T 27/ T 11

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES

FOP FOR AASHTO T 27

MATERIALS FINER THAN No. 200 SIEVE IN MINERAL AGGREGATE BY WASHING

FOP FOR AASHTO T 11

T 27/ T 11

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES

FOP FOR AASHTO T 27

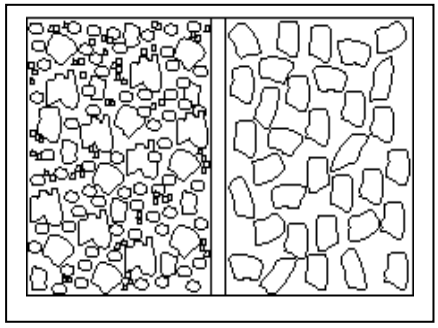
MATERIALS FINER THAN No. 200 SIEVE IN MINERAL AGGREGATE BY WASHING

FOP FOR AASHTO T 11

SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES FOP FOR AASHTO T 27

MATERIALS FINER THAN No. 200 SIEVE IN MINERAL AGGREGATE BY WASHING FOP FOR AASHTO T 11

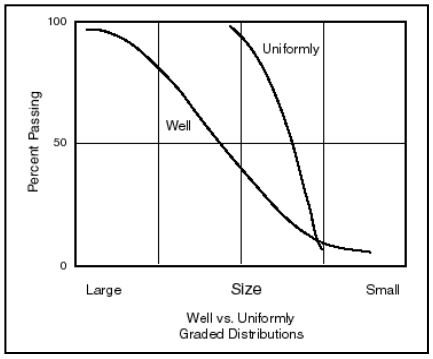
01



02

03

Well- vs. uniformly graded



04

Gradation curves

05

06

Washing sample

07

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.

Generally, well-graded material having an even distribution of particle sizes will have better load handling properties than poorly graded material consisting of a few size classes. Although other characteristics of aggregates contribute to its strength, the better a material is graded, the less material will be needed.

Scope

Sieve analyses determine 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 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 the procedure in AASHTO T 11, the sample is washed through a No. 200 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 in accordance with AASHTO T 11 performed in conjunction with AASHTO T 27. The procedure includes three method choices: A, B and C.

Apparatus

08

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. Meeting 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

Large sieve shaker

09

Sample Sieving

10

In all procedures it is required to shake the sample over nested sieves. The sieves are selected to furnish information required by specification. 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.

Sieves are shaken in a mechanical shaker for approximately 10 minutes, or the minimum time determined to provide complete separation for the sieve shaker being used.

Hand shaking

11

12

<u>Time Evaluation</u>

The minimum time requirement should be evaluated for each shaker at least annually, by the following method: Continue shaking for a sufficient period and in such a manner that, after completion, not more than 0.5 percent by mass of the total sample passes any sieve during one minute of continuous hand sieving.

Provide a snug-fitting pan and cover, and hold in a slightly inclined position in one hand. Strike 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. In determining sufficiency of sieving for sizes larger than No. 4, limit the material on the sieve to a single layer of particles.

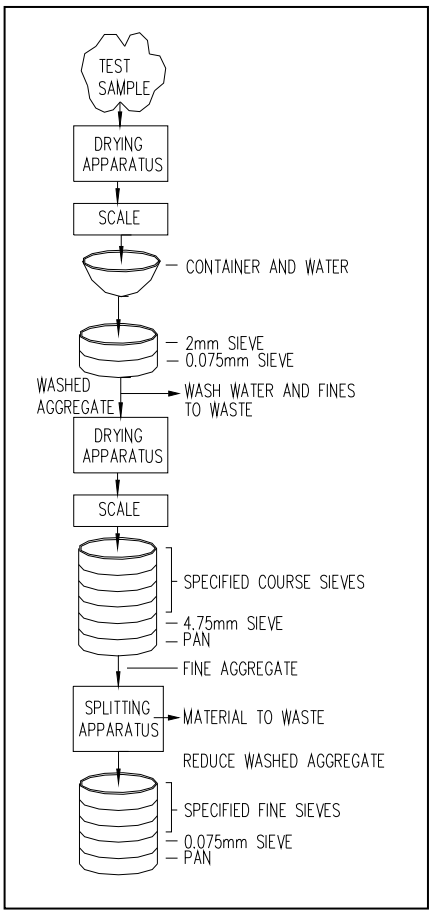
Overload Determination

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, the mass retained on any sieve shall not exceed 7 kg/m^2 (4 g/in^2) of sieving surface. For sieves with openings No. 4 and larger, the mass, in grams shall not exceed the product of 2.5 x (sieve opening in mm) x (effective sieving area). See Table 1.

