| Module 1 | Consensus Sampling and QC/QA |
| Module 2 | AASHTO T 176 Plastic Fines in Graded Aggregate and Soils by Use of the Sand Equivalent Test |
| Module 3 | AASHTO T 304 Uncompacted Void Content of Fine Aggregate |
| Module 4 | ASTM 5821 Determining the Percentage of Fractured Particles in Coarse Aggregate |
# HMA Aggregate (Consensus) Tests Certification Course

## 2019-2020 Season

<table>
<thead>
<tr>
<th>Time</th>
<th>Module</th>
<th>Location</th>
<th>Topic</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00-8:10</td>
<td>Intro</td>
<td>Lecture</td>
<td>Intro/welcome</td>
<td>Richardson</td>
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<tr>
<td>8:10-8:30</td>
<td>1</td>
<td>Lecture</td>
<td>Aggregate QC/QA</td>
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<tr>
<td>8:30-9:10</td>
<td>2</td>
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<td>Sand Equivalent</td>
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<tr>
<td>9:10-9:30</td>
<td>2</td>
<td>Lab</td>
<td>Sand Equivalent (start)</td>
<td>Lusher</td>
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<tr>
<td>9:30-9:40</td>
<td>2</td>
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<td>Break</td>
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<td>9:40-9:55</td>
<td>2</td>
<td>Lab</td>
<td>Sand Equivalent (Finish)</td>
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</tr>
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<td>9:55-10:15</td>
<td>3</td>
<td>Lecture</td>
<td>Fine Aggregate Particle Shape</td>
<td>Richardson</td>
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<td>10:15-10:35</td>
<td>3</td>
<td>Lab</td>
<td>Fine Aggregate Particle Shape</td>
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<td>10:35-10:50</td>
<td>4</td>
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<td>Fractured Face Count</td>
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<td>10:50-11:05</td>
<td>4</td>
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<td>Fractured Face Count</td>
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<td>11:05-11:15</td>
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<td>Break</td>
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<td>11:15-11:25</td>
<td>1-4</td>
<td>Lecture</td>
<td>Course Review</td>
<td>Richardson</td>
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<td>11:25-?</td>
<td>1-4</td>
<td>Lecture</td>
<td>Written Exam</td>
<td>Richardson</td>
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Once written exam is complete, the attendee can start their hands-on practice & proficiency exams. Whether the attendee wants to leave for lunch is their decision. Proficiency exam proctors will be on duty until all attendees have finished their proficiency exams.

<table>
<thead>
<tr>
<th>- Until all have finished</th>
<th>2-4</th>
<th>Lab</th>
<th>Hands-on practice &amp; Proficiency Exams</th>
<th>Staff</th>
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MODULE 1
HMA Aggregate Consensus Tests
1-2-07
1-23-07
1-28-07
3-9-07
11-9-07
12-23-08
2-26-10
5-17-11
12-18-13
12-20-14
12-28-16
1-30-18
12-19-19

SUPERPAVE
- A SHRP product (1993)
- SUperior PERforming asphalt PAVEments
- New way of specifying binders and aggregates, and a new mix design method
- Tied to pavement performance

PERFORMANCE BEHAVIOR-
Major
- Permanent distortion - this course
  - Rutting
  - Shoving
  - Corrugations
  - Fatigue cracking
  - Cold temperature cracking
- Moisture sensitivity (stripping) this course
What is it?

- QC…Contractor provides control of the process
- QA…Owner provides assurance that control is working
QC/QA
Who?

- Quality Control:
  - Aggregate Producer
  - Paving Contractor
- Quality Assurance:
  - Owner (MoDOT)

SUPERPAVE MIXTURE NAMES

- “SPnnnyzz”
- SP = Superpave
- nnn = nominal max size
  - 048 = 4.75 mm (#4)
  - 095 = 9.5 mm (3/8 in)
  - 125 = 12.5 mm (1/2 in)
  - 190 = 19.0 mm (3/4 in)
  - 250 = 25.0 mm (1 in)

- y = mixture design (ESAL’s)
  - F = < 300,000
  - E = 300,000 to < 3,000,000
  - C = 3,000,000 to < 30,000,000
  - B = ≥ 30,000,000
- zz = special designations
  - LP = Limestone Porphyry
  - SM = Stone Mastic Asphalt
  - SMR = SM Rural
  - NC = Non-Carbonate
  - LG = Lower Gyration
SUPERPAVE “NOMINAL MAXIMUM SIZE”

1. Look at the combined gradation of the hotmix. Identify the largest sieve that accumulatively retains 10% or more.
2. Move up one sieve larger--that is the “nominal maximum size” (NMS).
3. The “maximum size” is one size larger than the NMS.

MIX EXAMPLE

SP250B =
- Superpave
- 25 mm NMS
- "B" traffic level (≥ 30,000,000 ESALs)

USE OF ESAL’s IN MATERIAL SELECTION

- Level of aggregate quality is tied to level of traffic; for instance, the greater the design traffic, the more angular and cleaner the aggregate has to be.
- The choice of PG binder grade is tied to traffic level; for instance, the greater the design traffic, the more rut resistant the binder must be.
ESAL’s

- Conversion of damage from a given axle load to an equivalent number of passes of an 18,000 lb load on a single axle (equal damage)
- For instance, one pass of a 22,000 lb single axle is equivalent in damage to 2.2 passes of an 18,000 lb single axle load

ESAL Comparison

<table>
<thead>
<tr>
<th>Load</th>
<th>ESAL</th>
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<tbody>
<tr>
<td>80 kN</td>
<td>1</td>
</tr>
<tr>
<td>100 kN</td>
<td>2.2</td>
</tr>
<tr>
<td>44 kN</td>
<td>.09</td>
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</tbody>
</table>

18,000 lb. 22,000 lb. 10,000 lb.

ESAL’s

Another way...

- Conversion of a given vehicle to an equivalent number of passes of an 18,000 lb load on a single axle (equal damage)
- For instance, one pass of a certain 6 tire truck is equivalent in damage to 0.49 pass of an 18,000 lb single axle load
AGGREGATE INSPECTION

- QC and QA perform tests, compare results to each other and:
  - Standard Specifications
  - Job Special Provisions
  - Engineering Policy Guide (EPG) guidelines

2006 CHANGES

- Emphasis on end-result testing to allow quarries more flexibility during production
2006 CHANGES

- Aggregate acceptance is at the mixing facility
- Usage: MoDOT still sampling/testing ledges (initial approval of ledges & annual source approval)
- Still will visit quarries to assure that proper ledges are being used

403 REQUIRED TESTING:

- Gradation
- **Consensus tests**: FAA, SE, F&E, and CAA
- Deleterious Materials
- RAP
CONTRACTOR
Initiates contact with quarry
Samples product for the
purpose of designing a job mix
(1)

Makes production agreements
with producer

CONTRACTOR
Designs mix
Submits mix design to
District

MoDOT
mix review/ approval

PRODUCER
Ongoing production
Non job specific

MoDOT
Monitors geology & Performs
benchmark physical testing of
crushed product
Preliminary Ledge ID sampling
Annual source sampling during
production (ledge specific)

NOTES

1. The producer may use any combination of
ledges so long as the crushed product meets the
minimum requirements for that material section.

2. MoDOT will not set requirements for
aggregate quality control but the producer will
need to be able to designate what is in each
fraction.

3. Material acceptance is based on combined
belt sample.

4. Gradation & del for 401 mixes. Include
concensus tests for 403 mixes.

5. Percent Del.

6. PI on 401 mixes. If PI > 3 on job mix, TSR
will be required during mix production.
Contractor may elect to avoid TSR during
production by making available test results of PI
during aggregate production.

Production
Aggregate QC & QA is
per the agreement
between producer and
contractor (2)

CONTRACTOR
Produces final product
QC testing per contract
(3, 4, 5, 6)

MoDOT
QA testing per contract
Contract administration
Material acceptance is made
off the belt
SAMPLING: Aggregate Consensus

- Drum plant—cold feed belt
- Batch plant—cold feed belt
- Cannot use ignition oven residue
- Do not put additional filler (lime, etc) into the sample

SAMPLING Drum Plant Methods

- Off the combined cold feed belt
- Diverter

Cold Feed Blended Aggregate
SPLITTING METHODS

- Mechanical splitter
  - Riffle splitter
  - "Quartermaster"
- Quartering of pile

Fine Aggregate Riffle Splitter

Coarse Aggregate Riffle Splitter
Opposing 2 quarters are removed and combined for further quartering

Example Consensus Tests Sampling Scenario
- The most logical scenario – sample for consensus tests material (QC = 1 per 10,000 tons) at the same time sampling for gradation and deleterious materials (QC = 1 per 2 sublots)
- Assumptions:
  - SP125
  - Drum Plant

Consensus Test Material Must Be Sampled from the Cold Feed Belt*

50 Kg (110 lb) Reduce Sample Size per T 248

25 Kg (55 lb) Per AASHTO T 2 based on ½” NMS
25 Kg (55 lb) Per AASHTO T 2 based on ½” NMS
25 Kg (55 lbs) Cold Feed Sample

- Gradation ≥ 2Kg (T27)
- Flat&Elongated (F&E)
- FAA (possibly)
- Deleterious ≥ 3Kg (TM-71)
- Sand Equivalent (SE) or Clay Content
- % Fractured Particles & Uncompacted Voids (or FAA)

Consensus Tests Details

- 3.12Kg: Sand Equivalent (T176)
- +#4 +#4
- CAA (D5821) FAA (T304)
- Pulverize aggregations & remove fines from CA
- Wash, dry, sieve into fractions OR
- Accumulate fractions from 2/lot sieve analyses

QC AGGREGATE CONSENSUS SAMPLING/TESTING

- Independent:
  - 1 per 10,000 tons mix (at least 1 per project per mix however, could represent several mixes if using all the same fractions)

- Retained split:
  - ½ of each QC sample will be properly tagged and retained until QA has accepted the QC-QA comparison.
  - This sample is to be the ½ part of the last split when obtaining the proper testing size.
### QA AGGREGATE CONSENSUS

