Aggregate Testing

NDDOT Tech Certification 2014

Test Procedures and Forms

- Official and current test procedures are available online.
  www.dot.nd.gov/divisions/materials/testingmanual.htm
- Forms
  http://www.dot.nd.gov/dotnet/forms/forms.aspx

Specifications

- Standard Specifications for Roads and Bridges and
  - Supplemental Specifications are available on the web at:
  - *http://www.dot.nd.gov/dotnet/supplspecs/StandardSpecs.aspx*
- Plan Notes
  - Plan notes may contain project specifications
- Special Provisions
  - Special provisions may contain project specifications
- Addenda

Specifications

Excerpt from 105.05

'Supplemental Specifications will govern over Standard Specifications;

Plans will govern over Standard Specifications and Supplemental Specifications;

and Special Provisions will govern over Standard Specifications, Supplemental Specifications, and Plans.

Contract Provisions included in the Proposal Form shall be treated as Special Provisions and shall govern over Standard Specifications, Supplemental Specifications, and Plans.

Addenda shall govern over all items.'

Test Procedures and Specifications

- Test procedures online in the Field Sampling and Testing Manual are official version
  - Class manuals are current as of print date
  - Photos are added
  - Always refer to procedures
- This presentation and any other copies are provided as tools
  - Always verify you are using current version

Reference Sources

- Field Sampling and Testing manual
  - Test procedures
  - Sampling and testing responsibilities for Engineer
  - Sampling and testing frequencies for most types of projects
- Standard Specification for Roads and Bridges
  - Supplemental Specifications
- Plans and Special Provisions
  - Plan Notes or Special Provisions will be reference source for some project specifications

Printed Test Format

Basic overview of a test or procedure

Test Format

- Example of a ND modification to a test procedure

AASHTO T 11 - MATERIALS FINER THAN NO. 200 (75 µm) SIEVE IN MINERAL AGGREGATES BY WASHING

Conduct this procedure according to AASHTO T 11, NDDOT Modified.

The standard test procedure reports the percentage of material finer than the No. 200 sieve to the nearest 0.1% except if the result is 10% or more, than report to the nearest whole number. The NDDOT modification is report the accuracy to the same significant digit as the specification for the class of aggregate.

Consult the current edition of AASHTO for procedure in its entirety and the equipment specification details.

Test Format

- Reporting Example

REPORT

Report the percent of material finer than the No. 200 sieve to the same significant digit as the specification for the class of aggregate.

Test Format

- Tests may be revised – Revision Example
  - Changes will be indicated by revision dates – and paragraph marks

12/26/2012 Revised T 2

AASHTO T 2 – SAMPLING OF AGGREGATES

- SAMPLING FROM A WINDROW:

| Sample the windrow by removing the top one foot of material and obtain part of the sample from each side. Avoid the segregated coarser material at the bottom of the side slope. Combine three samples to form a composite sample.

Calculations and Rounding

Calculations and Rounding

- Calculate to one decimal place greater than the reporting requirement
  - Calculate to tenth (90.3) - Report as 90
  - Calculate to hundredth (4.53) – Report as 4.5
- Calculated numbers are not the reporting requirements

Calculations and Rounding

- Rounding Numbers
  - The NDDOT uses the rounding procedures ASTM E-29
  - Available in the Field Sampling and Testing manual

Calculations and Rounding

- Rounding Numbers Basic Example
  - Even numbers - round down
    - 94.5 will round to 94 (rounding to whole number)
    - 6.45 will round to 6.4 (rounding to the tenth)
  - Odd numbers - round up
    - 95.5 will round to 96 (rounding to the whole number)
    - 6.55 will round to 6.6 (rounding to the tenth)

Calculations and Rounding

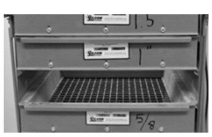
- Spreadsheets and calculators will not typically follow ASTM E-29
  - Calculations can vary slightly depending on how spreadsheets and calculators are designed
    - Generally the decimal accuracy is set too high

When test results are close to failing - manually calculate to verify calculations

Equipment Basics

Equipment Basics

- **Sieves** - device with woven mesh or wire with regularly spaced openings and of uniform size mounted in a frame. Used to separate material according to size.



Equipment Basics

- **Sieve size:** The size of the openings between cross wires of a testing sieve.
  - Measured by linear inch

Equipment Basics

- **Stack of Sieve:** Sieves placed in order of opening size. Sieves with larger openings on top, smaller openings on bottom.
- A pan is on bottom and a cover may be on the top.

Equipment Basics

- **Mechanical Shaker:** Device used to agitate sample through a series of sieves to perform sieve analysis

Equipment Basics

- Splitters – mechanical device to reduce a sample to smaller size
- Various sizes are available

Equipment Basics

- Fine Splitter will have 12 openings
- Coarse Splitter - even number, not less than 8 openings

Coarse Aggregate

Fine Aggregate

Equipment Basics

- Balances - device to measure the weight of a sample. Also may be referred to as a scale.
- Various weight capacities and accuracy
- All balances must be certified and calibrated

Equipment Basics

- Ovens – or heat source

Equipment Calibration/Verification

- Equipment verification or calibration records must be kept on file – and in each field lab
- NDDOT Qualified Laboratory Program
  - Available online on Materials and Research web page
  - *http://www.dot.nd.gov/divisions/materials/materials.htm*

Aggregate Tests

Common aggregate tests

T 2 - Sampling of Aggregates

- Why do we sample aggregate?
  - Preliminary investigation
    - Locating new sources
  - Control of Product
    - Aggregate production
  - Control of Operation
    - Required testing frequencies
  - Acceptance or rejection of material and products

T 2 - Sampling of Aggregates

- Where practical, samples to be tested for quality shall be obtained from the finished product.
- NDDOT Modification
  - Change in sample size
  - Added a procedure for sampling from a windrow.

T 2 - Sampling of Aggregates

- Go to T 2 in Chapter 2 for definitions
  - Nominal Maximum Aggregate Size
  - Maximum Aggregate Size
  - Sample Size requirements vary depending on aggregate particle size requirements

Size Of Sample To Be Obtained Fine Aggregate

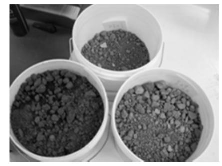
Nominal Size of Aggregate		KG (lb)
2.36 mm	(No. 8)	10 (25)
4.75 mm	(No. 4)	10 (25)

Size Of Sample To Be Obtained Coarse Aggregate

Nominal Size of Aggregate	KG	(lb)
9.5 mm (3/8 in)	4	(8)
12.5 mm (1/2 in)	8	(16)
16.0 mm (5/8 in)	15	(30)
19.0 mm (3/4 in)	20	(44)
25.0 mm (1 in)	40	(88)
37.5 mm (1-1/2 in)	60	(132)

T 2 - Sampling of Aggregates

- Samples obtained to run multiple tests must be large enough to be reduced and provide adequate sample sizes for each test
- One full pail weighs approximately 25 pounds



T 2 - Sampling of Aggregates

- Preferred sampling locations
  - Sampling from roadway
  - Sampling from a windrow
  - Sampling from a conveyor belt
  - Sampling from a flowing stream
  - Sampling from a truck
  - Sampling from a stockpile

Sampling of Aggregates

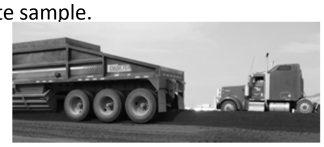
AASHTO T 2

T 2 - Sampling of Aggregates

- Sampling from the roadway
  - At least three equal increments selected at random in a unit.
  - Full depth of course.
  - Avoid contamination.
  - Not a common sampling location

T 2 - Sampling of Aggregates

- Sampling from a windrow
  - Remove the top foot of material and obtain part of the sample from each side of the windrow.
  - Combine three samples to form a composite sample.



T 2 - Sampling of Aggregates

- Sampling from a conveyor belt.
  – Insert two templates that are the shape of the belt.
  – Obtain all material from the belt
  – Obtain three samples to form the composite sample.

T 2 - Sampling of Aggregates

- Sampling from a flowing stream
  – Obtain at least three approximately equal increments.
  – Obtain sample from entire cross section.
  – Receptacle should be large enough to intercept entire stream
  – Combine to form the composite sample.

T 2 - Sampling of Aggregates

- Asphalt Plant Sampling – Belt and Flowing Stream

Hand held push button control for sampler

T 2 - Sampling of Aggregates

- Asphalt Plant Sampling – Belt and Flowing Stream

Control switch for auto sampler

Sample collection – opposite side

T 2 - Sampling of Aggregates

- Asphalt Plant Sampling – Belt and Flowing Stream

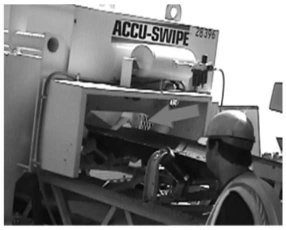
Control switch for auto sampler

T 2 - Sampling of Aggregates

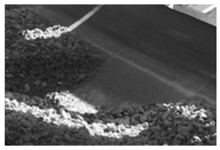
- Asphalt Plant Sampling – Belt and Flowing Stream

T 2 - Sampling of Aggregates

- Asphalt Plant Sampling – Belt and Flowing Stream



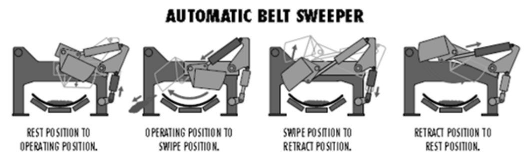
Sweep crosses belt



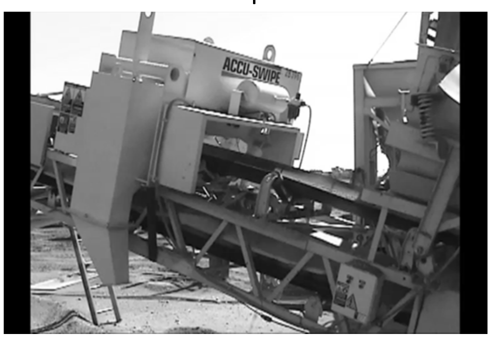
Belt – after sweep.
Example only - plant was not running

T 2 - Sampling of Aggregates

- Asphalt Plant Sampling – Belt and Flowing Stream



Accu-Swipe Video



T 2 - Sampling of Aggregates

- Sampling from a truck
  - Three trenches one foot wide by one foot deep.
  - Obtain three portions from each trench.
  - Not a commonly used method to sample aggregate

T 2 - Sampling of Aggregates

- Sampling from a stockpile
  - Insert a board vertically to prevent segregation.
  - Obtain sample from top third, middle third, and bottom third of the pile.

T 2 - Sampling of Aggregates

Sampling Constant

- Minimum of three (sub) samples
  - In some cases samples are not obtained all at one time
- Combine samples and mix thoroughly

T 2 - Sampling of Aggregates

- Review Procedure

Proper sampling and reducing are the essential first steps to ensure test results are representative of material.

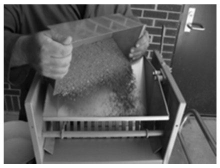
Improper sampling and reducing methods will affect all tests and is a common reason for discrepancies of test results.

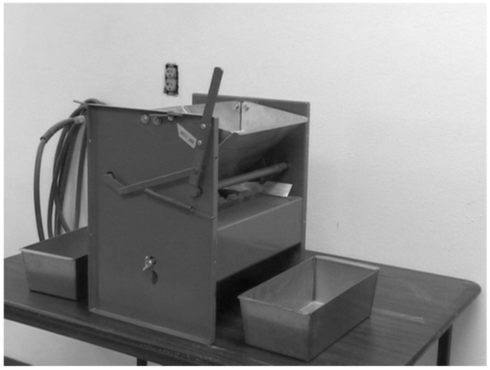
T 248 - Reducing Samples to Testing Size

- Reduction of samples of aggregate to appropriate size for testing.
- Intent is that the reduced portion used for testing will have the same material characteristics.

T 248 - Reducing Samples to Testing Size

- Two methods are acceptable. Either method may be used
  - Mechanical splitter
  - Quartering





T 248 - Reducing Samples to Testing Size

- Review Procedure

T 255 - Total Evaporable Moisture Content of Aggregate by Drying

- Determines percentage of evaporable moisture in a sample of aggregate by drying both surface moisture and moisture in the pores.

T 255 - Total Evaporable Moisture Content of Aggregate by Drying

- Heat sources allowed
  - Oven - ventilated
  - Hot plate
  - Stove
  - Microwave

Constant Weight Definition

- **Constant weight:** when drying a sample the difference in weight between checking the weight of a sample while it is drying.
- Constant weight is defined as when further drying will cause less than 0.1% additional loss in mass.

T 255 - Total Evaporable Moisture Content of Aggregate by Drying

- Oven Drying
  - May dry overnight or to constant weight
  - 20 minute increments for oven

T 255 - Total Evaporable Moisture Content of Aggregate by Drying

- Microwave drying
  - Aggregates and sample sizes can vary
  - Initial cycle may be 5 minutes
    - Adjust drying times as needed
    - Repeated drying cycles may be for approximately 2 minutes
  - Stir to ensure even drying
  - Use a heat sink

T 255 - Total Evaporable Moisture Content of Aggregate by Drying

- Stove top or Hot Plate
  - Stir to ensure even drying
  - Take care not to loose fines when stirring or from spoon
    - An indication of drying is when the material no longer sticks to the spoon

T 255 - Total Evaporable Moisture Content of Aggregate by Drying

- Review Procedure
- Review Formula and calculation

T 27 - Sieve Analysis of Fine and Coarse Aggregate

In a sieve analysis, a sample of dry aggregate of known weight is separated through a series of sieves with progressively smaller openings.

Once separated, the weight of particles retained on each sieve is recorded and the cumulative weight of the sieves compared to the total sample weight.

T 27 - Sieve Analysis of Fine and Coarse Aggregate

- The No. 4 sieve is designated as the division between the fine and coarse aggregate for asphalt and grading and base
- Gradation is the most common test performed on aggregates.

T 27 - Sieve Analysis of Fine and Coarse Aggregate

- No. 4 sieve

T 27 - Sieve Analysis of Fine and Coarse Aggregate

Fine Aggregate Shaker

Coarse Aggregate Shaker

T 27 - Sieve Analysis of Fine and Coarse Aggregate

- Sieve Overloading
- Sieve openings smaller than No.4:
  4.52 grams per square inch of area.
- Sieve openings No. 4 and larger:
  2.5 times the sieve opening times the effective sieve area.

T 27 - Sieve Analysis of Fine and Coarse Aggregate

Area of an 8” sieve = Πr^2

= 3.14 x $(7.5/2)^2$

= 44.16 sq in

Overload = Area x (4.52 grams/sq in)

<No. 4 = 44.16 x 4.52

= 199.5 grams (200)

T 27 - Sieve Analysis of Fine and Coarse Aggregate

- Coarse Aggregate

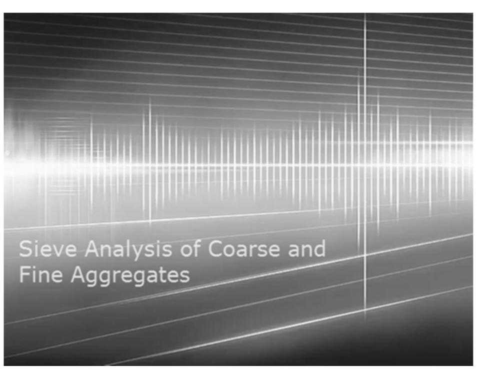
MAXIMUM ALLOWABLE QUANTITY OF MATERIAL RETAINED*

Sieve Opening Size	8" Diameter Sieve	14" Square Sieve
2" (50 mm)	7.9 lbs (3.6 kg)	33.7 lbs (15.3 kg)
1½" (37.5 mm)	6.0 lbs (2.7 kg)	25.4 lbs (11.5 kg)
1" (25.0 mm)	4.0 lbs (1.8 kg)	17.0 lbs (7.7 kg)
3/4" (19.0 mm)	3.1 lbs (1.4 kg)	12.8 lbs (5.8 kg)
1/2" (12.5 mm)	2.0 lbs (0.89 kg)	8.4 lbs (3.8 kg)
3/8" (9.5 mm)	1.5 lbs (0.67 kg)	6.4 lbs (2.9 kg)
No. 4 (4.75 mm)	0.7 lbs (0.33 kg)	3.3 lbs (1.5 kg)

*Table 1 of the AASHTO standard shows a complete table of different size sieves of the maximum allowable quantities of material retained on a sieve.

T 27 - Sieve Analysis of Fine and Coarse Aggregate

- Prevent Sieve Overloading
  - Insert additional sieves.
  - Split the sample into two or more portions.
  - Use larger size sieves.



T 27 - Sieve Analysis of Fine and Coarse Aggregate

- NDDOT Modification
  - Accuracy reported on the No. 200 sieve is to the same significant digit as specified in the specifications for the class of aggregate.

T 27 – Sieve Analysis of Fine and Coarse Aggregates

- Sieve Analysis/Gradations tests are most often ran to compare to something. It may be a specification, a class or size of material or another test value.
- You need to know what you are comparing to.

T 27 - Sieve Analysis of Fine and Coarse Aggregate

- Aggregates for asphalt paving mixtures have unique project "specifications"
  - Approved Mix Design band (Job Mix Formula)
    - Specs change based on moving average

T 27 - Sieve Analysis of Fine and Coarse Aggregate

- Grading and base, chip seals, foundation fill tests are specified by "Class"
  - Spec Book, 816.03 – aggregate and base
  - Supplemental Specifications
  - Special Provisions

T 27- Sieve Analysis of Fine and Coarse Aggregate

- Concrete aggregate gradations are specified by "Size"
  - 816.01 and 816.02
- or "Well-Graded" special provision

T 27 - Sieve Analysis of Fine and Coarse Aggregate

- Review Procedure
- Recorded on SFN 9987
  - SFN 2455 for concrete aggregate

Sieves and Brushes

Examples of which brush to use on each sieve.

No. 8, No. 10, No. 16 and No. 30

No. 40 and No. 50

No. 100

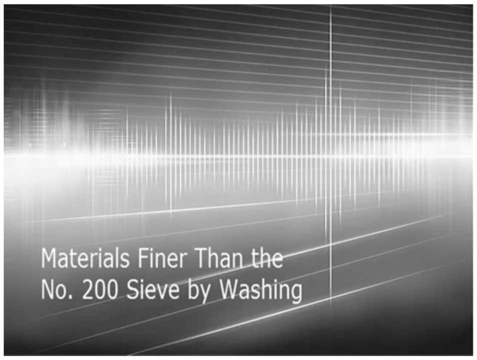
No. 200

T 11 - Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing

- When accurate determination of material finer than No. 200 in fine and coarse aggregate are desired.

T 11 - Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing

- NDDOT Modification
  - Accuracy reported on the No. 200 sieve is to the same significant digit as specified in the specifications for the class of aggregate.



T 11 - Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing

- Results are included in the calculation in for T 27

16	5/8"	0.0	0.0	0.0	100.0	99.5	100	
12.5	½"	88.2	88.2	2.2	97.8	90	100	
9.5	3/8"	333.3	421.5	10.6	89.4			
4.75	No. 4	990.6	1412.1	35.7	64.3	39	63	X
Minus No. 4		2543.3	3955.4	0.11%				
Wt. Check			3955.4					
Original Wt.		3959.6						

Sieve Size		Wt. Ret.		% Ret.	% Pass.	% Pass Tot Smpl	ND Spec.	
(mm)	No.	Non-Cum.	Cum.				Lower	Uppe
2.36	8	232.7	232.7	37.3	62.7	40.4		
2	10	35.2	267.9	42.9	57.1	36.7		
1.18	16	95.4	363.3	58.2	41.8	26.9		
600 um	30	81.1	444.4	71.2	28.8	18.5	14.6	35

T 11 - Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing

- Review Procedure
- Results are recorded on SFN 9987 or SFN 2455

T 11 and T 27 Calculations

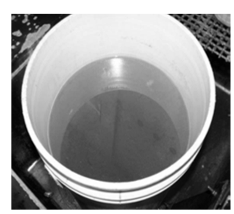
- Worksheet – SFN 9987
- Calculations for Coarse and Fine

T 113 - Lightweight Pieces in Aggregate

- Test is ran to determine the percentage of "lightweight pieces" or deleterious material in sample
- Lightweight pieces are commonly referred to as "Shale"
- Shale content of aggregates can vary greatly from one area of state to another

T 113 - Lightweight Pieces in Aggregate

- Determines the percentage of lightweight pieces in aggregates by means of sink-float separation in a heavy liquid.



T 113 - Lightweight Pieces in Aggregate

- Test is performed separately on the coarse and fine aggregate.


T 113 - Lightweight Pieces in Aggregate

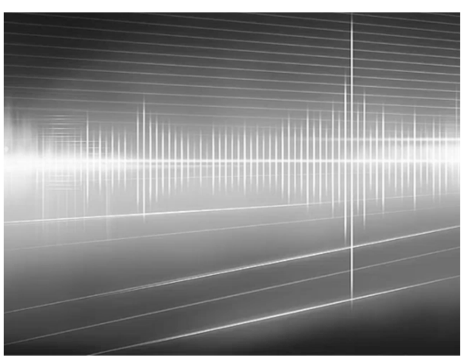
- NDDOT Modification
  - Uses material that passes the No. 4 sieve and retained on the No. 30 sieve.
  - Specific gravity of the heavy liquid is 1.95 ± 0.01.
  - Agitate the sample for 15 seconds and then rest for 30 seconds. For fine aggregate a maximum of three times.

T 113 - Lightweight Pieces in Aggregate

- Heavy Liquids
  - **Zinc chloride** for material having specific gravities less than 2.0
    - ND uses zinc chloride
  - Kerosene with 1,1,2,2 tetrabromoethane for material having specific gravities less than 2.95.
  - Zinc bromide for material having specific gravities less than 2.6.

T 113 - Lightweight Pieces in Aggregate

- This test requires use of hazardous chemicals
- Proper protective eyewear, clothing and gloves are required



T 113 - Lightweight Pieces in Aggregate

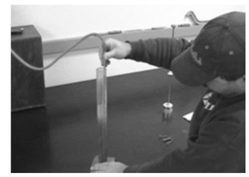
- Review Procedure
- Results are recorded on SFN 9987

Aggregate Tests

for Asphalt Mixtures

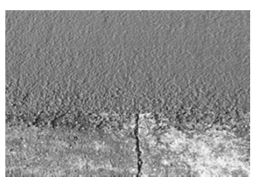
T 176 - Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

- Rapid field test to show relative proportions of clay material in soils or graded aggregate.
  - This test may be referred to as clay content or SE



T 176 - Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

- Used on asphalt paving projects
- Microsurfacing projects

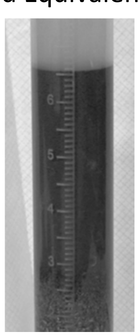


T 176 - Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

- Stock Solution
  - **Calcium chloride**
    - Solution has 30 day shelf life

T 176 - Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

- If the reading falls between one-tenth of an inch gradations, report the next higher reading.



T 176 - Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

- Calculations and reporting are unique
  - If the calculated sand equivalent is not a whole number, report as the next higher whole number.
  - If the average is not a whole number, raise it to the next whole number.

Sample Number	1	2	
Clay Reading[1] A	5.2	5.4	
Sand Reading[1] B	3.4	3.4	Average[2]
Sand Equivalent[2] $SE = \frac{B}{A}(100)$	65.4 (66)	62.9 (63)	64.5 (65)

T 176 - Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

- Specifications for this test for asphalt mixture paving projects is found in the spec book, 410
  - Microsurfacing specifications are currently found in supplemental specification 816.04

T 176 - Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

- Review Procedure
- Recorded on SFN 51730
  - Remember to round up – and round up again

T 304 - Uncompacted Void Content of Fine Aggregate

- Test is often referred to as the *Fine Aggregate Angularity or "FAA" test*
- Determines the loose uncompacted void content of a sample of fine aggregate

T 304 - Uncompacted Void Content of Fine Aggregate

- Used as a basis of asphalt mix designs
- Uncompacted void content provides an indication of the aggregates angularity, spherical shape and surface texture.
- Higher the numerical requirement the more durable the aggregate/asphalt mixture
  - Increase void content indicates greater angularity, less rounded and a rougher surface texture.

T 304 - Uncompacted Void Content of Fine Aggregate

- Only required for gyratory asphalt projects
- Gyratory mix designs are based on traffic levels with structural design related to fine aggregate angularity for mix type
- Mix type determines field compaction requirements
- FAA 40 to FAA 45
  - Additional specifications for each project may be found on plan notes
  - Bulk Specific Gravity results are needed to calculate FAA

T 304 - Uncompacted Void Content of Fine Aggregate

- Cylinder calibration value is needed to calculate results

Fine Aggregate Angularity Test

T 304 - Uncompacted Void Content of Fine Aggregate

- Review Test Procedure
- Recorded on SFN 51730
  - Cylinder Calibration recorded on SFN 51729

ASTM D 4791 - Flat Particles, Elongated Particle, or Flat and Elongated Particles in Coarse Aggregate

- Determines the percentage of particles that are:
  - Flat
  - Elongated
  - Flat and Elongated

ASTM D 4791 - Flat Particles, Elongated Particle, or Flat and Elongated Particles in Coarse Aggregate

- Setting on the proportional caliper device is 5:1.
- Material on a sieve is reduced until about 100 particles remain on a sieve.

ASTM D 4791 - Flat Particles, Elongated Particle, or Flat and Elongated Particles in Coarse Aggregate

- This ASTM version of the test is only used on asphalt paving projects
- Specification are in 410 section of spec book
  - Many sources of aggregate have very small percentage of flat and elongated particles

ASTM D 4791 - Flat Particles, Elongated Particle, or Flat and Elongated Particles in Coarse Aggregate

- Review Procedure
- Recorded on SFN 51700

Flat Particles, Elongated Particles Video – no audio

NDDOT 4 – Percentage of Fractured Particles in Coarse Aggregate

- NDDOT Standard
  - Referred to as Coarse Aggregate Angularity on plan note for asphalt paving projects
  - Will be called Fractured Faces for Classes of aggregate

NDDOT 4 – Percentage of Fractured Particles in Coarse Aggregate

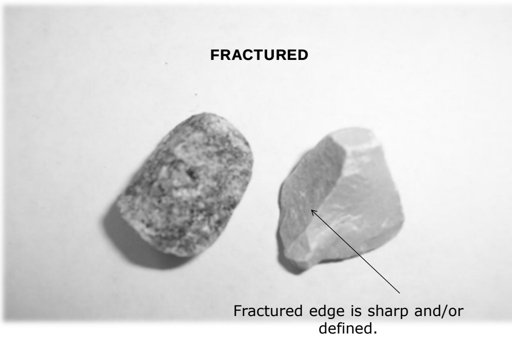
- Determines the percentage of particles by visual inspection having a fractured face.
- Fractured face is an area that is at least 25% of the largest cross section of the particle.

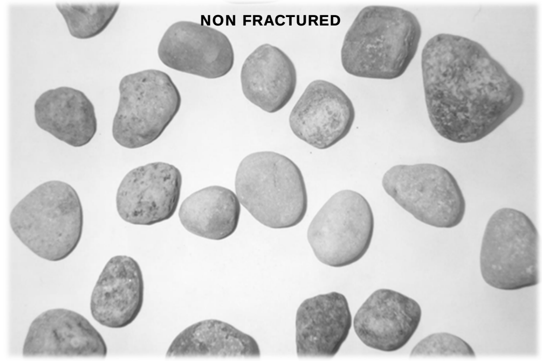
NDDOT 4 – Percentage of Fractured Particles in Coarse Aggregate

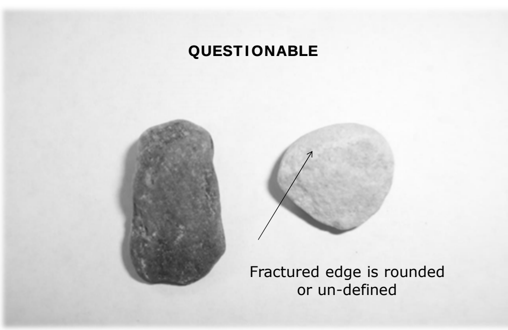
- Fracture is an angular, rough or broken surface of an aggregate particle created by a mechanical crusher, or by nature.
- A face will be considered fractured only if it has an projected area at least as large as one quarter of the maximum projected area of the particle and the face has sharp well defined edges.

NDDOT 4 – Percentage of Fractured Particles in Coarse Aggregate

- Material is separated into three portions
  - Fractured faces.
  - Questionable fractured faces.
  - No fractured faces.







NDDOT 4 – Percentage of Fractured Particles in Coarse Aggregate

- Review Procedure
- Recorded on SFN 9987

Worksheet Signatures

- For all worksheets or forms:
  - **Sign**
  - **Date**
  - If any corrections or change are made – sign/date – or make notation on electronic forms

410-P03 The Superpave FAA 45 shall conform to Section 410 of the Standard Specifications and Supplemental Specifications along with the following aggregate and mix design properties:

Test	Criteria	Reference
Coarse Aggregate Angularity	85% min	NDDOT Field Sampling/Testing Manual
Fine Aggregate Angularity	45% min	AASHTO T 304
Gyratory Effort, # Gyrations	N_{ini}=7, N_{des}=75, N_{max}=115	AASHTO R 35
Voids Filled with Asphalt	65-75%	AASHTO M 323, T 166
%G_{mm} @N_{ini}	89% Max	AASHTO M 323, T 166

Specific Gravity and other Aggregate Tests

Specific Gravity

- The ratio of the mass (or weight in air) of a unit volume of material to the mass of the same volume of water.

Specific Gravity

Archimedes Principle states “a body immersed in a fluid should be buoyed up with a force equal to the weight of the displaced fluid.”

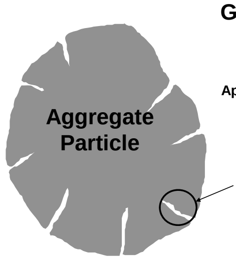
Apparent Specific Gravity

- The ratio of the weight in air of a unit volume of impermeable portion of aggregate to the weight in air of an equal volume of water.

Aggregate Apparent Specific Gravity

$$G_{sa} = \frac{\text{Dry Mass}}{\text{Appar. Vol}} \Big/ 1.000 \text{ g/cm}^3$$

Apparent Volume = volume of solid aggregate particle only



Pores not included

Bulk Specific Gravity

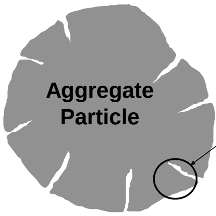
- The ratio of the weight in air of a unit volume of aggregate (including permeable and impermeable voids in the particles, but not including the voids between particles) to the weight in air of an equal volume of water.
- Used for asphalt mix analysis

Aggregate Bulk Specific Gravity

"SSD" Level

$$G_{sb} = \frac{\text{Dry Mass}}{\text{Bulk Vol}} \Big/ 1.000 \text{ g/cm}^3$$

Bulk Volume = solid volume + water permeable pore volume



Bulk Specific Gravity (SSD)

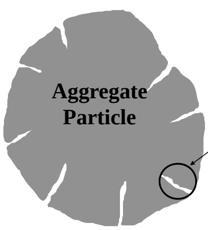
- The ratio of the mass in air of a unit volume of aggregate, including the mass of water within the voids filled to the extent achieved by submerging in water for approximately 15 hours *(but not including the voids between particles)* compared to the weight in air of an equal volume of water.
- Used in concrete applications

Bulk Specific Gravity (SSD)

"SSD" Level

$$Gsb = \frac{\text{Wet Mass}}{\text{Bulk Vol}} \Big/ 1.000 \text{ g/cm3}$$

Bulk Volume = solid volume + water permeable pore volume



Absorption

The increase in the mass of aggregate due to water in the pores of the material but not including water adhering to the outside surface of the particle

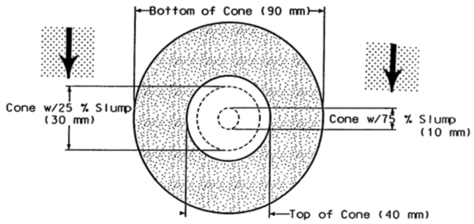
T 84 - Specific Gravity and Absorption of Fine Aggregate

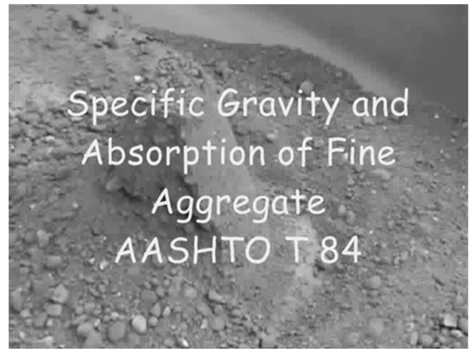
- This tests determines
  - Bulk specific gravity
  - Apparent specific gravity and
  - Absorption of fine aggregate.

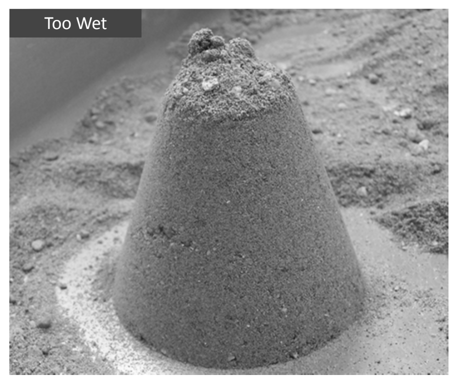
T 84 - Specific Gravity and Absorption of Fine Aggregate

- NDDOT Modification
  - Report specific gravity to the thousandth *vs hundredth* and absorption to the hundredth *vs tenth.*

T 84 - Specific Gravity and Absorption of Fine Aggregate







T 85 - Specific Gravity and Absorption of Course Aggregate

- This tests determines
  - Bulk specific gravity
  - Apparent specific gravity and
  - Absorption of coarse aggregate.

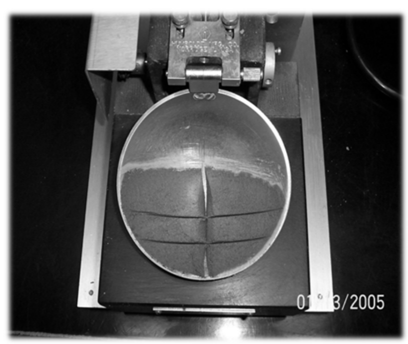
T 85 - Specific Gravity and Absorption of Coarse Aggregate

- NDDOT Modification
  - Report specific gravity to the thousandth *vs hundredth* and absorption to the hundredth *vs tenth*

Coarse Specific Gravity video

T 89 - Determining the Liquid Limit of Soils

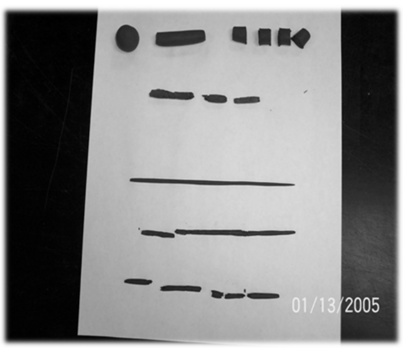
- Determines the moisture content at which the soil passes from a plastic to a liquid state.
- Two methods to determine liquid limit.



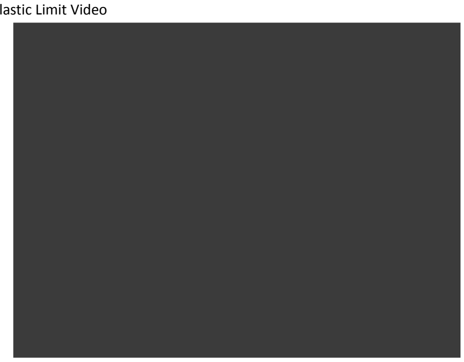
Liquid Limit Video

T 90 - Determining the Plastic Limit and Plasticity Index of Soils

- Determines the lowest water content at which the soil remains plastic.
- Plastic Index is the range where the material is in a plastic state.



Plastic Limit Video



NDDOT 3 - Shale, Iron Oxide Particles, Lignite and Other Coal, Soft Particles, Thin or Elongated Pieces

- NDDOT Standard
- Amount of deleterious material retained on the No. 4 sieve.
- Identify and hand pick deleterious material.

