

WSDOT FOP for WAQTC T 27/T 11

Sieve Analysis of Fine and Coarse Aggregates

Significance

Sieve analyses are performed on aggregates used in roadway bases and in portland cement and asphalt cement concretes. Sieve analyses reveal the size makeup of aggregate particles – from the largest to the smallest. A gradation curve or chart showing how evenly or unevenly the sizes are distributed between largest and smallest is created in this test. How an aggregate is graded has a major impact on the strength of the base or on the properties and performance of concrete. In portland cement concrete (PCC), for example, gradation influences shrinkage and shrinkage cracking, pumpability, finishability, permeability, and other characteristics.

Scope

This procedure covers sieve analysis in accordance with AASHTO T 27 and materials finer than No. 200 (75 μm) in accordance with AASHTO T 11. The procedure combines the two test methods.

Sieve analyses determines the gradation or distribution of aggregate particles within a given sample in order to determine compliance with design and production standards.

Accurate determination of material smaller than No. 200 (75 μm) cannot be made with AASHTO T 27 alone. If quantifying this material is required, it is recommended that AASHTO T 27 be used in conjunction with AASHTO T 11. Following AASHTO T 11, the sample is washed through a No. 200 (75 μm) sieve. The amount of material passing this sieve is determined by comparing dry sample masses before and after the washing process.

This procedure covers sieve analysis in accordance with AASHTO T 27 and materials finer than No. 200 (75 μm) in accordance with AASHTO T 11. The procedure includes two method choices, A and B.

Note: All Field Operating Procedures (FOPs) referred to in this procedure are WSDOT FOPs.

Apparatus

- Balance or Scale – Capacity sufficient for the masses shown in [Table 2](#), accurate to 0.1 percent of the sample mass or better and conform to the requirements of AASHTO M 231.
- Sieves – Meeting the requirements of AASHTO M 92.
- Mechanical Sieve Shaker – Meeting the requirements of AASHTO T 27.
- Suitable Drying Equipment – See FOP for AASHTO T 255.
- Containers and Utensils – A pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water.
- Optional mechanical washing device.

Sample Sieving

In all procedures, it is required to shake the sample over nested sieves. Sieves are selected to furnish information required by specification. The sieves are nested in order of decreasing size from the top to the bottom and the sample, or a portion of the sample, is placed on the top sieve. The sample may also be sieved in increments.

Sieves are shaken in a mechanical shaker for the minimum time determined to provide complete separation for the sieve shaker being used.

Time Evaluation

WSDOT has deleted this section.

Overload Determination

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

For sieves with openings smaller than No. 4 (4.75 mm), the mass retained on any sieve shall not exceed 4 g/in² (7 kg/m²) of sieving surface. For sieves with openings No. 4 (4.75 mm) and larger, the mass, in grams shall not exceed the product of 2.5 × (sieve opening in mm) × (effective sieving area). See Table 1.

Sieve Size in (mm)		8 ϕ (203)	12 ϕ (305)	12 × 12 (305 × 305)	14 × 14 (350 × 350)	16 × 24 (372 × 580)
		Sieving Area m ²				
		0.0285	0.0670	0.0929	0.1225	0.2158
3½	(90)	*	15.1	20.9	27.6	48.5
3	(75)	*	12.6	17.4	23.0	40.5
2½	(63)	*	10.6	14.6	19.3	34.0
2	(50)	3.6	8.4	11.6	15.3	27.0
1½	(37.5)	2.7	6.3	8.7	11.5	20.2
1	(25.0)	1.8	4.2	5.8	7.7	13.5
¾	(19.0)	1.4	3.2	4.4	5.8	10.2
⅝	(16.0)	1.1	2.7	3.7	4.9	8.6
½	(12.5)	0.89	2.1	2.9	3.8	6.7
⅜	(9.5)	0.67	1.6	2.2	2.9	5.1
¼	(6.3)	0.44	1.1	1.5	1.9	3.4
No. 4	(4.75)	0.33	0.80	1.1	1.5	2.6
Less than	(No. 4)	0.20	0.47	0.65	0.86	1.5

Sample sizes above are in kilograms. To convert to grams, multiply by 1,000. To convert to pounds, multiply by 2.2.