**SAMPLING/TESTING**

- **Independent:**
  - 1 per project minimum

- **QC retained split:**
  - 1 per project minimum

- **Small Quantity Projects (<4000 tons):** comparison not necessary

### AGGREGATE

**Acceptance:**

- *Be within tolerance of JMF values*
- Compare “favorably” with QA results

### COMPARISON TO SPECIFICATIONS:

**Field Tolerances**

**Consensus tests:**

- $\text{FAA}_{\text{spec}} - 2\%$
- $\text{CAA}_{\text{spec}} - 5\%$
- $\text{SE}_{\text{spec}} - 5\%$
- $\text{T&E}_{\text{spec}} + 2\%$
MoDOT MIXTURE TYPES

<table>
<thead>
<tr>
<th>Design Levels</th>
<th>Design Traffic (ESALS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>&lt; 300,000</td>
</tr>
<tr>
<td>E</td>
<td>300,000 to &lt; 3,000,000</td>
</tr>
<tr>
<td>C</td>
<td>3,000,000 to &lt; 30,000,000</td>
</tr>
<tr>
<td>B</td>
<td>≥ 30,000,000</td>
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</tbody>
</table>

SECTION 403 CONSENSUS REQUIREMENTS on blended aggregate (5:1)

<table>
<thead>
<tr>
<th>Design Level</th>
<th>CAA</th>
<th>FAA</th>
<th>SE</th>
<th>F&amp;E*</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>55/none</td>
<td>---</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>E</td>
<td>75/none</td>
<td>40</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>95/90</td>
<td>45</td>
<td>45</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>100/100</td>
<td>45</td>
<td>50</td>
<td>10</td>
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</tbody>
</table>

* SMA: ≤ 20% @ 3:1 and ≤ 5% @ 5:1

CONSENSUS REQUIREMENTS

- CAA, FAA, and SE are minimums; F&E are maximums
FIELD TOLERANCES
Applied to 403 Spec
Example: C mix

- FAA: 45 - 2 = minimum of 43
- SE: 45 - 5 = minimum of 40
- T&E: 10 + 2 = maximum of 12
- CAA: 95 - 5 = minimum of 90
  90 - 5 = 85
so....90/85

FIELD TOLERANCES
Example: C mix

- FAA result is 44-- is this acceptable in the field?

Spec minimum is 45, but with field tolerance applied, the minimum acceptable is
  45 – 2 = 43

So, yes 44 is acceptable

FIELD TOLERANCES
Example: C mix

- Fractured Face Count result= 92% single-faced and 87% multiple-faced. Is this acceptable?

- Spec minimums are 95/90, but with field tolerance applied, the minimum acceptables are 95-5=90 and 90-5=85, so:
  - 92/87 is greater than 90/85, so…acceptable
AGGREGATE

Acceptance:
■ Be within tolerance of JMF values
■ Compare “favorably” with QA results (close enough)

COMPARING QA TO QC
(QC Retained Sample)

Close Enough?
■ Consensus Tests:
  ■ CAA: QC ± 5%
  ■ FAA: QC ± 2%
  ■ SE: QC ± 8%
  ■ T&E: QC ± 1%

EXAMPLE COMPARISON
Test Results
■ FAA: QC = 46, QA = 48

■ Is there “favorable comparison”?
  ■ Yes, must be within 2, and they are
Reporting of Test Results

All QC test results will be maintained in a bound booklet format in the lab, and made available to the QA inspector at all times.

Reporting of Test Results

- The sample retained will be labeled with the following information:
  - Time and date of sample.
  - Product specification number (¾”, ⅜”, etc.).
  - Type of sample (belt, bin, stockpile, etc.).
  - Copy of QC test results.
  - Name of sampler/tester.

QC/QA Functions at the Hot Mix Facility

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>LOCATION</th>
<th>FREQUENCY</th>
</tr>
</thead>
</table>
| Aggregate | Aggregate gradation | Drum: Combined cold feed
            | 1 size smaller than NMSJMF - not to exceed 92.0% |
            | #8: not to exceed 2.0% beyond master spec |
            | #200: within master spec |
| Consensus tests | | | Drum: Combined cold feed
            | | | Batch: Combined cold feed
            | | | QC: 1 per 10,000 tons (min. 1 per project per mix type)
            | | | QA: 1 per project
            | | | QA: QC retained: 1 per project |
| Consensus tests | | | Drum: Combined cold feed
            | | | Batch: Combined cold feed
            | | | QC: 1 per 2 sublots
            | | | QA: 1 per 4 sublots
            | | | QA: QC retained: 1 per week |
| Consensus tests | | | Drum: Combined cold feed
            | | | Batch: Combined cold feed
            | | | QC: 1 per 2 sublots
            | | | QA: 1 per 4 sublots
<pre><code>        | | | QA: QC retained: 1 per week |
</code></pre>
<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>LOCATION</th>
<th>FREQUENCY</th>
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<tr>
<td><strong>Aggregate:</strong></td>
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<tr>
<td>Aggregate gradation</td>
<td>Drum: Combined cold feed</td>
<td>QC: 1 per 2 sublots</td>
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<tr>
<td>3 sieves:</td>
<td>Batch: Hot bins</td>
<td>QA: 1 per 4 sublots</td>
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<tr>
<td>1 size smaller than NMS$_{\text{JMF}}$: not to exceed 92.0%</td>
<td>Optional: T308 Residue</td>
<td>QA: QC retained: 1 per week</td>
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<tr>
<td>#8: not to exceed 2.0% beyond master spec</td>
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<tr>
<td>#200: within master spec</td>
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<td></td>
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<tr>
<td>Consensus tests:</td>
<td>Drum: Combined cold feed</td>
<td>QC: 1 per 10,000 tons (min. 1 per project per mix type)</td>
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<tr>
<td>$\text{FAA}_{\text{spec}}$: -2%</td>
<td>Batch: Combined cold feed</td>
<td>QA: 1 per project</td>
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<tr>
<td>$\text{CAA}_{\text{spec}}$: -5%</td>
<td></td>
<td>QA: QC retained: 1 per project</td>
</tr>
<tr>
<td>$\text{SE}_{\text{spec}}$: -5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{T&amp;E}_{\text{spec}}$: +2%</td>
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MODULE 2

Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

AASHTO T 176

1-2-07, 1-10-07, 1-11-07
1-23-07, 1-26-07
3-9-07, 11-9-07
11-18-09, 1-17-11
12-18-13, 2-11-14
12-29-14, 12-9-15
12-28-16
1-17-18
1-30-19
12-19-19
MODULE 2
Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
AASHTO T 176
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12-29-14, 12-9-15
12-28-16
1-17-18
1-30-19
12-19-19

CONTENTS
- General
- Significance and Use
- Equipment
- Sampling & Size Reduction
- Sample & Specimen Preparation
- Procedure
- Calculations
- Reporting
- Comparing to Specification
- Common Errors

“SAND” EQUIVALENT
- Liquid solution separates clay-like material from larger material
- The % of the total sample that has similar characteristics to sand is determined
- The greater the “Sand Equivalent”, the less clay-like material in the sample
"SAND" EQUIVALENT

- "Sand" is really “fine aggregate”
- All minus #4 material from the cold feed
- From several fractions (products) contributing minus #4 material

MoDOT MIXTURE TYPES

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## MISSOURI DEPARTMENT OF TRANSPORTATION - DIVISION OF MATERIALS

### ASPHALTIC CONCRETE TYPE SP125HB

**DATE**: 10/29/03  
**CONTRACTOR**: MY BUSINESS  
**SP125 03-16**

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<th>IDENT</th>
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<th>PRODUCER, LOCATION</th>
<th>BULK</th>
<th>APPAR</th>
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<th>SP. GR</th>
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<th>FORMATION</th>
<th>LEDGES</th>
<th>% CHERT</th>
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<tr>
<td>35JSJ001</td>
<td>100207. LD1</td>
<td>Hard Rock Stone, Dig Deep, MO</td>
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<th>35JSJ003</th>
<th>30CAJ016</th>
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<th>3/8&quot; MAN SAND</th>
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<td>100.0</td>
<td>4.2</td>
<td>1.0</td>
<td>4.2</td>
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<tr>
<td></td>
<td>#16</td>
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<td>40.7</td>
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<td>1.0</td>
<td>0.3</td>
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<td>0.3</td>
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<tr>
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<td>1.0</td>
<td>0.3</td>
<td>1.0</td>
<td>0.3</td>
</tr>
<tr>
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<td>5.4</td>
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<td>0.2</td>
<td>0.9</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>#200</td>
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<td>4.2</td>
<td>99.9</td>
<td>0.9</td>
<td>0.2</td>
<td>0.9</td>
<td>0.2</td>
</tr>
</tbody>
</table>

**MIX COMPOSITION**

- **MIX MIXES**: 4  
- **TSR**: 95  
- **TSR Wt.**: 95  
- **Nin**: 9  
- **MIN. AGG.**: 93.8%

**CHARACTERISTICS**

- **Gm = 2.308**  
- **V. M. A. = 14.4**

**ASHTO T312**

- **Gm = 2.629**  
- **% FILLED = 72**

**CALIBRATION NUMBER**

- **90004**

**MASTER GAUGE BACK CNT = 2196**

**SAMPLE WEIGHT = 7200**

**MIX COMPOSITION**

- **A1 = -5.234741**
- **A2 = 3.436895**

Aggregate & Mixture Properties Based on Contractor's Mix Design
CONSENSUS REQUIREMENTS on blended aggregate

<table>
<thead>
<tr>
<th>Design Level</th>
<th>CAA</th>
<th>FAA</th>
<th>SE</th>
<th>F&amp;E*</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>55/none</td>
<td>---</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>E</td>
<td>75/none</td>
<td>40</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>95/90</td>
<td>45</td>
<td>45</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>100/100</td>
<td>45</td>
<td>50</td>
<td>10</td>
</tr>
</tbody>
</table>

