METHOD OF TEST FOR RELATIVE DENSITY AND ABSORPTION OF FINE AGGREGATE

1. SCOPE

1.1 This method covers the determination of relative density (oven-dry and saturated-surface-dry), apparent relative density and absorption of fine aggregate.

2. REFERENCES

2.1 MTO Test Method LS-601 Test for Materials Finer than 75 um Sieve in Mineral Aggregates by Washing

2.2 AASHTO T 84 Specific Gravity and Absorption of Fine Aggregate

2.3 ASTM C128 Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

3. DEFINITION

Fine aggregate: For the purpose of this test, is all aggregate material passing the 4.75 mm sieve and predominantly coarser than the 75 µm sieve. This includes material passing the 4.75 mm sieve contained in the coarse aggregates.

4. SIGNIFICANCE AND USE

4.1 In addition to the Significance and Use given in the AASHTO procedure, further clarification is provided below in 4.2.

4.2 Bulk relative density is used in calculations of the VMA in asphalt mixtures. Slight biases in determining relative density may lead to inaccuracies in assessing the correct VMA. In order to minimize these inaccuracies, MTO has required the removal of fines from the fine aggregate for hot mix asphalt design purposes for over 40 years (Procedure 6.1). Procedure 6.2 has been developed for Superpave mixture design. The procedure is intended to be used on the proposed blend of fine aggregates. In developing the actual blend of materials to be used in the mixture, the designer should use whatever technique of AASHTO T 84 they deem most accurate in determining the relative densities of the individual components, and then blend proportionately to create a test sample.

5. PROCEDURE

5.1 Procedures of AASHTO T 84 shall be followed, except as noted below, for the determination of relative density, apparent relative density, and absorption of fine aggregate. The period of soaking in water shall be 15-19 h as specified by AASHTO (Note 1) except as noted below.

Note 1: The ASTM procedure specifies 24 ± 4 h of soaking.

5.2 If the aggregate contains material coarser than the 4.75 mm sieve, remove this material from the test sample. If the amount of material coarser than the 4.75 mm sieve is greater than 5% by mass of the sample, this material should be tested in LS-604. If the amount is less than 5% by mass, discard the material but assume that this material has the same density as the parent fine aggregate material in any calculations of density of the combined coarse and fine aggregates.

6. EXCEPTIONS TO AASHTO T 84

6.1 Individual fine aggregates for hydraulic cement concrete and for hot mix asphalt mixture design process

6.1.1 Obtain 2 representative sub-samples of approximately 1200 g of oven-dried fine aggregate by use of a sample splitter or by quartering.

6.1.2 Wash the samples over a 75 µm sieve in accordance with MTO LS-601, Method of Test for Material Finer Than 75 µm Sieve in Mineral Aggregates by Washing, until all material passing the 75 µm sieve is removed.

6.1.3 Saturate the samples in water by immersion for 24 ± 4 h for concrete fine aggregate and 15-19 h for asphalt fine aggregate.

6.1.4 Test the 2 sub-samples. For the purpose of determining the saturated surface dry condition, where possible, use the normal cone test.

6.1.5 If duplicate tests of relative density differ by more than 0.027, the materials shall be retested.

6.1.6 If duplicate tests of absorption differ by more than 0.31%, the materials shall be retested.

6.2 Blended fine aggregates for hot mix asphalt mixture design process (see Note 2).

6.2.1 Make up a sample of approximately 2400 g of oven-dried fine aggregate. This is made by weighing up, in volume or mass proportion in which it will be used in the asphalt mixture, a representative sample from each fine aggregate. Material in the blended coarse aggregate(s) which is finer than 4.75 mm shall also be added in the proportion in which the coarse aggregate will be blended with the fine aggregate (see Note 3) when the amount of material pass the 4.75 mm sieve in the blended coarse aggregate is greater than 5% by mass of the coarse aggregate. If the amount is less than 5% for the purposes of volume calculation, there is no need to test the pass 4.75 mm of the total coarse aggregate. Assume that the pass 4.75 mm material from the coarse aggregate has the same density as that of the coarse aggregate.

