COURSE CONTENT
HMA AGGREGATE CONSENSUS TESTS

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
(RE)CERTIFICATION COURSE
2016-2017 Season

Time	Module	Location	Topic	Instructor
8:00-8:10	Intro	Lecture	Intro/welcome	Richardson
8:10-8-30	1	Lecture	Aggregate QC/QA	Richardson
8:30-8:55	2	Lecture	Sand Equivalent	Richardson
8:55-9:15	2	Lab	Sand Equivalent (start)	Lusher
9:15-9:25			Break	
9:25-9:35	2	Lab	Sand Equivalent (Finish)	Lusher
9:35-9:55	3	Lecture	Fine Aggregate Particle Shape	Richardson
9:55-10:05	3	Lab	Fine Aggregate Particle Shape	Lusher
10:05-10:20	4	Lecture	Fractured Face Count	Richardson
10:20-10:30			Break	
10:35-10:40	4	Lab	Fractured Face Count	Lusher
10:40-11:00	1-4	Lecture	Course Review	Richardson
11:00-?	1-4	Lecture	Written Exam	Richardson
Once written exam is complete, the attendee can start their 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.				
?-Until all have finished	2-4	Lab	Proficiency Exams	Staff

MODULE 1

HMA Aggregate Consensus Tests

1-2-07
1-23-07
1-26-07
3-9-07
11-9-07
11-18-09
12-29-09
2-26-10
1-17-11
12-18-13
12-29-14
12-28-16

MODULE 1

HMA Aggregate Consensus Tests

1-2-07
1-23-07
1-26-07
3-9-07
11-9-07
11-18-09
12-29-09
2-26-10
1-17-11
12-18-13
12-29-14
12-28-16

SUPERPAVE

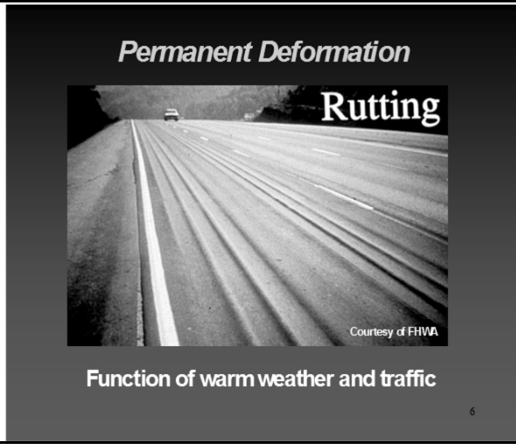
- A SHRP product (1993)
- SUperior PERforming asphalt PAVEments
- New way of specifying binders and aggregates, and a new mix design method
- Tied to pavement performance

2

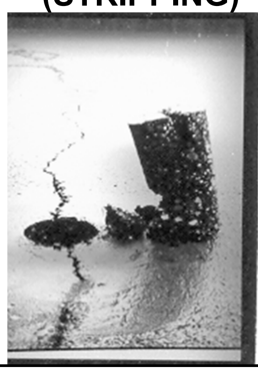
PERFORMANCE BEHAVIOR-Major

- ***Permanent distortion***-this course
  - Rutting
  - Shoving
  - Corrugations
- Fatigue cracking
- Cold temperature cracking
- ***Moisture sensitivity (stripping)*** this course

3



MOISTURE DAMAGE (STRIPPING)



QC/QA
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)

8

SUPERPAVE MIXTURE NAMES

- 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

9

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.

10

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.

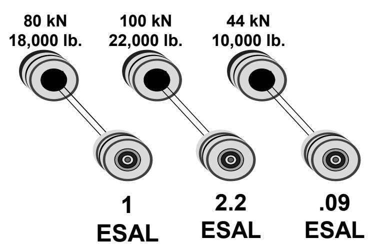
12

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

13

ESAL Comparison



14

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

15

16

AGGREGATE INSPECTION

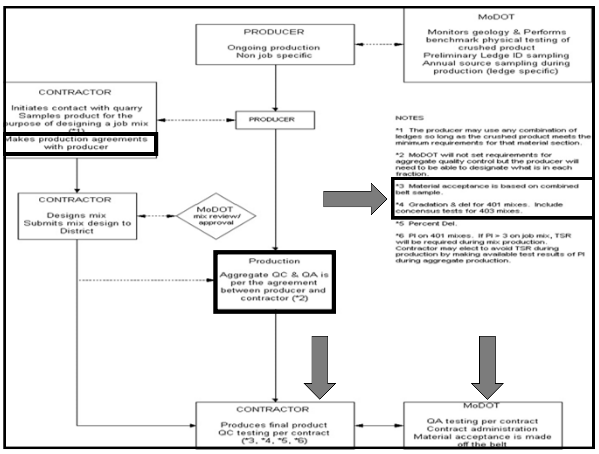
- QC and QA perform tests, compare results to each other and:
  - Standard Specifications
  - Job Special Provisions
  - Engineering Policy Guide (EPG) guidelines

2006 CHANGES

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

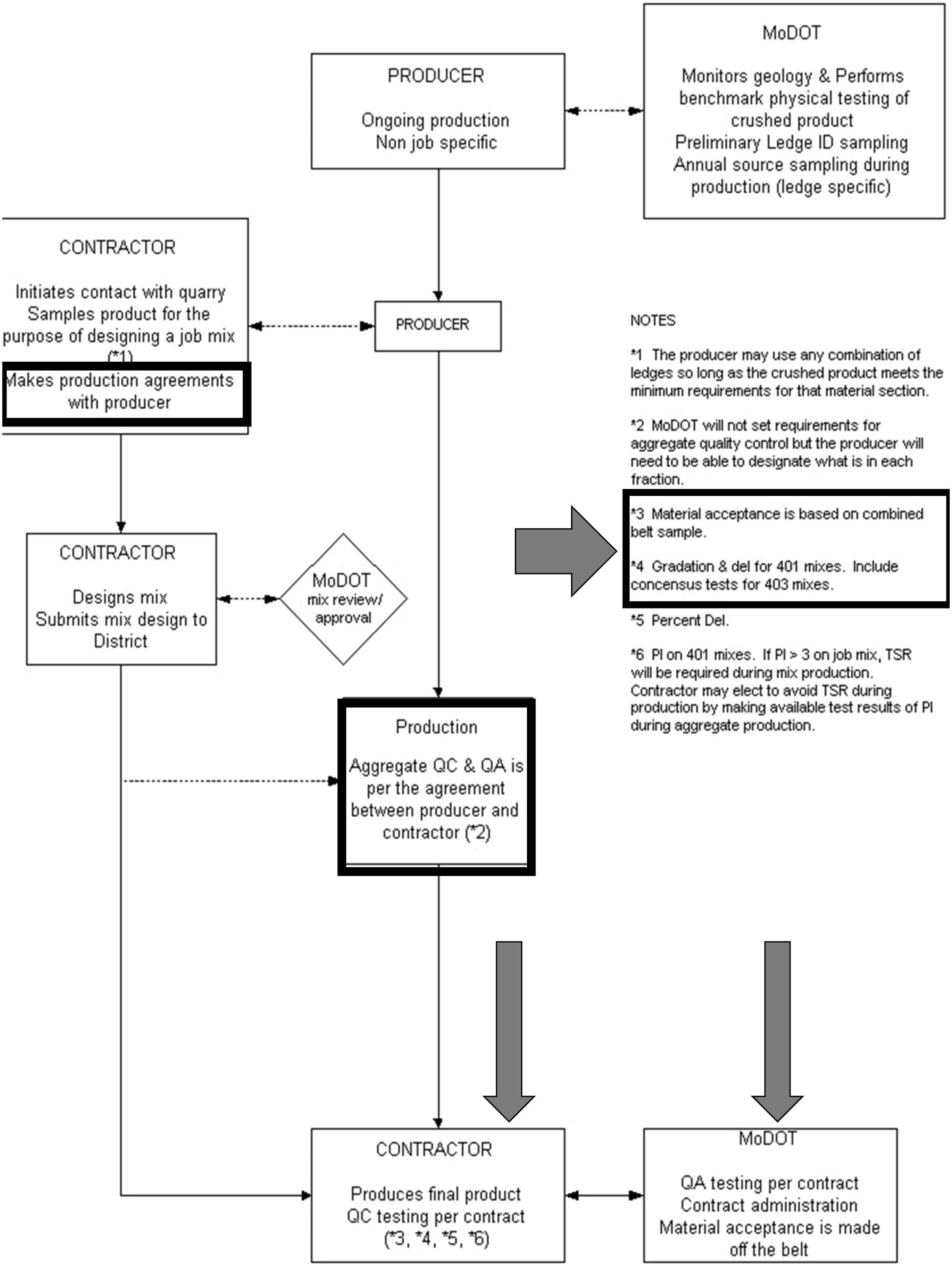
2006 CHANGES

- 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: Aggregate

- Gradation
- ***Consensus tests***: FAA, SE, F&E, and CAA
- Deleterious Materials
- RAP


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)
CONTRACTOR
Initiates contact with quarry
Samples product for the purpose of designing a job mix (*1)
Makes production agreements with producer
PRODUCER
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.
CONTRACTOR
Designs mix
Submits mix design to District
MoDOT
mix review/ approval
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

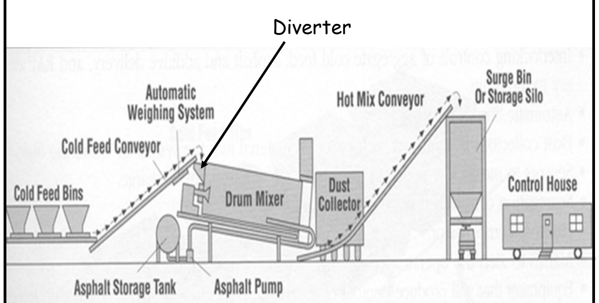
SAMPLING Drum Plant Methods

- Off the combined cold feed belt
- Diverter

Cold Feed Blended Aggregate

SAMPLING
Drum Plant
Cold Feed Belt

Drum Mix Plant



DIVERTER CHUTE

SPLITTING METHODS

- Mechanical splitter
  - Riffle splitter
  - “Quartermaster”
- Quartering of pile

Fine Aggregate Riffle Splitter

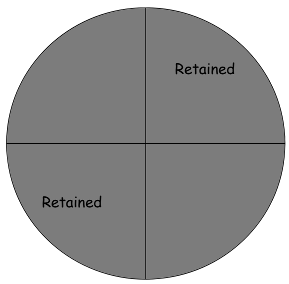
Coarse Aggregate Riffle Splitter

Coarse Aggregate Riffle Splitter

QUARTERMASTER

Splitting Down

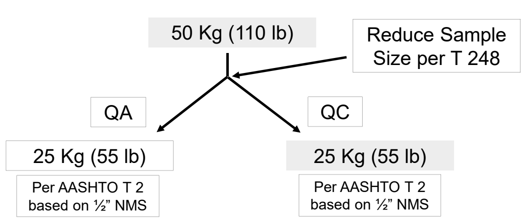
Opposing 2 quarters are removed and combined for further quartering



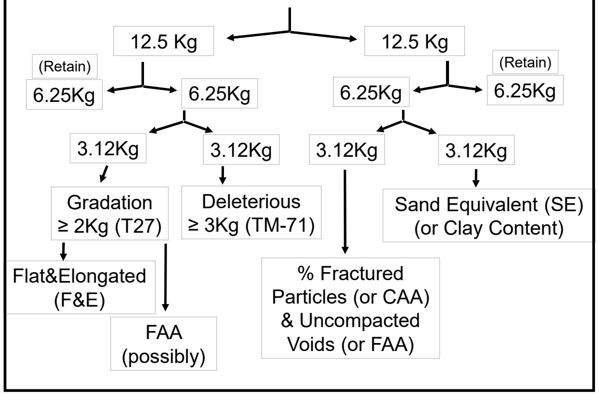
Example Consensus Tests Sampling Scenario

- 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

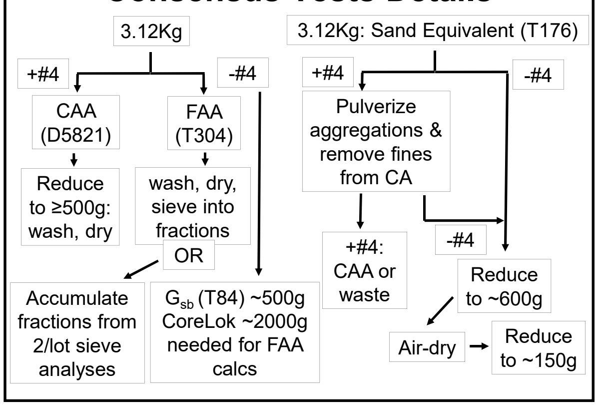
Consensus Test Material Must Be Sampled from the Cold Feed Belt*



25 Kg (55 lbs) Cold Feed Sample



Consensus Tests Details



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

Consensus tests:

- FAA_{spec} - 2%
- CAA_{spec} - 5%
- SE_{spec} - 5%
- $T\&E_{spec}$ + 2%

MoDOT MIXTURE TYPES

Design Levels	Design Traffic (ESALS)
F	< 3,000,000
E	300,000 to < 3,000,000
C	3,000,000 to < 30,000,000
B	≥ 30,000,000

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

Design Level	CAA	FAA	SE	F&E*
F	55/none	---	40	10
E	75/none	40	40	10
C	95/90	45	45	10
B	100/100	45	50	10

* 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 1
- CAA: 95 - 5= minimum of 90
  90 - 5= 85

so….90/85

Design Level	CAA	FAA	SE	F&E*
F	55/none	---	40	10
E	75/none	40	40	10
C	95/90	45	45	10
B	100/100	45	50	10

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

Aggregate

FUNCTION	LOCATION	FREQUENCY
Aggregate:		
Aggregate gradation 3 sieves: 1 size smaller than NMS_{JMF} : not to exceed 92.0% #8: not to exceed 2.0% beyond master spec #200: within master spec	Drum: Combined cold feed Batch: Hot bins Optional: T308 Residue	QC: 1 per 2 sublots QA: 1 per 4 sublots QA: QC retained: 1 per week
Consensus tests: FAA_{spec} -2% CAA_{spec} -5% SE_{spec} -5% $T\&E_{spec}$ +2%	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

QC/QA Functions at the Hot Mix Facility

Aggregate

FUNCTION	LOCATION	FREQUENCY
Aggregate:		
Aggregate gradation 3 sieves: 1 size smaller than NMS_{JMF} : not to exceed 92.0% #8: not to exceed 2.0% beyond master spec #200: within master spec	Drum: Combined cold feed Batch: Hot bins Optional: T308 Residue	QC: 1 per 2 sublots QA: 1 per 4 sublots QA: QC retained: 1 per week
Consensus tests: FAA_{spec} -2% CAA_{spec} -5% SE_{spec} -5% $T\&E_{spec}$ +2%	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

Module 2

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

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

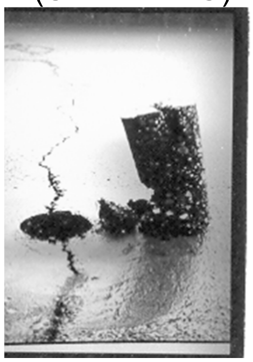
SAND EQUIVALENT

- 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

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)



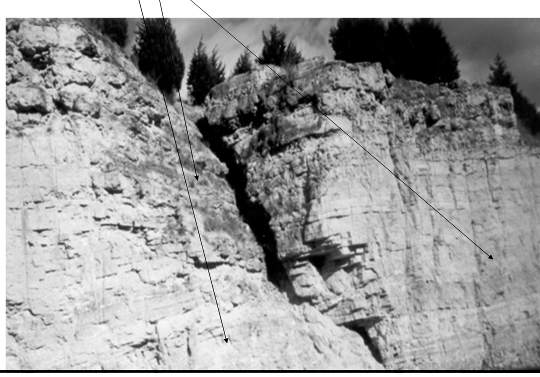
4

CONTAMINATION FROM:

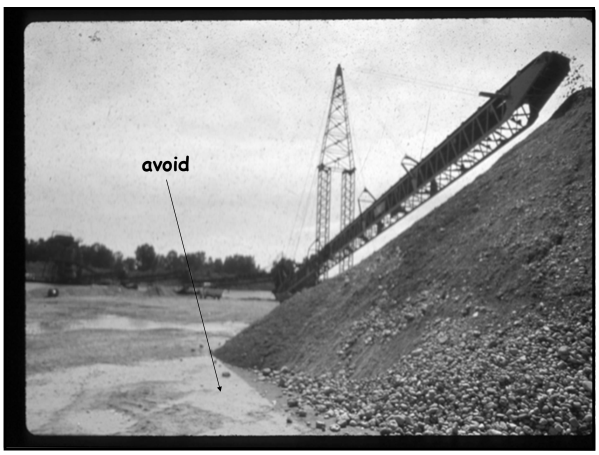
- Inclusion of non-durable material during quarrying (e.g., shale, soft rock, etc.)
- Poor stockpile management techniques (e.g., mud, dust, etc.)
- During delivery (e.g., contaminated truck beds)

AASHTO T 176 5

VARIATION IN LEDGES



STOCKPILES-note haul road close to finished stockpiles



MoDOT MIXTURE TYPES

Design Levels	Design Traffic (ESALS)
F	< 3,000,000
E	300,000 to < 3,000,000
C	3,000,000 to < 30,000,000
B	≥ 30,000,000

CONSENSUS REQUIREMENTS on blended aggregate (5:1)

Design Level	CAA	FAA	SE	F&E*
F	55/none	---	40	10
E	75/none	40	40	10
C	95/90	45	45	10
B	100/100	45	50	10

* SMA: ≤ 20% @ 3:1 and ≤ 5% @ 5:1

CONSENSUS REQUIREMENTS

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

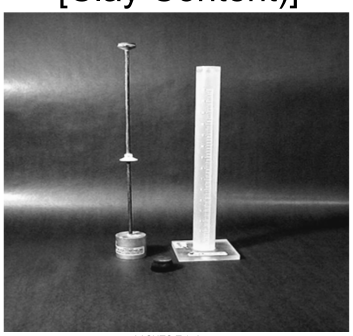
AASHTO T 176 12

SUMMARY OF METHOD

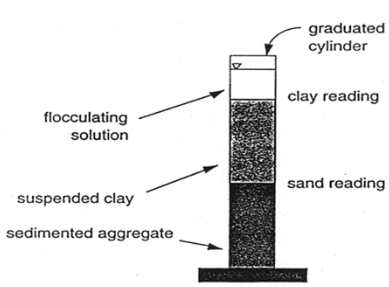
- Sample is shaken in water containing a flocculating solution
- Material is allowed to settle
- The Clay Reading and Sand Reading levels are measured
- Sand Equivalent is calculated

AASHTO T 176 13

SAND EQUIVALENT [Clay Content)]



AASHTO T 176 14



AASHTO T 176 15

Equipment

- Sieve 4.75mm (# 4)
- Sample splitter
- Straightedge or spatula
- Tinned measure (3 oz.)
- Plastic graduated cylinder
- Rubber stopper
- Wide-mouth funnel

AASHTO T 176 16

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)

AASHTO T 176 17

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

AASHTO T 176 18

For Labs Where Temperature Cannot Be Maintained at 22 ± 3 °C

- If samples meet minimum specs at low temperatures, no reference testing is required
- Otherwise, frequently submit reference samples to a lab where proper temperature control is maintained to compare
- If no difference, OK
- If significantly different, prepare conversion curves for each material tested

AASHTO T 176 19

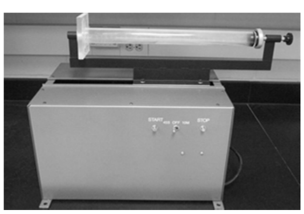
SHAKING METHODS

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

AASHTO T 176 20

MECHANICAL SHAKER

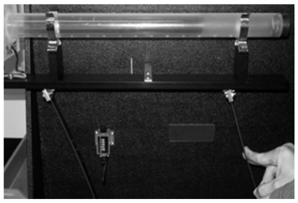
- Mechanical Shaker (powered)
  - 175 ± 2 cycles per min
  - Throw of 8.00 ± 0.04” (203.2 ± 1.0 mm)
  - Run for 45 ± 1 Seconds



AASHTO T 176 21

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



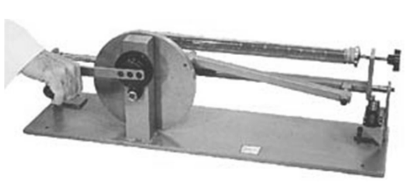
AASHTO T 176 22

HAND SHAKING

- Insert stopper and shake cylinder <u>90 cycles in 30 sec</u>
- Throw of 9 ± 1" (229 ± 25 mm)

AASHTO T 176 23

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

AASHTO T 176 24

Equipment

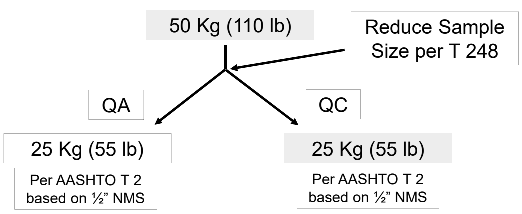
NOTE!

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.

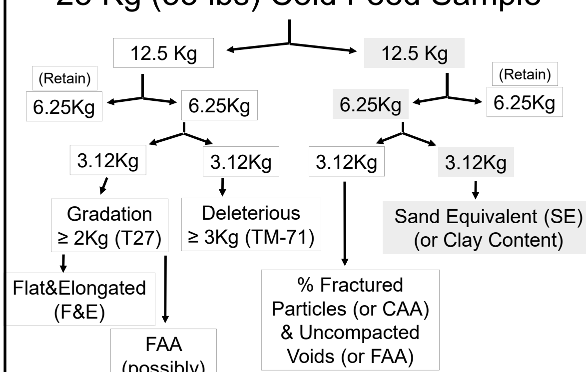
AASHTO T 176 25

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



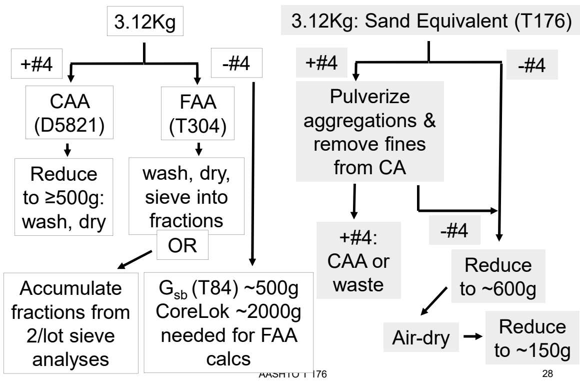
AASHTO T 176 26

25 Kg (55 lbs) Cold Feed Sample



AASHTO T 176 27

Consensus Tests Details



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.

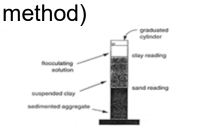
Sample Preparation

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

AASHTO T 176 31

ALTERNATE METHODS

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

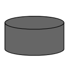


- Note: Non-oven dried SE results may be lower (oven-drying may lower the clay content, thus SE will calculate higher). Thus, if non-dried test result is lower than the minimum allowed, a new sample may need to be tested after oven drying

AASHTO T 176 32

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.

AASHTO T 176 33

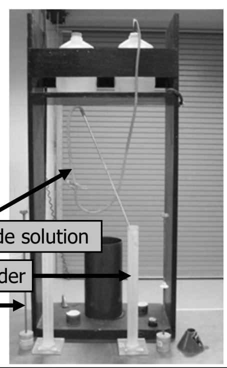
CAUTION

- 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

AASHTO T 176 34

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.)



AASHTO T 176

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.

AASHTO T 176 36

HAND SHAKING

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

AASHTO T 176 37

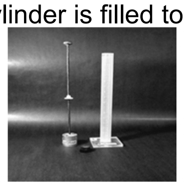
Procedure

- 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.

AASHTO T 176 38

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.



AASHTO T 176 39

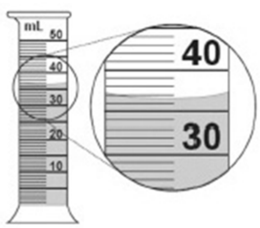
Procedure

- 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” (381mm) mark.

AASHTO T 176 40

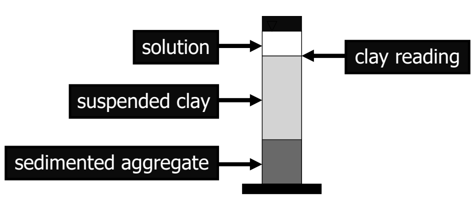
Procedure

- 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.



AASHTO T 176 41

CLAY READING



AASHTO T 176 42

Data Sheet - Sand Equivalent

Clay Reading	CR	7.0 in
Sand Reading **	SR	3.7 in
Sand Equivalent = (SR / CR) * 100		53 %

** Don’t forget to subtract 10” for the length of the indicator foot before recording the sand reading.

AASHTO T 176 43

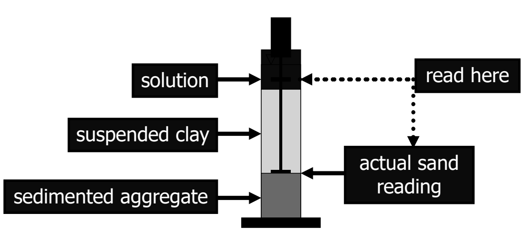
SAND READING

- 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.

AASHTO T 176 44

SAND READING

- 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**.



AASHTO T 176 45

Data Sheet - Sand Equivalent

Clay Reading	CR	7.0 in
Sand Reading **	SR	3.7 in
Sand Equivalent = (SR / CR) * 100		53 %

** 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.***

AASHTO T 176 46

Calculations

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

$$SE = \frac{Sand\ Reading}{Clay\ Reading} \times 100$$

AASHTO T 176 47

Data Sheet - Sand Equivalent

Clay Reading	CR	7.0 in
Sand Reading **	SR	3.7 in
Sand Equivalent = (SR / CR) * 100		53 %

** Don't forget to subtract 10" for the length of the indicator foot before recording the sand reading.

AASHTO T 176 48

Reporting

- When ***reporting*** the SE value, **always round up** to the ***next higher whole number***.
- Examples: 75.3 = 76
  43.8 = 44
  86.1 = 87

MoDOT MIXTURE TYPES

Design Levels	**Design Traffic (ESALS)**
F	< 3,000,000
E	300,000 to < 3,000,000
C	3,000,000 to < 30,000,000
B	≥ 30,000,000

CONSENSUS REQUIREMENTS on blended aggregate (5:1)

Design Level	CAA	FAA	SE	F&E*
F	55/none	---	40	10
E	75/none	40	40	10
C	95/90	45	45	10
B	100/100	45	50	10

* SMA: ≤ 20% @ 3:1 and ≤ 5% @ 5:1

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

AASHTO T 176 52

Common Testing Errors, cont'd.

- Organic (slimy) growth not removed from tubing and working solution container
- Improper sample preparation
- Sample not shaken properly in graduated cylinder
- Sample vibrated during sedimentation stage
- Sample not irrigated properly
- Irrigation tube holes clogged
- Hose gets soft and sticks together

AASHTO T 176 53

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

TABLE OF CONTENTS

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

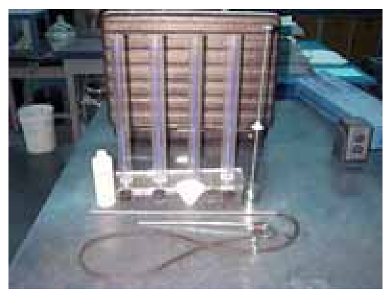


Figure 1 - Graduated Cylinder, Irrigation Tube, weighted foot Assembly and Siphon.

Mechanical Shaker

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+/-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.

40. Record the clay and sand readings.

41. 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:

$$SE = \frac{\text{Sand Reading x 100}}{\text{Clay Reading}}$$

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.

12/26/01

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

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

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

Design Levels	Design Traffic (ESALS)
F	< 3,000,000
E	300,000 to < 3,000,000
C	3,000,000 to < 30,000,000
B	≥ 30,000,000

CONSENSUS REQUIREMENTS on blended aggregate (5:1)

Design Level	CAA	FAA	SE	F&E*
F	55/none	---	40	10
E	75/none	40	40	10
C	95/90	45	45	10
B	100/100	45	50	10

* 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

AASHTO T 304 7

MORE ANGULAR SAND

- Better interlocking (thus, greater stability)
- Higher VMA

But…

- Higher cost
- Less compactibility

AASHTO T 304 8

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

AASHTO T 304 9

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.

AASHTO T 304 13

Equipment

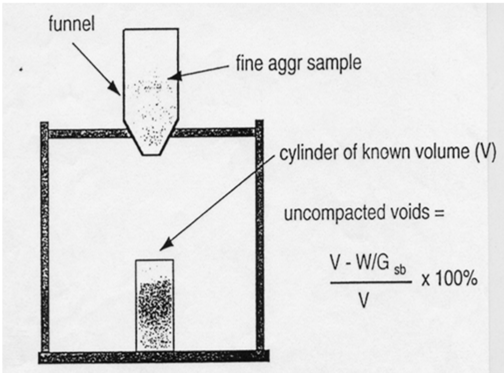
- Pan large enough to contain funnel stand and catch overflow of material
- Metal spatula with a ***straight-edge*** on the tip and side approximately 100mm (4 inches) long and 20 mm (0.8 inches) wide
- Balance accurate to 0.1 gram
- Pans for batching and weighing

AASHTO T 304 14

FINE AGGREGATE ANGULARITY (FAA)

[Fine Aggregate Particle Shape (FAPS)]

AASHTO T 304 15



AASHTO T 304 16

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

AASHTO T 304 17

25 Kg (55 lbs) Cold Feed Sample

12.5 Kg

(Retain) 6.25Kg

6.25Kg

3.12Kg

Gradation ≥ 2Kg (T27)

Flat&Elongated (F&E)

FAA (possibly)

3.12Kg

Deleterious ≥ 3Kg (TM-71)

12.5 Kg

6.25Kg

(Retain) 6.25Kg

3.12Kg

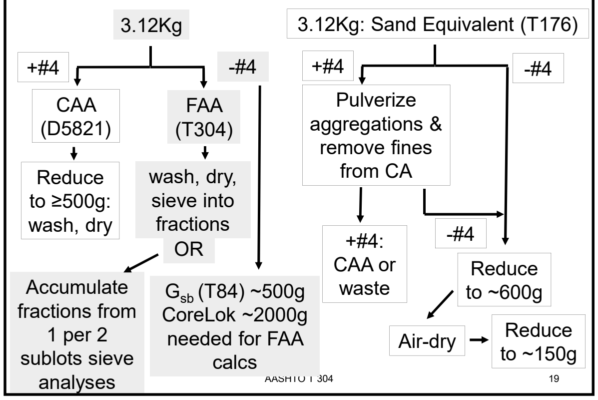
% Fractured Particles (or CAA) & Uncompacted Voids (or FAA)

3.12Kg

Sand Equivalent (SE) (or Clay Content)

AASHTO T 304 18

Consensus Tests Details



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):

Size Fraction	Mass, Grams
No.8 – No.16	44.0 ± 0.2
No.16 – No.30	57.0 ± 0.2
No.30 – No.50	72.0 ± 0.2
No.50 – No.100	17.0 ± 0.2

AASHTO T 304 22

METHOD A

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

AASHTO T 304 23

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.

AASHTO T 304 24

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.

AASHTO T 304 25

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.

AASHTO T 304 26

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.

AASHTO T 304 27

Test Procedure

- Calculate uncompacted voids as follows:

$$U = \left[\frac{V - \left(\frac{F}{G} \right)}{V} \right] x100$$

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

AASHTO T 304 28

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

AASHTO T 304 29

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).

AASHTO T 304 30

Combined G_{sb}

$$G_{sb,\,blend} = \frac{P1 + P2 + P3}{\frac{P1}{G_{sb1}} + \frac{P2}{G_{sb2}} + \frac{P3}{G_{sb3}}}$$

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

31

Combined G_{sb}

- This is not equal to:

$$G_{sb} = P_1G_1 + P_2G_2 + P_3G_3\ldots$$

AASHTO T 304 32

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

AASHTO T 304 33

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.

AASHTO T 304 34

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%.

AASHTO T 304 35

EXAMPLE

UNCOMPACTED VOID CONTENT OF FINE AGGREGATE
aka: Fine Aggregate Angularity (FAA): Fine Aggregate Particle Shape (FAPS)
AASHTO T 304: Test Method A

Type of Material	Manufactured Sand
Bulk Dry Specific Gravity [G_{sb}]	2.497

STANDARD GRADATION
All weights recorded to nearest 0.1 gram

Sieve Size	Weight Retained (g)		Actual Weight Retained (g)
	Individual	[redacted]	Tolerance = ± 0.2 grams on each fraction
#16	44	[redacted]	**44.2**
#30	57	[redacted]	**57.1**
#50	72	[redacted]	**72.0**
#100	17	[redacted]	**17.2**

AASHTO T 304 36

EXAMPLE

UNCOMPACTED VOIDS CALCULATIONS				
	Trial 1	Trial 2	Trial 1	Trial 2
Weight of sand + measure (g)	**318.0**	**316.4**		
Weight of measure (g)	**183.2**	**183.2**		
Weight of sand (g) [F]	**134.8**	**133.2**		
Volume of measure (cm^3) [V]	**99.8**	**99.8**		
Uncompacted Voids (%) [U]*	**45.9**	**46.5**		
Average Uncompacted Voids (%)	**46**.2			

$$U = \frac{V - \frac{F}{G_{sb}}}{V} \times 100$$

AASHTO T 304 37

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

AASHTO T 304 38

Answer to Natural Sand

$$U = \frac{99.9 - (156.4 / 2.643)}{99.9} x100 = 40.7$$

AASHTO T 304 39

Answer to Manufactured Sand

$$U = \frac{99.9-(143.2/2.735)}{99.9} x100 = 47.5$$

AASHTO T 304 40

CONSENSUS REQUIREMENTS on blended aggregate (5:1)

Design Level	CAA	FAA	SE	F&E*
F	55/none	---	40	10
E	75/none	40	40	10
C	95/90	45	45	10
B	100/100	45	50	10

* 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

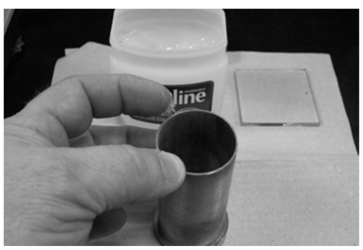
AASHTO T 304 42

VOLUME MEASURE CALIBRATION

AASHTO T 304 43

VOLUME MEASURE CALIBRATION

1. Apply grease to top edge of measure



AASHTO T 304 44

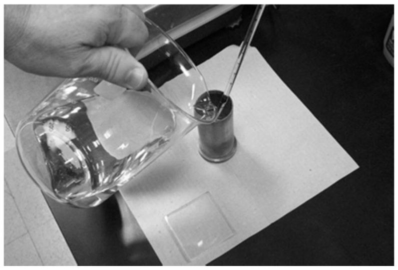
VOLUME MEASURE CALIBRATION

2. Weigh measure + glass plate + grease

AASHTO T 304 45

VOLUME MEASURE CALIBRATION

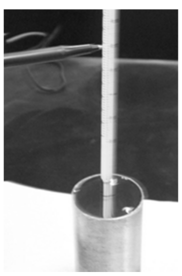
3. Fill with freshly boiled & cooled (18-24 C) deionized water



AASHTO T 304 46

VOLUME MEASURE CALIBRATION

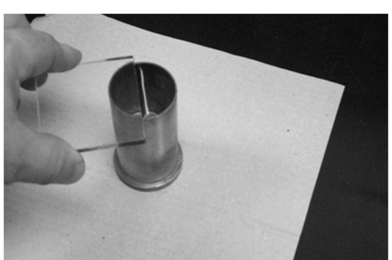
4. Record water temperature



47

VOLUME MEASURE CALIBRATION

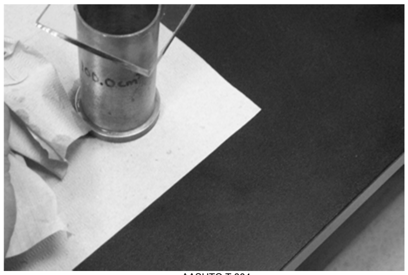
5. Place plate on measure (avoid air bubbles)



AASHTO T 304 48

VOLUME MEASURE CALIBRATION

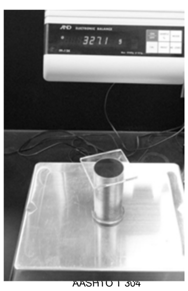
6. Dry surface of measure



AASHTO T 304 49

VOLUME MEASURE CALIBRATION

7. Weigh measure + plate + grease + ***water***



AASHTO T 304 50

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):

$$V = \frac{1000M}{D}$$

AASHTO T 304 51

DENSITY OF WATER

Temperature (°C)	Density (kg/m^3)
18.3	998.54
21.1	997.97
23.0	997.54
23.9	997.32

AASHTO T 304 52

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

Table of Contents

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:

$$V=1000 \frac{M}{D}$$

Where:

V = volume of cylinder, mL

M = net mass of water, g.

D = density of water kg/m³

Note: determine the volume to the nearest 0.1 mL.

°F	°C	lb/ft³	kg/m³
65	18.3	62.336	998.54
70	21.1	62.301	997.97
(73.4)	(23.0)	(62.274)	(997.54)
75	23.9	62.261	997.32

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.

Individual Size Fraction	**Mass, g**
Passing No. 8 – Retained on No. 16	44
Passing No. 16 – Retained on No. 30	57
Passing No. 30 – Retained on No. 50	72
Passing No. 50 – Retained on No. 100	17
Total	190

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.

Pouring sample into funnel

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.

Weighing the Cylinder

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 <u>two</u> 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

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

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

ASTM D 5821 3

Permanent Deformation

Function of warm weather and traffic

6

ASTM D 5821 4

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.

ASTM D 5821 5

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

ASTM D 5821 6

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.

ASTM D 5821 7

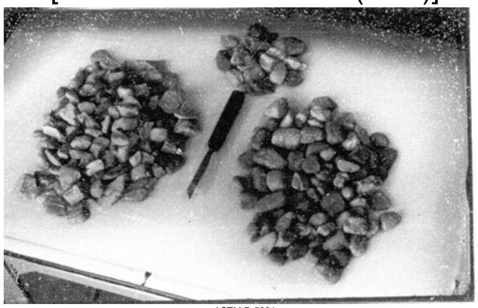
Test Specifications

- Refer to the Missouri Standard Specifications for Highway Construction Manual section 403 for the correct criteria.

ASTM D 5821 8

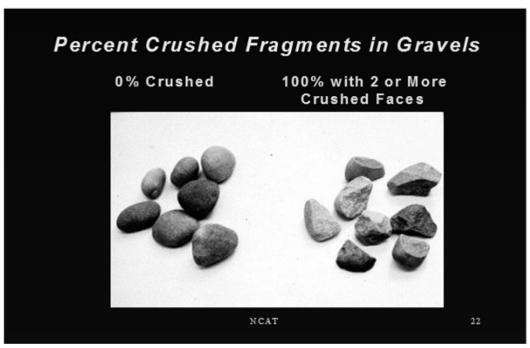
COARSE AGGREGATE ANGULARITY (CAA)

[Fractured Face Count (FFC)]



ASTM D 5821 9

CAA

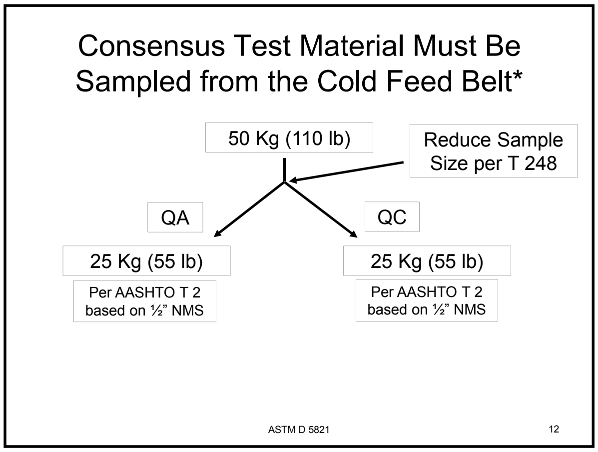


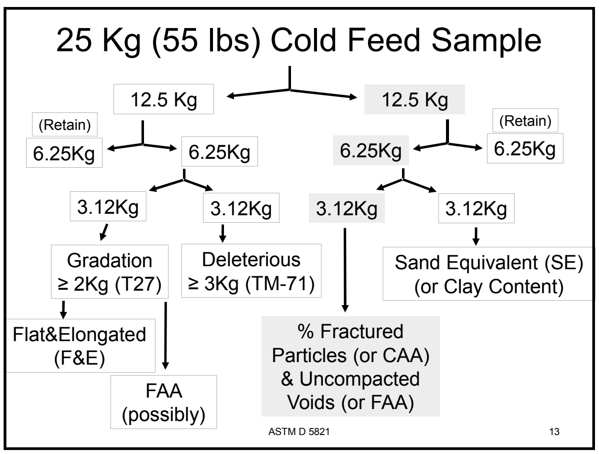
ASTM D 5821 10

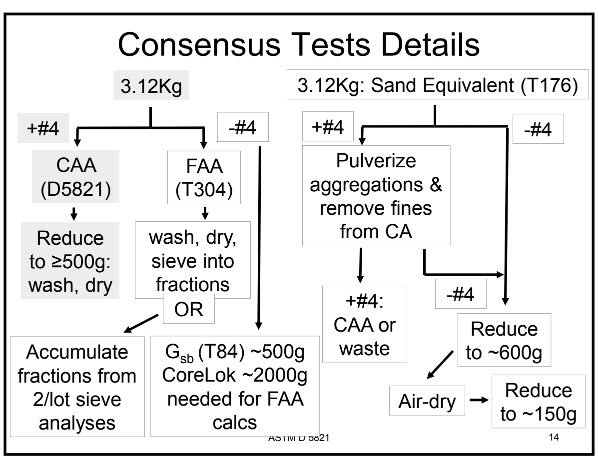
Equipment

- 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)

ASTM D 5821 11


Consensus Test Material Must Be Sampled from the Cold Feed Belt*
50 Kg (110 lb)
Reduce Sample Size per T 248
QA
QC
25 Kg (55 lb)
Per AASHTO T 2 based on ½" NMS
25 Kg (55 lb)
Per AASHTO T 2 based on ½" NMS
ASTM D 5821
12


25 Kg (55 lbs) Cold Feed Sample
12.5 Kg
12.5 Kg
(Retain)
6.25Kg
6.25Kg
6.25Kg
(Retain)
6.25Kg
3.12Kg
3.12Kg
3.12Kg
3.12Kg
Gradation ≥ 2Kg (T27)
Deleterious ≥ 3Kg (TM-71)
Sand Equivalent (SE) (or Clay Content)
Flat&Elongated (F&E)
FAA (possibly)
% Fractured Particles (or CAA) & Uncompacted Voids (or FAA)
ASTM D 5821
13


Consensus Tests Details
3.12Kg
3.12Kg: Sand Equivalent (T176)
+#4
-#4
+#4
-#4
CAA (D5821)
FAA (T304)
Pulverize aggregations & remove fines from CA
Reduce to ≥500g: wash, dry
wash, dry, sieve into fractions
OR
+#4: CAA or waste
-#4
Reduce to ~600g
Accumulate fractions from 2/lot sieve analyses
Gsb (T84) ~500g CoreLok ~2000g needed for FAA calcs
Air-dry
Reduce to ~150g
ASTM D 5821
14

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.