TABLE 1
Maximum Allowable Mass of Material Retained on a Sieve (g)
Nominal Sieve Size, (in.)—Exact size is smaller (see AASHTO T 27)

13

Sieve Size (in.)	8” ϕ	12” ϕ	12” x 12”	14” x 14”	16” x 24”
			Sieving Area m^2		
	0.0285	0.0670	0.0929	0.1225	0.2158
3½	*	15,100	20,900	27l600	48,500
3	*	12,600	17,400	23l000	40,500
2½	*	10,600	14,600	19,300	34,000
2	3600	8400	11,600	15,300	27,000
1½	2700	6300	8700	11,500	20,200
1	1800	4200	5800	7700	13,500
3/4	1400	3200	4400	5800	10,200
5/8	1100	2700	3700	4900	8600
1/2	890	2100	2900	3800	6700
3/8	670	1600	2200	2900	5100
1/4	440	1100	1500	1900	3400
No. 4	330	800	1100	1500	2600
-No. 4	200	470	650	1200	1300



14

Sample Preparation

Obtain samples in accordance with the FOP for AASHTO T 2 and reduce to the size shown in Table 2 in accordance with the FOP for AASHTO T 248.

These sample sizes are standard for aggregate testing but, due to equipment restraints, samples may need to be partitioned into several "subsamples." For example, a gradation that requires 220 lbs of material would not fit into a large tray shaker in one batch.

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 test sample sizes.

15

TABLE 2
Sample Sizes for Aggregate Gradation Test

Nominal Maximum Size* (in.)	Minimum Mass g	(lb)
No. 4	500	(1)
1/4	1000	(2)
3/8	1000	(2)
1/2	2000	(4)
3/4	5000	(11)
1	10,000	(22)
1½	15,000	(33)
2	20,000	(44)
2½	35,000	(77)
3	60,000	(130)
3½	100,000	(220)
4	150,000	(330)
5	300,000	(660)

16

*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.

Selection of Procedure

17 Agencies may specify what method will be performed. If a method is not specified method A will be performed.

Overview

18 Method A

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

Sieves

19 Method B

- Determine dry mass of original sample
- Wash through a No. 200 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

20 Method C

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

Procedure Method A

21 1. Dry the sample to a constant mass in accordance with the FOP for AASHTO T 255, and record to the nearest 0.1 percent of the total sample mass or 0.1 g.

2. When the specification requires that the amount of material finer than No. 200 be determined, perform Step 3 through Step 9 – otherwise, skip to Step 10.

22 3. Nest a sieve, such as a No. 10, above the No. 200 sieve.

23

Separation of material

4. Place the test sample in a container and add sufficient water to cover it.

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 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.

5. Agitate vigorously to ensure complete separation of the material finer than No. 200 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.

24

25

Flushing

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. If detergent or dispersing agent is used, continue washing until the agent is removed.
8. Remove the upper sieve and rinse the material retained on the No. 200 sieve until water passing through the sieve is reasonably clear.
9. Return all material retained on the nested sieves to the container by flushing into the washed sample.
10. Dry the washed aggregate to constant mass in accordance with the FOP for AASHTO T 255, and then cool prior to sieving. Record the "dry mass after washing."

Sieve Size mm (in)	Percent Passing
2	100
1½	95 – 100
3/4	55 – 75
1/4	35 – 50

26

27

Specification requirements

28

29

11. 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.

12. 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.

Note 2: Excessive shaking (more than 10 minutes) may result in degradation of the sample.

30

12” Dia. sieve shaker

31

32

Mass determination

13. Determine the mass retained on each sieve to the nearest 0.1 g. Ensure that all material trapped in the openings of the sieve are cleaned out and included in the mass retained.

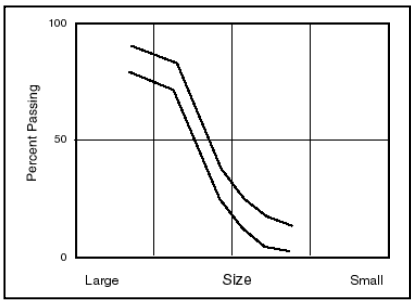
Note 3: Use coarse wire brushes to clean the No. 30 and larger sieves, and soft bristle brushes for smaller sieves.

33

Brushing sieve

34

14. In the case of coarse / fine aggregate mixtures, the minus No. 4 may be distributed among two or more sets of sieves to prevent overloading of individual sieves.