6.2.2 Thoroughly mix the blended sample and split this combined sample into two sub-samples of approximately 1200 g and perform the test on each sub-sample. Reclaimed asphalt pavement materials (RAP) shall not be blended into the virgin fine aggregate test sample. RAP materials shall be tested separately.

Note 2: Testing of blended fine aggregate is carried out only when specified by the owner.

Note 3: Example: The proposed asphalt mixture design will use two fine aggregates of essentially the same density, a natural sand and crusher screenings in the proportion of 1:2 by mass. In addition, the proportion of coarse aggregate will be 55% by mass and the coarse aggregate contains 12% by mass of material passing the 4.75 mm sieve. The proportion of fine aggregate from the coarse aggregate = 0.55 x 0.12% = 6.6% of the total fine aggregate. Proportion of virgin fine aggregate is therefore 100 - 6.6% = 93.4%. Proportion of natural sand = 93.4 x 1/3 = 31.1. Proportion of crusher screenings = 93.4 x 2/3 = 62.2. To make up a sample of 2400 g, weigh out and combine the following masses of sample: Natural sand (2400 g x 0.311%) = 746.4g; Crusher screenings (2400 x 0.622%) 1492.8 g; Pass 4.75 mm material from coarse aggregate (2400 x 0.066%) 158.4 g. The total mass of sample = 2397.6 g.

Note 4: If the densities of individual aggregates are within 0.02 of each other, the % by mass can be assumed to be the same as % by volume.

Note 5: If the densities of the individual fine aggregates used in the mix are significantly different, follow the example provided in Appendix B to prepare the test sample.

6.2.3 Wash each sub-sample over a 75 µm sieve in accordance with MTO LS-601, Method Of Test for Material Finer Than 75 µm Sieve in Mineral Aggregates by Washing, until all material passing the 75 µm sieve is removed.

6.2.4 Saturate the sub-samples in water by immersion for 15-19 h.

6.2.5 Test the 2 sub-samples. For the purpose of determining the saturated surface dry condition, where possible, use the normal cone test.

6.2.6 In cases where the fine aggregate slumps before the saturated surface dry condition is reached (normally fine aggregates with large amounts of material retained on the 2.36 and 1.18 mm sieves), remove the material coarser than the 2.36 mm sieve by dry sieving. Test the material pass 2.36 mm using the cone test. Test the material retained on the 2.36 mm sieve using procedure 4 of the test method using hard-finish paper towels (Note 6).

Note 6: Whatman No 541 filter paper may be suitable, is re-usable, and is available in approximately 500 x 500 mm sheets.

6.2.7 If duplicate tests of relative density differ by more than 0.027, the materials shall be retested.

6.2.8 If duplicate tests of absorption differ by more than 0.31%, the materials shall be retested.

6.3 Fine aggregates extracted from RAP for both Marshall and Superpave mix design.

6.3.1 Remove the asphalt from the RAP by solvent extraction with a suitable solvent. Soak the extracted aggregates in denatured methyl alcohol overnight, drain off the alcohol.

6.3.2 Wash the sample over a 75 µm sieve in accordance with MTO LS-601, Method of Test for Material Finer Than 75 µm Sieve in Mineral Aggregates by Washing, until all material passing the 75 µm sieve is removed. Use procedure B of the test method in which a wetting agent is used.

6.3.3 Follow the procedures of 6.1.

6.4 Combinations of virgin fine aggregate and RAP for both Marshall and Superpave processes.

6.4.1 Calculate the density of the fine aggregate in the asphalt mixture by using a calculation based on the density of the fine aggregate determined following 6.1 or 6.2 and the density of the RAP fine aggregate determined following 6.3. The calculation shall be based on the mass proportions of virgin fine aggregate to the mass proportion of fine aggregate contributed to the mixture by the RAP.

7. USE OF LABORATORY CONTROL AGGREGATE

7.1 Every ten samples, but at least every week in which a sample is tested, a sample of the standard reference aggregate shall also be tested. Material shall be taken from a stock supply of Sutherland sand maintained by the Soils and Aggregates Section, Ministry of Transportation, 1201 Wilson Avenue, Downsview, Ontario M3M 1J8 (Fax: 416-235-4101).

7.2 Control Chart Use: The per cent loss of the last twenty samples of reference material shall be plotted on a control chart in order to monitor the performance of the laboratory.

