained on any sieve at the completion of the sieving operation shall not exceed (**4g/in<sup>2</sup>**) of sieving surface area.
- For sieves with openings **#4 and greater**, the quantity retained in kg shall not exceed the product of:  
**2.5 X [sieve opening, mm x (effective sieving area, m<sup>2</sup>)]**  
 (This quantity is shown in AASHTO T27 Table 1)

See **Table 1** on the next slide for an example of allowable amounts on an 8" diameter sieve, and 14" square sieve.

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**AASHTO TABLE 1**

Maximum Allowable Quantity Of Material Retained\*

Sieve Opening Size	8" Diameter Sieve	14" Square Sieve
2" (50 mm)	7.9 lbs (3.6 kg)	33.7 lbs (15.3 kg)
1½" (37.5 mm)	6.0 lbs (2.7 kg)	25.4 lbs (11.5 kg)
1" (25.0 mm)	4.0 lbs (1.8 kg)	17.0 lbs (7.7 kg)
¾" (19.0 mm)	3.1 lbs (1.4 kg)	12.8 lbs (5.8 kg)
½" (12.5 mm)	2.0 lbs (0.89 kg)	8.4 lbs (3.8 kg)
¾" (9.5 mm)	1.5 lbs (0.67 kg)	6.4 lbs (2.9 kg)
No. 4 (4.75 mm)	0.7 lbs (0.33 kg)	3.3 lbs (1.5 kg)

\*Table 1 of the current AASHTO T 27 standard shows a complete table of different size sieves of the maximum allowable quantities of material retained on a sieve.

Sieve Overloading

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- To **prevent** sieve overloading on an individual sieve use one or more of the following methods:
  - Insert additional sieves.
  - Split sample into two or more portions, sieve each portion individually and combine the portions retained on the sieve before calculating the percentage of the sample on the sieve.
  - Use sieves having a larger frame size that provides a greater sieving area.

Sieve Overloading

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### SAMPLING

- Sample the aggregate in accordance with AASHTO R 90/ASTM D75.
- Thoroughly mix the sample and reduce to sample size using AASHTO R76.
- Use the Nominal Maximum Aggregate Size of the sample to determine the amount needed for testing from the MoDOT-EPG Chart on the next slide.

Note: The MoDOT-EPG Chart required amounts are different than that of AASHTO T 27.

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### **MoDOT-EPG CHART**

**MoDOT Sample Sizes for Aggregate Gradation Test**

Nominal Maximum Agg. Size in. (mm)	Minimum Mass of Test Sample lb. (g)
3/8" (9.5)	2.5 (1,000)
1/2" (12.5)	3.5 (1,500)
3/4" (19.0)	5.5 (2,500)
1" (25.0)	9 (4,000)
1 1/2" (37.5)	13.5 (6,000)

Dried Fine Aggregate, Minimum **500** grams.  
Found in the MoDOT EPG Section 1001 17

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### SAMPLE PREPARATION

- Dry the reduced sample to a constant mass in an oven at  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ). A hot plate can be used – fracturing of aggregates should be avoided.



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**PROCEDURE**  
**Sieve Analysis**



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- Weigh the dried sample and record the weight to the nearest gram. (Original Dry Mass)



Procedure – Original Dry Mass

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**PERFORM AASHTO T 11 (Optional)**

**NOTE:** Test T 11 is an **option**, but is generally used with T 27.

- Perform **AASHTO T 11** (Washing out the minus #200 fines from the sample).
- Dry the **washed aggregate** to a constant mass at  $230 \pm 9^\circ\text{F}$  ( $110 \pm 5^\circ\text{C}$ ).
- Allow to cool.
- Weigh the **washed dried sample** and record the weight to the nearest gram.

**Note:** This weight will be called the "Washed Dry Mass" on your sieve analysis worksheet.

Procedure – AASHTO T 11

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- Stack the sieves by assembling the required sieves in order of decreasing size.

• **NOTE:** Use of additional sieves may be added to prevent the required sieves from being overloaded.

- **NOTE:** For particles that are 3 inches and larger, use a Mechanical Screen-Shaker or Hand Sieve particles.



Procedure – Stacking Sieves

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*In order of decreasing size*

COARSE AGGREGATE STACK

FINE AGGREGATE STACK

Procedure – Stacking Sieves

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- Carefully load the sieves by taking the dried, pre-weighed sample and pour it into the top of the sieve stack.

- Do not lose any material.
- Put the lid on top.



Procedure – Loading Sieves

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- Agitate and shake each sieve **mechanically** or **by hand** for a sufficient period, established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy of sieving.
- **Sieving Criterion**
  - Shake until  $\leq 0.5\%$  by mass of the total sample passes during **1 minute** of continuous hand sieving.

Procedure - Agitation

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- Place the stack of sieves in a Mechanical Shaker set at the calibrated/verified time.  
(Approximately 7-10 min)

- If the timer was not calibrated/verified, **Hand Sieve** after agitation.



Procedure – Mechanical Agitation

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Shake until  $\leq 0.5\%$  by mass of the total sample passes during 1 minute of continuous hand sieving

**NOTE: Do NOT force particles or manipulate them to go through the sieve openings.**



Procedure – Manual Agitation

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- Method used to check mechanical shakers and hand sieving:
  - Tap side of sieve sharply with heel of hand 150 strokes/minute, rotating 1/6 turn every 25 strokes.
  - Shake until  $\leq 0.5\%$  by mass of the total sample passes during 1 minute of continuous hand sieving.



Procedure – Check for Sieving Thoroughness 28

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- After agitating the sample, unload and weigh the retained material on each sieve.
- Start with the largest sieve from the top of the stack and unload the retained aggregates using the appropriate BRUSH to clean out the sieves.



Procedure – Unloading and Weighing 29

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- Weigh and record the retained aggregates from each sieve using either the **Non-Cumulative procedure** or **Cumulative procedure**



Procedure – Unloading and Weighing 30

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**WEIGHING - Non - Cumulative Process**

- Unload each sieve fraction separately into its own individual (tared) pan.
- Weigh each pan separately and write the weight next to the corresponding sieve size on the report.
- Record to nearest 0.1 % by total mass, typically 1 gram.

**For The Minus #200**

- Tare out a different pan and unload the minus #200 material from the pan from the sieve nest and record the weight.