NDDOT 3 - Shale, Iron Oxide Particles, Lignite and Other Coal, Soft Particles, Thin or Elongated Pieces

- 3/8 sieve is used so that overloading does not occur on the No.4 sieve.
- Thin or elongated is defined as having a maximum thickness less than ¼ the maximum width or maximum length more than three times the maximum width.

Soft Particles

Additional Aggregate Tests

- T 96 - LA Abrasion
  - Resistance to degradation

Questions?

WELCOME !!

North Dakota QC/QA
Bituminous Technology

Aggregate Testing
Bismarck, ND

Acceptance Criteria

Common factors used for acceptance of materials and finished pavements

Acceptance Criteria

- **Depends on type of specifications used**
  - Method - Recipe
    - Spells out equipment, materials, methods, etc.
  - End result
    - Stresses testing not inspection
  - Quality Assurance
    - Statistically based contractor testing
  - Performance based
    - Emphasizes performance not construction
    - Warranties

Traditional Acceptance Criteria

- **Materials**
  - Asphalt binder properties
  - Aggregate gradation
  - Aggregate properties
  - Asphalt content
- **Pavement density**
- **Pavement smoothness**

There had never been mixture requirements until QC/QA

- **Specifications have always been "Recipe" related**
- **Density was the only test performed on the mixture after mixing**

ND Utilizes Two Criteria for Hot Bituminous Pavement (HBP)

- **Section 408 Non-QC/QA**
  - *Marshall* Compaction Hammer Specimen
    - Four Traffic Levels: Class 27/29/31/33
  - Superpave (Gyratory) Compactor
- **Section 409/410 QC/QA**
  - Superpave or *Gyratory* Compactor Specimen
    - Six Traffic Levels: Based on Fine Aggregate Angularity (FAA)=40,41,42,43,44,45
  - Marshall Compaction Hammer Specimen
    - Four Traffic Levels: Class 27/29/31/33

Important HMA Mix Properties

- **Stability**
- **Durability**
- **Impermeability**
- **Workability**
- **Flexibility**
- **Fatigue Resistance**
- **Skid Resistance**

Important HMA Mix Properties

How do we attain them?

- Materials Selection
- Volumetric design

Obtaining the right balance

Achieved through

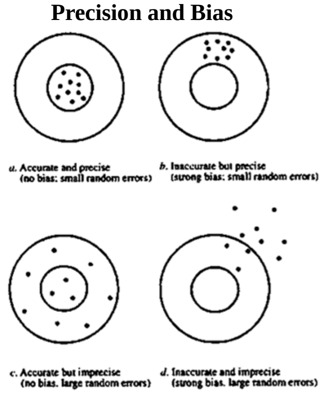
- **Volumetric Analysis of the Mixture**
- **Performance testing**
- **History**

Variability

- **Sampling**
- **Splitting**
- **Test Equipment**
- **Test Operator**
- **Test Method**
- ***Material Variability***

Test results will reflect all of the above…what we want to control the process with is accurate material variability assessment

Precision and Bias



Precision and Bias

$$x = \mu + \delta + e$$

measured value = true value + systematic error + random error

systematic error: bias; random error: precision; |----- accuracy -----|

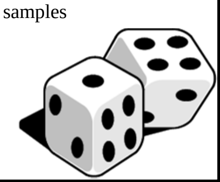
Random & Systematic Error Sources

- **Test Procedure**
- **Test Equipment**
- **Measurement**
- **Operator**
- **Sampling – Schedule & Method**
- **Splitting**
- **Reporting**

QC/QA Testing allows increased testing to assure volumetric properties are met.

The key to successful testing is -

- **Random sampling**
  - Any portion of the population has equal chance of being selected
  - Bias is introduced when judgment is used
    - Attempts to include “good and bad” samples
  - Use random number tables
    - Sampling/Testing Manual

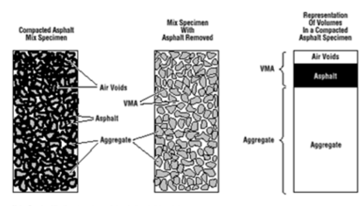


Random Numbers

- **Utilized in**
  - Aggregate and Mixture Sampling
  - Core Locations for Density Testing

Importance of Volumetric Properties

Experience shows that % air voids and the voids in the mineral aggregate relate to performance



Importance of VMA

- **VMA is the volume of the voids in a compacted aggregate sample to accommodate asphalt and air.**
  - Assure sufficient binder coating
  - Maintain 4% Air voids Ideally

Superpave Aggregate Properties

- **Consensus Properties - *Required***
  - Coarse Aggregate Angularity (CAA) – Fractured Faces
  - Fine Aggregate Angularity (FAA)
  - Flat, Elongated particles
  - Clay Content – (Sand Equivalent)
- **Source Properties - *Agency Option***
  - Toughness
  - Soundness
  - Deleterious Materials

Gyratory (*Superpave*) Mixture & Aggregate Relationship

- Aggregate Tests
  - Consensus Properties - required
  - Source Properties – Agency option
- Aggregate Criteria
  - Based on Aggregate Blend
  - Based on Traffic and *Depth into Pavement*
- Design Aggregate Structure
  - 0.45 Power Chart
  - Controls Points and PCS points

Consensus Mineral Aggregate Tests

- Course Aggregate Angularity (Percentage of Fractured Particles in Coarse Aggregate; NDDOT 4)
- Fine Aggregate Angularity (AASHTO T 304 - Method A)
- Flat and Elongated Particles (ASTM D 4791)
- Sand Equivalent (AASHTO T 176)

Source Mineral Aggregate Tests (QC/QA Superpave)

- Shale Content (Lightweight Pieces in Aggregate: AASHTO T113 ND Modified)
- Los Angeles Abrasion (AASHTO T 96)
- Deleterious Material % Spall (AASHTO T112, Clay Lumps and Friable Particles in Aggregate)

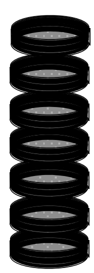
Sample Splitting AASHTO T248

- Accurate Splitting is essential
- Follow the rule of thumb
- There is no allowance in the QC / QA System for a “Bad Split”

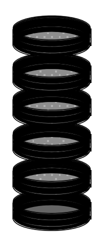
Aggregate Gradation Testing AASHTO T27/T11

- The gradation of the Mineral Aggregate is an analysis of the Particle Size Distribution.
- It is a primary factor in determining the volumetric properties of the HMA

Standard Aggregate Sieves



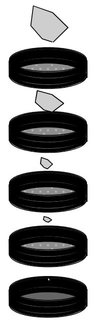
50 mm (2”)
37.5 mm (1½”)
25 mm (1”)
19 mm (3/4”)
12.5 mm (1/2”)
9.5 mm (3/8”)
4.75 mm (No. 4)



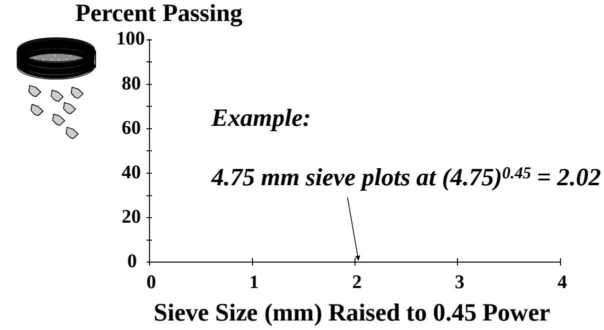
2.36 mm (No. 8)
1.18 mm (No. 16)
0.6 mm (No. 30)
0.3 mm (No. 50)
0.15 mm (No. 100)
0.075 mm (No. 200)

Superpave Aggregate Gradation

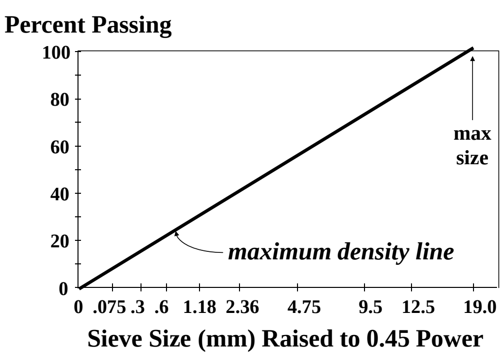
- **Use 0.45 Power Gradation Chart**
- **Blend Size Definitions**
  - maximum size
  - nominal maximum size
- **Gradation Limits**
  - control points
  - PCS point (% passing the #8 < > 39)



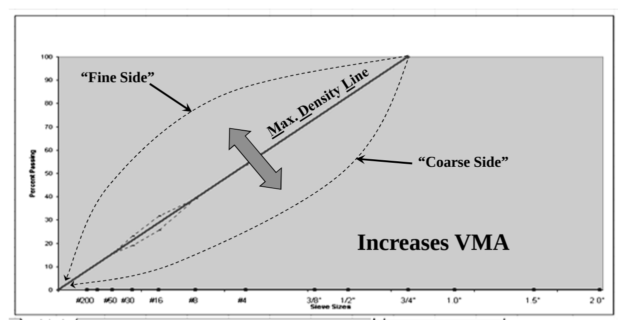
0.45 Power Grading Chart



0.45 Power Grading Chart



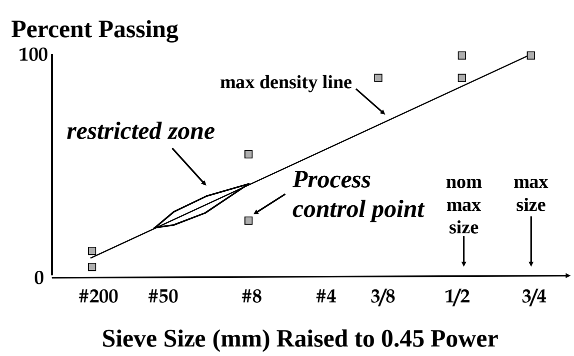
45^{th} Power Chart



Aggregate Size Definitions

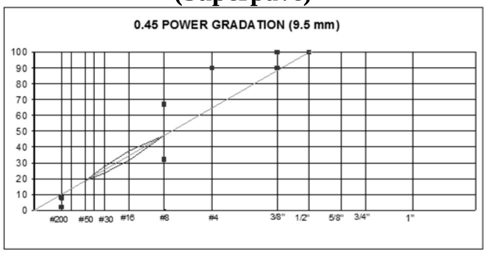
- ***Nominal Maximum* Aggregate Size**
  - one size larger than the first sieve to retain more than 10%
- ***Maximum* Aggregate Size**
  - one size larger than nominal maximum size

100
93
72
65
48
36
22
15
9
4



.45 Power Chart ½” Mix

(Superpave)



QC/QA Target Gradation Requirements (Marshall)

Sieve Size	Percent Passing
5/8” *	100
½” (12.5 mm)	90-100
# 4 (4.75 mm)	45-80
# 30 (0.425 mm)	10-35
# 200 (0.075 mm)	2.0-7.0

*** A tolerance of 2% in the amount passing the 5/8-inch sieve will be permitted providing all material passes the ¾-inch sieve**

QC/QA Target Gradation Requirements (Gyratory)

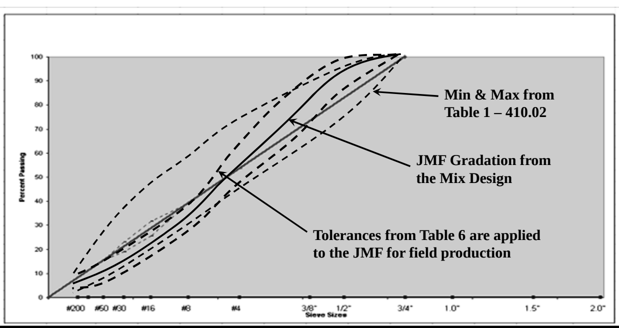
Sieve Size	Percent Passing
5/8”	100
½” (12.5 mm)	90-100
# 8 (2.36 mm)	28-58
# 200 (0.075 mm)	2.0-7.0

Superpave JMF Gradation Tolerances

TABLE 6 (410.04.0.2)

Attribute	Tolerance from Target Value
a. Sieve 1/2" (16 mm) thru #4 (4.75 mm)	± 6 %
b. Sieve #30	± 5 %
c. Sieve #200	± 2.0 %

QC/QA Gradation Requirements (Superpave)



Determine Aggregate Blend Properties

Calculate the blended aggregate gradation using the following formula

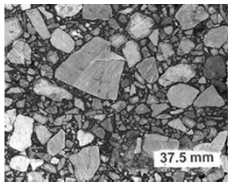
$$P = \frac{A \times a + B \times b + C \times c + ..}{100}.$$

where,

P = the % of combined aggregate for a given sieve
A,B,C, = % passing a sieve for an individual stockpile
a,b,c, = individual % of stockpiles by weight

Importance of Aggregate

- **Mineral aggregate has a great influence on the performance of an asphalt pavement as aggregates comprise 90 to 96 percent of the mixture weight and/or 82 to 88 percent of the aggregate volume.**

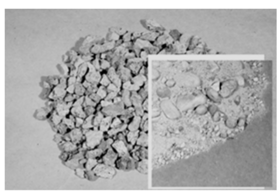


Aggregate Properties

- **Surface texture**
  - Rough surface increases mixture strength
  - Smooth surfaces produce “sliding effect”
  - Asphalt binders will typically adhere better to a rough textured surface
  - Surface texture will influence workability of the mixture

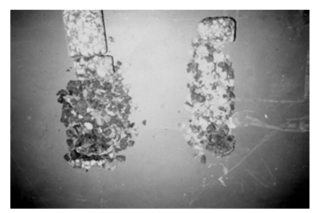
Aggregate Properties

- **Particle shape**
  - Also influences workability and compaction
  - Particle interlock, which produces higher mix strength, is higher with cubical shapes and lower for rounded particles
  - Percent crushing requirements (coarse/fine)



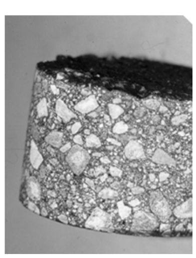
Aggregate Properties

- **Affinity for asphalt**
  - Hydrophobic -vs- hydrophilic
  - Stripping
    - Separation of the asphalt from the surface of the aggregate through the action of water
    - Liquid anti-strip additive
    - Hydrated lime



Aggregate Properties

- **Absorption**
  - Porosity of aggregate causes absorption of both water and asphalt binder
  - Additional amounts of asphalt binder needed
  - Additional drying time for mixing
  - Slag and other synthetic materials tend to be more absorptive than natural aggregates

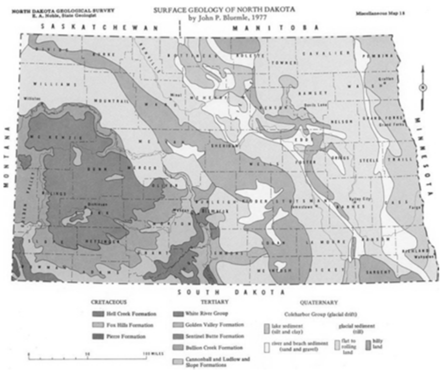


Selection Based on Economics

<u>Thought Process in Selection of Aggregate</u>

- **Proximity to Plant and/or Job-Site and Unit Cost**
- **Pre-Bid Testing for Viability**
- **Previous Use of Aggregate- Prior to Superpave**
- **Previous Use of Aggregate on Superpave Project**
- **Competitors Use of Given Aggregate Sources on Superpave Project**

Geology of ND



Fractured Face Count

- **Aggregate Fracture and Surface texture**
  - Rough surface increases mixture strength
  - Smooth surfaces produce "sliding effect"
  - Asphalt binders will typically adhere better to a rough textured surface
  - Surface texture will influence workability of the mixture

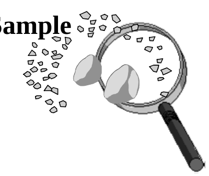
Aggregate Crushing Specifications (Superpave)

As specified on Plans:

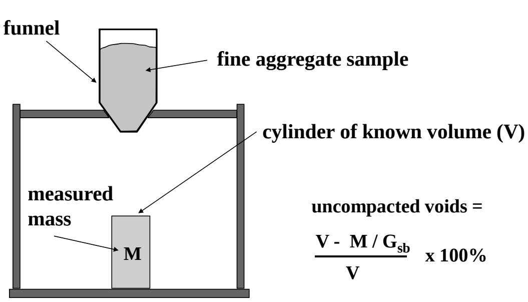
- **Coarse Aggregate Angularity (%)**
- **Fine Aggregate Angularity (%)**

QC/QA Superpave Fine Aggregate Angularity

- **Measured on - 2.36 mm Material**
- **Based on Air Voids in Loose Sample**
- **AASHTO T 304**
- **Requirements Depend on**
  - traffic level designation



Fine Aggregate Angularity



uncompacted voids =

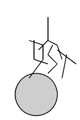
$$\frac{V - M / G_{sb}}{V} \times 100\%$$

Plasticity Index

The Plasticity Index is the numerical difference between the Liquid Limit and the Plastic Limit,

Or

The moisture range at which it remains plastic.

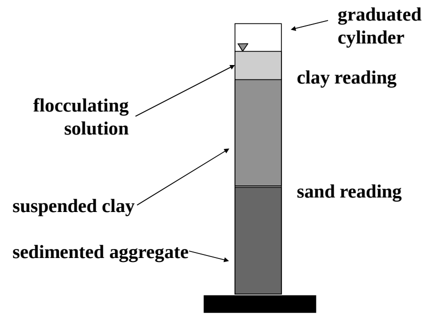


Clay Content

- Measured on - 4.75 mm Material
- Based on <u>Sand Equivalent</u> Value
- AASHTO T176
- Requirements Depend on traffic level designation

> How dirty is the sand ?

Clay Content



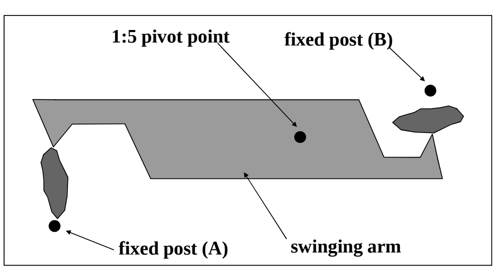
Lt Weight Particles Testing

- Coarse Shale Particles
  - Increase binder content
  - Pop outs
  - Raveling
  - Premature aging
- Fine Shale Particles
  - Increases stripping
  - Becomes P.I.

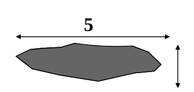
Flat, Elongated Particles

- Measured on + 4.75 mm Material
- Based on Dimensional Ratio of Particles
  - ratio of max to min dimension < 5
- ASTM D 4791
- Requirements Depend on
  - traffic level designation

Flat, Elongated Particles



Flat, Elongated Particles



Traffic ESALs	Percent	
.	.	
10 - 30 x 10^6	10	Maximum
.	.	
.	.	

percentage of flat and elongated particles

If 94% by weight and 84%-88% by volume of a Hot Bituminous Pavement is the aggregate structure, it is very important to monitor and control the aggregate in producing HBP!!!!

Questions???

Table of Contents
Aggregate Test Procedures

AASHTO T 2 – SAMPLING OF AGGREGATES

Conduct this procedure according to AASHTO T 2, NDDOT Modified

The test standard has a minimum size of sample to be obtained. NDDOT modification to the test standard is a change in the minimum size of sample to be obtained.

The test standard identifies a number of ways to collect samples. The NDDOT modification is to add an additional procedure which is sampling from a windrow.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

SCOPE

This test defines the procedures used to obtain samples that will show the nature and condition of the materials which they represent.

REFERENCED DOCUMENTS

AASHTO T 248, Reducing Samples of Aggregate to Testing Size

TERMINOLOGY

Maximum Size of Aggregate – the smallest sieve opening through which the entire amount of aggregate is required to pass.

Nominal Maximum Size – the smallest sieve opening through which the entire amount of the aggregate is permitted to pass.

Maximum Aggregate Size (Superpave) – one size larger than the nominal maximum aggregate size.

Nominal Maximum Aggregate Size (Superpave) – one size larger than the first sieve that retains more than 10% aggregate.

APPARATUS

Containers, pails or bags
Shovel
Scoop or spoon
Brush
Sampling tubes

TEST SPECIMEN

The sample size is based on the type and number of tests to be performed. The following table gives the approximate sample size required for different aggregate sizes.

SIZE OF SAMPLE	
Nominal Size of Aggregate[A]	Approximate Minimum Mass of Field Samples[B]
Fine Aggregate	
No. 8 (2.36 mm)	25 lbs (10 kg)
No. 4 (4.74 mm)	25 lbs (10 kg)
Coarse Aggregate	
3/8" (9.5 mm)	8 lbs (4 kg)
1/2" (12.5 mm)	16 lbs (8 kg)
5/8" (16.0 mm)	30 lbs (15 kg)
3/4" (19.0 mm)	44 lbs (20 kg)
1" (25.0 mm)	88 lbs (40 kg)
1½" (37.5 mm)	132 lbs (60 kg)

[A] For processed aggregate, use the nominal maximum size as indicated by the appropriate specification or description. If the specification or description does not indicate a nominal maximum size use the maximum size (sieve indicating 100% passing).

[B] For combined coarse and fine aggregates, for example, base or subbase, the minimum weight shall be the coarse aggregate minimums plus 25 lbs (10 kg).

PROCEDURE

When practicable, samples shall be obtained from the finished product. Sampling requires a number of individual samples that are combined to make a composite sample. Reduce the sample to the required size by quartering or splitting in accordance with T 248.

- SAMPLING FROM ROADWAY:

When taking samples from roadway material or in-place, take the samples from at least three approximately equal increments across the roadway. Obtain samples from the full depth of the course. Take care to avoid including material from the underlying subgrade or base course. Combine the samples to form a composite sample.

- SAMPLING FROM A FLOWING AGGREGATE STREAM:

Obtain at least three approximately equal increments and combine to form the required size sample. Collect the samples in a pan or by use of a sampling device. Take the samples from the entire cross section as it is being discharged. The receptacle should be of sufficient size to intercept the entire stream and hold the material without overflowing.

- SAMPLING FROM A WINDROW:

Sample the windrow by removing the top one foot of material and obtain part of the sample from each side. Avoid the segregated coarser material at the bottom of the side slope. Combine three samples to form a composite sample.

- SAMPLING FROM A CONVEYOR BELT:

Obtain at least three approximately equal increments and combine to form the required size sample. Stop the conveyor belt and clean off a section of material from the belt. Insert a template that conforms to the shape of the belt. Carefully remove all the material from the template. Use a scoop to remove as much of the material as possible. A brush and dust pan may be used to remove the fine material. Make sure to include all of the fine material. Space the three samples apart.

- SAMPLING FROM A STOCKPILE:

Segregation often occurs when materials are stockpiled. Thus, it is difficult to ensure unbiased samples from stockpiles. For coarse or mixed coarse and fine aggregate, make every effort to enlist the services of power equipment to develop a separate, small sampling pile composed of material from various levels and locations in the main pile. Combine several increments to compose the sample.

Where power equipment is not available, combine material from at least three increments; the top third, middle third, and bottom third of the pile. Insert a board vertically into the pile just above the sampling point to aid in preventing further segregation. Remove the outer layer, which may be segregated, and sample the material beneath.

An alternate sampling method is to insert a sampling tube into the pile at a minimum of five random locations to extract material to form a sample. Sampling tubes are approximately 1¼" (minimum) in diameter by 6 ft. (minimum) in length

- SAMPLING FROM A TRUCK:

  For coarse aggregate or composite of coarse and fine aggregate, sample from trucks. Take samples from a minimum of three trenches. Dig trenches across the truck box at points on the surface that appear to be representative of the material. Make the trench bottom approximately level, at least one-foot wide and one-foot below the surface of the aggregate. Take equal portions of material by pushing the shovel downward into the material in the bottom of the trench at three equally spaced locations. Do not scrape the material horizontally. Combine the nine portions (minimum) to form the combined sample from the truck.

  For sampling fine aggregate insert a sampling tube at a minimum of five locations. Sampling tube should be a minimum of 1¼" in diameter by 6 ft. in length.

NOTES

The contractor obtains all aggregate samples except verification samples.

It is desirable to sample any material as near as possible to, if not at, the final in-place position. Hierarchies of preferred sampling locations are in-place, windrow, conveyor belt, flowing stream, truck box, or stockpile.

AASHTO T 248 – REDUCING SAMPLES OF AGGREGATE TO TESTING SIZE

Conduct this procedure according to AASHTO T 248.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

SCOPE

This method covers the reduction of large samples of aggregate to the appropriate size for testing. Techniques used should minimize variation in measured characteristics between the test samples selected and the entire sample. The end product should be a sample representative of the source.

REFERENCED DOCUMENTS

AASHTO T 2, Sampling Aggregates

APPARATUS

Sample splitter
Straightedge shovel
Broom
Canvas or cloth
Brush

TEST SPECIMEN

Obtain sample according to T 2.

PROCEDURE

Two methods for reducing a sample are acceptable and either method may be used. A mechanical splitter is faster and more convenient than quartering. When reducing a sample by either method, do not attempt to obtain a sample of a predetermined weight. Divide and re-divide a large sample until the size of sample is within a desired range.

"Method A" - Mechanical Splitter

Sample splitter shall have an even number of equal width chutes, but not less than a total of eight for coarse aggregate, or 12 for fine aggregate. The chutes must discharge alternately to each side of the splitter. For coarse aggregate and mixed aggregate, the minimum chute width shall be approximately 50% larger than the

largest particle in the sample to be split. For dry fine aggregate with 100% passing the 3/8" sieve, use a splitter with chutes 1/2" to 3/4" wide.

Use a splitter with two receptacles and a hopper or straight-edged pan with a width equal to, or slightly less, than the overall width of the assembly of chutes. The receptacles hold the two sample halves following splitting. The hopper or straight-edged pan allows sample feeding at a controlled rate into the chutes.

Mix the sample thoroughly. Place the receptacles under the splitting chutes. Close the chute shut-off valve. Pour the sample into the chute hopper and distribute the sample evenly over the full length and width of the hopper. Pull the lever to allow the material to free flow through the chutes into the receptacles below. To further reduce the sample to the desired size, repeat the process using the material from one of the receptacles.

"Method B" - Quartering

Place the sample on a firm, fairly smooth surface, such as a floor, board, a piece of cloth, or canvas. Mix the material thoroughly by turning the entire sample over three times. While turning the sample the last time, deposit each shovelful on top of the preceding one to form a conical pile. If a canvas is used, alternately lift the corners and pull over the sample as if preparing to fold the canvas diagonally.

Flatten the material into a circular layer of uniform thickness by pressing down the apex with a shovel. The diameter shall be approximately four to eight times the thickness.

Divide the sample into approximately four equal parts by striking two perpendicular lines through the center of the sample. If a canvas is used, the separation may be accomplished by passing a broom handle underneath the canvas and lifting slightly. This must be done twice to form the two perpendicular lines of separation. Separate the four parts completely. Use a brush to make sure that all the fines are included in each part.

Next discard the two diagonally opposite quarters. Be careful to discard all the remaining fines from the discarded sections. Re-mix the remaining quarters and repeat the process until you obtain the desired sample size from the diagonally opposite quarters.

NOTES

For a very dry sample, uniformly dampen the material to prevent segregation and loss of fines.

A sample that has free moisture may be dried to at least surface-dry condition at a temperature that does not exceed those specified in any of the tests that will be completed on the sample.

A quick method to determine surface-dry is if the fine aggregate retains its shape when molded in the hand, it is wetter than surface-dry.

AASHTO T 255 – TOTAL EVAPORABLE MOISTURE CONTENT OF AGGREGATE BY DRYING

Conduct this procedure according to AASHTO T 255.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

SCOPE

This test method covers the determination of the percentage of evaporable moisture in a sample of aggregate by drying both surface moisture and moisture in the pores.

REFERENCED DOCUMENTS

AASHTO T 2, Sampling of Aggregates

APPARATUS

Balance
Hot plate, stove, oven, or microwave*
Sample container
Spoon or spatula

*It is preferable that the microwave oven have a vented chamber. The microwave oven shall have a power rating of about 700 watts with variable power control.

TEST SPECIMEN

Obtain sample according to T 2.

Sample size may be determined by the following table:

Sample Size for Aggregate	
Nominal Maximum Size of Aggregate	Mass of Normal Weight Aggregate Sample
No.4 (4.75 mm)	1 lb (0.5 kg)
3/8" (9.5 mm)	3 lbs (1.5 kg)
1/2” (12.5 mm)	4 lbs (2 kg)
3/4" (19.0 mm)	7 lbs (3 kg)
1" (25.0 mm)	9 lbs (4 kg)
1½" (37.5 mm)	13 lbs (6 kg)
2" (50 mm)	18 lbs (8 kg)
2½" (63 mm)	22 lbs (10 kg)
3" (75 mm)	29 lbs (13 kg)

Sample should be representative of the moisture content of the supply being tested and should not have mass less than the amounts listed in the above table. Protect the sample from moisture loss until the initial weight is determined.

PROCEDURE

Dry the sample by means of a selected source of heat. An oven capable of maintaining a temperature of 230 ± 9°F (110 ± 5°C) may be used.

Unless an oven is used, stir during drying to accelerate the process and avoid localized overheating. If a microwave oven is used, stirring is optional.

When drying a sample on a hot plate or stovetop, great care must be taken to keep from burning the sample or losing material when the sample is stirred.

Dry the sample until constant weight is achieved.

CALCULATIONS

Calculate the percent moisture as follows:

$$A = [(B - C)/C] \times 100$$

A = Percent moisture
B = Mass of original sample
C = Mass of dry sample

REPORT

Report percent moisture to the nearest 0.1%.

NOTE

Constant weight is defined as when further drying will cause less than 0.1% additional loss in mass.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

AASHTO T 11 - MATERIALS FINER THAN NO. 200 (75 µm) SIEVE IN MINERAL AGGREGATES BY WASHING

Conduct this procedure according to AASHTO T 11, NDDOT Modified.

The standard test procedure reports the percentage of material finer than the No. 200 sieve to the nearest 0.1% except if the result is 10% or more, than report to the nearest whole number. The NDDOT modification is report the accuracy to the same significant digit as the specification for the class of aggregate.

Consult the current edition of AASHTO for procedure in its entirety and the equipment specification details.

SCOPE

This test method determines the amount of material finer than the No. 200 sieve in aggregate by washing. Procedure A shall be used unless otherwise specified.

When accurate determinations of material finer than the No. 200 in fine or coarse aggregate are desired, this test method is used on the aggregate sample prior to dry sieving according to T 27. The results of this procedure are included in the calculations for T 27.

REFERENCED DOCUMENTS

AASHTO T 2, Sampling Aggregates
AASHTO T 27, Sieve Analysis of Fine and Coarse Aggregate
AASHTO T 248, Reducing Samples of Aggregate to Testing Size
AASHTO T 255, Total Evaporable Moisture Content of Aggregate by Drying

APPARATUS

Balance
Sieves: No. 16 and No. 200
Sample splitter
Oven
Washing container
Spoon

TEST SPECIMEN

Obtain sample according to T 2. Thoroughly mix and reduce according to T 248.

Test specimen shall be a representative sample based on the following table.

Nominal Maximum Size	Minimum Mass
No. 4 (4.75 mm) or smaller	300 g
3/8" (9.5 mm)	1000 g
3/4" (19.0 mm)	2500 g
1½" (37.5 mm)	5000 g

The sample size required for this test is a minimum after drying.

PROCEDURE

Record all information on SFN 9987 or 2455. Weights are recorded to the nearest 0.1 g.

Oven dry the sample according to T 255 at a temperature of 230 ± 9°F (110 ± 5°C). Weigh and record as original weight of sample.

Place the sample into the washing container and add sufficient water to cover. Stir and agitate the sample with the spoon until all fines are in suspension.

Slowly decant the water into the stacked No. 16 and 200 sieves being careful not to lose the coarser material of the sample.

Add a second charge of water to the sample in the washing container and stir, agitate, and decant. Repeat this process until the wash water is clear.

Wash any remaining material on the sieve back into the sample. Do not decant any water from the container except through a No. 200 sieve to avoid loss of material. Any remaining water should be evaporated by the drying procedure.

Oven dry the sample according to T 255 at a temperature of 230 ± 9°F (110 ± 5°C). Weigh and record as weight after wash.

CALCULATIONS

If this test has been ran for the purpose of accurate determination of material finer than the No. 200 in fine or coarse aggregate, the results of this procedure are determined by the calculations for T 27 on SFN 9987.

To calculate material passing the No. 200 sieve as percent of the total sample for coarse aggregate for concrete, subtract dry weight after washing from weight of total sample and divide result by weight of total sample. Multiply this result by 100 and record as material passing No. 200 sieve as percent of total sample. The equation is as follows:

$$A = [(B-C)/B] \times 100$$

A = percent of material finer than No. 200 sieve by washing
B = weight of total sample before washing
C = weight of dry sample after washing

REPORT

Report the percent of material finer than the No. 200 sieve to the same significant digit as the specification for the class of aggregate.

NOTES

A piece of rubber tubing may be attached to a water faucet and be used to rinse material from the sieves. The velocity of the water, which may be increased by pinching the tubing, should not be sufficient to cause splashing of the sample over the sides of the sieve.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

AASHTO T 27 – SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES

Conduct this procedure according to AASHTO T 27, NDDOT Modified.

The standard test procedure reports the percentage of material finer than the No. 200 sieve to the nearest 0.1%; except if the result is 10% or more, report to the nearest whole number. NDDOT modification is in the accuracy which is reported to the same significant digit as specified in the specifications for the class of aggregate.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

SCOPE

This test method determines the particle size distribution of fine and coarse aggregates by sieving. The No. 4 sieve is designated as the division between the fine and coarse aggregate.

REFERENCED DOCUMENTS

AASHTO T 2, Sampling Aggregates
AASHTO T 11, Materials Finer than No. 200 (75 µm) Sieve in Mineral Aggregates by Washing
AASHTO T 89, Determining the Liquid Limit of Soils
AASHTO T 90, Determining the Plastic Limit and Plasticity Index of Soils
AASHTO T 248, Reducing Samples of Aggregate to Testing Size
AASHTO T 255, Total Evaporable Moisture Content of Aggregate by Drying

APPARATUS

Balance
Sieves: 8" round, 12" round, or 14" square
Mechanical sieve shaker
Oven
Bronze brush
Paint brush, approximately 1" wide
Sample splitters, small and large
Mortar and rubber tipped pestle
Spoons
Large pans required for drying and handling sample

TEST SPECIMEN

Obtain sample according to T 2. Thoroughly mix and reduce according to T 248.

PROCEDURE

Use SFN 9987 or 2455 to record all information. All weights are recorded to the nearest 0.1 g.

Dry the sample according to T 255 at a temperature of 230 ± 9°F (110 ± 5°C).

Select sieves to furnish the information required by the specifications covering the material to be tested. Use of additional sieves may be desirable to prevent the required sieves from becoming overloaded.

The quantity retained on any sieve, with openings smaller than the No. 4 sieve, at the completion of the sieving operation shall not exceed 4 g per sq.in. of sieving surface area. If this occurs it is considered overloading of the sieve. The overload amount for an 8" diameter sieve is 200 g.

The quantity retained on any sieve, with openings of No. 4 and larger, at the completion of the sieving operation shall not exceed 2.5 times sieve opening times effective sieve area. If this occurs, it is considered overloading of the sieve. The following table shows the maximum amount of material to be retained on a sieve before being considered overloaded.

MAXIMUM ALLOWABLE QUANTITY OF MATERIAL RETAINED*

Sieve Opening Size	8" Diameter Sieve	14" Square Sieve
2" (50 mm)	7.9 lbs (3.6 kg)	33.7 lbs (15.3 kg)
1½" (37.5 mm)	6.0 lbs (2.7 kg)	25.4 lbs (11.5 kg)
1" (25.0 mm)	4.0 lbs (1.8 kg)	17.0 lbs (7.7 kg)
3/4" (19.0 mm)	3.1 lbs (1.4 kg)	12.8 lbs (5.8 kg)
1/2" (12.5 mm)	2.0 lbs (0.89 kg)	8.4 lbs (3.8 kg)
3/8" (9.5 mm)	1.5 lbs (0.67 kg)	6.4 lbs (2.9 kg)
No. 4 (4.75 mm)	0.7 lbs (0.33 kg)	3.3 lbs (1.5 kg)

*Table 1 of the AASHTO standard shows a complete table of different size sieves of the maximum allowable quantities of material retained on a sieve.