7.3 The mean absorption of the Sutherland standard reference aggregate is 1.85%. Individual test data should not normally be greater than 2.12% or less than 1.58%.

7.4 The mean relative density (oven-dry) of the Sutherland standard reference aggregate is 2.611. Individual test data should not normally be greater than 2.629 or less than 2.593.

8. REPORT

The report shall include the following:

8.1 Relative density values shall be reported to the nearest 0.001 and indicate the basis for relative density as either oven-dry (OD), saturated-surface dry (SSD) or apparent.

8.2 Report the absorption result to the nearest 0.01%.

8.3 When two determinations are made on a fine aggregate, the mean of the results shall be reported as the final "test result".

8.4 When a sample has been separated on the 2.36 mm sieve and the density and absorption of the retained 2.36 mm material determined separately from the pass 2.36 mm material, this shall be noted and the individual and weighted mean densities and absorptions reported together with the calculation.

8.5 When fine aggregate extracted from RAP has been tested and the density combined with that of the virgin fine aggregate, the individual densities and absorptions of the extracted RAP aggregate and virgin fine aggregate shall be reported. The weighted mean density and absorption shall also be reported together with the calculation.

8.6 The per cent absorption and relative density of the last twenty samples of reference material on control charts.

9. PRECISION

9.1 The estimates of precision for fine aggregates passing 4.75 mm and retained on 75 µm are based on the results from the proficiency sample testing program conducted by MTO. The data are based on the analyses of the test results from 80 to 100 laboratories that tested ten pairs of fine aggregate proficiency test samples covering twelve year period from 2000 to 2011. The criteria for judging the acceptability of test results obtained by this test method on a range of aggregates found in Ontario are as follows:

Test Result	Standard Deviations (1s)		Acceptable Range (d2s)	
	Single-Operator	Multi-Laboratory	Single-Operator	Multi-Laboratory
Relative Density (O.D)	0.006	0.012	0.017	0.034
Absorption [B]	0.07	0.16	0.20	0.45

[A] These numbers represent, respectively, Standard Deviations (1s) and Acceptable Range (d2s) limits as described in ASTM C670. [B] Precision estimates are based on fine aggregates with absorption of less than 2% and may differ for aggregates having absorption values greater than 2%.

APPENDIX A

Non-Mandatory Information

Discussion on sources of bias in determining absorption and relative density

It has been found that there are significant differences in density when washed versus unwashed fine aggregate densities are compared. This is thought to be due to the fines retained in fine aggregate affecting the assessment of the saturated surface dry condition. This was thought to be caused by some weak cementing action of the fines (Woolf, 1936). Recent work has shown that fines may cause the formation of agglomerations of fine aggregate particles prior to attaining the saturated surface dry condition. These agglomerations have a higher porosity and lower density than that of the constituent particles. The point of saturated surface dryness is that of the agglomerations and not of the individual particles. The effect is most pronounced with crusher screenings containing over 6 or 7% fines (pass 75 μm sieve), but may occur with all materials containing fines greater than about 4%. Following the conventional AASHTO method, where fines are not removed, nearly always results in a higher absorption and a lower bulk relative density compared with the MTO procedure where fines are removed prior to determining the saturated surface dry condition. It should be noted that the original procedure was developed for concrete sands, which are nearly always of low fines content. The test has been subsequently adopted for use on manufactured sands and screenings. The Ministry of Transportation adopted a modified test where fines were removed prior to testing in the 1960's.

In studies (Rogers, 1980) of the comparison of bulk relative density of 26 samples of coarse aggregate and companion crusher screenings, it was found that the screenings on average had almost the same density (screenings were on average 0.003 more dense) as that of the corresponding coarse aggregate and had slightly higher average absorption (by approx 0.1%). This study was done using a test in which the fines were removed by washing prior to determining density. It was thought that the modified test (removal of fines by washing) gave a good approximation of likely density of the screenings. There was one notable exception to this, which was with vuggy, porous dolostones (Silurian reefal dolostone of the Niagara Escarpment). In this case, the process of crushing removes vugs and reduces porosity so that the screenings (2.772) were on average about 0.11 more dense than the coarse aggregate (2.662) and had half as much absorption (1.57%-0.74%). Further crushing to remove all pores would theoretically result in a density close to that of the density of the dolomite mineral (2.86).

A limited study of the difference in values obtained between immersing the sample versus mixing in 6% water and allowing to stand for 24 h was conducted in 2004 by MTO. In repeated tests (n = 11)

on one fine aggregate, it was found that the 6% water method, on average, resulted in higher absorption by 0.23% (1.80% versus 1.58%) and relative density was 0.17 less compared to the sand that was immersed in water.

REFERENCES

Woolf, D.O., *The cone method for determining the absorption by sand*, ASTM Proceedings, vol. 36, pp. 411-425, 1936.

Rogers, C.A., *Precision and accuracy of the test for absorption and relative density of fine aggregate, Ontario Ministry of Transportation, Soils and Aggregates Section, unpublished report (file no. 3162-2-4-605), 19 pages, 1980.*

APPENDIX B

Development of Equations for Preparation of Test Samples with Different Densities

The equation is derived for an asphalt mix consisting of two types of fine aggregates with different densities and fine aggregate from the coarse aggregate. The coarse aggregate in the mix Pc% and the coarse aggregate contain P_f% by mass of material finer than 4.75 mm. The mass of fine aggregate No. 1 in the blended portion M_1 in grams and P_1% by volume. The fine aggregate No. 2 has a mass of M_2 and P_2% by volume.

Percentage of fine aggregate from the coarse aggregate = $\left(\frac{P_f}{100}\right)P_c$

Mass of fine aggregate from coarse aggregate M_f in grams = $(M_t)\left(\frac{P_f}{100}\right)\left(\frac{P_c}{100}\right)$

Mass of blended fine aggregates (No. 1 & No. 2) in the test sample = $(M_t - M_f)$ grams

$$P_1 + P_2 = 100$$

$$M_1 = G_1V_1 \text{ and } M_2 = G_2V_2$$

$$(V_1)/(V_2) = (P_1)/(P_2)$$

$$M_1 + M_2 = (M_t - M_f)$$

Where, G and V are the bulk specific gravity and volume of fine aggregates No. 1 and No. 2, respectively.

Manipulation of the above equations yields masses M_1 and M_2 of fine aggregates in the test sample.

$$M_1 = (M_t - M_f)\left[\frac{(P_1G_1)}{(P_1G_1 + P_2G_2)}\right] \text{ and}$$

$$M_2 = (M_t - M_f)\left[\frac{(P_2G_2)}{(P_1G_1 + P_2G_2)}\right]$$

Example: The proposed asphalt mix will use two fine aggregates, a natural sand and crusher screenings in the proportion of 33%-67% by volume. The bulk specific gravity of natural sand and screenings are 2.650 and 2.750, respectively. The coarse aggregate portion of the mix will be 55% by mass and the coarse aggregate contain 12% by mass of material finer than 4.75 mm. Prepare 2400 g of test sample in the proportion of fine aggregates expected in the proposed asphalt mix.

The portion of the fine aggregate from the coarse aggregate = 2400 x (12/100) x (55/100)

= 158.5 g

Mass of blended fine aggregates (No. 1 & No. 2) in the test sample = (2400 – 158.5)

= 2241.5 g

Mass of natural sand in the test sample = (2241.5) (2.65 x 33)/(2.650 x 33 + 2.750 x 67)

= 721.5 g

Mass of screenings in the test sample = (2241.5) (2.75 x 67)/(2.650 x 33 + 2.750 x 67)

= 1520.0 g

The total mass of tests sample = 158.5 + 721.5 + 1520. 0 = 2400.0 g

Ministry of Transportation Ontario

RELATIVE DENSITY & ABSORPTION - FINE AGGREGATE

LAB NO.	TEMP °C	FLASK NO.	FLASK MASS	MASS OF FLASK + SAND	MASS OF SAT. SUR. DRY SAND IN AIR B	MASS OF SAND + FLASK + WATER	MASS OF WATER ADDED W	VOLUME OF FLASK V	MASS OF DRY SAND IN AIR A

PH-CC-332 78-06

DATE _____

OPERATOR _____

COMPUTED BY _____

Figure 1 Relative Density and Absorption – Fine Aggregate Data Card