WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION
MATERIALS PROCEDURE

SOUNDNESS OF AGGREGATES USING SODIUM SULFATE

1. PURPOSE

1.1 To establish a procedure testing aggregates for soundness following guidelines set forth by AASHTO T-104.

2. SCOPE

2.1 This procedure is designed to determine resistance to disintegration by saturated solution of sodium sulfate in both coarse and fine aggregates.

3. APPLICABLE DOCUMENTS

3.1 Reference to standard specifications and other standard procedures shall be the applicable current edition of the published document(s).

3.1.1 West Virginia Department of Transportation, Division of Highways Standard Specifications Road and Bridges.

3.1.2 Standard Method of Test for Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate, American Association of State Highway Transportation Officials (AASHTO), Designation: T 104-99 (2016).

3.1.3 Standard Test Method for Evaluation of Durability of Rock for Erosion Control Using Sodium Sulfate or Magnesium Sulfate, ASTM International (ASTM), Designation D5240/D5240M – 12.

4. APPARATUS

4.1 Sieves, containers for samples, apparatus for immersing samples in solution, suitable means of regulating temperature of the samples in the sodium sulfate solution, thermometer, temperature recorder, balance, drying oven, hydrometer, and other equipment as specified in AASHTO T-104, Sections 3.1 thru 3.9.

4.1.1 Before starting a test, all equipment, especially sieves, shall be inspected, adjusted and cleaned as necessary.

5. SPECIAL SOLUTION REQUIRED

5.1 Prepare the sodium sulfate solution for immersion of test samples in accordance with AASHTO T-104, Section 4.1 and 4.1.1 (Notes 2 and 3).

5.2 Prepare the barium chloride solution for rinse verification of a tested sample in accordance with AASHTO T-104, Section 4.2.

NOTE: After the new sulfate solution has been maintained at the designated temperature for at least 48 hours and prior to use, it is recommended that crushed limestone be introduced into the new sulfate solution for an additional 48-hour period. This is to prevent any harmful chemical reaction which may occur between the carbonates and the freshly prepared sulfate solution.

6. SAMPLES

6.1 Fine Aggregate

6.1.1 A representative portion shall be split from the field sample by means of a sample splitter or quartering. The test portion shall be of such size that it will yield not less than 120 grams. of each of the following sieve fractions which are present in amounts of 5 percent or more in accordance with the mid-band grading of standard aggregate sizes for fine aggregates.

6.1.2 The test portion shall consist of material from which the sizes finer than the No. 4 (4.75 mm) sieve have been removed.

6.1.3 The sample shall be of such a size that it will yield the following amounts of the different sizes that are available in amounts of 5 percent or more:

Table 6.1.3 – FINE AGGREGATE TEST PORTION

PASSING SIEVE		RETAINING SIEVE	
English	Metric	English	Metric
3/8"	(9.5 mm)	No. 4	(4.75 mm)
No. 4	(4.75 mm)	No. 8	(2.36 mm)
No. 8	(2.36 mm)	No. 16	(1.18 mm)
No. 16	(1.18 mm)	No. 30	(600 µm)
No. 30	(600 µm)	No. 50	(300 µm)

6.1.4 When setting up test portions in accordance with Section 6.2.3, such as combining 1 inch (25 mm) and ¾ inch (19 mm) material, should there be insufficient material of one of these sizes or should there be no material at all of one of these sizes; then, reduce the test portion by the applicable mass specified in Section 6.2.3 for the size not available.

6.1.5 When test portion sizes are not available in sufficient quantities to make up the desired test portion, or are less than 5 % of the aggregate being tested then those sizes shall not be tested.

6.2 Coarse Aggregate

6.2.1 A representative portion shall be split from a field sample by means of a sample splitter or quartering.

6.2.2 The test portion shall consist of material from which the sizes finer than the No. 4 (4.75 mm) sieve have been removed.

6.2.3 The sample shall be of such a size that it will yield the following amounts of the different sizes that are available in amounts of 5 percent or more:

Table 6.2.3 – COARSE AGGERGATE TEST PORTION

SIEVE TEST PORTIONS		MASS (g)
2 1/2 inches to 1 1/2 inches (63 mm to 37.5 mm)		5000 ± 300
Consisting of:		
	2 1/2 inches to 2 inches (63 mm to 50 mm) material	3000 ± 300
	2 inches to 1 1/2 inches (50 mm to 37.5 mm) material	2000 ± 200
1 1/2 inches to 3/4 inches (37.5 mm to 19 mm)		1500 ± 50
Consisting of:		
	1 1/2 inches to 1-inch (37.5 mm to 25 mm) material	1000 ± 50
	1 inch to 3/4-inch (25 mm to 19 mm) material	500 ± 30
3/4 inch to 3/8-inch (19 mm to 19 mm) material		1000 ± 10
Consisting of:		
	3/4 inch to 1/2 inch (19 mm to 12.5 mm material)	670 ± 10
	1/2 inch to 3/8-inch (12.5 mm to 9.5 mm) material	330 ± 5
3/8 inch (9.5 mm) to No. 4 (9.5 mm to 4.75 mm)		300 ± 5