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**WEIGHING - Cumulative Process**

- Unload the material retained on the largest sieve into a tared pan and record the weight to the nearest 0.1% of the total mass, typically 1 gram.
- **Do not tare (zero) scale**, add material from next sieve into the same pan, record the combined weight.
- Repeat unloading and recording the combined weight until all sieves have been unloaded from the sieve stack into the same pan.

**For The Minus #200**

- Tare out a different pan and unload the minus #200 material from the pan from the sieve nest and record the weight.

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**CALCULATE AND REPORT**

Depending upon the form, the material tested and the specification, the report shall include one of the following:

- Total percentage of material passing each sieve.
- Total percentage of material retained on each sieve.
- Percentage of material retained between consecutive sieves.
- ✓ All values for the percent passing are reported to the nearest whole number for all sieves including material passing the (No. #200) sieve for values  $\geq 10\%$ .
- ✓ Material passing the (No. # 200) sieve for values less than 10% , reported to the nearest tenth (0.1)%.

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### SIEVING ACCURACY

- **MoDOT sieving accuracy:** Sieving accuracy tolerance for sieve analysis is  $\pm 1$  gram per sieve used. This can be found in the MoDOT EPG.

**We will use MODOT sieving accuracy for this certification.**

- **AASHTO T 27 sieving accuracy:** The total mass of the material after sieving should check closely with the total original dry mass of the sample placed on the sieves. If the two amounts differ by more than **0.3%**, based on the total original dry sample mass, the results should not be used for acceptance purposes.

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### CALCULATIONS -NON-CUMULATIVE

**Equation for all sieves:**

$$\% \text{Passing} = \frac{\text{total weight passing}}{\text{original dry weight}} \times 100$$

**Equation for the pan (Minus #200):**

$$\% \text{ passing \#200} = \frac{(T11 \text{ loss} + \text{pan weight})}{\text{original dry weight}} \times 100$$

**Equation for T11 loss:**

A = Total % passing #200       $A = \frac{(B-C)}{B} \times 100$   
 B = Original dry mass of sample  
 C = Dry mass of sample after washing & drying to constant mass.

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### CALCULATIONS - CUMULATIVE

**Equation for all sieves:**

$$\% \text{Passing} = 1 - \left( \frac{\text{cumulative weight}}{\text{original dry weight}} \right) \times 100$$

**Equation for the pan (Minus #200):**

$$\% \text{ passing \#200} = \frac{(T11 \text{ loss} + \text{pan weight})}{\text{original dry weight}} \times 100$$

**Equation for T11 loss:**

A = Total % passing #200       $A = \frac{(B-C)}{B} \times 100$   
 B = Original dry mass of sample  
 C = Dry mass of sample after washing & drying to constant mass

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Calculation of the Fineness Modulus  
"FOR INFORMATION ONLY"

- Calculate the fineness modulus, when required, by adding the total percentages of material in the sample that are coarser than each of the following sieves (cumulative percentages retained), and dividing the sum by 100; Sieves: #100, #50, #30, #16, #8, #4, # 3/8, # 3/4, # 1 1/2, and larger, increasing the ratio of 2 to 1.
- Report the fineness modulus to the nearest 0.01%.

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**COMMON ERRORS**

- Insufficient sample size.
- Overloading sieves.
- Loss of material when transferring from sieve to weighing pan.
- Insufficient cleaning of sieves.
- Using worn or cracked sieves.
- Sieving not thorough.
- Losing material performing AASHTO T 11. (washing minus #200) prior to gradation.

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**SIEVE ANALYSIS  
PRACTICE  
PROBLEMS**

\*We will use Mo-DOT EPG sieving accuracy for this certification.

NOTE: At the end of the module you will find enlarged copies of the slides and blank practice sheets.

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## CUMULATIVE - Problem 1A

Updated 2/1/2018

Dry Original Mass (g): 5226 (A)  
 (T11) Dry Washed Mass (g): 5195  
 Washing Loss (g): 31

Sieve Size	Cumulative wt. Retained (g)	% Retained	% Passing
37.5mm (1½")			
25mm (1")	<b>0</b>	<b>0</b>	<b>100</b>
19mm (¾")	<b>0+464 = 464</b>	<b>(464/5226) x 100 = 9</b>	<b>100-9 = 91</b>
12.5mm (½")	<b>464+2304 = 2768</b>	<b>(2768/5226) x 100=53</b>	<b>100-53 = 47</b>
9.5mm (⅜")	<b>2768+1162 = 3930</b>	<b>(3930/5226) x 100 = 75</b>	<b>100-75 = 25</b>
4.75mm (#4)	<b>5112</b>	<b>98</b>	<b>100 - 98 = 2</b>
2.36mm (# 8)	<b>5165</b>	<b>99</b>	<b>1</b>
1.18mm (#16)			
600µm (#30)			
300µm (#50)			
150µm (#100)			
75µm (#200)	<b>5165 + 26 = 5191</b>		
<b>Total Weight Retained:</b>	5224 (B)	Also add Total -200	

Pan	2	
Washing Loss (g):	31	% Passing -200
<b>=Total Minus #200</b>	<b>33</b>	<b>(33/A)*100=0.6</b>
		<b>0.6</b>

## NON-CUMULATIVE - Problem 1A

Dry Original Mass (g): 5226 (A)  
 (T11) Dry Washed Mass (g): 5195  
 Washing Loss (g): 31

Sieve Size	Indiv. Sieve Wt. Retained (g)		% Passing
37.5mm (1½")			
25mm (1")	<b>0</b>	<b>A - 0 = 5226</b>	<b>(5226/5226) x 100 =100</b>
19mm (¾")	<b>464</b>	<b>5226-464=4762</b>	<b>(4762/5226) x 100 = 91</b>
12.5mm (½")	<b>2304</b>	<b>4762-2304 =2458</b>	<b>(2458/5226) x 100 = 47</b>
9.5mm (⅜")	<b>1162</b>	<b>2458-1162 = 1296</b>	<b>(1296/5226) x 100 = 25</b>
4.75mm (#4)	<b>1182</b>	114	<b>2</b>
2.36mm (# 8)	<b>53</b>	61	<b>1</b>
1.18mm (#16)			
600µm (#30)			
300µm (#50)			
150µm (#100)			
75µm (#200)	<b>26</b>		
<b>Total Weight Retained:</b>	5224 (B)	Also add Total -200	