Specifications envelope

Calculations

The total mass of material after sieving should check closely 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.

35 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 sieve masses or cumulative sieve masses by the total mass of the initial dry sample. If the same test sample was first tested by AASHTO T 11, use the total dry sample mass prior to washing in AASHTO T 11 as the basis for calculating all percentages. Report percent passing as indicated in the "Report" section at the end of this FOP.

36

Percent Retained: 37

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 Cumulative Mass from Methods B or C

$$IPR = \frac{IMR}{M} \times 100 \quad \textbf{OR} \quad CPR = \frac{CMR}{M} \times 100$$ 38

Percent Passing (Calculated):

Where:

PP = Percent Passing

PPP = Previous Percent Passing 39

$$PP = PPP - IPR \quad \textbf{OR} \quad PP = 100 - CPR$$

Calculation Method A

Calculate percent retained on and passing each sieve on the basis of the total mass of the initial dry sample. This will include any material finer than No. 200 that was washed out.

40

Example: Dry mass of total sample, before washing: 5168.7 g

Dry mass of sample, after washing out the No. 200 minus: 4911.3 g

Amount of No. 200 minus washed out: 5168.7 g – 4911.3 g = 257.4 g

Gradation on All Screens

Sieve Size (in.)	Individual Mass Retained, g (IMR)	Individual Percent Retained (IPR)	Cum. Mass Retained, g (CMR)	Cum. Percent Retained (CPR)	Calc'd Percent Passing (PP)	Reported Percent Passing* (RPP)
3/4	0	0	0	0.0	100.0	100
1/2	724.7	14.0	724.7	14.0	86.0	86
3/8	619.2	12.0	1343.9	26.0	74.0	74
No. 4	1189.8	23.0	2533.7	49.0	51.0	51
No. 8	877.6	17.0	3411.3	66.0	34.0	34
No. 16	574.8	11.1	3986.1	77.1	22.9	23
No. 30	329.8	6.4	4315.9	83.5	16.5	16
No. 50	228.5	4.4	4544.4	87.9	12.1	12
No. 100	205.7	4.0	4750.1	91.9	8.1	8
No. 200	135.4	2.6	4885.5	94.5	5.5	5.5
Pan	20.4		4905.9			

*Report No.200 sieve to 0.1 percent. Report all others to 1 percent.

$$\text{Check sum}: \frac{4911.3 - 4905.9}{4911.3} \times 100 = 0.11\%, \text{ is within the } 0.3 \text{ percent requirement}$$

41,42, 43,44

Percent Retained:

$$\text{3/8 Sieve } 12.0\% = \frac{619.0}{5168.7} \times 100 \quad \text{OR} \quad 26.0\% = \frac{1343.9}{5168.7} \times 100$$

Percent Passing (Calculated):

3/8 Sieve 74.0% = 86.0 – 12.0 or 74.0% = 100 – 26.0

Procedure Method B

45 1. Perform steps 1 thru 10 from "Procedure Method A", then continue as follows:

46 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 with the pan at the bottom to retain the minus No. 4.

3. Place the sample, or a portion of the sample, on the top sieve. Sieves may already be in the mechanical shaker or 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.

Note 2: Excessive shaking (more than 10 minutes) may result in degradation of the sample.

4. Determine the individual or cumulative mass retained on each sieve to the nearest 0.1 percent or 0.1 g. Ensure that all material trapped in the opening of the sieve are cleaned out and include in the mass retained.

Note 3: Use coarse wire brushes to clean the No. 30 and larger sieves, and soft bristle brushes for smaller sieves.

5. Determine the mass of the material in the pan [minus No. 4] (M_1).

6. Reduce the minus No. 4 using a mechanical splitter in accordance with the 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 split (M_2).

7. 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 with a pan at the bottom to retain the minus No. 200.

8. Repeat steps 3 and 4, Method B, with the minus No. 4 split including determining the mass of the material in the pan.

9a. Compute the "Adjusted Individual Mass Retained" of the size increment of the original sample as follows when determining "Individual Mass Retained."

$$IMR = \frac{M_1}{M_2} \times B$$

where:

IMR = Adjusted mass retained of the size increment based on a total sample mass.

M_1 = mass of the minus No. 4 sieve in total sample.

M_2 = mass of the minus No. 4 sieve actually sieved.

B = individual mass of the size increment in the reduced portion sieved.

9b. Compute the "Adjusted Cumulative Mass Retained" of the size increment of the original sample as follows when determining "Cumulative Mass Retained":

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

where:

CMR = Total cumulative mass retained of the size increment based on a total sample.

M_1 = mass of the minus No. 4 sieve in total sample.