6.2.4 When setting up test portions in accordance with Section 6.2.3, such as combining 1 inch (25 mm) and ¾ inch (19 mm) material, should there be insufficient material of one of these sizes or should there be no material at all of one of these sizes; then, reduce the test portion by the applicable mass specified in Section 6.2.3 for the size not available.

6.2.5 When test portion sizes are not available in sufficient quantities to make up the desired test portion, or are less than 5% of the aggregate being tested then those sizes shall not be tested.

6.3 For purposes of evaluating the entire sample, test portion sizes that are not tested will be calculated in accordance with Section 11.8.

6.4 When an aggregate sample contains both fine and coarse material, the fine and coarse fractions shall be tested separately. Each fraction shall be prepared and tested in accordance with the procedures for fine aggregate and coarse aggregate, respectively (6.1 and 6.2).

6.4.1 Calculate and report test results by combining the final results of both the coarse and fine aggregate test fractions. Calculations are based on the mid-bands (weighted average) of standard aggregate sizes as found in Table 6.4.1.

Table 6.4.1 – Mid Band Gradations

SOUNDNESS OF AGGREGATES BY SODIUM SULFATE: MP 703.00.22										
SIZE	**REC/PROP**	**1½ in**	**3/4 in**	**3/8 in**	**# 4**	**# 8**	**# 16**	**# 30**	**# 50**	**∑ MID-BAND**
AASHTO #3	% PASS MID	48	48	2						**98**
AASHTO #3	MID-BAND	48	50	1						**98**
AASHTO #4	MID-BAND	5	88	5						**98**
AASHTO #56	MID-BAND		38	55	5					**98**
AASHTO #57	MID-BAND		28	42	25	3				**98**
AASHTO #68	MID-BAND		5	45	35	10	3			**98**
AASHTO #7	MID-BAND			45	48	5				**98**
AASHTO #78	MID-BAND			42	42	10	2			**96**
AASHTO #8	MID-BAND			5	58	20	13		3	**98**
AASHTO #89	MID-BAND			5	58	20	13	3		**98**
AASHTO #9	MID-BAND			0	8	68	20		3	**98**
MORTAR SAND	MID-BAND					5	36	25	12	**78**
FINE AGGREGATE	MID-BAND			0	3	22	17	17	22	**80**
WV 704.6.2A CLASS 1	MID-BAND		30	22	13	10	9	5	4	**93**
WV 704.6.2A CLASS 2	MID-BAND		10	20	15	14	11	7	7	**84**
WV 704.6.2A CLASS 8	MID-BAND		10	24	11	21	2	4	12	**84**
WV 704.6.2A CLASS 9	MID-BAND		10	20	15	12	9	8	4	**78**
WV 704.6.2A CLASS 10	MID-BAND		15	19	14	12	9	6	4	**78**

7. PREPARATION OF TEST SAMPLES

7.1 The fine aggregate shall be washed over a No. 50 (300 µm) sieve. Washing shall be continued until the wash water becomes clear, the material retained on the No. 50 (300 µm) sieve shall be dried to a constant weight at 230 ±9°F (110 ±5° C).

7.1.1 The washed portion shall be separated into different sizes by sieving as follows: Make a rough grading of the sample by means of a set of nested sieves as specified

in 6.1.2 by mechanically sieving for 5 minutes. From the fractions obtained in this manner, select samples from each sieve of sufficient size to yield not less than 100 grams. (Generally, a 120 gram sample will be sufficient.) Renest the sieves with intermediate retainer pans to prevent intermingling and mechanically shake for 10 minutes, then check for thoroughness of sieving as defined in AASHTO T-27, Paragraph 7.4. If necessary, continue sieving until the requirements of Paragraph 7.4 are met.

7.1.2 Weigh out test portions of 100 ±0.5 grams from each of the separated sieve fractions. Record initial weights to nearest 0.1 gram.

7.1.3 Fine aggregate sticking in the meshes of the sieves shall not be used in preparing the test portion. Carefully clean the sieves after each use by removing and discarding any particles sticking in the meshes of the sieves.