Maximum Allowable Mass of Material Retained On a Sieve (kg)

Table 1

Sample Preparation

Obtain samples in accordance with FOP for AASHTO T 2 and reduce to the size shown in Table 2 in accordance with FOP for AASHTO T 248. If the gradation sample is obtained from FOP for AASHTO T 308, the Ignition Furnace, proceed to Procedure Method A, Step 2.

Nominal Maximum Size* in (mm)		Minimum Dry Mass lb (kg)	
US No. 4	(4.75)	1	(0.5)
¼	(6.3)	2	(1)
⅜	(9.5)	2	(1)
½	(12.5)	5	(2)
⅝	(16.0)	5	(2)
¾	(19.0)	7	(3)
1	(25.0)	13	(6)
1¼	(31.5)	17	(7.5)
1½	(37.5)	20	(9)
2	(50)	22	(10)
2½	(63)	27	(12)
3	(75)	33	(15)
3½	(90)	44	(20)

*For aggregate, the nominal maximum size sieve is the largest standard sieve opening listed in the applicable specification upon which more than 1 percent of the material is permitted to be retained. For concrete aggregate, the nominal maximum size sieve is the smallest standard sieve opening through which the entire amount of aggregate is permitted to pass.

Sample Sizes for Aggregate Gradation Test

Table 2

Note: For an aggregate specification having a generally unrestrictive gradation (i.e., wide range of permissible upper sizes), where the source consistently fully passes a screen substantially smaller than the maximum specified size, the nominal maximum size, for the purpose of defining sampling and test specimen size requirements may be adjusted to the screen, found by experience to retain no more than 5 percent of the materials.

WSDOT Note 1: These sample sizes are standard for aggregate testing but, due to equipment restraints, samples may need to be partitioned into several “subsamples” (see Method A).

Overview

Method A – This method is the preferred method of sieve analysis for HMA aggregate.

- Determine dry mass of original sample.
- Wash through a No. 200 (75 µm) sieve.
- Determine dry mass of washed sample.
- Sieve material.

Method B

- Determine dry mass of original sample.
- Wash through a No. 200 (75 µm) sieve.
- Determine dry mass of washed sample.
- Sieve coarse material.
- Determine mass of fine material.
- Reduce fine portion.
- Determine mass of reduced portion.
- Sieve fine portion.

Procedure Method A

1. Dry the sample in accordance with FOP for AASHTO T 255, and record to the nearest 0.1 percent of total mass or better.
2. When the specification requires that the amount of material finer than No. 200 (75 μm) be determined, do Step 3 through Step 9. Otherwise, skip to Step 10.

WSDOT Note 2: If the applicable specification requires that the amount passing the No. 200 (75 μm) sieve be determined on a portion of the sample passing a sieve smaller than the nominal maximum size of the aggregate, separate the sample on the designated sieve and determine the mass of the material passing that sieve to 0.1 percent of the mass of this portion of the test sample. Use the mass as the original dry mass of the test sample.

3. Nest a sieve, any sieve ranging from a No. 8 (2.36 mm) to a No. 16 (1.18 mm) may be used, above the No. 200 (75 μm) sieve.
4. Place the test sample in a container and add sufficient water to cover it.

WSDOT requires the use of a detergent, dispersing agent, or other wetting solution when washing a sample from FOP for AASHTO T 308, an ignition furnace sample.

WSDOT Note 3: A detergent, dispensing agent, or other wetting solution may be added to the water to assure a thorough separation of the material finer than the No. 200 (75 μm) 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.