* SMA: ≤ 20% @ 3:1 and ≤ 5% @ 5:1

CONSENSUS REQUIREMENTS

CAA, FAA, and SE are minimums; F&E are maximums

CONTENTS

- General
- Significance and Use
- Equipment
- Sampling & Size Reduction
- Sample & Specimen Preparation
- Procedure
- Calculations
- Reporting
- Comparing to Specification
- Common Errors
Significance & Use

"This test method is used to determine the proportion of detrimental fines in the portion passing the No. 4 sieve of soils or graded aggregate" (AASHTO T176-17)

LOW SAND EQUIVALENT

- A large amount of clay-like material can coat the aggregate surfaces and prevent the liquid asphalt from completely coating and adhering
- This harms bonding of asphalt to aggregate --- *stripping* in presence of water

MOISTURE DAMAGE (STRIPPING)
CONTAMINATION FROM:

- Inclusion of non-durable material during quarrying (e.g., shale, soft rock, etc.)
- Poor stockpile management techniques (e.g., mud, dust, etc.)
- During delivery (e.g., contaminated truck beds)

VARIATION IN LEDGES

STOCKPILES—note haul road close to finished stockpiles
Equipment
- Sieve 4.75mm (#4)
- Sample splitter
- Straightedge or spatula
- Tinned measure (3 oz.)
- Plastic graduated cylinder
- Rubber stopper
- Wide-mouth funnel

Equipment
- Calcium chloride concentrated stock flocculating solution
- Calcium chloride flocculating working solution
- Irrigation tube
- Timer
- Weighted foot assembly
- Oven capable of maintaining 230 ± 9°F (110 ± 5°C)

FLOCCULATING SOLUTION
- Stock solution- 4 alternate recipes
- Working solution- dilute 85 ± 5 ml with water to obtain 1 gal total
  - Discard after 30 days
  - Maintain at 22 ± 3 °C (72 ± 5 °F)
  - Keep out of sunlight
For Labs Where Temperature Cannot Be Maintained at 22 ± 3 °C
- If samples meet minimum specs at low temperatures, no reference testing is required (slower reactions, less floccing, greater CR, lower SE)
- Otherwise, frequently submit reference samples to a lab where proper temperature control is maintained to compare to field results
- If no difference, OK
- If significantly different, prepare conversion curves for each material tested

SHAKING METHODS
- Shaking methods hierarchy:
  - Mechanical: preferred but not mandated
  - Manual
  - Hand

MECHANICAL SHAKER
- Mechanical Shaker (powered)
  - 175 ± 2 cycles per min
  - Throw of 8.00 ± 0.04" (203.2 ± 1.0 mm)
  - Run for 45 ± 1 Seconds
MANUAL SHAKER

- Manually Operated Shaker
  - Oscillating motion of 100 complete cycles in 45 ± 5 seconds
  - A hand-assisted half stroke length of 5.0 ± 0.2'' (127 ± 5 mm)
  - Run for 100 strokes

HAND SHAKING

- Insert stopper and shake cylinder 90 cycles in 30 sec
- Throw of 9 ± 1'' (229 ± 25 mm)

GILSON

- Operate at 1 rev per second for 45 sec
- Desired result is 131 strokes in 45 sec (3 rev/sec)
- Stroke length 8.00 in. (203.2 mm)
- If used, this rate info must be stated in QC plan
- Not considered acceptable for dispute resolution
Equipment

NOTE!
The mechanical shaker is the equipment of choice for this test method.
Any disputes of test results will first rely on the result performed on the mechanical shaker.

CONTENTS
- General
- Significance and Use
- Equipment
  - Sampling & Size Reduction
    - Sample & Specimen Preparation
    - Procedure
    - Calculations
    - Reporting
    - Comparing to Specification
    - Common Errors

Consensus Test Material Must Be Sampled from the Cold Feed Belt
Consensus Test Material Must Be Sampled from the Cold Feed Belt

Baghouse

Silos

Combined cold feed belt

Drum

RAP feed

Cold bins
Consensus Test Material Must Be Sampled from the Cold Feed Belt*

50 Kg (110 lb)

25 Kg (55 lb)

25 Kg (55 lb)

Reduce Sample Size per T 248

QA

QC

Per AASHTO T 2 based on ½" NMS

Per AASHTO T 2 based on ½" NMS

25 Kg (55 lbs) Cold Feed Sample

12.5 Kg

12.5 Kg

6.25Kg

6.25Kg

3.12Kg

3.12Kg

3.12Kg

3.12Kg

Gradation ≥ 2Kg (T27)

Deleterious ≥ 3Kg (TM-71)

% Fractured Particles (or CAA) & Uncompacted Voids (or FAA)

Split Over #4 Sieve

Plus #4: Coarse Aggregate (CA):

• CAA

• F&F

Minus #4: Fine Aggregate (FA):

• FAA

• SE
Consensus Tests Details

3.12Kg: Sand Equivalent (T176)

- #4
  - CAA (D5821)
  - FAA (T304)

- #4
  - Pulverize aggregations & remove fines from CA

+ #4
  - CAA or waste
  - Reduce to ~600g

Air-dry Reduce to ~150g

SUMMARY OF METHOD

- Sample is shaken in water containing a flocculating solution
- Material is allowed to settle
- The Clay Reading and Sand Reading levels are measured
- Sand Equivalent is calculated

CONTENTS

- General
- Significance and Use
- Equipment
- Sampling & Size Reduction
- Sample & Specimen Preparation
- Procedure
- Calculations
- Reporting
- Comparing to Specification
- Common Errors
Sample Preparation
- At every step, be sure to capture all the dust
- Moistening is allowed
Sample Preparation

- Reduce sample size
- Shake over a #4 (4.75mm) sieve.
- Any clumps or dust should be broken apart; the (-#4) should be included with the passing material.
- Remove coatings on (+#4) material (by rubbing it between the hands-ASTM)- include with the passing material.

Sample Preparation

- At this point, the sample should be ~ 600g
- Adjust the moisture (dry or wet)

ALTERNATE METHODS

1) A: Dried
   - Oven dried (reference method)
   - Air dried
2) B: Pre-wet

Note: Non-oven (air) dried SE results may be lower (oven-drying may lower the clay content, thus SE will calculate higher). Thus, if non-dried test result is lower than the minimum allowed, a new sample may need to be tested after oven drying, which may raise SE.
Sample Preparation
Method A (air dry)

- The minus #4 material is then split or quartered until you have enough material to slightly overfill the tin measure (~120 to 150 g)
- While filling the tin measure, tap the bottom edge on a hard surface to consolidate.
- Using a spatula or straightedge, strike off the tin measure level full.

CAUTION

- Reduce sample size properly (don't just dip out a specimen)
- Use entire tin full
- Avoid using a spatula to scoop material from a pile—may concentrate the fines

CONTENTS

- General
- Significance and Use
- Equipment
- Sampling & Size Reduction
- Sample & Specimen Preparation
- Procedure
- Calculations
- Reporting
- Comparing to Specification
- Common Errors
Procedure

- Siphon 4.0 ± 0.1" (101.6 ± 2.5mm) of solution into graduated cylinder.
- Using the wide-mouthed funnel, pour sample into cylinder incrementally, deairing as you go
- Tap the bottom of the cylinder sharply with the heel of your hand several times (this is to release air bubbles and to promote thorough wetting of the material.)

Procedure

- Start timer
- Leave sample undisturbed for 10 ± 1 min.
- Place rubber stopper in cylinder and partially invert to loosen material.
- After loosening material, place in the shaker and shake for prescribed amount of time for the shaker being used.

HAND SHAKING

- Insert stopper and shake cylinder 90 cycles in 30 sec
- Throw of 9 ± 1" (229 ± 25 mm)
Procedure
- Set cylinder upright and remove rubber stopper.
- Insert irrigation tube, rinsing the walls of the cylinder as the irrigator is lowered.
  - The container of solution should be maintained 36” to 46” above the cylinder bottom.

Procedure
- Force the irrigator through the material to the bottom of the cylinder by applying a gentle stabbing and twisting action while solution flows from the irrigator tube.
- Continue this action while flushing the fines upward until the cylinder is filled to the 15” (381 mm) level.

Procedure
- Allow cylinder to remain undisturbed for 20 min. ± 15 sec.
- Determine final level by judging the bottom of the meniscus to be between the top two graduations not to exceed the 15” (381 mm) mark.
Procedure

- Read and record the level of the top of the clay suspension, always rounding up. This is the "Clay Reading".
- Ex. between 36 & 37, call it 37
- If unable to get a clear reading, consult test method for further instructions.

CLAY READING

Data Sheet – “Sand” Equivalent

<table>
<thead>
<tr>
<th>Clay Reading</th>
<th>CR</th>
<th>7.0 in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Reading **</td>
<td>SR</td>
<td></td>
</tr>
<tr>
<td>Sand Equivalent = ( SR / CR ) * 100</td>
<td>SE</td>
<td></td>
</tr>
</tbody>
</table>
Gently lower the weighted foot assembly into the cylinder taking care not to touch the sides of the cylinder until it rests on the settled material. As the weighted foot assembly comes to rest on the sand, tip the assembly toward the graduations until the indicator touches the inside of the cylinder.

Subtract 10" (254mm) from level indicated by the extreme top edge of the indicator and record this value as the "Sand Reading". Again always round up.