7.1.4 Place the individual test portions into separate containers for testing. Containers for all fractions finer than the No. 4 (4.75 mm) sieve shall be the standard 3 inch (76 mm) diameter testing sieves, with two sieves nested to completely enclose the sample. Screen sizes to be used with each fraction are as follows:

Table 7.1.4 – CONTAINER SIEVE SIZES

TEST PORTION SIEVE SIZE		**CONTAINER SIEVE SIZE**	
English	**Metric**	**English**	**Metric**
3/8" - No. 4	(9.5 mm) - (4.75 mm)	No.10	(2 mm)
No. 4 - No. 8	(4.75 mm) - (2.36 mm)	No.10	(2 mm)
No. 8 - No. 16	(2.36 mm) - (1.18 mm)	No. 20	(850 µm)
No. 16 - No. 30	(1.18 mm) - (600 µm)	No. 40	(425 µm)
No. 30 - No. 50	(600 µm) - (300 µm)	No. 50	(250 µm)

7.2 Coarse Aggregate

7.2.1 The coarse aggregate sample shall be mechanically sieved for 10 minutes or hand sieved to refusal until none of the particles being sieved are passed in one minutes

time, so as to yield sufficient quantities of the different sizes within the tolerances of Paragraph 6.3.1.

NOTE: Finger manipulation of the particles may be used to determine refusal.

7.2.2 Thoroughly wash the individual fractions over a No.4 (4.75 mm) screen and dry to constant weight at a temperature of 230 ±9°F (110 ±5° C).

7.2.3 Weigh out the amounts required for test portions as specified in Paragraph 6.3.1. Record the initial weights to the nearest gram.

7.2.4 Place the test portions into separate containers for testing.

NOTE: Containers for the 3/8 inches (9.5 mm) to No. 4 (4.75 mm) fraction shall be constructed of 1/8 inches (3.2 mm) galvanized hardware cloth with dimensions approximately 3 inches (76 mm) x 3 inches (76 mm) x 2 inches (51 mm) deep. Containers for ¾ inches (19 mm) to 3/8 inches (9.5 mm) fractions shall be constructed of ¼ inches (6.4 mm) galvanized hardware cloth with dimensions approximately 4 ½ inches (114 mm) x 4 ½ inches (140 mm) x 1 ½ inches (38 mm) deep. Containers for the plus ¾ inches (19 mm) fractions shall be constructed of ¼ inches (6.4 mm) galvanized hardware cloth with dimensions approximately 4 ½ inches (114 mm) x 6 ½ inches (165 mm) x 3 inches (76 mm) deep. Place the test portions into separate containers for testing.

7.3 Ledge rock submitted for testing before final commercial preparation shall be crushed. Testing shall be performed in accordance to Section 7.2.

7.4 Stone for riprap, special rock fill, rock gutter, etc. shall be tested in accordance with their intended use. Representative test portions shall be selected from the sample and tested as follows: The sample shall be thoroughly washed and dried to a constant weight at a temperature of 230 ±9°F (110 ±5° C). Allow the sample to cool to room temperature. Place the test portion into suitable containers for testing.

8. PROCEDURE

8.1 The samples shall be immersed in the prepared solution of sodium sulfate for not less than 16 hours nor more than 18 hours in such a manner that the solution covers them to a depth of at least 12.7 mm.

NOTE: Suitably weighted wire grids placed over the sample containers will prevent lightweight aggregates from floating out of the container.

8.2 The solution should be covered to reduce evaporation and prevent the accidental addition of extraneous materials into the test portions.

8.3 The samples shall remain immersed in the solution at a temperature of 70 ±2°F (21 ±1° C) for the immersion period.

8.4 Remove the test portions from the solution and allow to drain for 15 ± 5 minutes, and then place in the drying oven. The temperature of the oven shall have been brought previously to 230 ±9°F (110 ±5° C). Dry samples at the specific temperature until constant weight has been achieved.

NOTE: Time required to establish a condition of constant weight can be attained as follows: With the oven containing the maximum sample load expected, check the weight losses of test samples by removing and weighing them, without cooling, at intervals of 2 to 4 hours, make enough checks to establish required drying time for the least favorable oven location (See AASHTO T-104) and sample condition. A condition of constant weight will be considered to have been achieved when weight loss is less than 0.1 percent of sample weight in 4 hours of drying. When such a determination has been made, samples may be considered to have attained a constant weight when they have been dried at the specified temperature for an equal or longer period of time than that which has previously been found to be adequate for producing the desired constant weight condition under equal or heavier loading conditions of the oven.