5. Agitate vigorously to ensure complete separation of the material finer than No. 200 (75 μm) from coarser particles and bring the fine material into suspension above the coarser material. When using a mechanical washing device, exercise caution to not degrade the sample.
6. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, being careful not to pour out the coarser particles.
7. Add a second change of water to the sample remaining in the container, agitate, and repeat Step 6. Repeat the operation until the wash water is reasonably clear.
8. Return all material retained on the nested sieves to the container by flushing into the washed sample.

WSDOT Note 4: A suction device may be used to extract excess water from the washed sample container. Caution will be used to avoid removing any material greater than the No. 200.

9. Dry the washed aggregate in accordance with FOP for AASHTO T 255, and then cool prior to sieving. Record the cooled dry mass.
10. Select sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom and place the sample, or a portion of the sample, on the top sieve.
11. Place sieves in mechanical shaker and shake for a minimum of 10 minutes, or the minimum time determined to provide complete separation if this time is greater than 10 minutes for the sieve shaker being used.

12. Determine the individual or cumulative mass retained on each sieve and the pan to the nearest 0.1 percent or 0.1 g.

WSDOT Note 5: Use coarse wire brushes to clean the No. 40 (425 μm) and larger sieves and soft bristle brushes for smaller sieves.

Calculations

The total mass of material after sieving should be verified with the mass before sieving. If performing T 11 with T 27, this would be the dry mass after wash. If performing just T 27, this would be the original dry mass. When the masses before and after sieving differ by more than 0.3 percent, do not use the results for acceptance purposes. When performing the gradation from HMA using T 308, the masses before and after sieving shall not differ by more than 0.2 percent.

Calculate the total percentages passing, individual or cumulative percentages retained, or percentages in various size fractions to the nearest 0.1 percent by dividing the masses for Method A, or adjusted masses for Methods B and C, on the individual sieves by the total mass of the initial dry sample. If the same test sample was first tested by T 11, use the total dry sample mass prior to washing in T 11 as the basis for calculating all percentages. Report percent passing as indicated in the “Report” section at the end of this FOP.

Percent Retained:

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

Where:

IPR = Individual Percent Retained

CPR = Cumulative Percent Retained

M = Total Dry Sample mass before washing

IMR = Individual Mass Retained OR Adjusted Individual mass from Methods B or C

CMR = Cumulative Mass Retained OR Adjusted Individual mass from Methods B or C

OR

Percent Passing (Calculated):

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

Where:

PP = Percent Passing

PPP = Previous Percent Passing

Calculate cumulative percent retained on and passing each sieve on the basis of the dry mass of total sample, before washing. This will include any material finer than No. 200 (75 μm) that was washed out.

Divide the cumulative masses, or the corrected masses, on the individual sieves by the total mass of the initial dry sample (prior to washing) to determine the percent retained on and passing each sieve. Calculate the percent retained on and passing each sieve. Report percent passing as indicated in the “Report” section at the end of this FOP.

Example:

Dry mass of total sample, before washing: 3214.0 g

Dry mass of sample, after washing out the No. 200 (75 µm) minus: 3085.1 g

For the ½" sieve:

Cumulative Mass retained on ½" sieve = 161.0 g

Cumulative % retained = $\frac{161.0}{3214.0} \times 100 = 5.0\%$ retained

% passing = 100-5.0 = 95% passing ½" sieve

Sieve Size in (mm)		Cumulative Mass Retained (g)	Cumulative Percent Retained	Reported Percent Passing*
¾	(19.0)	0	0	100
½	(12.5)	161.0	5.0	95
⅜	(9.5)	642.0	20.0	80
No. 4	(4.75)	1118.3	34.8	65
**No. 6	(3.35)	1515.2		
No. 10	(2.0)	1914.7	59.6	40
No. 40	(0.425)	2631.6	81.9	18
No. 80	(0.210)	2862.7	89.1	11
No. 200	(0.075)	3051.1	94.9	5.1
Pan		3086.4		

*Report No. 200 (75 µm) sieve to 0.1 percent. Report all others to 1 percent.