Don’t forget to subtract 10" for the length of the indicator foot before recording the sand reading. Ex: 13.7 – 10.0 = 3.7 in.
Calculations

Calculate the sand equivalent (SE) to the nearest 0.1 using the following formula:

\[
SE = \frac{\text{Sand Reading}}{\text{Clay Reading}} \times 100
\]

Data Sheet – “Sand” Equivalent

<table>
<thead>
<tr>
<th>Clay Reading</th>
<th>CR</th>
<th>7.0 in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Reading **</td>
<td>SR</td>
<td>3.7 in</td>
</tr>
<tr>
<td>Sand Equivalent = ( SR / CR ) * 100</td>
<td>SE</td>
<td>52.9 %</td>
</tr>
</tbody>
</table>

SE = [3.7 / 7.0] x 100
   = 52.9
General

Significance and Use

Equipment

Sampling & Size Reduction

Sample & Specimen Preparation

Procedure

Calculations

Reporting

Comparing to Specification

Common Errors

AASHTO T 176 61

Reporting

When reporting the SE value, always round up to the next higher whole number

In our example, 52.9 → “53”

Other examples: 52.1 = 53

52.5 = 53

AASHTO T 176 62

Averaging SE Values

41.2, 43.8, 40.9

Round up to whole numbers: 42, 44, 41

\[ SE = \frac{42 + 44 + 41}{3} = 42.3 \]

Report as “43”

AASHTO T 176 62
Comparing to 403 Specification During Mix Submittal

<table>
<thead>
<tr>
<th>Design Levels</th>
<th>Design Traffic (ESALS)</th>
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<tr>
<td>F</td>
<td>&lt; 300,000</td>
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<tr>
<td>E</td>
<td>300,000 to &lt; 3,000,000</td>
</tr>
<tr>
<td>C</td>
<td>3,000,000 to &lt; 30,000,000</td>
</tr>
<tr>
<td>B</td>
<td>≥ 30,000,000</td>
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</table>

Comparing to 403 Specification During Mix Submittal “C” Traffic Level

<table>
<thead>
<tr>
<th>Design Level</th>
<th>CAA</th>
<th>FAA</th>
<th>SE</th>
<th>F&amp;E*</th>
</tr>
</thead>
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<td>F</td>
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<td>---</td>
<td>40</td>
<td>10</td>
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<tr>
<td>E</td>
<td>75/none</td>
<td>40</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>95/90</td>
<td>45</td>
<td>45</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>100/100</td>
<td>45</td>
<td>50</td>
<td>10</td>
</tr>
</tbody>
</table>

53 greater than 45: so is “acceptable”
Comparing to 403 Specification With Field Tolerance During Mix Production “C” Traffic Level

- Spec with field tolerance: 45 - 5 = 40 minimum
- 53 is greater than 40: is “acceptable”

CONTENTS
- General
- Significance and Use
- Equipment
- Sampling & Size Reduction
- Sample & Specimen Preparation
- Procedure
- Calculations
- Reporting
- Comparing to Specification
- Common Errors
- Common Testing Errors

- Concentrated stock solution has a shelf life notice with the material—old stuff gets used
- Calcium chloride working solution not mixed properly
- Calcium chloride solution not maintained properly (has a certain shelf life):
  - Used outside acceptable temperature range
  - Not checked for organic growth
  - Exposed to direct sunlight
  - Not discarded after 30 days
- New solution added to old solution
<table>
<thead>
<tr>
<th>Common Testing Errors, cont'd.</th>
</tr>
</thead>
<tbody>
<tr>
<td>■ Organic (slimy) growth not removed from tubing and working solution container</td>
</tr>
<tr>
<td>■ Improper sample preparation</td>
</tr>
<tr>
<td>■ Sample not shaken properly in graduated cylinder</td>
</tr>
<tr>
<td>■ Sample vibrated during sedimentation stage</td>
</tr>
<tr>
<td>■ Sample not irrigated properly</td>
</tr>
<tr>
<td>■ Irrigation tube holes clogged</td>
</tr>
<tr>
<td>■ Hose gets soft and sticks together</td>
</tr>
</tbody>
</table>
PLASTIC FINES IN GRADED AGGREGATE AND SOILS BY USE OF THE SAND EQUIVALENT TEST

AASHTO T176

Developed by
Multi-Regional Aggregate Training & Certification Group
Revised 2006
Note
Successful completion of the following training materials, including examination and performance evaluations are prerequisites for this training package.

- AASHTO T 176, Standard method of Testing for Plastic Fines in Graded Aggregate and Soils By Use of Sand Equivalent Test.

Reference AASHTO Tests

- AASHTO T 2, Standard Practice for Sampling Aggregate
- AASHTO T 27, Sieve Analysis of Fine and Coarse Aggregate
- AASHTO T 248, Reducing Samples of Aggregate to Testing Size
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<th>Page</th>
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</thead>
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<td>Agg-T176-1</td>
</tr>
<tr>
<td>Apparatus</td>
<td>Agg-T176-1</td>
</tr>
<tr>
<td>Summary of Test</td>
<td>Agg-T176-2</td>
</tr>
<tr>
<td>Sample Preparation</td>
<td>Agg-T176-2</td>
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<tr>
<td>Test Procedure</td>
<td>Agg-T176-3</td>
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<tr>
<td>Calculations</td>
<td>Agg-T176-4</td>
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<tr>
<td>Common Testing Errors</td>
<td>Agg-T176-4</td>
</tr>
<tr>
<td>Glossary</td>
<td>Agg-T176-5</td>
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</table>
Plastic Fines in Graded Aggregate and Soils by Use of the Sand Equivalent Test

Scope

The Sand Equivalent Test uses a liquid solution to separate the clay-like material (fine dust) from the larger material in a sample that passes the No. 4 sieve. Once the clay-like material is separated the percent or amount of material in a sample that has similar characteristics to sand can be determined. A higher sand equivalent value indicates that there is less clay-like material in a sample. Clay-like materials have a direct effect on the performance of Hot Mix Asphalt (HMA) and the amount should be controlled to provide quality bituminous mixtures. A large amount of clay-like particles can coat the aggregate surfaces and prevent the liquid asphalt from completely coating and adhering to the aggregate.

Apparatus

The following equipment is needed to perform the sand equivalent test. The equipment needs to conform to the specifications and dimensions of the standard test method. Additional accessory items are also noted in a list of materials in the standard test method.

- A plastic graduated cylinder with a rubber stopper
- Irrigation Tube
- Weighted foot assembly
- Siphon assembly
- Tinned Measure
- Wide-Mouth Funnel
- A clock or watch
- A mechanical or manual shaker
- Bottle of solution

Note:
The solution is placed on a shelf 915mm ± 25 mm (36 in.±1 in.) above the work surface.
Summary of Test

The sand equivalent value of a prepared sample is determined by placing the sample into a graduated cylinder with the test solution. After the sample has soaked, the cylinder is capped off or sealed. The cylinder is then shaken in a horizontal position to completely mix the sample and solution.

There are three separate methods that can be used to shake a sample. The preferred or recommended method is the method using a mechanical shaker. The other two, the manual shaker or the hand method can be used, but each one has specific requirements that must be maintained to obtain accurate results.

When the mixing is finished the cylinder is stood upright, irrigated and allowed to stand undisturbed. The sample will sink toward the base of the cylinder. The heavier particles will sink to the bottom of the cylinder rapidly and the suspended fine material will slowly settle toward the bottom. After 20 minutes + 15 sec. the top of the suspended material is noted as the clay reading. The sand reading is noted after a weighted assembly is lowered into the cylinder and it comes to rest on the surface of the sand or coarse material that has settled out. Once the readings are obtained a simple calculation is used to determine the sand equivalent value.

Test Precautions

This test method has numerous steps where errors can be introduced, unless certain details are carefully controlled or monitored before and during the test procedure. The prepared solution of calcium chloride, glycerin and formaldehyde solution should be mixed, used and maintained with care. The Material Safety Data Sheets should be used for any safety issues associated with this test when using the noted solution.

Most of the precautions are associated with good laboratory techniques and watching the details. The sample preparation and the shaking of the sample have specific requirements that are needed for accurate test procedures, and test results.

Sample Preparation

The test is conducted on soils or graded aggregate passing the 4.75mm (No. 4) sieve. When separating the sample special care should be made to collect all the minus 4.75mm (No. 4) material. Any clumps or dust should be broken apart and included with the material passing the 4.75mm (No. 4) sieve.

Split the sample into the desired number of test samples, with enough material to slightly overfill the tin measure. Set up each test sample by either one of the alternate methods described in the standard specification, or the referee method (mechanical shaker).
Test Procedure

The following step by step procedure for the mechanical shaker (Reference Method) is recommended to understand the laboratory techniques needed for accurate test results.

1. Allow the initial sample to air dry.

2. Split or quarter the sample until you have slightly more material than it will take to fill a 3 ounce tin cup.

3. Place the tin cup in a larger flat container. A bread pan will work.

4. Take the sample obtained by splitting or quartering and slowly pour the sample into the tin cup.

5. As you pour the sample, gently tap the bottom edge of the tin cup on a hard surface (the bottom of the large flat container will work.)

6. After filling, strike off the top of the tin cup with a straight edge.

7. Oven dry the sample to a constant weight at 110 ± 5°C (230 ± 9°F).

8. Place one of the plastic graduated cylinders under the elevated siphon assembly.

9. Siphon 4.0+/-.1 inches of working calcium chloride solution into the cylinder.

10. Pour the content of the tin cup into the solution.

11. Tap the bottom of the cylinder several times with the heel of your hand to help release trapped air bubbles and promote thorough wetting of the sample.

12. Let the cylinder and sample stand undisturbed for 10 +/-1 minutes.

13. Place the rubber stopper in the cylinder.

14. Loosen the material from the bottom of the cylinder.

15. Place the cylinder in the Mechanical Shaker.

16. Tighten the screw to hold the cylinder.

17. Turn the Mechanical Shaker on.

18. BE SURE TO HOLD THE MECHANICAL SHAKER IN PLACE, IF IT HAS NOT BEEN ANCHORED TO A FIRM FLAT SURFACE. Allow the machine to shake the sample for 45 ± 1 second.
19. When the shaker is finished, loosen the screw.

20. Remove the cylinder.

21. Remove the stopper.

22. Place the cylinder under the siphon assembly.

23. Place the irrigation tube into the cylinder.

24. Loosen the restraints on the siphon tube.

25. Rinse the material from the cylinder walls as you lower the tube into the cylinder.

26. Force the irrigation tube through the sample.

27. Twist the irrigation tube, forcing the fine material into suspension.

28. Keep forcing and twisting the tube through the sample.

29. Keep doing this until the fluid level reaches approximately 15 inches.

30. Raise the tube, keeping the fluid level at the 15 inch mark.

31. Replace the restraints on the siphon tube.

32. Allow the cylinder and sample to stand undisturbed for 20 minutes +/- 15 seconds.

33. After this time take the Clay reading.

34. Read the top of the Clay suspension. If the suspension level is between lines take the highest reading.

35. Insert the weighted foot assembly. (Refer to the standard test method for specific notes of the weighted foot assemblies.)