8.5 After removal of the test portions from the solution, the specific gravity and temperature of the solution shall be determined and recorded. Any necessary adjustments to the specific gravity and temperature can be made upon removal of the test portions from the solution.

8.6 After drying, allow samples to cool to room temperature, when they shall again be immersed in the prepared solution as described in 8.1.

NOTE: If the test must be continued over a weekend, leave the samples in an oven-dried condition (constant weight) at room temperature and resume the cycles on the next work day.

8.7 Repeat the steps outlined in Paragraphs 8.1 through 8.6 until five immersions and drying cycles have been completed.

NOTE: A record shall be kept of the number of cycles that each test portion undergoes to prevent over or under cycling.

9. QUANTITATIVE EXAMINATION

9.1 After the final drying cycle, cool the test portions to room temperature. Wash the test portions free of the sodium sulfate solution by soaking the test portions in a

circulatory bath of water at 110 ± 10°F (43 ± 6° C) for one hour or more as determined by the reaction of the rinse water with barium chloride ($BaCL_2$). If reaction occurs, as evidenced by a milky, white precipitate, continue washing and rinsing. Washing may be considered complete when no reaction occurs. In the washing operation, the samples shall not be subjected to impact or abrasion that may tend to break up particles.

NOTE: The washing procedure may be accomplished more effectively if the test portions were placed in the bottom of a tank where hot water may be introduced near the bottom and allowed to overflow. After the sodium sulfate solution has been removed, each fraction of the sample shall be dried to a constant weight at 230 ±9°F (110 ±5° C). When the test portions have dried, allow them to cool to room temperature.

9.2 Mechanically sieve the fine aggregate fraction for 10 minutes over the same sieves with intermediate retainer pans as specified in Paragraph 6.1.2. Weigh the residue retained after sieving, including all material cleaned from the meshes of the screen to the nearest 0.1 gram and record.

9.3 Hand sieve the coarse aggregate fraction over the sieve shown below for the appropriate size of particle:

Table 9.3 –SIEVE SIZE

SIZE OF AGGREGATE		**SIEVE USED TO DETERMINE LOSS**	
English	**Metric**	**English**	**Metric**
2 1/2 inches to 1 1/2 inches	(63 mm) to (37.5 mm)	1 1/4 inch	(31.5 mm)
1 1/2 inches to 3/4 inches	(37.5 mm) to (19 mm)	5/8 inch	(16.0 mm)
3/4 inch to 3/8 inch	(19 mm) to (9.5mm)	5/16 inch	(8.0 mm)
3/8 inch to No. 4	(9.5 mm) to (4.75 mm)	No. 5	(4.0mm)

9.4 Hand sieving shall be conducted with agitation sufficient only to assure that all undersize material passes the designated sieve. No extra manipulation shall be employed to break up particles or cause them to pass the sieves. Weigh the residue retained after sieving, including all material cleaned from the meshes of the screen to the nearest gram and record. Ledge rock examination shall be conducted in the same

manner as for any coarse aggregate using the appropriately designated sieve shown above for the appropriate sized particles. Weigh to the nearest gram and record.

9.5 In the case of stone for riprap, special rock fill, rock gutters, etc., weigh the sample to the nearest gram and record.

NOTE: The difference between each of these amounts and the initial weight of the fraction of the sample tested is the loss in the test and is to be expressed as a percentage of the initial weight.

10. MID-BAND GRADATION REQUIREMENTS

10.1 Mid-bands are the percent retained at stated testing sieve sizes defined in AASHTO T-104 and in Section 10 and Table 6.4.1 of this MP and are computed from the mean of the most and least permitted passing from largest to smallest sieve based on aggregate sizes as defined in West Virginia Department of Transportation, Division of Highways, Standards Specifications, Roads and Bridges, Sections 702, 703, and 704, or the average percent retained based on sieve analysis of representative samples of the source.

10.2 Fine Aggregate

Table 10.2 – MID BAND GRADATING FOR FINE AGGREGATE

PASSING SIEVE	RETAINED ON SIEVE	PERCENT RETAINED
3/8" (9.5 mm)	No. 4 (4.75 mm)	2
No. 4 (4.75 mm)	No. 8 (2.36 mm)	20
No. 8 (2.36 mm)	No. 16 (1.18 mm)	16
No. 16 (1.18 mm)	No. 30 (600 µm)	23
No. 30 (600 µm)	No. 50 (300 µm)	20

10.2.1 The gradation used to calculate the weighted percentage loss shall normally be a mid-band grading of standard sized fine aggregate as follows:

10.3 Mortar Sand

10.3.1 The gradation used to calculate the weighted percentage loss for mortar sand shall normally be a mid-band grading of a standard mortar sand as follows:

