METHOD OF TEST FOR
DETERMINATION OF PERCENT CRUSHED PARTICLES
IN PROCESSED COARSE AGGREGATE

1. SCOPE
1.1 This method covers the visual determination of the percent, by mass, of crushed particles in a processed coarse aggregate.
1.2 In conjunction, this method also covers the visual determination of the percent, by mass, of cementations in a coarse aggregate.
1.3 Two procedures are given. Method A is suitable for well-graded materials with equal representation from all particle sizes passing the 26.5 mm sieve, retained by the 4.75 mm sieve. Method B is suitable for materials that have an uneven distribution of particles across the various sieve fractions between the 26.5 mm and the 4.75 mm sieves, i.e., gap-graded or poorly graded materials, or where greater accuracy is required, e.g. referee testing

Note: This test method covers only the fractions of coarse aggregate passing 26.5 mm and retained on 4.75mm sieve.

2. REFERENCES
2.2 LS-600, Method of Dry Preparation of Aggregates for the Determination of Physical Constants.
2.3 LS-602, Method of Test for Sieve Analysis of Aggregates.
2.4 LS-621, Method of Test for Determination of Amount of Asphalt Coated Particles in Coarse Aggregate.

3. DEFINITION
3.1 A CRUSHED PARTICLE is defined as a piece of coarse aggregate with at least one well-defined face resulting from fracture. The area of the crushed face should be at least 20 percent of the total surface area and the edges should be sharp (Figures 1, 2 and 3). Particles with smooth faces and rounded edges, or with only small chips removed, are not considered crushed (Figures 4, 5 and 6).
3.2 A CEMENTATION is defined as a group of aggregate particles cemented together which may or may not include a host (dominant) particle.
4. **APPARATUS**

4.1 BALANCE: Of sufficient capacity and readable to 1 g or less and accurate to within 0.1% of the test load at any point within the range of use.

5. **PREPARATION OF TEST SAMPLE**

5.1 Prepare the coarse aggregate according to LS-600.

5.2 Dry the sample sufficiently to obtain a clean separation of particles on the 4.75 mm sieve.

**Method A**

5.3 Separate the sample into the following three fractions by sieving according to LS-602: (i) material retained on the 26.5 mm sieve; (ii) material passing the 26.5 mm sieve, retained on the 4.75 mm sieve, and (iii) material passing the 4.75 mm sieve.

5.4 Reduce the fraction passing the 26.5 mm sieve, retained on the 4.75 mm sieve by splitting or quartering to approximately the masses given in Table 1.

*Note: The largest particle size is determined from the smallest sieve in Table 1 that 95% or more of the material passes.*

<table>
<thead>
<tr>
<th>Largest particle size (&gt;95% passing sieve)</th>
<th>Mass (minimum), g</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.5 mm</td>
<td>1000</td>
</tr>
<tr>
<td>16.0 mm</td>
<td>850</td>
</tr>
<tr>
<td>13.2 mm</td>
<td>500</td>
</tr>
<tr>
<td>9.5 mm</td>
<td>200</td>
</tr>
<tr>
<td>6.7 mm</td>
<td>75</td>
</tr>
</tbody>
</table>

5.5 When the sample tested contains a mixture of natural aggregate, recovered crushed concrete and/or recovered asphaltic material, the size of test sample shall be increased so that the amount of natural aggregate in the test sample meets the requirements of Table 1.

5.6 Weigh and record the mass of material to the nearest 1 g.
Method B

5.7 Separate the sample by sieving according to LS-602 into one or more of the individual fractions indicated in Table 2.

5.8 Prepare the test sample from each coarse aggregate fraction representing at least 5% or more of the submitted sample according to the minimum masses shown in Table 2.

<table>
<thead>
<tr>
<th>Coarse Aggregate Fraction</th>
<th>Mass (minimum), g</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.5 mm</td>
<td>19.0 mm</td>
</tr>
<tr>
<td>19.0 mm</td>
<td>13.2 mm</td>
</tr>
<tr>
<td>13.2 mm</td>
<td>9.5 mm</td>
</tr>
<tr>
<td>9.5 mm</td>
<td>6.7 mm</td>
</tr>
<tr>
<td>6.7 mm</td>
<td>4.75 mm</td>
</tr>
</tbody>
</table>

5.9 When the test sample contains a mixture of natural aggregate, recovered crushed concrete, recovered asphaltic material, glass and/or ceramic material, the size of test sample shall be increased so that the amount of natural aggregate and recovered crushed concrete in the test sample meets the requirements of Table 2.

5.10 Weigh and record the mass of material of each fraction to the nearest 1 g.

6. TEST PROCEDURE

6.1 Spread the test sample (Method A) or each fraction of the test sample (Method B) on a clean, flat surface large enough to permit individual particles to be visually inspected.

6.2 Separate any asphaltic, glass or ceramic material from test sample. Do not separate any asphalt stained particles as defined by LS-621.

6.3 Separate any crushed recovered concrete particles from the test sample and classify them as crushed particles.

6.4 Separate the natural aggregate particles into crushed and uncrushed portions. Separation of cemented particles shall be according to whether the host particle is crushed or uncrushed. When there is no host particle present, cemented particles shall be considered as uncrushed cementations.

Note: If dirt or dust films make it difficult to determine if the particles have well-defined fractured faces, it is permissible to wash the particles. However, the sample should be dried before weighing.
6.5 Weigh and record the mass of each crushed, uncrushed and cementation portion of the sample or fraction to the nearest 1 g. Table 3 is a laboratory worksheet for recording test data and calculations.

7. CALCUATION

Method A
7.1 Calculate the percentage of crushed particles for the test sample (to one decimal place) using the following formula:

\[
\% \text{ crushed particles} = \frac{A + B}{A + B + C + D} \times 100
\]

where

- \( A \) = mass of crushed particles
- \( B \) = mass of crushed cementations
- \( C \) = mass of uncrushed particles
- \( D \) = mass of uncrushed cementations

Method B
7.2 If the test sample was prepared according to Method B, calculate the percent of crushed natural aggregate particles for each fraction (to one decimal place), using the following formula:

\[
\% \text{ crushed particles} = \frac{A + B}{A + B + C + D} \times 100
\]

where

- \( A \) = mass of crushed particles
- \( B \) = mass of crushed cementations
- \( C \) = mass of uncrushed particles
- \( D \) = mass of uncrushed cementations

7.3 Compute the percent of each fraction specified in Table 2 using the gradation test (LS-602) results of the coarse aggregate portion, i.e., based on the total mass of material retained on 4.75 mm sieve.

7.4 Calculate the percent crushed particles weighted average value for each fraction as the product of the percentage of each fraction calculated in Section 7.3 and the percent crushed particles for that fraction.

7.5 Calculate the percent crushed particles weighted average value of the test sample as the sum of the weighted average value for each fraction divided by 100.

7.6 If the amount of cemented particles is required, use the following formula:

\[
\% \text{ cemented particles} = \frac{B + D}{A + B + C + D} \times 100
\]
Then calculate the weighted average value.

7.7 For the purpose of calculating the weighted average, consider any fraction (not tested) containing less than 5% of the test sample to have a value equal to the average of the next smaller and the next larger fractions. If one of these sizes is missing, assign the same value as the next larger or smaller fraction, whichever is present.

8. **REPORTING OF RESULTS**

8.1 Report the method used for sample preparation and testing (Method A or Method B).

8.2 Report the % crushed particles (Method A) or weighted average % crushed particles (Method B) to the nearest whole percent.

9. **GENERAL NOTES**

9.1 Material used in this test may be re-used if insufficient material is available for other required tests.

10. **PRECISION**

10.1 The estimates of precision for coarse aggregate passing 19.0 mm and retained on 4.75 mm 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 202 to 227 laboratories that tested twelve pairs of coarse aggregate proficiency test samples covering twelve year period from 2000 to 2011.

10.2 Precision estimates are based on aggregates having a nominal maximum size of 19.0 mm with percent crushed values ranging from 55% to 85%. The single-operator standard deviation has been found to be 2.1\(^A\). Therefore, results of two properly conducted tests on samples of the same aggregate by the same operator using the same equipment are not expected to differ by more than 5.9\(^A\) of their average, 95% of the time. The multi-laboratory standard deviation has been found to be 4.7\(^A\). Therefore, the results of two properly conducted tests by different laboratories on samples of the same aggregate are not expected to differ by more than 13.2\(^A\) of their average, 95% of the time.

\(^A\) These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C670.
Figure 1. Crushed particle (sharp edges, rough surfaces).

Figure 2. Crushed particle (sharp edges, smooth surfaces).

Figure 3. Crushed particle (round edges, rough surfaces).
Figure 4. Uncrushed particle (chipped only).

Figure 5. Uncrushed particle (round edges, smooth surfaces).

Figure 6. Uncrushed particle (rounded particles, smooth surfaces).
Table 3. Percent Crushed Particles Worksheet (all masses in grams)

<table>
<thead>
<tr>
<th>Sample No.: _____________________</th>
<th>Date:  _________________________</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>Method A</th>
<th>Mass of Test Specimen</th>
<th>Crushed Particles, Mass (A)</th>
<th>Crushed Cementations, Mass (B)</th>
<th>Uncrushed Particles, Mass (C)</th>
<th>Uncrushed Cementations, Mass (D)</th>
<th>% Crushed Particles 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.5–4.75 mm</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Method B</th>
<th>Mass of Test Specimen</th>
<th>Percent of Each Fraction 2</th>
<th>Crushed Particles, Mass (A)</th>
<th>Crushed Cementations, Mass (B)</th>
<th>Uncrushed Particles, Mass (C)</th>
<th>Uncrushed Cementations, Mass (D)</th>
<th>% Crushed Particles 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.5–19.0 mm</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>19.0–13.2 mm</td>
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<tr>
<td>13.2–9.5 mm</td>
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<td></td>
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<tr>
<td>9.5–6.7 mm</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>6.7–4.75 mm</td>
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</tr>
</tbody>
</table>

Notes:
1. Not including reclaimed asphaltic, glass or ceramic material
2. As determined by LS-602 in 7.3
3. \[ \frac{A+B}{A+B+C+D} \times 100 \]
4. % crushed particles (per fraction) x % of each fraction

Remarks: ______________________________________________________________________________________________________________________

Operator: ___________________________

% Crushed particles, Weighted Average: \( \frac{\sum \text{Weighted per fraction}}{\sum \text{Weighted per fraction}} \times 100 \)