M_2 = mass of the minus No. 4 sieve actually sieved.

B = cumulative mass of the size increment in the reduced portion sieved.

D = mass of plus No. 4 portion of sample.

Method B Sample Calculation

Sample calculation for percent retained and percent passing each sieve in accordance with Method B when the previously washed No. 4 minus material is split,

Example:

Dry mass of total sample, before washing: 3214.0 g 47

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

Amount of No. 200 minus washed out: 3214.0 g – 3085.1 g = 128.9 g

Gradation on Coarse Screens 48

Sieve Size (in.)	Individual Mass Retained, g (IMR)	Individual Percent Retained (IPR)	Cumulative Mass Retained, g (CMR)	Cumulative Percent Retained (CPR)	Calculated Percent Passing (CPP)
5/8	0	0	0	0	100
1/2	161.1	5.0	161.1	5.0	95.0
3/8	481.4	15.0	642.5	20.0	80.0
No. 4	475.8	14.8	1118.3	34.8	65.2
Pan	1966.7 (**M_1**)		3085.0		

$$\text{Coarse check sum}: \frac{3085.1 - 3085.0}{3085.1} \times 100 = 0.00\%, \text{ is within the } 0.3\% \text{ requirement}$$

Note 4: The pan mass determined in the laboratory (M_1) and the calculated mass (3085.1 – 1118.3 = 1966.8) should be the same if no material was lost.

The pan (1966.7 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 **M_2**.

In order to account for the fact that only a portion of the minus No. 4 material was sieved, the mass of material retained on the smaller sieves is adjusted by a factor equal to M_1/M_2. The factor determined from M_1/M_2 must be carried to three decimal places. Both the individual mass retained and cumulative mass retained formulas are shown.

<u>Individual Mass Retained:</u>

M_1 = total mass of the No. 4 minus before reducing

M_2 = mass before sieving from the reduced portion of the No. 4 minus.

$$\frac{M_1}{M_2} = \frac{1{,}966.7 \text{ g}}{512.8 \text{ g}} = 3.835$$ 49

Each "individual mass retained" on the fine sieves must be multiplied by this adjustment factor.

For example, the overall mass retained on the No. 10 sieve is:

3.835 x 207.1 g = 794.2 g as shown in the following tables:

Final Gradation on All Screens
Calculation by Individual Mass

50

Sieve Size (in.)	Individual Mass Retained, g (IMR)	Adjusted Individual Mass Retained, g (AIMR)	Individual Percent Retained (IPP)	Calc'd Percent Passing (CPP)	Reported Percent Passing* (RPP)
5/8	0	0	0.0	100.0	100
1/2	161.1	161.1	5.0	95.0	95
3/8	481.4	481.4	15.0	80.0	80
No. 4	475.8	475.8	14.8	65.2	65
No. 10	207.1 *x 3.835*	794.2	24.7	40.5	40
No. 40	187.9 *x 3.835*	720.6	22.4	18.1	18
No. 80	59.9 *x 3.835*	229.7	7.1	11.0	11
No. 200	49.1 *x 3.835*	188.3	5.9	5.1	5.1
Pan	7.8 *x 3.835*	29.9			
Dry mass of total sample, before washing: 3214.0 g					

*Report No.200 sieve to 0.1 percent. Report all others to 1 percent.

$$\text{Fine check sum}: \frac{512.8 - 511.8}{512.8} \times 100 = 0.20\%, \text{ is within the } 0.3 \text{ percent requirement}$$

For Percent Passing (Calculated) see "Calculation" under Method A.

Cumulative Mass Retained:

M_1 = total mass of the minus No. 4 before reducing.

M_2 = mass before sieving of the reduced portion of the minus No. 4.

$$\frac{M_1}{M_2} = \frac{1{,}966.8\text{ g}}{512.8\text{ g}} = 3.835$$ 51

Each "cumulative mass retained" on the fine sieves must be multiplied by this adjustment factor then the cumulative mass of plus No. 4 portion of sample is added to equal the adjusted cumulative mass retained.