Preventing overloading of material on an individual sieve can be accomplished by one of the following methods:

- Insert an additional sieve with opening size intermediate between the sieve that may be overloaded and the sieve immediately above that sieve.
- Split the sample into two or more portions, sieve each portion individually and combine the portions retained on the sieve before calculating the percentage of the sample on the sieve.

- Use sieves having a larger frame size and providing a greater sieving area.

The portion finer than the No. 4 sieve may be reduced using a mechanical splitter.

Nest the sieves in order of decreasing size of opening from top to bottom and place the sample on the top sieve. Agitate the sieves by hand or by mechanical apparatus until meeting the criteria for adequacy of sieving.

When using a mechanical shaker, place the sample in the stack of sieves and shake until not more than 0.5% by weight of the total sample passes any sieve during one minute. Approximately 10 minutes will be sufficient for most material. Use manual shaking of the material on any one sieve to check on the thoroughness of sieving by any mechanical shaker.

Remove the top sieve, brush the retained material into a pan, weigh and record. Be sure to thoroughly clean each sieve. Repeat this process with each succeeding sieve, brushing the material into individual pans, and record the non-cumulative weights.

CALCULATIONS

Add the non-cumulative weight retained on the largest sieve to the weight retained on the next smallest sieve and record in the cumulative column.

Calculate the percent retained on each sieve by dividing each weight by the original total dry weight and multiplying by 100. This is the percent retained. Subtract each of these values from 100 to obtain the percent passing each sieve. Continue this process for each sieve. The equations are as follows:

Percent retained on sieve = (Cumulative weight/Total weight) x 100
Percent passing = 100 - Percent retained on sieve

This calculation is completed for both the coarse and fine aggregate.

If an accurate determination of the amount of material passing the No. 200 was accomplished by performing T 11, subtract the weight after wash from the original weight and record as wash loss.

Add together the cumulative weight retained on the No. 200, the weight of the Minus No. 200 material, and the wash loss, and record as the weight check.

To calculate the percent passing of the total sample for the fine portion of the aggregate, multiply the percent passing the No. 4 times the percent passing on each individual sieve in the fine aggregate portion and divide by 100. The equation is as follows:

Percent total sample = [(Percent passing No.4) x (Percent passing smaller sieve)]/100

Final calculations of percentages passing are reported to the nearest whole number with the exception of the No. 200, which is reported to same significant digit as specified by the specification for the class of aggregate.

For both the Plus No. 4 and Minus No. 4, compare the original weight to the weight check. Subtract the smaller value from the larger value, divide the result by the original weight, and multiply by 100, to obtain the percent difference. For acceptance purposes, the two must not differ by more than 0.3%.

NOTES

Accurate determination of material finer than the No. 200 sieve cannot be achieved by using this method alone. Test method T 11 for material finer than the No. 200 sieve by washing should be employed.

Sieves mounted in frames larger than standard 8" diameter are used for testing coarse aggregate to reduce the possibility of overloading the sieves.

When working with mixed materials that are coated, lumpy, or baked together, the material must be pulverized enough to separate the particles and remove the coating as much as possible. The idea is to pulverize enough to separate most of the particles, without breaking up any appreciable amount of individual material particles.

In brushing the material out of the sieves, use the bronze brush for approximately the No. 30 sieve and coarser, and the paintbrush for the finer sieves. Tapping the sieves lightly with a stick of wood on the retaining ring to facilitate removal of the particles is acceptable. Do not attempt to completely remove all the particles, but examine each sieve visually before and after sieving. The amount of aggregate particles stuck in the mesh must appear to remain approximately the same for accurate results.

Examine the sieves constantly for damage, which will affect the test results. A common occurrence is the separation of the mesh from the side of the sieve, especially in the finer sieves. Hold the sieves up to a light to inspect for damages.

Dry the sample according to T 255 using an oven at a temperature of 230±9°F (110±5°C). If the sample is used to determine T 89, liquid limit, and T 90, plastic limit, the sample must be dried using an oven at a temperature of 140°F (60°C).

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

AASHTO T 113 – LIGHTWEIGHT PIECES IN AGGREGATE

Conduct this procedure according to AASHTO T 113, NDDOT Modified.

The standard test procedure uses saturated surface dry material. NDDOT modification is to use material that is dried to a constant weight.

The standard test procedure uses material for the fine aggregate that passes the No. 4 and is retained on the No. 50 sieve. NDDOT modification is to use material for the fine aggregate that passes the No. 4 and is retained on the No. 30 sieve.

The standard test procedure uses a heavy liquid with a specific gravity of 2.00±0.01. NDDOT modification is to use a heavy liquid with a specific gravity of 1.95±0.01.

The standard test procedure does not indicate a time period for stirring and resting the sample. The NDDOT modification for the fine aggregate is to agitate the sample for 15 seconds and then allow resting for 30 seconds before removing the lightweight pieces. This is done a maximum of three times.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

SCOPE

This test method determines the percentage of lightweight pieces in aggregate by means of sink-float separation in a heavy liquid with a specific gravity of 1.95±0.01. This test is performed separately on the coarse and fine portions of aggregate. The No. 4 sieve is designated as the division between the fine and coarse aggregate.

REFERENCED DOCUMENTS

AASHTO T 2, Sampling Aggregates
AASHTO T 27, Sieve Analysis of Fine and Coarse Aggregate
AASHTO T 248, Reducing Samples of Aggregate to Testing Size
AASHTO T 255, Total Evaporable Moisture Content of Aggregate by Drying

APPARATUS

Balance
Sieves: No. 4 (4.75 mm) and No. 30 (600 µm)
Specific gravity hydrometer
Zinc chloride
Enamel pans
Glass beaker
Fine strainer
Spoon
Oven

TEST SPECIMEN

Obtain a sample according to T 2 and reduce according to T 248.
Test specimen shall be a representative sample determined from the following table:

Nominal Maximum Size of Aggregate	Minimum Mass of Sample
No. 4 (4.74 mm)	200 g
3/4" (19.0 mm)	3000 g
1½" (37.5 mm)	5000 g
3" (75 mm)	10,000 g

If the nominal maximum size of the aggregate to be tested is not listed above, use the next larger size to determine the sample size.

Dry the sample according to T 255 at a temperature of 230±9°F (110±5°C). Cover the sample and cool to room temperature.

Perform sieve analysis according to T 27. The material retained on the No. 4 sieve will be used for the coarse aggregate portion. The material passing the No. 4 and retained on the No. 30 sieve will be used for the fine aggregate portion.

PROCEDURE

Record all information on SFN 9987. All weights are recorded to the nearest 0.1 g.

Coarse Aggregate:

Weigh the sample and record as weight of Plus No. 4 material.

Place the coarse portion into the zinc chloride solution. The volume of the liquid should be three times the volume of the aggregate.

Using the strainer, skim off floating particles and place the lightweight pieces into a pan. Repeatedly agitate, rest, and remove the floating particles from the sample until no additional particles float to the surface.

Use hot water to wash the zinc chloride solution from the lightweight pieces. Dry according to T 255 at a temperature of 230±9°F (110±5°C). Weigh and record as weight of lightweight pieces in Plus No. 4 material.

Fine Aggregate:

Weigh the sample and record as weight of Minus No. 4 Plus No. 30 material.

Place the fine aggregate portion in a nonabsorbent container, preferably a glass beaker. Pour zinc chloride solution in with the sample. The volume of liquid should be three times the volume of the aggregate.

Agitate to bring all particles into suspension by stirring for a period of 15 seconds. Allow the sample to rest for 30 seconds.

After the rest period, decant the floating lightweight pieces onto a No. 30 sieve or smaller. Repeatedly agitate, rest, and remove the floating particles from the sample until no additional particles float to the surface. This process may be completed up to a maximum of three times.

Use hot water to wash the zinc chloride solution off the lightweight pieces. Dry according to T 255 at a temperature of 230±9°F (110±5°C). Weigh and record as weight of lightweight pieces Minus No. 4 Plus No. 30 material.

CALCULATIONS

Coarse Aggregate:

To calculate the percent of lightweight pieces in the coarse aggregate portion, divide the weight of material that floats by the weight of the Plus No. 4 material. The equation is as follows:

$$A = (B/C) \times 100$$

A = Percent of lightweight pieces in the coarse aggregate
B = Weight of coarse lightweight pieces
C = Weight of sample of the coarse aggregate

To determine the percent of coarse lightweight pieces in the total sample, multiply the percent of lightweight pieces in the coarse portion times the percent of the total sample retained on the No. 4 sieve. Multiply this result by 100. The equation is as follows:

$$D = (A \times E) \times 100$$

D = Percent coarse lightweight pieces, total sample
A = Percent of lightweight pieces in the coarse aggregate
E = Percent of total sample retained on the No. 4

Fine Aggregate:

To calculate the percent of lightweight pieces in the fine aggregate portion, divide the weight of material that floats by the total weight of the fine portion. Multiply this result by 100.

The equation is as follows:

$$F = (G/H) \times 100$$

F = Percent of lightweight pieces in fine aggregate
G = Weight of fine lightweight pieces
H = Weight of sample of the fine aggregate

To determine the percent of fine lightweight pieces in the total sample, multiply the percent of lightweight pieces in the fine portion times the result of the percent of the total sample passing the No. 4 sieve minus the percent passing the No. 30 total sample. Multiply this result by 100. The equation is as follows:

$$I = (F \times J) \times 100$$

I = Percent fine lightweight pieces, total sample
F = Percent of lightweight pieces in fine aggregate
J = Result of the percent passing No. 4 minus the percent passing No. 30 total sample

REPORT: Report individual results to the nearest 0.01%.

Lightweight Pieces Total Sample:

To determine the lightweight pieces in total sample combine the percent fine lightweight pieces total sample and percent coarse lightweight pieces total sample. The equation is as follows:

$$H = D + I$$

H = Percent lightweight pieces total sample
D = Percent coarse lightweight pieces, total sample
I = Percent fine lightweight pieces, total sample

REPORT: Report to the nearest 0.1%.

NOTES

Zinc chloride is a poison. Handle and store accordingly. Avoid zinc chloride dust or vapor from the solution by wearing an appropriate mask or work under a vent hood. The zinc chloride solution is corrosive to skin and clothing. Use safety goggles, rubber gloves, and a rubberized apron to avoid contact with skin or clothing.

To prepare a zinc chloride solution, mix zinc chloride with water at room temperature at a rate of approximately 3 parts zinc chloride to 1 part water. This would be a mix proportion of about 2800 g of zinc chloride to about 1100 mL of water. During mixing the solution heats up considerably so allow time for the solution to cool to room temperature. Use a specific gravity hydrometer to adjust the specific gravity to 1.95±0.01 by adding water or zinc chloride in small quantities. Adding an additional amount of zinc chloride will increase the specific gravity or adding water will decrease the specific gravity.

To reuse the zinc chloride solution, check the specific gravity and adjust before each use.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

AASHTO T 176 – PLASTIC FINES IN GRADED AGGREGATES AND SOILS BY USE OF THE SAND EQUIVALENT TEST

Conduct this procedure according to AASHTO T 176.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

The following describes Alternate “Method 2”.

SCOPE

This test is intended to serve as a rapid field test to show the relative proportions of fine dust or claylike material in soils or graded aggregates.

REFERENCED DOCUMENTS

AASHTO T 2, Sampling of Aggregates
AASHTO T 248, Reducing Samples of Aggregate to Testing Size

APPARATUS

Pan
Trowel
Damp cloth
Plastic splitting cloth
3-oz. sample tins
Spatula or straightedge
Graduated plastic cylinder
Stock calcium chloride solution
Funnel
Clock or stop watch
Rubber stopper
Mechanical sand equivalent
Shaker
Irrigation tube
Weighted foot assembly
No. 4 sieve (4.75 mm)

TEST SPECIMEN

Obtain a sample according to T 2. Thoroughly mix and reduce according to T 248.

Test specimen should be approximately 1000 to 1500 g of unwashed soil or graded aggregate that passes the No. 4 sieve. All aggregations of fine grained soil should be pulverized to pass the sieve and all fines shall be cleaned from the particles retained on the sieve and then included with the material passing.

SAMPLE PREPARATION

Place the sample in the pan and use a trowel to mix. Add just enough water so that when a small portion of the sample is squeezed tightly a cast is formed. If the cast can be carefully handled without breaking, the correct moisture has been obtained. If the cast crumbles it will be necessary to add water and remix. If free water is visible the sample is too wet and must be drained and air dried.

Cover the sample with a damp cloth and let stand for a minimum of 15 minutes. Do not allow the cloth to touch the material.

If the original sample allows a cast without adding water, you may omit the 15 minute standing period and proceed with the test.

After the standing period, place the sample on a splitting cloth and mix by alternately lifting each corner of the cloth and pulling it over the sample toward the diagonally opposite corner, causing the material to be rolled. When the material appears homogeneous, finish the mixing with the sample in a pile near the center of the cloth.

Using one hand, push the 3-oz. tin through the base of the pile. Hold the other hand on the opposite side of the pile to cause the material to fill the tin. Press firmly with the palm to compact the maximum amount into the tin. Strike off the top of the tin with a spatula or straightedge to create a level surface. Cover the sample.

Mix the remaining material on the splitting cloth as previously mixed, and again finish the mixing with the sample in a pile near the center of the cloth. Obtain a second sample using the same procedure as used to obtain the first sample.

Siphon 4 ± 0.1" (101.6 ± 2.5 mm) of calcium chloride solution into the graduated cylinder.

PROCEDURE

Record all information on SFN 51730. Record readings to 0.1.

The complete procedure will be run twice. The results of each test will be averaged. The average is reported as the sand equivalent.

Using a funnel, pour the sample from the tin into the cylinder. Tap the bottom of the cylinder sharply with the heel of the hand several times to remove air bubbles.

Allow the wetted specimen to stand undisturbed for 10 ± 1 minutes.

Stopper the cylinder and shake gently to loosen the material. This can be achieved by partially inverting the cylinder and shaking it simultaneously. After loosening the material, place the cylinder in a mechanical shaker for 45±1 seconds.

Following the shaking, set the cylinder upright and remove the stopper. Using the irrigation tube, rinse material on the cylinder wall down with the calcium chloride solution as the irrigation tube is being lowered in the cylinder. Force the irrigation tube through the material to the bottom of the cylinder using a gentle stabbing and twisting motion. Continue to gently stab and twist the irrigation tube until the calcium chloride solution approaches the 15" (381 mm) mark. Then raise the irrigation tube slowly at a rate that maintains the liquid level at about the 15" (381 mm) mark as the irrigation tube is being removed. Stop the flow of the calcium chloride solution just before the irrigation tube is entirely withdrawn. Adjust the calcium chloride solution level to 15".

Allow the cylinder to sit undisturbed for 20 minutes ± 15 seconds. Read the level of the top of the clay suspension. This is referred as the clay reading. If no clear line is visible, allow the sample to stand for up to 10 more minutes. If the line is still not clear, discard the sample and rerun the test with three samples from the same material. Read and record the clay column height requiring the shortest sedimentation period only.

Next determine the sand reading. This is done by gently lowering the weighted foot into the cylinder until it comes to rest. Take the reading of the extreme top edge of the indicator and subtract 10" from this value to obtain the sand reading. Record this as the sand reading.

Report the clay and sand readings to the nearest 0.1 of an inch. If the reading falls between the 0.1 of an inch graduations, report to the next higher reading.

Repeat this process for the second sample obtained and record the clay and sand readings.

CALCULATIONS

Calculate the sand equivalent by dividing the sand reading by the clay reading and multiply the results by 100. The equation is as follows:

Sand Equivalent = (Sand reading/Clay reading) x 100

Complete the calculations for both tests.

If the calculated sand equivalent is not a whole number, round up to the next higher whole number.

REPORT

Average the two test results. If the average is not a whole number, raise it to the next whole number.

NOTES

A one-gallon bottle of calcium chloride solution shall be placed on a shelf 36±1" above the work surface.

Prepare the calcium chloride solution by diluting one measuring tin (85 ± 5 mL) of stock calcium chloride to 1 gal. (3.8 L) of distilled or demineralized water. The working solution has a maximum shelf life of 30 days.

The temperature of the calcium chloride solution should be maintained at 72±5°F (22 ± 3°C).

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

AASHTO T 304 – UNCOMPACTED VOID CONTENT OF FINE AGGREGATE

Conduct this procedure according to AASHTO T 304, NDDOT Modified.

The test procedure states the uncompacted voids be reported to the nearest 0.1%. NDDOT modification is to report the uncompacted voids to the nearest whole number.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

The following describes “Method A”.

SCOPE

This method determines the loose uncompacted void content of a sample of fine aggregate. When measured on any aggregate of a known grading, uncompacted void content provides an indication of the aggregate’s angularity, spherical shape, and surface texture compared to other fine aggregates tested in the same grading.

This test is also referred to as the "Fine Aggregate Angularity Test."

REFERENCED DOCUMENTS

AASHTO T 2, Sampling of Aggregates
AASHTO T 11, Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing
AASHTO T 19, Bulk Density (Unit Weight) and Voids in Aggregate
AASHTO T 27, Sieve Analysis of Fine and Coarse Aggregate
AASHTO T 84, Specific Gravity and Absorption of Fine Aggregate
AASHTO T 248, Reducing Samples of Aggregate to Testing Size
AASHTO T 255, Total Evaporable Moisture Content of Aggregate by Drying

APPARATUS

Balance, accurate to 0.1 g
100 mL Cylinder
200 mL Funnel
Funnel stand, 3 or 4 legged
Glass plate, 60 x 60 mm by 4 mm thick
Grease
Pan, large enough to contain cylinder and funnel stand
Metal spatula with straight edge
Pans

TEST SPECIMEN

Obtain a sample of aggregate according to T 2. Thoroughly mix and reduce according to T 248.

Test specimen shall be a representative sample of approximately 1000 g of fine aggregate.

Wash the sample over a No. 100 or No. 200 sieve according to T 11. Dry the sample according to T 255. Perform a gradation according to T 27.

Remove the individual fractions as defined by table below. Place the material from each fraction into separate containers.

A 190-g sample is needed and portions retained from each individual sieve are combined in the following amounts:

Individual Size Fraction	Weight
No. 8 to No. 16	44 g
No. 16 to No. 30	57 g
No. 30 to No. 50	72 g
No. 50 to No. 100	17 g

PROCEDURE

All information is recorded on SFN 51701. Weights are recorded to the nearest 0.1 g.

The cylinder calibration procedure is included at the end of this procedure.

Thoroughly mix the 190-g sample with the spatula.

Weigh the empty cylinder and record as weight of cylinder.

Set up the funnel apparatus with a pan underneath to catch any loose aggregate. Place the empty cylinder under the funnel. Funnel must be 115 ± 2 mm (4.53 ± 0.08") above the top of the cylinder.

Hold your finger over the bottom of the funnel and pour the sample into the top. Level the material in the funnel with the metal spatula. Release your finger allowing the sample to flow into the cylinder.

Strike off the top of the cylinder by a rapid single pass with a straightedge.

The blade of the spatula must be vertical, keeping the edge horizontal and in light contact with the top of the measure. Brush away any loose material from the outside and weigh the cylinder plus aggregate.

Weigh and record as weight of cylinder plus aggregate.

Retain and recombine all material for the second trial. Repeat the procedure.

CALCULATIONS

The percent of uncompacted voids content of fine aggregate is calculated as follows:

Uncompacted Voids in Percent = [(V – (F/G)]/V x 100

V = Volume of calibrated cylinder in mL
F = Net weight of sample in cylinder, gross weight mass of empty cylinder
G = Bulk specific gravity, dry, as determined by T 84

Average the results of the two trials.

REPORT

Report the percentage of uncompacted voids to the nearest whole percent.

NOTES

After strike-off, the cylinder may be tapped lightly to compact the sample to make it easier to transfer the container to the balance without spilling any of the sample.

If the specific gravity of fine aggregate is not known, determine by T 84.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

CYLINDER CALIBRATION

Calibrate the cylinder according to T 304. Record the information on SFN 51729. Record the weights to the nearest 0.1 g. Use T 19 as a reference to determine the density of the water.
Apply a light coat of grease to the top edge of the dry, empty cylinder. Weigh the cylinder, grease, and glass strike-off plate. Record the weight.

Fill the cylinder with freshly boiled, deionized water cooled to a temperature of 64 to 75°F (18 to 24°C). Record the temperature of the water.

Slide the glass plate on the measure making sure no air bubbles remain. Dry the outside of the cylinder and weigh, including the strike-off plate. Record the weight.

The volume of the cylinder is calculated as follows:

$$V = 1000 \times (M/D)$$

V = Volume of cylinder, mL
M = Net mass of water, g
D = Density of water

Density of water is determined by using T 19. The following table can be used to determine the density of water.

Density of Water		
°F	°C	kg/m^3
60	15.6	999.01
65	18.3	998.54
70	21.1	997.97
73.4	23.0	997.54
75	23.9	997.32
80	26.7	996.59

Calculate volume to nearest 0.1 mL.

If the volume is greater than 100.0 mL, the upper edge may be ground until the volume is exactly 100.0 mL.

ASTM D 4791 – FLAT PARTICLES, ELONGATED PARTICLES, OR FLAT AND ELONGATED PARTICLES IN COARSE AGGREGATE

Conduct this procedure according to ASTM D 4791.

Consult the current edition of ASTM for procedure in its entirety and equipment specification details.

SCOPE

The test method covers the determination of the percentages of flat particles, elongated particles, or flat and elongated particles in coarse aggregate.

REFERENCED DOCUMENTS

AASHTO T 2, Sampling of Aggregates
AASHTO T 27, Sieve Analysis of Fine and Coarse Aggregate
AASHTO T 248, Reducing Samples of Aggregate to Testing Size
AASHTO T 255, Total Evaporable Moisture Content of Aggregate by Drying

APPARATUS

Balance
Pan
Proportional Caliper Device
Oven
Sieves: 1½" (37.5 mm), 1" (25.0 mm), 3/4" (19.0 mm),
1/2" (12.5 mm), and 3/8" (9.5 mm)

TEST SPECIMEN

Obtain sample according to T 2. Thoroughly mix and reduce according to T 248.

The following table is used to determine the initial sample size needed.

Nominal Max Size	Sample Size
3/8" (9.5 mm)	2 lbs (1 kg)
1/2" (12.5 mm)	4 lbs (2 kg)
3/4" (19.0 mm)	11 lbs (5 kg)
1" (25.0 mm)	22 lbs (10 kg)
1½" (37.5 mm)	33 lbs (15 kg)

PROCEDURE

Record the information on SFN 51700. All weights are recorded to the nearest 0.1 g.

Dry the sample according to T 255 at a temperature of 230 ± 9°F (110 ± 5°C). Weigh and record as weight of total sample.

Run a dry sieve analysis according to T 27. Discard material passing the 3/8" (9.5 mm) sieve. For each size sieve with at least 10% retained, reduce the sample according to T 248 until about 100 particles remain. Weigh and record.

If a sieve has less than 10% retained, do not test it.

Use the 5:1 setting on the proportional caliper device. Use the longest dimension of the particle to set the large gap on the device. Tighten the lever. If the particle can fit through the small gap, it is flat or elongated. Set aside all flat or elongated particles from each individual sieve size. Weigh and record each portion after the entire sample has been tested.

CALCULATIONS

To calculate for a single sieve, divide the weight of particles determined to be flat and elongated by the weight of the 100 particles then multiply the result by 100. The equation is as follows:

$$A = (B/C) \times 100$$

A = Percent flat and elongated particles
B = Weight of flat and elongated material
C = Total weight of sample on sieve

If a sieve has less than 10% retained, use the value for the next size larger or smaller sieve that retained 10%. If both a larger and smaller size retained 10%, use the average.

Refer to SFN 51700 for remainder of calculations.

REPORT

Report the results of flat or elongated particles to the nearest whole percent.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

NDDOT 4 - PERCENTAGE OF FRACTURED PARTICLES IN COARSE AGGREGATE

Conduct this procedure according to the standard defined by NDDOT.

SCOPE

This procedure determines the percentage of particles, which by visual inspection have a fractured face.

A fractured face is an area that is at least 25% of the largest cross section of the particle.

REFERENCED PROCEDURES

AASHTO T 2, Sampling Aggregates
AASHTO T248, Reducing Samples of Aggregate to Testing Size
AASHTO T 255, Total Evaporable Moisture Content of Aggregate by Drying

APPARATUS

Balance
No. 4 sieve
Spatula
Pan
Oven

TEST SPECIMEN

Obtain a sample according to T 2. Reduce the sample according to T 248. Final sample size needed is approximately 500 g.

Wash and dry according to T 255 at a temperature of 230 ± 9°F (110 ± 5°C). Sieve the sample over a No. 4 sieve. Test only material retained on the No. 4 sieve. This is considered the weight of the total sample. Discard the material that passes the No. 4 sieve.

PROCEDURE

Record all information on SFN 9987. All weights are recorded to the nearest 0.1 g.

Spread the sample on a clean flat surface large enough to permit the material to be spread thinly for careful inspection. Use the spatula or similar tool to separate the

material into three separate portions:

1. Fractured particles.
2. Questionable fractured particles.
3. Particles with no fractured faces.

The requirement of the fracture is dependent on the class of aggregate and the particles will have either one or two fractured faces.

Place each portion into individual pans. Weigh and record each portion.

CALCULATIONS

Percentage of particles with fractured faces is calculated according to the following formula:

Fractured Faces = [WF + (WQ/2)]/WA x 100

WF = Weight of fractured particles
WQ = Weight of questionable fractured particles
WA = Weight of total sample

REPORT

Report the percentage of particles with fractured faces to the nearest 1%.

NOTES

A fractured face may be natural or caused by a mechanical process.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

AASHTO T 84 – SPECIFIC GRAVITY AND ABSORPTION OF FINE AGGREGATE

Conduct this procedure according to AASHTO T 84, NDDOT Modified.

The standard test procedure uses a 500 mL pycnometer (flask) while the NDDOT uses a 1000 mL pycnometer. The standard test procedure uses a 1000 g sample which is soaked 15 to 19 hours. The NDDOT modification is to use an 1100 g sample which is soaked for 17±1 hours.

The standard test procedure specifies the aggregate is in a surface dry condition when the aggregate slumps slightly when the mold is removed. The NDDOT modification specifies that the aggregate is in a surface dry condition when the mold is removed and 25% to 75% of the top diameter of the surface slumps.

A glass cover plate is used with the pycnometer.

The standard test procedure specifies that the sample in the pycnometer may be immersed in circulating water to adjust its temperature to 73.4°±3°F (23±1.7°C). NDDOT requires placement of the sample in the pycnometer in a water bath for 60±15 minutes.

The standard procedure specifies that the calculated specific gravity be recorded to the hundredth and the calculated absorption to the tenth of a percent. The NDDOT modification is to record the calculated specific gravity to the thousandths and the calculated absorption to the hundredth of a percent.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

SCOPE

This test method covers the determination of the bulk specific gravity and the apparent specific gravity on the basis of mass of saturated surface dry aggregate and absorption of a fine aggregate sample. Fine aggregate is defined as material that passes the No. 4 sieve.

REFERENCED DOCUMENTS

AASHTO T 2, Sampling of Aggregates
AASHTO T 248, Reducing Samples of Aggregate to Testing Size
AASHTO T 255, Total Evaporable Moisture Content of Aggregate by Drying

APPARATUS

Balance
Pycnometer (flask) and glass cover plate
Metal mold in the form of a frustum of a cone
Metal tamper with a mass of 340±15 g and tamping face 25±3 mm in diameter
Pan
Spoon
Small fan
Temperature-controlled water bath
Sieves: No. 4 (4.75 m)
Oven

TEST SPECIMEN

Obtain sample according to T 2. Thoroughly mix and reduce to testing size according to T 248.

Test specimen shall be a representative sample of approximately 1100 g of material passing the No. 4 sieve.

FLASK CALIBRATION

Calibrate the flask by determining the weight of the flask full of distilled water at 73.4 ± 3°F (23 ± 1.7°C). Overfill the flask so the water is convexed above the brim. Very carefully slide a cover plate over the brim of the flask. The flask should be free of any air bubbles. Wipe any moisture on the outside of the flask and weigh the flask, water, and cover plate. Record this weight as weight of flask, cover plate, and water. Empty the flask and repeat the calibration. Repeated weights should agree within 0.2 g.

PROCEDURE

Record all information on SFN 2199. Weights are recorded to the nearest 0.1 g.

Dry the sample according to T 255, at a temperature of 230 ± 9°F (110 ± 5°C). Allow the sample to cool to a comfortable handling temperature.

Place the sample in a pan, cover with distilled water, and soak for 17±1 hours. After the soak period carefully remove excess water. Take care to avoid loss of any fines.

Spread the entire sample on a flat, non-absorbent surface and expose it to a gently moving current of warm air produced by the fan set at a low speed. Stir the sample frequently to obtain uniform drying.

The purpose of the slow, uniform drying is to bring the fines to a saturated surface dry condition. In this condition moisture fills the pores of each particle while the surface of the particle is dry. If non-uniform drying is allowed, the results may be in error because over-dried portions of the aggregate will not be saturated. Continue the process until the sample approaches a free flowing condition. It is intended the first trial of the cone test be made with some surface water in the sample.

Place the mold (large diameter down) on a smooth, level, firm, non-absorbent surface and fill with the partially dried material. Fill the cone to overflowing. Heap additional material above the top of the mold by holding the mold with cupped fingers and pouring material on top of the mold. Tamp the surface of the material in the mold 25 times with the tamper. Each drop of the tamper should start 0.2" (5 mm) above the top of the fine aggregate. Allow the tamper to fall freely during each drop. Adjust the starting height after each drop. Distribute the drop evenly over the entire surface.

Remove the material spilled around the mold and slowly lift the mold vertically.

If surface moisture is still present in the sample, the fine aggregate will retain the molded shape and additional drying is required. If the sample slumps on the first try, the material has dried past the saturated surface dry state. It is possible to get the fine aggregate too dry on the first attempt, but the test can be saved by adding a few mL of water to the sample, mixing it, covering, and allowing the sample to set for 30 minutes before rechecking. Only one recheck is permitted.

Test the tamped fine aggregate at frequent intervals until 25 to 75% of the top diameter of the cone slumps. At this point the material has reached the saturated surface dry condition. Immediately weigh out exactly 500 g of the saturated surface dry material for introduction into the flask.

Partially fill the flask with distilled water. Immediately introduce 500 g of the saturated surface dry material into the flask. Add distilled water until the neck of the flask is partially filled. Roll and agitate the flask to eliminate the air bubbles. Periodically stop agitating and rolling the flask to allow the air bubbles to rise to the top and be eliminated. Continue the agitating, rolling, and bubble elimination procedures until all the bubbles are eliminated. It normally takes about 15 to 20 minutes to eliminate the air bubbles.

Place the flask in a water bath at 73.4 ± 3°F (23 ± 1.7°C) for 60±15 minutes. To eliminate air bubbles, periodically remove the flask from the water bath, gently agitate it, and place it back in the water bath. All the air bubbles must be removed. This requires good technique and judgment. If the air bubbles are not completely removed, the results will be erratic. After the flask has been in the water bath for the specified time, remove.

After removal from the water bath, add distilled water to bring the level to the top of the flask. Overfill the flask so that the water is convexed over the brim and slide the glass cover plate along the brim. The flask should be free of any air bubbles. Wipe any moisture from the flask and weigh the flask, cover plate, sample and water. Record this weight as weight of flask, cover plate, sample, and water to top of flask.

Carefully pour the sample and the water into a tarred pan. Rinse the residue from the flask into the pan with a squeeze bottle. Oven dry the sample according to T 255 at a temperature of 230 ± 9°F (110 ± 5°C). Cover and allow the sample to cool to room temperature for 30 to 90 minutes. Weigh and record as weight of oven dry sample.

CALCULATIONS AND REPORTING

To calculate bulk specific gravity, divide the dry weight in air by the results of the flask filled with water plus weight of the saturated surface dry sample minus the weight of the flask with sample and water to top of flask. The equation is as follows:

Bulk Specific Gravity = A/(B + S - C)

A = weight of oven dry sample
B = weight of flask and cover plate filled with water
C = weight of flask, cover, sample and water to top of flask
S = weight of saturated surface dry sample (500 g)

Report the result to the 0.001.

To calculate bulk specific gravity (Saturated Surface Dry), divide the weight of saturated surface dry sample by the results of the flask filled with water plus weight of the saturated surface dry sample minus the weight of the flask with sample and water to top of flask. The equation is as follows:

Bulk Specific Gravity (Saturated Surface Dry) = S/(B + S - C)

Report the result to the 0.001.

To calculate apparent specific gravity, divide the weight of oven dry sample in air by the results of the flask filled with water plus weight of oven dry sample in air minus the weight of the flask with sample and water to top of flask. The equation is as follows:

Apparent Specific Gravity = A/(B+A-C)

Report the result to the 0.001.

To calculate absorption, subtract the weight of oven dry sample in air from the weight of saturated surface dry sample and divide the result by the weight of oven dry sample in air. Multiply this result by 100. The equation is as follows:

Absorption = [(S-A)/A] x 100

Report the result to the nearest 0.01%.

NOTES

Dipping the tip of a paper towel into the pycnometer has been found to be useful in dispersing the foam that sometimes builds up when eliminating the air bubbles.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

AASHTO T 85 – SPECIFIC GRAVITY AND ABSORPTION OF COARSE AGGREGATE

Conduct this procedure according to AASHTO T 85, NDDOT Modified.

The standard test procedure soaks the sample for 15 to 19 hours. The NDDOT modification is to soak the sample for 17±1 hours.

The standard procedure specifies that the calculated specific gravities be recorded to the hundredth and the calculated absorption be recorded to the tenth of a percent. The NDDOT modification is to record the calculated specific gravity to the thousandths and the calculated absorption to the hundredth of a percent.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

SCOPE

This test method for coarse aggregate covers the determination of bulk specific gravity, bulk specific gravity saturated surface dry, apparent specific gravity, and water absorption of coarse aggregates. Material retained on the No. 4 sieve and above is considered coarse.

REFERENCED DOCUMENTS

AASHTO T 2, Sampling of Aggregates
AASHTO T 27, Sieve Analysis of Fine and Coarse Aggregate
AASHTO T 248, Reducing Samples of Aggregate to Testing Size
AASHTO T 255, Total Evaporable Moisture Content of Aggregate by Drying

APPARATUS

Sample container, either a wire basket made with No. 6 wire or finer mesh, or a bucket

Balance, equipped with apparatus for suspending sample container

Suspended apparatus of the smallest practical size

Water tank with overflow outlet

Sieves: No. 4 (4.75 mm) or other sizes as needed

Oven

Thermometer

Absorbent towels

TEST SPECIMEN

Obtain sample according to T 2. Thoroughly mix and reduce according to T 248.

Determine sample size needed from the following table.

Nominal Maximum Size	Minimum Mass of Test Sample
1/2" (12.5 mm)	4 lbs (2 kg)
3/4" (19.0 mm)	7 lbs (3 kg)
1" (25.0 mm)	9 lbs (4 kg)
1½" (37.5 mm)	11 lbs (5 kg)
2" (50 mm)	18 lbs (8 kg)

PROCEDURE

Record all information on SFN 10081. All weights are recorded to the nearest 0.1 g.

Dry sieve all material on the No. 4 sieve. Discard all material passing the No. 4 sieve. Wash the remaining sample to remove any dust or other coatings from the surface.

Dry the sample according to T 255 at a temperature of 230 ± 9°F (110 ± 5°C). Then allow the sample to cool to a comfortable handling temperature. Immerse the aggregate in water at room temperature for a period of 17±1 hour.

Remove the sample from the water and roll in a large absorbent cloth until all visible films of water are removed. At this point the sample is in a saturated surface dry condition (SSD). Place the sample in a container. Weigh, and record as weight of saturated surface dry sample in air. Record to 0.1% of sample mass.

After weighing, place the saturated surface dry sample in the sample basket. Immerse in water that is at a temperature of 73.4 ± 3°F (23.0 ± 1.7°C). Take care to remove all entrapped air before weighing by shaking the basket while immersed. Determine the weight and record as weight of saturated sample in water.