36. MAKE SURE THAT YOU DO NOT ALLOW THE INDICATOR TO HIT THE MOUTH OF THE CYLINDER.

37. Lower the assembly into the solution until the foot comes to rest on the sand.

38. Take the sand reading. If the indicator is between 2 lines take the highest reading.

39. Record the clay and sand readings.

40. Enter the clay and sand readings in the Sand Equivalency formula and complete the calculations.
**Calculations**

Calculate the sand equivalent (SE) value to the nearest 0.1 using the following formula:

\[
SE = \frac{\text{Sand Reading} \times 100}{\text{Clay Reading}}
\]

**Common Testing Errors**

- Calcium Chloride Solution not mixed properly, used outside of the temperature range or not checked for organic growth.
- Vibrations or jarring while sample is settling out in the solution.
- Improper sample preparations (splitting & test sample preparations.)
- Solution exposed to direct sunlight.
- Sample not irrigated correctly.
- Sample not shaker properly in graduated cylinder.
GLOSSARY

**Irrigation Tube** - Metal tube pushed thru material to help force clay-like material into suspension.

**Weighted Foot Assembly** - Device used to measure the height of the nonclay-like material.

**Siphon Assembly** - A gallon container and flexible hose used to introduce the solution into the irrigation tube.

**Mechanical Shaker** - Used to agitate the sample and solution before irrigation.
MEMO for AASHTO T 176

AASHTO T 176, Plastic Fines in Graded Aggregates and Soils by the use of the Sand Equivalent Test

Shaker Requirements

There is a manually operated shaker out on the market from Gilson, model SE-6. It uses a hand crank to throw the cylinder a stroke of 203.2 mm (8.00 inches). Gilson recommends this device be operated at 1 revolution per second for 45 seconds. At 3 strokes per revolution this would yield 131 strokes. This would be equivalent to the mechanical requirements. This device is not specified in the AASHTO Test Method.

The following issues should be considered when reviewing the acceptability of a shaker for this test method:

1. The electrical mechanical shaker is the device used for dispute resolution. If a District is considering purchasing a shaker the electrical mechanical device is recommended.

2. If the Gilson model SE-6 device is to be used it must be specified in the QC plan with the following information included about its operation.

   The Gilson Hand Crank Model for Sand Equivalent testing is being used to shake the samples. The shaker will be operated by cranking at approximately 1 revolution per second for 45 seconds. The device is capable of 3 strokes per 1 revolution. The desired result will be for 131 strokes in the 45 seconds. Any disputed results will be referenced to an electrical mechanical model shaker.
MODULE 3

Uncompacted Void
Content of Fine Aggregate
AASHTO T 304

1-2-07
1-10-07
1-11-07
1-23-07
1-26-07
11-9-07
2-26-10
11-9-10
1-17-11
12-18-13
12-29-14
1-13-16
12-28-16
1-17-18
1-30-19
12-19-19
Scope

- Test determines the *loose uncompacted void content* of a sample of fine aggregate
- When performed on an aggregate sample of a known standard grading (Method A), this measurement provides an indication of *particle shape*

SCOPE

- The materials angularity, roundness or surface texture relative to other materials of the same standard grading is indicated by the percent of voids determined by this test
- The Superpave Asphalt Mix Design Method sets minimum requirements for void content that vary depending on traffic loads.
MoDOT MIXTURE TYPES

<table>
<thead>
<tr>
<th>Design Levels</th>
<th>Design Traffic (ESALS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>&lt; 300,000</td>
</tr>
<tr>
<td>E</td>
<td>300,000 to &lt; 3,000,000</td>
</tr>
<tr>
<td>C</td>
<td>3,000,000 to &lt; 30,000,000</td>
</tr>
<tr>
<td>B</td>
<td>≥ 30,000,000</td>
</tr>
</tbody>
</table>

CONSENSUS REQUIREMENTS on blended aggregate (5:1)

<table>
<thead>
<tr>
<th>Design Level</th>
<th>CAA</th>
<th>FAA</th>
<th>SE</th>
<th>F&amp;E*</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>55/none</td>
<td>---</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>E</td>
<td>75/none</td>
<td>40</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>95/90</td>
<td>45</td>
<td>45</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>100/100</td>
<td>45</td>
<td>50</td>
<td>10</td>
</tr>
</tbody>
</table>

* SMA: ≤ 20% @ 3:1 and ≤ 5% @ 5:1

CONSENSUS REQUIREMENTS

- CAA, FAA, and SE are minimums; F&E are maximums
REASON FOR THE SPECIFICATION

- The purpose is to maximize shear strength in either bound or un-bound aggregate mixtures
- Increased shear strength helps resist rutting

MORE ANGULAR FINE AGGREGATE

- Better interlocking (thus, greater stability)
- Higher VMA
But...
- Higher cost
- Less compactibility

TO INCREASE VMA:
Use a More Angular Sand

- More angular aggregate will provide more voids for a given gradation
- Replace some natural sand with manufactured sand
Summary of Test Method

- Using Method A, a **standard gradation** is built
- The sample is allowed to free-fall from a funnel into a cylinder of a known volume
- Using the bulk dry specific gravity of the sample (AASHTO T 84), the percent of void space in the cylinder is calculated
- This value is known as the Fine Aggregate Angularity Value or FAA

Typical Test Results

- Using Method A:
  
  Natural Sands – 35 to 43 percent
  Crushed Products – 43 to 50 percent

BLENDED AGGREGATES

- Possible for a low angularity material to be blended with a greater angularity material and meet the specification
- The materials must be tested after blending
- A calculated weighted average of separate materials may not give the same results as an actual test of the blend
INDIVIDUAL FRACTIONS

- Individual fractions may be tested for FAA as a check on process control, but acceptance is based on tests of the blended aggregates.

Equipment

- Cylinder measuring approximately 39mm (1.56 inches) in diameter, 86mm (3.44 inches) deep with a capacity of approximately 100 ml. Calibrated when new and annually.
- Funnel and funnel stand conforming to Figure 2, AASHTO T 304
- Glass plate for calibrating cylindrical measure.

Equipment

- Pan large enough to contain funnel stand and catch overflow of material
- Metal spatula with a *straight-edge* on the tip and side approximately 100mm (4 inches) long and 20 mm (0.8 inches) wide
- Balance accurate to 0.1 gram
- Pans for batching and weighing
FINE AGGREGATE ANGULARITY (FAA)
[Fine Aggregate Particle Shape (FAPS)]

Consensus Test Material Must Be Sampled from the Cold Feed Belt

- Cold bins
- Drum RAP feed
- Silos
- Combined cold feed belt
- Baghouse
**Consensus Test Material Must Be Sampled from the Cold Feed Belt**

- **50 Kg (110 lb)**
- **25 Kg (55 lb)**

Per AASHTO T 2 based on ½” NMS

- **Reduce Sample Size per T 248**

**25 Kg (55 lbs) Cold Feed Sample**

- **12.5 Kg**
  - **6.25 Kg**
  - **3.12 Kg**
  - **Gradation ≥ 2Kg (T27)**
  - **Flat&Elongated (F&E)**
  - **FAA (possibly)**

- **12.5 Kg**
  - **6.25 Kg**
  - **3.12 Kg**
  - **Deleterious ≥ 3Kg (TM-71)**
  - **% Fractured Particles (or CAA)** & **Uncompacted Voids (or FAA)**

- **6.25 Kg**
  - **3.12 Kg**

**Sand Equivalent (SE)** (or Clay Content)

**Split Over #4 Sieve**

- **Plus #4: Coarse Aggregate (CA):**
  - CAA
  - F&E

- **Minus #4: Fine Aggregate (FA):**
  - FAA
  - SE
**Test Procedure**

- **Wash representative sample** (T 11)
  - Size of sample depends on gradation
  - Generally 500 – 700 g
- Dry the washed sample at 230 ± 9°F (110 ± 5° C) to a constant weight
- Sieve material (AASHTO T 27) and keep fractions separate.

---

**Test Procedure**

- Remove the following size fractions and retain in separate labeled container:
  - Passing No. 8 – Retained on No. 16
  - Passing No. 16 – Retained on No. 30
  - Passing No. 30 – Retained on No. 50
  - Passing No. 50 – Retained on No. 100
Test Procedure

- Weigh individual size fractions and combine them as follows (record to the nearest 0.1 g):

<table>
<thead>
<tr>
<th>Size Fraction</th>
<th>Mass, Grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.8 – No.16</td>
<td>44.0 ± 0.2</td>
</tr>
<tr>
<td>No.16 – No.30</td>
<td>57.0 ± 0.2</td>
</tr>
<tr>
<td>No.30 – No.50</td>
<td>72.0 ± 0.2</td>
</tr>
<tr>
<td>No.50 – No.100</td>
<td>17.0 ± 0.2</td>
</tr>
</tbody>
</table>

METHOD A

- When combined, the fractions form a *standard gradation*

Test Procedure

- Mix combined material with spatula until homogeneous.
- Place a pan on towel and put the apparatus in the pan.
- Place finger under opening of funnel to seal opening.
- Pour sample into funnel and level with spatula.
Test Procedure

- Quickly remove finger from funnel and allow sample to free-fall into the calibrated cylinder.
- Take care not to vibrate or disturb the material in the cylinder to avoid further consolidation.

Test Procedure

- Strike off excess material in a single pass with the edge of spatula held in a vertical position.
- At this point additional compaction will not affect test results.
- Lightly tap cylinder using spatula to consolidate and aid in handling.