Table 10.3.1 – MID-BAND GRADING FOR MORTAR SAND

PASSING SIEVE	RETAINED ON SIEVE	PERCENT RETAINED
No. 4 (4.75 mm)	No. 8 (2.36 mm)	5
No. 8 (2.36 mm)	No. 16 (1.18 mm)	31
No. 16 (1.18 mm)	No. 30 (600 µm)	21
No. 30 (600 µm)	No. 50 (300 µm)	17

NOTE: If the fraction retained on the No. 4 (4.75 mm) for fine aggregate (or a No. 8 (2.36 mm) for mortar sand) is not available in the amount of 5 percent or more, it shall not be tested.

10.4 Coarse Aggregate

10.4.1 Hand sieve the coarse aggregate fraction over the sieve shown below for the appropriate size of particle:

10.4.2 The gradation used to calculate the weighted percentage loss for aggregate consisting of a combination of coarse and fine fractions shall be the mid-band grading of the sizes of aggregate being tested. Table I lists mid-band weightings for Concrete Aggregates, Base Course Aggregates, Classes 1, 2, 7, 8, and 9.

10.5 The percentage loss for stone and riprap, rock gutter, special rock fill, etc., shall be the total percentage loss of the test portion. No weighting will be necessary.

10.6 The gradation used to calculate the weighted percentage loss when the standard size is unknown shall be governed by the largest size particle present in the test portion, as listed in Table 10.6.

TABLE 10.6 MID-BAND GRADATIONS WHEN THE SPECIFIC AGGREGATE SIZE IS UNKNOWN

SOUNDNESS OF AGGREGATES BY SODIUM SULFATE							
TOP SIZE OF AGGREGATE		**1½ in**	**3/4 in**	**3/8 in**	**No. 4**	**No. 8**	**No. 16**
SIEVE SIZE	**REC/PROP**	**2 in**	**1½ in**	**1 in**	**3/4 in**	**1/2 in**	**3/8 in**
2 1/2" - 1 1/12"	MID-BAND	47	5				
1 1/2" - 3/4"	MID-BAND	47	87	36	5		
3/4" - 3/8"	MID-BAND	6	8	47	57	37	
3/8" -#4	MID-BAND			15	33	48	

11. CALCULATIONS

11.1 The report shall include the following data and shall be recorded on Form HS-9. Refer to Form HS-9 on the WVDOH, MCS&T Webpage Tool Box[1]. A sample of this form is also attached for reference.

11.2 Weighted average calculated from each fraction, based on the grading of the sample as received for examination determined by using T27 or, preferably, on the average grading of the material from that portion of the supply of which the sample is representative; that being the mid-band grading (A) of standard sized aggregates as listed in Table 6.4.1.

11.3 The weight of each sieve fraction before testing is expressed as an initial weight (B).

11.4 The weight of each sieve fraction of each sample retained after sieving is expressed as a final weight (C).

11.5 The weight loss (D) of each fraction of each sample is the difference between the initial sieve fraction weight (B) and the final sieve fraction weight (C).

$$D = (B - C)$$

11.6 The percentage of loss (E) is calculated for each sieve fraction, as a quotient of the weight loss (D) and the initial weight (B) of each sieve fraction.

$$E = D/B \times 100$$

11.7 The weighted percentage loss (F) is calculated for each sieve fraction, as a product of the percentage of loss (E) and the mid-band grading (A) of the portion of the sample testeddivided by the sum of all mid-band gradings of the sample as tested.

$$F = E \times A$$

11.7.1 Portions of the sample not tested shall have a mid-band of zero.

11.7.2 The weighted percentage loss shall be calculated to the nearest 0.1 percent.

11.7.3 Sizes finer than the Number 50 (0.300 mm) sieve shall be assumed to have 0 percent loss.

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[1] http://transportation.wv.gov/highways/mcst/Pages/tbox.aspx

11.8 The total weighted percentage loss is calculated as the sum of each weighted percentage loss (F) of each sieve fraction divided by the sum of mid-bands for the aggregate sample tested.

$$\text{Total weighted percentage loss} = \sum F / \sum A$$

11.9 For aggregates containing appreciable amounts of both fine and coarse material calculate their weighted percentage losses collectively for both the minus No.4 (4.75 mm) and plus No. 4 (4.75 mm) fractions based on their mid-band gradings, considering both the fine and coarse fractions combined as 100 percent. Report the results jointly giving the percentage of the minus 4.75 mm and plus 4.75 mm material as one sample.

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RLS: MBs
Attachment