Pan	2	
Washing Loss (g):	31	% Passing -200
<b>=Total Minus #200</b>	<b>33</b>	<b>(33/A)*100=0.6</b>
		<b>0.6</b>



**Non - Cumulative Process - Sample 1A**

Original Dry Mass:	(A) 5226	g
(AASHTO T11) Dry Mass Washed:	5195	g
Washing Loss (Minus #200)	31	g

Enlarged

Sieve Size	Indiv. Sieve Weight Retd. (g)		Weight Passing (g)		Reported % Passing
25mm (1")	0	$A - 0 =$	5226	$\frac{5226}{5226} \times 100 =$	100
19mm (¾")	464	$5226 - 464 =$	4762	$\frac{4762}{5226} \times 100 =$	91
12.5mm (½")	2304	$4762 - 2304 =$	2458	$\frac{2458}{5226} \times 100 =$	47
9.5mm (⅜")	1162	$2458 - 1162 =$	1296	$\frac{1296}{5226} \times 100 =$	25
4.75mm (#4)	1182	$1296 - 1182 =$	114	$\frac{114}{5226} \times 100 =$	2
2.36mm (#8)	53	$114 - 53 =$	61	$\frac{61}{5226} \times 100 =$	1
1.18mm (#16)					
600µm (#30)					
300µm (#50)					
300µm (#50)					
150µm (#100)					
75µm (#200)	26	$61 - 26 =$	35		X
Pan (Minus #200)	2				X
Washing Loss (Minus #200)	31				X
Total (Minus #20)	33	$= 2 + 31$		$\frac{33}{5226} \times 100 =$	0.6
<b>Total Weight Retained :</b>	<b>(B) 5224</b>				

Accuracy Check = (A-B) = Less than 1/sieve? Yes

$(5226-5224) = 2 < 7$

**Non-Cumulative Process - Sample 1A**

Original Dry Mass:	(A) 5226	g
(AASHTO T11) Dry Mass Washed:	5195	g
Washing Loss:	31	g

Enlarged

Sieve Size	Indiv. Sieve Weight Retd. (g)	Weight Passing (g)		Reported % Passing
25mm (1")	0	5226		100%
19mm (¾")	464	4762		91
12.5mm (½")	2304	2458		47
9.5mm (⅜")	1162	1296		25
4.75mm (#4)	1182	114		2
2.36mm (#8)	53	61		1
1.18mm (#16)				
600µm (#30)				
300µm (#50)				
300µm (#50)				
150µm (#100)				
75µm (#200)	26	35	X	X
Pan (Minus #200)	2			X
Washing Loss (Minus #200)	31			X
Total (Minus #20)	33			0.6
<b>Total Weight Retained :</b>	<b>(B) 5224</b>			

Accuracy Check = (A-B) = Less than 1/sieve? Yes



Cumulative Process - Sample 1A							
Original Dry Mass: (A) 5226							
(AASHTO T11) Dry Mass Washed: 5195							
Washing Loss (Minus #200) 31							
Sieve Size	Indiv. Sieve Weight Retd. (g)		Total Retained (g)		% Retained		Reported % Passing
25mm (1")	0		0		0		100
19mm (¾")	464	0 + 464 =	464	$\frac{464}{5226} \times 100 =$	8.9	100 - 8.9 =	91
12.5mm (½")	2304	464 + 2304 =	2768	$\frac{2768}{5226} \times 100 =$	53.0	100 - 53.0 =	47
9.5mm (⅜")	1162	2768 + 1162 =	3930	$\frac{3930}{5226} \times 100 =$	75.2	100 - 75.2 =	25
4.75mm (#4)	1182	3930 + 1182 =	5112	$\frac{5112}{5226} \times 100 =$	97.8	100 - 97.8 =	2
2.36mm (#8)	53	5112 + 53 =	5165	$\frac{5165}{5226} \times 100 =$	98.8	100 - 98.8 =	1
1.18mm (#16)							
600µm (#30)							
300µm (#50)							
300µm (#50)							
150µm (#100)							
75µm (#200)	26	5165 + 26 =	5191		X		X
Pan (Minus #200)	2						X
Washing Loss (Minus #200)	31						X
Total (Minus #20)	33	= 2 + 31		$\frac{33}{5226} \times 100 =$			0.6
Total Weight Retained: (B) 5224		= 33 + 5191					
Accuracy Check = (A-B) = Less than 1/sieve?	Yes	(5226-5224) = 2 < 7					

Enlarged

Cumulative Process - Sample 1A							
Original Dry Mass: (A) 5226							
(AASHTO T11) Dry Mass Washed: 5195							
Washing Loss: 31							
Sieve Size	Indiv. Sieve Weight Retd. (g)	Total Retained (g)		% Retained		Reported % Passing	
25mm (1")	0	0		0		100	
19mm (¾")	464	464		8.9		91	
12.5mm (½")	2304	2768		53.0		47	
9.5mm (⅜")	1162	3930		75.2		25	
4.75mm (#4)	1182	5112		97.8		2	
2.36mm (#8)	53	5165		98.8		1	
1.18mm (#16)				0.0		100	
600µm (#30)				0.0		100	
300µm (#50)				0.0		100	
300µm (#50)				0.0		100	
150µm (#100)				0.0		100	
75µm (#200)	26	5191		X		X	
Pan (Minus #200)	2					X	
Washing Loss (Minus #200)	31					X	
Total (Minus #20)	33					0.6	
Total Weight Retained: (B) 5224							
Accuracy Check = (A-B) = Less than 1/sieve?	Yes						

Enlarged



**CUMULATIVE Sample 2B****ANSWERS – 2B**

Dry Original Mass (g): 5040 (A)  
 (T11) Dry Washed Mass (g): 4571  
 Washing Loss (g): 469

Sieve Size	Cumulative wt. Retained (g)	% Retained	% Passing
37.5mm (1½")			
25mm (1")			
19mm (¾")	0	0	100
12.5mm (½")	1150	23	77
9.5mm (⅜")			
4.75mm (#4)	2850	57	43
2.36mm (# 8)	4125	82	18
1.18mm (#16)			
600µm (#30)			
300µm (#50)			
150µm (#100)			
75µm (#200)	4523		
<b>Total Weight Retained:</b>	5036	(B)	
Pan	44		
Washing Loss (g):	469		% Passing -200
<b>=Total Minus #200</b>	513		10