Test Procedure

- After strike off, remove excess sand from the outside of the cylinder mold using a small brush.
- Weigh the cylinder with sample and record to the nearest 0.1 gram.
- Retain and recombine all material for a second trial.
Test Procedure

- Calculate uncompacted voids as follows:

$$U = \left( \frac{V - \frac{F}{G}}{V} \right) \times 100$$

Where:
- $V =$ Volume of calibrated cylinder in ml
- $F =$ Net mass of sample in cylinder (gross mass – empty cylinder)
- $G =$ Bulk Dry Specific Gravity
- $U =$ Uncompacted Voids in Percent

Bulk Specific Gravity

- Of the aggregate blend passing the #4 sieve
- If any of the specific gravities of the blended materials differs by 0.05 from the typical sp grav, the sp grav of each fraction must be determined

SPECIFIC GRAVITY
Alternate Acceptable Methods

- Run T 84 specific gravity of the T 304 built specimen (best method)
- Run T 84 on the minus #4 material off the combined cold feed
- Calculate the weighted average (by % in the mix) sp gravity from results of T 84 testing of the individual fractions in the mix that have previously been run (MoDOT runs T 85 for a material with greater than 10% minus #4, and runs the T84 on the minus #4 material—these are averaged and reported as T85 sp gravity, but the T84 result is available).
Combined $G_{sb}$

\[
G_{sb,\text{blend}} = \frac{P_1 + P_2 + P_3}{\frac{P_1}{G_{sb1}} + \frac{P_2}{G_{sb2}} + \frac{P_3}{G_{sb3}}}
\]

- $P$ = % of each aggregate
- $G_{sb} = T84$ (minus #4) bulk specific gravity of each aggregate

UNFAVORABLE COMPARISON

- Of the four consensus tests, FAA is the most prone to “unfavorable comparison” because of inconsistent specific gravity (eg. Just using $G_{sb}$ from JMF)
- Other problem: non-washed specimen
**Test Procedure**

- Repeat test using recombined sample.
- Calculate and report average of two trials.
- Experience has shown that variability in results decreases with operator experience and an increase in the number of trials performed.

**Reporting**

- Results of each individual trial and the final average is reported to the nearest tenth, 0.1%.
- For comparison to MoDOT specifications, the final value of the averaged trials is rounded to the nearest whole number, 1%.

**EXAMPLE**

**UNCOMPACTED VOID CONTENT OF FINE AGGREGATE**

<table>
<thead>
<tr>
<th>Type of Material</th>
<th>Manufactured Sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Dry Specific Gravity ($G_d$)</td>
<td>2.487</td>
</tr>
</tbody>
</table>

**STANDARD OXIDATION**

All weights reported to nearest 0.1 gram.

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Weight Retained (g)</th>
<th>Actual Weight Retained (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#10</td>
<td>64</td>
<td>44.2</td>
</tr>
<tr>
<td>#50</td>
<td>72</td>
<td>57.1</td>
</tr>
<tr>
<td>#100</td>
<td>17</td>
<td>17.2</td>
</tr>
</tbody>
</table>

**Tolerance**: $\pm$ 0.2 grams on each fraction.
EXAMPLE

<table>
<thead>
<tr>
<th>UNCOMPACTED VOIDS CALCULATIONS</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of sand + measure (g)</td>
<td>318.0</td>
<td>316.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight of measure (g)</td>
<td>183.2</td>
<td>183.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight of sand (g) [F]</td>
<td>134.8</td>
<td>133.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume of measure (cm³) [V]</td>
<td>99.8</td>
<td>99.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncompacted voids (%) [U]</td>
<td>45.9</td>
<td>46.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Uncompacted voids (%)</td>
<td>46.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ \frac{F - G}{G} \times 100 = \frac{156.4 - 2.643}{2.643} \times 100 = 45.9 \]

\[ \frac{45.9 - 46.2}{2} = 45.2 \]

Report: 4.62  Compare to spec: 46

More Sample Problems

Natural Sand | Manufactured Sand
---|---
F = 156.4 grams | F = 143.2 grams
G = 2.643 | G = 2.735

Volume of cylinder is 99.9 ml

Calculate Uncompacted Void Content

Answer to Natural Sand

\[ U = \frac{99.9 - (156.4/2.643)}{99.9} \times 100 = 40.7 \]
Answer to Manufactured Sand

\[ U = \frac{99.9 - (143.2/2.735)}{99.9} \times 100 = 47.5 \]

CONSENSUS REQUIREMENTS on blended aggregate (5:1)

<table>
<thead>
<tr>
<th>Design Level</th>
<th>CAA</th>
<th>FAA</th>
<th>SE</th>
<th>F&amp;E*</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>55/none</td>
<td>---</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>E</td>
<td>75/none</td>
<td>40</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>95/90</td>
<td>45</td>
<td>45</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>100/100</td>
<td>45</td>
<td>50</td>
<td>10</td>
</tr>
</tbody>
</table>

* SMA: ≤ 20% @ 3:1 and ≤ 5% @ 5:1

Common Testing Errors

- Improper calibration or damage to test cylinder resulting in a change of volume
- Vibration in test area causing over-compaction of sample in test cylinder
- Erroneous specific gravity used in calculation
  - A difference of 0.05 specific gravity can cause an error of 1.0% FAA
VOLUME MEASURE CALIBRATION

1. Apply grease to top edge of measure

2. Weigh measure + glass plate + grease
VOLUME MEASURE CALIBRATION

3. Fill with freshly boiled & cooled (18-24 C) deionized water

VOLUME MEASURE CALIBRATION

4. Record water temperature

VOLUME MEASURE CALIBRATION

5. Place plate on measure (avoid air bubbles)
VOLUME MEASURE CALIBRATION

6. Dry surface of measure

VOLUME MEASURE CALIBRATION

7. Weigh measure + plate + grease + water

VOLUME MEASURE CALIBRATION

8. Calculate the net mass of the water (M)
9. Look up density of water at test temperature (D)
10. Calculate (nearest 0.1 ml):

\[ V = \frac{1000 M}{D} \]
# DENSITY OF WATER

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Density (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.3</td>
<td>998.54</td>
</tr>
<tr>
<td>21.1</td>
<td>997.97</td>
</tr>
<tr>
<td>23.0</td>
<td>997.54</td>
</tr>
<tr>
<td>23.9</td>
<td>997.32</td>
</tr>
</tbody>
</table>
UNCOMPACTED VOID CONTENT OF FINE AGGREGATE

AASHTO T 304

Developed by
Multi-Regional Aggregates Training & Certification Group
Revised 2006
NOTE

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package.

- AASHTO T84, Specific Gravity of Fine Aggregates
- AASHTO T11, Materials Finer than 75μm (No. 200) Sieve by Washing.
- AASHTO T27, Sieve Analysis of Coarse and Fine Aggregate
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  Common Testing Errors ......................................................................................... AGG-T304-2
Apparatus .................................................................................................................. AGG-T304-2
Procedure .................................................................................................................. AGG-T304-3

GLOSSARY .................................................................................................................. AGG-T304-6
AASHTO T304, Uncompacted Void Content of Fine Aggregate

Scope

This method determines the loose uncompacted void content of a sample of fine aggregate. When performed on an aggregate sample of a known, standard grading (Method A), this measurement provides an indication of particle shape. The materials’ angularity, roundness or surface texture relative to other materials of the same standard grading is indicated by the percent of voids determined by this test. The Gyratory Superpave asphalt mix design method sets minimum requirements for void content that vary depending on traffic loads and depth from the surface of the asphaltic concrete pavement. In this method, the prepared sample is allowed to free-fall through a standard funnel of a specified diameter, from a specified height into a small cylinder of known volume (nominal 100 ml).

The material is then leveled with the top of the calibrated cylinder and weighed. Because the volume and weight of the cylinder are known, the weight of the sample contained in the cylinder can be calculated. Using the Bulk Dry Specific Gravity (As determined by AASHTO T84), the volume of the material in the cylinder is calculated. By subtracting the calculated volume of material from the calibrated volume of the testing cylinder, the volume of voids can be calculated.

When performed on an “as received” sample (Method C), this method can serve as an indicator of the effect the fine aggregate can have on the workability of Portland Cement concrete.

NOTE:
This manual covers Test method A only.
Summary of Test Method

A sample of sand is prepared in accordance with one of three methods. Method A, a standard gradation, is the most common used. The sample is allowed to free-fall from a funnel into a cylinder of known volume. Using the bulk dry specific gravity of the sample as determined by AASHTO T84, the percent of void space in the cylinder is calculated. This value is known as the Fine Aggregate Angularity Value or FAA.

Typical Test Results

Using Method A, values typically range between 35 to 43 for natural sands and from 43 to 50 for crushed products. Values are obtained from more than one test of the same sample.

Common Testing Errors

- Improper calibration of test cylinder or damage to test cylinder resulting in a change in volume.
- Vibration in test area resulting in over-compaction of sample in test cylinder.
- Erroneous specific gravity used in calculation. A difference of 0.05 specific gravity can cause an error of 1.0-% FAA value.

Apparatus

- Cylindrical measure approximately 39 mm (1.56 in.) in diameter, 86 mm (3.44 in.) deep with a capacity of approximately 100-mL.
- Funnel conforming to figure 2 in AASHTO T304.
- Funnel Stand conforming to figure 2 in AASHTO T304.
- Glass Plate for calibrating cylindrical measure.
- Pan large enough to contain funnel stand and to catch overflow material.
- Metal spatula with a straight edge approximately 100 mm (4.0 in.) long and 20 mm (0.8 in.) wide.
- Balance accurate and readable to 0.1 grams.

Calibration of Cylindrical Measure

1. Apply a light coat of grease to the top edge of the dry, empty cylindrical measure.
2. Weigh the greased measure and glass plate.
3. Fill the measure with freshly boiled, deionized water at a temperature of 18° to 24° C (64° to 75° F). Record the water temperature.
4. Place the glass plate over the measure, being sure no air bubbles remain.
5. Dry the outer surface of the measure, weigh and record to the nearest 0.1 g.

6. Empty the measure and clean off the grease. Dry the measure, weigh and record to the nearest 0.1 g.

7. Calculate the volume of the measure as follows:

\[ V = \frac{1000 \times M}{D} \]

Where:

- \( V \) = volume of cylinder, mL
- \( M \) = net mass of water, g.
- \( D \) = density of water kg/m³

<table>
<thead>
<tr>
<th>°F</th>
<th>°C</th>
<th>lb/ft³</th>
<th>kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>18.3</td>
<td>62.336</td>
<td>998.54</td>
</tr>
<tr>
<td>70</td>
<td>21.1</td>
<td>62.301</td>
<td>997.97</td>
</tr>
<tr>
<td>(73.4)</td>
<td>(23.0)</td>
<td>(62.274)</td>
<td>(997.54)</td>
</tr>
<tr>
<td>75</td>
<td>23.9</td>
<td>62.261</td>
<td>997.32</td>
</tr>
</tbody>
</table>

**Density of Water (ASTM C 29/C 29M)**

**Procedure** – Only Method A will be covered in this procedure, for other methods consult AASHTO T304

1. Weigh and combine the following quantities of fine aggregate, which has been washed, dried and sieved in accordance with AASHTO T11 and T27.

<table>
<thead>
<tr>
<th>Individual Size Fraction</th>
<th>Mass, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passing No. 8 – Retained on No. 16</td>
<td>44</td>
</tr>
<tr>
<td>Passing No. 16 – Retained on No. 30</td>
<td>57</td>
</tr>
<tr>
<td>Passing No. 30 – Retained on No. 50</td>
<td>72</td>
</tr>
<tr>
<td>Passing No. 50 – Retained on No. 100</td>
<td>17</td>
</tr>
<tr>
<td>Total</td>
<td>190</td>
</tr>
</tbody>
</table>

**NOTE:**
The tolerance on each amount is ± 0.2 g.
2. Mix combined sample thoroughly with spatula.

3. Position the jar and funnel section in the stand and center the cylindrical measure.

4. Place finger under opening in funnel to seal opening. Pour mixed sample into funnel and level the material with the spatula.

5. Quickly remove finger from funnel and allow sample to free-fall into the calibrated cylinder.

6. Take care not to vibrate or unnecessarily disturb the material in the cylinder to avoid further consolidation. Strike off the excess material above the lip of the cylinder with the spatula edge, held in a vertical position, using one continuous motion.

7. After striking off, remove any excess sand from the outside of the cylinder using a small brush. At this point, additional compaction of the material in the cylinder will not affect the test results and will aid in handling.

8. Weigh the cylinder with the sample and record to the nearest 0.1 grams. Retain and recombine all materials for the next trial.
Calculate uncompacted voids content as follows:

\[ U = \frac{V - (F \div G)}{V} \times 100 \]

Where:
- \( V \) = Volume of calibrated cylinder in mL (cubic centimeters)
- \( F \) = Net Mass of Sample in Cylinder (Gross mass minus mass of empty cylinder)
- \( G \) = Bulk dry specific gravity as determined by AASHTO T84
- \( U \) = Uncompacted Voids in Percent (reported to nearest 0.1%)

9. Repeat test using recombined sample. Calculate and report average of at least two trials.
GLOSSARY

**Voids**- Difference between the total volume and the volume occupied only by the aggregate particles. The amount of void space (or air space) is a function of the aggregate gradation, particle shape and texture, and the amount of compaction of the material.

**Uncompacted Voids**- The amount of void space present when the material is in an uncompacted, unconsolidated state.

**Bulk Dry Specific Gravity**- The ratio of the mass in air of a unit volume of aggregate at a stated temperature to the mass in air of an equal volume of gas-free distilled water at the stated temperature.

**Angularity**- A description of the degree of roughness, surface irregularities or sharp angles of the aggregate particles (i.e. particle shape).
MODULE 4

Percent of Fractured Particles in Coarse Aggregates
Fractured Face Count (FFC)
Coarse Aggregate Angularity (CAA)

ASTM D 5821
1-2-07
1-23-07
1-26-07
11-9-07
1-17-11
4-27-12
12-18-13
12-29-14
12-9-15
1-17-18
1-30-19
12-19-19
MODULE 4
Percent of Fractured Particles in Coarse Aggregates
Fractured Face Count (FFC)
Coarse Aggregate Angularity (CAA)

ASTM D 5821

Scope
- This test procedure determines the amount (percent) of fracture faced rock particles by visual inspection.
- Specifications contain minimum requirements for percentage of crushed rock particles.
- Specifications apply to aggregate after the fractions have been combined (blended).

Introduction
- This method can be used to determine acceptability of coarse, dense graded, and open graded aggregates.
- Primarily used for bituminous aggregates.
REASON FOR THE SPECIFICATION

- The purpose is to maximize shear strength in either bound or un-bound aggregate mixtures
- Increased shear strength helps resist rutting

Terminology

- Fractured Face – An angular, rough, or broken surface of an aggregate particle created by crushing, other artificial means, or by nature.
- Natural fractures can be accepted as long as they are similar to fractures produced by a crusher.

Permanent Deformation

Rutting

Function of warm weather and traffic
Terminology

- Fractured Particle – A particle of aggregate having at least the minimum number of fractured faces specified (usually one or two).
- A broken surface constituting an area to be at least 25% of the maximum particle cross-sectional area

Test Specifications

- This test method is primarily used on gravel products.
- Crushed limestone, dolomite, steel slag, and porphyry are considered to have 100 percent multiple (2 or more) fractured faces and will not be tested, unless visual inspection indicates that undesirable particle shapes are being produced.

Test Specifications

- Refer to the Missouri Standard Specifications for Highway Construction Manual section 403 for the correct criteria.
COARSE AGGREGATE ANGULARITY (CAA)
[Fractured Face Count (FFC)]

CAA
Plus #4 Material on the Aggregate Blend

Equipment
- No.4 (4.75mm) Sieve
- Balance – accurate to 0.1 g.
- Spatula or similar tool to help sort particles
- Proper containers to put the sorted particles in for weighing purposes.
- Sample size reduction device (eg. riffle splitter)
Consensus Test Material Must Be Sampled from the Cold Feed Belt

- Baghouse
- Cold bins
- Combined cold feed belt
- Drum
- RAP feed

Consensus Test Material Must Be Sampled from the Cold Feed Belt*

- 50 Kg (110 lb)
- Reduce Sample Size per T 248

- QA
- 25 Kg (55 lb)
  - Per AASHTO T 2 based on ½" NMS
- QC
- 25 Kg (55 lb)
  - Per AASHTO T 2 based on ½" NMS

25 Kg (55 lbs) Cold Feed Sample

- 12.5 Kg
  - (Retain) 6.25Kg
  - 3.12Kg
    - Gradation ≥ 2Kg (T27)
    - Flat&Elongated (F&E)
    - FAA (possibly)
  - Deleterious ≥ 3Kg (TM-71)
- 12.5 Kg
  - (Retain) 6.25Kg
  - 3.12Kg
    - Sand Equivalent (SE)
      - (or Clay Content)
- 12.5 Kg
  - (Retain) 6.25Kg
  - 3.12Kg
    - % Fractured Particles (or CAA)
      - & Uncompacted Voids (or FAA)

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Split Over #4 Sieve

Plus #4: Coarse Aggregate (CA):
- CAA
- F&E

Minus #4: Fine Aggregate (FA):
- FAA
- SE

Consensus Tests Details

3.12Kg: Sand Equivalent (T176)

- Pulverize aggregations & remove fines from CA
- Accumulate fractions from 2/lot sieve analyses
- Gsb (T84) ~500g CoreLok ~2000g needed for FAA calcs
- Reduce to ≥500g: wash, dry
- FAA (T304)
- CAA (D5821)
- OR
- Reduce to ~150g
- Air-dry

Sample Preparation

- Dry the sample sufficiently to obtain a clean separation of fine and coarse material.
- Sieve the sample over a No.4 (4.75mm) sieve and keep what is retained on the sieve.
- Reduce the sample down using a splitter to the proper test size.
Sample Preparation

- The test sample size is based on Nominal Maximum Size.
- Nominal Maximum Size is defined as the largest sieve upon which any material is retained.
- The mass of the test sample shall be large enough so that the largest particle is not more than 1% of the sample mass, or the test sample shall be at least as large as indicated in the following table, whichever is smaller.
- Sample mass ≥ 100 x largest particle mass
- Example: 6 g rock → 600 g sample mass

Sample Preparation

<table>
<thead>
<tr>
<th>Nominal Maximum Size</th>
<th>Minimum Sample Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>⅜” (9.5mm)</td>
<td>200 g (0.5lb.)</td>
</tr>
<tr>
<td>⅛” (12.5mm)</td>
<td>500 g (1 lb.)</td>
</tr>
<tr>
<td>⅜” (19.0mm)</td>
<td>1500 g (3 lbs.)</td>
</tr>
<tr>
<td>1” (25.0mm)</td>
<td>3000 g (6.5 lbs.)</td>
</tr>
<tr>
<td>1 ½” (37.5mm)</td>
<td>7500 g (16.5 lbs.)</td>
</tr>
<tr>
<td>2” (50.0mm)</td>
<td>15,000 g (33 lbs.)</td>
</tr>
</tbody>
</table>

Option for Lessening the Amount of Material to Test:

1. Separate on the 3/8” sieve
   1. Split plus 3/8” material down to ≥ 1500 g
   2. Test the plus 3/8” material
2. Separate the minus 3/8” material on the #4 sieve
   1. Split minus (3/8”-to-#4) material down to ≥ 200 g
   2. Test the minus (3/8”-to-#4) material
3. Calculate the percent fractured face for each portion (+3/8” and 3/8”-to-#4)
4. Report using weighted average. See Appendix for example.
Test Procedure

- Wash and dry plus No.4 (4.75mm) material to a constant mass, 0.1% of the original dry sample mass.
- Spread sample on clean surface and evaluate each particle.
- The fractured face, when viewed directly, must constitute at least 25% of the maximum cross-sectional area.

Procedure - Fractured Face Count

- Separate sample into 3 piles:
  - Pile 1 - no fractured faces
  - Pile 2 - one fractured face
  - Pile 3 - two or more fractured faces
- Weigh all 3 piles
- A face must be at least 25% of the maximum particle cross-sectional outline to be a fractured face.

COARSE AGGREGATE ANGULARITY (CAA)  
(Fractured Face Count (FFC))
Judgment Call
1, 2, or 3?