**Intermediate sieve used to prevent overloading the U.S. No. 10 sieve.

Gradation On All Screens

Test Validation: $(3086.4 - 3085.1)/3085.1 \times 100 = 0.04\%$ which is within the 0.3 percent requirement and the results can be used for acceptance purposes.

Procedure Method B

1. Perform steps 1 through 9 from the Procedure Method A, then continue as follows:
2. Select sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom through the No. 4 (4.75 mm) with a pan at the bottom to retain the minus No. 4 (4.75 mm). See Table 1.
3. Place sieves in mechanical shaker and shake for a minimum of 10 minutes, or the minimum time determined to provide complete separation if this time is greater than 10 minutes for the sieve shaker being used.
4. Determine the individual or cumulative mass retained on each sieve and the pan to the nearest 0.1 percent or 0.1 g. Ensure that all material trapped in the openings of the sieve are cleaned out and included in the mass retained (see Note 5).
5. Determine the mass retained on each sieve to the nearest 0.1 percent of the total mass or better.
6. Determine the mass of the material in the pan (minus No. 4 (4.75 mm)).
7. Reduce the minus No. 4 (4.75 mm) using a mechanical splitter in accordance with FOP for AASHTO T 248 to produce a sample with a mass of 500 g minimum. Determine and record the mass of the minus No. 4 (4.75 mm) split.
8. Select sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom through the No. 200 (75 μ m) with a pan at the bottom to retain the minus No. 200 (75 μ m).
9. Place sieves in mechanical shaker and shake for a minimum of 10 minutes, or the minimum time determined to provide complete separation if this time is greater than 10 minutes for the sieve shaker being used.
10. Determine the individual or cumulative mass retained on each sieve and the pan to the nearest 0.1 percent or 0.1 g. Ensure that all material trapped in the openings of the sieve are cleaned out and included in the mass retained (see Note 5).

Calculations

Compute the “Adjusted Cumulative Mass Retained” of the size increment of the original sample as follows when determining “Cumulative Mass Retained”:

Divide the cumulative masses, or the corrected masses, on the individual sieves by the total mass of the initial dry sample (prior to washing) to determine the percent retained on and passing each sieve. Calculate the percent retained on and passing each sieve. Report percent passing as indicated in the “Report” section at the end of this FOP.

When material passing the No. 4 (4.75 mm) sieve is split and only a portion of that is tested, the proportionate share of the amount passing the No. 200 (75 μ m) sieve must be added to the sample mass to obtain a corrected test mass. This corrected test mass is used to calculate the gradation of the material passing the No. 4 (4.75 mm) sieve.

$$C = \left(\frac{M_1}{M_2} \times B \right) + D$$

Where:

- C = Total cumulative mass retained of the size increment based on a total sample
- M₁ = Mass of fraction finer than No. 4 (4.75 mm) sieve in total sample
- M₂ = Mass of reduced portion of material finer than No. 4 (4.75 mm) sieve actually sieved
- B = Cumulative mass of the size increment in the reduced portion sieved
- D = Cumulative mass of plus No. 4 (4.75 mm) portion of sample

Example:

Dry mass of total sample, before washing: 3214.0 g

Dry mass of sample, after washing out the No. 200 (75 μm) minus: 3085.1 g

Sieve Size in (mm)		Cumulative Mass Retained (g)	Cumulative Percent Retained	Reported Percent Passing
¾	(19.0)	0	0	100
½	(12.5)	161.0	5.0	95
⅜	(9.50)	642.0	20.0	80
No. 4	(4.75)	1118.3	34.8	65

Gradation On Coarse Screens

Pan = 1968.0

Test Validation: $(1118.3 + 1968.0 - 3085.1)/3085.1 \times 100 = 0.04\%$ which is within the 0.3 percent requirement and the results can be used for acceptance purposes.

The actual mass of material passing the No. 4 (4.75 mm) sieve and retained in the pan is 1968.0 g. This is M₁.