MoDOT Accuracy Check = (A-B) = Less than 1/sieve? 5040 - 5036 = 4 4 < 5 = YES

**Non - CUMULATIVE Sample 2B**

Dry Original Mass (g): 5040 (A)  
 (T11) Dry Washed Mass (g): 4571  
 Washing Loss (g): 469

Sieve Size	Cumulative wt. Retained (g)		% Passing
37.5mm (1½")			
25mm (1")			
19mm (¾")	0	5040	100
12.5mm (½")	1150	3890	77
9.5mm (⅜")			
4.75mm (#4)	1700	2190	43
2.36mm (# 8)	1275	915	18
1.18mm (#16)			
600µm (#30)			
300µm (#50)			
150µm (#100)			
75µm (#200)	398		
<b>Total Weight Retained:</b>	5036	(B)	
Pan	44		
Washing Loss (g):	469		% Passing -200
<b>=Total Minus #200</b>	513		10



## Category: 1001 General Requirements for Material – Engineering Policy Guide

### 1001.5 Field Testing Procedures

#### 1001.5.1 Sieve Analysis

The frequency of aggregate Quality Assurance tests shall be in accordance with the specifications. This includes retained samples from quality control tests and independent samples. Sieve analysis of mineral filler shall be in accordance with AASHTO T37. Sieve analysis for the determination of particle size distribution of coarse and fine aggregate shall be performed in accordance with AASHTO T27 and T11, with the following exceptions.

##### 1001.5.1.1 Apparatus



##### Sample being split

- (a) Stove - Electric, natural gas, propane, or other suitable burner capable of maintaining a controlled temperature, may be used in lieu of an oven.
- (b) Pans - Pans of sufficient size and quantity for washing and drying samples and for holding separated fractions of material.
- (c) Brass sieve brush.
- (d) Large spoon or trowel.
- (e) Sample splitter.

##### 1001.5.1.2 Sample Preparation

Samples of aggregate for sieve analysis shall be taken in accordance with [EPG 1001.3 Sampling Procedures](#) and reduced to the proper size for testing in accordance with [AASHTO T248](#) [AASHTO R76](#). The sample for testing shall be approximately the size shown below and shall be the end result of the

sampling method. The selection of samples of an exact predetermined weight (mass) shall not be attempted.

**Table 1001.5.1.2 Size of Testing**

<b>Coarse Aggregate</b>	
<b>Maximum Size of Particle<sup>1</sup></b>	<b>Minimum Weight (Mass) of Sample lb. (kg)</b>
2" (50 mm)	20 (9)
1-1/2" (37.5 mm)	13.5 (6)
1" (25.0 mm)	9 (4)
3/4" (19.0 mm)	5.5 (2.5)
1/2" (12.5 mm)	3.5 (1.5)
3/8" (9.5 mm)	2.5 (1)
<sup>1</sup> Maximum size of particle is defined as the smallest sieve through which 100 percent of material will pass.	
<b>Fine Aggregate</b>	
Manufactured Fines and Natural Sand	500 grams

### 1001.5.1.3 Procedure

The sieve analysis shall be performed in accordance AASHTO T27. When determination of the minus 200 material is required, this shall be performed in accordance with AASHTO T11. A dry gradation may be run on any material where the accuracy of the sieve analysis does not require washing. The district Construction and Materials Engineer should be consulted when there is a question as to whether a dry or washed gradation should be run.

### 1001.5.1.4 Worksheet Form T-630R and Calculations, Passing Basis

One method for calculating gradation on a passing basis is as follows: The material that has been separated by the sieving operation shall be weighed starting with the largest size retained. This weight (mass) shall be recorded in the plant inspector's workbook on the line corresponding to the sieve on which the material is retained. Examples are given in [Fig 1001.10.2 Form T-630R Example 1, page 1](#) and

[page 2](#). The second largest sized material is then added to the largest size in the weigh pan and the accumulated total is recorded on the line corresponding to the sieve on which the material is retained. This operation is continued with the accumulated total being recorded on the line corresponding to the sieve on which the material is retained down to the smallest sieve, in this example, the No. 200 (75  $\mu$ m) size sieve. The final quantity of material remaining in the pan (in this instance, minus No. 200 (75  $\mu$ m) material) should be recorded on the line designated as "PAN." The "PAN + LOSS" is the sum of the "LOSS" from washing over a No. 200 (75  $\mu$ m) sieve plus the amount retained in the "PAN". The quantity retained on the smallest sieve is then added to the quantity in the "PAN + LOSS" and is to be recorded on the line designated as "TOTAL". The "TOTAL" should equal the original dry weight (mass) within a tolerance of one gram for each sieve that the material passed through. The difference between the "TOTAL" and the "ORIGINAL DRY WEIGHT (MASS)" is recorded on the line designated "DIFFERENCE". Tolerance for the sieving is plus or minus 1 gram per sieve. In the examples above, the tolerance should be equal to or less than plus or minus 5 grams (five sieves were used, beginning with the smallest sieve through which 100 percent passed). This tolerance is to be recorded on the line designated as "SIEVE ACCURACY".

The total amount of material finer than the smallest sieve shall be determined by adding the weight (mass) of material passing the smallest sieve obtained by dry sieving to that lost by washing. In the example, the amount lost by washing as recorded on the "LOSS" line was found to be 442 grams. The 7 on the "PAN" line shows that 7 additional grams were obtained in the dry sieving operation. This total quantity, 449 grams, is recorded on the "PAN + LOSS" line.

Except for the smallest sieve used, the percent passing is determined by dividing the quantity shown for each sieve by the original dry weight (mass) and subtracting the percentage from 100. The percentage passing the smallest sieve is found by dividing the quantity shown on the "PAN + LOSS" line by the original dry weight (mass). The percentage for the smallest sieve is shown on the line for that sieve.

Enter the SM Sample ID in the column next to "RECORD NO," then enter information from Form T-630R in SM.

The following shows Form T-630R being used to record the gradation of a material produced to meet Section 1003 specifications.

FORM T-630R

PLANT INSPECTION AGGREGATE WORKSHEET

MATERIAL \_\_\_\_\_ PRODUCT OR SPEC. NO \_\_\_\_\_  
 FACILITY CODE \_\_\_\_\_ PRODUCER \_\_\_\_\_  
 PURCHASE ORDER NO. \_\_\_\_\_ PLANT LOCATION \_\_\_\_\_  
 CONSIGNED TO \_\_\_\_\_ LEDGE \_\_\_\_\_  
 DESIGNATION \_\_\_\_\_

MECHANICAL SIEVE ANALYSIS

RECORD NO.							
DATE							
INSPECTOR							
ORIG/WET WT.	%	%	%	%	%	%	
ORIG DRY WT.							
WASHED DRY WT.							
LOSS							
FIELD MOIST.							SPEC LIMIT
37.5 mm (1 1/2")							
25 mm (1")							
19 mm (3/4")							
12.5 mm (1/2")							
9.5 mm (3/8")							
4.75 mm (# 4)							
2.36 mm (# 8)							
2.0 mm (#10)							
1.18 mm (#16)							
850 µm (# 20)							
600 µm (# 30)							
425 µm (# 40)							
300 µm (# 50)							
150 µm (#100)							
75 µm (#200)							
PAN							
PAN + LOSS							
TOTAL							
DIFFERENCE							
SIEVE ACCURACY							
TONS ACC/REJ.							
QUALITY DETERMINATION							
ORIG. WT.							
DELT							
SHALE							
CHERT							
OTHER							
TOTAL DELT							
PLASTICITY INDEX							
IN COMPUTER	<input type="checkbox"/>						

REPORT DATA AND REMARKS

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Original Dry Mass: (A)	g
(AASHTO T11) Dry Mass Washed:	g
Washing Loss:	g

Sieve Size	Indiv. Sieve Weight Retd. (g)		Reported % Passing
25mm (1")			
19mm (¾")			
12.5mm (½")			
9.5mm (⅜")			
4.75mm (#4)			
2.36mm (#8)			
1.18mm (#16)			
600µm (#30)			
300µm (#50)			
150µm (#100)			
75µm (#200)		X	X
Pan (Minus #200)			X
Washing Loss (Minus #200)			X
Total (Minus #20)			
<b>Total Weight Retained : (B)</b>			

Accuracy Check = (A-B) = Less than 1/sieve?



Original Dry Mass: (A)	g
(AASHTO T11) Dry Mass Washed:	g
Washing Loss:	g

Sieve Size	Indiv. Sieve Weight Retd. (g)		Reported % Passing
25mm (1")			
19mm (¾")			
12.5mm (½")			
9.5mm (⅜")			
4.75mm (#4)			
2.36mm (#8)			
1.18mm (#16)			
600µm (#30)			
300µm (#50)			
150µm (#100)			
75µm (#200)		X	X
Pan (Minus #200)			X
Washing Loss (Minus #200)			X
Total (Minus #20)			
<b>Total Weight Retained : (B)</b>			

Accuracy Check = (A-B) = Less than 1/sieve?



Original Dry Mass: <b>(A)</b>	g
(AASHTO T11) Dry Mass Washed:	g
Washing Loss:	g

Sieve Size	Indiv. Sieve Weight Retd. (g)		Reported % Passing
25mm (1")			
19mm (¾")			
12.5mm (½")			
9.5mm (⅜")			
4.75mm (#4)			
2.36mm (#8)			
1.18mm (#16)			
600µm (#30)			
300µm (#50)			
150µm (#100)			
75µm (#200)		X	X
Pan (Minus #200)			X
Washing Loss (Minus #200)			X
Total (Minus #20)			
<b>Total Weight Retained : (B)</b>			

Accuracy Check = (A-B) = Less than 1/sieve?



## AASHTO T 27: Sieve Analysis of Fine and Coarse Aggregate PROFICIENCY CHECKLIST

Applicant \_\_\_\_\_

Employer \_\_\_\_\_

Trial#	1	2
<b>Fine Aggregate</b>		
1. Reduced per AASHTO R76		
2. Minimum sample mass 500 g		
<b>Coarse Aggregate</b>		
1. Reduced per AASHTO R76 used sample size determined from nominal maximum aggregate size, and MoDOT' s EPG chart		
2. Sample dried to constant mass at 230 ± 9°F (110 ± 5°C), weighed to nearest 0.1% by mass (typically 1 gram) and recorded		
- AASHTO T 11 may be performed at this point, Washing Material Finer Than No. 200 Sieve, dried to a constant mass at 230 ± 9°F (110 ± 5°C), weight recorded and weight loss calculated to nearest whole number		
3. Stacked appropriate sieves in descending order		
4. Poured sample in the top sieve without losing material		
5. Agitated <b>Manually</b> or <b>Mechanically</b>		
- <b>Manual Sieving</b> continued until not more than 0.5% by mass of the total sample passes a given sieve during 1 minute of continuous hand sieving		
- <b>Mechanical Sieving</b> Verified annually		
- Timer verified/calibrated for sieving thoroughness. (Established by trial or checked by measurement on the actual test sample to meet the 0.5% criteria as in hand sieving above. (Records kept in the lab)		
- Set at verified/calibrated time approximately 7-10 min.		
- Or if timer not verified/calibrated, hand sieved afterwards for sieving accuracy		
6. Precautions taken to not overload sieves		
7. Weighed material in each sieve either by <b>Non-Cumulative</b> or <b>Cumulative</b> method		
8. Total mass of material after sieving agrees with mass before sieving to within 1 gram per sieve used (If not, do not use for acceptance testing)		
9. Percentages calculated to nearest 0.1% and reported to nearest whole number		
10. Percentage calculations based on original dry sample mass, including the passing No. 200 fraction if T 11 was used		

PASS    PASS

FAIL    FAIL

Examiner: \_\_\_\_\_

Date: \_\_\_\_\_



**MoDOT TM 71**

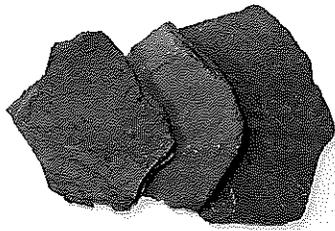
**DELETERIOUS CONTENT**

**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

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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

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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

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### CALCULATIONS

• % Deleterious Substances =  $\frac{C}{W} \times 100$

- **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 PROBLEM

1A

Sample: 1002 Material (Asphalt) ID NO. \_\_\_ Date: \_\_\_

Mass, grams			
Original Mass #4	3000		
Deleterious Rock (Very soft rock)	55	Percent	
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		ID NO. _____ Date: _____	
Sample: <u>1002</u> <u>Material (Asphalt)</u>			
Mass, grams			
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

1A

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EXAMPLE PROLEM		ID NO. _____ Date: _____	
Sample: <u>1002</u> <u>Material (Asphalt)</u>			
Mass, grams			
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

1B

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EXAMPLE PROLEM		ID NO. _____ Date: _____	
Sample: <u>1002</u> <u>Material</u>			
Mass, grams			
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

1B

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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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<b>EXAMPLE PROBLEM</b>		<b>1A</b>
Sample: <u>1002</u> Material ( <u>Asphalt</u> )	ID NO. _____	Date: _____
<b>Mass, grams</b>		
Original Mass +4	3000	
Deleterious Rock (Very soft rock)	55	
Shale	7	= <input type="text"/> % Shale
OFM	3	= <input type="text"/> % OFM
Soft Chert	15	
Hard Chert	114	
<b>Percent</b>		
Deleterious Rock + Soft Chert =	<input type="text"/>	= <input type="text"/> % Total Deleterious Rock
Deleterious Rock + Soft Chert + Shale + OFM =	<input type="text"/>	= <input type="text"/> % Total Deleterious Material
Hard Chert + Soft Chert =	<input type="text"/>	= <input type="text"/> % Total Chert

<b>EXAMPLE PROBLEM</b>		<b>1A</b>
Sample: <u>1002</u> Material ( <u>Asphalt</u> )	ID NO. _____	Date: _____
<b>Mass, grams</b>		
Original Mass +4	3000	
Deleterious Rock (Very soft rock)	55	
Shale	7	= <input type="text" value="0.2"/> % Shale
OFM	3	= <input type="text" value="0.1"/> % OFM
Soft Chert	15	
Hard Chert	114	
<b>Percent</b>		
Deleterious Rock + Soft Chert =	70	= <input type="text" value="2.3"/> % Total Deleterious Rock
Deleterious Rock + Soft Chert + Shale + OFM =	80	= <input type="text" value="2.7"/> % Total Deleterious Material
Hard Chert + Soft Chert =	129	= <input type="text" value="4.3"/> % Total Chert



EXAMPLE PROBLEM		1B	
Sample: <u>1002</u> Material ( <u>Asphalt</u> )	ID NO. _____	Date: _____	
		Mass, grams	
Original Mass +4	3000		
Deleterious Rock (Very soft rock)	60	Percent	
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		1B	
Sample: <u>1002</u> Material	ID NO. _____	Date: _____	
		Mass, grams	
Original Mass +4	3000		
Deleterious Rock (Very soft rock)	60	Percent	
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 – Engineering Policy Guide

#### 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 <sup>1</sup> , in. (mm)	Sample Size, g
2 (50)	10,000
1 ½ (37.5)	9,000
1 (25.0)	5,000
¾ (19.0)	3,000
½ (12.5)	2,000
⅜ (9.5)	1,000

<sup>1</sup> 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:

$$P = 100 \times C / W$$

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](#)

### 106.3.2.71 TM-71 Deleterious Content of Aggregate – Engineering Policy Guide

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 140°F)																			
2. Reduced the sample according to the Maximum Size aggregate using the TM71 table below: Note: Surplus this amount for sieving																			
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 50%; text-align: center;">Maximum Size Inches (mm)</th> <th style="width: 50%; text-align: center;">Minimum Sample Size of +4 material</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">2 (50)</td> <td style="text-align: center;">10,000 grams</td> </tr> <tr> <td style="text-align: center;">1½ (37.5)</td> <td style="text-align: center;">9,000 grams</td> </tr> <tr> <td style="text-align: center;">1 (25.0)</td> <td style="text-align: center;">5,000 grams</td> </tr> <tr> <td style="text-align: center;">¾ (19.0)</td> <td style="text-align: center;">3,000 grams</td> </tr> <tr> <td style="text-align: center;">½ (12.5)</td> <td style="text-align: center;">2,000 grams</td> </tr> <tr> <td style="text-align: center;">⅜ (9.5)</td> <td style="text-align: center;">1,000 grams</td> </tr> <tr> <td colspan="2" style="text-align: center; font-size: small;">Maximum size is defined as the smallest sieve through which 100% of the material will pass.</td> </tr> </tbody> </table>	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.				
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.																			
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 <b>(Do not soak the particles in water)</b>																			
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																			
<b>NOTES:</b> <ul style="list-style-type: none"> <li>❖ Groups are defined in the test method and will vary based on product type as well as the presence of any given group</li> <li>❖ For 1002 material, keep soft chert separate as it will be included in both deleterious and hard chert</li> </ul>																			
10. Calculate the percentage of each group identified, report to nearest 0.1% for each category $P = \frac{C}{W} \times 100$ 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: \_\_\_\_\_



**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. 12/06/2019

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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.
- Method A 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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- Method A is a reflection of the original procedure as developed prior to Superpave and is intended for all non-Superpave applications *and will NOT be covered in this certification. For more information on Method A, see the Appendix.*
- Method B 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 coarse 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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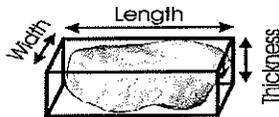
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### Definitions



- **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

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### 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.

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**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)

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**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

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**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

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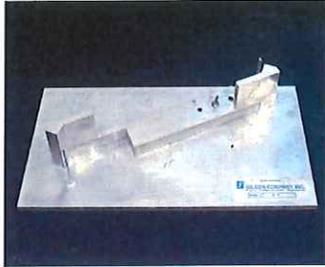
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### EQUIPMENT

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



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### 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.

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### **ASTM D4791 Sample Size**

Maximum Retained Sieve Size in.(mm)	Minimum Amounts lb. (Mass in grams)
$\frac{3}{8}$ " (9.5)	2 (1000)
$\frac{1}{2}$ " (12.5)	4 (2000)
$\frac{3}{4}$ " (19.0)	11 (5000)
1" (25.0)	22 (10,000)
1 1/2" (37.5)	33 (15,000)

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**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 @  $230 \pm 9^\circ\text{C}$  ( $110 \pm 5^\circ\text{C}$ )
- Perform AASHTO T27
- Test all sieves with more than 10% retained on the #4 sieve and above as required by MoDOT specifications.

Sampling

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**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.

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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

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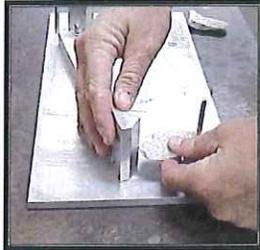
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## Evaluating Aggregates



**Figure 1**  
Checking Elongation



**Figure 2**  
Checking Flatness

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## 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.

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A = Weight retained on each particular sieve

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

C = Weight of mass tested (Approximately 100 pieces)

D = Weight of flat and elongated particles

$$E = \frac{D}{C} \times 100 \quad \text{Report to nearest 1\%}$$

$$F = \frac{B}{\text{TPR}} \quad \text{Report to nearest 0.001}$$

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

Calculations & Reporting

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**Common testing errors:**

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

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**Class Room  
F&E  
Problems**

There are enlarged copies at the end of this module.

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**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 Avg. (G)
37.5mm 1 1/2"	0						
25.0mm 1"	0						
19.0mm 3/4"	2644		1973	8			
12.5mm 1/2"	3232		1632	44			
9.5mm 3/8"	69		0	0			
4.75mm #4	119		0	0			
Total % Retained (TPR)			(TPR)				
						Total	

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

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 1/2"	0						
25.0mm 1"	0						
19.0mm 3/4"	2644	42.0	1973	8	0	.436	0
12.5mm 1/2"	3232	51.3	1632	44	3	.533	2
9.5mm 3/8"	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	29%

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**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 1/2"							
25.0mm 1"	0		0	0			
19.0mm 3/4"	2710		1840	13			
12.5mm 1/2"	3352		1588	51			
9.5mm 3/8"	70		0	0			
4.75mm #4	1252		825	33			
Total % Retained			(TPR)				
						Total	

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**Flat and Elongated by Mass** **Problem 2B**

Original Mass of Sample 7400 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 1/2"							
25.0mm 1"	0		0	0			
19.0mm 3/4"	2710	37.1	1840	13	1		
12.5mm 1/2"	3352	44.5	1588	51	3		
9.5mm 3/8"	70	1.0	0	0	4		
4.75mm #4	1252	17.2	825	33	4		
Total % Retained		99.8	(TPR)				
						Total	

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

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**Flat and Elongated by Mass** **Answers 2B**

Original Mass of Sample 7200 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 1/2"								
25.0mm 1"	0		0	0				
19.0mm 3/4"	2710	37.1	1840	13	1	0.572	0	
12.5mm 1/2"	3252	44.5	1588	51	3	0.446	1	
9.5mm 3/8"	70	1.0 -10%	0	0	0	0.010	0	
4.75mm #4	1252	17.2	325	33	4	0.172	1	
<b>Total % Retained</b>		<b>99.8</b>	<b>(TPR)</b>			<b>1.000</b>		
For column E where zero is: $3 \div 4 = 7(7 - 2) = 3.5 = 4$ Using the number above and below the zero, add, divide by 2 = 4							<b>Total</b>	<b>2%</b>

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**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 1/2"							
25.0mm 1"							
19.0mm 3/4"							
12.5mm 1/2"		10.2	102	4			
9.5mm 3/8"		10.5	104	1			
4.75mm #4		35.8	109	3			
<b>Total % Retained (TPR)</b>		<b>56.5</b>	<b>(TPR)</b>				
<b>Total</b>							

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**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 1/2"							
25.0mm 1"							
19.0mm 3/4"							
12.5mm 1/2"		10.2	102	4	4	0.181	1
9.5mm 3/8"		10.5	104	1	1	0.186	0
4.75mm #4		35.8	109	3	3	0.634	2
<b>Total % Retained (TPR)</b>		<b>56.5</b>	<b>(TPR)</b>				
<b>Total</b>							<b>3</b>

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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 1/2"	0						
25.0mm 1"	0		0	0			
19.0mm 3/4"	2644		1973	8			
12.5mm 1/2"	3232		1632	44			
9.5mm 3/8"	69		0	0			
4.75mm #4	119		0	0			
<b>Total % Retained</b>			<b>(TPR)</b>				
						<b>Total</b>	

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

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

$$F = \frac{B}{\text{TPR}} \quad (9.1) \text{ (E\&G) Calculated to nearest 1\%}$$

(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.

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 1/2"	0						
25.0mm 1"	0		0	0			
19.0mm 3/4"	2644	42.0	1973	8	0	0.436	0
12.5mm 1/2"	3232	51.3	1632	44	3	0.533	2
9.5mm 3/8"	69	1.1<10%	0	0	3	0.011	0
4.75mm #4	119	1.9<10%	0	0	3	0.020	0
<b>Total % Retained</b>		<b>96.3</b>	<b>(TPR)</b>			<b>1.000</b>	
						<b>Total</b>	<b>2%</b>

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

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

$$F = \frac{B}{TPR} \quad (9.1) \text{ (E\&G) Calculated to nearest 1\%}$$

(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 1/2"							
25.0mm 1"	0		0	0			
19.0mm 3/4"	2710		1840	13			
12.5mm 1/2"	3252		1588	51			
9.5mm 3/8"	70		0	0			
4.75mm #4	1252		825	33			
<b>Total % Retained</b>			<b>(TPR)</b>				
						<b>Total</b>	

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

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

$$F = \frac{B}{TPR} \quad (9.1) \text{ (E\&G) Calculated to nearest 1\%}$$

(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 1/2"							
25.0mm 1"	0		0	0			
19.0mm 3/4"	2710	37.1	1840	13	1	0.372	0
12.5mm 1/2"	3252	44.5	1588	51	3	0.446	1
9.5mm 3/8"	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

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

C = Weight of mass tested (Approximately 100 pieces)

D = Weight of Flat and Elongated particles

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

$$F = \frac{B}{TPR} \quad (9.1) \text{ (E\&G) Calculated to nearest 1\%}$$

(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 3C

Project: J8P0633 Mix Design: SP250 05-43 Date: 7/25/08.  
 Material/Stockpile ID 3/4" 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 1/2"							
25.0mm 1"			0	0			
19.0mm 3/4"			0	0			
12.5mm 1/2"		10.2	102	4			
9.5mm 3/8"		10.5	104	1			
4.75mm #4		35.8	109	3			
<b>Total % Retained</b>		<b>56.5</b>	<b>(TPR)</b>				
						<b>Total</b>	

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

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

$$F = \frac{B}{\text{TPR}} \quad (9.1) \text{ (E\&G) Calculated to nearest 1\%}$$

(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 3/4" Fraction Technician: Bob Potet

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 1/2"							
25.0mm 1"			0	0			
19.0mm 3/4"			0	0			
12.5mm 1/2"		10.2	102	4	4	0.181	1
9.5mm 3/8"		10.5	104	1	1	0.186	0
4.75mm #4		35.8	109	3	3	0.634	2
<b>Total % Retained</b>		<b>56.5</b>	<b>(TPR)</b>			<b>1.001</b>	
						<b>Total</b>	<b>3</b>

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

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

$$F = \frac{B}{\text{TPR}} \quad (9.1) \text{ (E\&G) Calculated to nearest 1\%}$$

(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.



**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																	
<table border="1" style="margin: auto; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;">Nominal Maximum Size in. (mm)</th> <th style="text-align: center;">Minimum Mass lb. (g.)</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">3/8 (9.5)</td> <td style="text-align: center;">2 (1000)</td> </tr> <tr> <td style="text-align: center;">1/2 (12.5)</td> <td style="text-align: center;">4 (2000)</td> </tr> <tr> <td style="text-align: center;">3/4 (19.0)</td> <td style="text-align: center;">11 (5000)</td> </tr> <tr> <td style="text-align: center;">1 (25.0)</td> <td style="text-align: center;">22 (10,000)</td> </tr> <tr> <td style="text-align: center;">1 1/2 (37.5)</td> <td style="text-align: center;">33 (15,000)</td> </tr> <tr> <td style="text-align: center;">2 (50)</td> <td style="text-align: center;">44 (20,000)</td> </tr> </tbody> </table>	Nominal Maximum Size in. (mm)	Minimum Mass lb. (g.)	3/8 (9.5)	2 (1000)	1/2 (12.5)	4 (2000)	3/4 (19.0)	11 (5000)	1 (25.0)	22 (10,000)	1 1/2 (37.5)	33 (15,000)	2 (50)	44 (20,000)			
Nominal Maximum Size in. (mm)	Minimum Mass lb. (g.)																
3/8 (9.5)	2 (1000)																
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3/4 (19.0)	11 (5000)																
1 (25.0)	22 (10,000)																
1 1/2 (37.5)	33 (15,000)																
2 (50)	44 (20,000)																
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: <b>By Particle Count:</b> 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  <b>By Mass:</b> Use the material retained on the #4 or 3/4" sieve and above as required by MoDOT EPG specifications 1002, 1005, etc.																	
<b>Procedure: Method B - Flat and Elongated Particle Test</b>																	
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																	
<b>Calculations</b>																	
Percentage of flat and elongated particles calculated to nearest 1% for each sieve size as required																	

PASS PASS

FAIL FAIL

Examiner: \_\_\_\_\_ Date: \_\_\_\_\_



# Appendix

## Aggregate Technician





**FLAT AND ELONGATED PARTICLES (ASTM D4791)**

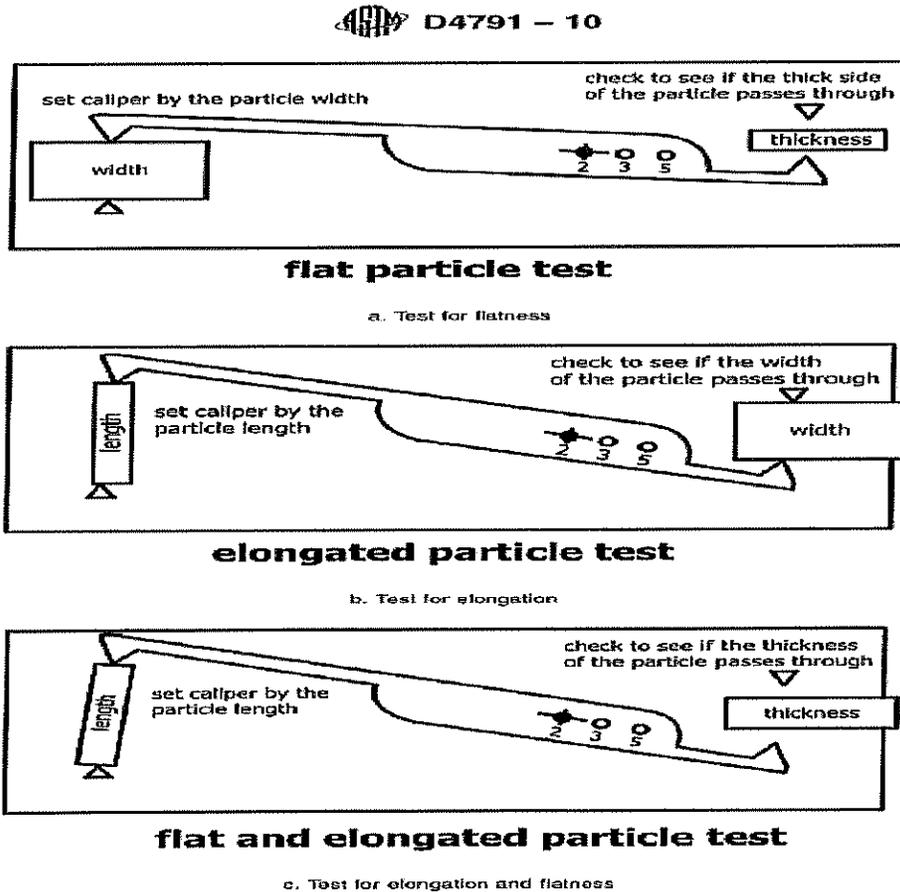
**8.3 Method A**

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 group 2.

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 mass, as required.



# 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.