Judgment Call
Big Enough?

Calculations
"Single"-face % FFC (at least one face)
(Sum of all particles with fractured faces):

\[ P = \left[ \frac{F_1 + F_2}{F_1 + F_2 + N} \right] \times 100 \]

P = Percentage of particles with the specified number of fractured faces.
F_1 = Mass or count of fractured particles with one fractured face
F_2 = Mass or count of fractured particles with 2 or more fractured faces
N = Mass or count of particles not meeting the fractured particle criteria.
Calculations

Multiple-face % FFC:
(Particles with 2 or more fractured faces): 

\[ P = \frac{F_2}{F_1 + F_2 + N} \times 100 \]

P = Percentage of particles with the specified number of fractured faces.
F_1 = Mass or count of fractured particles with one fractured face
F_2 = Mass or count of fractured particles with 2 or more fractured faces
N = Mass or count of particles not meeting the fractured particle criteria.

Reporting

The calculated results of the fractured faces are reported to the nearest 1%.

EXAMPLE

Data Sheet – Fractured Face Count

| Weight of particles with no Frac. Faces | N    | 93.2 |
| Weight of particles with 1 Frac. Face  | F1   | 52.2 |
| Weight of particles with 2 or more Frac. Faces | F2   | 99.1 |

Single % FFC = \[ \frac{F_1}{F_1 + F_2 + N} \times 100 \]

Multiple % FFC = \[ \frac{F_2}{F_1 + F_2 + N} \times 100 \]

Note that the single % FFC includes all the multiple faces.
EXAMPLE, cont'd.

\[ P = \frac{52.2 + 99.1}{52.2 + 99.1 + 93.2} \times 100 = 62 \]

\[ P = \frac{99.1}{52.2 + 99.1 + 93.2} \times 100 = 41 \]

MoDOT MIXTURE TYPES

<table>
<thead>
<tr>
<th>Design Levels</th>
<th>Design Traffic (ESALS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>&lt; 3,000,000</td>
</tr>
<tr>
<td>E</td>
<td>300,000 to &lt; 3,000,000</td>
</tr>
<tr>
<td>C</td>
<td>3,000,000 to &lt; 30,000,000</td>
</tr>
<tr>
<td>B</td>
<td>≥ 30,000,000</td>
</tr>
</tbody>
</table>

CONSENSUS REQUIREMENTS on blended aggregate (5:1)

<table>
<thead>
<tr>
<th>Design Level</th>
<th>CAA</th>
<th>FAA</th>
<th>SE</th>
<th>F&amp;E*</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>55/mone</td>
<td>---</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>E</td>
<td>75/mone</td>
<td>40</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>95/90</td>
<td>45</td>
<td>45</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>100/100</td>
<td>45</td>
<td>50</td>
<td>10</td>
</tr>
</tbody>
</table>

* SMA: ≤ 20% @ 3:1 and ≤ 5% @ 5:1

Minimums
SPECIFICATIONS

- 75/-- means the blend must have at least 75% one or more fractured faces, no requirement on multiple faces
- 95/90- means the blend must have at least 95% one or more fractured faces, and at least 90% multiple faces
- 100/100 means the blend must have at least 100% one or more fractured faces, 100% multiple faces
DETERMINING PERCENT OF FRACTURED PARTICLES IN COARSE AGGREGATE

ASTM D 5821

Developed by
Multi-regional Aggregate Training & Certification Group
Revised 2006
NOTE

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package.

Reference ASTM Standard Tests

- ASTM C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregate
- ASTM C 702 Practice of Reducing Field Samples of Aggregate to Test Size
- ASTM D 75 Practice of Sampling Aggregate

Reference AASHTO Tests to ASTM Standard Tests Listed Above

- AASHTO T 2 is identical to ASTM D 75
- AASHTO T 248 is identical to ASTM C 702
- AASHTO T 27 does differ slightly with ASTM C 136
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SCOPE

This test procedure determines the amount (percent) of fracture faced rock particles, by visual inspection that meets specific requirements. The fractured face of each rock particle must meet a minimum cross-sectional area (See Terminology). Specifications contain requirements for percentage of crushed rock particles, with the purpose of maximizing shear strength in either bound or unbound aggregate mixtures. This method can be used in determining the acceptability of coarse, dense-graded, and open-graded aggregates with respect to such requirements. This procedure is used primarily for aggregates used in hot-mix asphalt.

TERMINOLOGY

Fractured Face - A fractured face is defined as being caused either by mechanical means or by nature and should have sharp or slightly blunted edges. Natural fractures, to be accepted, must be similar to fractures produced by a crusher. A broken surface constituting an area equal to at least 25% of the maximum cross-sectional area of the particle.

Note: The AASHTO method specifies a criteria of 50%.

Fractured Rock Particle - A rock particle having at least one fractured face, or two fractured faces, as required for that class/type of aggregate in the specifications.

EQUIPMENT

A. Sieves - A set of sieves appropriate for the sample type.
B. Balance - appropriate for the size of sample and accurate to 0.1g.
C. Spatula or similar tool to aid in sorting the aggregate particles.
D. Splitter.
E. Pans, bowls, or paper containers.
Non-Fractured Material

Fractured Material

Fractured Material
Does Not Meet Guidelines
SAMPLE PREPARATION

Air-dry the representative sample prior to the coarse gradation process so that there is a clean separation of the particles. A total + 4.75mm (No. 4) sample could be set up for testing or if the nominal maximum size of the aggregate is 19mm (¾ in.) or larger, the + 4.75mm (No. 4) material can be split into two representative fractions. It will be necessary to determine the correct proportions between the two fractions and this may be calculated from gradation results. All the material passing the 9.5mm (⅜ in.) sieve and retained on the appropriate sieves for the selected fractions (normally the 4.75mm (#4) sieve) are weighed and the sum of the weights equal the total +4.75mm (No. 4) material. Then the material from the minus 9.5mm (⅜ in.) fraction is split down to the required minimum 200g (0.5 lb) sample size and tested. Splitting the minus 9.5mm (⅜ in) material is done to reduce the number of aggregate particles that must be inspected, when the sample contains a large amount of material passing the 9.5mm (⅜ in) sieve.

See below for *nominal maximum sieve sizes and minimum sample sizes.*

<table>
<thead>
<tr>
<th>NOMINAL MAXIMUM SIEVE SIZES</th>
<th>NOMINAL MAXIMUM SIEVE SIZES</th>
<th>MINIMUM TEST SAMPLE SIZE + #4</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>Inch</td>
<td>(grams)</td>
</tr>
<tr>
<td>9.5</td>
<td>⅜”</td>
<td>200</td>
</tr>
<tr>
<td>12.5</td>
<td>½”</td>
<td>500</td>
</tr>
<tr>
<td>19.0</td>
<td>¾”</td>
<td>1500</td>
</tr>
<tr>
<td>25.0</td>
<td>1”</td>
<td>3000</td>
</tr>
<tr>
<td>37.5</td>
<td>1½”</td>
<td>7500</td>
</tr>
</tbody>
</table>

* NOTE: Nominal maximum sieve size is defined as the largest sieve size listed in the applicable specification upon which any material is permitted to be retained.
TEST PROCEDURE

A. Wash and then dry to a constant mass (weight). Weigh the test sample to the nearest 0.1g and record as “Test Sample Weight”.

B. Spread the test sample on a clean, flat surface large enough to permit the material to be spread thinly for careful inspection and evaluation.

C. Using the spatula or a similar tool separate the particles into one of the following two categories.

   1. Fractured Particles, using the criteria of "one or more fractured faces" or "two or more fractured faces" as is consistent with the requirements in the specifications.

   2. Particles not meeting the specified criteria

D. Determine the mass (or count) of the "Fractured Particles" and "Particles not meeting the specified criteria" separately and record the weights.

COMMON TESTING ERRORS

➢ Sample not representative
CALCULATION

Case where determination is performed on 2 fractions separately, then the weighted average is calculated.

A. Calculate the percentage of fractured particles for each separate fraction as follows:

\[
P = \frac{F}{F + N} \times 100
\]

Where:
- \( F \) = Weight of crushed particles with at least the specified number of fractured faces, in grams.
- \( N \) = Weight of the particles not meeting the specified requirements, in grams.

In the example, 19.0 to 9.5 mm (3/4" to 3/8") size:

\[
F = 782 \\
N = 1068
\]

\[
P = \frac{782}{782 + 1068} \times 100 = 42.3\%
\]

In the example, 9.5 to 4.75 mm (3/8" - No. 4) size:

\[
F = 385 \\
N = 85
\]

\[
P = \frac{385}{385 + 85} \times 100 = 81.9\%
\]
B. Total Percentage of Fractured Particles Retained on the 4.75mm (No. 4) Sieve.

Determine the percentages of the 19.0 to 9.5 mm (3/4" to 3/8") and the 9.5 to 4.75 mm (3/8" to No. 4) fractions using the material retained on the 4.75 mm (No. 4) sieve as 100%.

Example:

19.0 - 9.5 mm (3/4" - 3/8") Material = 3766g
9.5 - 4.75 mm (3/8" - No. 4) Material = 7314g
Total +4.75 mm (No. 4) Material = 11080g

Percent 19.0 - 9.5 mm (3/4" - 3/8") = \( \frac{3766}{11080} \times 100 = 34\% \)
Percent 9.5 - 4.75 mm (3/8" - No. 4) = \( \frac{7314}{11080} \times 100 = 66\% \)

Total Percent Fractured Particles = 100 \( x \)

(\% Fractured Particles 19.0 - 9.5mm [3/4" to 3/8"] \( x \) (% of 19.0 - 9.5mm [3/4" to 3/8"] Material)

+ 

(\% Fractured Particles 9.5 - 4.75mm [3/8" - No. 4]) \( x \)

(% of 9.5 - 4.75mm [3/8" - No. 4] Material)

In the Example:

100 \([0.423 \times 0.34] + [0.819 \times 0.66]\) =

100 \([0.144] + [0.541]\) = 68.5% Fractured Particle