For example, the adjusted cumulative mass retained on the No. 40 sieve is:

3.835 x 395.0 = 1514.8

1514.8 + 1118.3 = 2633.1 52

"Total Cumulative Mass Retained" as shown in the following table:

Final Gradation on All Screens
Calculation by Cumulative Mass 53

Sieve Size mm (in.)	**Cumulative Mass Retained, g (CMR)**	**Adjusted Cumulative Mass Retained, g (ACMR)**	**Total Cum. Mass Retnd., g (TCMR)**	**Cum. Percent Retnd. (CPR)**	**Calc'd Percent Passing (PP)**	**Reported Percent Passing* (RPP)**
5/8	0		0	0.0	100.0	100.0
1/2	161.1		161.1	5.0	95.0	95
3/8	642.5		642.5	20.0	80.0	80
No. 4	1118.3		**1118.3**	34.8	65.2	65
No. 10	207.1 *x 3.835*	794.2 + *1118.3*	1912.5	59.5	40.5	40
No. 40	395.0 *x 3.835*	1514.8 + *1118.3*	2633.1	81.9	18.1	18
No. 80	454.9 *x 3.835*	1744.5 + *1118.3*	2862.8	89.1	10.9	11
No. 200	504.0 *x 3.835*	1932.8 + *1118.3*	3051.1	94.9	5.1	5.1
Pan	511.8 *x 3.835*	1962.8 + *1118.3*	3081.1			

*Report No.200 sieve to 0.1 percent. Report all others to 1 percent.

$$\text{Fine check sum}: \frac{512.8 - 511.8}{512.8} \times 100 = 0.20\%, \text{ is within the } 0.3 \text{ percent requirement}$$

For Percent Passing (Calculated) see "Calculation" under Method A.

Procedure Method C

54 1. Dry sample in accordance with FOP for AASHTO T 255. Determine and record the total dry mass of the sample to the nearest 0.1 percent.

55 ***Note 6:*** AASHTO T 27 allows for coarse aggregate to be run in a moist condition unless the nominal maximum size of the aggregate is smaller than 1/2 in., the coarse aggregate (CA) contains appreciable material finer than No. 4, or the coarse aggregate is highly absorptive.

56 2. Break up any aggregations or lumps of clay, silt or adhering fines to pass the No. 4 sieve. If substantial coatings remain on the coarse particles in amounts that would affect the percent passing any of the specification sieves, the sample should be tested with either Method A or Method B.

3. 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 with a pan at the bottom to retain the minus No. 4.

57 4. Place the sample, or a portion of the sample, on the top sieve. Sieves may already be in the mechanical shaker or 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.

Note 2: Excessive shaking (more than 10 minutes) may result in degradation of the sample.

5. Determine the individual or cumulative mass retained on each sieve 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.

Note 3: Use coarse wire brushes to clean the No. 30 and larger sieves, and soft bristle brushes for smaller sieves.

58

59

6. Determine the mass of the material in the pan [minus No. 4] (M_1).
7. Reduce the minus No. 4 using a mechanical splitter in accordance with the FOP for AASHTO T 248 to produce a sample with a mass of 500 g minimum.
8. Determine and record the mass of the minus No. 4 split (M_3).
9. Perform steps 3 thru 10 of Method A (Wash) on the minus No. 4 split.
10. Select fine sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom through the No. 200 with a pan at the bottom to retain the minus No. 200.
11. Repeat steps 4 and 5, Method C, with the minus No. 4 including determining the mass of the material in the pan.

12a. Compute the "Adjusted Individual Mass Retained" of the size increment of the original sample as follows when determining "Individual Mass Retained":

$$IMR = \frac{M_1}{M_3} \times B$$

where:

IMR = Adjusted individual mass of the size increment on a total sample basis.

M_1 = mass of the minus No. 4 sieve in total sample.

M_3 = mass of reduced portion of the minus No. 4 before washing.

B = mass of the size increment in the reduced portion sieved.

12b. Compute the "Adjusted Cumulative Mass Retained" of the size increment of the original sample as follows when determining "Cumulative Mass Retained":

$$CMR = \left(\frac{M_1}{M_3} \times B \right) + D$$

where:

CMR = Total cumulative mass of the size increment based on a total sample mass.

M_1 = mass of the minus No. 4 sieve in total sample.

M_3 = mass of reduced portion of material finer than No. 4 before washing.

B = cumulative mass of the size increment in the reduced portion sieved.

D = cumulative mass of plus No. 4 portion of sample.

Method C Sample Calculation

Sample calculation for percent retained and percent passing each sieve in accordance with Method C when the No. 4 minus material is split and then washed:

Dry Mass of total sample: 3304.5 g

Dry Mass of minus No. 4 reduced portion before wash: 527.6 g

Dry Mass of minus No. 4 reduced portion after wash: 495.3 g 60

Gradation on Coarse Sieves 61

Sieve Size (in.)	Individual Mass Retained, g (IMR)	Individual Percent Retained (IPR)	Cumulative Mass Retained, g (CMR)	Cumulative Percent Retained (CPR)	Calculated Percent Passing (PP)
5/8	0	0	0	0	100.0
1/2	125.9	3.8	125.9	3.8	96.2
3/8	478.2	14.5	604.1	18.3	81.7
No. 4	691.5	20.9	1295.6	39.2	60.8
Pan	2008.9 **(M_1)**		3304.5		
Total Dry Mass = 3304.5					

$$\text{Coarse check sum}: \frac{3304.5 - 3304.5}{3304.5} \times 100 = 0.00\%, \text{ is within the } 0.3 \text{ percent requirement}$$

Note 4: The pan mass determined in the laboratory (M1) and the calculated mass (3304.5 – 1295.6 = 2008.9) should be the same if no material was lost.

The pan (2008.9 g) 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 **527.6 g**. This is **M_3**.

In order to account for the fact that only a portion of the minus No. 4 material was washed and sieved, the mass of material retained on the smaller sieves is adjusted by a factor equal to M_1/M_3. The factor determined from M_1/M_3 must be carried to three decimal places. Both individual mass retained and cumulative mass retained formulas are shown.

<u>Individual mass retained:</u> 62

M_1 = total mass of the minus No. 4 before reducing.

M_3 = mass before washing of the reduced portion of the minus No. 4.

$$\frac{M_1}{M_3} = \frac{2008.9 \text{ g}}{527.6 \text{ g}} = 3.808$$ 63

Each "individual mass retained" on the fine sieves must be multiplied by this adjustment factor.

For example, the overall mass retained on the No. 10 sieve is:

3.808 x 194.3 = 739.9 as shown in the following table.

Final Gradation on All Sieves

64

Calculation by Individual Mass

Sieve Size (in.)	Individual Mass Retained, g (IMR)	Adjusted Individual Mass Retained, g (AIMR)	Individual Percent Retained (IPR)	Calculated Percent Passing (PP)	Reported Percent Passing* (RPP)
5/8	0	0	0.0	100.0	100
1/2	125.9	125.9	3.8	96.2	96
3/8	478.2	478.2	14.5	81.7	82
No. 4	691.5	691.5	20.9	60.8	61
No. 10	194.3 *x 3.808*	739.9	22.4	38.4	38
No. 40	171.3 *x 3.808*	652.3	19.7	18.7	19
No. 80	65.2 *x 3.808*	248.3	7.5	11.2	11
No. 200	53.6 *x 3.808*	204.1	6.2	5.0	5.0
Pan	10.7 *x 3.808*	40.7			

Dry mass of minus No. 4 sample, before washing: 527.6 g

Dry mass of minus No. 4 sample, after washing: 495.3 g

*Report No. 200 sieve to 0.1 percent. Report all others to 1 percent

$$\text{Fine check sum}: \frac{495.3 - 495.1}{495.3} \times 100 = 0.04\%, \text{ is within the } 0.3 \text{ percent requirement}$$

For Percent Passing (Calculated) see "Calculation" under Method A.

<u>Cumulative mass retained:</u>

M_1 = total mass of the minus No. 4 before reducing.

M_3 = mass before washing of the reduced portion of the minus No. 4.

$$\frac{M_1}{M_3} = \frac{2008.9 \text{ g}}{527.6 \text{ g}} = 3.808$$ 65

Each "cumulative mass retained" on the fine sieves must be multiplied by this adjustment factor then the cumulative mass of plus No. 4 portion of sample is added to equal the total cumulative mass retained .

For example, the adjusted cumulative mass retained on the No. 40 sieve is:

3.808 x 365.6 g = 1392.2 g

1392.2 + 1295.6 g = 2687.8 "Total Cumulative Mass Retained" as shown in the following table. 66

Final Gradation on All Sieves
Calculation by Cumulative Mass

67

Sieve Size (in.)	Cumulative Mass Retained, g (CMR)	Adjusted Cumulative Mass Retained, g (ACMR)	Total Cum. Mass Retnd., g (TCMR)	Cum. Percent Retnd. (CPR)	Cal'd Percent Passing (PP)	Reported Percent Passing* (RPP)
5/8	0		0	0.0	100.0	100.0
1/2	125.9		125.9	3.8	96.2	96
3/8	604.1		604.1	18.3	81.7	82
No. 4	1295.6		**1295.6**	39.2	60.8	61
No. 10	194.3 *x 3.808*	739.9 + *1295.6*	2035.5	61.6	38.4	38
No. 40	365.6 *x 3.808*	1392.2 + *1295.6*	2687.8	81.3	18.7	19
No. 80	430.8 *x 3.808*	1640.5 + *1295.6*	2936.1	88.9	11.1	11
No. 200	484.4 *x 3.808*	1844.6 + *1295.6*	3140.2	95.0		5.0
Pan	495.1 *x 3.808*	1885.3 + *1295.6*	3180.9			

Dry mass of minus No. 4 sample, before washing: 527.6 g

Dry mass of minus No. 4 sample, after washing: 495.3 g

*Report No. 200 sieve to 0.1 percent. Report all others to 1 percent

$$\text{Fine check sum}: \frac{495.3 - 495.1}{495.3} \times 100 = 0.04\%, \text{ is within the } 0.3 \text{ percent requirement}$$

For Percent Passing (Calculated) see "Calculation" under Method A.

68

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 FA in PCC. Variations in the FM from the same source could lead to concerns for the uniformity of the PCC being produced due to changes in the surface area the paste must cover. If these variations exceed agency set limits, changes to the mix design may be required.

The sum of the cumulative percentages retained on specified sieves 6”, 3”, 1½, 3/4”, 3/8”, No. 4, No. 8, No. 16, No. 30, No. 50, and No. 100 divided by 100 gives the FM.

Sample Calculation

69

	Example A				**Example B**		
	Percent				**Percent**		
		Retained				**Retained**	
Sieve Size (in)	**Passing**		**On Spec’d Sieves***		**Passing**		**On Spec’d Sieves***
*3	100	0	0		100	0	0
2½	100	0	--		100	0	--
2	100	0	--		100	0	--
*1½	100	0	0		100	0	0
1	53	47	--		100	0	--
*3/4	15	85	85		100	0	0
1/2	0	100	--		100	0	--
*3/8	0	100	100		100	0	0
1/4	0	100	--		100	0	--
*No. 4	0	100	100		100	0	0
*No. 8	0	100	100		87	13	13
*No. 16	0	100	100		69	31	31
*No. 30	0	100	100		44	56	56
*No. 50	0	100	100		18	82	82
*No. 100	0	100	100		4	96	96
			$\sum = 785$				$\sum = 278$
			FM = 7.85				FM = 2.78

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

70

Report

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

- Mass retained on each sieve
- Percent retained on each sieve
- Cumulative mass retained on each sieve
- Cumulative percent retained on each sieve
- Percent passing each sieve to the nearest 1 percent except for the percent passing the No. 200 sieve, which shall be reported to the nearest 0.1 percent
- FM to the nearest 0.01

Tips!

71

- Check specification to see if material must be washed and split.
- Comply with Agency Method selection requirements.
- Do not lose <u>any</u> material when running the test.
- Remember to base calculations on <u>the total mass of the initial dry sample</u>.
- Check calculations for accuracy and sieves for damage or plugging, if results look “odd” or if the material suddenly goes out of spec.
- Save all material for rerunning.

REVIEW QUESTIONS

1. What are the differences between methods A, B, & C?

2. Describe how sieves should be cleaned.

3. What should be done to protect the No. 200 sieve during washing?

4. Once a washed sample is placed in the oven and dried to a constant mass, what is the next step?

5. The maximum mass, in g/m^2, of material retained on any sieve No.4 and larger may not exceed 2.5 times the sieve opening in mm. How much may be retained on the 12.5 mm (1/2 in) sieve, 8” in diameter?

6. For how long should material be sieved on the shaker?

7. How much unexplained sample mass may be lost before you would have to rerun an aggregate sample?

8. Calculate the FM for the material below.

	Percent		
		Retained	
Sieve Size mm (in)	**Passing**		
4	100		
3	100		
2½	100		
2	100		
1½	100		
1	100		
3/4	100		
1/2	100		
3/8	97		
1/4	52		
No.4	33		
No.8	27		
No.16	16		
No.30	12		
No.50	8		
No100	3		

PERFORMANCE EXAM CHECKLIST

METHOD A
SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES
FOP FOR AASHTO T 27
MATERIALS FINER THAN 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. Test sample dried to a constant mass by FOP for AASHTO T 255?	_____	_____
3. Test sample cooled and mass determined to nearest 0.1 percent or 0.1 g?	_____	_____
4. Sample placed in container and covered with water? (If specification requires that the amount of material finer than the No. 200 sieve is to be determined.)	_____	_____
5. Contents of the container vigorously agitated?	_____	_____
6. Complete separation of coarse and fine particles achieved?	_____	_____
7. Wash water poured through nested sieves such as No. 10 and No. 200?	_____	_____
8. Operation continued until wash water is clear?	_____	_____
9. Material retained on sieves returned to washed sample?	_____	_____
10. Washed aggregate dried to a constant mass by FOP for AASHTO T 255?	_____	_____
11. Washed aggregate cooled and mass determined 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 residue on each sieve and pan determined to 0.1 g?	_____	_____
15. Total mass of material after sieving agrees with mass before sieving to within 0.3 percent?	_____	_____

OVER

Procedure Element	**Trial 1**	**Trial 2**
16. Percentages calculated to the nearest 0.1 percent and reported to the nearest whole number, except No.200 - reported to the nearest 0.1 percent?	_____	_____
17. Percentage calculations based on original dry sample mass?	_____	_____
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 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. Test sample dried to a constant mass by FOP for AASHTO T 255?	_____	_____
3. Test sample cooled and mass determined to nearest 0.1 percent or 0.1 g?	_____	_____
4. Sample placed in container and covered with water? (If specification requires that the amount of material finer than the No. 200 sieve is to be determined.)	_____	_____
5. Contents of the container vigorously agitated?	_____	_____
6. Complete separation of coarse and fine particles achieved?	_____	_____
7. Wash water poured through nested sieves such as No. 10 and No. 200?	_____	_____
8. Operation continued until wash water is clear?	_____	_____
9. Material retained on sieves returned to washed sample?	_____	_____
10. Washed aggregate dried to a constant mass by FOP for AASHTO T 255?	_____	_____
11. Washed aggregate cooled and mass determined 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 residue 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?	_____	_____

OVER

Procedure Element	**Trial 1**	**Trial 2**
16. Material in pan reduced in accordance with FOP for AASHTO T 248 to a minimum sample size of 500 g and weighed to the nearest 0.1 g?	_____	_____
17. Sample placed in nest of sieves specified? (Additional sieves may be used to prevent overloading as allowed in FOP.)	_____	_____
18. Material sieved in verified mechanical shaker for proper time?	_____	_____
19. Mass of residue on each sieve and pan determined to the nearest percent or 0.1 g?	_____	_____
20. Total mass of material after sieving agrees with mass before sieving to within 0.3 percent?	_____	_____
21. Percentages calculated to the nearest 0.1 percent and reported to the nearest whole number, except No. 200 - reported to the nearest 0.1 percent?	_____	_____
22. Percentage calculations based on original dry sample mass?	_____	_____
23. 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 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.	Test sample dried to a constant mass by FOP for AASHTO T 255?	_____	_____
3.	Test sample cooled and mass determined to the nearest 0.1 percent or 0.1 g?	_____	_____
4.	Sample placed in nest of sieves specified? (Additional sieves may be used to prevent overloading as allowed in FOP.)	_____	_____
5.	Material sieved in verified mechanical shaker for proper time?	_____	_____
6.	Mass of residue on each sieve and in pan determined to the nearest 0.1 percent or 0.1 g?	_____	_____
7.	Complete separation of coarse and fine particles achieved?	_____	_____
8.	Total mass of material after sieving agrees with mass before sieving to within 0.3 percent?	_____	_____
9.	Material in pan reduced to test size for washing in accordance with FOP for AASHTO T 248?	_____	_____
10.	Mass of the fine aggregate wash sample determined to nearest 0.1 g?	_____	_____
11.	Sample placed in container and covered with water?	_____	_____
12.	Contents of the container vigorously agitated?	_____	_____
13.	Complete separation of coarse and fine particles achieved?	_____	_____
14.	Wash water poured through a set of nested sieves, such as a No. 10 over the No. 200?	_____	_____
15.	Operation continued until wash water is clear?	_____	_____
16.	Material retained on sieves returned to washed sample?	_____	_____

OVER

Procedure Element		**Trial 1**	**Trial 2**
17.	Washed aggregate dried to a constant mass in accordance with FOP for AASHTO T 255?	_____	_____
18.	Washed aggregate cooled and mass determined to nearest 0.1 g?	_____	_____
19.	Sample placed in nest of sieves specified? (Additional sieves may be used to prevent overloading as allowed in FOP.)	_____	_____
20.	Material sieved in verified mechanical shaker for proper time?	_____	_____
21.	Mass of residue on each sieve and in pan determined to nearest 0.1 g?	_____	_____
22.	Total mass of material after sieving agrees with mass after washing to within 0.3 percent?	_____	_____
23.	Calculations performed and results reported properly?	_____	_____
24.	Percentage calculations based on original dry sample mass?	_____	_____

Comments: First attempt: Pass ☐ Fail ☐ Second attempt: Pass ☐ Fail ☐

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Examiner Signature _____ WAQTC #:_____