Remove the sample from water and place in a pan.

Dry the sample according to T 255 at a temperature of 230 ± 9°F (110 ± 5°C). Allow the sample to cool until comfortable to handle. Weigh and record as weight of oven dry sample in air.

CALCULATIONS AND REPORTING

To calculate bulk specific gravity, divide the dry weight in air by the results of the saturated surface dry weight minus the weight in water. The equation is as follows:

Bulk Specific Gravity = A/(B - C)

A = Weight of oven dry sample in air
B = Weight of saturated surface dry sample in air
C = Weight of saturated sample in water

Report the result to 0.001.

To calculate bulk specific gravity SSD, divide the saturated surface dry weight by the results of the saturated surface dry weight minus the weight in water. The equation is as follows:

Bulk Specific Gravity SSD = B/(B - C)

Report the result to 0.001.

To calculate apparent specific gravity, divide the dry weight in air by the results of the dry weight in air minus the weight in water. The equation is as follows:

Apparent Specific Gravity = A/(A - C)

Report the result to 0.001.

To calculate absorption, subtract the weight of oven dry sample in air from the saturated surface dry sample in air and divide result by the weight of oven dry sample in air. Multiply this result by 100. The equation is as follows:

Absorption = [(B - A)/A] x 100

Report the result to the nearest 0.01%.

NOTES

If the sample is for use in concrete mixtures in which they will be used in their natural condition, the initial drying requirement is eliminated and if the surfaces have been kept continuously wet until the test, the soaking time may also be eliminated.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

AASHTO T 89 - DETERMINING THE LIQUID LIMIT OF SOILS

Conduct this procedure according to AASHTO T 89.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

The following describes Method B.

SCOPE

The liquid limit of a soil is the moisture content at which the soil passes from a plastic to a liquid state.

The numerical difference between the liquid limit and the plastic limit is the plasticity index.

REFERENCED DOCUMENTS

AASHTO T 87, Dry Preparation of Disturbed Soils and Soil-Aggregate Samples for Test
AASHTO T 265, Laboratory Determination of Moisture Content of Soils

APPARATUS

Mixing dish
Spatulas
Liquid limit device, manual or mechanical
Grooving tool*
Gauge for the liquid limit device
Moisture proof container with covers
Balance
Oven
Distilled water

*Either a flat or curved grooving tool may be used but interchanging grooving tools during testing is prohibited.

PROCEDURE

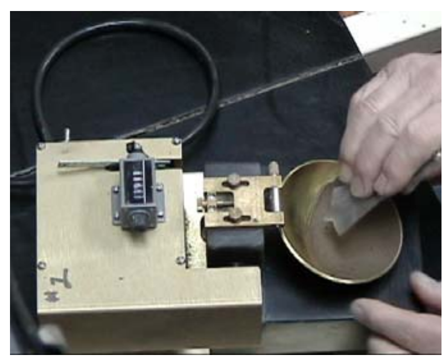
Take a sample of approximately 50 g from the thoroughly mixed portion of the 100 g obtained in accordance with T 87. The portion of the material used passes the No. 40 (0.425 mm) sieve.

Place the sample in the mixing dish and thoroughly mix with 8 to 10 mL of distilled water by alternately and repeatedly stirring, kneading, and chopping with a spatula. Add additional water in increments of 1 to 3 mL and thoroughly mix until a stiff uniform mass of soil and water is achieved.

Once testing begins, do not add additional dry soil to the moistened soil. Do not use the cup of the liquid limit device to mix the soil and water. If too much moisture has been added to the sample, the sample is to be discarded or mixed and kneaded until natural evaporation lowers the moisture content into an acceptable range.

After obtaining a uniform mass of soil and water, place a sufficient quantity of the mixture in the cup above the spot where the cup rests on the base. Squeeze and spread the mixture level with the spatula and at the same time trim the material to a depth of 10 mm at the point of maximum thickness. Use as few strokes of the spatula as possible. Use care to prevent the entrapment of air bubbles within the mass. Return the excess soil to the mixing dish and cover to retain the moisture in the sample.

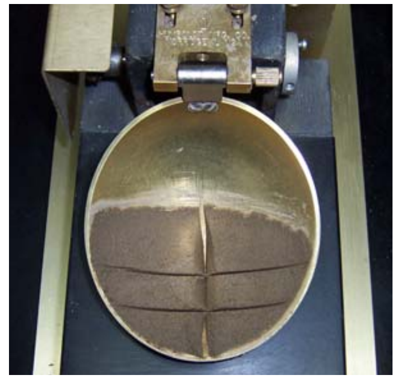
Divide the soil with a firm stroke of the grooving tool along the diameter through the centerline of the cam follower so that a clean, sharp groove is formed. Up to six strokes from the back to front are permitted to avoid tearing the sides of the groove or slipping of the soil cake on the cup. Increase the depth of the groove with each stroke and scrape the bottom of the cup with only the last stroke.



Lift and drop the cup containing the prepared sample by turning the crank at a rate of approximately two revolutions per second for 22 to 28 blows. If the two sides of the sample come in contact at the bottom of the groove along a distance of approximately 1/2" (13 mm) within 22 to 28 blows, stop and record the preliminary closure blow count.

Return the soil to the mixing dish, remix, and then repeat the procedure. If the second closure occurs in the acceptable range and is within two blows of the first, record the blow count and obtain a moisture content sample. This blow count will be used in the correction calculation.

If the two sides fail to come in contact at approximately 1/2" (13 mm) by 28 blows, return the soil to the mixing dish and add additional water in increments of 1 to 3 mL. If the sides come together at approximately 1/2" (13 mm) in less than 22 blows, the soil is too wet. Discard and start over with a new 50-g sample using less water or knead the sample until natural evaporation lowers the moisture content to an acceptable range.



Observe at least two groove closures before accepting the test results as the liquid limit. This is to ensure the accepted number of blows is truly characteristic of the soil under test.

When two groove closures have been achieved within the requirements of the test, obtain a moisture content sample.

To obtain the moisture content sample, remove a slice of soil approximately as wide as the spatula extending from edge to edge at right angles to the groove. Include that portion of the groove in which the material flowed together. Place in a suitable tared container and cover.

Weigh and record to the nearest 0.01 g.

Return the remaining soil to the mixing dish. Determine moisture content of the sample according to T 265.

CALCULATIONS

Calculate the percent moisture as follows:

A = [(B - C)/C] x 100

A = Percent moisture
B = Mass of original sample
C = Mass of dry sample

Calculate moisture to the nearest 0.1%.

The percent moisture is the liquid limit.

Upon completion of the calculation, a correction factor is applied to determine the liquid limit at 25 blows.

The correction factor uses the percent of moisture multiplied by a factor (k) of the second closure blow count. Calculation of the liquid limit is shown below the following table:

Number of Blows N	Factor for Liquid Limit k
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014

Liquid Limit, corrected for closure at 25 blows $= k \, x \, W_N$

k = Factor given in the table
W_N = Moisture content at number of blows

REPORT

Report the corrected liquid limit to the nearest whole number.

NOTES

If soil slides on the liquid limit cup surface instead of flows, return the sample to the mixing dish, add more water, re-mix and return to the cup. Cut with the grooving tool. If the sample continues to slide on the cup at less than 25 blows, the test is not applicable and a note should be made that the liquid limit cannot be determined.

The amount of time needed for a material to absorb the water will depend on the material being tested. Some soils are slow to absorb water and it is possible to add water so fast that a false liquid limit value is obtained.

Sandy or silty material may require less water than the initial amount of 8 to 10 mL of water, and increments of 1 to 3 mL.

CALIBRATION

Calibration is to be done annually as a minimum and whenever damage or repair is needed.

The center of the point of the cup, which comes in contact with the base, must be 10±2 mm, above the base. The gauge is used for this measurement. Secure the adjustment plate by tightening the screws. With the gauge in place, check the adjustment by revolving the crank rapidly several times. If the adjustment is correct, a slight ringing sound will be heard when the cam strikes the cam follower. If the cup is raised off the gauge or no sound is heard, further adjustment is necessary.

AASHTO T 90 – DETERMINING THE PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS

Conduct this procedure according to AASHTO T 90.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

SCOPE

The plastic limit of a soil is the lowest water content at which the soil remains plastic.

The plasticity index of a soil is the numerical difference between the liquid limit and the plastic limit. It is the moisture content at which the soil is in a plastic state.

REFERENCED DOCUMENTS

AASHTO T 87, Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test
AASHTO T 89, Determining the Liquid Limit of Soils
AASHTO T 265, Laboratory Determination of Moisture Content of Soils

APPARATUS

Mixing dish
Spatula
Ground glass plate or unglazed paper
Plastic Limit Rolling device with unglazed paper (optional)
Moisture proof sample cans (3 oz. capacity)
Balance
Oven
Distilled water

PROCEDURE

Record information on SFN 9987 or 10086.

Material passing the No. 40 (0.425 mm) sieve prepared according to T 87 is needed for this test.

If both the liquid and the plastic limits are required, take a test sample of approximately 8 g from the thoroughly wet and mixed portion of the soil prepared for T 89, the liquid limit. Take the sample at any stage the sample is plastic enough to be shaped into a ball without sticking to the fingers. Set aside and allow to air dry until completion of the liquid limit test. If the sample is too dry, add more water and re-mix.

If only the plastic limit is required, take a quantity of air-dried soil weighing about 20 g and mix with distilled or tap water in the mixing dish until the sample becomes plastic enough to be easily shaped into a ball. Use a portion of this ball that weighs approximately 8 g for the test sample.

Squeeze and form the 8-g test sample into an ellipsoidal-shaped mass. Sub-sample to 1.5 to 2 g portions and roll between the palm or fingers and the ground glass plate or piece of paper with sufficient pressure to roll the sample into a uniform thread about 1/8" in diameter throughout its length. Roll at a rate of 80 to 90 strokes per minute. A stroke is a complete forward and back motion, returning to the starting place. A plastic limit rolling device may also be used. The rolling procedure should be completed in two minutes.

When the diameter of the thread reaches 1/8", break the thread into six or eight pieces and squeeze the pieces together between the thumbs and fingers of both hands into a roughly uniform ellipsoidal shape and re-roll. Continue this procedure until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a thread. The crumbling may occur when the thread has a diameter greater than 1/8". This is considered a satisfactory end point provided that the soil has been previously rolled into a thread 1/8" in diameter.

Do not attempt to produce failure at exactly 1/8" in diameter by allowing the thread to reach 1/8", then reducing the rate of rolling or the hand pressure, or both, and continuing the rolling without further deformation until the thread falls apart. It is permissible to reduce the total amount of deformation for feeble plastic soils by making the initial diameter of the ellipsoidal shaped mass near the required 1/8" final diameter.

Gather the portion of the crumbled soil together and place in a container and cover.

Repeat this procedure until the entire 8-g specimen is completely tested. Weigh to the nearest 0.01 g and record. Determine the moisture content according to T 265.

CALCULATIONS

Calculate the percent moisture as follows:

$$A = [(B - C)/C] \times 100$$

A = Percent moisture
B = Mass of original sample
C = Mass of dry sample

Calculate moisture to the nearest 0.1%.

The percent moisture is the plastic limit.

REPORT

Report the plastic limit to the nearest whole number.

PLASTICITY INDEX CALCULATION

The plasticity index of soil is the difference between its liquid limit and its plastic limit.

Plasticity Index = Liquid Limit - Plastic Limit

REPORT

Report the plasticity index to the nearest whole number.

NOTES

Report the plastic limit as non plastic (NP) when the plastic limit is equal to or greater than the liquid limit, or when the liquid limit or plastic limit cannot be determined.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

NDDOT 3 – SHALE, IRON OXIDE PARTICLES, LIGNITE AND OTHER COAL, SOFT PARTICLES, THIN OR ELONGATED PIECES

Conduct this procedure according to the standard defined by the NDDOT.

SCOPE

This test method determines the amount of deleterious material retained on the No. 4 sieve.

Deleterious material may be shale, hard iron oxide particles, lignite and other coal, and thin or elongated pieces.

REFERENCED PROCEDURES

AASHTO T 2, Sampling Aggregates
AASHTO T 248, Reducing Samples of Aggregate to Testing Size
AASHTO T 255, Total Evaporable Moisture Content of Aggregate by Drying

APPARATUS

Balance
Sieves: 3/8" (9.5 mm) and No. 4 (4.75 mm)
Pans
Ball pin hammer
Plate
Oven

TEST SPECIMEN

Obtain sample according to T 2. Split sample according to T 248.

Test specimen shall be a representative sample of approximately 2500 g.

PROCEDURE

Record the information on SFN 2455. All weights are recorded to the nearest 0.1 g.

Wash and dry the sample according to T 255 at a temperature of 230±9°F (110±5°C). Material obtained in conjunction with other test procedures that has already been washed and dried may be used.

Stack the 3/8" and No. 4 sieves on a pan.

Place the sample in the stack of sieves and shake with the mechanical shaker until not more than 0.5% by weight of the total sample passes any sieve during one minute. Approximately 10 minutes will be sufficient for most materials.

Remove material retained on the 3/8" and No. 4 sieves and combine into one pan. Weigh and record as weight of Plus No. 4 fraction. Material passing the No. 4 sieve

can be discarded.

Hand pick the shale, hard iron oxide particles, lignite and other coal, and thin or elongated pieces and place in separate pans. Weigh each pan and record.

Check the remainder of the sample for soft particles. To determine if particles are soft, use a small 4 oz. ball pin hammer and a flat, non-deflecting plate. Take the hammer and strike each particle with a minimum amount of effort to see if it cracks on impact. A drop of 4" to 5" is sufficient. Place cracked material in container and weigh and record.

CALCULATIONS

Calculate the percentages of hand picked deleterious material by dividing that weight by the weight of the Plus No. 4 fraction and multiplying by 100. The equation is as follows:

$$A = (B/C) \times 100$$

A = Percent deleterious material
B = Combined hand picked portions
C = Weight of Plus No. 4 fraction

REPORT

Report the results to the nearest 0.1%.

NOTES

The 3/8" sieve is used to prevent overloading on the No. 4 sieve.

Thin or elongated pieces are defined as having a maximum thickness less than 1/4 the maximum width, or maximum length more than three times the maximum width.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

EXAMPLE GRADATION

AGGREGATE SAMPLE WORKSHEET

North Dakota Department of Transportation, Materials & Research

SFN 9987 (Rev. 07-2007)

PCN	15934
Laboratory No.	CA-229-07
Field Sample No.	OMG-112-07
Pit Location	NE1/4 28-128-56
Owner	Mahrer Pit
Project	HES-8-032(025)010
County	
Material/Specification	Cl-29
Date Received	10/16/2007
Date Sampled	10/3/2007
Sampled From	Belt
Submitted By	Scacher

(mm)	Ret.	Wt. Ret. Non-Cum.	Wt. Ret. Cum.	% Ret.	% Pass	ND Spec.
100	4"					
90	3 1/2"					
75	3"					
63	2 1/2"					
50	2"	0				
37.5	1 1/2"	0				
25.0	1"	0				
19.0	3/4"	0				
16.0	5/8"	0	0	0	100.0	100
12.5	1/2"	301.0	301.0	7.5	92.5	70 - 100
9.5	3/8"	384.5	685.5	17.0	83.0	
4.75	No. 4	628.0	1313.5	32.6	67.4	40 - 70
Minus No. 4		2707.5	[(4023-4021)/4023]100 = 0.05			
Wt.Check		4021.0				
Original Wt.		4023.0	OK			

AASHTO T-27 Tested By: ________

(mm)	Ret.	Wt. Ret. Non-Cum.	Wt. Ret. Cum.	% Ret.	% Pass	% Pass Tot. Smpl.	ND Spec.
2.36	No. 8	96.4	96.4	25.1	74.9	50.5	
2.00	No. 10	21.8	118.2	30.7	69.3	46.6	
1.18	No. 16	66.5	184.7	48.0	52.0	35.0	
600µm	No. 30	75.2	259.9	67.6	32.4	21.8	15-35
425µm	No. 40	35.9	295.8	77.0	23.0	15.5	
300µm	No. 50	22.3	318.1	82.8	17.2	11.6	
150µm	No. 100	25.1	343.2	89.3	10.7	7.2	
75µm	No. 200	9.7	352.9	91.8	8.2	5.52	2.0-7.0
Minus No. 200		1.1	[(384.4-384.2)/384.4]100 = 0.05				
Original Wt.		384.4					
Wt. After Wash		354.2	OK				
Wash Loss		30.2					
Wt.Check		384.2					

FRACTURED FACES

FF = Percentage of particles with fractured faces

WF = Weight of fractured particles	149.0
WQ = Wt. of questionable fract. particles	1.9
WA = Weight of total sample	152.0
FF = [WF + (WQ/2)]/WA X 100	
FF =	98.7
ND Spec	65.0

Tested By: ________ AASHTO T-27 Tested By: ________ AASHTO T-11 Tested By: ________

LIGHTWEIGHT PIECES

+ No. 4 Material

(A) % Retained on No.4 Sieve	=	32.6 %
(B) % Passing No. 30, Total Sample	=	21.8 %
(C) % Pass No. 4 – % Pass No. 30, [100–(A+B)]	=	45.5 %
(D) Total Sample A+B+C	=	100.0 %
(E) Weight of Lt Wt Pieces in + No. 4 Mtrl.	=	27 g
(F) Weight of + No. 4 Material	=	1313.5 g
(G) Lt Wt Pieces, + No. 4 Mtrl (E/F)x100	=	2.06 %
(H) Lt Wt Pieces, + No. 4 Mtrl., % of Total Sample (GxA)/100		0.67 %

– No. 4, + No. 30 Material

(I) Weight of Lt Wt Pieces, -No. 4, + No. 30 Mtrl.	=	8.9 g
(J) Weight of – No. 4, + No. 30 Material	=	259.9 g
(K) Lt Wt Pieces, – No. 4, + No. 30 (I/J)x100	=	3.42 %
(L) Lt Wt Pieces, – No. 4, + No. 30 Material % of Total Sample (KxC)/100	=	1.56 %
(M) Lightweight Pieces in Total Sample (H+L)	=	2.2 %

AASHTO T-113 Tested By: ________

* Attention Advised

Distribution:

☐ ____________ District

☐ Central Lab.

________ Date

________ Testing Lab Supervisor

Moisture Content Calculations

T 255 – Total Evaporable Moisture Content of Aggregates by Drying

Calculate the percent moisture:

$A = [(B - C)/C] \times 100$

A = Percent moisture

B = Mass of original sample

C = Mass of dry sample

Wet weight of sample and container	1229.9
Dry weight of sample and container	1181.4

Calculate the moisture

AGGREGATE SAMPLE WORKSHEET

North Dakota Department of Transportation, Materials & Research

SFN 9987 (Rev. 07-2007)

PCN	
Laboratory No.	CA-1-2012
Field Sample No.	
Pit Location	
Owner	
Project	5-094(001)090
County	Burleigh
Material/Specification	5
Date Received	6/1/2012
Date Sampled	5/30/2012
Sampled From	Windrow
Submitted By	

(mm)	Ret.	Wt. Ret. Non-Cum.	Wt. Ret. Cum.	% Ret.	% Pass	ND Spec.
100	4"					
90	3 1/2"					
75	3"					
63	2 1/2"					
50	2"					
37.5	1 1/2"					
25.0	1"	0				100
19.0	3/4"	271.0				90-100
16.0	5/8"	551.5				
12.5	1/2"	733.0				
9.5	3/8"	685.5				
4.75	No. 4	1666.0				35-70
Minus No. 4		7071.0				
Wt.Check						
Original Wt.		10983.5				

AASHTO T-27 Tested By: ________

FRACTURED FACES

FF = Percentage of particles with fractured faces

WF = Weight of fractured particles

WQ = Wt. of questionable fract. particles

WA = Weight of total sample

FF = [WF + (WQ/2)]/WA X 100

FF =

ND Spec

Tested By: ________

(mm)	Ret.	Wt. Ret. Non-Cum.	Wt. Ret. Cum.	% Ret.	% Pass	% Pass Tot. Smpl.	ND Spec.
2.36	No. 8	80.9					
2.00	No. 10	21.7					
1.18	No. 16	69.1					
600µm	No. 30	111.2					16-40
425µm	No. 40	53.9					
300µm	No. 50	30.2					
150µm	No. 100	24.3					
75µm	No. 200	21.6					4-10
Minus No. 200		4.8					
Original Wt.		443.7					
Wt. After Wash		417.4					
Wash Loss							
Wt.Check							

AASHTO T-27 Tested By: ________ AASHTO T-11 Tested By: ________

LIGHTWEIGHT PIECES

+ No. 4 Material			– No. 4, + No. 30 Material		
(A) % Retained on No.4 Sieve	=	%	(I) Weight of Lt Wt Pieces, -No. 4, + No. 30 Mtrl.	=	27.2 g
(B) % Passing No. 30, Total Sample	=	%	(J) Weight of – No. 4, + No. 30 Material	=	g
(C) % Pass No. 4 – % Pass No. 30, [100–(A+B)]	=	%	(K) Lt Wt Pieces, – No. 4, + No. 30 (I/J)x100	=	%
(D) Total Sample A+B+C	=	100.0 %	(L) Lt Wt Pieces, – No. 4, + No. 30 Material % of Total Sample (KxC)/100	=	%
(E) Weight of Lt Wt Pieces in + No. 4 Mtrl.	=	208.5 g			
(F) Weight of + No. 4 Material	=	g			
(G) Lt Wt Pieces, + No. 4 Mtrl (E/F)x100	=	%			
(H) Lt Wt Pieces, + No. 4 Mtrl., % of Total Sample (GxA)/100					%
			(M) Lightweight Pieces in Total Sample (H+L)	=	%

AASHTO T-113 Tested By: ________

* Attention Advised

Distribution:

☐ ____________________ District

☐ Central Lab.

________ Date

________ Testing Lab Supervisor

UNCOMPACTED VOID CONTENT OF FINE AGGREGATE CYLINDER CALIBRATION

North Dakota Department of Transportation, Materials & Research

SFN 51729 (Rev. 01-2009)

Reference AASHTO T19

Temperature

°F.	°C.	Kg/m^3
60	15.6	999.01
65	18.3	998.54
70	21.1	997.97
73.4	23.0	997.54
75	23.9	997.32
80	26.7	996.59
85	29.4	995.83

Calibration

Wt. Cylinder + grease + glass	= 194.9	g A
Wt. Cylinder + glass + water	= 297.3	g B
T_{water}	= 73.4	° F
Wt. water = B - A	=	g M
Density of water (Reference ASTM C29 or above)	= 997.54	Kg/m^3 D
Volume of cylinder = $\frac{1000M}{D}$	=	mL

AASHTO T-304

Calibrated by	
Date Calibrated	

UNCOMPACTED VOID CONTENT OF FINE AGGREGATE

North Dakota Department of Transportation, Materials & Research

SFN 51701 (Rev. 01-2008)

Project Aggregate Testing	PCN
District	Engineer
Contractor	Submitted By
Date Sampled	Material
Specification	Size or Class
Sample From	Field Sample Number

Pit Location

Sand	Gravel
Aggregate	Pit Owner

Sample Number	1	2	Average*
Dry bulk specific gravity (G)	2.585	2.585	
Volume of cylinder, mL (V)	102.7	102.7	
Weight of cylinder, gram (A)	149.9	149.9	
Wt. of cylinder + aggregate, gram (B)	304.8	304.9	
Wt. of aggregate, gram (F) = B - A			
Uncompacted void content $U = \frac{V - (F/G)}{V} \times 100$			

*round and report to whole number

AASHTO T 304, Method A Tested by ________

Sieve Size	Mass, gram
No. 16 (1.18 mm)	44
No. 30 (600 µm)	57
No. 50 (300 µm)	72
No. 100 (150 µm)	17
Total	190

SAND EQUIVALENT OF FINE AGGREGATE

North Dakota Department of Transportation, Materials & Research
SFN 51730 (Rev. 1-2009)

Project Aggregate Testing Class	PCN
District	Engineer
Contractor	Submitted By
Date Sampled	Material
Specification	Size or Class
Sample From	Field Sample Number

Pit Location

Sand	Gravel
Aggregate	Pit Owner

Sample Number	1	2	
Clay Reading[1] A	5.1	4.7	
Sand Reading[1] B	3.4	3.1	Average[2]
Sand Equivalent[2] $SE = \frac{B}{A}(100)$			

[1]Report to the nearest 0.1 in. If reading falls between 0.1 inch graduations, report the next higher reading.
[2]Report as a whole number. If the calculated value is not a whole number, report the next higher whole number.

AASHTO T176, Tested by ______________

FLAT OR ELONGATED PARTICLES IN COARSE AGGREGATE

North Dakota Department of Transportation, Materials & Research

SFN 51700 (Rev. 06-2013)

Project Aggregate Testing - Student	PCN
District	Engineer
Contractor	Submitted By
Date Sampled	Material
Specification	Size or Class
Sample From	Field Sample Number

Pit Location

Sand	Gravel
Aggregate	Pit Owner

Total Weight of Sample (B) (gram) including -9.5 mm (3/8") material						7210.5		
Sieve Size		Weight Retained	Percent* Retained	Weight (~100 particles)	Weight Flat/Elongated	Percent Flat/Elongated	(G) = A x F
Mm	In.	(A) (gram)	(C) = $\frac{A}{B}$ x 100	(D) (gram)	(E) (gram)	(F) = $\frac{E}{D}$ x 100	
37.5	1 1/2						
25.0	1	350.0					
19.0	3/4	1355.0		575.2	0		
12.5	1/2	1405.0		497.8	13.6		
9.5	3/8	1499.0		349.8	22.5		
(H) = Sum of (A)					I = Sum of (G)		
					Weighted Average = $\frac{I}{H}$		

*If the sieve has < 10% retained, do not test it. Use the value for the next size larger or smaller that has ≥ 10% retained. If both a larger and smaller size have ≥ 10% retained, use the average.

ASTM D 4791 Tested by ____________

FINE AGGREGATE SPECIFIC GRAVITY WORKSHEET

North Dakota Department of Transportation, Materials & Research

SFN 2199 (Rev.01-2009)

Pit Location	Laboratory Number Aggregate Testing
Owner	Project
Sampled From	PCN
Submitted By	Date Received

Weight of oven dry sample.	484.0 grams (A)
Weight of saturated surface dry sample in air.	500.0 grams
Weight of flask, cover plate, and water to top of flask.	1327.6 grams (B)
Weight of flask, cover plate, sample, and water to top of flask.	1636.6 grams (C)

Bulk Specific Gravity

$$\frac{A}{B + 500 - C} = \frac{\quad}{\quad + 500 - \quad} = \underline{\qquad} = \underline{\qquad}$$

Apparent Specific Gravity

$$\frac{A}{B + A - C} = \frac{\quad}{\quad + \quad - \quad} = \underline{\qquad} = \underline{\qquad}$$

Absorption

$$\frac{500 - A}{A} \times 100 = \frac{500 - \quad}{\quad} \times 100 = \underline{\qquad} \times 100 = \underline{\qquad}\ \%$$

Test T-84 Tested By: ______

Concrete Aggregate

Bulk Specific Gravity (saturated surface dry).

$$\frac{500}{B + 500 - C} = \frac{500}{\quad + 500 - \quad} = \underline{\qquad} = \underline{\qquad}$$

Test T-84 Tested By: ______

COARSE AGGREGATE SPECIFIC GRAVITY WORKSHEET
North Dakota Department of Transportation, Materials & Research
SFN 10081 (Rev. 01-2009)

Pit Location	Laboratory Number
Owner	Project Aggregate Testing
Sampled From	PCN
Submitted By	Date Received

Weight of oven dry sample in air.	1227.9	grams (A)
Weight of saturated surface dry sample in air.	1252.0	grams (B)
Weight of saturated sample in water.	781.6	grams (C)

Bulk Specific Gravity

$\frac{A}{B - C}$ = ____________ - ____________ = ____________ = ____________

Apparent Specific Gravity

$\frac{A}{A - C}$ = ____________ - ____________ = ____________ = ____________

Absorption

$\frac{B - A}{A}$ x 100 = ____________ x 100 = ____________ x 100 = ____________ %

Test T-85 Tested By: ______

Concrete Aggregate

Bulk Specific Gravity (saturated surface dry).

$\frac{B}{B - C}$ = ____________ - ____________ = ____________ = ____________

Test T-85 Tested By: ______

AGGREGATE SAMPLE WORKSHEET

Department of Transportation, Materials & Research
SFN 9987 (Rev. 07-2007)

PCN	
Laboratory No.	
Field Sample No.	
Pit Location	NE1/4 28-128-56
Owner	State of ND
Project	Class Worksheet
County	
Material/Specification	Superpave FAA 42
Date Received	7/7/13
Date Sampled	
Sampled From	
Submitted By	

Sieve Size		Wt. Ret.		% Ret.	% Pass.	ND Spec.		Failing Sieve
(mm)	(Inch)	Non-Cum.	Cum.			Lower	Upper	
100	4"							
90	3 ½"							
75	3"							
63	2 ½"							
50	2"							
37.5	1 ½"							
25	1"							
19	3/4"							
16	5/8"	0.0				100	100	
12.5	½"	329.2				90	100	
9.5	3/8"	512.4						
4.75	No. 4	1151.4				55	67	
Minus No. 4		3259.2						
Wt. Check								
Original Wt.		5264.3						

Sieve Size		Wt. Ret.		% Ret.	% Pass.	% Pass Tot Smpl	ND Spec.		Failing Sieve
(mm)	No.	Non-Cum.	Cum.				Lower	Upper	
2.36	8	126.8							
2	10	26.7							
1.18	16	66.5							
600 um	30	54.0					13	23	
425 um	40	18.8							
300 um	50	14.7							
150 um	100	15.4							
75 um	200	7.0					3.6	7.0	
Minus No. 200 (75 um)		1.0							
Original Wt.		361.4							
Wt. After Wash		330.7							
Wash Loss									
Wt. Check									

FRACTURED FACES

FF= % of Particles w/fractured faces	
WF= Weight of fractured particles	**196.1**
WQ= Wt of questionable fractured particles	**14.0**
WA= Weight of total sample	**242.0**
FF= (WF +WQ/2)/WA X 100	ND Spec 75%

LIGHTWEIGHT PIECES

+No. 4 (4.75mm) Material			- No. 4, + No. 30 Material		
(A) % Retained on No. 4 Sieve	=		(I) Weight of Lt. Wt. Pieces, -No. 4, + No. 30 Mtrl.	=	**8.9**
(B) % Passing No. 30, Total Sample	=				
(C) % Pass No. 4 - % Pass No. 30 [100-(A+B)]	=		(J) Weight of - No. 4, + No. 30 Material	=	
(D) Total Sample A+B+C	=		(K) Lt. Wt. Pieces, - No. 4, + No. 30 (I/J)x100	=	
(E) Wt. of Lt. Wt. Pieces in + No. 4 Mtrl.	=	**87.0**	(L) Lt. Wt. Pieces, - No. 4, + No. 30 Material % of Total Sample (KxC)/100	=	
(F) Weight of + No. 4 Material	=				
(G) Lt. Wt. Pieces, + 4 Mtrl (E/F)x100	=				
(H) Lt. Wt. Pieces, + No. 4 Mtrl., % of Total Sample (GxA)/100				=	ND Spec.
			(M) Lightweight Pieces in Total Sample (H+L)	=	5%

SAND EQUIVALENT OF FINE AGGREGATE

North Dakota Department of Transportation, Materials & Research

SFN 51730 (Rev. 1-2009)

Project Class Worksheet	PCN
District	Engineer
Contractor	Submitted By
Date Sampled	Material
Specification	Size or Class
Sample From	Field Sample Number

Pit Location

Sand	Gravel
Aggregate	Pit Owner

Sample Number	1	2	
Clay Reading[1] A	7.6	7.3	
Sand Reading[1] B	3.2	3.0	Average[2]
Sand Equivalent[2] $SE = \frac{B}{A}(100)$			

[1]Report to the nearest 0.1 in. If reading falls between 0.1 inch graduations, report the next higher reading.
[2]Report as a whole number. If the calculated value is not a whole number, report the next higher whole number.

AASHTO T176, Tested by ______________

CERTIFICATION

I hereby certify the attached supplemental specifications effective on October 1, 2013.

.

/S/ *18 July 2013*

Bob Fode, P.E., Director
Office of Project Development

Date:

302.04 C DEPOSITING AND LAYDOWN **PAGE 163** **03/01/13**

Insert the following at the end of Section 302.04 C:

The Contractor shall uniformly mix the aggregate placed in windrows before spreading.

302.04 D COMPACTION **PAGE 164** **5/20/11**

In Section 302.04 D delete the sentence “If geotextile fabric is specified, Section 709 will govern compaction requirements.” and insert the following, “If geotextile fabric is specified, Section 709 will govern compaction requirements for the first lift above the fabric.”

302.06 BASIS OF PAYMENT **PAGE 165** **10/17/08**

Delete the parenthesis around M Gal.

304.06 BASIS OF PAYMENT **PAGE 169** **2/20/09**

In Section 304.06 delete the phrase under Pay Unit “Ton or Cubic Yard” and insert “Square Yard”.

306.06 BASIS OF PAYMENT **PAGE 173** **10/17/08**

Delete the parenthesis around M Gal.

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400 BITUMINOUS PAVEMENT **PAGE 175** **10/21/11**
1/1/12
10/01/13

Insert the following in Section 421:

SECTION 421
MICRO SURFACING

421.01 DESCRIPTION.

Micro Surfacing is a thin overlay material which has properties based on a mixture of modified emulsified asphalt, mineral aggregate, water and additives which are proportioned, mixed and uniformly spread over a properly prepared surface.

421.02 MATERIALS.

The material shall meet the following:

Item	**Section**
Aggregates	816.04
Bitumen	818.03
Tack Coat	401.00

A. Modifier. Special quick-setting emulsifier agents shall be mixed into the asphalt emulsion. The emulsified asphalt shall be formulated so that a paving mixture is applied at a thickness of one inch with the relative humidity at 59% or less and the ambient air temperature at 75° F or higher, the material shall cure sufficiently to carry rolling traffic in one hour with no damage to the surface, as verified by the Engineer.

B. Water. The water shall be potable and shall be free of harmful soluble salts.

C. Additives. A liquid field control additive is introduced and blended with water to provide effective control of the required quick-set properties. This additive shall be made available by the chemical supplier or emulsion manufacturer and certified as being compatible with the mixture.

421.03 EQUIPMENT.

The equipment shall meet the following:

Item	**Section**
Truck Scales	151.07
Mixing Equipment	151.09 A
Proportioning Devices	151.09 B
Emulsion Pump	151.09 C
Spreading Equipment	151.09 D
Rut Box	151.09 E

Machine Calibration. Each mixing unit to be used in performance of the work shall be calibrated in the presence of the Engineer prior to construction, or previous calibration documentation covering the exact materials to be used may be acceptable provided they were made during that calendar year. The documentation shall include the individual calibration of each material at various settings, which can be related to the machine metering devices.

421.04 CONSTRUCTION REQUIREMENTS.

A. Mix Design. Before start of work, the Contractor shall submit a mix design covering the specific material to be used on the project. This design shall be performed by a qualified laboratory. Once the materials are approved, no substitution will be permitted unless first tested and approved by the laboratory preparing the mix design.

The qualified laboratory shall develop the job mix design and present certified test results for the Contractors approval. Compatibility of the aggregate and emulsion shall be certified by the emulsion manufacturer. All component material used in the mix design shall be representative of the material proposed by the Contractor for use on the project. The mix design will meet the following:

TEST	*ISSA TEST NO.	SPECIFICATION
Mix Time @ 77°F (25°C)	TB-113	Controllable to 120 Seconds Minimum
Wet Cohesion @ 30 Minutes Minimum (Set) @ 60 Minutes Minimum (Traffic)	TB-139	12 kg-cm Minimum 20 kg-cm or Near Spin Minimum
Wet Stripping	TB-114	Pass (90% Minimum)
Wet-Track Abrasion Loss One-hour Soak Six-day Soak	TB-100	50 g/ft2 (538 g/m^2) Maximum 75 g/ft2 (807 g/m^2) Maximum

Lateral Displacement Specific Gravity after 1,000 Cycles of 125 lb (56.71 kg)	TB-147	5% Maximum 2.10 Maximum
Excess Asphalt by LWT Sand Adhesion	TB-109	50 g/ft^2 (538 g/m^2) Maximum
Classification Compatibility	TB-144	11 Grade Points Minimum (AAA, BAA)

* International Slurry Surfacing Association (ISSA)

The percentage of each individual material required shall be shown in the laboratory report.

The Engineer will review the design mix, all Micro Surfacing materials and methods prior to use. The component materials shall be within the following limits.

Residual Asphalt -	5% to 9% by dry weight of aggregate
Mineral Additive -	0.5% to 3% by dry weight of aggregate
Modifier -	As required to provide specified properties
Field Control Additive -	As required to provide the specified properties
Water -	As required to produce consistency

B. Stockpile. The mineral aggregate shall be stockpiled according to Section 106.06. The mineral aggregate shall be screened prior to being weighed for job site delivery.

C. Test Strip. A 1000-foot long, one lane wide test strip shall be constructed for each machine used on the project. A test section shall be done at sunrise. The machines shall be compared for variances in surface texture and appearance. The Engineer may direct any such variations to be corrected prior to production application beginning.

The emulsion shall not exceed 122° F. Construction of the test strip shall be postponed until the emulsion temperature is less than 122° F.

A new test strip shall be constructed whenever the system used in the job mix changes or there is field evidence that the system is out of control. The system includes the following: emulsion, aggregate supplier, type of mineral filler, and the lay-down machine.

In place of construction of a test strip, the Contractor may submit evidence of successful construction of a test strip on another Department project using the same mix designs. The project must have been constructed in the same construction season. The system used for the test strip must be identical to all parts of the proposed system.

Normal traffic shall be carried on the test strip within one and one-half hours after application, without any damage occurring. The Engineer will inspect the completed test strip after 12 hours of traffic to determine if the mix design is acceptable. Full production may begin after the Engineer accepts a test strip. The Engineer shall approve the location of the test strip.

D. Weather Limitations. The material shall be spread only when the road surface and atmospheric temperatures are at least 45° F and rising and the weather is not rainy and there is no forecast of temperatures below 32° F within 48 hours from the time of placement of the mixture.

E. Traffic Control. Suitable methods shall be used by the Contractor to protect the microsurface from traffic until the new surface will support traffic without damage.

The Contractor shall furnish flag persons, pilot cars, signs, and lights according to Section 704.

On two-lane, two-way traffic highways, the Contractor shall provide additional flaggers and signs at each end of the operation and at all major intersections within the operation area. These flaggers and signs will be in addition to the flaggers used with the pilot car. The flaggers will be on the project during the application operation when a pilot car is being used. Flaggers and pilot car(s) shall not be bid separately, but shall be included in the price bid for other items.

On four-lane highways the additional flaggers will not be required.

F. Surface Preparation.

1. **General.** The area to be surfaced shall be thoroughly cleaned of vegetation, loose aggregate and soil, particularly soil that is bound to the surface. Manholes, valve boxes and other service entrances will be protected from the surfacing material.

2. **Tack Coat.** If required by the plans, the Contractor shall apply a tack coat. The tack coat shall be allowed to cure before the application of the micro surfacing.

G. Application.

1. **General**. The surface shall be pre-wetted by fogging with water ahead of the spreader box when required by local conditions. The rate of application of the fog spray shall be adjusted during the day to suit temperatures, surface texture, humidity and dryness of the pavement surface.

   The Micro Surfacing mixture shall be of the desired consistency upon leaving the mixer and no additional materials should be added. A sufficient amount of material shall be carried in all parts of the spreader at all times so that a complete coverage is obtained. Overloading of the spreader is not permitted. No lumping, balling, or unmixed aggregate shall be permitted.

   No streaks may be left in the finished surface. If excessive streaking develops, the job will be stopped until the contractor proves to the Engineer that the situation has been corrected.

   The spreader box shall be cleaned to be free of material buildup at the start of each work day. If material buildup begins to affect performance during operations, the Contractor shall stop operations and clean the spreader box.

2. **Joints.** No excessive buildup, uncovered areas or unsightly appearances shall be permitted on longitudinal or transverse joints. The Contractor shall provide suitable width spreading equipment to produce a minimum number of longitudinal joints throughout the project. When possible, longitudinal joints shall be placed on lane lines. Half passes and odd width passes will be used only in minimum amounts. If half passes are used, they shall not be the last pass of any paved areas.

3. **Mix Stability.** The Micro Surfacing mixture shall possess sufficient stability so that premature breaking of the material in the spreader box does not occur. The mixture shall be homogeneous during and following mixing and spreading. It shall be free of excess water or emulsion, free of segregation of the emulsion and free of segregation of aggregate fines from coarse aggregate.

4. **Hand Work.** Areas which cannot be reached with the mixing machine shall be surfaced using hand squeegees to provide complete and uniform coverage. The area to be hand worked shall be lightly dampened prior to mix placement. Care shall be exercised to leave no unsightly appearance from handwork.

   Handwork shall be smoothed with a burlap drag to remove all ridges and valleys and to match the surface of the machine placed material unless another method of finishing is approved by the Engineer. Handwork shall be completed at the time of the machine-applied application.

5. **Lines.** Care shall be taken to insure straight lines along curbs and shoulders. No runoff on these areas will be permitted. Lines at intersections will be kept straight to provide a neat appearance.

421.05 METHOD OF MEASUREMENT.

Aggregate for Micro Surfacing. The dry aggregate weight will be measured by the ton. Weight of any moisture determined from moisture tests conducted will be subtracted from the weight of the aggregate for the purpose of obtaining a dry aggregate weight. The aggregate will be accepted at the job location stockpile or when loading into the support units for delivery to the lay-down machine.

Asphalt Emulsion for Micro Surfacing. Asphalt emulsion measured by the gallon.

421.06 BASIS OF PAYMENT.

Pay Item	**Pay Unit**
Aggregate for Micro-Surfacing Type __	Ton
Asphalt Emulsion for Microsurfacing	Gal

This payment shall be full compensation for all labor, equipment, additives, modifiers, and material necessary to complete work.

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400 BITUMINOUS PAVEMENT **PAGE 175** **10/21/11**
1/1/12
10/01/13

Insert the following in Section 422:

SECTION 422
SLURRY SEAL

422.01 DESCRIPTION.

The slurry seal shall consist of a mixture of an approved emulsified asphalt, mineral aggregate, water, mineral filler, and specified additives which are proportioned, mixed and uniformly spread over a properly prepared surface. The completed slurry seal shall leave a homogeneous mat, adhere firmly to the prepared surface, and have a skid-resistant surface texture.

422.02 MATERIALS.

The material shall meet the following:

Item	**Section**
Aggregates	816.05
Bitumen	818.04
Tack Coat	401.00

A. **Water.** The water shall be potable and shall be free of harmful soluble salts.

B. **Additives** The liquid field control additive is introduced and blended with water to provide effective control of the required set properties. This additive shall be made available by the chemical supplier or emulsion manufacturer and certified as being compatible with the mixture.

The mix design shall include the minimum and maximum allowances for the liquid field control additive in the mix. The mix design shall include the Wet Cohesion test results of the mix at the maximum allowable liquid field control additive. The test results shall meet the following requirements:

*ISSA TEST NO.	DESCRIPTION	SPECIFICATION
ISSA TB-139 @ 80° F	Wet Cohesion at 30 Minutes Wet cohesion at 60 Minutes	12 kg-cm Minimum 20kg-cm Minimum

*International Slurry Surfacing Association (ISSA)

422.03 EQUIPMENT.

The equipment shall meet the following:

Item	**Section**
Truck Scales	151.07
Mixing Equipment	151.09 A
Proportioning Devices	151.09 B
Emulsion Pump	151.09 C
Spreading Equipment	151.09 D

Machine Calibration.

Each mixing unit to be used in performance of the work shall be calibrated in the presence of the Engineer prior to construction. The documentation shall include the individual calibration of each material at various settings, which can be related to the machine metering devices. No machine will be allowed to work on the project until the calibration has been completed and accepted.

To aid in the calibration of slurry machines, the laboratory shall also report the quantitative effects of moisture content on the unit weight of the aggregate (bulking effect) per AASHTO T 19, Rodding Procedure.

422.04 CONSTRUCTION REQUIREMENTS.

A. **Mix Design**. Before work begins, the Contractor shall submit a signed mix design covering the specific material to be used on the project. This mix design shall be performed by a laboratory qualified in designing emulsified asphalt slurry seal surfacing.

The qualified laboratory shall present certified test results for the Contractors approval. Once the materials are approved, no substitution will be permitted unless first tested and approved by the laboratory preparing the mix design.

Compatibility of the aggregate, emulsion, mineral filler, and other additives shall be verified by the mix design. All component material used in the mix design shall be representative of the material proposed by the Contractor for use on the project.

The mix design report must clearly show the minimum and maximum proportions of mineral fill, water, usage additive(s) and asphalt emulsion based on the dry weight of the aggregate.

The following table lists the required tests and mix specifications:

ISSA TEST NO.	DESCRIPTION	SPECIFICATION
ISSA TB-106	Slurry Seal Consistency	3 cm Maximum
ISSA TB-139 @ 77° F	Wet Cohesion at 30 Minutes (Set)	12 kg-cm Minimum

	Wet cohesion at 60 Minutes	20kg-cm Minimum
ISSA TB-109	Excess Asphalt by LWT Sand Adhesion	50 g/sq.ft. Maximum
ISSA TB-114	Wet Stripping	Pass (90% Minimum)
ISSA TB-100	Wet-Track Abrasion Loss, One-hour Soak	75 g/sq. ft.
ISSA TB-113	Mix Time*	Controllable to 180 Seconds Minimum

*The mixing test and set-time test should be performed at the highest temperatures expected during construction.

The Engineer will approve the mix design and all slurry sealing materials and methods prior to use. The component materials shall be within the following limits:

COMPONENT MATERIALS	LIMITS
Residual Asphalt	Type II: 8.0% to 13.5% Type III: 6.5% to 12% (By dry weight of aggregate)
Mineral Filler	0.5% to 2.0% (By dry weight of aggregate
Additives	As required to provide the specified properties and meet the wet cohesion requirements
Water	As required to produce consistency

B. Weather Limitations. The slurry seal shall not be applied if either the pavement or air temperature is below 50° F. and falling, but may be applied when both pavement and air temperatures are above 45° F. and rising. No slurry seal shall be applied when there is danger that the finished product will freeze before 24 hours. No slurry seal shall be applied when there is a weather forecast of rainfall or humidity greater than 75% within 48 hours of scheduled placement. The mixture shall not be applied when weather conditions prolong opening to traffic beyond a reasonable time.

C. Preparation of Surface.

1. **General.** The area to be surfaced shall be thoroughly cleaned of vegetation, loose aggregate and soil, particularly soil that is bound to the surface.

2. **Tack Coat.** If required by the plans, the Contractor shall apply a tack coat. The tack coat shall be allowed to cure before the application of the slurry seal.

D. Application

1. **General.** The surface shall be pre-wetted by fogging with water ahead of the spreader box when required by local conditions. The rate of application of the fog spray shall be adjusted during the day to suit temperatures, surface texture, humidity and dryness of the pavement surface.

The slurry seal coat mixture shall be of the desired consistency upon leaving the mixer and no additional materials should be added. A sufficient amount of material shall be carried in all parts of the spreader at all times so that a complete coverage is obtained. Overloading of the spreader shall be avoided. No lumping, balling, or unmixed aggregate shall be permitted.

No streaks may be left in the finished surface. If excessive streaking develops, the job will be stopped until the Contractor proves to the Engineer that the situation has been corrected.

All excess material shall be removed from the job site prior to opening the road.

The spreader box shall be cleaned to be free of material buildup at the start of each work day. If material buildup begins to affect performance during operations, the Contractor shall stop operations and clean the spreader box.

2. **Joints.** No excessive buildup, uncovered areas or unsightly appearances shall be permitted on longitudinal or transverse joints. The Contractor shall provide suitable width spreading equipment to produce a minimum number of longitudinal joints throughout the project. When possible, longitudinal joints shall be placed on lane. The longitudinal joint where two passes join shall be neat appearing, uniform and lapped. Half passes and odd width passes will be used only in minimum amounts. If half passes are used, they shall not be the last pass of any paved areas.

E. Mix Stability. The slurry seal coat mixture shall possess sufficient stability so that premature breaking of the material in the spreader box does not occur. The mixture shall be homogeneous during and following mixing and spreading. It shall be free of excess water or emulsion, free of segregation of the emulsion and free of segregation of aggregate fines from coarse aggregate.

F. Hand Work. Areas which cannot be reached with the mixing machine shall be surfaced using hand squeegees to provide complete and uniform coverage. The area to be hand worked shall be lightly dampened prior to mix placement.

Handwork shall be smoothed with a burlap drag to remove all ridges and valleys and to match the surface of the machine placed material unless another method of finishing is approved by the Engineer. Handwork shall be completed at the time of the machine-applied application.

G. Lines. Care shall be taken to insure straight lines along curbs and shoulders. No runoff on these areas will be permitted. Lines at intersections will be kept straight to provide a neat appearance.

H. Traffic Control. The Contractor shall furnish flag persons, pilot cars, signs, and lights according to Section 704.

On two-lane, two-way traffic highways, the Contractor shall provide additional flaggers and signs at each end of the operation and at all major intersections within the operation area. These flaggers and signs will be in addition to the flaggers used with the pilot car. The flaggers will be on the project during the application operation when a pilot car is being used. Flaggers and pilot car(s) shall not be bid separately, but shall be included in the price bid for other items.

On four-lane highways the additional flaggers will not be required.

422.05 METHOD OF MEASUREMENT.

Aggregate for Slurry Seal. The dry aggregate weight will be measured by the ton. Weight of any moisture determined from moisture tests conducted will be subtracted from the weight of the aggregate for the purpose of obtaining a dry aggregate weight. The aggregate will be accepted at the job location stockpile or when loading into the support units for delivery to the lay-down machine.

PAVEMENT DENSITY ADJUSTMENT OF UNIT BID PRICE PER LOT

Table1:

Superpave FAA 40-43 Class 27, 29	
Percent Payment	**Avg. Pavement Density**
1.00	≥ 91.0%
0.98	90.0% - 90.9%
0.95	89.5% - 89.9%
0.91	89.0% - 89.4%
0.85	88.5% - 88.9%
0.70	88.0% - 88.4%
**	< 88.0%

Table 2:

Superpave FAA 44-45 Class 31, 33	
Percent Payment	**Avg. Pavement Density**
1.00	≥ 92.0%***
0.98	91.0% - 91.9%
0.95	90.5% - 90.9%
0.91	90.0% - 90.4%
0.85	89.5% - 89.9%
0.70	89.0% - 89.4%
**	< 89.0%

**The Engineer will determine whether the material may remain in place. The Pay Factor for the material allowed to remain in place shall be 0.70.

The density of the field cores will be determined according to the Department's Field Sampling and Testing Manual.

***The minimum required density will be reduced by 1% for the bottom lift constructed on aggregate base and reclaimed or cold in place (CIP) recycled base courses. If the average density of the field cores is less than 91% of the daily average MTD the unit price of the hot bituminous pavement will be adjusted according to Table 1.

410.04 QUALITY CONTROL PLAN **PAGE 237** **10/17/08**

In Section 410.04 delete the phrase "Special Provision" in its entirety and insert the following "specification".

410.04 ENGINEER'S LABORATORY **PAGE 237** **3/01/13**

Delete the first and second sentences in Section 410.04 "Engineer's Laboratory" in its entirety and insert the following:

The Contractor shall provide an additional Type C laboratory and the testing equipment to be used during actual mix production by the Department's aggregate lab and asphalt mix tester.

410.04 A PIT OPERATIONS AND STOCKPILING OF AGGREGATE
PAGE 238 **2/20/09**

In Section 410.04 A delete the third paragraph starting with "The mix design will not" in its entirety and insert the following:

- The mix design will not be approved and mix production will not begin.

410.04 A.1 DEPARTMENT-DEVELOPED MIX DESIGN **PAGE 238** **1/1/12**

Delete the first sentence in Section 410.04 A.1 in its entirety and insert the following:

The Plans will specify when the Department will develop the mix design.

410.04 A.2 CONTRACTOR-DEVELOPED MIX DESIGN PAGE 238 1/1/12

Delete the first sentence in Section 410.04 A.2 in its entirety and insert the following:

The Contractor shall develop the mix design.

Insert the following Subsection after Section 410.04 A.2.b and change the existing Subsection c to Subsection d:

c. The mix design shall be submitted for approval a minimum seven days before the material is used.

410.05 C.2 CONTRACTOR CORING PAGE 250 2/20/09 10/15/10

In Section 410.05 C.2 in the first sentence of the first paragraph delete the phrase “one core” and insert the phrase “two cores”.

410.05 C.3 COMPACTION PAYMENT SCHEDULE PAGE 251 2/20/09 3/26/10

Delete Section 410.05 C.3 in its entirety and insert the following:

3. Compaction Payment Schedule.

Acceptance of mainline pavement placed on any production day will be based on the average density of the pavement compared to the daily average maximum theoretical density (MTD) determined for each lot of pavement placed. The average density of the field cores shall be at least 91.0% or 92.0% of the daily average MTD depending on the class of mix. If the average density of the field cores is less than specified for the daily average MTD, the unit price of the hot bituminous pavement will be adjusted according to the following tables:

PAVEMENT DENSITY ADJUSTMENT OF UNIT BID PRICE PER LOT

Table1:

Superpave FAA 40-43 Class 27, 29	
Percent Payment	**Avg. Pavement Density**
1.00	≥ 91.0%
0.98	90.0% - 90.9%
0.95	89.5% - 89.9%
0.91	89.0% - 89.4%
0.85	88.5% - 88.9%
0.70	88.0% - 88.4%
**	< 88.0%

Table 2:

Superpave FAA 44-45 Class 31, 33	
Percent Payment	**Avg. Pavement Density**
1.00	≥ 92.0%***
0.98	91.0% - 91.9%
0.95	90.5% - 90.9%
0.91	90.0% - 90.4%
0.85	89.5% - 89.9%
0.70	89.0% - 89.4%
**	< 89.0%

**The Engineer will determine whether the material may remain in place. The Pay Factor for the material allowed to remain in place shall be 0.70.

The density of the field cores will be determined according to the Department's Field Sampling and Testing Manual.

***The minimum required density will be reduced by 1% for the bottom lift constructed on aggregate base and reclaimed or cold in place (CIP) recycled base courses. If the average density of the field cores is less than 91% of the daily average MTD the unit price of the hot bituminous pavement will be adjusted according to Table 1.

411.03 A MILLING PAVEMENT SURFACE PAGE 254 2/20/09

In Section 411.03 A after the eighth paragraph add the following paragraph:

When the milled material is used in Recycled Asphalt Pavement (RAP), a maximum of 500 feet per area may be milled for the mix design. The Contractor shall place the pavement overlay within twenty one calendar days after the mix design is approved.

420.04 E PROTECTION OF TRAFFIC AND PRESERVATION OF THE SEAL COAT
PAGE 258 4/17/09
5/15/09

In the last sentence of the second paragraph in Section 420.04 E delete the word "bud" in its entirety and insert the following: "bid".

In Section 420.04 E after the fourth paragraph add the following paragraph:

When pavement marking according to section 762.04 is not specified; before sealing operations the Contractor shall install and remove spotting tabs according to section 762.04 D.1.e. The cost of the spotting tabs and their installation and removal shall be included in the price bid for other items.

550.04 G.1 GENERAL PAGE 269 10/21/11

In section 550.04 G.1 delete the sixth paragraph in its entirety, beginning with "Continuous rumble strips…"

550.04 I.2 TRANSVERSE CONTRACTION JOINTS PAGE 272 10/21/11

Delete the sixth paragraph of Section 550.04 I.2 starting with "Dowel baskets shall…" in its entirety and insert the following:

Dowel baskets shall be placed a minimum of 2000 feet ahead of the paving operation to allow adequate time to be properly inspected.

550.04 I.2 TRANSVERSABLE CONTRACTION JOINTS PAGE 273 10/17/08

Add the word "or" after "lithium grease," in the first sentence of the last paragraph starting with "A uniform coat".

D. Composite. Panels shall have a minimum thickness of 0.16 inches and shall be yellow or brick red in color throughout the panel. Panels shall have a minimum compressive strength of 25,000 PSI according to ASTM D 695. Panels shall have a minimum flexural strength of 25,000 PSI according to ASTM D 790. Panels shall have a minimum tensile strength of 11,500 according to ASTM D 638. The panels shall show no signs of deterioration or other defects from salt spray after 1,000 hours of exposure according to ASTM B 117. Panels shall have a maximum water absorption of 0.07% according to ASTM D 570.

802.01 F TESTS ON CONCRETE **PAGE 532** **10/15/10**

In Section 802.01 F.6 insert the following sentence “A correction factor of 0.92 for compressive strength shall be applied to 4x8 inch concrete cylinders.” following the second sentence in the first paragraph.

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816 AGGREGATES **PAGE 539** **10/21/11**
7/1/12

Insert the following in Section 816:

816.04 AGGREGATE FOR MICRO SURFACING.

A. General. The mineral aggregate used shall be of the type and grade specified below for Micro Surfacing. The aggregate shall be manufactured crushed stone such as granite, slag, limestone, or other high quality aggregate or combination thereof.

B. Sampling and Testing.

Sampling	AASHTO T 2
Reducing Sample to Test Size	AASHTO T 248
Sieve Analysis	AASHTO T 27

C. Gradation. The aggregate, including natural fines, shall meet the referenced gradation requirements when tested by AASHTO methods T 11.

SIEVE SIZE	TYPE II %PASSING	TYPE III %PASSING	STOCKPILE TOLERANCE
3/8”	100	100	-
#4	90 -100	70-90	± 5%
#8	65 – 90	45-70	±5%
#16	45 – 70	28-50	±5%
#30	30 – 50	19-34	±5%

#50	18 – 30	12-25	±4%
#100	10 – 21	7-18	±3%
#200	5 – 15	5-15	±2%

After the target gradation has been submitted (which is the gradation that the mix design is based on), then the percent passing each sieve shall not vary by more than the stockpile tolerance for each individual sieve and still remain within the gradation band.

The stockpile shall be approved for use based on five gradation tests according to AASHTO T 27. If the average of the five tests are within the gradation tolerances, then the materials will be approved for use. If the average of the five tests is not within the gradation tolerances, the contractor will be given the choice to either remove the material or blend other aggregate with the stockpiled material to bring it into specification. Materials used in blending must meet the quality tests before blending and must be blended in a manner to produce a consistent gradation. If blending is used, it will require that a new mix design be performed.

Screening shall be required at the stockpile prior to delivery to the paving machine to prevent having oversize material in the mix.

The Contractor shall perform a gradation test every 500 tons of material produced. The gradation tests shall include the sand equivalency test.

D. Deleterious Substances - To limit the permissible amount of clay-like fines in an aggregate, a sand equivalency of 60 or higher is required when tested by AASHTO T 176. The sand equivalency test shall be performed during the gradation tests during the production of the stockpile.

E. Soundness - The aggregate shall have a weighted loss of not more than 15% when the sodium sulfate test is used or not more than 20% when the magnesium sulfate test is used. Soundness shall be tested in accordance with AASHTO T 104. The soundness test shall be preformed and accepted before the production of the stockpile.

F. Hardness - The aggregate wear, from abrasion resistance, shall be a maximum of 35%, when using AASHTO T 96 test methods. The hardness test shall be preformed and accepted before the production of the stockpile.

G. Additives. A mineral additive shall be introduced to the mineral aggregate and may be any recognized brand of non air-entrained portland cement, fly ash or hydrated lime all free of lumps, or other approved mineral additive. It may be accepted upon visual inspection. The amount of mineral additive needed shall be determined by the laboratory mix design and will be considered as part of the material gradation Requirement. The mineral additive will not be paid for directly, but shall be incidental to the bid unit price of "Aggregate for Micro Surfacing".

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816 AGGREGATES **PAGE 539** **10/21/11**
7/1/12

Insert the following in Section 816:

816.05 AGGREGATE FOR SLURRY SEAL.

A. General. The mineral aggregate used shall be of the type and grade specified below for slurry seal coats. The aggregate shall be manufactured crushed stone such as granite, slag, limestone, or other high quality aggregate or combination thereof. To assure the material is totally crushed, 100 percent of the parent aggregate will be larger than the largest stone in the gradation to be used.

B. Sampling and Testing.

Sampling	AASHTO T 2
Reducing Sample to Test Size	AASHTO T 248
Sieve Analysis	AASHTO T 27

C. Gradation Requirements. The aggregate shall meet the referenced gradation requirements when tested by AASHTO methods T 11 and T 27. The job mix (target) gradation shall be within the band shown in the following table:

SIEVE SIZE	TYPE II %PASSING	TYPE III %PASSING	STOCKPILE TOLERANCE
3/8"	100	100	-
#4	90 -100	70-90	± 5%
#8	65 – 90	45-70	±5%
#16	45 – 70	28-50	±5%
#30	30 – 50	19-34	±5%
#50	18 – 30	12-25	±4%
#100	10 – 21	7-18	±3%
#200	5 – 15	5-15	±2%

After the target gradation has been submitted (which is the mix design's gradation basis) the percent passing each sieve shall not vary by more than the stockpile tolerance and still remain within the gradation band.

The stockpile shall be approved for use based on five gradation tests according to AASHTO T 27. If the average of the five tests is within the gradation tolerances then the material will be approved for use. If the average of the five tests is not within the gradation tolerances, the contractor will be given the choice to either remove the material or blend other aggregates with the stockpile material to bring it into specifications. Materials used in blending must meet the quality tests before blending and must be blended in a manner to produce a consistent gradation. This may require a new mix design. Screening shall be required at the stockpile to prevent having oversize materials in the mix.

The Contractor shall perform a gradation test every 500 tons of material produced. The gradation tests shall include the sand equivalency test.

D. Deleterious Substances. To limit the permissible amount of clay-like fines in an aggregate, a sand equivalency of 60 or higher is required when tested by AASHTO T 176. The sand equivalency test shall be performed during the gradation tests during the production of the stockpile.

E. Soundness. The aggregate shall have a weighted loss of not more than 15% when the sodium sulfate test is used or not more than 25% when the magnesium sulfate test is used. Soundness shall be tested once during production of stockpile, in accordance with AASHTO T 104. The soundness test shall be performed and accepted before the production of the stockpile.

F. Hardness. The aggregate wear, from abrasion resistance, shall be a maximum of 35%, when using AASHTO T 96. The abrasion test is to be run on the aggregate before it is crushed. The aggregate should meet approved polishing valves. The hardness test shall be performed and accepted before the production of the stockpile.

816.03 B SPECIFIC REQUIREMENTS **PAGE 543** **2/19/10** **10/15/10**

In Table II: Aggregates for Asphalt Mixes, Blotter, and Seal Coats in Section 816.03 B insert the following column between Class 41 and Class 42:

Sieve Size Percent Passing	Chip Seal
	41M
3”	
1-1/2”	
1-1/4”	
1”	
3/4”	
5/8”	
1/2”	
3/8”	100
No. 4	20-70
No. 8	0-17
No. 16	
No. 30	
No. 50	
No. 200	0-1.5
Shale[1]	8.0%
L. A. Abrasion[1]	40%
Plasticity Index[2]	
Fractured Faces[3]	50%
Crushed Fines[4]	

817.02 C PROCESSED VIRGIN AGGREGATE FOR BLEND **PAGE 546** **3/01/13**

Insert the following sentence at the end of the first paragraph:

Virgin aggregate shall be Class 5 Aggregate and meet the requirements in Section 816.

817.02 D PROCESSED VIRGIN AGGREGATE IN LIEU OF SALVAGED BASE

PAGE 547 5/15/09

In Section 817.02 D after the first sentence insert the following sentence:

The Contractor shall not substitute Class 5 Aggregate Base in lieu of Salvage Base without approval from the Engineer.

817.02 F BITUMINOUS COMBINED MATERIAL PAGE 547 2/18/11

In Section 817.02 F.2 delete the first sentence in its entirety and insert the following:

The Contractor may, at his option, combine stockpiled material containing bitumen with aggregate or salvaged concrete. Stockpiled material containing bitumen shall be incorporated at a rate of 30 percent minimum to 50 percent maximum by total weight with aggregate or recycled concrete, without the required extraction sampling and testing (either initial or routine as specified in Section 302.02 B).Total weight is the combined weight of the stockpiled material containing bitumen and aggregate or salvaged concrete.

In Section 817.02 F.3 delete the first sentence in its entirety and insert the following:

If existing bituminous material from the project is incorporated into the Salvaged Base, the bituminous material shall be incorporated at a rate of 30 percent minimum to 50 percent maximum by total weight, with aggregate or recycled concrete. Total weight is the combined weight of the bituminous material and aggregate or salvaged concrete.

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818 BITUMINOUS MATERIALS PAGE 548 10/21/11

Insert the following in Section 818:

818.03 BITUMINOUS MATERIALS FOR MICRO SURFACING.

A. Emulsified Asphalt. The emulsified asphalt shall be polymer or latex modified. The polymer material shall be milled or blended into the asphalt or emulsifier solution prior to the emulsification process. The latex shall be milled into the emulsion.

The emulsified asphalt and emulsified asphalt residue shall meet the requirements specified in AASHTO M 208 for CQS-1h. It shall pass all applicable storage and settlement tests and have a minimum residue after distillation of 62%. The cement mixing test will be waived for this emulsion.

B. Modifier. Special quick-setting emulsifier agents shall be milled into the asphalt emulsion.

C. Special Residue Properties. Distillation of residue will be at a temperature of 350° F for 20 minutes. Softening point of the residue shall be 135° F minimum, absolute viscosity shall be 8,000 poise minimum using the average of two bulbs with the methods of ASTM D 2171 and #13 Canon-Manning viscosity tubes.

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818 BITUMINOUS MATERIALS PAGE 548 10/21/11

Insert the following in Section 818:

818.04 BITUMINOUS MATERIALS FOR SLURRY SEAL.

Emulsified Asphalt. The emulsified asphalt shall conform to Grade CQS-1h as specified in AASHTO M 140 and AASHTO M 208. The cement mixing test is waived. The CQS-1h emulsified asphalt shall also meet the following:

Material	Test	Requirement
Emulsion	AASHTO T 59	60% Minimum Residue After Distillation
Emulsion Residue	AASHTO T 49	40-100 Penetration at 77 degrees F

818.02 E ANIONIC EMULSIFIED ASPHALT PAGE 549 2/20/09

In Section 818.02 E in the second table with the first column heading "Property" delete the fourth column labeled "HFRS 2P" in its entirety.

822.02 TESTING PAGE 555 2/19/10

Delete Section 822.02 C in its entirety.

Delete Section 822.02 D in its entirety.

830.02 D SMOOTH WALL STEEL PIPE CULVERT PAGE 560 2/18/11

Delete Section 830.02 B in its entirety and insert the following:

Smooth Wall Steel Pipe Culvert. Smooth wall steel pipe culvert shall be welded steel pipe of new material, meeting ASTM Specifications A 139, Grade B with a minimum yield strength of 35,000 psi. No hydrostatic testing will be performed. The following minimum wall thickness shall be used:

Diameter of Pipe	Minimum Wall Thickness Through Roadway Embankment
24 inches	0.312 inch
30 inches	0.406 inch
36 inches	0.469 inch
42 inches	0.500 inch
48 inches	0.563 inch
54 inches	0.656 inch
60 inches	0.719 inch
66 inches	0.813 inch
72 inches	0.875 inch

856.01 EROSION CONTROL FABRIC PAGE 573 2/20/09

In Section 856.01 in second sentence in the paragraph after Table 856-1 Erosion Control blanket delete the word "with" and insert the following word "within".

Properties	Minimum	Maximum
Total Solids, % by weight of compound	42	
% Reflectance in 72 hours (ASTM E 1347	65	
Loss of Water, kg/m^2 in 24 hours (ASTM C 156)		0.15
Loss of Water, kg/m^2 in 72 hours (ASTM C 156)		0.40
Setting Test, mL/100 mL in 72 hours		2
V.O.C. Content, g/L		350
Infrated Spectrum Vehicle	100% alpha-methylstyrene	

The Settling Test procedure is available at the Department's Materials and Research Division.

The shelf life of the product shall be six months from the date of manufacture.

Curing materials shall meet the following:

Liquid-Membrane-Forming Compounds,
White Pigmented, Type 2, Class B .... AASHTO M 148

D. Geotextile Fabric. The Geotextile fabric shall be a highly absorbent fabric made from a light colored, nonwoven material that weighs a minimum of 8 ounces per square yard.

SECTION 812
WATER

812.01 WATER.

Water used in mixing or curing concrete, cement-treated bases, lime-treated bases, and fly ash treated bases shall be clean and free of oil, acid, alkali, organic matter, and other substances damaging to the finished product. Water will be tested according to AASHTO T 26. Water known to be of potable quality may be used without testing. Where the source of water is relatively shallow, the intake shall be enclosed to exclude silt, mud, grass, or other foreign materials.

When water used for mixing with Portland Cement has a pH value less than 4.5 or more than 8.5, the water shall be tested by casting and testing mortar cubes according to AASHTO T 106. The seven-day compressive strengths shall equal at least 90 percent of the companion test specimens made using distilled water.

The water must also meet the autoclave expansion and time of setting tests criteria given in AASHTO T 26.

SECTION 816
AGGREGATES

816.01 FINE AGGREGATE FOR CONCRETE.

A. **General.** Fine aggregate for concrete shall meet AASHTO M 6 with the following changes:

1. **Gradation.** Fine aggregate shall meet the following:

Sieve Size	Percent Passing
3/8 Inch	100
No. 4	95-100
No. 16	45-80
No. 50	10-30
No. 100	0-10
No. 200	0-3

2. **Test Methods and Requirements.** Only the following tests from AASHTO M 6 will be used:

Test	Method	Requirements
Sampling	AASHTO T 2	
Reducing Sample to Test Size	AASHTO T 248	
Lightweight pieces in Aggregate	AASHTO T 113*	2% max.
Organic impurities	AASHTO T 21	Not darker than the reference std. color
Mortar-making properties	AASHTO T 71	
Sieve analysis	AASHTO T 27	
Soundness (sodium sulfate)	AASHTO T 104	10% max.
Material Passing No. 200 Sieve	AASHTO T 11	

*Oven-dry weights will be substituted for saturated surface-dry weights. The percentage of lightweight pieces will be based on the total sample submitted for testing. Lightweight pieces will be those with a specific gravity less than 1.95. The No. 30 sieve will be substituted for the No. 50 sieve. Agitate the sample by stirring for a period of 15 seconds. Allow the sample to settle for 30 seconds and decant. Perform this procedure until the specimen is free of floating pieces or a maximum of three times.

816.02 COARSE AGGREGATE FOR CONCRETE.

A. **General.** Coarse Aggregate shall consist of gravel, crushed gravel, crushed stone, or other approved inert materials of similar characteristics, or a combination thereof, meeting the following:

1. **Gradation.** The gradation shall meet the following:

Size No. and Percent Passing by Weight

Sieve Size	3	4	5
1-1/2 inch	100		
1 inch	95-100	100	
3/4 inch		90-100	100
1/2 inch	25-65		90-100
3/8 inch	15-55	20-55	40-70
No. 4	0-10	0-10	0-15
No. 8	0-5	0-5	0-5
No. 200 (Max)	1.0	1.0	1.0

2. **Test Methods and Requirements.**

	Test	Method	Requirements Max. Percent by Weight of the Plus No. 4 Fraction
a.	Shale	NDDOT Method**	0.7
b.	Iron Oxide Particles	NDDOT Method**	4.0*
c.	Lignite and Other Coal	NDDOT Method**	0.5
d.	Soft Particles Exclusive of a, b, c (Includes clay, and other friable material)	NDDOT Method**	2.5
e.	Thin or Elongated Pieces (maximum thickness less than 1/4 the maximum width, or maximum length more than three times the maximum width)	NDDOT Method**	15.0
f.	Material Passing No. 200 Sieve	AASHTO T 11	
g.	L.A. Abrasion	AASHTO T 96	40.0
h.	Soundness (Sodium Sulfate)	AASHTO T 104	12
i.	Sampling	AASHTO T 2	
j.	Reducing Sample to Test Size	AASHTO T 248	
k.	Sieve Analysis	AASHTO T 27	

***NOTE:** For spall repairs for concrete pavements and for bridge deck overlays, the maximum iron oxide particles shall be 2.0 percent.

**Field Sampling and Testing Manual

Coarse aggregate for use in concrete that is subjected to moisture, extended exposure to humid atmosphere, or contact with moist ground shall not contain any materials that are deleteriously reactive with the alkalies in the cement in a quantity sufficient to cause excessive expansion of mortar or concrete. If such materials are present in injurious quantities, the coarse aggregate may be used with a cement containing less than 0.6 percent alkalies calculated as sodium oxide or with the addition of a material that has been shown to prevent harmful expansion due to the alkali-aggregate reaction. The reactivity shall be determined according to the test methods specified in AASHTO M 80.

816.03 AGGREGATES FOR SURFACING, BASE, ASPHALT MIXES, BLOTTER, AND SEAL COATS.

A. **General.** The material shall consist of sound, durable particles of gravel or sand which may include limited quantities of fine soil particles as binding material. It shall be free of sod, roots, and other organic matter. The physical characteristics and quality of the materials shall be approved by the Engineer.

CLASS OF AGGREGATE AND SPECIFICATION LIMITS

B. **Specific Requirements**.

Table I: Aggregates for Subgrade Repair, Trench Backfill, Bases, and Surfacing

Sieve Size Percent Passing	Permeable Trench Backfill	Aggr. for Subgrade Repair[5]	Aggr. for Blended Base	Shldr. Aggr. Surface	Aggr. Base[5]	Permeable Base Aggr.	Temp. Traffic Surface Aggr.	Aggr. Surface
	2	3	3M	4	5	7	8	13
3”		100						
1-1/2”							100	
1-1/4”								
1”			100		100	100		100
3/4”	100	80-100	80-100	100	90-100	95-100		70-100
5/8”								
1/2”						85-100		
3/8”	50-95					60-90		
No. 4		35-85	35-85	35-85	35-70	15-25	35-80	38-75
No. 8						2-10		22-62
No. 10	0-15							
No. 16								
No. 30	0-4	20-50	20-50	10-50	16-40			12-45
No. 50								
No. 100								
No. 200		0-15	4-10	7-17	4-10	0-3		7-15
Shale[1]		12%	12%	15%	12%	8%	20%	12%
L. A. Abrasion[1]				50%	50%	40%		50%
Plasticity Index[2]								
Fractured Faces[3]				10%	10%	85%		10%

Footnotes for Tables I and II:

[1] Maximum Allowable Percentages.

[2] Maximum allowable unless range shown. N.P. = Non Plastic as per AASHTO T-90. Use material passing the No. 40 sieve (standard method). For Class 5 aggregate the maximum allowable Plasticity Index shall be determined from the following formula: Max. allowable PI for Class 5 = 10 - (% Passing No. 40 Sieve / 10)

[3] Minimum weight percentage allowable for the portion of the aggregate retained on a No. 4 sieve having at least 1 fractured face for Classes 4, 5, 13, 27, 29, 31, and 33, and at least 2 fractured faces for Class 7.

[4] Minimum percentage of material passing a No. 4 sieve that is composed of fractured material produced by a crushing process. The Contractor shall demonstrate that the crushing operation produces this result.

[5] Salvaged Base meeting the requirements of Section 302 and 817 may be substituted for Cl. 3 or Cl. 5 virgin aggregate, unless otherwise specified on the Plans.

816.03 B

Table II: Aggregates for Asphalt Mixes, Blotter, and Seal Coats

Sieve Size Percent Passing	Asphalt Hot Mix Low to High Quality				Chip Seal	Chip Seal	Chip Seal	Blotter Sand	Sand Seal
	27	29	31	33	41	42	43	44	45
3”									
1-1/2”									
1-1/4”									
1”									
3/4”									
5/8”	100	100	100	100				100	
1/2”	70-100	70-100	70-100	70-100					
3/8”					100	100	100		100
No. 4	40-70	40-70	40-70	40-70	20-70	20-70	20-70	90-100	85-100
No. 8					0-17	2-20	0-17		
No. 16									45-80
No. 30	15-35	15-35	15-35	15-35					
No. 50									10-30
No. 200	2.0-7.0	2.0-7.0	2.0-7.0	2.0-7.0	0-1.5	0-5	0-2	0-20	0-3
Shale[1]	5.0%	5.0%	5.0%	5.0%	8.0%	8.0%	8.0%		3.0%
L. A. Abrasion[1]	40%	40%	40%	40%	40%	40%	40%		
Plasticity Index[2]	3	3	N.P.	N.P.					
Fractured Faces[3]	55%	65%	75%	95%					
Crushed Fines[4]	10%	40%	60%	80%					

Footnotes for Tables I and II:

[1] Maximum Allowable Percentages.

[2] Maximum allowable unless range shown. N.P. = Non Plastic as per AASHTO T-90. Use material passing the No. 40 sieve (standard method). For Class 5 aggregate the maximum allowable Plasticity Index shall be determined from the following formula: Max. allowable PI for Class 5 = 10 - (% Passing No. 40 Sieve / 10)

[3] Minimum weight percentage allowable for the portion of the aggregate retained on a No. 4 sieve having at least 1 fractured face for Classes 4, 5, 13, 27, 29, 31, and 33, and at least 2 fractured faces for Class 7.

[4] Minimum percentage of material passing a No. 4 sieve that is composed of fractured material produced by a crushing process. The Contractor shall demonstrate that the crushing operation produces this result.

[5] Salvaged Base meeting the requirements of Section 302 and 817 may be substituted for Cl. 3 or Cl. 5 virgin aggregate, unless otherwise specified on the Plans.

Asphalt Mix Tests

QC/QA Asphalt Mix Tests

- Asphalt mix tests are run on the asphalt mix that has been sampled from the roadway
- Or during mix design process

QC/QA Asphalt Mix Tests

- Majority of asphalt paving projects are QC/QA
  - Quality Control (Q/C) – Contractor
  - Quality Assurance (Q/A) – Engineer
    - *may also be called Verification Testing*
  - Independent Assurance (IA) – District
  - Dispute Resolution – Materials and Research

QC/QA Asphalt Mix Tests

- Sampling and Testing requirements are found in:
  - Spec Book (Section 410)
  - Field Sampling and Testing Manual (Section 400 and Appendices)

QC/QA Asphalt Mix Tests

- Specifications for Asphalt Mix Tests
  - Based on mix design parameters
  - Daily averages
  - Average density of all cores

QC/QA Asphalt Mix Tests

- Contractor test results (QC) are used
  - Engineer (QA) tests are a “check”
  - District/Independent Assurance also a “check”
- Engineer (QA) runs tests on independent sample
  - Unless the sample is a split sample

QC/QA Asphalt Mix Tests

- QC – Contractor has test tolerance tables for allowable working range *(Spec Book, 410, Table 6)*
- QA/Engineer has different Tolerance Tables for test tolerances with Contractor tests *(Field Sampling Manual, 410)*
- IA/District has Tolerance Table for correlation test results to compare to QC *(Spec Book, 410 Table 7, and Field Sampling Manual)*
  - Tolerances are different for each

Asphalt Sampling and Reducing

QC/QA Asphalt Mix Tests

- Engineer determines when and where samples are to be taken
- Sampling location and times are determined by using random numbers

Random Sampling

TABLE OF RANDOM NUMBERS WITH EXAMPLES

0.76	0.52	0.01	0.35	0.86	0.34	0.67	0.35	0.48	0.76	0.80	0.95	0.90	0.91	0.17
0.64	0.89	0.47	0.42	0.96	0.24	0.80	0.52	0.40	0.37	0.20	0.63	0.61	0.04	0.02
0.19	0.64	0.50	0.93	0.03	0.23	0.20	0.90	0.25	0.60	0.15	0.95	0.33	0.47	0.64
0.09	0.37	0.67	0.07	0.15	0.38	0.31	0.13	0.11	0.65	0.88	0.67	0.67	0.43	0.97
0.80	0.15	0.73	0.61	0.47	0.64	0.03	0.23	0.66	0.53	0.98	0.95	0.11	0.68	0.77
0.34	0.07	0.27	0.68	0.50	0.36	0.69	0.73	0.61	0.70	0.65	0.81	0.33	0.98	0.85
0.45	0.57	0.18	0.24	0.06	0.35	0.30	0.34	0.26	0.14	0.86	0.79	0.90	0.74	0.39
0.02	0.05	0.16	0.56	0.92	0.68	0.66	0.57	0.48	0.18	0.73	0.05	0.38	0.52	0.47
0.05	0.32	0.54	0.70	0.48	0.90	0.55	0.35	0.75	0.48	0.28	0.46	0.82	0.87	0.09
0.03	0.52	0.96	0.47	0.78	0.35	0.80	0.83	0.42	0.82	0.60	0.93	0.52	0.03	0.44

NDDOT 5 Sampling and Reducing Asphalt Mix

- Asphalt mix is sampled from behind the paver
  - Sampled In-place
  - Approximately 72 pound sample needed
    - Approximately two buckets

NDDOT 5 Sampling and Reducing Asphalt Mix

- Asphalt mix is reduced by quartering
  - One quarter is used for RICE test
  - Opposite quarter is used for a gyratory specimen
    - Second gyratory specimen is made use either remaining quarter
    - Remaining quarter held for any needed re-test
    - Must be held until QA tests are complete

NDDOT 5 Sampling and Reducing Asphalt Mix

- The contractor obtains his own sample
- The Engineer obtains an independent sample
  - Unless the sample is a split sample

Video- no audio

NDDOT 5 Sampling and Reducing Asphalt Mix

- Review Procedure

Asphalt Mix Tests

T 166 Bulk Specific Gravity Of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens

- Test specimens may be either laboratory molded or cores taken from HMA pavements.
- Referenced to as Bulk Specific Gravity (mix)
- Nomenclature is G_{mb}
- Recorded to 0.001

T 166 Bulk Specific Gravity Of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens

- If sample is cored specimen it must be dried to constant weight before testing
  - May obtain wet weight first and record – then dry to constant

T 166 Bulk Specific Gravity Of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens

- Constant weight for T 166 is defined as when further drying does not change the weight by more than 0.05% at two-hour intervals.

T 166 Bulk Specific Gravity Of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens

- Use a balance with basket/cages suspended in water
- Water bath must have overflow
- Water temperature is 77±1.8°F

Video – no audio

T 166 Bulk Specific Gravity Of Compacted Asphalt Mixtures Using Saturated Surface-dry Specimens

- Review Procedure
- Complete worksheets - SFN 50289

T 209 - Theoretical Maximum Specific Gravity And Density Of Hot Mix Asphalt

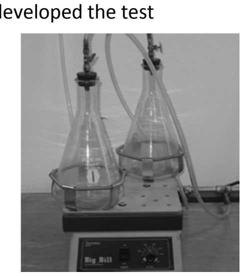
- This test determines the theoretical maximum specific gravity and density of uncompacted asphalt paving mixtures at 77°F (25°C).
- Referred to as “maximum specific gravity”
- Nomenclature is G_{mm}

T 209 - Theoretical Maximum Specific Gravity And Density Of Hot Mix Asphalt

- Test may be ran on laboratory mix or from mix obtained from behind the paver
- Cure laboratory prepared samples
- Cure time is not needed for plant produced mix
  - Absorption takes place during production

T 209 - Theoretical Maximum Specific Gravity And Density Of Hot Mix Asphalt

- Often referred to as “RICE” test
- Named after James Rice, who developed the test procedure
- Two tests ran
- Tests must be within 0.011
  - Results averaged



T 209 - Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt

- The theoretical maximum specific gravity (G_{mm}) of a HMA mixture is the specific gravity excluding air voids.
- The theory is that if all the air voids were eliminated from an asphalt mix sample, the combined specific gravity of the remaining aggregate and asphalt binder would be the theoretical maximum specific gravity – **zero air voids.**

T 209 - Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt

- Theoretical maximum specific gravity can be multiplied by the density of water (62.4 lb/ft^3 or 1000 g/L) to obtain a theoretical maximum density (TMD) or "Rice" density.

T 209 - Theoretical Maximum Specific Gravity And Density Of Hot Mix Asphalt

- Theoretical maximum specific gravity is a critical asphalt mix characteristic because it is used to calculate percent air voids in compacted asphalt mix.
- This calculation is used both in Superpave mix design and determination of in-place air voids in the field.
- *Definition from: www.pavementinteractive.org*

T 209 - Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt

- A measure of bulk specific gravity is made by coring the pavement, and determining bulk specific gravity on the core and then comparing the results to the most current theoretical maximum specific gravity (Rice) test results.
- The calculation determines the air voids of the in-place asphalt mix

Video – no audio

T 209 - Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt

- Review Procedure
- Complete worksheets SFN 50289
  - SFN 50289 also has a calculation for Air Voids

T 312 - Preparing And Determining Density Of Hot Mix Asphalt (HMA) Specimens By Means Of The Superpave Gyratory Compactor

This test is used to prepare specimens for determining the mechanical and volumetric properties of Hot Mix Asphalt (HMA) using the Superpave gyratory compactor.

The specimens simulate the density, aggregate orientation, and structural characteristics obtained in the actual roadway when proper construction procedure is used in the placement paving mix.

T 312 - Preparing And Determining Density Of Hot Mix Asphalt (HMA) Specimens By Means Of The Superpave Gyratory Compactor

- Approximately 4700 grams of loose asphalt mix is needed for each plug
  - One quarter of sample from behind paver
- Two plugs are made

T 312 - Preparing And Determining Density Of Hot Mix Asphalt (HMA) Specimens By Means Of The Superpave Gyratory Compactor

- Heat asphalt mix to 270±5°F
- Heat mold, base plate, funnel and spoon to prevent mix from sticking
- Use filter paper on top and bottom of mix in mold
- Plug height must be 115±5 mm

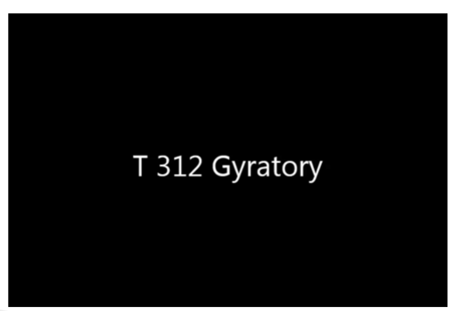
T 312 - Preparing And Determining Density Of Hot Mix Asphalt (HMA) Specimens By Means Of The Superpave Gyratory Compactor

- Take care when removing the plug from the mold
- Cool if necessary
- Each plugs is then tested using T 166 -Bulk Specific Gravity Of Compacted Asphalt Mixtures Using Saturated Surface-dry Specimens.

T 312 - Preparing And Determining Density Of Hot Mix Asphalt (HMA) Specimens By Means Of The Superpave Gyratory Compactor

- There are a number of models of gyratory compactors available

Video- no audio



NDDOT 2 - Contractor Coring

- Review Procedure

NDDOT 2 - Contractor Coring

- Contractor core information, location, time, results of T 166 are recorded on SFN 10071
- Average of each set of cores is transferred to SFN 59132
  - Average density of cores is basis for payment (Supplemental Specification)
  - Core density average is compared to average of RICE/Maximum Theoretical Density tests 410.05 C.3

Liquid Asphalt Sampling

NDDOT 1 - Sampling Of Bituminous Materials

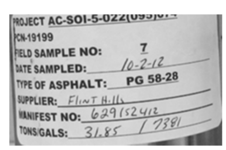
- Contractor sampling of liquid asphalt
  - *PG Sampling also described in Appendix 400-E*
- Samples obtained by Contractor under observation of Engineer

NDDOT 1 - Sampling Of Bituminous Materials

- PG Asphalt: A sample is defined as two one-liter metal, screw top containers filled with asphalt.
  - Randomly obtain two one-liter samples of asphalt from each 250 tons for each supplier
  - For each grade of asphalt

NDDOT 1 - Sampling Of Bituminous Materials

- Proper Labeling includes:
- Refer to NDDOT 1



T 312 - Preparing And Determining Density Of Hot Mix Asphalt (HMA) Specimens By Means Of The Superpave Gyratory Compactor

- Review Procedure
- The gyratory specimens are tested by T 166
- Information from T 166 is recorded on SFN 50289

Coring

NDDOT 2 - Contractor Coring

- Density of in-place asphalt mix is determined by "coring"
  - Coring is cutting cores from the mat

NDDOT 2 - Contractor Coring

- Contractor cuts the cores under observation of Engineer
  - Core location is determined by the Engineer using random numbers
    - The frequency is determined by the number of sublots paved
  - Reference – Spec Book 410.05.C.2

NDDOT 2 - Contractor Coring

- One set of (two) cores from each location are taken
  - After cores are cut they are sawed to represent the lift paved and given to the Engineer (QA field lab) for testing
  - One additional full depth core per mile - is cut for the Materials Coordinator for Independent testing
    - Additional core is only needed on projects located on the National Highway System

NDDOT 2 - Contractor Coring

- Extra (third) core taken is given to Materials Coordinator
    - Core is not sawed by Contractor
  - T 166 Bulk Specific Gravity test is performed

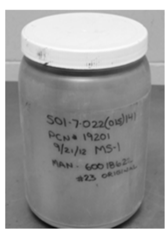
NDDOT 1 - Sampling Of Bituminous Materials

- This style of can should be used for PG samples:
- Cone-top quart size
- Approximate dimensions are:
  - 3.5 inches by 6.25

NDDOT 1 - Sampling Of Bituminous Materials

NDDOT 1 - Sampling Of Bituminous Materials

- Emulsion Sample:
- Two ***one-half gallon*** plastic containers
  - This will be a change to the printed version of NDDOT 1



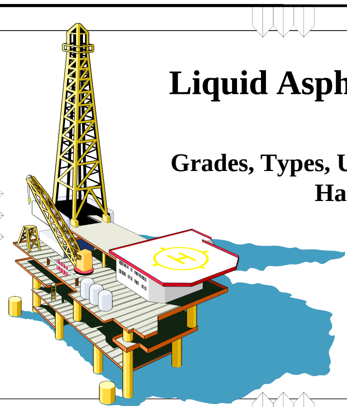
Common Terminology

Asphalt Paving Terminology

- Lot - one day's placement of pavement, one paver width wide (410.05 C.1)
- Sublot - 2,000 foot portion of lot
  - If a partial sublot at the end of the day's production is less than 1,000, The Engineer will include it in the last complete sublot.
  - The Engineer will consider a partial sublot greater than 1,000 feet a separate sublot.

- For all worksheets or forms:
  - **Sign**
  - **Date**

    If any corrections or change are made – sign/date – or make notation on electronic forms



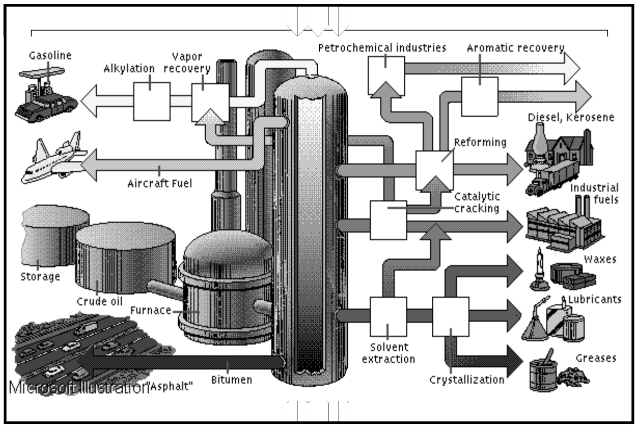
Liquid Asphalt Materials

Grades, Types, Usage, Storing and Handling

Asphalt - Definition:

"A dark brown to black cementitious material in which the predominating constituents are bitumens which occur in nature or are obtained in petroleum processing."

(ASTM D8)

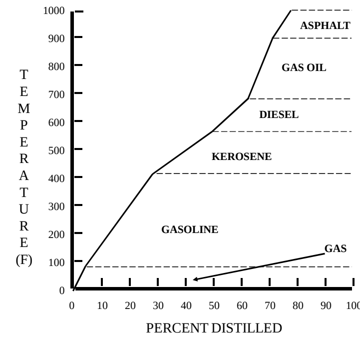


Asphalt Types

- **Natural asphalt deposits**
  - Natural evaporation of volatile portions of petroleum leaving the asphalt fractions
  - Lake asphalt
    - Trinidad
    - Bermudez
  - Rock asphalt
    - Natural asphalt deposits in porous rock

Asphalt Types

- **Petroleum asphalt**
  - Produced through the process of distillation of crude petroleum
    - Accomplished by raising the temperature of the crude in stages
    - Different fractions separate at various temperatures
    - Lighter fractions - Simple distillation
    - Heavy distillates - Vacuum distillation, solvent extraction

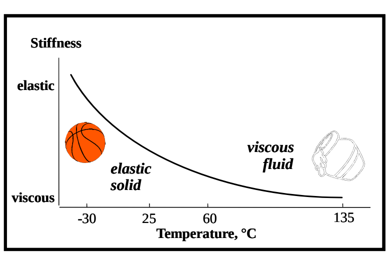


Asphalt Types

- **Refining produces asphalt with specific characteristics for varied uses**
  - Paving asphalt
  - Roofing asphalt
  - Other special uses

Asphalt Types

- **Paving asphalt**
  - Asphalt cement
  - Cutback asphalt
  - Emulsified asphalt

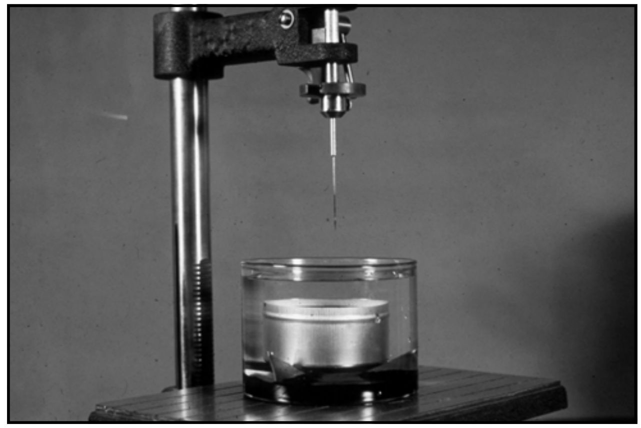


Asphalt Cement

- **Graded by several different systems**
  - Penetration (PEN)
  - Viscosity (AC)
  - Viscosity after aging (AR)
  - Performance graded (PG)
- **Primarily used for hot mix asphalt paving**

Asphalt Cement

- **Penetration graded asphalt (PEN)**
  - Standard needle allowed to sink into sample under specified load
  - The distance the needle travels in a given amount of time measured in 0.1 mm
  - Test run at 25° C (77° F)
  - Original asphalt is tested
  - Empirical test

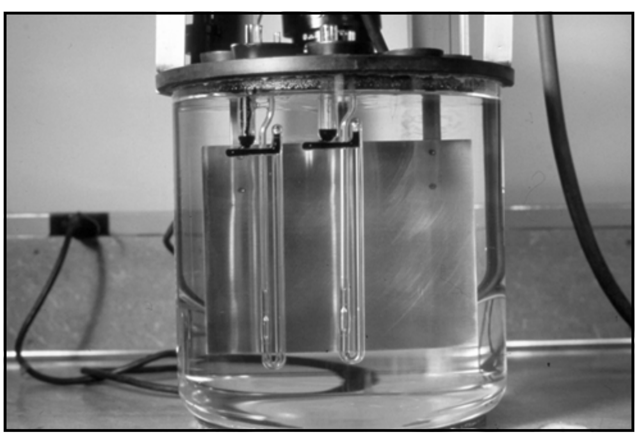


Asphalt Cement

Test On Original Asphalt	Penetration Grade 120-150	Penetration Grade 85-100
Penetration, 25 C (77 F), 100 g - 5 sec	**120 min. - 150 max.**	**85 min. - 100 max.**
Flash Point, COC, C (F), minimum	**219 (425)**	**232 (450)**
Ductility, 25 C (77 F), cm-minimum	**100**	**100**
Solubility in Trichloroethylene, % min.	**99.0**	**99.0**
Tests On Aged Asphalt (TFOT)		
Loss on heating, % maximum	**1.3**	**1.0**
Percent of original penetration, min.	**46**	**50**
Ductility of residue, minimum	**100**	**75**

Asphalt Cement

- **Viscosity graded asphalt (AC)**
  - A measure of the resistance of the material to flow
  - Measured in poises at 60°C (140°F)
    - Absolute viscosity
  - Requirement at 135° C (275° F) in centistokes
    - Kinematic viscosity



Asphalt Cement

- **Viscosity graded asphalt (cont.)**
  - 60° C (140° F) chosen to simulate in-service temperatures of pavements
  - 135° C (275° F) chosen to simulate mixing and laydown temperatures for hot-mix asphalt pavements

Asphalt Cement

Test	Viscosity Grade AC-10	AC-20
Viscosity, 60 C (140 F), poises	1000 ± 200	2000 ± 400
Viscosity, 125 C (275 F), Cs-minimum	250	300
Penetration, 25 C (77 F), minimum	80	60
Flash Point, COC, C (F), minimum	219 (425)	232 (450)
Solubility in Trichloroethylene, % min.	99.0	99.0
Test on residue from TFOT:		
Loss on heating, % max. (optional)	0.5	0.5
Viscosity, 60 C (140 F), poises-max.	4000	8000
Ductility, 25 C (77 F), cm-minimum	75	50

Asphalt Cement

- **Viscosity after aging (AR)**
  - AR - "Aged Residue"
  - Primarily used in western states
  - Attempts to identify material characteristics after placed in pavement
  - Rolling Thin Film Oven Test (AASHTO T 240)
    - Simulates aging during mixing in asphalt plant
  - Standard is poises at 60° C (140° F)

Asphalt Cement

Test On Residue From RTFO	Viscosity Grade AR-40	AR-80
Viscosity, 60 C (140 F), poises	4000 ± 1000	8000 ± 2000
Viscosity, 135 C (275 F), Cs-minimum	275	400
Penetration, 25 C (77 F), minimum	25	20
Percent of original penetration, min.	45	50
Ductility, 25 C (77 F), cm-minimum	75	75
Tests On Original Asphalt		
Flash Point, COC, C (F), minimum	227 (440)	232 (450)
Solubility in Trichloroethylene, % min.	99.0	99.0

Asphalt Cement

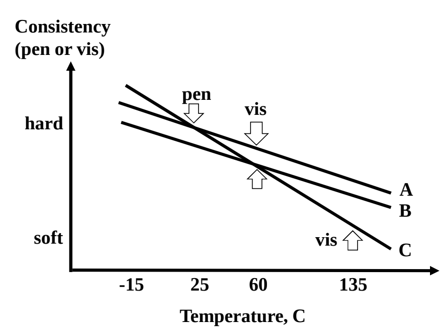
- **Performance graded asphalt (PG)**
  - Product of Strategic Highway Research Program (SHRP)
  - Provides a temperature range through which the asphalt must meet certain physical properties
  - New tests and specification developed
  - Tests properties a various stages in life of asphalt
    - Original, short term aged, long term aged

Asphalt Cement

Anticipated Low Pavement Temperature (° C)

PG 58-34

Anticipated High Pavement Temperature (° C)



Combined States Binder Group (CSBG)

Producer Quality Control Program

Cutback Asphalt

- **Asphalt cement which has been liquefied by blending with petroleum solvents**
  - When exposed to the atmosphere, solvents evaporate
  - Asphalt cement remains behind
  - Classifications: Function of solvent used
    - RC - Rapid curing
    - MC - Medium curing
    - SC - Slow curing

Cutbacks = Asphalt + Solvent

Cutbacks Cure

Solvent	Cure	Grades
Gasoline, Naptha	R C	70, 250, 800 or 3000
# 2 Diesel, Kerosene	M C	30, 70, 250…..3000
Bunker fuels, heavy oils	S C	70, 250, 800 or 3000

TABLE 1 SPECIFICATIONS FOR RAPID-CURING (RC) LIQUID ASPHALTS

CHARACTERISTICS	AASHO Test Method	ASTM Test Method	GRADES			
			RC-70	RC-250	RC-800	RC-3000
Kinematic Viscosity at 140 F, cSt	T 201	D2170	70-140	250-500	800-1600	3000-6000
Flash Point (Tag Open Cup), F	T 79	D1310	....	80+	80+	80+
Distillation	T 78	D402				
Distillate (percent by Volume of Total Distillate to 680 F)						
To 374 F			10+	....	....	....
To 437 F			50+	35+	15+	....
To 500 F			70+	60+	45+	25+
To 600 F			85+	80+	75+	70+
Residue from Distillation to 680 F, percent Volume by Difference			55+	65+	75+	80+
Tests on Residue from Distillation						
Penetration, 77 F, 100 g, 5 sec	T 49	D5	80-120	80-120	80-120	80-120
Ductility, 77 F, cm	T 51	D113	100+	100+	100+	100+
Solubility in Trichloroethylene, percent	T 44	D2042	99.5+	99.5+	99.5+	99.5+
Water, percent	T 55	D95	0.2−	0.2−	0.2−	0.2−

General Requirement—The material shall not foam when heated to application temperature recommended by The Asphalt Institute.

Note: When the Heptane-Xylene Equivalent Test is specified by the consumer, a negative soat test with 35 oercent xylene after 1 hour will be required, AASHO Method T 102.

TABLE 2 SPECIFICATIONS FOR MEDIUM-CURING (MC) LIQUID ASPHALTS

CHARACTERISTICS	AASHO Test Method	ASTM Test Method	GRADES				
			MC-30	MC-70	MC-250	MC-800	MC-3000
Kinematic Viscosity at 140 F, cSt	T 201	D2170	30-60	70-140	250-500	800-1600	3000-6000
Flash Point (Tag Open Cup), F [1]	T 79	D1310	100+	100+	150+	150+	150+
Distillation	T 78	D402					
Distillate (percent by Volume of Total Distillate to 680 F)							
To 437 F			25−	20−	0-10	....	....
To 500 F			40-70	20-60	15-55	35−	15−
To 600 F			75-93	65-90	60-87	45-80	15-75
Residue from Distillation to 680 F, percent Volume by Difference			50+	55+	67+	75+	80+
Tests on Residue from Distillation							
Penetration, 77 F, 100 g, 5 sec	T 49	D5	120-250	120-250	120-250	120-250	120-250
Ductility, 77 F, cm[2]	T 51	D113	100+	100+	100+	100+	100+
Solubility in Trichloroethylene, percent	T 44	D2042	99.5+	99.5+	99.5+	99.5+	99.5+
Water, percent	T 55	D95	0.2−	0.2−	0.2−	0.2−	0.2−

General Requirement—The material shall not foam when heated to application temperature recommended by The Asphalt Institute.

Note: When the Heptane-Xylene Equivalent Test is specified by the consumer, a negative spot test with 35 percent xylene after 1 hour will be required, AASHO Method T 102.

[1] Flash Point by Cleveland Open Cup may be used for products having a flash point greater than 175 F.
[2] If penetration of residue is more than 200 and its ductility at 77 F is less than 100, the material will be acceptable if its ductility at 60 F is 100+.

TABLE 3 SPECIFICATIONS FOR SLOW-CURING (SC) LIQUID ASPHALTS AND ROAD OILS

CHARACTERISTICS	AASHO Test Method	ASTM Test Method	GRADES			
			SC-70	SC-250	SC-800	SC-3000
Kinematic Viscosity at 140 F, cSt	T 201	D2170	70-140	250-500	800-1600	3000-6000
Flash Point (Cleveland Open Cup), F	T 48	D92	150+	175+	200+	225+
Distillation						
Total Distillate to 680 F, percent by Volume	T 78	D402	10-30	4-20	2-12	5−
Kinematic Viscosity of Residue, 140 F, Stokes	T 201	D2170	4-70	8-100	20-160	40-350
Asphalt Residue of 100 Penetration, percent	T 56	D243	50+	60+	70+	80+
Ductility of 100 Penetration Residue at 77 F, cm	T 51	D113	100+	100+	100+	100+
Solubility in Trichloroethylene, percent	T 44	D2042	99.5+	99.5+	99.5+	99.5+
Water, percent	T 55	D95	0.5−	0.5−	0.5−	0.5−

General Requirement—The material shall not foam when heated to application temperatute recommended by The Asphalt Institute.

Note: When the Heptane-Xylene Equivalent Test is specified by the consumer, a negative spot test with 35 oercent xylene after 1 hour will be required, AASHO Method T 102.

Cutback Asphalt

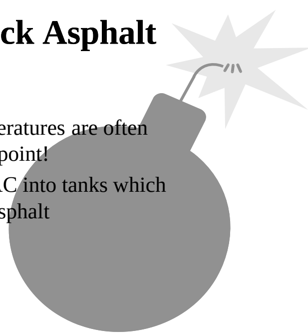
- Classifications (cont.)
  - Associated number, (70, 250, 800, 3000 etc.) represent the minimum kinematic viscosity in centistokes - 60° C (140° F)
- RC, MC and SC-3000 are about the same consistency as AC 2.5 (AC Tested at 135° C)
- The RC and MC-30,70 grades can be poured at room temperature

Cutback Asphalt

- **Primary uses**
  - Can be used with cold aggregates w/ little heat
  - RC and MC grades
    - Road mix, stockpile mixes, prime, tack and seal coats
    - High energy products used for solvents
  - SC grades
    - Road mixing, cold mix patch, stockpiling

Cutback Asphalt

- **Precautions**
  - Application temperatures are often higher than flash point!
  - Do not load hot AC into tanks which contain cutback asphalt



Asphalt Emulsions	Rapid Curing (RC) Cutbacks	Medium Curing (MC) Cutbacks	Slow Curing (SC) Cutbacks Road Oils
WATER AND EMULSIFIER	GASOLINE OR NAPHTHA	KEROSENE	SLOWLY & NON-VOLATILE OILS
ASPHALT CEMENT	ASPHALT CEMENT	ASPHALT CEMENT	ASPHALT CEMENT

Emulsified and Cutback Products

Asphalt Emulsions

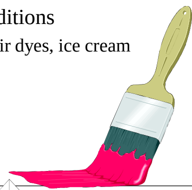
- **Emulsions used today were developed in 1920's**
- **Major uses**
  - Surface treatments
  - Patching
  - Stabilization
  - Slurry sealing
  - Recycling

Asphalt Emulsions

- **Factors which increased usage**
  - Energy crisis of 1970's
    - Petroleum solvents not required
    - Used without additional heating
  - Reduced atmospheric pollution
  - Ability to coat damp aggregates
  - Variety of emulsion types
  - Economical - less fuel consumption

Asphalt Emulsions

- **Emulsion technology**
  - Using mechanical and/or chemical processes to combine two or more materials that would not mix under normal conditions
    - Mayonnaise, paints, hair dyes, ice cream



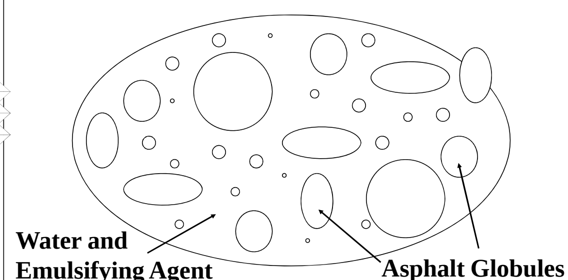
Asphalt Emulsions

- **Composition**
  - Asphalt cement
  - Water
  - Emulsifying agent
    - May contain a stabilizer

Asphalt Emulsions

- **Consist of two normally immiscible phases**
  - Continuous phase - water and emulsifier
  - Discontinuous phase - asphalt

Asphalt Emulsions



Asphalt Emulsions

- **Emulsion must be stable**
  - Asphalt particles remain in suspension
    - Pumping
    - Prolonged storage
    - Mixing
- **Emulsion should break easily**
  - Contact with aggregate in mixer
  - Sprayed on road surface
- **After cure, asphalt retains original properties**

Asphalt Emulsions

Emulsions => "Set" or "Break"

C R S	1, 2
C MS	1, 2
C S S	1, 1-h

Cationic - Positive Charge

Anionic - Negative charge

SPECIFICATIONS FOR ANIONIC EMULSIFIED ASPHALTS

CHARACTERISTICS	AASHO Test Method	ASTM Test Method	GRADES: Rapid Setting RS-1	GRADES: Rapid Setting RS-2	GRADES: Medium Setting MS-2	GRADES: Slow Setting SS-1	GRADES: Slow Setting SS-1h
Tests on Emulsion[1]							
Furol Viscosity at 77 F, sec			20-100		100+	20-100	20-100
Furol Viscosity at 122 F, sec				75-400			
Distillation Residue, percent by Weight			57+	62+	62+	57+	57+
Settlement, 5 days, percent Difference	T 59	D244	3−	3−	3−	3−	3−
Demulsibility							
35 ml of 0.02 N $CaCl_2$, percent			60+	50+			
50 ml of 0.10 N $CaCl_2$, percent					30−		
Sieve Test (Retained on No. 20), percent			0.10−	0.10−	0.10−	0.10−	0.10−
Cement Mixing Test, percent						2.0−	2.0−
Tests on Residue from Distillation							
Penetration, 77 F, 100 g, 5 sec	T 49		100-200	100-200	100-200	100-200	40-90
Solubility in Trichloroethylene, percent	T 44	D2042	97.5+	97.5+	97.5+	97.5+	97.5+
Ductility, 77 F, cm	T 51	D113	40+	40+	40+	40+	40+

[1] All tests shall be performed within 30 days from the date of emulsion shipment.

SPECIFICATIONS FOR CATIONIC EMULSIFIED ASPHALTS

CHARACTERISTICS	AASHO Test Method	ASTM Test Method	GRADES: Rapid Setting CRS-1	GRADES: Rapid Setting CRS-2	GRADES: Medium Setting CMS-2S	GRADES: Medium Setting CMS-2	GRADES: Slow Setting CSS-1	GRADES: Slow Setting CSS-1h
Tests on Emulsion[1]								
Furol Viscosity at 77 F, sec	T 59	D244					20-100	20-100
Furol Viscosity at 122 F, sec	T 59	D244	20-100	100-400	50-500	50-500		
Settlement, 5 days,[2] percent Difference	T 59	D244	5−	5−	5−	5−	5−	5−
Sieve Test (Retained on No. 20), percent[3]	T 59	D244	0.10−	0.10−	0.10−	0.10−	0.10−	0.10−
Aggregate Coating—Water Resistance Test[4]		D244						
Dry Aggregate (Job) percent Coated					80+	80+		
Wet Aggregate (Job), percent Coated					60+	60+		
Cement Mixing Test, percent	T 59	D244					2−	2−
Particle Charge Test	T 59	D244	Positive	Positive	Positive	Positive		
pH	T 200	E70					6.7−	6.7−
Distillation: Residue, percent by Weight	T 59	D244	60+	65+	60+	65+	57+	57+
Oil Distillate,[5] percent by Vol of Emulsion	T 59	D244	3−	3−	20−	12−		
Tests on Residue								
Penetration, 77 F, 100 g, 5 sec	T 49	D5	100-250	100-250	100-250	100-250	100-200	40-90
Solubility in Trichloroethylene, percent	T 44	D2042	97.0+	97.0+	97.0+	97.0+	97.0+	97.0+
Ductility, 77 F, cm	T 51	D113	40+	40+	40+	40+	40+	40+

[1] All tests shall be performed within 30 days from the date of emulsion shipment.
[2] The test requirement for settlement may be waived when the emulsified asphalt is used in less than 5 days; or the purchaser may require that the settlement test be run from the time the sample is received until it is used, if the elapsed time is less than 5 days.
[3] Except that distilled water is used instead of sodium oleate solution.
[4] Calcium carbonate shall not be added to the job aggregate when making the aggregate coating—water resistance test.
[5] Volume of oil distillate may be determined by reading on the graduated cylinder which is used to collect total distillate.

Asphalt Emulsions

- **Classification**
  - Anionic
    - Negatively charged asphalt particles
  - Cationic
    - Positively charged asphalt particles
  - Dependent on type of emulsifying agent used

Asphalt Emulsions

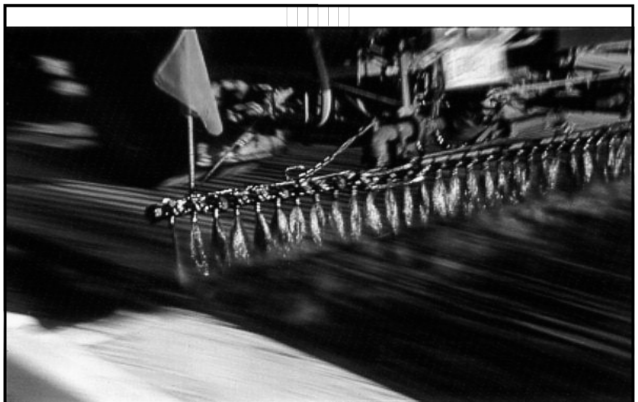
- **Anionic Grades**
  - RS - Rapid Setting
  - MS - Medium Setting
  - SS - Slow Setting
- **Cationic Grades**
  - CRS - Rapid Setting
  - CMS - Medium Setting
  - CSS - Slow Setting
- **Mixing ability**
  - RS grades do not mix well with aggregates
  - MS grades mix well with coarse but not fine aggregates
  - SS grades mix well with fine aggregates

Asphalt Emulsions

- **Classification (cont.)**
  - Numbers and letters after the grade refer to viscosity of the emulsion and hardness of base asphalt
    - CRS-2 has a higher viscosity than CRS-1 to prevent runoff
    - SS-1h uses a harder base asphalt than does SS-1
  - QS - Quick setting emulsions
    - Used for slurry seals

Asphalt Emulsions

- **High float emulsions**
  - Designated by HF
    - HFMS-1, HFMS-2, HFMS-2h, HFMS-2s
  - Use added chemicals to allow for thicker asphalt film with little drainage
  - Primarily used for cold plant mix and road mix applications
- Emulsion specifications - MS-19



Asphalt Emulsions

◆ **Factors affecting breaking and curing**
- Absorption rate of aggregates
- Aggregate moisture content
- Aggregate gradation - surface area
- Weather conditions - temp, humidity, wind
- Type and amount of emulsifying agent
- Intensity of aggregate charge
- Mechanical manipulation and rolling

Asphalt Emulsions

◆ **Storage and handling**
- Store between 10° and 85° C (50° and 185° F)
- Use tall, vertical tanks for storage
- Do not used forced air to agitate
- Do not mix anionic and cationic grades
- Do not dilute RS grades with water
- MS and SS grades can be diluted
  - Add water to emulsion slowly
  - Do not add emulsion to tank of water
- Do not add hot asphalt cement to emulsion tank

WELCOME !!
North Dakota QC/QA
Bituminous Technology
Mix Testing

Bismarck, ND

Acceptance Criteria

Common factors used for acceptance of materials and finished pavements

Acceptance Criteria

- **Depends on type of specifications used**
  - Method - Recipe
    - Spells out equipment, materials, methods, etc.
  - End result
    - Stresses testing not inspection
  - Quality Assurance
    - Statistically based contractor testing
  - Performance based
    - Emphasizes performance not construction
    - Warranties

Traditional Acceptance Criteria

- **Materials**
  - Asphalt binder properties
  - Aggregate gradation
  - Aggregate properties
  - Asphalt content
- **Pavement density**
- **Pavement smoothness**

There have never been mixture requirements

- **Specifications have always been "Recipe" related**
- **Density was the only test performed on the mixture after mixing**

ND Utilizes Two Methods of QC/QA for Hot Bituminous Pavement (HBP)

- **Section 409: Hot Bituminous Pavement Quality Control/Quality Assurance**
  - *Marshall* Compaction Hammer Specimen
  - Four Traffic Levels: Class 27/29/31/33
- **Section 410: Hot Bituminous Pavement Superpave Quality Control/Quality Assurance**
  - *Gyratory* Compactor Specimen
  - Six Traffic Levels: FAA40/41/42/43/44/45

ND Utilizes Two Methods of QC/QA for Hot Bituminous Pavement (Con't)

- **The predominant specification since 2006 has been the Superpave QC/QA Specification**
  - Adjustments made to traffic levels, specification limits for consensus aggregate properties and compaction levels dictated by Fine Aggregate Angularity (FAA) requirements**: FAA41 (ex.)**

ND Utilizes Two Methods of QC/QA for Hot Bituminous Pavement (Con't)

- **The use of QC/QA Specifications for Hot Bituminous Pavement (Marshall) has been receding the last six years**
  - Smaller tonnage projects
  - Ancillary (non-travelway) asphalt concrete tonnage
  - Marshall mixes and QC/QA Specification will continue but with nominal projects in the future

Important HMA Mix Properties

- **Stability**
- **Durability**
- **Impermeability**
- **Workability**
- **Flexibility**
- **Fatigue Resistance**
- **Skid Resistance**

Important HMA Mix Properties

How do we attain them?

- Materials Selection
- Volumetric design

Obtaining the right balance

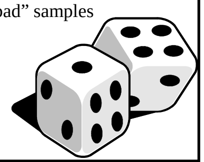
Achieved through

- **Volumetric Analysis of the Mixture**
- **Future Performance testing**

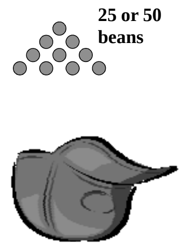
QC/QA Testing allows increased testing to assure volumetric properties are met.

The key to successful testing is -

- **Random sampling**
  - Any portion of the population has equal chance of being selected
  - Bias is introduced when judgment is used
    - Attempts to include "good and bad" samples
  - Use random number table



Entering the random number chart



25 – Columns

50 - Rows

Pull out 1 column number and 1 row number

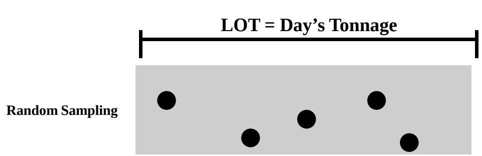
SDDOT
TABLE OF RANDOM NUMBERS

.53.74.23.99.67	.61.32.28.69.84	.94.62.67.86.24	.98.33.74.19.95	.47.53.53.38.09
.63.38.06.86.54	.99.00.65.26.94	.02.82.90.23.07	.79.62.67.80.60	.75.91.12.81.19
.35.30.58.21.46	.06.72.17.10.94	.25.21.31.75.96	.49.28.24.00.49	.55.65.79.78.07
.63.43.36.82.69	.65.51.18.37.88	.61.38.44.12.45	.32.92.85.88.65	.54.34.81.85.35
.98.25.37.55.26	.01.91.82.81.46	.74.71.12.94.97	.24.02.71.37.07	.03.92.18.66.75
.02.63.21.17.69	.71.50.80.89.56	.38.15.70.11.48	.43.40.45.86.98	.00.83.26.91.03
.64.55.22.21.82	.48.22.28.06.00	.61.54.13.43.91	.82.78.12.23.29	.06.66.24.12.27
.85.07.26.13.89	.01.10.07.82.04	.59.63.69.36.03	.69.11.15.83.80	.13.29.54.19.28

Random Numbers

- **Utilized in**
  - Aggregate and Mixture Sampling
  - Core Locations for Density Testing

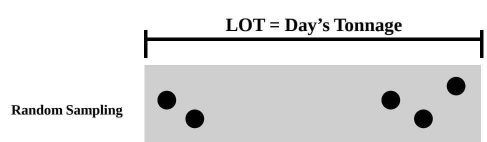
Pure Random Sampling



Samples generally spread throughout the area to be sampled

Multiple Samples (Sublots) per Lot

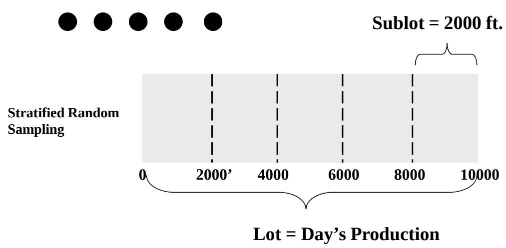
Pure Random Sampling



Clustered samples are also possible and undesirable

Variable Sublots (2000 ft.) per Lot

ND QC/QA uses Stratified Random Sampling



Aggregate and Mixture Sampling QC / QA Specification 409.2

"The Contractor obtains mix samples from behind the paver at random times as specified by the Engineer. A mix sample is obtained each an aggregate sample is obtained for sieve analysis."

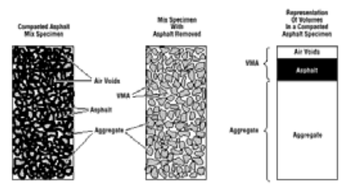
In general: 1 mix sample per 1500 tons

Sample Splitting NDDOT 5

- Accurate Splitting is essential
- Follow the rule of thumb
- There is no allowance in the QC / QA System for a "Bad Split"

Importance of Volumetric Properties

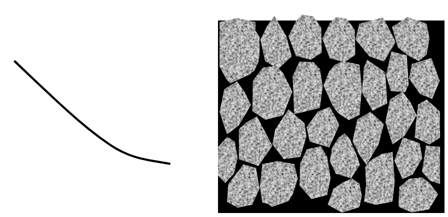
Experience shows that % air voids and the voids in the mineral aggregate relate to performance



Importance of Air Voids

- Field performance has shown that mixtures designed below 3% air voids are susceptible to rutting and shoving
- Mixtures designed over 5% Air Voids are susceptible to raveling, oxidation and a general lack of durability
- 4% Air Void Design allows for thermal expansion of the binder along with a cushion for future compaction

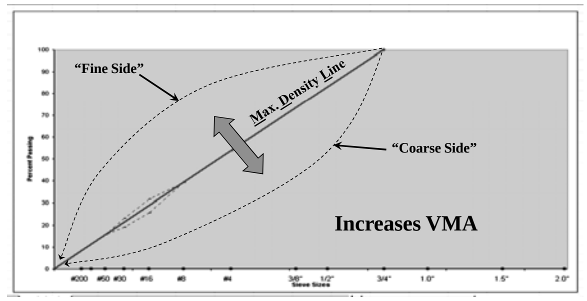
Air Voids



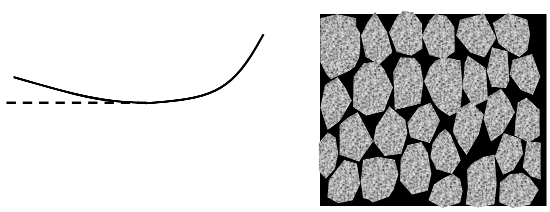
Importance of VMA

- **VMA is the volume of the voids in a compacted aggregate sample to accommodate asphalt and air.**
  - Assure sufficient binder coating
  - Maintain 4% Air voids

45th Power Chart



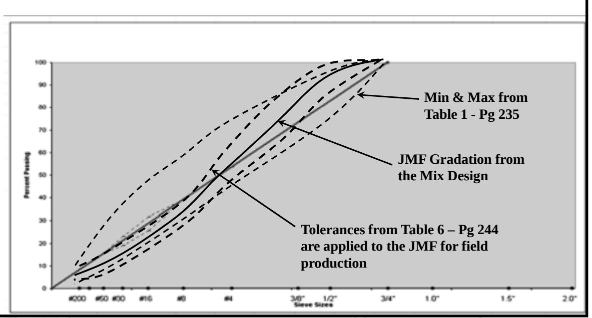
VMA



Volumetric Analysis History

- **Not a new concept; has played a role in most mixture design methods**
- **Is currently the best available method to readily measure mixture properties in the field on plant produced mix.**

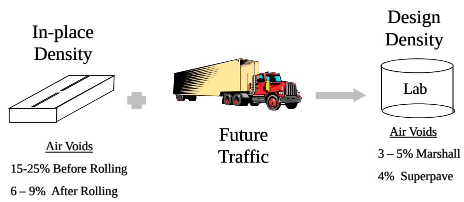
QC/QA Gradation Requirements



Bulk Specific Gravity of Compacted Asphalt Mixtures Using SSD Specimens (409: Marshall Method) AASHTO T166

Bulk Specific Gravity of Laboratory Compacted Mix

- **This test provides ½ of the information needed to calculate Air Voids**



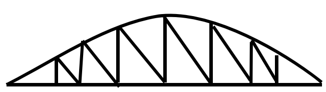
Specific Gravity

What is a Specific Gravity ?

It is the ratio between the density of anything compared to the density of water

$$G = \frac{\dfrac{M_x}{V_x}}{\dfrac{M_{H_2O}}{V_{H_2O}}} \quad \Big\} = 1.000 \text{ gram / cm}^3$$

Specific Gravity is the bridge between volume and mass



Volume

V=M/ G

$$G = \frac{M}{V}$$

Mass

M=V*G

In the metric system
specific gravity = unit weight

Questions

North Dakota QC/QA
Bituminous Technology
Hot Bituminous Pavement (HBP)
Mix Testing

Field Verification & Quality Assessment

Bismarck, ND

Mixture Testing

QC is the responsibility of the Contractor

"The Contractor will be required to perform random sampling and testing on the aggregate and bituminous mixture as the mix is produced and placed on the roadway"

Mixture Testing (con't)

QC HMA

"The Contractor obtains mix samples from behind the paver at random times as determined by the Engineer. A mix sample is obtained each time an aggregate sample is obtained for sieve analysis. The sample is obtained according to NDDOT 5, *Sampling and Splitting Field Verification Hot Mix Asphalt (HMA) Samples*."

50# ~~~409
72#~~410

Sampling and Splitting HMA.wmv

Determine Aggregate Blend Properties

Calculate the blended aggregate gradation using the following formula

$$P = \frac{A \times a + B \times b + C \times c + ..}{100}.$$

where,
P = the % of combined aggregate for a given sieve
A,B,C, = % passing a sieve for an individual stockpile
a,b,c, = individual % of stockpiles by weight

Bulk Specific Gravity of Compacted Bituminous Mixtures Using SSD Specimens
(G_{mb})

AASHTO T 166

***AASHTO T 166 is utilized by the NDDOT to determine* G_{mb} for:**

1) **Field Mix Marshall Plugs (409)**
2) **Field Mix Gyratory Plugs (410)**
3) **In-Place Density Cores (409/410)**

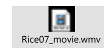
Bulk SPg movie.wmv

Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
(G_{mm})
"Rice Test"

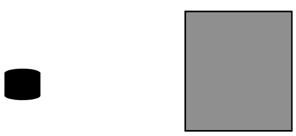
AASHTO T 209 ND Modified

AASHTO T 209 is utilized by the NDDOT to determine **G_{mm} for:**

1) Volumetric Analysis of Field Mix (409/410)
2) Pavement (In-Place) Density (409/410)



Specific Gravity Testing



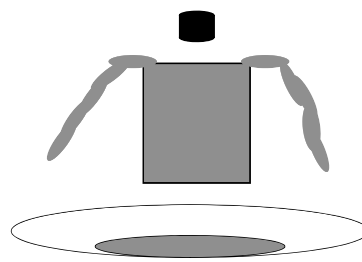
1 cc H_20 = 1 gram

What would an equal volume of water weigh submerged?

The difference between the weight in air and the weight in water equals the volume of the object in cm^3 !!

Archimedes' Principle of Buoyancy

Specific Gravity Testing



$$G = \frac{M}{V}$$

Rice Testing

Weight of the water displaced equals the volume of the sample

---

Gmm = Theoretical Maximum Specific Gravity or Rice

V_a Working Range	Tolerance
a. 409 % Air Voids	2%-6% (Single Test)
	3%-5% (Moving Avg.)
b. 410 % Air Voids	2%-6% (Single Test)
	2.5%-5% (Mvg. Avg.)
	4.0% Target

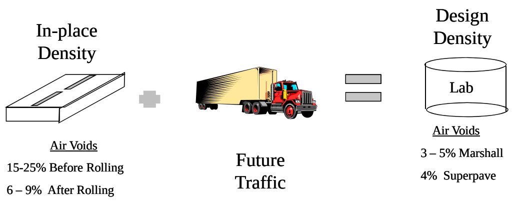
Air Void Calculation

$$Va = \left(\frac{Gmm - Gmb}{Gmm}\right) \times 100$$

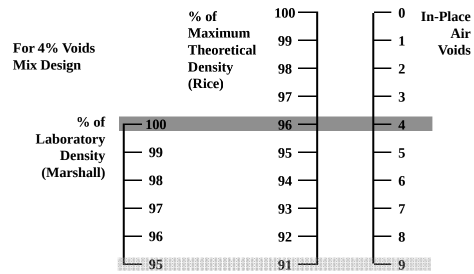
- **Va = % Air Voids in the mixture**
- **Gmb = bulk specific gravity of the mixture**
- **Gmm = theoretical maximum specific gravity of the mixture**

Density Specifications

Simulate the in-place density of HMA after it has endured several years of traffic in the roadway



Density Specifications



Theoretical Maximum Specific Gravity

Benefits

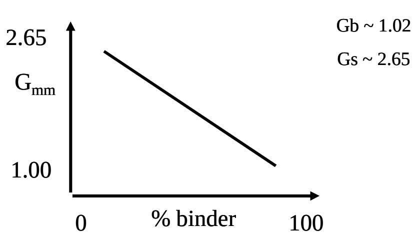
– More Consistent
– More Repeatable
– Easier to perform
– Asphalt sensitive

Consistency

Gmb Variables

- **Mix Temperature**
- **Compaction**
  - SGC – angle
  - SGC – pressure
  - Marshall – blow count
  - Marshall – rodding
- **Aggregate alignment**

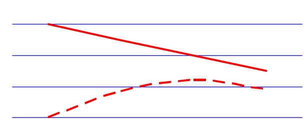
Gmm at Other Asphalt Contents



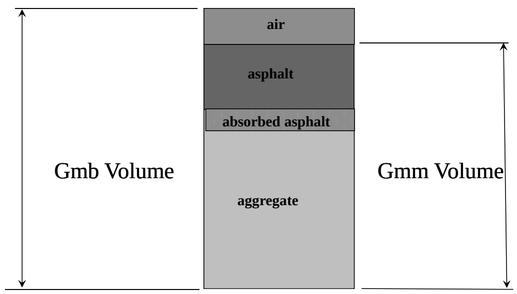
Representative sampling is critical !!

Pros and Cons of Gmm

- **Excellent parameter for field monitoring**
- **Can promote over asphalted mixtures in the field**

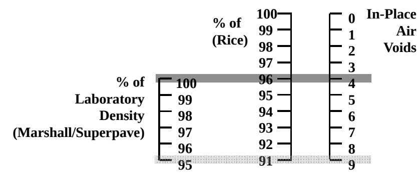


Gmb Vs Gmm



Compaction (Core) Testing

This procedure is for determining the density of in place asphalt concrete pavement.



Compaction (Core) Testing

- Randomly select 2 core sites per sublot. Core locations determined by the Engineer.
- A lot is defined as a day**'s production.**
- **A sublot is defined as one paver width (excluding shoulders), 2000 ft. long, depth (thickness) specified for pavement course**

Compaction (Core) Testing AASHTO T 166

Calculate the Bulk Specific Gravity to the nearest 0.001.

$$\frac{A}{B - C}$$

A = Mass in grams of the dry core in air.

B = Mass in grams of the saturated surface dry core in air.

C = Mass in grams of the core in water.

Compaction (Core) Testing AASHTO T 209

Calculate the Maximum Specific Gravity to the nearest 0.001.

$$\frac{A}{(A+D-E)}$$

A = Mass (grams) of the oven dry sample in air

D = Mass (grams) of container filled with water

E = Mass (grams) of container filled with sample and water

Compaction (Core) Testing

Calculate the Unit Weight of Specimens:

<u>UW = G x Density of Water</u>

G = Specific Gravity (G_{mb} or G_{mm})

Density of Water = 62.4 lbs./ft^3

Calculate Core Density

<u>Unit Wt. (Bulk)/Unit Wt. (Max.) x 100%</u>

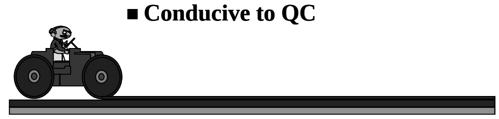
Superpave Gyratory Compaction and Mixture Requirements

North Dakota Department of Transportation

Dakota Asphalt Pavement Association

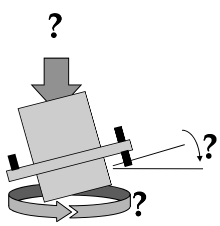
Goals of Compaction Method

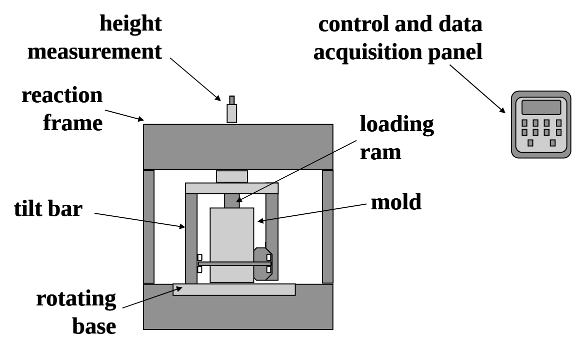
- Simulate field densification
  - traffic
  - climate
- Accommodate large aggregates
- Measure compactability
- Conducive to QC

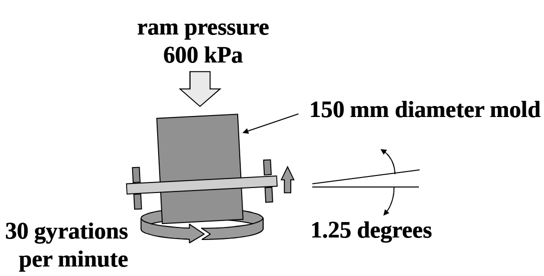


Superpave Gyratory Compactor

- Basis
  - Texas equipment
  - French operational characteristics
- 150 mm diameter
  - up to 37.5 mm nominal size
- Height Recordation

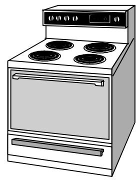




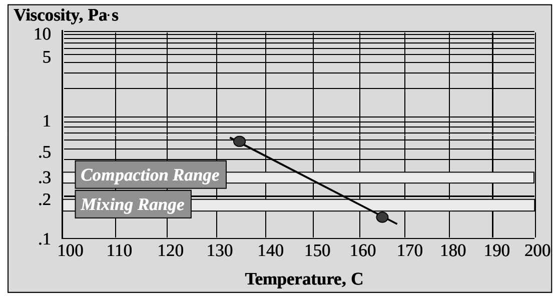


Specimen Preparation

- ■ Mechanical mixer
  - 0.170 Pa-s binder viscosity
- ■ Short term oven aging
  - 2 hours at mix compaction temperature

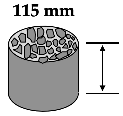


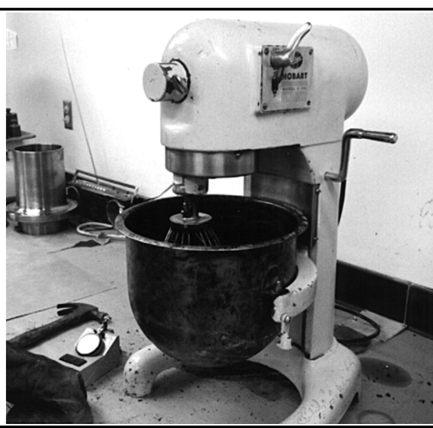
Mixing/Compaction Temps

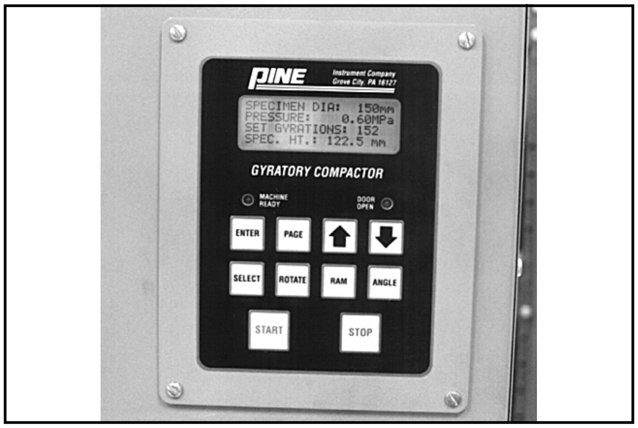


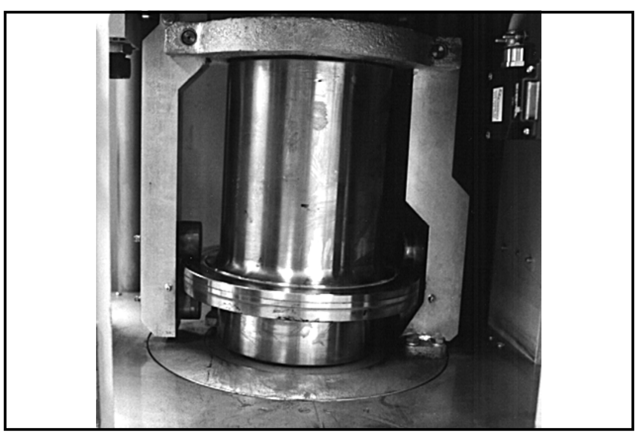
Specimen Preparation

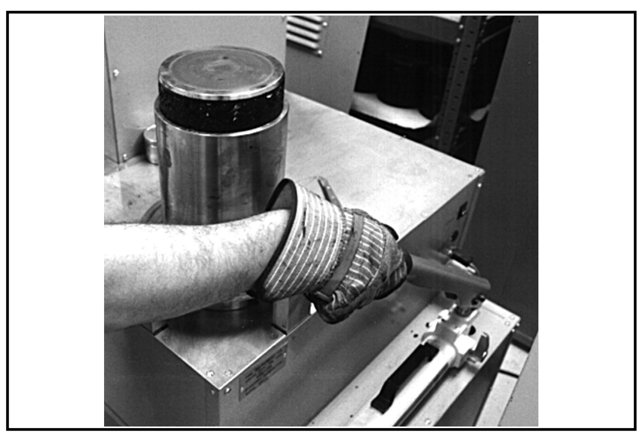
- ■ Specimen Height
  - Mix Design - 115 mm (4700 g)
  - Mix Analysis - 140 mm (5500 g)
  - Moisture Sens. - 95 mm (3500 g)
- ■ Loose Specimen for Max. Theor. (Rice)
  - varies with nominal max size
    - 19 mm (2000 g)
    - 12.5 mm (1500 g)



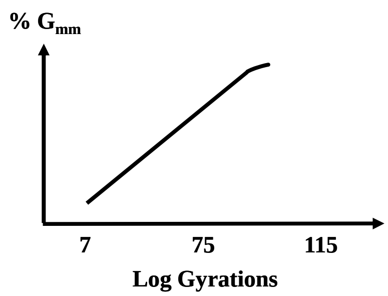



PINE
Instrument Company
Grove City, PA 16127
SPECIMEN DIA: 150mm
PRESSURE: 0.60MPa
SET GYRATIONS: 152
SPEC. HT.: 122.5 mm
GYRATORY COMPACTOR
MACHINE READY
DOOR OPEN
ENTER
PAGE
SELECT
ROTATE
RAM
ANGLE
START
STOP

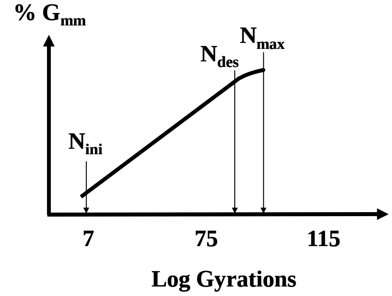




SGC Results

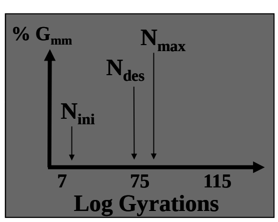


Three Points on SGC Curve

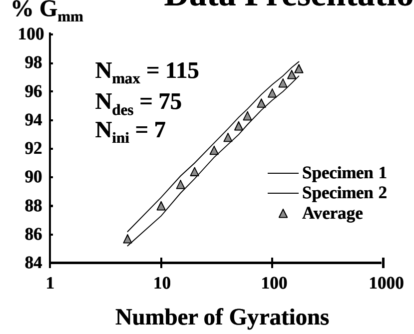


Design Compaction

- N_{des} based on
  - average design high air temp
  - traffic level
- Log N_{max} = 1.10 Log N_{des}
- Log N_{ini} = 0.45 Log N_{des}
- (Use Table)



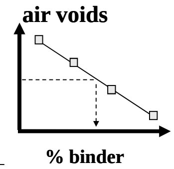
Data Presentation



Superpave Mixture Requirements

- **Specimen Height**
- **Mixture Volumetrics**
  - **Air Voids**
  - **Voids in the Mineral Aggregate (VMA)**
  - **Voids Filled with Asphalt (VFA)**
  - **Mixture Density Characteristics**
- **Dust to Binder Ratio**
- **Moisture Sensitivity**

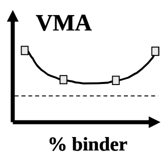
Mix Air Voids Requirement



Traffic #Trucks / or ESALs	Design % Air
FAA 40	4
FAA 41	4
FAA 42	4
FAA 43	4
FAA 44	4
FAA 45	4

Mix VMA Requirements

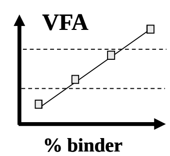
Voids in the Mineral Aggregate (Superpave Requirements)



Nom Max Size (mm)	Minimum VMA %
9.5	15.0
12.5	**14.0 (NDDOT 410)**
19	13.0
25	12.0
37.5	11.0

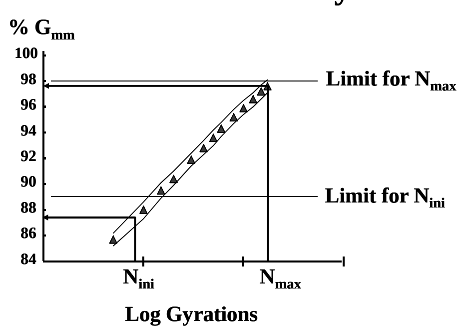
Mix VFA Requirements

Voids Filled with Asphalt



Traffic Truck# / ESALs	Range of VFA %
As Specified	65 – 75 (Typ)

Mixture Density



Mixture Density Requirements

N_{ini} = As Specified 7 (Typical)

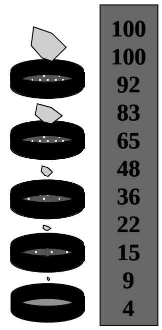
N_{des} = As Specified 75 (Typical)

N_{max} = As Specified 115 (Typical)

Mixture Densification N_{ini}= As Spec. 89%G_{mm} max. (Typ.)
Mixture Densification N_{max}= 98%G_{mm} max.