The pan (1968.0 grams) was reduced in accordance with the FOP for AASHTO T 248, so that at least 500 g are available. In this case, the mass determined was 512.8 g. This is M₂.

Sieve Size in (mm)		Cumulative Mass Retained (g)
No. 4	(4.75)	0
No. 10	(2.00)	207.5
No. 40	(0.425)	394.3
No. 80	(0.210)	454.5
No. 200	(0.075)	503.6
Pan		512.8

Gradation On Fine Screens

Test Validation: $(512.8 - 512.8)/512.8 = 0.0\%$ which is within the 0.3 percent requirement and the results can be used for acceptance purposes.

For the No. 10 sieve:

$$M_1 = 1968.0\text{g}$$

$$M_2 = 512.8\text{g}$$

$$B = 207.5\text{g}$$

$$D = 1118.3\text{g}$$

$$C = \frac{M_1}{M_2} \times B + D = \frac{1968.0\text{g}}{512.8\text{g}} \times 207.5\text{g} + 1118.3\text{g} = 1914.7\text{g}$$

$$\% \text{ retained} = \frac{1914.7\text{g}}{3214.0\text{g}} = 59.6\%$$

$$\% \text{ passing} = 100 - 59.6 = 40.4\%, \text{ reported as } 40\%$$

Sieve Size in (mm)		Cumulative Mass Retained (g)	Adjusted Cumulative Mass Retained (g)	Cum. Percent Retained	Reported Percent Passing*
¾	(19.0)	0	0	0	100.0
½	(12.5)	161.1	161.1	5.0	95
⅜	(9.5)	642.5	642.5	20.0	80
No. 4	(4.75)	1118.3	1118.3	34.8	65
No. 10	(2.0)	207.5 × 3.838 + 1118.3	1914.7	59.6	40
No. 40	(0.425)	394.3 × 3.838 + 1118.3	2631.6	81.6	18
No. 80	(0.210)	454.5 × 3.838 + 1118.3	2862.7	89.1	11
No. 200	(0.075)	503.6 × 3.838 + 1118.3	3051.1	94.9	5.1
Pan		512.8 × 3.838 + 1118.3	3086.4		

*Report No. 200 (75 µm) sieve to 0.1 percent. Report all others to 1 percent.

Final Gradation On All Screens

Alternative Method B

As an alternate method to account for the fact that only a portion of the minus No. 4 (4.75 mm) material was sieved, multiply the fine screen “Percent Passing” values by the percent passing the No. 4 (4.75 mm) sieve obtained in the coarse screen procedure, 65 percent in this case.

The mass retained in the pan must be corrected to include the proper percent of No. 200 (.075 mm) minus material washed out.

Divide the cumulative masses, or the corrected masses, on the individual sieves by the corrected pan mass of the initial dry sample (prior to washing) to determine the percent retained on and passing each sieve. Calculate the percent retained on and passing each sieve. Report percent passing as indicated in the “Report” section at the end of this FOP.

Dry mass of total sample, before washing: 3214.0 g

Dry mass of sample, after washing out the No. 200 (75 µm) minus: 3085.1 g

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

Sieve Size in (mm)		Cumulative Mass Retained (g)	Cumulative Percent Retained	Reported Percent Passing
¾	(19.0)	0	0	100
½	(12.5)	161.0	5.0	95
⅜	(9.50)	642.0	20.0	80
No. 4	(4.75)	1118.3	34.8	65

Gradation On Coarse Screens

Pan = 1968.0

$$\text{Test validation: } \frac{1118.3 + 1968.0 - 3085.1}{3085.1} \times 100 = 0.04\%$$

which is within the 0.3 percent requirement and the results can be used for acceptance purposes.

The actual mass of material passing the No. 4 (4.75 mm) sieve and retained in the pan is 1968.0 g. This is M_3 .