ASTM D 5821 15

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

ASTM D 5821 16

Sample Preparation

Nominal Maximum Size	Minimum Sample Mass
⅜” (9.5mm)	200 g (0.5lb.)
½” (12.5mm)	500 g (1 lb.)
¾” (19.0mm)	1500 g (3 lbs.)
1” (25.0mm)	3000 g (6.5 lbs.)
1 ½” (37.5mm)	7500 g (16.5 lbs.)
2” (50.0mm)	15,000 g (33 lbs.)

ASTM D 5821 17

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.

ASTM D 5821 18

Test Procedure

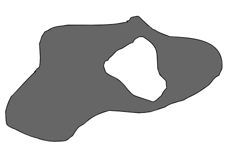
- Wash and dry plus No.4 (4.75mm) material to a constant mass, 0.1% of the original dry sample mass.
- Spread sample on clean surface and evaluate each particle.
- The fractured face, when viewed directly, must constitute at least 25% of the maximum cross sectional area.

ASTM D 5821 19

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

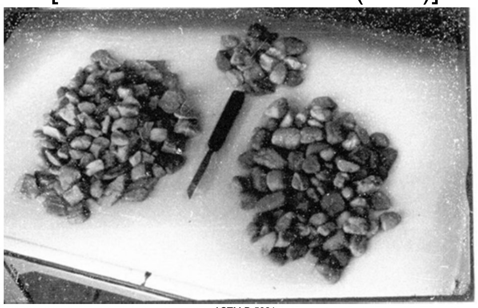
A face must be at least **25%** of the maximum particle cross-sectional outline to be a fractured face.



ASTM D 5821 20

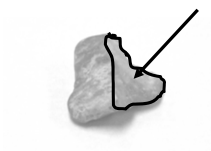
COARSE AGGREGATE ANGULARITY (CAA)

[Fractured Face Count (FFC)]



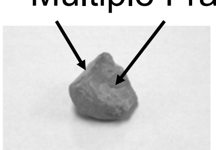
ASTM D 5821 21

Single Fractured Face



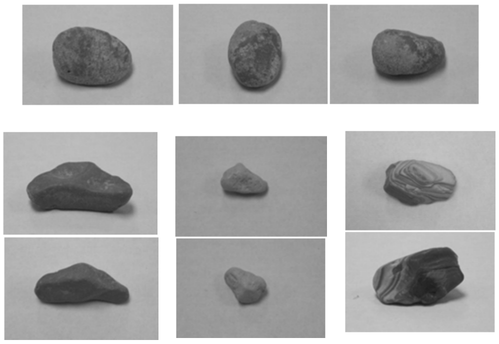
ASTM D 5821 22

Multiple Fractured Faces



ASTM D 5821 23

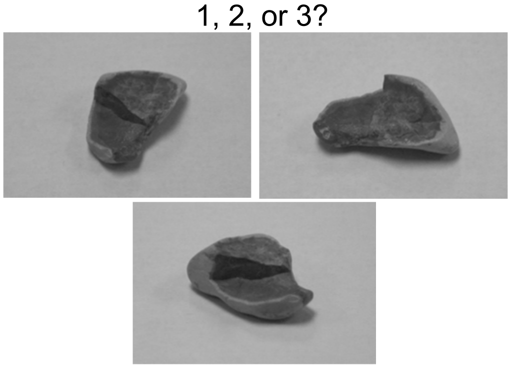
No Fractured Faces



ASTM D 5821 24

Judgment Call

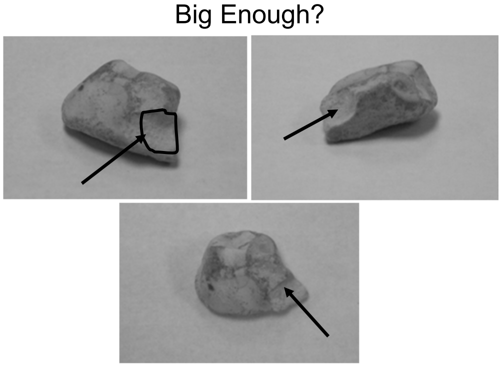
1, 2, or 3?



ASTM D 5821 25

Judgment Call

Big Enough?



ASTM D 5821 26

Calculations

"Single"-face % FFC

(Sum of ***all*** particles with fractured faces):

$$P = \left[\frac{F_1 + F_2}{F_1 + F_2 + N} \right] x100$$

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.

ASTM D 5821 27

Calculations

Multiple-face % FFC:

(Particles with ***2 or more*** fractured faces):

$$P = \left[\frac{F_2}{F_1 + F_2 + N} \right] x100$$

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.

ASTM D 5821 28

Reporting

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

ASTM D 5821 29

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 = $P=\left[\frac{F_1+F_2}{F_1+F_2+N}\right]x100$		62
Multiple % FFC = $P=\left[\frac{F_2}{F_1+F_2+N}\right]x100$		41

- Note that the single % FFC includes all the multiple faces.

ASTM D 5821 30

MoDOT MIXTURE TYPES

Design Levels	Design Traffic (ESALS)
F	< 3,000,000
E	300,000 to < 3,000,000
C	3,000,000 to < 30,000,000
B	≥ 30,000,000

CONSENSUS REQUIREMENTS on blended aggregate (5:1)

Design Level	CAA	FAA	SE	F&E*
F	55/none	---	40	10
E	75/none	40	40	10
C	95/90	45	45	10
B	100/100	45	50	10

* 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

ASTM D 5821 33

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

TABLE OF CONTENTS

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.

SPLIT SAMPLE AND SINGLE SAMPLE SIZES

NOMINAL MAXIMUM SIEVE SIZES	NOMINAL MAXIMUM SIEVE SIZES	MINIMUM TEST SAMPLE SIZE + #4	
mm	Inch	(grams)	(Approx. lbs)
9.5	⅜”	200	0.5
12.5	½"	500	1
19.0	¾”	1500	3
25.0	1”	3000	6.5
37.5	1½”	7500	16 .5

**** 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:

$$\text{Percent Fractured Particles } (\mathbf{P}) = \frac{F}{F + N} \times 100$$

Where: F = Weight of crushed particles with at least the specified number of fractured faces, in grams.
= (F1 + F2) or (F2)
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

$$\mathbf{P} = \frac{782}{782 + 1068} \times 100 = 42.3\%$$

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

F = 385
N = 85

$$\mathbf{P} = \frac{385}{385 + 85} \times 100 = 81.9\%$$

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 x 0.34) + (0.819 x 0.66)] =

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