

**APPENDIX A
FIELD OPERATING PROCEDURES – SHORT FORMS**

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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

| Nominal Maximum | | Minimum Mass | |
|------------------------|---------|---------------------|-------|
| Size* | | | |
| mm (in.) | | g (lb) | |
| 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 1 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.

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.

| Procedure Element | Trial 1 | Trial 2 |
|--|----------------|----------------|
| Conveyor Belts – Method A (From the Belt) | | |
| 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? | _____ | _____ |
| Conveyor Belts – Method B (From the Belt Discharge) | | |
| 5. Sampling device passed through full stream of material twice (once in each direction) as it runs off end of belt? | _____ | _____ |
| Transport Units | | |
| 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? | _____ | _____ |
| Roadways Method A (Berm or Windrow) | | |
| 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? | _____ | _____ |
| Roadways Method B (In-place) | | |
| 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 _____

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.

| Procedure Element | Trial 1 | Trial 2 |
|---|----------------|----------------|
| 1. How is a sample obtained from a conveyor belt using Method A? | | |
| 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. | _____ | _____ |
| 2. How is a sample obtained from a conveyor belt using Method 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). | _____ | _____ |
| 3. How is a sample obtained from a Transport Unit? | | |
| a. Divide the unit into four quadrants. | _____ | _____ |
| b. Dig 0.3 m (1 ft.) below surface. | _____ | _____ |
| c. Obtain an increment from each quadrant. | _____ | _____ |
| 4. Describe the procedure for sampling from roadways Method A (Berm or Windrow). | | |
| 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 |
|--|----------------|----------------|
| 5. Describe the procedure for sampling from roadway Method B (In-place). | | |
| a. Sample after spreading, before compaction. | _____ | _____ |
| b. Sample the material full depth without obtaining underlying material. | _____ | _____ |
| c. Take at least three approximately equal increments. | _____ | _____ |
| 6. Describe the procedure for sampling a stockpile Method A (Loader Sampling). | | |
| 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. | _____ | _____ |
| 7. Describe the procedure for sampling a stockpile Method B (Stockpile Face Sampling). | | |
| 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. | _____ | _____ |
| 8. Describe the procedure for sampling a stockpile Method C – Alternate Tube Method (Fine Aggregate). | | |
| a. Remove the outer layer of segregated material. | _____ | _____ |
| b. Obtain increments from at least five locations. | _____ | _____ |
| 9. After obtaining the increments what should you do before performing R 76? | | |
| a. Increments mixed thoroughly to form sample. | _____ | _____ |

Comments: First attempt: Pass_____Fail_____ Second attempt: Pass_____Fail_____

Examiner Signature _____ WAQTC #: _____

PERFORMANCE EXAM CHECKLIST

**REDUCING FIELD SAMPLES OF AGGREGATE 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? _____
- 5. Mechanical splitter checked or alternative used? _____

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____

Examiner Signature _____ **WAQTC #:** _____

REDUCING SAMPLES OF AGGREGATE 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, appropriate for the amount and size of the material being reduced

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 – 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

| | Drier than SSD | Wetter than SSD |
|-----------------------|--------------------------|--------------------------|
| 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 two clean empty receptacles under the splitter.
2. Empty the sample into the hopper or pan without loss of material.
3. Uniformly distribute the material in the hopper or pan from edge to edge so that approximately equal amounts flow through each chute.
4. Discharge the material at a uniform rate, allowing it to flow freely through the chutes.
5. Remove any material retained on the surface of the splitter and place into the appropriate receptacle.
6. Using one of the two receptacles containing material, repeat Steps 1 through 6 until the material in one of the two receptacles is the appropriate sample size for the required test.
7. Retain and properly identify the remaining unused sample for further testing if required.

Mechanical Splitter Check

- 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.