The pan (1968.0 grams) was reduced in accordance with FOP for AASHTO T 248, so that at least 500 g are available. In this case, the mass determined was 512.8 g. This is M_4 .

$$\text{Corrected pan mass} = M_4 + \frac{(M_4)(C_1)}{M_3}$$

Where:

M_4 = Mass retained in the pan from the split of the No. 4 (4.75 mm) minus

M_3 = Mass of the No. 4 (4.75 mm) minus of entire sample, not including No. 200 (.075 mm) minus washed out

C_1 = Mass of No. 200 (.075 mm) minus washed out

Sieve Size in (mm)		Cumulative Mass Retained (g)	Cumulative Percent Retained	Percent Passing
No. 4	(4.75)	0	0	100.0
No. 10	(2.00)	207.5	38.0	62.0
No. 40	(0.425)	394.3	72.2	27.8
No. 80	(0.210)	454.5	83.2	16.8
No. 200	(0.075)	503.6	92.2	7.8
Pan		512.8		

The corrected pan mass is the mass used to calculate the percent retained for the fine grading.

Example:

$$M_4 = 512.8\text{g}$$

$$M_3 = 1968.0\text{g}$$

$$C_1 = 128.9\text{g}$$

$$\text{Corrected pan mass} = 512.8\text{g} + \frac{(512.8\text{g})(128.9\text{g})}{1968.0\text{g}} = 546.4\text{g}$$

For the No. 10 sieve:

$$\text{Mass of No. 10 sieve} = 207.5\text{g}$$

$$\text{Corrected Pan Mass} = 546.4\text{g}$$

$$\text{Cumulative \% retained} = \frac{207.5\text{g}}{546.4\text{g}} = 38\%$$

$$\% \text{ passing} = 100 - 38.0 = 62.0\%$$

$$\text{Adjusted \% passing No. 10} = \% \text{ passing No. 10} \times \% \text{ No. 4} = 62.0 \times 0.65 = 40\%$$

Sieve Size in (mm)		Adjustment	Reported Percent Passing*
¾	(19.0)		100
½	(12.5)		95
⅜	(9.5)		80
No. 4	(4.75)	100 × .65 =	65
No. 10	(2.00)	62.0 × .65 =	40
No. 40	(0.425)	27.8 × .65 =	18
No. 80	(0.210)	16.8 × .65 =	11
No. 200	(0.075)	7.8 × .65 =	5.1

*Report No. 200 (75 µm) sieve to 0.1 percent. Report all others to 1 percent.

Final Gradation On All Screens

Sample Calculation for Fineness Modulus

Fineness Modulus (FM) is used in determining the degree of uniformity of 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 FA in PCC.

The FM is the sum of the percentages retained on specified sieves, for PCC fine aggregate they are: No. 4 (4.75 mm), No. 8 (2.36 mm), No. 16 (1.18 mm), No. 30 (0.60 mm), No. 50 (0.30 mm), and No. 100 (0.15 mm) divided by 100 gives the FM.

The following example is for WSDOT Class 2 Sand:

Sieve Size in (mm)		Percent Passing	Percent Retained	Percent Retained on Specified Sieves
No. 4	4.75 mm	100	0	0
No. 8	2.36 mm	87	13	13
No. 16	1.18 mm	69	31	31
No. 30	0.60 mm	44	56	56
No. 50	0.30 mm	18	82	82
No. 100	0.15 mm	4	96	96
				= 278
				FM = 2.78

Report

Results shall be reported on standard forms approved for use by the agency. Depending on the agency, this may include:

- Cumulative mass retained on each sieve.
- Cumulative percent retained on each sieve.
- Percent passing and retained on each sieve shall be reported to the nearest 1 percent except for the percent passing the U.S. No. 200 (75 μ m) sieve, which shall be reported to the nearest 0.1 percent.
- FM to the nearest 0.01 percent for WSDOT Class 2 Sand.

Report the results using one or more of the following:

- Materials Testing System (MATS)
- DOT Forms [422-020](#), [422-020A](#), or [422-020B](#)
- Form approved in writing by the State Materials Engineer

Comments: