

## **SAMPLING AGGREGATE PRODUCTS FOP FOR AASHTO R 90**

### **Scope**

This procedure covers sampling of coarse, fine, or a combination of coarse and fine aggregates (CA and FA) in accordance with AASHTO R 90-18. Sampling from conveyor belts, transport units, roadways, and stockpiles is covered.

### **Apparatus**

- Shovels or scoops, or both
- Brooms, brushes, and scraping tools
- Sampling tubes of acceptable dimensions
- Mechanical sampling systems: normally 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
- Belt template
- Sampling containers

### **Procedure – General**

Sampling is as important as testing. The technician shall use every precaution to obtain samples that are representative of the material. Determine the time or location for sampling in a random manner.

1. Wherever samples are taken, obtain multiple increments of approximately equal size.
2. Mix the increments thoroughly to form a field sample that meets or exceeds the minimum mass recommended in Table 1.

**TABLE 1**  
**Recommended Sample Sizes**

<b>Nominal Maximum Size*</b>		<b>Minimum Mass</b>	
<b>mm (in.)</b>		<b>g (lb)</b>	
90	(3 1/2)	175,000	(385)
75	(3)	150,000	(330)
63	(2 1/2)	125,000	(275)
50	(2)	100,000	(220)
37.5	(1 1/2)	75,000	(165)
25.0	(1)	50,000	(110)
19.0	(3/4)	25,000	(55)
12.5	(1/2)	15,000	(35)
9.5	(3/8)	10,000	(25)
4.75	(No. 4)	10,000	(25)
2.36	(No. 8)	10,000	(25)

\* One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size. Maximum size is one size larger than nominal maximum size.

**Note 1:** Sample size is based upon the test(s) required. As a general rule, the field sample size should be such that, when split twice will provide a testing sample of proper size. For example, the sample size may be four times that shown in Table 2 of the FOP for AASHTO T 27/T 11, if that mass is more appropriate.

## Procedure – Specific Situations

### Conveyor Belts

Avoid sampling at the beginning or end of the aggregate run due to the potential for segregation. Be careful when sampling in the rain. Make sure to capture fines that may stick to the belt or that the rain tends to wash away.

#### Method A (From the Belt)

1. Stop the belt.
2. Set the sampling template in place on the belt, avoiding intrusion by adjacent material.
3. Remove the material from inside the template, including all fines.
4. Obtain at least three approximately equal increments.
5. Combine the increments to form a single sample.

**Method B (From the Belt Discharge)**

1. Pass a sampling device through the full stream of the material as it runs off the end of the conveyor belt. The sampling device may be manually, semi-automatic or automatically powered.
2. The sampling device shall pass through the stream at least twice, once in each direction, without overfilling while maintaining a constant speed during the sampling process.
3. When emptying the sampling device into the container, include all fines.
4. Combine the increments to form a single sample.

**Transport Units**

1. Visually divide the unit into four quadrants.
2. Identify one sampling location in each quadrant.
3. Dig down and remove approximately 0.3 m (1 ft.) of material to avoid surface segregation. Obtain each increment from below this level.
4. Combine the increments to form a single sample.

**Roadways****Method A (Berm or Windrow)**

- Obtain sample before spreading.
- Take the increments from at least three random locations along the fully formed windrow or berm. Do not take the increments from the beginning or the end of the windrow or berm.
- Obtain full cross-section samples of approximately equal size at each location. Take care to exclude the underlying material.
- Combine the increments to form a single sample.

*Note 2:* Obtaining samples from berms or windrows may yield extra-large samples and may not be the preferred sampling location.

**Method B (In-Place)**

- Obtain sample after spreading and before compaction.
- Take the increments from at least three random locations.
- Obtain full-depth increments of approximately equal size from each location. Take care to exclude the underlying material.
- Combine the increments to form a single sample.

## **Stockpiles**

### **Method A – Loader Sampling**

1. Direct the loader operator to enter the stockpile with the bucket at least 150 mm (6 in.) above ground level without contaminating the stockpile.
2. Discard the first bucketful.
3. Have the loader re-enter the stockpile and obtain a full loader bucket of the material, tilt the bucket back and up.
4. Form a small sampling pile at the base of the stockpile by gently rolling the material out of the bucket with the bucket just high enough to permit free-flow of the material. (Repeat as necessary.)
5. Create a flat surface by having the loader back drag the small pile.
6. Visually divide the flat surface into four quadrants.
7. Collect an increment from each quadrant by fully inserting the shovel into the flat pile as vertically as possible, take care to exclude the underlying material, roll back the shovel and lift the material slowly out of the pile to avoid material rolling off the shovel.

### **Method B – Stockpile Face Sampling**

1. Create horizontal surfaces with vertical faces in the top, middle, and bottom third of the stockpile with a shovel or loader.
2. Prevent continued sloughing by shoving a flat board against the vertical face. Sloughed material will be discarded to create the horizontal surface.
3. Obtain sample from the horizontal surface as close to the intersection as possible of the horizontal and vertical faces.
4. Obtain at least one increment of equal size from each of the top, middle, and bottom thirds of the pile.
5. Combine the increments to form a single sample.

### **Method C – Alternate Tube Method (Fine Aggregate)**

1. Remove the outer layer that may have become segregated.
2. Using a sampling tube, obtain one increment of equal size from a minimum of five random locations on the pile.
3. Combine the increments to form a single sample.

**Note 3:** Obtaining samples at stockpiles should be avoided whenever possible due to problems involved in obtaining a representative gradation of material.

**Identification and Shipping**

- Identify samples according to agency standards.
- Include sample report (below).
- Ship samples in containers that will prevent loss, contamination, or damage of material.

**Report**

- On forms approved by the agency
- Date
- Time
- Sample ID
- Sampling method
- Location
- Quantity represented
- Material type
- Supplier



**PERFORMANCE EXAM CHECKLIST****SAMPLING AGGREGATE PRODUCTS  
FOP FOR AASHTO R 90**

Participant Name \_\_\_\_\_ Exam Date \_\_\_\_\_

**Record the symbols “P” for passing or “F” for failing on each step of the checklist.**

<b>Procedure Element</b>	<b>Trial 1</b>	<b>Trial 2</b>
<b>Conveyor Belts – Method A (From the Belt)</b>		
1. Belt stopped?	_____	_____
2. Sampling template set on belt, avoiding intrusion of adjacent material?	_____	_____
3. Sample, including all fines, scooped off?	_____	_____
4. Samples taken in at least three approximately equal increments?	_____	_____
<b>Conveyor Belts – Method B (From the Belt Discharge)</b>		
5. Sampling device passed through full stream of material twice (once in each direction) as it runs off end of belt?	_____	_____
<b>Transport Units</b>		
6. Unit divided into four quadrants?	_____	_____
7. Increment obtained from each quadrant, 0.3 m (1ft.) below surface?	_____	_____
8. Increments combined to make up the sample?	_____	_____
<b>Roadways Method A (Berm or Windrow)</b>		
9. Sample taken before spreading?	_____	_____
10. Full depth of material taken?	_____	_____
11. Underlying material excluded?	_____	_____
12. Samples taken in at least three approximately equal increments?	_____	_____
<b>Roadways Method B (In-place)</b>		
13. Sample taken after spreading?	_____	_____
14. Full depth of material taken?	_____	_____
15. Underlying material excluded?	_____	_____
16. Samples taken in at least three approximately equal increments?	_____	_____

**OVER**

**Stockpile Method A– (Loader sampling)**

17. Loader operator directed to enter the stockpile with the bucket at least 150 mm (6 in.) above ground level without contaminating the stockpile? \_\_\_\_\_
18. First bucketful discarded? \_\_\_\_\_
19. The loader re-entered the stockpile and obtained a full loader bucket of the material with the bucket tilted back and up? \_\_\_\_\_
20. A small sampling pile formed at the base of the stockpile by gently rolling the material out of the bucket with the bucket just high enough to permit free-flow of the material? \_\_\_\_\_
21. A flat surface created by the loader back dragging the small pile? \_\_\_\_\_
22. Increment sampled from each quadrant by fully inserting the shovel into the flat pile as vertically as possible, care taken to exclude the underlying material? \_\_\_\_\_

**Stockpile Method B (Stockpile Face)**

23. Created horizontal surfaces with vertical faces? \_\_\_\_\_
24. At least one increment taken from each of the top, middle, and bottom thirds of the stockpile. \_\_\_\_\_

**Stockpile Method C – Alternate Tube Method (Fine Aggregate)**

25. Outer layer removed? \_\_\_\_\_
26. Increments taken from at least five locations with a sampling tube? \_\_\_\_\_

**General**

27. Increments mixed thoroughly to form sample? \_\_\_\_\_

Comments: First attempt: Pass\_\_\_\_ Fail\_\_\_\_ Second attempt: Pass\_\_\_\_ Fail\_\_\_\_

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Examiner Signature \_\_\_\_\_ WAQTC #: \_\_\_\_\_



**PERFORMANCE EXAM CHECKLIST (ORAL)****SAMPLING OF AGGREGATE PRODUCTS  
FOP FOR AASHTO R 90**

Participant Name \_\_\_\_\_ Exam Date \_\_\_\_\_

Record the symbols “P” for passing or “F” for failing on each step of the checklist.

<b>Procedure Element</b>	<b>Trial 1</b>	<b>Trial 2</b>
<b>1. How is a sample obtained from a conveyor belt using Method A?</b>		
a. Stop the belt.	_____	_____
b. Set the sampling template on belt, avoiding intrusion of adjacent material.	_____	_____
c. All the material is removed from belt including all fines.	_____	_____
d. Take at least approximately three equal increments.	_____	_____
<b>2. How is a sample obtained from a conveyor belt using Method B?</b>		
a. Pass the sampling device through a full stream of material as it runs off the end of the belt.	_____	_____
b. The device must be passed through at least twice (once in each direction).	_____	_____
<b>3. How is a sample obtained from a Transport Unit?</b>		
a. Divide the unit into four quadrants.	_____	_____
b. Dig 0.3 m (1 ft.) below surface.	_____	_____
c. Obtain an increment from each quadrant.	_____	_____
<b>4. Describe the procedure for sampling from roadways Method A (Berm or Windrow).</b>		
a. Sample before spreading	_____	_____
b. Sample the material full depth without obtaining underlying material.	_____	_____
c. Take at least three approximately equal increments.	_____	_____

**OVER**

Procedure Element	Trial 1	Trial 2
<b>5. Describe the procedure for sampling from roadway Method B (In-place).</b>		
a. Sample after spreading, before compaction.	_____	_____
b. Sample the material full depth without obtaining underlying material.	_____	_____
c. Take at least three approximately equal increments.	_____	_____
<b>6. Describe the procedure for sampling a stockpile Method A (Loader Sampling).</b>		
a. Loader removes contaminates and creates sampling pile.	_____	_____
b. Loader back drags pile to create a flat surface.	_____	_____
c. Divide the flat surface into four quadrants.	_____	_____
d. Take an approximately equal increment from each quadrant, excluding the underlying material.	_____	_____
<b>7. Describe the procedure for sampling a stockpile Method B (Stockpile Face Sampling).</b>		
a. Create horizontal surfaces with vertical faces with a shovel.	_____	_____
b. At least one increment taken from each of the top, middle, and bottom thirds of the stockpile.	_____	_____
<b>8. Describe the procedure for sampling a stockpile Method C – Alternate Tube Method (Fine Aggregate).</b>		
a. Remove the outer layer of segregated material.	_____	_____
b. Obtain increments from at least five locations.	_____	_____
<b>9. After obtaining the increments what should you do before performing R 76?</b>		
a. Increments mixed thoroughly to form sample.	_____	_____

Comments: First attempt: Pass\_\_\_\_\_Fail\_\_\_\_\_ Second attempt: Pass\_\_\_\_\_Fail\_\_\_\_\_

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Examiner Signature \_\_\_\_\_ WAQTC #: \_\_\_\_\_

## **REDUCING SAMPLES OF AGGREGATES TO TESTING SIZE FOP FOR AASHTO R 76**

### **Scope**

This procedure covers the reduction of samples to the appropriate size for testing in accordance with AASHTO R 76-16. Techniques are used that minimize variations in characteristics between test samples and field samples. Method A (Mechanical Splitter) and Method B (Quartering) are covered.

This FOP applies to fine aggregate (FA), coarse aggregate (CA), and mixes of the two (FA / CA) and may also be used on soils.

### **Apparatus**

#### **Method A – Mechanical Splitter**

Splitter chutes:

- Even number of equal width chutes
- Discharge alternately to each side
- Minimum of 8 chutes total for CA and FA / CA, 12 chutes total for FA
- Width:
  - Minimum 50 percent larger than largest particle
  - Maximum chute width of 19 mm (3/4 in.) for fine aggregate passing the 9.5 mm (3/8 in.) sieve

Feed control:

- Hopper or straightedge pan with a width equal to or slightly less than the overall width of the assembly of chutes
- Capable of feeding the splitter at a controlled rate

Splitter receptacles / pans:

- Capable of holding two halves of the sample following splitting

The splitter and accessory equipment shall be so designed that the sample will flow smoothly without restriction or loss of material.

### Method B – Quartering

- Straightedge scoop, shovel, or trowel
- Broom or brush
- Canvas or plastic sheet, approximately 2 by 3 m (6 by 9 ft)

### Method Selection

Samples of CA may be reduced by either Method A or Method B.

Samples of FA which are drier than the saturated surface dry (SSD) condition, as described in AASHTO T 84, shall be reduced by a mechanical splitter according to Method A. As a quick approximation, if the fine aggregate will retain its shape when molded with the hand, it is wetter than SSD.

Samples of FA / CA which are drier than SSD may be reduced by Method A or Method B.

Samples of FA and FA / CA that are at SSD or wetter than SSD shall be reduced by Method B, or the entire sample may be dried to the SSD condition – using temperatures that do not exceed those specified for any of the tests contemplated – and then reduced to test sample size using Method A.

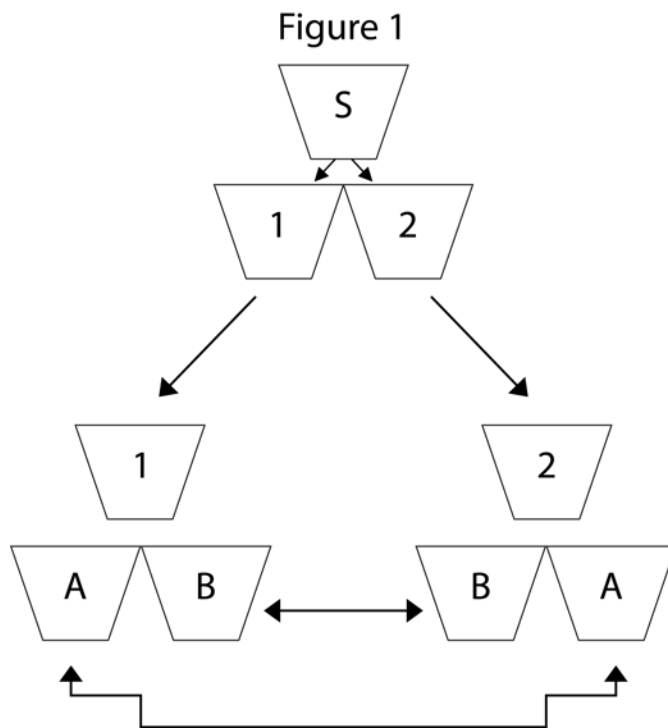
**Table 1**

	<b>Drier than SSD</b>	<b>Wetter than SSD</b>
Fine Aggregate (FA)	Method A (Mechanical)	Method B (Quartering)
Mixture of FA/CA	Either Method	Method B (Quartering)
Coarse Aggregate (CA)	Either Method	Either Method

## Procedure

### Method A – Mechanical Splitter

1. Place the sample in the hopper or pan and uniformly distribute it from edge to edge so that approximately equal amounts flow through each chute. The rate at which the sample is introduced shall be such as to allow free flowing through the chutes into the pans below.
2. Reduce the sample from one of the two pans as many times as necessary to reduce the sample to meet the minimum size specified for the intended test. The portion of the material collected in the other pan may be reserved for reduction in size for other tests.
3. As a check for effective reduction, determine the mass of each reduced portion. If the percent difference of the two masses is greater than 5 percent, corrective action must be taken. In lieu of the check for effective reduction, use the method illustrated in Figure 1.



- Sample (S) is an amount greater than or equal to twice the mass needed for testing. Sample (S) is reduced in a mechanical splitter to yield parts (1) and (2).
- Part (1) is further reduced yielding (A) and (B) while part (2) is reduced to yield (B) and (A).
- Final testing sample is produced by combining alternate pans, i.e. A/A or B/B only.

## Calculation

$$\frac{\text{Smaller Mass}}{\text{Larger Mass}} = \text{Ratio} \quad (1 - \text{ratio}) \times 100 = \% \text{ Difference}$$

Splitter check: 5127 g total sample mass

Splitter pan #1: 2583 g

Splitter pan #2: 2544 g

$$\frac{2544 \text{ g}}{2583 \text{ g}} = 0.985 \quad (1 - 0.985) \times 100 = 1.5\%$$

## Procedure

### Method B – Quartering

Use either of the following two procedures or a combination of both.

#### Procedure 1: Quartering on a clean, hard, level surface:

1. Place the sample on a hard, clean, level surface where there will be neither loss of material nor the accidental addition of foreign material.
2. Mix the material thoroughly by turning the entire sample over a minimum of four times. With the last turning, shovel the entire sample into a conical pile by depositing each shovelful on top of the preceding one.
3. Flatten the conical pile to a uniform thickness and diameter by pressing down with a shovel. The diameter should be four to eight times the thickness.
4. Divide the flattened pile into four approximately equal quarters with a shovel or trowel.
5. Remove two diagonally opposite quarters, including all fine material, and brush the cleared spaces clean.
6. Successively mix and quarter the remaining material until the sample is reduced to the desired size.
7. The final test sample consists of two diagonally opposite quarters.

**Procedure 2: Quartering on a canvas or plastic sheet:**

1. Place the sample on the sheet.
2. Mix the material thoroughly a minimum of four times by pulling each corner of the sheet horizontally over the sample toward the opposite corner. After the last turn, form a conical pile.
3. Flatten the conical pile to a uniform thickness and diameter by pressing down with a shovel. The diameter should be four to eight times the thickness.
4. Divide the flattened pile into four approximately equal quarters with a shovel or trowel, or, insert a stick or pipe beneath the sheet and under the center of the pile, then lift both ends of the stick, dividing the sample into two roughly equal parts. Remove the stick leaving a fold of the sheet between the divided portions. Insert the stick under the center of the pile at right angles to the first division and again lift both ends of the stick, dividing the sample into four roughly equal quarters.
5. Remove two diagonally opposite quarters, being careful to clean the fines from the sheet.
6. Successively mix and quarter the remaining material until the sample size is reduced to the desired size.
7. The final test sample consists of two diagonally opposite quarters.





**PERFORMANCE EXAM CHECKLIST****REDUCING FIELD SAMPLES OF AGGREGATES TO TESTING SIZE  
FOP FOR AASHTO R 76**

Participant Name \_\_\_\_\_ Exam Date \_\_\_\_\_

**Record the symbols "P" for passing or "F" for failing on each step of the checklist.****Trial 1   Trial 2****Method A - Splitting**

- |   |       |       |
|---|-------|-------|
| 1. Chutes appropriate size and number?                                  | _____ | _____ |
| 2. Material spread uniformly on feeder?                                 | _____ | _____ |
| 3. Rate of feed slow enough so that sample flows freely through chutes? | _____ | _____ |
| 4. Material in one pan re-split until desired mass is obtained?         | _____ | _____ |

**Method B - Quartering**

- |   |       |       |
|---|-------|-------|
| 1. Sample placed on clean, hard, and level surface?   | _____ | _____ |
| 2. Mixed by turning over 4 times with shovel or by pulling sheet horizontally over pile?        | _____ | _____ |
| 3. Conical pile formed without loss of material?  | _____ | _____ |
| 4. Pile flattened to uniform thickness and diameter?  | _____ | _____ |
| 5. Diameter equal to about 4 to 8 times thickness?  | _____ | _____ |
| 6. Divided into 4 equal portions with shovel or trowel without loss of material?                | _____ | _____ |
| 7. Two diagonally opposite quarters, including all fine material, removed?                      | _____ | _____ |
| 8. Process continued until desired sample size is obtained when two opposite quarters combined? | _____ | _____ |

*The sample may be placed upon a sheet and a stick or pipe may be placed under the sheet to divide the pile into quarters.*

Comments:      First attempt:    Pass\_\_\_\_Fail\_\_\_\_      Second attempt:    Pass\_\_\_\_Fail\_\_\_\_

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**Examiner Signature** \_\_\_\_\_ **WAQTC #:** \_\_\_\_\_



## **TOTAL EVAPORABLE MOISTURE CONTENT OF AGGREGATE BY DRYING FOP FOR AASHTO T 255**

### **Scope**

This procedure covers the determination of moisture content of aggregate in accordance with AASHTO T 255-00. It may also be used for other construction materials.

### **Overview**

Moisture content is determined by comparing the wet mass of a sample and the mass of the sample after drying to constant mass. The term constant mass is used to define when a sample is dry.

*Constant mass* – the state at which a mass does not change more than a given percent, after additional drying for a defined time interval, at a required temperature.

### **Apparatus**

- Balance or scale: Capacity sufficient for the principle sample mass, accurate to 0.1 percent of sample mass or readable to 0.1 g, meeting the requirements of AASHTO M 231.
- Containers: clean, dry and capable of being sealed
- Suitable drying containers
- Microwave safe container with ventilated lids
- Heat source, controlled
  - Forced draft oven
  - Ventilated oven
  - Convection oven
- Heat source, uncontrolled
  - Infrared heater, hot plate, fry pan, or any other device/method that will dry the sample without altering the material being dried
  - Microwave oven (900 watts minimum)
- Hot pads or gloves
- Utensils such as spoons

## Sample Preparation

In accordance with the FOP for AASHTO R 90 obtain a representative sample in its existing condition. The representative sample size is based on Table 1 or other information that may be specified by the agency.

**TABLE 1**  
**Sample Sizes for Moisture Content of Aggregate**

<b>Nominal Maximum Size* mm (in.)</b>	<b>Minimum Sample Mass g (lb)</b>
150 (6)	50,000 (110)
100 (4)	25,000 (55)
90 (3 1/2)	16,000 (35)
75 (3)	13,000 (29)
63 (2 1/2)	10,000 (22)
50 (2)	8000 (18)
37.5 (1 1/2)	6000 (13)
25.0 (1)	4000 (9)
19.0 (3/4)	3000 (7)
12.5 (1/2)	2000 (4)
9.5 (3/8)	1500 (3.3)
4.75 (No. 4)	500 (1.1)

\* One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Immediately seal or cover samples to prevent any change in moisture content or follow the steps in “Procedure.”

## Procedure

Determine all masses to the nearest 0.1 percent of the sample mass or to the nearest 0.1 g.

When determining the mass of hot samples or containers or both, place and tare a buffer between the sample container and the balance. This will eliminate damage to or interference with the operation of the balance or scale.

1. Determine and record the mass of the container (and lid for microwave drying).
2. Place the wet sample in the container.
  - a. For oven(s), hot plates, infrared heaters, etc.: Spread the sample in the container.
  - b. For microwave oven: Heap sample in the container; cover with ventilated lid.
3. Determine and record the total mass of the container and wet sample.
4. Determine and record the wet mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 3.
5. Place the sample in one of the following drying apparatus:
  - a. Controlled heat source (oven): at  $110 \pm 5^{\circ}\text{C}$  ( $230 \pm 9^{\circ}\text{F}$ ).
  - b. Uncontrolled heat source (Hot plate, infrared heater, etc.): Stir frequently to avoid localized overheating.
6. Dry until sample appears moisture free.
7. Determine mass of sample and container.
8. Determine and record the mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 7.
9. Return sample and container to the heat source for additional drying.
  - a. Controlled (oven): 30 minutes
  - b. Uncontrolled (Hot plate, infrared heater, etc.): 10 minutes
  - c. Uncontrolled (Microwave oven): 2 minutes

**Caution:** Some minerals in the sample may cause the aggregate to overheat, altering the aggregate gradation.

10. Determine mass of sample and container.

11. Determine and record the mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 10.
12. Determine percent change by subtracting the new mass determination ( $M_n$ ) from the previous mass determination ( $M_p$ ) divide by the previous mass determination ( $M_p$ ) multiply by 100.
13. Continue drying, performing steps 9 through 12, until there is less than a 0.10 percent change after additional drying time.
14. Constant mass has been achieved; sample is defined as dry.
15. Allow the sample to cool. Determine and record the total mass of the container and dry sample.
16. Determine and record the dry mass of the sample by subtracting the mass of the container determined in Step 1 from the mass of the container and sample determined in Step 15.
17. Determine and record percent moisture (w) by subtracting the final dry mass determination ( $M_D$ ) from the initial wet mass determination ( $M_W$ ) divide by the final dry mass determination ( $M_D$ ) multiply by 100.

**Table 2**  
**Methods of Drying**

Heat Source	Specific Instructions	Drying intervals to achieve constant mass (minutes)
<b>Controlled:</b> Forced Draft Oven (preferred), Ventilated Oven, or Convection Oven	$110 \pm 5^{\circ}\text{C}$ ( $230 \pm 9^{\circ}\text{F}$ )	30
<b>Uncontrolled:</b>		
Hot plate, Infrared heater, etc.	Stir frequently	10
Microwave	Heap sample and cover with ventilated lid	2

**Calculation****Constant Mass:**

Calculate constant mass using the following formula:

$$\% \text{ Change} = \frac{M_p - M_n}{M_p} \times 100$$

where:

$M_p$  = previous mass measurement

$M_n$  = new mass measurement

**Example:**

Mass of container: 1232.1 g

Mass of container after first drying cycle: 2637.2 g

Mass,  $M_p$ , of possibly dry sample: 2637.2 g - 1232.1 g = 1405.1 g

Mass of container and dry sample after second drying cycle: 2634.1 g

Mass,  $M_n$ , of dry sample: 2634.1 g - 1232.1 g = 1402.0 g

$$\% \text{ Change} = \frac{1405.1 \text{ g} - 1402.0 \text{ g}}{1405.1 \text{ g}} \times 100 = 0.22\%$$

*0.22 percent is not less than 0.10 percent, so continue drying*

Mass of container and dry sample after third drying cycle: 2633.0 g

Mass,  $M_n$ , of dry sample: 2633.0 g - 1232.1 g = 1400.9 g

$$\% \text{ Change} = \frac{1402.0 \text{ g} - 1400.9 \text{ g}}{1402.0 \text{ g}} \times 100 = 0.08\%$$

*0.08 percent is less than 0.10 percent, so constant mass has been reached*

**Moisture Content:**

Calculate the moisture content,  $w$ , as a percent, using the following formula:

$$w = \frac{M_W - M_D}{M_D} \times 100$$

where:

$w$  = moisture content, percent

$M_W$  = wet mass

$M_D$  = dry mass

**Example:**

Mass of container: 1232.1 g

Mass of container and wet sample: 2764.7 g

Mass,  $M_W$ , of wet sample:  $2764.7 \text{ g} - 1232.1 \text{ g} = 1532.6 \text{ g}$

Mass of container and dry sample (COOLED): 2633.5 g

Mass,  $M_D$ , of dry sample:  $2633.5 \text{ g} - 1232.1 \text{ g} = 1401.4 \text{ g}$

$$w = \frac{1532.6 \text{ g} - 1401.4 \text{ g}}{1401.4 \text{ g}} \times 100 = \frac{131.7 \text{ g}}{1401.4 \text{ g}} = 9.40\% \text{ report } 9.4\%$$

**Report**

- Results on forms approved by the agency
- Sample ID
- $M_W$ , wet mass
- $M_D$ , dry mass
- Moisture content to the nearest 0.1 percent



**PERFORMANCE EXAM CHECKLIST**  
**TOTAL MOISTURE CONTENT OF AGGREGATE BY DRYING**  
**FOP FOR AASHTO T 255**

Participant Name \_\_\_\_\_ Exam Date \_\_\_\_\_

**Record the symbols “P” for passing or “F” for failing on each step of the checklist.**

<b>Procedure Element</b>	<b>Trial 1</b>	<b>Trial 2</b>
1. Representative sample of appropriate mass obtained?	_____	_____
2. Mass of container determined to 0.1 percent or 0.1 g?	_____	_____
3. Sample placed in container and wet mass determined to 0.1 percent or 0.1 g?	_____	_____
4. Test sample mass conforms to the required mass?	_____	_____
5. Loss of moisture avoided prior to mass determination?	_____	_____
6. Sample dried by a suitable heat source?	_____	_____
7. If aggregate heated by means other than a controlled oven, is sample stirred to avoid localized overheating?	_____	_____
8. If heated in a microwave, heaped and covered with a ventilated lid	_____	_____
9. Is aggregate heated for the additional, specified time?	_____	_____
a. Forced draft, ventilated, convection ovens – 30 minutes		
b. Microwave – 2 minutes		
c. Other – 10 minutes		
10. Mass determined and compared to previous mass – showing less than 0.10 percent loss?	_____	_____
11. Sample cooled before dry mass determination to 0.1 percent or 0.1 g?	_____	_____
12. Calculations performed properly, and results reported to the nearest 0.1 percent?	_____	_____

**Comments:**      First attempt: Pass \_\_\_\_\_ Fail \_\_\_\_\_      Second attempt: Pass \_\_\_\_\_ Fail \_\_\_\_\_

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**Examiner Signature** \_\_\_\_\_ **WAQTC #:** \_\_\_\_\_



**SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES**  
**FOP FOR AASHTO T 27**  
**MATERIALS FINER THAN 75  $\mu\text{m}$  (NO. 200) SIEVE IN MINERAL AGGREGATE**  
**BY WASHING**  
**FOP FOR AASHTO T 11**

**Scope**

A sieve analysis, or ‘gradation,’ measures distribution of aggregate particle sizes within a given sample.

Accurate determination of the amount of material smaller than 75  $\mu\text{m}$  (No. 200) cannot be made using just AASHTO T 27. If quantifying this material is required, use AASHTO T 11 in conjunction with AASHTO T 27.

This FOP covers sieve analysis in accordance with AASHTO T 27-14 and materials finer than 75  $\mu\text{m}$  (No. 200) in accordance with AASHTO T 11-05 performed in conjunction with AASHTO T 27. The procedure includes three methods: A, B, and C.

**Apparatus**

- Balance or scale: Capacity sufficient for the masses shown in Table 1, accurate to 0.1 percent of the sample mass or readable to 0.1 g, and meeting the requirements of AASHTO M 231
- Sieves: Meeting the requirements of ASTM E11
- Mechanical sieve shaker: Meeting the requirements of AASHTO T 27
- Suitable drying equipment (refer to FOP for AASHTO T 255)
- Containers and utensils: A pan or vessel of sufficient size to contain the sample covered with water and permit vigorous agitation without loss of material or water
- Optional
  - Mechanical washing device
  - Mallet: With a rubber or rawhide head having a mass of  $0.57 \pm 0.23$  kg ( $1.25 \pm 0.5$  lb)

**Sample Sieving**

- In all procedures, the sample is shaken in nested sieves. Sieves are selected to furnish information required by specification. Intermediate sieves are added for additional information or to avoid overloading sieves, or both.
- The sieves are nested in order of increasing size from the bottom to the top, and the sample, or a portion of the sample, is placed on the top sieve.
- The loaded sieves are shaken in a mechanical shaker for approximately 10 minutes, refer to Annex A; *Time Evaluation*.

- Care must be taken so that sieves are not overloaded, refer to Annex B; *Overload Determination*. The sample may be sieved in increments and the mass retained for each sieve added together from each sample increment to avoid overloading sieves.

### Sample Preparation

Obtain samples according to the FOP for AASHTO R 90 and reduce to sample size, shown in Table 1, according to the FOP for AASHTO R 76.

**TABLE 1**  
**Sample Sizes for Aggregate Gradation Test**

Nominal Maximum Size* mm (in.)		Minimum Dry Mass g (lb)	
125	(5)	300,000	(660)
100	(4)	150,000	(330)
90	(3 1/2)	100,000	(220)
75	(3)	60,000	(130)
63	(2 1/2)	35,000	(77)
50	(2)	20,000	(44)
37.5	(1 1/2)	15,000	(33)
25.0	(1)	10,000	(22)
19.0	(3/4)	5000	(11)
12.5	(1/2)	2000	(4)
9.5	(3/8)	1000	(2)
6.3	(1/4)	1000	(2)
4.75	(No. 4)	500	(1)

\*Nominal maximum size: One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps between specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Sample sizes in Table 1 are standard for aggregate sieve analysis, due to equipment restraints samples may need to be divided into several “subsamples.” For example, a gradation that requires 100 kg (220 lbs.) of material would not fit into a large tray shaker all at once.

Some agencies permit reduced sample sizes if it is proven that doing so is not detrimental to the test results. Some agencies require larger sample sizes. Check agency guidelines for required or permitted sample sizes.

**Selection of Procedure**

Agencies may specify which method to perform. If a method is not specified, perform Method A.

**Overview****Method A**

- Determine original dry mass of the sample
- Wash over a 75µm (No. 200) sieve
- Determine dry mass of washed sample
- Sieve washed sample
- Calculate and report percent retained and passing each sieve

**Method B**

- Determine original dry mass of the sample
- Wash over a 75 µm (No. 200) sieve
- Determine dry mass of washed sample
- Sieve sample through coarse sieves, 4.75 mm (No. 4) sieves and larger
- Determine mass of fine material, minus 4.75 mm (No. 4)
- Reduce fine material
- Determine mass of reduced portion
- Sieve reduced portion
- Calculate and report percent retained and passing each sieve

**Method C**

- Determine original dry mass of the sample
- Sieve sample through coarse sieves, 4.75 mm (No. 4) sieves and larger
- Determine mass of fine material, minus 4.75 mm (No. 4)
- Reduce fine material
- Determine mass of reduced portion
- Wash reduced portion over a 75µm (No. 200) sieve
- Determine dry mass of washed reduced portion
- Sieve washed reduced portion
- Calculate and report percent retained and passing each sieve

## Procedure Method A

1. Dry the sample to constant mass according to the FOP for AASHTO T 255. Cool to room temperature. Determine and record the original dry mass of the sample to the nearest 0.1 percent or 0.1 g. Designate this mass as *M*.

When the specification does not require the amount of material finer than 75  $\mu\text{m}$  (No. 200) be determined by washing, skip to Step 11.

2. Nest a sieve, such as a 2.0 mm (No. 10), above the 75  $\mu\text{m}$  (No. 200) sieve.
3. Place the sample in a container and cover with water.

**Note 1:** A detergent, dispersing agent, or other wetting solution may be added to the water to assure a thorough separation of the material finer than the 75  $\mu\text{m}$  (No. 200) sieve from the coarser particles. There should be enough wetting agent to produce a small amount of suds when the sample is agitated. Excessive suds may overflow the sieves and carry material away with them.

4. Agitate vigorously to ensure complete separation of the material finer than 75  $\mu\text{m}$  (No. 200) from coarser particles and bring the fine material into suspension above the coarser material. Avoid degradation of the sample when using a mechanical washing device.
5. Immediately pour the wash water containing the suspended material over the nested sieves; be careful not to pour out the coarser particles or over fill the 75  $\mu\text{m}$  (No. 200) sieve.
6. Add water to cover material remaining in the container, agitate, and repeat Step 5. Continue until the wash water is reasonably clear.
7. Remove the upper sieve and return material retained to the washed sample.
8. Rinse the material retained on the 75  $\mu\text{m}$  (No. 200) sieve until water passing through the sieve is reasonably clear and detergent or dispersing agent is removed, if used.
9. Return all material retained on the 75  $\mu\text{m}$  (No. 200) sieve to the container by rinsing into the washed sample.

**Note 2:** Excess water may be carefully removed with a bulb syringe; the removed water must be discharged back over the 75  $\mu\text{m}$  (No. 200) sieve to prevent loss of fines.

10. Dry the washed sample to constant mass according to the FOP for AASHTO T 255. Cool to room temperature. Determine and record the dry mass of the sample.
11. Select sieves required by the specification and those necessary to avoid overloading. With a pan on bottom, nest the sieves increasing in size starting with the 75  $\mu\text{m}$  (No. 200).
12. Place the washed sample, or a portion of the washed sample, on the top sieve. Sieves may already be in the mechanical shaker, if not place sieves in mechanical shaker and shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).

**Note 3:** Excessive shaking (more than 10 minutes) may result in degradation of the sample.

13. Determine and record the individual or cumulative mass retained for each sieve and in the pan. Ensure that all material trapped in full openings of the sieve are removed and included in the mass retained.

**Note 4:** For sieves 4.75 mm (No. 4) and larger, check material trapped in less than a full opening by sieving over a full opening. Use coarse wire brushes to clean the 600 µm (No. 30) and larger sieves, and soft bristle brushes for smaller sieves.

**Note 5:** In the case of coarse / fine aggregate mixtures, distribute the minus 4.75 mm (No. 4) among two or more sets of sieves to prevent overloading of individual sieves.

14. Perform the *Check Sum* calculation – Verify the *total mass after sieving* agrees with the *dry mass before sieving* to within 0.3 percent. The *dry mass before sieving* is the dry mass after wash or the original dry mass (*M*) if performing the sieve analysis without washing. Do not use test results for acceptance if the *Check Sum* result is greater than 0.3 percent.
15. Calculate the total percentages passing, and the individual or cumulative percentages retained to the nearest 0.1 percent by dividing the individual sieve masses or cumulative sieve masses by the original dry mass (*M*) of the sample.
16. Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

## Method A Calculations

### Check Sum

$$\text{Check Sum} = \frac{\text{dry mass before sieving} - \text{total mass after sieving}}{\text{dry mass before sieving}} \times 100$$

### Percent Retained

$$\text{IPR} = \frac{\text{IMR}}{M} \times 100 \quad \text{or} \quad \text{CPR} = \frac{\text{CMR}}{M} \times 100$$

Where:

IPR	=	Individual Percent Retained
CPR	=	Cumulative Percent Retained
M	=	Original dry mass of the sample
IMR	=	Individual Mass Retained
CMR	=	Cumulative Mass Retained

**Percent Passing (PP)**

$$PP = PPP - IPR \quad \text{or} \quad PP = 100 - CPR$$

Where:

PP = Percent Passing

PPP = Previous Percent Passing

**Method A Example Individual Mass Retained**

Original dry mass of the sample (*M*): 5168.7 g

Dry mass of the sample after washing: 4911.3 g

Total mass after sieving equals

Sum of Individual Masses Retained (IMR),  
including minus 75  $\mu$ m (No. 200) in the pan: 4905.9 g

Amount of 75 $\mu$ m (No. 200) minus washed out (5168.7 g – 4911.3 g): 257.4 g

**Check Sum**

$$Check\ Sum = \frac{4911.3\ g - 4905.9\ g}{4911.3\ g} \times 100 = 0.1\%$$

The result is less than 0.3 percent therefore the results can be used for acceptance purposes.

**Individual Percent Retained (IPR) for 9.5 mm (3/8 in.) sieve:**

$$IPR = \frac{619.2\ g}{5168.7\ g} \times 100 = 12.0\%$$

**Percent Passing (PP) 9.5 mm (3/8 in.) sieve:**

$$PP = 86.0\% - 12.0\% = 74.0\%$$

**Reported Percent Passing = 74%**



**Method A Individual  
Gradation on All Sieves**

Sieve Size mm (in.)	Individual Mass Retained g (IMR)	Determine IPR Divide IMR by <i>M</i> and multiply by 100	Individual Percent Retained (IPR)	Determine PP by subtracting IPR from Previous PP	Percent Passing (PP)	Reported Percent Passing*
19.0 (3/4)	0		0		100.0	100
12.5 (1/2)	724.7	$\frac{724.7}{5168.7} \times 100 =$	14.0	$100.0 - 14.0 =$	86.0	86
9.5 (3/8)	619.2	$\frac{619.2}{5168.7} \times 100 =$	12.0	$86.0 - 12.0 =$	74.0	74
4.75 (No. 4)	1189.8	$\frac{1189.8}{5168.7} \times 100 =$	23.0	$74.0 - 23.0 =$	51.0	51
2.36 (No. 8)	877.6	$\frac{877.6}{5168.7} \times 100 =$	17.0	$51.0 - 17.0 =$	34.0	34
1.18 (No. 16)	574.8	$\frac{574.8}{5168.7} \times 100 =$	11.1	$34.0 - 11.1 =$	22.9	23
0.600 (No. 30)	329.8	$\frac{329.8}{5168.7} \times 100 =$	6.4	$22.9 - 6.4 =$	16.5	17
0.300 (No. 50)	228.5	$\frac{228.5}{5168.7} \times 100 =$	4.4	$16.5 - 4.4 =$	12.1	12
0.150 (No. 100)	205.7	$\frac{205.7}{5168.7} \times 100 =$	4.0	$12.1 - 4.0 =$	8.1	8
0.075 (No. 200)	135.4	$\frac{135.7}{5168.7} \times 100 =$	2.6	$8.1 - 2.6 =$	5.5	5.5
minus 0.075 (No. 200) in the pan	20.4					
Total mass after sieving = sum of sieves + mass in the pan = 4905.9 g						
Original dry mass of the sample ( <i>M</i> ): 5168.7g						

\* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

**Method A Example Cumulative Mass Retained**

Original dry mass of the sample ( $M$ ): 5168.7 g

Dry mass of the sample after washing: 4911.3 g

Total mass after sieving equals Final Cumulative Mass Retained  
(FCMR) (includes minus 75  $\mu\text{m}$  (No. 200) from the pan): 4905.9 g

Amount of 75 $\mu\text{m}$  (No. 200) minus washed out (5168.7 g – 4911.3 g): 257.4 g

**Check Sum**

$$\text{Check Sum} = \frac{4911.3 \text{ g} - 4905.9 \text{ g}}{4911.3 \text{ g}} \times 100 = 0.1\%$$

The result is less than 0.3 percent therefore the results can be used for acceptance purposes.

**Cumulative Percent Retained (CPR) for 9.5 mm (3/8 in.) sieve:**

$$\text{CPR} = \frac{1343.9 \text{ g}}{5168.7 \text{ g}} \times 100 = 26.0\%$$

**Percent Passing (PP) 9.5 mm (3/8 in.) sieve:**

$$\text{PP} = 100.0\% - 26.0\% = 74.0\%$$

**Reported Percent Passing = 74%**

**Method A Cumulative  
Gradation on All Sieves**

Sieve Size mm (in.)	Cumulative Mass Retained g (CMR)	Determine CPR Divide CMR by M and multiply by 100	Cumulative Percent Retained (CPR)	Determine PP by subtracting CPR from 100.0	Percent Passing (PP)	Reported Percent Passing*
19.0 (3/4)	0		0.0		100.0	100
12.5 (1/2)	724.7	$\frac{724.7}{5168.7} \times 100 =$	14.0	$100.0 - 14.0 =$	86.0	86
9.5 (3/8)	1343.9	$\frac{1343.9}{5168.7} \times 100 =$	26.0	$100.0 - 26.0 =$	74.0	74
4.75 (No. 4)	2533.7	$\frac{2533.7}{5168.7} \times 100 =$	49.0	$100.0 - 49.0 =$	51.0	51
2.36 (No. 8)	3411.3	$\frac{3411.3}{5168.7} \times 100 =$	66.0	$100.0 - 66.0 =$	34.0	34
1.18 (No. 16)	3986.1	$\frac{3986.1}{5168.7} \times 100 =$	77.1	$100.0 - 77.1 =$	22.9	23
0.600 (No. 30)	4315.9	$\frac{4315.9}{5168.7} \times 100 =$	83.5	$100.0 - 83.5 =$	16.5	17
0.300 (No. 50)	4544.4	$\frac{4544.4}{5168.7} \times 100 =$	87.9	$100.0 - 87.9 =$	12.1	12
0.150 (No. 100)	4750.1	$\frac{4750.1}{5168.7} \times 100 =$	91.9	$100.0 - 91.9 =$	8.1	8
0.075 (No. 200)	4885.5	$\frac{4885.5}{5168.7} \times 100 =$	94.5	$100.0 - 94.5 =$	5.5	5.5
FCMR	4905.9					
Total mass after sieving: 4905.9 g						
Original dry mass of the sample (M): 5168.7 g						

\* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

**Procedure Method B**

1. Dry the sample to constant mass according to the FOP for AASHTO T 255. Cool to room temperature. Determine and record the original dry mass of the sample to the nearest 0.1 percent or 0.1 g. Designate this mass as *M*.

When the specification does not require the amount of material finer than 75  $\mu\text{m}$  (No. 200) be determined by washing, skip to Step 11.

2. Nest a protective sieve, such as a 2.0 mm (No. 10), above the 75  $\mu\text{m}$  (No. 200) sieve.
3. Place the sample in a container and cover with water.

**Note 1:** A detergent, dispersing agent, or other wetting solution may be added to the water to assure a thorough separation of the material finer than the 75  $\mu\text{m}$  (No. 200) sieve from the coarser particles. There should be enough wetting agent to produce a small amount of suds when the sample is agitated. Excessive suds may overflow the sieves and carry material away with them.

4. Agitate vigorously to ensure complete separation of the material finer than 75  $\mu\text{m}$  (No. 200) from coarser particles and bring the fine material into suspension above the coarser material. Avoid degradation of the sample when using a mechanical washing device.
5. Immediately pour the wash water containing the suspended material over the nested sieves; be careful not to pour out the coarser particles or over fill the 75  $\mu\text{m}$  (No. 200) sieve.
6. Add water to cover material remaining in the container, agitate, and repeat Step 5. Continue until the wash water is reasonably clear.
7. Remove the upper sieve and return material retained to the washed sample.
8. Rinse the material retained on the 75  $\mu\text{m}$  (No. 200) sieve until water passing through the sieve is reasonably clear and detergent or dispersing agent is removed, if used.
9. Return all material retained on the 75  $\mu\text{m}$  (No. 200) sieve to the container by rinsing into the washed sample.

**Note 2:** Excess water may be carefully removed with a bulb syringe; the removed water must be discharged back over the 75  $\mu\text{m}$  (No. 200) sieve to prevent loss of fines.

10. Dry the washed sample to constant mass according to the FOP for AASHTO T 255. Cool to room temperature. Determine and record the dry mass after wash.
11. Select sieves required by the specification and those necessary to avoid overloading. With a pan on bottom, nest the sieves increasing in size starting with the 4.75 mm (No. 4).
12. Place the washed sample, or a portion of the washed sample, on the top sieve. Sieves may already be in the mechanical shaker, if not place the sieves in the mechanical shaker and shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).

**Note 3:** Excessive shaking (more than 10 minutes) may result in degradation of the sample.

13. Determine and record the individual or cumulative mass retained for each sieve. Ensure that all particles trapped in full openings of the sieve are removed and included in the mass retained.

**Note 4:** For sieves 4.75 mm (No. 4) and larger, check material trapped in less than a full opening by sieving over a full opening. Use coarse wire brushes to clean the 600  $\mu\text{m}$  (No. 30) and larger sieves, and soft hair bristle for smaller sieves.

14. Determine and record the mass of the minus 4.75 mm (No. 4) material in the pan. Designate this mass as  $M_1$ .
  15. Perform the *Coarse Check Sum* calculation – Verify the *total mass after coarse sieving* agrees with the *dry mass before sieving* to within 0.3 percent. The *dry mass before sieving* is the dry mass after wash or the original dry mass ( $M$ ) if performing the sieve analysis without washing. Do not use test results for acceptance if the *Check Sum* result is greater than 0.3 percent.
  16. Reduce the minus 4.75 mm (No. 4) according to the FOP for AASHTO R 76 to produce a sample with a minimum mass of 500 g. Determine and record the mass of the minus 4.75 mm (No. 4) split, designate this mass as  $M_2$ .
  17. Select sieves required by the specification and those necessary to avoid overloading. With a pan on bottom, nest the sieves increasing in size starting with the 75  $\mu\text{m}$  (No. 200) up to, but not including, the 4.75 mm (No. 4) sieve.
  18. Place the sample portion on the top sieve and place the sieves in the mechanical shaker. Shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).
  19. Determine and record the individual or cumulative mass retained for each sieve and in the pan. Ensure that all particles trapped in full openings of the sieve are removed and included in the mass retained.
- Note 4:** For sieves 4.75 mm (No. 4) and larger, check material trapped in less than a full opening by sieving over a full opening. Use coarse wire brushes to clean the 600  $\mu\text{m}$  (No. 30) and larger sieves, and soft hair bristle for smaller sieves.
20. Perform the *Fine Check Sum* calculation – Verify the *total mass after sieving* agrees with the *dry mass before sieving* ( $M_2$ ) to within 0.3 percent. Do not use test results for acceptance if the *Check Sum* result is greater than 0.3 percent.
  21. Calculate to the nearest 0.1 percent, the Individual Mass Retained (IMR) or Cumulative Mass Retained (CMR) of the size increment of the reduced sample and the original sample.
  22. Calculate the total percent passing.
  23. Report total percent passing to 1 percent except report the 75  $\mu\text{m}$  (No. 200) sieve to 0.1 percent.

**Method B Calculations****Check Sum**

$$\text{Coarse Check Sum} = \frac{\text{dry mass before sieving} - \text{total mass after coarse sieving}}{\text{dry mass before sieving}} \times 100$$

$$\text{Fine Check Sum} = \frac{M_2 - \text{total mass after fine sieving}}{M_2} \times 100$$

**Percent Retained for 4.75 mm (No. 4) and larger**

$$IPR = \frac{IMR}{M} \times 100 \quad \text{or} \quad CPR = \frac{CMR}{M} \times 100$$

Where:

IPR	=	Individual Percent Retained
CPR	=	Cumulative Percent Retained
M	=	Original dry mass of the sample
IMR	=	Individual Mass Retained
CMR	=	Cumulative Mass Retained

**Percent Passing (PP) for 4.75 mm (No. 4) and larger**

$$PP = PPP - IPR \quad \text{or} \quad PP = 100 - CPR$$

Where:

PP	=	Percent Passing
PPP	=	Previous Percent Passing

**Minus 4.75mm (No. 4) adjustment factor (R)**

The mass of material retained for each sieve is multiplied by the adjustment factor, the total mass of the minus 4.75 mm (No. 4) from the pan,  $M_1$ , divided by the mass of the reduced split of minus 4.75 mm (No. 4),  $M_2$ . For consistency, this adjustment factor is carried to three decimal places.

$$R = \frac{M_1}{M_2}$$

where:

- R = minus 4.75 mm (No. 4) adjustment factor
- $M_1$  = total mass of minus 4.75 mm (No. 4) before reducing
- $M_2$  = mass of the reduced split of minus 4.75 mm (No. 4)

**Adjusted Individual Mass Retained (AIMR):**

$$AIMR = R \times B$$

where:

- AIMR = Adjusted Individual Mass Retained
- R = minus 4.75 mm (No. 4) adjustment factor
- B = individual mass of the size increment in the reduced portion sieved

**Adjusted Cumulative Mass Retained (ACMR)**

$$ACMR = (R \times B) + D$$

where:

- ACMR = Adjusted Cumulative Mass Retained
- R = minus 4.75 mm (No. 4) adjustment factor
- B = cumulative mass of the size increment in the reduced portion sieved
- D = cumulative mass of plus 4.75mm (No. 4) portion of sample

**Method B Example Individual Mass Retained**

Dry mass of total sample, before washing: 3214.0 g

Dry mass of sample after washing: 3085.1 g

Total mass after sieving

Sum of Individual Masses Retained (IMR) plus the  
minus 4.75 mm (No. 4) from the pan: 3085.0 g

Amount of 75 µm (No. 200) minus washed out (3214.0 g – 3085.1 g): 128.9 g

**Coarse Check Sum**

$$\text{Coarse Check Sum} = \frac{3085.1 \text{ g} - 3085.0 \text{ g}}{3085.1 \text{ g}} \times 100 = 0.0\%$$

The result is less than 0.3 percent therefore the results can be used for acceptance purposes.

**Individual Percent Retained (IPR) for 9.5 mm (3/8 in.) sieve**

$$IPR = \frac{481.4 \text{ g}}{3214.0 \text{ g}} \times 100 = 15.0\%$$

**Percent Passing (PP) for 9.5 mm (3/8 in.) sieve:**

$$PP = 95.0\% - 15.0\% = 80.0\%$$

**Reported Percent Passing = 80%**



**Method B Individual  
Gradation on Coarse Sieves**

Sieve Size mm (in.)	Individual Mass Retained g (IMR)	Determine IPR Divide IMR by M and multiply by 100	Individual Percent Retained (IPR)	Determine PP by subtracting IPR from Previous PP	Percent Passing (PP)
16.0 (5/8)	0		0		100
12.5 (1/2)	161.1	$\frac{161.1}{3214.0} \times 100 =$	5.0	$100.0 - 5.0 =$	95.0
9.50 (3/8)	481.4	$\frac{481.4}{3214.0} \times 100 =$	15.0	$95.0 - 15.0 =$	80.0
4.75 (No. 4)	475.8	$\frac{475.8}{3214.0} \times 100 =$	14.8	$80.0 - 14.8 =$	65.2
Minus 4.75 (No. 4) in the pan	1966.7 ( $M_1$ )				
Total mass after sieving = sum of sieves + mass in the pan = 3085.0 g					
Original dry mass of the sample ( $M$ ): 3214.0 g					

**Fine Sample**

The minus 4.75 mm (No. 4) from the pan,  $M_1$  (1966.7 g), was reduced according to the FOP for AASHTO R 76, to at least 500 g. In this case, the reduced mass was determined to be **512.8 g**. This is  $M_2$ .

The reduced mass was sieved.

Total mass after sieving equals

Sum of Individual Masses Retained (IMR) including  
minus 75  $\mu$ m (No. 200) in the pan

511.8 g

**Fine Check Sum**

$$\text{Fine Check Sum} = \frac{512.8 \text{ g} - 511.8 \text{ g}}{512.8 \text{ g}} \times 100 = 0.2\%$$

The result is less than 0.3 percent therefore the results can be used for acceptance purposes.

**Adjustment Factor (*R*) for Adjusted Individual Mass Retained (AIMR) on minus 4.75 (No. 4) sieves**

The mass of material retained for each sieve is multiplied by the adjustment factor (*R*) carried to three decimal places.

$$R = \frac{M_1}{M_2} = \frac{1,966.7 \text{ g}}{512.8 \text{ g}} = 3.835$$

where:

*R* = minus 4.75 mm (No. 4) adjustment factor

*M*<sub>1</sub> = total mass of minus 4.75 mm (No. 4) from the pan

*M*<sub>2</sub> = mass of the reduced split of minus 4.75 mm (No. 4)

Each “individual mass retained” on the fine sieves must be multiplied by *R* to obtain the *Adjusted Individual Mass Retained*.

**Adjusted Individual Mass Retained (AIMR) for 2.00 mm (No. 10) sieve**

$$\text{AIMR} = 3.835 \times 207.1 \text{ g} = 794.2 \text{ g}$$

**Individual Percent Retained (IPR) for 2.00 mm (No. 10) sieve:**

$$\text{IPR} = \frac{794.2 \text{ g}}{3214.0 \text{ g}} \times 100 = 24.7\%$$

**Percent Passing (PP) 2 mm (No. 10) sieve:**

$$PP = 65.2\% - 24.7\% = 40.5\%$$

**Reported Percent Passing = 41%**

**Method B Individual  
Gradation on Fine Sieves**

Sieve Size mm (in.)	Individual Mass Retained g (IMR)	Determine TIMR Multiply IMR by $R \left( \frac{M_1}{M_2} \right)$	Total Individual Mass Retained (TIMR)
2.00 (No. 10)	207.1	$207.1 \times 3.835 =$	794.2
0.425 (No. 40)	187.9	$187.9 \times 3.835 =$	720.6
0.210 (No. 80)	59.9	$59.9 \times 3.835 =$	229.7
0.075 (No. 200)	49.1	$49.1 \times 3.835 =$	188.3
minus 0.075 (No. 200) in the pan	7.8		
Total mass after sieving = sum of fine sieves + the mass in the pan = 511.8 g			

**Method B Individual  
Final Gradation on All Sieves**

Sieve Size mm (in.)	Total Individual Mass Retained g (TIMR)	Determine IPR Divide TIMR by M and multiply by 100	Individual Percent Retained (IPR)	Determine PP by subtracting IPR from Previous PP	Percent Passing (PP)	Reported Percent Passing*
16.0 (5/8)	0		0		100	100
12.5 (1/2)	161.1	$\frac{161.1}{3214.0} \times 100 =$	5.0	$100.0 - 5.0 =$	95.0	95
9.50 (3/8)	481.4	$\frac{481.4}{3214.0} \times 100 =$	15.0	$95.0 - 15.0 =$	80.0	80
4.75 (No. 4)	475.8	$\frac{475.8}{3214.0} \times 100 =$	14.8	$80.0 - 14.8 =$	65.2	65
2.00 (No. 10)	794.2	$\frac{794.2}{3214.0} \times 100 =$	24.7	$65.2 - 24.7 =$	40.5	41
0.425 (No. 40)	720.6	$\frac{720.6}{3214.0} \times 100 =$	22.4	$40.5 - 22.4 =$	18.1	18
0.210 (No. 80)	229.7	$\frac{229.7}{3214.0} \times 100 =$	7.1	$18.1 - 7.1 =$	11.0	11
0.075 (No. 200)	188.3	$\frac{188.3}{3214.0} \times 100 =$	5.9	$11.0 - 5.9 =$	5.1	5.1
minus 0.075 (No. 200) in the pan	29.9					
Original dry mass of the sample (M): 3214.0 g						

\* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

**Method B Example Cumulative Mass Retained**

Original dry mass of the sample (*M*): 3214.0 g

Dry mass of sample after washing: 3085.1 g

Total mass after sieving equals

Cumulative Mass Retained (CMR) on the 4.75 (No. 4)  
plus the minus 4.75 mm (No. 4) in the pan: 3085.0 g

Amount of 75 µm (No. 200) minus washed out (3214.0 g – 3085.1 g): 128.9 g

**Coarse Check Sum**

$$\text{Coarse Check Sum} = \frac{3085.1 \text{ g} - 3085.0 \text{ g}}{3085.1 \text{ g}} \times 100 = 0.0\%$$

The result is less than 0.3 percent therefore the results can be used for acceptance purposes.

**Cumulative Percent Retained (CPR) for 9.5 mm (3/8 in.) sieve**

$$CPR = \frac{642.5 \text{ g}}{3214.0 \text{ g}} \times 100 = 20.0\%$$

**Percent Passing (PP) for 9.5 mm (3/8 in.) sieve**

$$PP = 100.0\% - 20.0\% = 80.0\%$$

**Reported Percent Passing = 80%**

**Method B Cumulative  
Gradation on Coarse Sieves**

Sieve Size mm (in.)	Cumulative Mass Retained g (CMR)	Determine CPR Divide CMR by M and multiply by 100	Cumulative Percent Retained (CPR)	Determine PP by subtracting CPR from 100.0	Percent Passing (PP)
16.0 (5/8)	0		0		100
12.5 (1/2)	161.1	$\frac{161.1}{3214.0} \times 100 =$	5.0	$100.0 - 5.0 =$	95.0
9.50 (3/8)	642.5	$\frac{642.5}{3214.0} \times 100 =$	20.0	$100.0 - 20.0 =$	80.0
4.75 (No. 4)	1118.3 (D)	$\frac{1118.3}{3214.0} \times 100 =$	34.8	$100.0 - 34.8 =$	65.2
Minus 4.75 (No. 4) in the pan	1966.7 ( $M_1$ )				
CMR: $1118.3 + 1966.7 = 3085.0$					
Original dry mass of the sample (M): 3214.0 g					

### Fine Sample

The mass of minus 4.75 mm (No. 4) material in the pan,  $M_1$  (1966.7 g), was reduced according to the FOP for AASHTO R 76, to at least 500 g. In this case, the reduced mass was determined to be **512.8 g**. This is  $M_2$ .

The reduced mass was sieved.

Total mass after fine sieving equals

Final Cumulative Mass Retained (FCMR) (includes minus  
75  $\mu\text{m}$  (No. 200) from the pan): 511.8 g

### Fine Check Sum

$$\text{Fine Check Sum} = \frac{512.8 \text{ g} - 511.8 \text{ g}}{512.8 \text{ g}} \times 100 = 0.2\%$$

The result is less than 0.3 percent therefore the results can be used for acceptance purposes.

The cumulative mass of material retained for each sieve is multiplied by the adjustment factor ( $R$ ) carried to three decimal places and added to the cumulative mass retained on the 4.75 mm (No. 4) sieve,  $D$ , to obtain the *Adjusted Cumulative Mass Retained (ACMR)*.

**Adjustment factor ( $R$ ) for Cumulative Mass Retained (CMR) in minus 4.75 (No. 4) sieves**

$$R = \frac{M_1}{M_2} = \frac{1,966.7 \text{ g}}{512.8 \text{ g}} = 3.835$$

where:

$R$  = minus 4.75 mm (No. 4) adjustment factor

$M_1$  = total mass of minus 4.75 mm (No. 4) from the pan

$M_2$  = mass of the reduced split of minus 4.75 mm (No. 4)

**Adjusted Cumulative Mass Retained (ACMR) for the 2.00 mm (No. 10) sieve**

$$ACMR = 3.835 \times 207.1 \text{ g} = 794.2 \text{ g}$$

**Total Cumulative Mass Retained (TCMR) for the 2.00 mm (No. 10) sieve**

$$TCMR = 794.2 \text{ g} + 1118.3 \text{ g} = 1912.5 \text{ g}$$

**Cumulative Percent Retained (CPR) for 2.00 mm (No. 10) sieve:**

$$CPR = \frac{1912.5 \text{ g}}{3214.0 \text{ g}} \times 100 = 59.5\%$$

**Percent Passing (PP) 2.00 mm (No. 10) sieve:**

$$PP = 100.0\% - 59.5\% = 40.5\%$$

**Reported Percent Passing = 41%**

**Method B Cumulative  
Gradation on Fine Sieves**

Sieve Size mm (in.)	Cumulative Mass Retained, g (CMR)	Determine AIMR Multiply IMR by $R \left( \frac{M_1}{M_2} \right)$ and adding D	Total Cumulative Mass Retained (TCMR)
2.00 (No. 10)	207.1	$207.1 \times 3.835 + 1118.3 =$	1912.5
0.425 (No. 40)	395.0	$395.0 \times 3.835 + 1118.3 =$	2633.1
0.210 (No. 80)	454.9	$454.9 \times 3.835 + 1118.3 =$	2862.8
0.075 (No. 200)	504.0	$504.0 \times 3.835 + 1118.3 =$	3051.1
FCMR	511.8		
Total sum of masses on fine sieves + minus 75 $\mu$ m (No. 200) in the pan = 511.8			



**Method B Cumulative  
Final Gradation on All Sieves**

Sieve Size mm (in.)	Cumulative Mass Retained g (CMR)	Determine CPR Divide CMR by M and multiply by 100	Cumulative Percent Retained (CPR)	Determine PP by subtracting CPR from 100.0	Percent Passing (PP)	Reported Percent Passing*
16.0 (5/8)	0		0		100.0	100
12.5 (1/2)	161.1	$\frac{161.1}{3214.0} \times 100 =$	5.0	$100.0 - 5.0 =$	95.0	95
9.5 (3/8)	642.5	$\frac{642.5}{3214.0} \times 100 =$	20.0	$100.0 - 20.0 =$	80.0	80
4.75 (No. 4)	1118.3 (D)	$\frac{1118.3}{3214.0} \times 100 =$	34.8	$100.0 - 34.8 =$	65.2	65
2.00 (No. 10)	1912.5	$\frac{1912.5}{3214.0} \times 100 =$	59.5	$100.0 - 59.5 =$	40.5	41
0.425 (No. 40)	2633.1	$\frac{2633.1}{3214.0} \times 100 =$	81.9	$100.0 - 81.9 =$	18.1	18
0.210 (No. 80)	2862.8	$\frac{2862.8}{3214.0} \times 100 =$	89.1	$100.0 - 89.1 =$	10.9	11
0.075 (No. 200)	3051.1	$\frac{3051.1}{3214.0} \times 100 =$	94.9	$100.0 - 94.9 =$	5.1	5.1
FCMR	3081.1					
Original dry mass of the sample (M): 3214.0 g						

\* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

## Procedure Method C

1. Dry the sample to constant mass according to the FOP for AASHTO T 255. Cool to room temperature. Determine and record the original dry mass of the sample to the nearest 0.1 percent or 0.1 g. Designate this mass as  $M$ .
2. Break up any aggregations or lumps of clay, silt or adhering fines to pass the 4.75 mm (No. 4) sieve.
3. Select sieves required by the specification and those necessary to avoid overloading. With a pan on bottom, nest the sieves increasing in size starting with the 4.75 mm (No. 4) sieve.
4. Place the sample, or a portion of the sample, on the top sieve. Sieves may already be in the mechanical shaker, if not place the sieves in the mechanical shaker and shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).

**Note 3:** Excessive shaking (more than 10 minutes) may result in degradation of the sample.

5. Determine and record the cumulative mass retained for each sieve. Ensure that all material trapped in full openings of the sieve are removed and included in the mass retained.

**Note 4:** For sieves 4.75 mm (No. 4) and larger, check material trapped in less than a full opening sieving over a full opening. Use coarse wire brushes to clean the 600  $\mu\text{m}$  (No. 30) and larger sieves, and soft bristle brush for smaller sieves.

6. Determine and record the mass of the minus 4.75 mm (No. 4) material in the pan. Designate this mass as  $M_1$ .
7. Perform the *Coarse Check Sum* calculation –Verify the *total mass after coarse sieving* agrees with the *original dry mass (M)* within 0.3 percent.
8. Reduce the minus 4.75 mm (No. 4) according to the FOP for AASHTO R 76, to produce a sample with a minimum mass of 500 g.
9. Determine and record the mass of the minus 4.75 mm (No. 4) split, designate this mass as  $M_3$ .
10. Nest a protective sieve, such as a 2.0 mm (No. 10), above the 75  $\mu\text{m}$  (No. 200) sieve.
11. Place the sample in a container and cover with water.

**Note 1:** A detergent, dispersing agent, or other wetting solution may be added to the water to assure a thorough separation of the material finer than the 75  $\mu\text{m}$  (No. 200) sieve from the coarser particles. There should be enough wetting agent to produce a small amount of suds when the sample is agitated. Excessive suds may overflow the sieves and carry material away with them.

12. Agitate vigorously to ensure complete separation of the material finer than 75  $\mu\text{m}$  (No. 200) from coarser particles and bring the fine material into suspension above the coarser material. Avoid degradation of the sample when using a mechanical washing device.
13. Immediately pour the wash water containing the suspended material over the nested sieves; be careful not to pour out the coarser particles or over fill the 75  $\mu\text{m}$  (No. 200) sieve.

14. Add water to cover material remaining in the container, agitate, and repeat Step 12. Repeat until the wash water is reasonably clear.
  15. Remove the upper sieve and return material retained to the washed sample.
  16. Rinse the material retained on the 75  $\mu\text{m}$  (No. 200) sieve until water passing through the sieve is reasonably clear and detergent or dispersing agent is removed, if used.
  17. Return all material retained on the 75  $\mu\text{m}$  (No. 200) sieve to the container by flushing into the washed sample.
- Note 2:** Excess water may be carefully removed with a bulb syringe; the removed water must be discharged back over the 75  $\mu\text{m}$  (No. 200) sieve to prevent loss of fines.
18. Dry the washed sample portion to constant mass according to the FOP for AASHTO T 255. Cool to room temperature. Determine and record the dry mass, designate this mass as *dry mass before sieving*.
  19. Select sieves required by the specification and those necessary to avoid overloading. With a pan on bottom, nest the sieves increasing in size starting with the 75  $\mu\text{m}$  (No. 200) sieve up to, but not including, the 4.75 mm (No. 4) sieve.
  20. Place the washed sample portion on the top sieve. Place the sieves in the mechanical shaker and shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).
- Note 3:** Excessive shaking (more than 10 minutes) may result in degradation of the sample.
21. Determine and record the cumulative mass retained for each sieve. Ensure that all material trapped in full openings of the sieve are removed and included in the mass retained.
- Note 4:** For sieves 4.75 mm (No. 4) and larger, check material trapped in less than a full opening by sieving over a full opening. Use coarse wire brushes to clean the 600  $\mu\text{m}$  (No. 30) and larger sieves, and soft bristle brushes for smaller sieves.
22. Perform the *Fine Check Sum* calculation – Verify the *total mass after fine sieving* agrees with the *dry mass before sieving* within 0.3 percent. Do not use test results for acceptance if the *Check Sum* is greater than 0.3 percent.
  23. Calculate the Cumulative Percent Retained (CPR) and Percent Passing (PP) for the 4.75 mm (No. 4) and larger.
  24. Calculate the Cumulative Percent Retained (CPR<sub>#4</sub>) and the Percent Passing (PP<sub>#4</sub>) for minus 4.75 mm (No. 4) split and Percent Passing (PP) for the minus 4.75 mm (No. 4).
  25. Report total percent passing to 1 percent except report the 75  $\mu\text{m}$  (No. 200) sieve to 0.1 percent.

**Method C Calculations****Check Sum**

$$\text{Coarse check sum} = \frac{M - \text{total mass after coarse sieving}}{M} \times 100$$

$$\text{Fine check sum} = \frac{\text{dry mass before sieving} - \text{total mass after fine sieving}}{\text{dry mass before sieving}} \times 100$$

where:

M = Original dry mass of the sample

**Cumulative Percent Retained (CPR) for 4.75 mm (No. 4) sieve and larger**

$$CPR = \frac{CMR}{M} \times 100$$

where:

CPR = Cumulative Percent Retained of the size increment for the total sample

CMR = Cumulative Mass Retained of the size increment for the total sample

M = Total dry sample mass before washing

**Percent Passing (PP) 4.75 mm (No. 4) sieve and larger**

$$PP = 100 - CPR$$

where:

PP = Percent Passing of the size increment for the total sample

CPR = Cumulative Percent Retained of the size increment for the total sample

**Or, calculate PP for sieves larger than 4.75 mm (No. 4) sieve without calculating CPR**

$$\frac{M - CMR}{M} \times 100$$

**Cumulative Percent Retained (CPR<sub>#4</sub>) for minus 4.75 mm (No. 4) split**

$$CPR_{\#4} = \frac{CMR_{\#4}}{M_3} \times 100$$

where:

CPR<sub>#4</sub> = Cumulative Percent Retained for the sieve sizes of M<sub>3</sub>

CMR<sub>#4</sub> = Cumulative Mass Retained for the sieve sizes of M<sub>3</sub>

M<sub>3</sub> = Total mass of the minus 4.75 mm (No. 4) split before washing

**Percent Passing (PP<sub>#4</sub>) for minus 4.75 mm (No. 4) split**

$$PP_{\#4} = 100 - CPR_{\#4}$$

where:

PP<sub>#4</sub> = Percent Passing for the sieve sizes of M<sub>3</sub>

CPR<sub>#4</sub> = Cumulative Percent Retained for the sieve sizes of M<sub>3</sub>

**Percent Passing (PP) for sieves smaller than 4.75 mm (No. 4) sieve**

$$PP = \frac{(PP_{\#4} \times \#4 PP)}{100}$$

where:

PP = Total Percent Passing

PP<sub>#4</sub> = Percent Passing for the sieve sizes of M<sub>3</sub>

#4 PP = Total Percent Passing the 4.75 mm (No. 4) sieve

**Or, calculate PP for sieves smaller than 4.75 mm (No. 4) sieve without calculating CPR-#4 and PP-#4**

$$PP = \frac{\#4 PP}{M_3} \times (M_3 - CMR_{\#4})$$

where:

- PP = Total Percent Passing
- #4 PP = Total Percent Passing the 4.75 mm (No. 4) sieve
- M<sub>3</sub> = Total mass of the minus 4.75 mm (No. 4) split before washing
- CMR-#4 = Cumulative Mass Retained for the sieve sizes of M<sub>3</sub>

### Method C Example

Original dry mass of the sample (M): 3304.5 g

Total mass after sieving equals

Cumulative Mass Retained (CMR) on the 4.75 (No. 4) plus the  
minus 4.75 mm (No. 4) from the pan: 3085.0 g

### Coarse Check Sum

$$Coarse Check Sum = \frac{3304.5 g - 3304.5 g}{3304.5 g} \times 100 = 0.0\%$$

The result is less than 0.3 percent therefore the results can be used for acceptance purposes.

### Cumulative Percent Retained (CPR) for the 9.5 mm (3/8 in.) sieve:

$$CPR = \frac{604.1 g}{3304.5 g} \times 100 = 18.3\%$$

**Percent Passing (PP) for the 9.5 mm (3/8 in.) sieve:**

$$PP = 100.0\% - 18.3\% = 81.7\%$$

**Reported Percent Passing = 82%**

**Example for Alternate Percent Passing (PP) formula for the 9.5 mm (3/8 in.) sieve:**

$$PP = \frac{3304.5 - 604.1}{3304.5} \times 100 = 81.7\%$$

**Reported Percent Passing = 82%**

**Method C Cumulative  
Gradation on Coarse Sieves**

Sieve Size mm (in.)	Cumulative Mass Retained, g (CMR)	Determine CPR Divide CMR by M and multiply by 100	Cumulative Percent Retained (CPR)	Determine PP by subtracting CPR from 100.0	Percent Passing (PP)	Reported Percent Passing*
16.0 (5/8)	0		0.0		100.0	100
12.5 (1/2)	125.9	$\frac{125.9}{3304.5} \times 100 =$	3.8	$100.0 - 3.8 =$	96.2	96
9.50 (3/8)	604.1	$\frac{604.1}{3304.5} \times 100 =$	18.3	$100.0 - 18.3 =$	81.7	82
4.75 (No. 4)	1295.6	$\frac{1295.6}{3304.5} \times 100 =$	39.2	$100.0 - 39.2 =$	<b>60.8</b> <b>(#4 PP)</b>	61
Mass in pan	2008.9					
CMR: $1295.6 + 2008.9 = 3304.5$						
Original dry mass of the sample ( <i>M</i> ) = 3304.5						

**Fine Sample**

The pan (2008.9 g) was reduced according to the FOP for AASHTO R 76, to at least 500 g. In this case, the reduced mass was determined to be **527.6 g**. This is  $M_3$ .

Dry mass of minus 4.75mm (No. 4) reduced portion before wash ( $M_3$ ): 527.6 g

Dry mass of minus 4.75mm (No. 4) reduced portion after wash: 495.3 g

Total mass after fine sieving equals

Final Cumulative Mass Retained (FCMR)  
(includes minus 75  $\mu$ m (No. 200) from the pan): 495.1 g

**Fine Check Sum**

$$\text{Fine Check Sum} = \frac{495.3 \text{ g} - 495.1 \text{ g}}{495.3 \text{ g}} \times 100 = 0.04\%$$

The result is less than 0.3 percent therefore the results can be used for acceptance purposes.

**Cumulative Percent Retained (CPR<sub>#4</sub>) for minus 4.75 mm (No. 4) for the 2.0 mm (No. 10) sieve:**

$$CPR_{\#4} = \frac{194.3 \text{ g}}{527.6 \text{ g}} \times 100 = 36.8\%$$

**Percent Passing (PP<sub>#4</sub>) for minus 4.75 mm (No. 4) for the 2.0 mm (No. 10) sieve:**

$$PP_{\#4} = 100.0\% - 36.8\% = 63.2\%$$



**Method C Cumulative  
Gradation on Fine Sieves**

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Sieve Size mm (in.)	Cumulative Mass Retained g (CMR <sub>#4</sub> )	Determine CPR <sub>#4</sub> Divide CMR by M <sub>3</sub> and multiply by 100	Cumulative Percent Retained <sub>#4</sub> (CPR <sub>#4</sub> )	Determine PP <sub>#4</sub> by subtracting CPR <sub>#4</sub> from 100.0	Percent Passing <sub>#4</sub> (PP <sub>#4</sub> )
2.0 (No. 10)	194.3	$\frac{194.3}{527.6} \times 100 =$	36.8	$100.0 - 36.8 =$	63.2
0.425 (No. 40)	365.6	$\frac{365.6}{527.6} \times 100 =$	69.3	$100.0 - 69.3 =$	30.7
0.210 (No. 80)	430.8	$\frac{430.8}{527.6} \times 100 =$	81.7	$100.0 - 81.7 =$	18.3
0.075 (No. 200)	484.4	$\frac{484.4}{527.6} \times 100 =$	91.8	$100.0 - 91.8 =$	8.2
FCMR	495.1				
Dry mass of minus 4.75mm (No. 4) reduced portion before wash (M <sub>3</sub> ): 527.6 g					
Dry mass after washing: 495.3 g					

**Percent Passing (PP) for the 2.0 mm (No. 10) sieve for the entire sample:**

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#4 PP (Total Percent Passing the 4.75 mm (No. 4) sieve) = 60.8%

$$PP = \frac{63.2\% \times 60.8\%}{100} = 38.4\%$$

**Reported Percent Passing = 38%**

**Method C Cumulative  
Final Gradation on All Sieves**

Sieve Size mm (in.)	Cumulative Mass Retained g (CMR)	Cumulative Percent Retained (CPR)	Percent Passing (PP -#4)	Determine PP multiply PP -#4 by #4 PP and divide by 100	Percent Passing (PP)	Reported Percent Passing*
16.0 (5/8)	0	0.0			100.0	100
12.5 (1/2)	125.9	3.8			96.2	96
9.5 (3/8)	604.1	18.3			81.7	82
4.75 (No. 4)	1295.6	39.2			<b>60.8</b> <b>(#4 PP)</b>	61
2.0 (No. 10)	194.3	36.8	63.2	$\frac{63.2 \times 60.8}{100} =$	38.4	38
0.425 (No. 40)	365.6	69.3	30.7	$\frac{30.7 \times 60.8}{100} =$	18.7	19
0.210 (No. 80)	430.8	81.7	18.3	$\frac{18.3 \times 60.8}{100} =$	11.1	11
0.075 (No. 200)	484.4	91.8	8.2	$\frac{8.2 \times 60.8}{100} =$	5.0	5.0
FCMR	495.1					

\* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

**Example for Alternate Percent Passing (PP) for the 4.75 mm (No. 4) sieve for the entire sample:**

#4 PP (Total Percent Passing the 4.75 mm (No. 4) sieve) = 60.8%

$$PP = \frac{60.8\%}{527.6} \times (527.6 - 194.3) = 38.4\%$$

**Reported Percent Passing = 38%**

**Alternate Method C Cumulative  
Gradation on Coarse Sieves**

Sieve Size mm (in.)	Cumulative Mass Retained, g (CMR)	Determine PP subtract CMR from M, divide result by M multiply by 100	Percent Passing (PP)	Reported Percent Passing*
16.0 (5/8)	0.0		100.0	100
12.5 (1/2)	125.9	$\frac{3304.5 - 125.9}{3304.5} \times 100 =$	96.2	96
9.5 (3/8)	604.1	$\frac{3304.5 - 604.1}{3304.5} \times 100 =$	81.7	82
4.75 (No. 4)	1295.6	$\frac{3304.5 - 1295.6}{3304.5} \times 100 =$	<b>60.8</b> <b>(#4 PP)</b>	61
Mass in Pan	2008.9			
Cumulative sieved mass: $1295.6 + 2008.9 = 3304.5$				
Original dry mass of the sample ( $M$ ) = 3304.5				

**Alternate Method C Cumulative  
Gradation on Fine Sieves**

<b>Sieve Size mm (in.)</b>	<b>Cumulative Mass Retained g (CMR<sub>#4</sub>)</b>	<b>Determine PP<sub>#4</sub> subtract CMR<sub>#4</sub> from M<sub>3</sub>, divide result by M<sub>3</sub> multiply by 100</b>	<b>Percent Passing<sub>#4</sub> (PP<sub>#4</sub>)</b>
2.0 (No. 10)	194.3	$\frac{527.6 - 194.3}{527.6} \times 100 =$	63.2
0.425 (No. 40)	365.6	$\frac{527.6 - 365.6}{527.6} \times 100 =$	30.7
0.210 (No. 80)	430.8	$\frac{527.6 - 430.8}{527.6} \times 100 =$	18.3
0.075 (No. 200)	484.4	$\frac{527.6 - 484.4}{527.6} \times 100 =$	8.2
FCMR	495.1		
Dry mass of minus 4.75mm (No. 4) reduced portion before wash (M <sub>3</sub> ): 527.6 g			
Dry mass after washing: 495.3 g			

**Alternate Method C Cumulative  
Final Gradation on All Sieves**

Sieve Size mm (in.)	Percent Passing <sub>#4</sub> (PP <sub>#4</sub> )	Determine PP multiply PP <sub>#4</sub> by #4 PP and divide by 100	Determined Percent Passing (PP)	Reported Percent Passing*
16.0 (5/8)			100.0	100
12.5 (1/2)			96.2	96
9.5 (3/8)			81.7	82
4.75 (No. 4)			<b>60.8</b> <b>(#4 PP)</b>	61
2.0 (No. 10)	63.2	$\frac{63.2 \times 60.8}{100} =$	38.4	38
0.425 (No. 40)	30.7	$\frac{30.7 \times 60.8}{100} =$	18.7	19
0.210 (No. 80)	18.3	$\frac{18.3 \times 60.8}{100} =$	11.1	11
0.075 (No. 200)	8.2	$\frac{8.2 \times 60.8}{100} =$	5.0	5.0

\* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

## FINENESS MODULUS

Fineness Modulus (FM) is used in determining the degree of uniformity of the aggregate gradation in PCC mix designs. It is an empirical number relating to the fineness of the aggregate. The higher the FM the coarser the aggregate. Values of 2.40 to 3.00 are common for fine aggregate in PCC.

The sum of the cumulative percentages retained on specified sieves in the following table divided by 100 gives the FM.

### Sample Calculation

	Example A				Example B		
	Percent				Percent		
		Retained				Retained	
Sieve Size mm (in)	Passing		On Spec'd Sieves*		Passing		On Spec'd Sieves*
75*(3)	100	0	0		100	0	0
37.5*(11/2)	100	0	0		100	0	0
19*(3/4)	15	85	85		100	0	0
9.5*(3/8)	0	100	100		100	0	0
4.75*(No.4)	0	100	100		100	0	0
2.36*(No.8)	0	100	100		87	13	13
1.18*(No.16)	0	100	100		69	31	31
0.60*(No.30)	0	100	100		44	56	56
0.30*(No.50)	0	100	100		18	82	82
0.15*(100)	0	100	100		4	96	96
			$\Sigma = 785$				$\Sigma = 278$
			FM = 7.85				FM = 2.78

In decreasing size order, each \* sieve is one-half the size of the preceding \* sieve.

**Report**

- Results on forms approved by the agency
- Sample ID
- Percent passing for each sieve
- Individual mass retained for each sieve
- Individual percent retained for each sieve
- or
- Cumulative mass retained for each sieve
- Cumulative percent retained for each sieve
- FM to the nearest 0.01

Report percentages to the nearest 1 percent except for the percent passing the 75  $\mu\text{m}$  (No. 200) sieve, which shall be reported to the nearest 0.1 percent.

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**ANNEX A****Time Evaluation**

The sieving time for each mechanical sieve shaker shall be checked at least annually to determine the time required for complete separation of the sample by the following method:

1. Shake the sample over nested sieves for approximately 10 minutes.
2. Provide a snug-fitting pan and cover for each sieve and hold in a slightly inclined position in one hand.
3. Hand shake each sieve by striking the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turning the sieve about one sixth of a revolution at intervals of about 25 strokes.

**Note A1:** A mallet may be used instead of the heel of the hand if comparable force is used.

If more than 0.5 percent by mass of the total sample before sieving passes any sieve after one minute of continuous hand shaking adjust shaker time and re-check.

In determining sieving time for sieve sizes larger than 4.75 mm (No. 4), limit the material on the sieve to a single layer of particles.



**ANNEX B****Overload Determination**

Additional sieves may be necessary to keep from overloading sieves or to provide other information, such as fineness modulus. The sample may also be sieved in increments to prevent overloading.

- For sieves with openings smaller than 4.75 mm (No. 4), the mass retained on any sieve shall not exceed 7 kg/m<sup>2</sup> (4 g/in<sup>2</sup>) of sieving surface.
- For sieves with openings 4.75 mm (No. 4) and larger, the mass, in grams shall not exceed the product of 2.5 × (sieve opening in mm) × (effective sieving area). See Table B1.

**TABLE B1**

**Maximum Allowable Mass of Material Retained on a Sieve, g**  
**Nominal Sieve Size, mm (in.)**  
**Exact size is smaller (see AASHTO T 27)**

Sieve Size		203 dia	305 dia	305 by 305	350 by 350	372 by 580
mm (in.)		(8)	(12)	(12 × 12)	(14 × 14)	(16 × 24)
		Sieving Area m <sup>2</sup>				
		0.0285	0.0670	0.0929	0.1225	0.2158
90	(3 1/2)	*	15,100	20,900	27,600	48,500
75	(3)	*	12,600	17,400	23,000	40,500
63	(2 1/2)	*	10,600	14,600	19,300	34,000
50	(2)	3600	8400	11,600	15,300	27,000
37.5	(1 1/2)	2700	6300	8700	11,500	20,200
25.0	(1)	1800	4200	5800	7700	13,500
19.0	(3/4)	1400	3200	4400	5800	10,200
16.0	(5/8)	1100	2700	3700	4900	8600
12.5	(1/2)	890	2100	2900	3800	6700
9.5	(3/8)	670	1600	2200	2900	5100
6.3	(1/4)	440	1100	1500	1900	3400
4.75	(No. 4)	330	800	1100	1500	2600
-4.75	(-No. 4)	200	470	650	860	1510



**PERFORMANCE EXAM CHECKLIST****METHOD A****SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES****FOP FOR AASHTO T 27****MATERIALS FINER THAN 75  $\mu\text{m}$  (No. 200) SIEVE IN MINERAL AGGREGATE  
BY WASHING****FOP FOR AASHTO T 11**

Participant Name \_\_\_\_\_ Exam Date \_\_\_\_\_

**Record the symbols “P” for passing or “F” for failing on each step of the checklist.**

<b>Procedure Element</b>	<b>Trial 1</b>	<b>Trial 2</b>
1. Minimum sample mass meets requirement of Table 1?	_____	_____
2. Sample dried to a constant mass by FOP for AASHTO T 255?	_____	_____
3. Sample cooled, and original dry mass of the sample recorded to the nearest 0.1 percent or 0.1 g?	_____	_____
4. Sample placed in container and covered with water?	_____	_____
5. Contents of the container vigorously agitated?	_____	_____
6. Suspension of minus 75 $\mu\text{m}$ (No. 200) achieved?	_____	_____
7. Wash water poured through nested sieves such as 2 mm (No. 10) and 75 $\mu\text{m}$ (No. 200)?	_____	_____
8. Operation continued until wash water is reasonably clear?	_____	_____
9. Material retained on sieves returned to washed sample?	_____	_____
10. Washed sample dried to a constant mass by FOP for AASHTO T 255?	_____	_____
11. Washed sample cooled, and dry mass recorded to the nearest 0.1 percent or 0.1 g?	_____	_____
12. Sample placed in nest of sieves specified? (Additional sieves may be used to prevent overloading as allowed in FOP.)	_____	_____
13. Material sieved in verified mechanical shaker for proper time?	_____	_____
14. Mass of material on each sieve and pan recorded to 0.1 g?	_____	_____
15. Total mass of material after sieving agrees with mass before sieving to within 0.3 percent (check sum)?	_____	_____

**OVER**

Procedure Element	Trial 1	Trial 2
16. Percentages calculated to the nearest 0.1 percent and reported to the nearest whole number, except 75 $\mu\text{m}$ (No. 200) which is reported to the nearest 0.1 percent?	_____	_____
17. Percentage calculations based on original dry mass of the sample?	_____	_____
18. Calculations performed properly?	_____	_____

Comments: First attempt: Pass \_\_\_\_\_ Fail \_\_\_\_\_ Second attempt: Pass \_\_\_\_\_ Fail \_\_\_\_\_

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Examiner Signature \_\_\_\_\_ WAQTC #: \_\_\_\_\_

**PERFORMANCE EXAM CHECKLIST****METHOD B****SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES****FOP FOR AASHTO T 27****MATERIALS FINER THAN 75  $\mu\text{m}$  (No. 200) SIEVE IN MINERAL AGGREGATE  
BY WASHING****FOP FOR AASHTO T 11**

Participant Name \_\_\_\_\_ Exam Date \_\_\_\_\_

**Record the symbols “P” for passing or “F” for failing on each step of the checklist.**

<b>Procedure Element</b>	<b>Trial 1</b>	<b>Trial 2</b>
1. Minimum sample mass meets requirement of Table 1?	_____	_____
2. Sample dried to a constant mass by FOP for AASHTO T 255?	_____	_____
3. Sample cooled, and original dry mass of the sample recorded to the nearest 0.1 percent or 0.1 g?	_____	_____
4. Sample placed in container and covered with water?	_____	_____
5. Contents of the container vigorously agitated?	_____	_____
6. Suspension of minus 75 $\mu\text{m}$ (No. 200) achieved?	_____	_____
7. Wash water poured through nested sieves such as 2 mm (No. 10) and 75 $\mu\text{m}$ (No. 200)?	_____	_____
8. Operation continued until wash water is reasonably clear?	_____	_____
9. Material retained on sieves returned to washed sample?	_____	_____
10. Washed sample dried to a constant mass by FOP for AASHTO T 255?	_____	_____
11. Washed sample cooled, and dry mass recorded to nearest 0.1 percent or 0.1 g?	_____	_____
12. Sample placed in nest of sieves specified? (Additional sieves may be used to prevent overloading as allowed in FOP.)	_____	_____
13. Material sieved in verified mechanical shaker for proper time?	_____	_____
14. Mass of material on each sieve and pan determined to the nearest 0.1 percent or 0.1 g?	_____	_____
15. Total mass of material after sieving agrees with mass before sieving to within 0.3 percent (coarse check sum)?	_____	_____

**OVER**

Procedure Element	Trial 1	Trial 2
16. Material in pan reduced in accordance with FOP for AASHTO R 76 to at least 500 g?	_____	_____
17. Mass of minus 4.75 mm (No. 4) split recorded to the nearest 0.1 g?	_____	_____
18. Sample placed in nest of sieves specified? (Additional sieves may be used to prevent overloading as allowed in FOP.)	_____	_____
19. Material sieved in verified mechanical shaker for proper time?	_____	_____
20. Mass of material on each sieve and pan recorded to the nearest percent or 0.1 g?	_____	_____
21. Total mass of material after sieving agrees with mass before sieving to within 0.3 percent (fine check sum)?	_____	_____
22. Percentages calculated to the nearest 0.1 percent and reported to the nearest whole number, except 75 $\mu$ m (No.200) which is reported to the nearest 0.1 percent?	_____	_____
23. Percentage calculations based on original dry mass of the sample?	_____	_____
24. Calculations performed properly?	_____	_____

Comments: First attempt: Pass\_\_\_\_\_Fail\_\_\_\_\_ Second attempt: Pass\_\_\_\_\_Fail\_\_\_\_\_

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Examiner Signature \_\_\_\_\_ WAQTC #: \_\_\_\_\_

## **DETERMINING THE PERCENTAGE OF FRACTURE IN COARSE AGGREGATE FOP FOR AASHTO T 335**

### **Scope**

This procedure covers the determination of the percentage, by mass, of a coarse aggregate (CA) sample that consists of fractured particles meeting specified requirements in accordance with AASHTO T 335-09.

In this FOP, a sample of aggregate is screened on the sieve separating CA and fine aggregate (FA). This sieve will be identified in the agency's specifications but might be the 4.75 mm (No. 4) sieve. CA particles are visually evaluated to determine conformance to the specified fracture. The percentage of conforming particles, by mass, is calculated for comparison to the specifications.

### **Apparatus**

- Balance or scale: Capacity sufficient for the principle sample mass, accurate to 0.1 percent of the sample mass or readable to 0.1 g and meeting the requirements of AASHTO M 231.
- Sieves: Meeting requirements of the FOP for AASHTO T 27/T 11.
- Splitter: Meeting the requirements of FOP for AASHTO R 76.

### **Terminology**

1. Fractured Face: An angular, rough, or broken surface of an aggregate particle created by crushing or by other means. A face is considered a "fractured face" whenever one-half or more of the projected area, when viewed normal to that face, is fractured with sharp and well-defined edges. This excludes small nicks.
2. Fractured particle: A particle of aggregate having at least the minimum number of fractured faces specified. (This is usually one or two.)

### **Sampling and Sample Preparation**

1. Sample and reduce the aggregate in accordance with the FOPs for AASHTO R 90 and R 76.
2. When the specifications list only a total fracture percentage, the sample shall be prepared in accordance with Method 1. When the specifications require that the fracture be counted and reported on each sieve, the sample shall be prepared in accordance with Method 2.

### 3. Method 1 - Combined Fracture Determination

- a. Dry the sample sufficiently to obtain a clean separation of FA and CA material in the sieving operation.
- b. Sieve the sample in accordance with the FOP for AASHTO T 27/ T 11 over the 4.75 mm (No. 4) sieve, or the appropriate sieve listed in the agency's specifications for this material.

**Note 1:** Where necessary, wash the sample over the sieve designated for the determination of fractured particles to remove any remaining fine material, and dry to a constant mass in accordance with the FOP for AASHTO T 255.

- c. Reduce the sample using Method A – Mechanical Splitter, in accordance with the FOP for AASHTO R 76, to the appropriate test size. This test size should be slightly larger than shown in Table 1, to account for loss of fines through washing if necessary.

**TABLE 1**  
**Sample Size**  
**Method 1 (Combined Sieve Fracture)**

Nominal Maximum Size* mm (in.)	Minimum Cumulative Sample Mass Retained on 4.75 mm (No. 4) Sieve g (lb)
37.5 (1 1/2)	2500 (6)
25.0 (1)	1500 (3.5)
19.0 (3/4)	1000 (2.5)
12.5 (1/2)	700 (1.5)
9.5 (3/8)	400 (0.9)
4.75 (No. 4)	200 (0.4)

\* One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

### 4. Method 2 – Individual Sieve Fracture Determination

- a. Dry the sample sufficiently to obtain a clean separation of FA and CA material in the sieving operation. A washed sample from the gradation determination (the FOP for T 27/T 11) may be used.
- b. If not, sieve the sample in accordance with the FOP for AASHTO T 27 over the sieves listed in the specifications for this material.

**Note 2:** If overload (buffer) sieves are used the material from that sieve must be added to the next specification sieve.



- c. The size of test sample for each sieve shall meet the minimum size shown in Table 2. Utilize the total retained sieve mass or select a representative portion from each sieve mass by splitting or quartering in accordance with the FOP for AASHTO R 76.

**Note 3:** Where necessary, wash the sample over the sieves designated for the determination of fractured particles to remove any remaining fine material, and dry to a constant mass in accordance with the FOP for AASHTO T 255.

**TABLE 2**  
**Sample Size**  
**Method 2 (Individual Sieve Fracture)**

Sieve Size mm (in.)	Minimum Sample Mass g (lb)
31.5 (1 1/4)	1500 (3.5)
25.0 (1)	1000 (2.2)
19.0 (3/4)	700 (1.5)
16.0 (5/8)	500 (1.0)
12.5 (1/2)	300 (0.7)
9.5 (3/8)	200 (0.5)
6.3 (1/4)	100 (0.2)
4.75 (No. 4)	100 (0.2)
2.36 (No. 8)	25 (0.1)
2.00 (No. 10)	25 (0.1)

**Note 4:** If fracture is determined on a sample obtained for gradation, use the mass retained on the individual sieves, even if it is less than the minimum listed in Table 2. If less than 5 percent of the total mass is retained on a single specification sieve, include that material on the next smaller specification sieve. If a smaller specification sieve does not exist, this material shall not be included in the fracture determination.

## Procedure

1. After cooling, spread the dried sample on a clean, flat surface.
2. Examine each particle face and determine if the particle meets the fracture criteria.
3. Separate the sample into three categories:
  - Fractured particles meeting the criteria
  - Particles not meeting the criteria
  - Questionable or borderline particles
4. Determine the dry mass of particles in each category to the nearest 0.1 g.
5. Calculate the percent questionable particles.

6. Resort the questionable particles when more than 15 percent is present. Continue sorting until there is no more than 15 percent in the questionable category.
7. Calculate the percent fractured particles meeting criteria to nearest 0.1 percent. Report to 1 percent.

### Calculation

Calculate the mass percentage of questionable particles to the nearest 1 percent using the following formula:

$$\%Q = \frac{Q}{F + Q + N} \times 100$$

where:

%Q = Percent of questionable fractured particles  
 F = Mass of fractured particles  
 Q = Mass of questionable or borderline particles  
 N = Mass of unfractured particles

### Example:

$$\%Q = \frac{97.6 \text{ g}}{632.6 \text{ g} + 97.6 \text{ g} + 352.6 \text{ g}} \times 100 = 9.0\%$$

where:

Mass of fractured particles = 632.6 g  
 Mass of questionable particles = 97.6 g  
 Mass of unfractured particles = 352.6 g

Calculate the mass percentage of fractured faces to the nearest 0.1 percent using the following formula:

$$P = \frac{\frac{Q}{2} + F}{F + Q + N} \times 100$$

where:

P = Percent of fracture  
 F = Mass of fractured particles  
 Q = Mass of questionable particles  
 N = Mass of unfractured particles

**Example:**

$$P = \frac{\frac{97.6 \text{ g}}{2} + 632.6 \text{ g}}{632.6 \text{ g} + 97.6 \text{ g} + 352.6 \text{ g}} \times 100 = 62.9\% \quad \text{Report 63\%}$$

where:

Mass of fractured particles	=	632.6 g,
Mass of questionable particles	=	97.6 g
Mass of unfractured particles	=	352.6 g

**Report**

- Results on forms approved by the agency
- Sample ID
- Fractured particles to the nearest 1 percent.



**PERFORMANCE EXAM CHECKLIST****DETERMINING THE PERCENTAGE OF FRACTURE IN COARSE AGGREGATE  
FOP FOR AASHTO T 335**

Participant Name \_\_\_\_\_ Exam Date \_\_\_\_\_

**Record the symbols “P” for passing or “F” for failing on each step of the checklist.**

<b>Procedure Element</b>	<b>Trial 1</b>	<b>Trial 2</b>
1. Sample properly sieved through specified sieve(s)?	_____	_____
2. Sample reduced to correct size?	_____	_____
3. Sample dried and cooled, if necessary?	_____	_____
4. Particles separated into fractured, unfractured, and questionable categories?	_____	_____
5. Dry mass of each category determined to nearest 0.1 g?	_____	_____
6. Questionable category resorted if more than 15 percent of total mass falls in that category?	_____	_____
7. Fracture calculation performed correctly?	_____	_____

Comments: First attempt: Pass\_\_\_\_Fail\_\_\_\_ Second attempt: Pass\_\_\_\_Fail\_\_\_\_

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**Examiner Signature** \_\_\_\_\_ **WAQTC #:** \_\_\_\_\_



## **PLASTIC FINES IN GRADED AGGREGATES AND SOILS BY THE USE OF THE SAND EQUIVALENT TEST FOP FOR AASHTO T 176**

### **Scope**

This procedure covers the determination of plastic fines in accordance with AASHTO T 176-08. It serves as a rapid test to show the relative proportion of fine dust or clay-like materials in fine aggregates (FA) and soils.

### **Apparatus**

See AASHTO T 176 for a detailed listing of sand equivalent apparatus. Note that the siphon tube and blow tube may be glass or stainless steel as well as copper.

- Graduated plastic cylinder.
- Rubber stopper.
- Irrigator tube.
- Weighted foot assembly: Having a mass of  $1000 \pm 5\text{g}$ . There are two models of the weighted foot assembly. The older model has a guide cap that fits over the upper end of the graduated cylinder and centers the rod in the cylinder. It is read using a slot in the centering screws. The newer model has a sand-reading indicator 254 mm (10 in.) above this point and is preferred for testing clay-like materials.
- Bottle: clean, glass or plastic, of sufficient size to hold working solution
- Siphon assembly: The siphon assembly will be fitted to a 4 L (1 gal.) bottle of working calcium chloride solution placed on a shelf  $915 \pm 25\text{ mm}$  ( $36 \pm 1\text{ in.}$ ) above the work surface.
- Measuring can: With a capacity of  $85 \pm 5\text{ mL}$  (3 oz.).
- Funnel: With a wide-mouth for transferring sample into the graduated cylinder.
- Quartering cloth: 600 mm (2 ft.) square nonabsorbent cloth, such as plastic or oilcloth.
- Mechanical splitter: See the FOP for AASHTO R 76.
- Strike-off bar: A straightedge or spatula.
- Clock or watch reading in minutes and seconds.

- Manually-operated sand equivalent shaker: Capable of producing an oscillating motion at a rate of 100 complete cycles in  $45 \pm 5$  seconds, with a hand assisted half stroke length of  $127 \pm 5$  mm ( $5 \pm 0.2$  in.). It may be held stable by hand during the shaking operation. It is recommended that this shaker be fastened securely to a firm and level mount, by bolts or clamps, if a large number of determinations are to be made.
- Mechanical shaker: See AASHTO T 176 for equipment and procedure.
- Oven: Capable of maintaining a temperature of  $110 \pm 5^{\circ}\text{C}$  ( $230 \pm 9^{\circ}\text{F}$ ).
- Thermometer: Calibrated liquid-in-glass or electronic digital type designed for total immersion and accurate to  $0.1^{\circ}\text{C}$  ( $0.2^{\circ}\text{F}$ ).

## Materials

- Stock calcium chloride solution: Obtain commercially prepared calcium chloride stock solution meeting AASHTO requirements.
- Working calcium chloride solution: Make 3.8 L (1 gal) of working solution. Fill the bottle with 2 L (1/2 gal) of distilled or demineralized water, add one 3 oz. measuring can ( $85 \pm 5$  mL) of stock calcium chloride solution. Agitate vigorously for 1 to 2 minutes. Add the remainder of the water, approximately 2 L (1/2 gal.) for a total of 3.8 L (1 gal) of working solution. Repeat the agitation process. Tap water may be used if it is proven to be non-detrimental to the test and if it is allowed by the agency. The shelf life of the working solution is approximately 30 days. Label working solution with the date mixed. Discard working solutions more than 30 days old.

*Note 1:* The graduated cylinder filled to 4.4 in. contains 88 mL and may be used to measure the stock solution.

## Control

The temperature of the working solution should be maintained at  $22 \pm 3^{\circ}\text{C}$  ( $72 \pm 5^{\circ}\text{F}$ ) during the performance of the test. If field conditions preclude the maintenance of the temperature range, reference samples should be submitted to the Central/Regional Laboratory, as required by the agency, where proper temperature control is possible. Samples that meet the minimum sand equivalent requirement at a working solution temperature outside of the temperature range need not be subject to reference testing.

## Sample Preparation

1. Obtain the sample in accordance with the FOP for AASHTO R 90 and reduce in accordance with the FOP for AASHTO R 76.
2. Prepare sand equivalent test samples from the material passing the 4.75 mm (No. 4) sieve. If the material is in clods, break it up and re-screen it over a 4.75 mm (No. 4) sieve.



sieve. All fines shall be cleaned from particles retained on the 4.75 mm (No. 4) sieve and included with the material passing that sieve.

3. Split or quarter 1000 to 1500 g of material from the portion passing the 4.75 mm (No. 4) sieve. Use extreme care to obtain a truly representative portion of the original sample.

**Note 2:** Experiments show that, as the amount of material being reduced by splitting or quartering is decreased, the accuracy of providing representative portions is reduced. It is imperative that the sample be split or quartered carefully. When it appears necessary, dampen the material before splitting or quartering to avoid segregation or loss of fines.

**Note 3:** All tests, including reference tests, will be performed utilizing Alternative Method No. 2 as described in AASHTO T 176, unless otherwise specified.

4. The sample must have the proper moisture content to achieve reliable results. This condition is determined by tightly squeezing a small portion of the thoroughly mixed sample in the palm of the hand. If the cast that is formed permits careful handling without breaking, the correct moisture content has been obtained.

**Note 4:** Clean sands having little 75  $\mu\text{m}$  (No. 200), such as sand for Portland Cement Concrete (PCC), may not form a cast.

If the material is too dry, the cast will crumble and it will be necessary to add water and remix and retest until the material forms a cast. When the moisture content is altered to provide the required cast, the altered sample should be placed in a pan, covered with a lid or with a damp cloth that does not touch the material, and allowed to stand for a minimum of 15 minutes. Samples that have been sieved without being air-dried and still retain enough natural moisture are exempted from this requirement.

If the material shows any free water, it is too wet to test and must be drained and air dried. Mix frequently to ensure uniformity. This drying process should continue until squeezing provides the required cast.

5. Place the sample on the quartering cloth and mix by alternately lifting each corner of the cloth and pulling it over the sample toward the diagonally opposite corner, being careful to keep the top of the cloth parallel to the bottom, thus causing the material to be rolled. When the material appears homogeneous, finish the mixing with the sample in a pile near the center of the cloth.
6. Fill the measuring can by pushing it through the base of the pile while exerting pressure with the hand against the pile on the side opposite the measuring can. As the can is moved through the pile, hold enough pressure with the hand to cause the material to fill the tin to overflowing. Press firmly with the palm of the hand, compacting the material and placing the maximum amount in the can. Strike off the can level full with the straightedge or spatula.
7. When required, repeat steps 5 and 6 to obtain additional samples.

## Procedure

1. Start the siphon by forcing air into the top of the solution bottle through the tube while the pinch clamp is open. Siphon  $101.6 \pm 2.5$  mm ( $4 \pm 0.1$  in.) of working calcium chloride solution into the plastic cylinder.
2. Pour the prepared test sample from the measuring can into the plastic cylinder, using the funnel to avoid spilling.
3. Tap the bottom of the cylinder sharply on the heel of the hand several times to release air bubbles and to promote thorough wetting of the sample.
4. Allow the wetted sample to stand undisturbed for  $10 \pm 1$  minutes.
5. At the end of the 10-minute period, stopper the cylinder and loosen the material from the bottom by simultaneously partially inverting and shaking the cylinder.
6. After loosening the material from the bottom of the cylinder, shake the cylinder and contents by any one of the following methods:
  - a. Mechanical Method – Place the stoppered cylinder in the mechanical shaker, set the timer, and allow the machine to shake the cylinder and contents for  $45 \pm 1$  seconds.

**Caution:** Agencies may require additional operator qualifications for the next two methods.

- b. Manually-operated Shaker Method – Secure the stoppered cylinder in the three spring clamps on the carriage of the manually-operated sand equivalent shaker and set the stroke counter to zero. Stand directly in front of the shaker and force the pointer to the stroke limit marker painted on the backboard by applying an abrupt horizontal thrust to the upper portion of the right hand spring strap.

Remove the hand from the strap and allow the spring action of the straps to move the carriage and cylinder in the opposite direction without assistance or hindrance. Apply enough force to the right-hand spring steel strap during the thrust portion of each stroke to move the pointer to the stroke limit marker by pushing against the strap with the ends of the fingers to maintain a smooth oscillating motion. The center of the stroke limit marker is positioned to provide the proper stroke length and its width provides the maximum allowable limits of variation.

Proper shaking action is accomplished when the tip of the pointer reverses direction within the marker limits. Proper shaking action can best be maintained by using only the forearm and wrist action to propel the shaker. Continue shaking for 100 strokes.

- c. Hand Method – Hold the cylinder in a horizontal position and shake it vigorously in a horizontal linear motion from end to end. Shake the cylinder 90 cycles in approximately 30 seconds using a throw of  $229 \text{ mm} \pm 25 \text{ mm}$  ( $9 \pm 1$  in.). A cycle is defined as a complete back and forth motion. To properly shake the cylinder at this

speed, it will be necessary for the operator to shake with the forearms only, relaxing the body and shoulders.

7. Set the cylinder upright on the work table and remove the stopper.
8. Insert the irrigator tube in the cylinder and rinse material from the cylinder walls as the irrigator is lowered. Force the irrigator through the material to the bottom of the cylinder by applying a gentle stabbing and twisting action while the working solution flows from the irrigator tip. Work the irrigator tube to the bottom of the cylinder as quickly as possible, since it becomes more difficult to do this as the washing proceeds. This flushes the fine material into suspension above the coarser sand particles.

Continue to apply a stabbing and twisting action while flushing the fines upward until the cylinder is filled to the 381 mm (15 in.) mark. Then raise the irrigator slowly without shutting off the flow so that the liquid level is maintained at about 381 mm (15 in.) while the irrigator is being withdrawn. Regulate the flow just before the irrigator is entirely withdrawn and adjust the final level to 381 mm (15 in.).

**Note 5:** Occasionally the holes in the tip of the irrigator tube may become clogged by a particle of sand. If the obstruction cannot be freed by any other method, use a pin or other sharp object to force it out, using extreme care not to enlarge the size of the opening. Also, keep the tip sharp as an aid to penetrating the sample.

9. Allow the cylinder and contents to stand undisturbed for 20 minutes  $\pm$  15 seconds. Start timing immediately after withdrawing the irrigator tube.

**Note 6:** Any vibration or movement of the cylinder during this time will interfere with the normal settling rate of the suspended clay and will cause an erroneous result.

10. Clay and sand readings:

- a. At the end of the 20-minute sedimentation period, read and record the level of the top of the clay suspension. This is referred to as the clay reading.

**Note 7:** If no clear line of demarcation has formed at the end of the 20-minute sedimentation period, allow the sample to stand undisturbed until a clay reading can be obtained, then immediately read and record the level of the top of the clay suspension and the total sedimentation time. If the total sedimentation time exceeds 30 minutes, rerun the test using three individual samples of the same material. Read and record the clay column height of the sample requiring the shortest sedimentation period only. Once a sedimentation time has been established, subsequent tests will be run using that time. The time will be recorded along with the test results on all reports.

- b. After the clay reading has been taken, place the weighted foot assembly over the cylinder and gently lower the assembly until it comes to rest on the sand. Do not allow the indicator to hit the mouth of the cylinder as the assembly is being lowered. Subtract 254 mm (10 in.) from the level indicated by the extreme top edge of the indicator and record this value as the sand reading.
- c. If clay or sand readings fall between 2.5 mm (0.1 in.) graduations, record the level of the higher graduation as the reading. For example, a clay reading that appears to be 7.95 would be recorded as 8.0; a sand reading that appears to be 3.22 would be recorded as 3.3.

- d. If two Sand Equivalent (SE) samples are run on the same material and the second varies by more than  $\pm 4$ , based on the first cylinder result, additional tests shall be run.
- e. If three or more Sand Equivalent (SE) samples are run on the same material, average the results. If an individual result varies by more than  $\pm 4$ , based on the average result, additional tests shall be run.

## Calculations

Calculate the SE to the nearest 0.1 using the following formula:

$$SE = \frac{\text{Sand Reading}}{\text{Clay Reading}} \times 100$$

### Example:

$$\begin{array}{lcl} \text{Sand Reading} & = & 3.3 \\ \text{Clay Reading} & = & 8.0 \end{array}$$

$$SE = \frac{3.3}{8.0} \times 100 = 41.25 \text{ or } 41.3 \quad \text{Report 42}$$

**Note 8:** This example reflects the use of equipment made with English units. At this time, equipment made with metric units is not available.

Report the SE as the next higher whole number. In the example above, the 41.3 would be reported as 42. An SE of 41.0 would be reported as 41.

When averaging two or more samples, raise each calculated SE value to the next higher whole number (reported value) before averaging.

### Example:

$$\begin{array}{lcl} \text{calculated value 1} & = & 41.3 \\ \text{calculated value 2} & = & 42.8 \end{array}$$

These values are reported as 42 and 43, respectively.

Average the two reported values:

$$\text{Average SE} = \frac{42 + 43}{2} = 42.5 \quad \text{Report 43}$$

If the average value is not a whole number, raise it to the next higher whole number.

## Report

- Results on forms approved by the agency
- Sample ID
- Results to the next higher whole number
- Sedimentation time if over 20 minutes



**PERFORMANCE EXAM CHECKLIST****PLASTIC FINES IN GRADED AGGREGATES AND SOILS BY THE USE OF THE SAND EQUIVALENT TEST  
FOP FOR AASHTO T 176**

Participant Name \_\_\_\_\_ Exam Date \_\_\_\_\_

**Record the symbols "P" for passing or "F" for failing on each step of the checklist.**

<b>Procedure Element</b>	<b>Trial 1</b>	<b>Trial 2</b>
<b>Sample Preparation</b>		
1. Sample passed through 4.75 mm (No. 4) sieve?	_____	_____
2. Material in clods broken up and re-screened?	_____	_____
3. Split or quarter 1,000 to 1,500 g of material passing the 4.75 mm (No. 4) sieve? NOTE: If necessary, the material may be dampened before splitting to avoid segregation or loss of fines.	_____	_____
4. No fines lost?	_____	_____
5. Working solution dated?	_____	_____
6. Temperature of working solution $22 \pm 3^{\circ}\text{C}$ ( $72 \pm 5^{\circ}\text{F}$ )?	_____	_____
7. Working calcium chloride solution $915 \pm 25$ mm ( $36 \pm 1$ in) above the work surface?	_____	_____
8. $101.6 \pm 2.5$ mm ( $4 \pm 0.1$ in) working calcium chloride solution siphoned into cylinder?	_____	_____
9. Material checked for moisture condition by tightly squeezing small portion in palm of hand and forming a cast?	_____	_____
10. Sample at proper water content?		
a. If too dry (cast crumbles easily) water added, re-mixed, covered, and allowed to stand for at least 15 minutes?	_____	_____
b. If too wet (shows free water) sample drained, air dried and mixed frequently?	_____	_____
11. Sample placed on splitting cloth and mixed by alternately lifting each corner of the cloth and pulling it over the sample toward diagonally opposite corner, causing material to be rolled?	_____	_____
12. Is material thoroughly mixed?	_____	_____
13. When material appears to be homogeneous, mixing finished with sample in a pile near center of cloth?	_____	_____
14. Fill the 85 mL (3 oz) tin by pushing through base of pile with other hand on opposite side of pile?	_____	_____

**OVER**

Procedure Element	Trial 1	Trial 2
15. Material fills tin to overflowing?	_____	_____
16. Material compacted into tin with palm of hand?	_____	_____
17. Tin struck off level full using spatula or straightedge?	_____	_____
18. Prepared sample funneled into cylinder with no loss of fines?	_____	_____
19. Bottom of cylinder tapped sharply on heel of hand several times to release air bubbles?	_____	_____
20. Wetted sample allowed to stand undisturbed for 10 min. $\pm 1$ min.?	_____	_____
21. Cylinder stoppered and material loosened from bottom by shaking?	_____	_____
22. Stoppered cylinder placed properly in mechanical shaker and cylinder shaken $45 \pm 1$ seconds?	_____	_____
23. Following shaking, cylinder set vertical on work surface and stopper removed?	_____	_____
24. Irrigator tube inserted in cylinder and material rinsed from cylinder walls as irrigator is lowered?	_____	_____
25. Irrigator tube forced through material to bottom of cylinder by gentle stabbing and twisting action?	_____	_____
26. Stabbing and twisting motion applied until cylinder filled to 381 mm (15 in.) mark?	_____	_____
27. Liquid raised and maintained at 381 mm (15 in.) mark while irrigator is being withdrawn?	_____	_____
28. Liquid at the 381 mm (15 in.) mark?	_____	_____
29. Contents let stand 20 minutes $\pm 15$ seconds?	_____	_____
30. Timing started immediately after withdrawal of irrigator?	_____	_____
31. No vibration or disturbance of the sample?	_____	_____
32. Readings taken at 20 minutes or up to 30 minutes, when a definite line appears?	_____	_____
33. Clay level correctly read, rounded, and recorded?	_____	_____
34. Weighted foot assembly lowered into cylinder without hitting mouth of cylinder?	_____	_____
35. Sand level correctly read, rounded, and recorded?	_____	_____
36. Calculations performed correctly?	_____	_____
Comments: First attempt: Pass_____Fail_____ Second attempt: Pass_____Fail_____		

Examiner Signature \_\_\_\_\_ WAQTC #: \_\_\_\_\_