Aggregates

NEW AGGREGATE TEST PROCEDURES

Major Aggregate Research Projects

- NCHRP 4-19: Aggregate Tests Related to Asphalt Concrete Performance in Pavements
- NCHRP 4-30: Test Methods for Characterizing Aggregate Shape, Angularity and Texture

NCHRP 4-19

- Aggregate properties important
- Current aggregate tests - empirical
- Identify aggregate tests related to performance

Coarse Aggregate Particle Shape and Surface Texture

What is the best aggregate particle shape methods which are related to rutting and fatigue cracking of HMA mixtures?
Flat and Elongated Particles

Uncompacted Voids in Coarse Aggregate

NCHRP 4-19 Recommended Tests

- Uncompacted voids
- Flat or elongated 2:1 ratio

Flat & Elongated Ratios

<table>
<thead>
<tr>
<th>Ratio</th>
<th>2:1</th>
<th>3:1 to 4:1</th>
<th>4:1 to 5:1</th>
<th>&gt;5:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2:1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:1</td>
<td>28</td>
<td>42</td>
<td>17</td>
<td>10</td>
</tr>
<tr>
<td>3:1 to 4:1</td>
<td>17</td>
<td>10</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4:1 to 5:1</td>
<td>10</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;5:1</td>
<td></td>
<td></td>
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</tbody>
</table>

Understanding and evaluating how particle shape affects performance requires examination of all of the shapes found within the sample.

Multiple Ratio Analysis provides significantly more detailed information about the different particle shapes.

New Methods for Measuring Coarse Aggregate Shape and Texture
Martin Marietta has developed a low cost device to sort particles into five different flat and elongated ratios, that combines the ruggedness of a 1/2 ton press with the sensitivity of a digital caliper.

Particles are rapidly sorted by placing them on the lower platen, lowering the shaft to make contact with the particle, and then using a footswitch to transfer the measurement data into an Excel spreadsheet.

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:1</td>
<td>3.32</td>
<td>6.70</td>
</tr>
<tr>
<td>2:1</td>
<td>3.29</td>
<td>10.96</td>
</tr>
<tr>
<td>3:1</td>
<td>4.24</td>
<td>11.54</td>
</tr>
<tr>
<td>4:1</td>
<td>1.37</td>
<td>22.15</td>
</tr>
<tr>
<td>&gt;5:1</td>
<td>4.72</td>
<td>16.17</td>
</tr>
</tbody>
</table>

The spreadsheet calculates the flat and elongated ratio for the operator, and then uses a color coding system to indicate to the operator which flat and elongated category the particle should be placed in. After sorting all the particles, simply determine the mass of each flat and elongated category to calculate the percent.

Particle Shape Multiple Ratio Analysis

Individual Size Fractions Grouped by F&E Ratios

Some sample showing MPA profile by sieve size, revealing very detailed particle shape information.
AMRL F&E Proficiency Sample
ASTM D4791

<table>
<thead>
<tr>
<th>PARTICLE SIZE</th>
<th>AVE. F&amp;E</th>
<th>STD. DEV.</th>
<th>COEFF. VAR.</th>
<th>D2S</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5mm</td>
<td>14.5</td>
<td>7.1</td>
<td>48.9</td>
<td>20.1</td>
</tr>
<tr>
<td>9.5mm</td>
<td>18.5</td>
<td>8.2</td>
<td>44.3</td>
<td>23.2</td>
</tr>
<tr>
<td>4.75mm</td>
<td>26.2</td>
<td>11.1</td>
<td>42.3</td>
<td>31.4</td>
</tr>
</tbody>
</table>

High Standard Deviations are typical when labs use the traditional single-ratio proportional caliper.

Different Operators For Same Sample
(Approximately 400 pieces)

<table>
<thead>
<tr>
<th>Flat and Elongated Ratios</th>
<th>Operator A</th>
<th>Operator B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Accuracy with the new MRA device. Operator A was experienced, while Operator B had no experience.

VDG-40 VIDEOGRADER

- Designed as a grading device
- Precise measurement of particle area from which length & width are calculated
- Estimate of thickness using a flatness factor

Good Material

WipShape – 3 Dimensional
Laser-Based Aggregate Scanning System –3D

Power Source 110 VAC

Control Line

Linear Motion Guide

Laser Scanning Laser Plane

Support Frame

Computer Scanning Platform

LASS – Gradation Data

LASS – Shape

LASS – Angularity and Texture

NCHRP 4-30: Test Methods for Characterizing Aggregate Shape, Texture, & Angularity

 Investigators: Masad, Button, Little – Texas A&M & TTI
Tutumluer – University of Illinois

- Speed
- Accuracy - (Sound concepts behind answers)
- Reliability
- Repetitiveness – (individual & inter-lab)
- Ability to perform SUPERPAVE specification compliance testing
- Inexpensive (of course !!!)
Need for Three Orthogonal Views

Do we get sufficient information from one or two orthogonal views to estimate volume?

The University of Illinois Aggregate Image Analyzer

Captures 1000 Particles in approx. 70 min.