Calculation

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

Splitter check: 5127 g total sample mass

Splitter pan #1: 2583 g

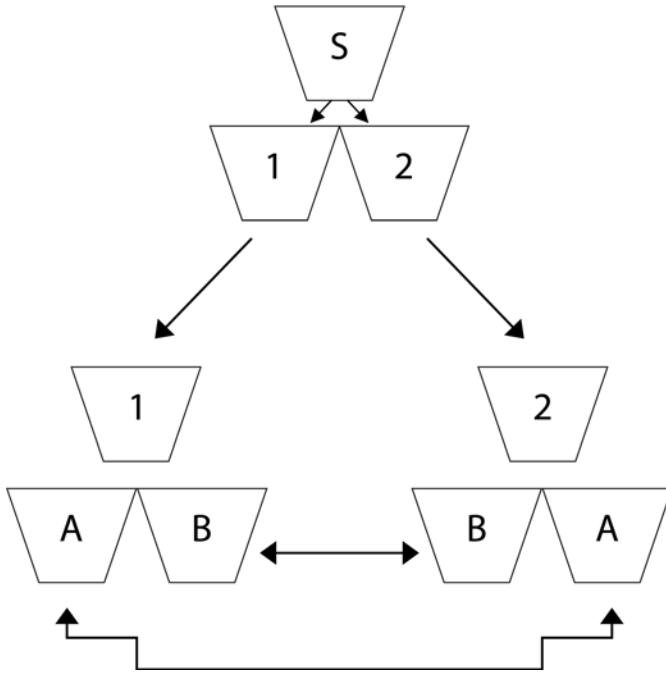
Splitter pan #2: 2544 g

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

Alternative to Mechanical Splitter Check

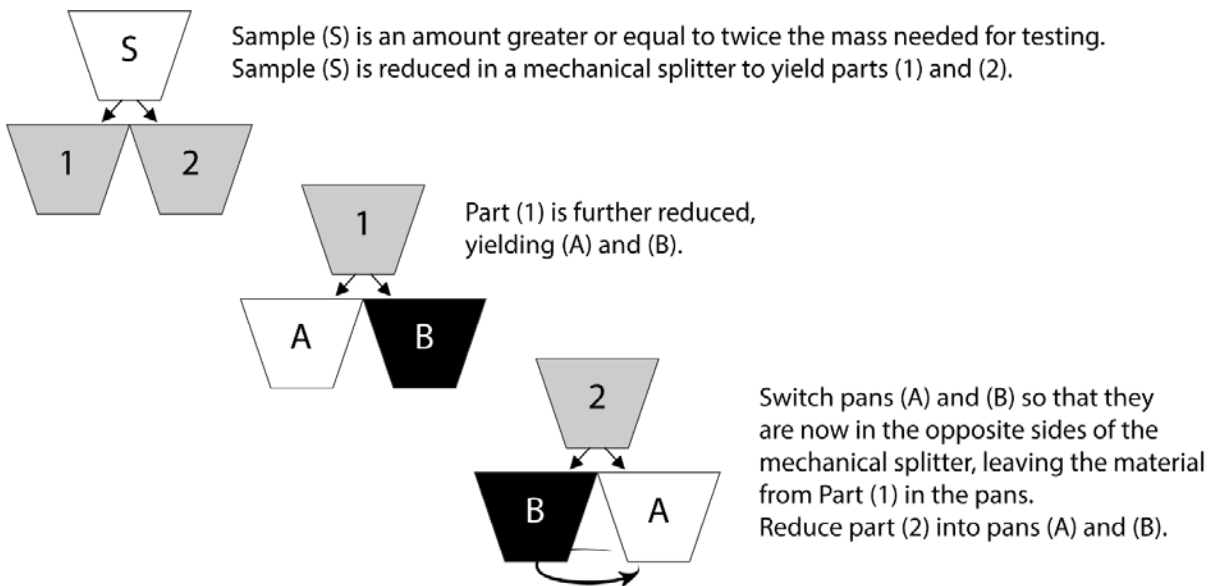
- In lieu of determining the mass of each reduced portion, use the method illustrated in Figure 1 or 2 during reduction.

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.

Figure 2



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
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.

| Procedure Element | Trial 1 | Trial 2 |
|---|----------------|----------------|
| 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 _____

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

| Nominal Maximum Size* mm (in.) | Minimum Sample Mass g (lb) |
|---|---------------------------------------|
| 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 (M_w) 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 (M_D) 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) |
|---|---|---|
| Controlled: Forced Draft Oven (preferred), Ventilated Oven, or Convection Oven | $110 \pm 5^\circ\text{C}$ ($230 \pm 9^\circ\text{F}$) | 30 |
| Uncontrolled: | | |
| 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 sample after second drying cycle: 2634.1 g

Mass, M_n , of 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 sample after third drying cycle: 2633.0 g

Mass, M_n , of 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 g - 1232.1 g = 1532.6 g

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

Mass, M_D , of dry sample: 2633.5 g - 1232.1 g = 1401.4 g

$$w = \frac{1532.6 \text{ g} - 1401.4 \text{ g}}{1401.4 \text{ g}} \times 100 = \frac{131.2 \text{ g}}{1401.4 \text{ g}} = 9.40\% \text{ report } 9.4\%$$

Report

- 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

**METHOD A
SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES
FOP FOR AASHTO T 27
MATERIALS FINER THAN 75 µm (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.

| Procedure Element | Trial 1 | Trial 2 |
|--|----------------|----------------|
| 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 µm (No. 200) achieved? | _____ | _____ |
| 7. Wash water poured through nested sieves such as 2 mm (No. 10) and 75 µm (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 μm (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 _____

Examiner Signature _____ **WAQTC #:** _____

PERFORMANCE EXAM CHECKLIST

**METHOD B
SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES
FOP FOR AASHTO T 27
MATERIALS FINER THAN 75 µm (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.

| Procedure Element | Trial 1 | Trial 2 |
|--|----------------|----------------|
| 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 µm (No. 200) achieved? | _____ | _____ |
| 7. Wash water poured through nested sieves such as 2 mm (No. 10) and 75 µm (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 μm (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_____

Examiner Signature _____ **WAQTC #:** _____

PERFORMANCE EXAM CHECKLIST

**METHOD C
SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES
FOP FOR AASHTO T 27
MATERIALS FINER THAN 75 µm (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.

| Procedure Element | Trial 1 | Trial 2 |
|---|----------------|----------------|
| 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. Material aggregations and clay lumps, silt, or adhering fines broken up? | _____ | _____ |
| 5. Sample placed in nest of sieves specified? (Additional sieves may be used to prevent overloading as allowed in FOP.) | _____ | _____ |
| 6. Material sieved in verified mechanical shaker for proper time? | _____ | _____ |
| 7. Mass of material on each sieve and in pan determined to the nearest 0.1 percent or 0.1 g? | _____ | _____ |
| 8. Complete separation of coarse and fine particles achieved? | _____ | _____ |
| 9. Total mass of material after sieving agrees with original dry mass of sample to within 0.3 percent (coarse check sum)? | _____ | _____ |
| 10. Material in pan reduced to test size for washing in accordance with FOP for AASHTO R 76? | _____ | _____ |
| 11. Mass of the minus 4.75 mm (No. 4) split sample recorded to the nearest 0.1 g? | _____ | _____ |
| 12. Test sample placed in container and covered with water? | _____ | _____ |
| 13. Contents of the container vigorously agitated? | _____ | _____ |
| 14. Suspension of minus 75 µm (No. 200) achieved? | _____ | _____ |

OVER

| Procedure Element | Trial 1 | Trial 2 |
|--|---------|---------|
| 15. Wash water poured through a set of nested sieves, such as a 2.0 mm (No. 10) over the 75 μm (No. 200)? | _____ | _____ |
| 16. Operation continued until wash water is reasonably clear? | _____ | _____ |
| 17. Material retained on sieves returned to washed sample? | _____ | _____ |
| 18. Washed test sample dried to a constant mass in accordance with FOP for AASHTO T 255? | _____ | _____ |
| 19. Washed test sample cooled, and dry mass recorded to the nearest 0.1 g? | _____ | _____ |
| 20. Test sample placed in nest of sieves specified? (Additional sieves may be used to prevent overloading as allowed in FOP.) | _____ | _____ |
| 21. Material sieved in verified mechanical shaker for proper time? | _____ | _____ |
| 22. Mass of material on each sieve and in pan determined to nearest 0.1g? | _____ | _____ |
| 23. Total mass of material after sieving agrees with mass after washing to within 0.3 percent (fine check sum)? | _____ | _____ |
| 24. Percentages calculated to the nearest 0.1 percent and reported to the nearest whole number, except 75 μm (No. 200) which is reported to the nearest 0.1 percent? | _____ | _____ |
| 25. Calculations performed, and results reported properly? | _____ | _____ |
| 26. Percentage calculations based on original dry mass of the sample? | _____ | _____ |

Comments: First attempt: Pass _____ Fail _____ Second attempt: Pass _____ Fail _____

Examiner Signature _____ WAQTC #: _____

**SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES
FOP FOR AASHTO T 27
MATERIALS FINER THAN 75 µM (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 µm (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 27-20 and materials finer than 75 µm (No. 200) in accordance with AASHTO T 11-20 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 ± 0.23 kg (1.25 ± 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 75 μ m (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 μ m (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 75 μ m (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 μm (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 μm (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 μm (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 μm (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.

Note 2: Washing longer than 10 minutes in a mechanical washer has been shown to cause significant amounts of degradation depending upon aggregate type.

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 μm (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 μm (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 μm (No. 200) sieve to the container by rinsing into the washed sample.

Note 3: Excess water may be carefully removed with a bulb syringe; the removed water must be discharged back over the 75 μm (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 as described in Annex B. With a pan on bottom, nest the sieves increasing in size starting with the 75 μm (No. 200).
12. Place the sample, or a portion of the 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 4: 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 5: 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 6: 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 (<i>M</i>): | 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 μm (No. 200) in the pan: | 4905.9 g |
| Amount of 75μm (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 (<i>M</i>): | 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 µm (No. 200) from the pan): | 4905.9 g |
| Amount of 75µm (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 μ m (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 μm (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 μm (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 μm (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 μm (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.

Note 2: Washing longer than 10 minutes in a mechanical washer has been shown to cause significant amounts of degradation depending upon aggregate type.

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 μm (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 μm (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 μm (No. 200) sieve to the container by rinsing into the washed sample.

Note 3: Excess water may be carefully removed with a bulb syringe; the removed water must be discharged back over the 75 μm (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 as described in Annex B. With a pan on bottom, nest the sieves increasing in size starting with the 4.75 mm (No. 4).
12. 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 4: 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 5:* 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 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 as described in Annex B. With a pan on bottom, nest the sieves increasing in size starting with the 75 μm (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 6:* 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 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 μm (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

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

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

$$\text{PP} = 95.0\% - 15.0\% = 80.0\%$$

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 μ 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
- M₁ = total mass of minus 4.75 mm (No. 4) from the pan
- M₂ = 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 (<i>M</i>): | 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 μ 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 μm (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 as described in Annex B. 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 1: 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 2: 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 μm (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 μm (No. 200) sieve.
11. Place the sample in a container and cover with water.

Note 3: 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 μm (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 μm (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.

Note 4: Washing longer than 10 minutes in a mechanical washer has been shown to cause significant amounts of degradation depending upon aggregate type.

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 μm (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 μm (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 μm (No. 200) sieve to the container by flushing into the washed sample.
- Note 5:** Excess water may be carefully removed with a bulb syringe; the removed water must be discharged back over the 75 μm (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 as described in Annex B. With a pan on bottom, nest the sieves increasing in size starting with the 75 μm (No. 200) sieve up to, but not including, the 4.75 mm (No. 4) sieve.
 20. Place the 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 6:** 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 7:** 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.
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_{#4}) and the Percent Passing (PP_{#4}) 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 μm (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_{#4}) for minus 4.75 mm (No. 4) split

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

where:

- CPR_{#4} = Cumulative Percent Retained for the sieve sizes of M₃
 CMR_{#4} = Cumulative Mass Retained for the sieve sizes of M₃
 M₃ = Total mass of the minus 4.75 mm (No. 4) split before washing

Percent Passing (PP_{#4}) for minus 4.75 mm (No. 4) split

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

where:

- PP_{#4} = Percent Passing for the sieve sizes of M₃
 CPR_{#4} = Cumulative Percent Retained for the sieve sizes of M₃

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_{#4} = Percent Passing for the sieve sizes of M₃
 #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
- M₃ = Total mass of the minus 4.75 mm (No. 4) split before washing
- CMR-#4 = Cumulative Mass Retained for the sieve sizes of M₃

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

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

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

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

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

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 | $100.0 - 39.2 =$ | 60.8 (#4 PP) | 61 |
| Mass in pan | 2008.9 | | | | | |
| CMR: 1295.6 + 2008.9 = 3304.5 | | | | | | |
| Original dry mass of the sample (M): 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 μ 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_{#4}) 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_{#4}) 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 _{#4}) | Determine CPR _{#4} Divide CMR by M ₃ and multiply by 100 | Cumulative Percent Retained _{#4} (CPR _{#4}) | Determine PP _{#4} by subtracting CPR _{#4} from 100.0 | Percent Passing _{#4} (PP _{#4}) |
|---|--|---|---|--|---|
| 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 ₃): 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 | | | 60.8 (#4 PP) | 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 | $\frac{3304.5 - 1295.6}{3304.5} \times 100 =$ | 60.8 (#4 PP) | 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**

| Sieve Size mm (in.) | Cumulative Mass Retained g (CMR _{#4}) | Determine PP _{#4} subtract CMR _{#4} from M ₃ , divide result by M ₃ multiply by 100 | Percent Passing _{#4} (PP _{#4}) |
|---|--|---|---|
| 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 ₃): 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 _{#4} (PP _{#4}) | Determine PP multiply PP _{#4} 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) | | | 60.8 (#4 PP) | 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

- 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 μm (No. 200) sieve, which shall be reported to the nearest 0.1 percent.

ANNEX A**Time Evaluation**

(Mandatory information)

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**

(Mandatory information)

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/m² (4 g/in²) 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 ² | | | | |
| | | 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 |

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. Re-sort 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:

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

Given:

- 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:

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

Given:

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

Report

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

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.

| Procedure Element | Trial 1 | Trial 2 |
|---|----------------|----------------|
| Sample Preparation | | |
| 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 ±3°C (72 ±5°F)? | _____ | _____ |
| 7. Working calcium chloride solution 915 ±25 mm (36 ±1in) above the work surface? | _____ | _____ |
| 8. 101.6 ±2.5 mm (4 ±0.1in) 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. ±1 min.? | _____ | _____ |
| 21. Cylinder stoppered and material loosened from bottom by shaking? | _____ | _____ |
| 22. Stoppered cylinder placed properly in mechanical shaker and cylinder shaken 45 ±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 ±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 #: _____

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 176-02. 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 ± 5 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 ± 25 mm (36 ± 1 in.) above the work surface.
- Measuring can: With a capacity of 85 ± 5 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 ± 5 seconds, with a hand assisted half stroke length of 127 ± 5 mm (5 ± 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°C (0.2°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 ± 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. Sieve the sample over 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. Clean all fines from particles retained on the 4.75 mm (No. 4) sieve and include 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 using 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 μm (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 mm \pm 25 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 ±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 ±4, based on the average result, additional tests shall be run.

Calculations

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

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

Example

Given:

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

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

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:

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

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

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