The University of Illinois Aggregate Image Analyzer

Fine Aggregate Particle Shape and Surface Texture

What is the best aggregate particle shape and texture method related to rutting of HMA mixtures?
Fine Aggregate Tests Evaluated in NCHRP 4-19

- Index of aggregate particle shape and texture (ASTM D3398)
- Uncompacted voids (AASHTO T304)
- Particle shape (Image analysis - Univ. of Arkansas method)
  - EAPP Index
  - Roundness Index

NCHRP 4-19 Recommended Test

Uncompacted voids (AASHTO T304)

Concerns About FAA

- Some cubical crushed materials, mainly limestone sources, produce uncompacted voids < 45%
- Fine aggregate specific gravity effects results
- Material passing the #4 sieve but retained on the #8 sieve is not tested

CAR Test Shearing Head

Shear Resistance vs. Fine Aggregate Angularity

11th Annual ICAR Symposium
David Jahn
Martin Marietta Aggregates
What is the best aggregate test method that indicates presence of detrimental fines which may induce stripping in HMA mixtures?

- NCHRP 4-19 recommend using methylene blue test to evaluate plastic fines in the fine aggregate.
Aggregate Toughness/ Abrasion Resistance

- Needed to resist crushing, degradation, and disintegration during stockpiling, mix production, construction, and traffic
- Los Angeles abrasion test commonly used (no significant validation data)

Durability/ Soundness

- Needed to resist breakdown or disintegration when subjected to wetting/drying and/or freezing/thawing
- Sulfate soundness commonly used

Which aggregate tests are related to performance of HMA in terms of raveling, popouts, or potholes?
NCHRP 4-19 Conclusions

- Micro-Deval and Magnesium sulfate loss are the two best indicators of potential pavement performance
- Losses of 18% maximum for both appear to separate good and fair from poor performers

Problem: Measuring $G_{sb}$

- Time consuming, approximately 2 days
- Coarse Agg. repeatable except with irregular shapes such as slag
- Fine Agg. Slump effected by:
  - grading
  - angularity
  - fines (< 0.075 mm)

NCAT Study on Determination of $G_{sb}$ for Fine Aggregates: Research Objective

The objective of this research study is to develop an automated method for the determination of Saturated Surface Dry condition for the calculation of bulk specific gravity of fine aggregates
**Corelok™ Method to Determine Fine Aggregate Gsb**

- Determine mass of fine aggregate in air
- Determine mass of bag
- Vacuum seal in resilient plastic bag
- Open corner of bag under water and determine mass

**Corelok™ Method to Determine Fine Aggregate Gsb**

- Add a split sample to pycnometer, partially filled with water
- Stir to remove air
- Spray surface with alcohol
- Clamp lid and fill with water
- Weigh
- All within 2 minutes!

**Gilson Company, Inc.**

- Determine weight of oven-dry sample
- Add 6% water to sample
- Test
- Separate determination of apparent gravity

**Typical High-Absorption Plot**

- SSD Point
- Regression Lines
- Humidity Curve

**Typical Low-Absorption Plot**

- SSD Point
- Regression Lines
- Humidity Curve
SSDetect Method to Determine Fine Aggregate Gsb

- SSDetect is based on the "dry to wet" method
- A small pump injects water into the sample, the sample is mixed with an orbital action
- Capillary action transports the water to internal pores
- Infrared light is used to detect the SSD state

Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>% Passing No. 200</th>
<th>Uncomp. Voids, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Limerock</td>
<td>5.9</td>
<td>47.5</td>
</tr>
<tr>
<td>B Washed Diabase</td>
<td>7.5</td>
<td>48.8</td>
</tr>
<tr>
<td>C Diabase</td>
<td>14.3</td>
<td>48.8</td>
</tr>
<tr>
<td>D Slag</td>
<td>7.1</td>
<td>50.7</td>
</tr>
<tr>
<td>E Round Natural Sand</td>
<td>0.9</td>
<td>41.2</td>
</tr>
<tr>
<td>F Angular Natural Sand</td>
<td>3.4</td>
<td>45.1</td>
</tr>
</tbody>
</table>

Round Robin

- Three Methods Evaluated to date:
  - AASHTO T-84
  - Corelok
  - SSDetect
- Conducted according to ASTM C 802 & E 691
- Samples Split, randomly selected, random testing order
- Samples sent to 12 labs for each method

Dry Bulk Specific Gravity

Recommended Precision Statement – D2S

<table>
<thead>
<tr>
<th>Method</th>
<th>Within-Lab</th>
<th>Between-Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Corelok</td>
<td>SSDetect</td>
</tr>
<tr>
<td>Gsb</td>
<td>0.104</td>
<td>0.039</td>
</tr>
<tr>
<td>Gsa</td>
<td>0.024</td>
<td>0.019</td>
</tr>
<tr>
<td>Water Abs.</td>
<td>1.023</td>
<td>0.560</td>
</tr>
</tbody>
</table>
Conclusions

- The Corelok and SSDetect methods offer significant time savings over AASHTO T 84
- Both the Corelok and SSDetect produce results similar to AASHTO T 84
- Where significant differences occur, the bias was generally smaller for the SSDetect method
- The SSDetect offers improved precision over AASHTO T 84