Mix Requirement for Dust to Binder Ratio

$$0.6 \le \frac{\text{\% weight of - 0.075 material}}{\text{\% weight of } \textit{effective} \text{ asphalt}} \le 1.3$$



Unabsorbed binder in mix

0.6-1.3 (Top Lift) 0.6-1.4 (Bottom Lift)

Superpave Test Method

- **AASHTO T 312:** ***Preparing and Determining Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor***

Gyratory07_movie.wmv

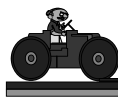
409 Compaction and Mixture Requirements

North Dakota Department of Transportation

Dakota Asphalt Pavement Association

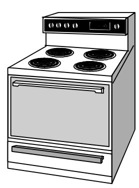
Marshall Compaction Method

- 50 Blow per Side – All Mixture Types
- Slant Foot – Rotating Base
- AASHTO T 245
  - Stability
  - Plastic Flow
- Three Specimens (Replicates) Per Sample



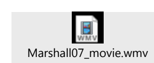
Specimen Preparation

- Sample Conditioning
  - 270 +/- 5 deg. F.
- Molds and Hammer Face(s)
  - 200 to 300 deg. F.
- Specimen (Molded) 4 in. dia. by 2.5 +/- 0.05 in. height



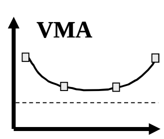
Specimen Preparation

- Specimen Amount
  - 1200 grams per mold



Mix VMA Requirements

Voids in the Mineral Aggregate



Class	VMA %
27	14.0 – 16.0
29	14.0 – 16.0
31	14.0 - 16.0
33	14.0 – 16.0

Stability Requirements

Minimum Value

Mix	Lbs.
27	1200
29	1500
31	1650
33	1800

Flow Requirements

Mix	Flow (0.01 in.)
27	8 to 18
29	8 to 18
31	8 to 16
33	8 to 16

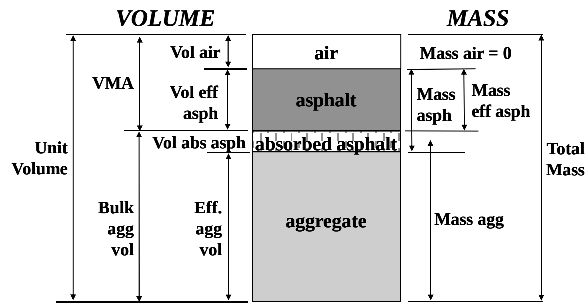
Fines/Asphalt Ratio

Mix	Top Lift	Lower Lift
27	0.6-1.3	0.6-1.4
29	0.6-1.3	0.6-1.4
31	0.6-1.3	0.6-1.4
33	0.6-1.3	0.6-1.4

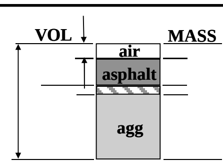
Asphalt Mixture Volumetrics

North Dakota Department of Transportation

Dakota Asphalt Pavement Association

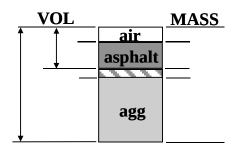


Air Voids



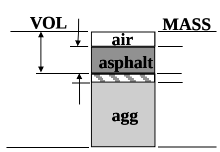
- **Definition**
  - –volume concentration of air voids
- **% by volume total mix, V_a**
- **Measure G_{mm} at known P_b to get G_{se}**
- **V_a - Calculated using G_{se} , G_{mm} , and G_{mb}**

Voids in Mineral Aggregate (VMA)



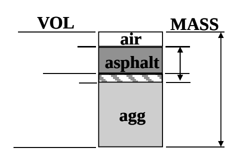
- **Definition**
  - –volume concentration of *intergranular* void space in a compacted mix
- **% by volume total mix**
- ***Does not* include volume of absorbed asphalt (use G_{sb} *not* G_{se})**

Voids Filled with Asphalt (VFA)



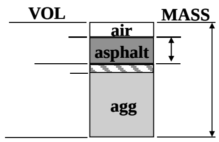
- **Definition**
  - –percentage of VMA filled with asphalt
- **Similar to degree of saturation in soils**

Asphalt Content



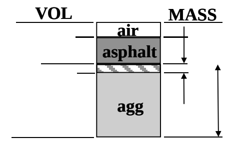
- **Total Asphalt Content**
  - –mass concentration of total asphalt binder
- **% by mass of total mix, P_b**

Effective Asphalt Content



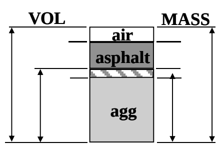
- Definition
  - mass concentration of asphalt not lost to absorption
- % by mass of total mix, P_{be}

Absorbed Asphalt Content



- Definition
  - mass concentration of asphalt absorbed by aggregate
- % by mass of aggregate, P_{ba}

Specific Gravity



- {mix, agg, and binder}
- Bridge Between Mass and Volume

$$G = \frac{\frac{M_o}{V_o}}{\frac{M_w}{V_w}}$$

$\frac{M_w}{V_w} = 1.000\ g/cm^3$ (approx density of water at 25º C)

Specific Gravity

- Relates Density

$$D = G \times 1.000$$

D: Density in g/cm³; G: specific gravity of object; 1.000: density of water

Specific Gravity

- Relates Volume

$$V = \frac{M}{G \times 1.000}$$

V: volume of object; M: mass of object; G: specific gravity of object; 1.000: density of water

Specific Gravity

- Relates Mass

$$M = V \times G \times 1.000$$

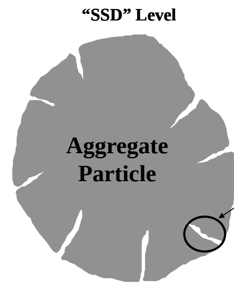
M: mass of object; V: volume of object; G: specific gravity of object; 1.000: density of water

Aggregate Specific Gravity
3 Types

Same Mass

- Bulk (G_{sb}) Volume
- Effective (G_{se}) Volume
  - excludes absorbed asphalt volume
- Apparent (G_{sa}) Volume
  - excludes absorbed water volume

Aggregate Bulk Specific Gravity



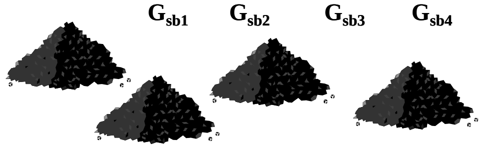
$$G_{sb} = \frac{\text{Dry Mass}}{\text{Bulk Vol}} \Big/ 1.000\ g/cm^3$$

Bulk Volume = solid volume + water permeable pore volume

Combined Aggregate Bulk Specific Gravity

Weighted Average

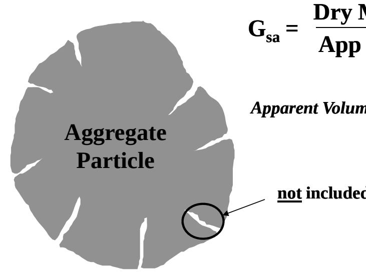
$$G_{sb}\ (\text{combined}) = \frac{100}{\frac{P_1\%}{G_{sb1}} + \frac{P_2\%}{G_{sb2}} + \frac{P_3\%}{G_{sb3}} + \frac{P_4\%}{G_{sb4}}}$$



Aggregate Apparent Specific Gravity

$$G_{sa} = \frac{\text{Dry Mass}}{\text{App Vol}} \Big/ 1.000\ g/cm^3$$

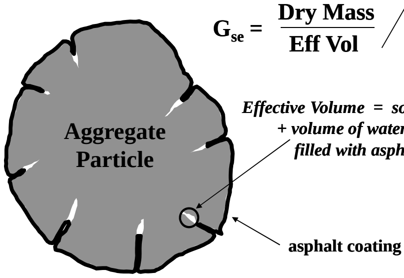
Apparent Volume = volume of solid aggregate particle only



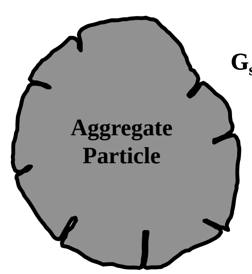
Aggregate Effective Specific Gravity

$$G_{se} = \frac{\text{Dry Mass}}{\text{Eff Vol}} \Big/ 1.000\ g/cm^3$$

Effective Volume = solid volume + volume of water permeable pores not filled with asphalt



Aggregate Effective Specific Gravity



$$G_{se} = \frac{100 - P_b}{\frac{100}{G_{mm}} - \frac{P_b}{G_b}}$$

G_{mm}: measured "Rice" gravity

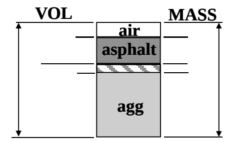
G_b: measured

Aggregate Specific Gravities

- G_{sb} - lowest value ("highest aggregate volume")
- G_{se} - middle value
- G_{sa} - highest value ("lowest aggregate volume")

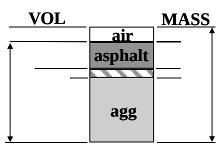
$$\frac{\text{Mass}}{\text{Volume}}$$

Bulk Specific Gravity - Mix

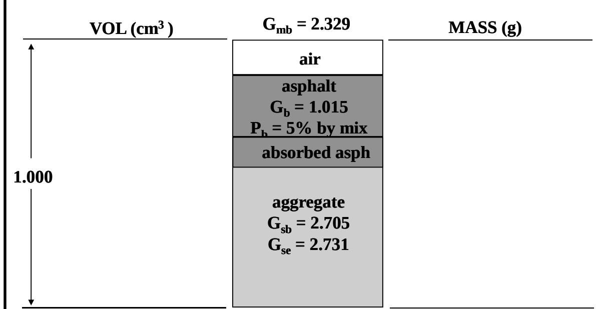


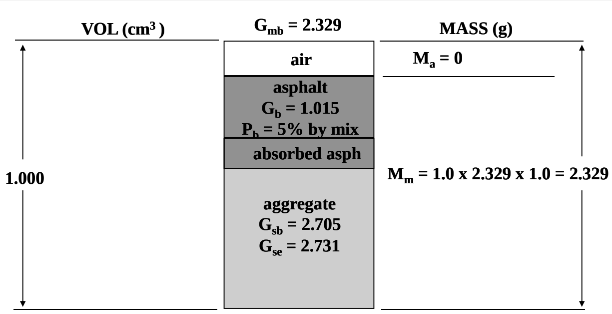
- Definition
  - mass of a unit volume of mix compared to unit volume of water
  - Use G_{mb}
- "Bulk Density"
  - contains several materials

Maximum Theoretical Specific Gravity - Mix

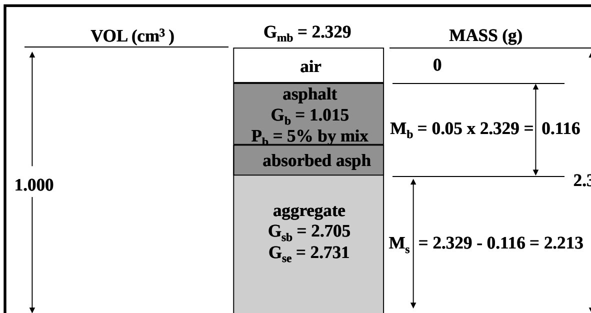


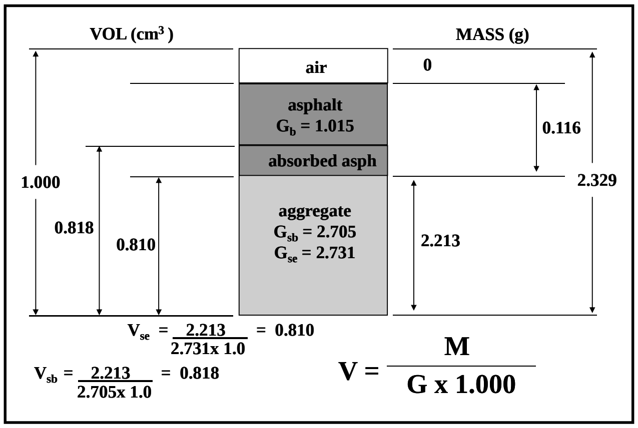
- Definition
  - mass per volume of material containing no air voids, compared to unit volume of water
- Normally Use G_{mm}

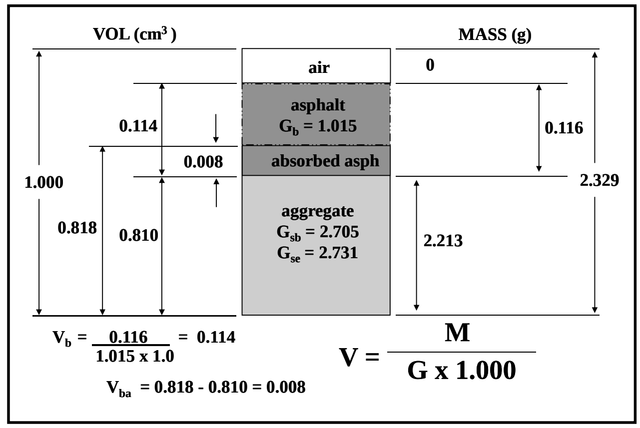


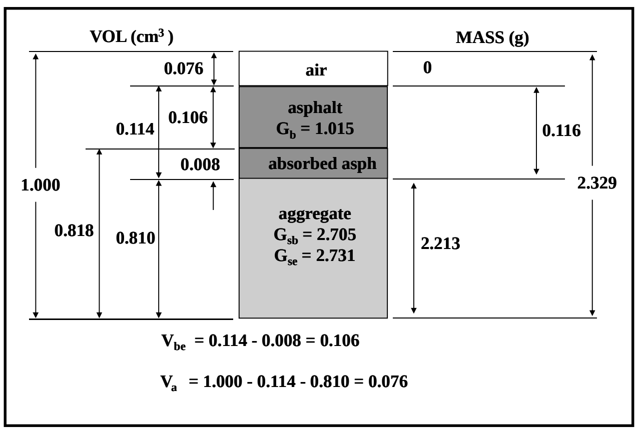


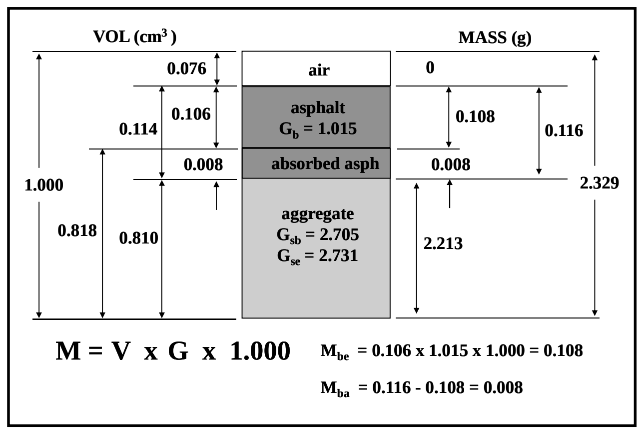
$$M = V \times G \times 1.000$$

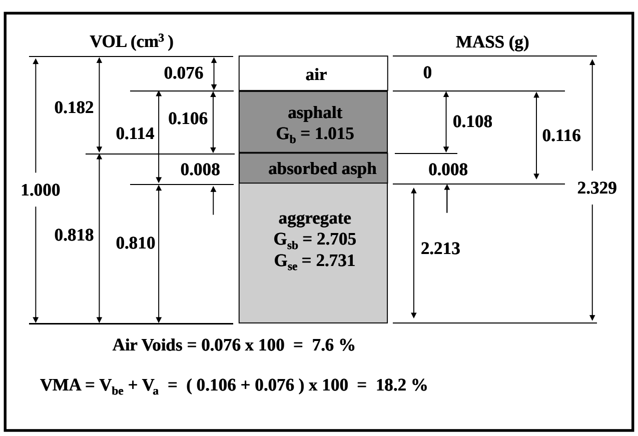


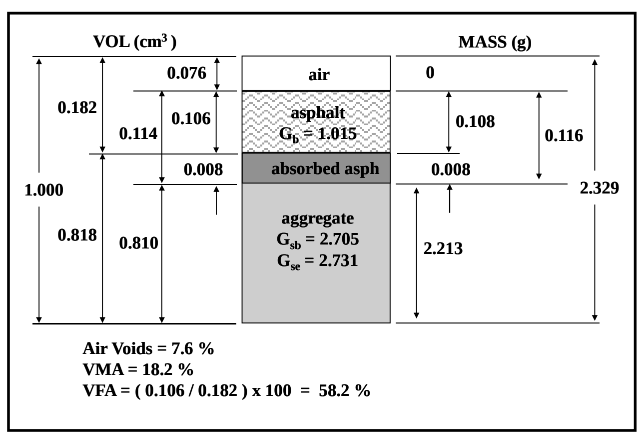

VOL (cm³)
MASS (g)
air
0
asphalt
Gb = 1.015
absorbed asph
aggregate
Gsb = 2.705
Gse = 2.731
1.000
0.818
0.810
0.116
2.329
2.213
Vse = 2.213 / 2.731x 1.0 = 0.810
Vsb = 2.213 / 2.705x 1.0 = 0.818
V = M / G x 1.000

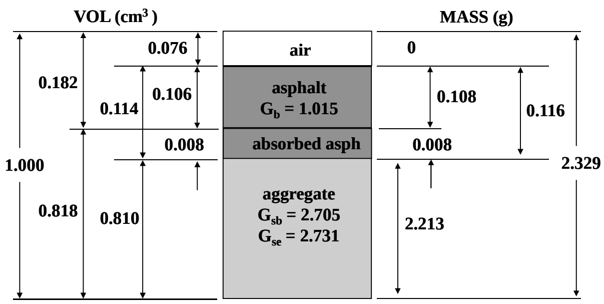

VOL (cm³)
MASS (g)
air
0
asphalt
Gb = 1.015
absorbed asph
aggregate
Gsb = 2.705
Gse = 2.731
0.114
0.008
1.000
0.818
0.810
0.116
2.329
2.213
Vb = 0.116 / 1.015 x 1.0 = 0.114
Vba = 0.818 - 0.810 = 0.008
V = M / G x 1.000


VOL (cm³)
MASS (g)
0.076
air
0
0.114
0.106
asphalt
Gb = 1.015
0.008
absorbed asph
aggregate
Gsb = 2.705
Gse = 2.731
1.000
0.818
0.810
0.116
2.329
2.213
Vbe = 0.114 - 0.008 = 0.106
Va = 1.000 - 0.114 - 0.810 = 0.076


VOL (cm³)
MASS (g)
0.076
air
0
0.114
0.106
asphalt
Gb = 1.015
0.108
0.116
0.008
absorbed asph
0.008
aggregate
Gsb = 2.705
Gse = 2.731
1.000
0.818
0.810
2.329
2.213
M = V x G x 1.000
Mbe = 0.106 x 1.015 x 1.000 = 0.108
Mba = 0.116 - 0.108 = 0.008

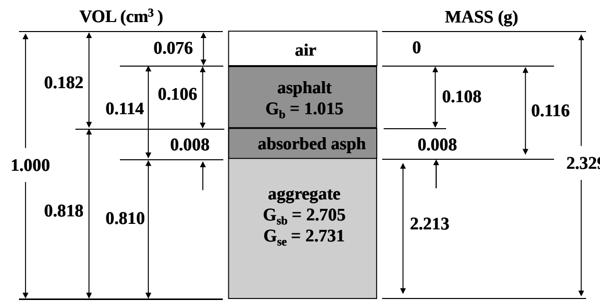

VOL (cm³)
MASS (g)
0.076
air
0
0.182
0.114
0.106
asphalt
Gb = 1.015
0.108
0.116
0.008
absorbed asph
0.008
aggregate
Gsb = 2.705
Gse = 2.731
1.000
0.818
0.810
2.329
2.213
Air Voids = 0.076 x 100 = 7.6 %
VMA = Vbe + Va = (0.106 + 0.076) x 100 = 18.2 %


VOL (cm³)
MASS (g)
0.076
air
0
0.182
0.114
0.106
asphalt
Gb = 1.015
0.108
0.116
0.008
absorbed asph
0.008
aggregate
Gsb = 2.705
Gse = 2.731
1.000
0.818
0.810
2.329
2.213
Air Voids = 7.6 %
VMA = 18.2 %
VFA = (0.106 / 0.182) x 100 = 58.2 %



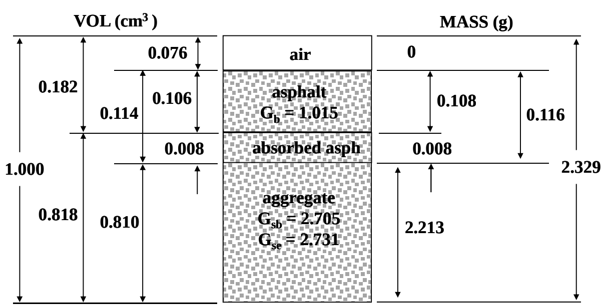
Air Voids = 7.6 %
VMA = 18.2 %
VFA = 58.2 %

Eff. Asp. Cont. = (0.108 / 2.329) x 100 = 4.6 %



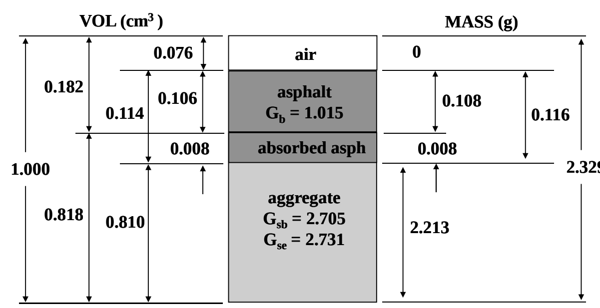
Air Voids = 7.6%
VMA = 18.2 %
VFA = 58.2 %

Effective Asphalt Content = 4.6%
Abs. Asph. Cont. = (0.008 / 2.213) x 100 = 0.4%



Air Voids = 7.6%
VMA = 18.2 %
VFA = 58.2 %

Max Theo Sp Grav $= \dfrac{2.329}{\dfrac{1.000 - 0.076}{1.000}} = 2.521$



Air Voids = 7.6%
VMA = 18.2 %
VFA = 58.2 %

Effective Asphalt Content = 4.6%
Absorbed Asphalt Content = 0.4%
Max Theo Sp Grav = 2.521

- **While the component diagram is a useful tool in understanding the weight-volume relationships, equations are typically used in spreadsheets and computer programs to determine the volumetric properties of hot mix asphalt.**

$$G_{mm} = \frac{100}{\dfrac{P_s}{G_{se}} + \dfrac{P_b}{G_b}}$$

$$V_a = \left(\frac{G_{mm} - G_{mb}}{G_{mm}}\right) \times 100$$

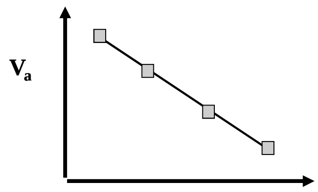
$$VMA = 100 - \frac{G_{mb} \times P_s}{G_{sb}}$$

$$VFA = \left(\frac{VMA - V_a}{VMA}\right) \times 100$$

$$P_{be} = P_b - \frac{P_{ba} \times P_s}{100}$$

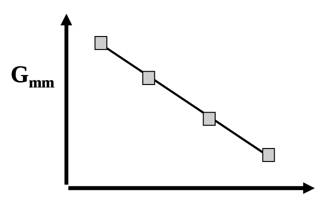
$$P_{ba} = 100 \times \left(\frac{G_{se} - G_{sb}}{G_{se} \times G_{sb}}\right) \times G_b$$

Air Void Content



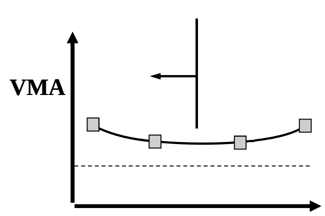
- Superpave design criteria is 4 percent.
- Adjustments for factors such as traffic or climate are made using other inputs, such as design compactive effort.

Maximum Theoretical Specific Gravity at Other Asphalt Contents



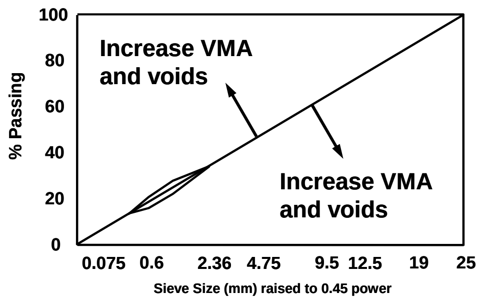
- The relationship between G_{mm} and asphalt content is a straight line.
- For each 0.5 percent change in asphalt content, G_{mm} will change in equivalent increments ranging from 0.018 to 0.021.
- 1999 change: <u>Two</u> G_{mm} tests at each asphalt content.

Voids in the Mineral Aggregate



- Mixes should be selected on the “dry” side of the bottom of the U-shaped VMA curve.
- The desired range - at the bottom of curve, or to the left up to 0.5% asphalt.
- Mixes selected on the “wet” side (to the right of the U-shape) tend to bleed and exhibit flow in the field.

Voids in the Mineral Aggregate

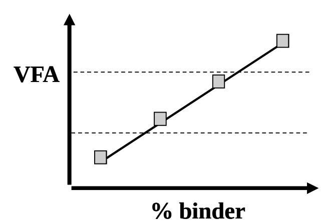


- As the aggregate gradation moves away from the maximum density line, VMA and air voids increase.

VMA Adjustments

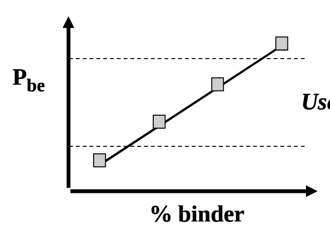
1. Increase or decrease FA20/FA01 blend.
   - Changes 600 µm
   - Changes on minus 75 µm
2. Increase or decrease chips in binder
   - Changes 4.75 mm to 2.36 mm material
3. Increase or decrease minus 75 µm (mineral filler)
4. Change sources

Voids Filled With Asphalt



- VFA is specified to avoid mixes that are too dry (low VFA, causing low durability) and too wet (high VFA, prone to rutting).

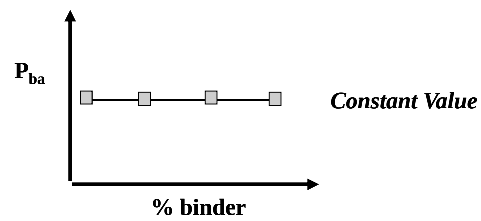
Effective Asphalt Content



Used in Dust to Binder Ratio

- Effective asphalt content increases proportionately with increasing asphalt content.

Absorbed Asphalt Content



- While absorption in the lab is constant, it is a very important property to control in the field when an absorptive aggregate is being used. If silo and/or haul time varies a lot, the effects on the absorbed asphalt can be significant.

Asphalt Mix Tests

QC/QA Asphalt Mix Tests

- Asphalt mix tests are run on the asphalt mix that has been sampled from the roadway
- Or during mix design process

QC/QA Asphalt Mix Tests

- Majority of asphalt paving projects are QC/QA
  - Quality Control (Q/C) – Contractor
  - Quality Assurance (Q/A) – Engineer
    - *may also be called Verification Testing*
  - Independent Assurance (IA) – District
  - Dispute Resolution – Materials and Research

QC/QA Asphalt Mix Tests

- Sampling and Testing requirements are found in:
  - Spec Book (Section 410)
  - Field Sampling and Testing Manual (Section 400 and Appendices)

QC/QA Asphalt Mix Tests

- Specifications for Asphalt Mix Tests
  - Based on mix design parameters
  - Daily averages
  - Average density of all cores

QC/QA Asphalt Mix Tests

- Contractor test results (QC) are used
  - Engineer (QA) tests are a “check”
  - District/Independent Assurance also a “check”
- Engineer (QA) runs tests on independent sample
  - Unless the sample is a split sample

QC/QA Asphalt Mix Tests

- QC – Contractor has test tolerance tables for allowable working range *(Spec Book, 410, Table 6)*
- QA/Engineer has different Tolerance Tables for test tolerances with Contractor tests *(Field Sampling Manual, 410)*
- IA/District has Tolerance Table for correlation test results to compare to QC *(Spec Book, 410 Table 7, and Field Sampling Manual)*
  - Tolerances are different for each

Asphalt Sampling and Reducing

QC/QA Asphalt Mix Tests

- Engineer determines when and where samples are to be taken
- Sampling location and times are determined by using random numbers

Random Sampling

TABLE OF RANDOM NUMBERS WITH EXAMPLES

0.76	0.52	0.01	0.35	0.86	0.34	0.67	0.35	0.48	0.76	0.80	0.95	0.90	0.91	0.17
0.64	0.89	0.47	0.42	0.96	0.24	0.80	0.52	0.40	0.37	0.20	0.63	0.61	0.04	0.02
0.19	0.64	0.50	0.93	0.03	0.23	0.20	0.90	0.25	0.60	0.15	0.95	0.33	0.47	0.64
0.09	0.37	0.67	0.07	0.15	0.38	0.31	0.13	0.11	0.65	0.88	0.67	0.67	0.43	0.97
0.80	0.15	0.73	0.61	0.47	0.64	0.03	0.23	0.66	0.53	0.98	0.95	0.11	0.68	0.77
0.34	0.07	0.27	0.68	0.50	0.36	0.69	0.73	0.61	0.70	0.65	0.81	0.33	0.98	0.85
0.45	0.57	0.18	0.24	0.06	0.35	0.30	0.34	0.26	0.14	0.86	0.79	0.90	0.74	0.39
0.02	0.05	0.16	0.56	0.92	0.68	0.66	0.57	0.48	0.18	0.73	0.05	0.38	0.52	0.47
0.05	0.32	0.54	0.70	0.48	0.90	0.55	0.35	0.75	0.48	0.28	0.46	0.82	0.87	0.09
0.03	0.52	0.96	0.47	0.78	0.35	0.80	0.83	0.42	0.82	0.60	0.93	0.52	0.03	0.44

NDDOT 5 Sampling and Reducing Asphalt Mix

- Asphalt mix is sampled from behind the paver
  - Sampled In-place
  - Approximately 72 pound sample needed
    - Approximately two buckets

NDDOT 5 Sampling and Reducing Asphalt Mix

- Asphalt mix is reduced by quartering
  - One quarter is used for RICE test
  - Opposite quarter is used for a gyratory specimen
    - Second gyratory specimen is made use either remaining quarter
    - Remaining quarter held for any needed re-test
    - Must be held until QA tests are complete

NDDOT 5 Sampling and Reducing Asphalt Mix

- The contractor obtains his own sample
- The Engineer obtains an independent sample
  - Unless the sample is a split sample

Video- no audio

NDDOT 5 Sampling and Reducing Asphalt Mix

- Review Procedure

Asphalt Mix Tests

T 166 Bulk Specific Gravity Of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens

- Test specimens may be either laboratory molded or cores taken from HMA pavements.
- Referenced to as Bulk Specific Gravity (mix)
- Nomenclature is G_{mb}
- Recorded to 0.001

T 166 Bulk Specific Gravity Of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens

- If sample is cored specimen it must be dried to constant weight before testing
  - May obtain wet weight first and record – then dry to constant

T 166 Bulk Specific Gravity Of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens

- Constant weight for T 166 is defined as when further drying does not change the weight by more than 0.05% at two-hour intervals.

T 166 Bulk Specific Gravity Of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens

- Use a balance with basket/cages suspended in water
- Water bath must have overflow
- Water temperature is 77±1.8°F

Video – no audio

T 166 Bulk Specific Gravity Of Compacted Asphalt Mixtures Using Saturated Surface-dry Specimens

- Review Procedure
- Complete worksheets - SFN 50289

T 209 - Theoretical Maximum Specific Gravity And Density Of Hot Mix Asphalt

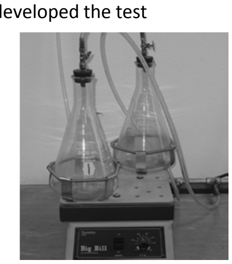
- This test determines the theoretical maximum specific gravity and density of uncompacted asphalt paving mixtures at 77°F (25°C).
- Referred to as “maximum specific gravity”
- Nomenclature is G_{mm}

T 209 - Theoretical Maximum Specific Gravity And Density Of Hot Mix Asphalt

- Test may be ran on laboratory mix or from mix obtained from behind the paver
- Cure laboratory prepared samples
- Cure time is not needed for plant produced mix
  - Absorption takes place during production

T 209 - Theoretical Maximum Specific Gravity And Density Of Hot Mix Asphalt

- Often referred to as “RICE” test
- Named after James Rice, who developed the test procedure
- Two tests ran
- Tests must be within 0.011
  - Results averaged



T 209 - Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt

- The theoretical maximum specific gravity (G_{mm}) of a HMA mixture is the specific gravity excluding air voids.
- The theory is that if all the air voids were eliminated from an asphalt mix sample, the combined specific gravity of the remaining aggregate and asphalt binder would be the theoretical maximum specific gravity – **zero air voids.**

T 209 - Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt

- Theoretical maximum specific gravity can be multiplied by the density of water (62.4 lb/ft^3 or 1000 g/L) to obtain a theoretical maximum density (TMD) or "Rice" density.

T 209 - Theoretical Maximum Specific Gravity And Density Of Hot Mix Asphalt

- Theoretical maximum specific gravity is a critical asphalt mix characteristic because it is used to calculate percent air voids in compacted asphalt mix.
- This calculation is used both in Superpave mix design and determination of in-place air voids in the field.
- *Definition from: www.pavementinteractive.org*

T 209 - Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt

- A measure of bulk specific gravity is made by coring the pavement, and determining bulk specific gravity on the core and then comparing the results to the most current theoretical maximum specific gravity (Rice) test results.
- The calculation determines the air voids of the in-place asphalt mix

Video – no audio

T 209 - Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt

- Review Procedure
- Complete worksheets SFN 50289
  - SFN 50289 also has a calculation for Air Voids

T 312 - Preparing And Determining Density Of Hot Mix Asphalt (HMA) Specimens By Means Of The Superpave Gyratory Compactor

This test is used to prepare specimens for determining the mechanical and volumetric properties of Hot Mix Asphalt (HMA) using the Superpave gyratory compactor.

The specimens simulate the density, aggregate orientation, and structural characteristics obtained in the actual roadway when proper construction procedure is used in the placement paving mix.

T 312 - Preparing And Determining Density Of Hot Mix Asphalt (HMA) Specimens By Means Of The Superpave Gyratory Compactor

- Approximately 4700 grams of loose asphalt mix is needed for each plug
  - One quarter of sample from behind paver
- Two plugs are made

T 312 - Preparing And Determining Density Of Hot Mix Asphalt (HMA) Specimens By Means Of The Superpave Gyratory Compactor

- Heat asphalt mix to 270±5°F
- Heat mold, base plate, funnel and spoon to prevent mix from sticking
- Use filter paper on top and bottom of mix in mold
- Plug height must be 115±5 mm

T 312 - Preparing And Determining Density Of Hot Mix Asphalt (HMA) Specimens By Means Of The Superpave Gyratory Compactor

- Take care when removing the plug from the mold
- Cool if necessary
- Each plugs is then tested using T 166 -Bulk Specific Gravity Of Compacted Asphalt Mixtures Using Saturated Surface-dry Specimens.

T 312 - Preparing And Determining Density Of Hot Mix Asphalt (HMA) Specimens By Means Of The Superpave Gyratory Compactor

- There are a number of models of gyratory compactors available

Video- no audio

T 312 Gyratory

T 312 - Preparing And Determining Density Of Hot Mix Asphalt (HMA) Specimens By Means Of The Superpave Gyratory Compactor

- Review Procedure
- The gyratory specimens are tested by T 166
- Information from T 166 is recorded on SFN 50289

Coring

NDDOT 2 - Contractor Coring

- Density of in-place asphalt mix is determined by "coring"
  - Coring is cutting cores from the mat

NDDOT 2 - Contractor Coring

- Contractor cuts the cores under observation of Engineer
  - Core location is determined by the Engineer using random numbers
    - The frequency is determined by the number of sublots paved
  - Reference – Spec Book 410.05.C.2

NDDOT 2 - Contractor Coring

- One set of (two) cores from each location are taken
  - After cores are cut they are sawed to represent the lift paved and given to the Engineer (QA field lab) for testing
  - One additional full depth core per mile - is cut for the Materials Coordinator for Independent testing
    - Additional core is only needed on projects located on the National Highway System

NDDOT 2 - Contractor Coring

- Extra (third) core taken is given to Materials Coordinator
  - Core is not sawed by Contractor
  - T 166 Bulk Specific Gravity test is performed

NDDOT 2 - Contractor Coring

- Review Procedure

NDDOT 2 - Contractor Coring

- Contractor core information, location, time, results of T 166 are recorded on SFN 10071
- Average of each set of cores is transferred to SFN 59132
  - Average density of cores is basis for payment (Supplemental Specification)
  - Core density average is compared to average of RICE/Maximum Theoretical Density tests 410.05 C.3

Liquid Asphalt Sampling

NDDOT 1 - Sampling Of Bituminous Materials

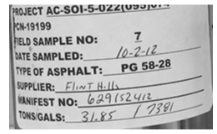
- Contractor sampling of liquid asphalt
  - *PG Sampling also described in Appendix 400-E*
- Samples obtained by Contractor under observation of Engineer

NDDOT 1 - Sampling Of Bituminous Materials

- PG Asphalt: A sample is defined as two one-liter metal, screw top containers filled with asphalt.
  - Randomly obtain two one-liter samples of asphalt from each 250 tons for each supplier
  - For each grade of asphalt

NDDOT 1 - Sampling Of Bituminous Materials

- Proper Labeling includes:
- Refer to NDDOT 1



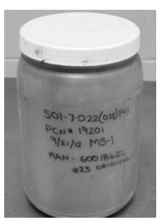
NDDOT 1 - Sampling Of Bituminous Materials

- This style of can should be used for PG samples:
- Cone-top quart size
- Approximate dimensions are:
  - 3.5 inches by 6.25

NDDOT 1 - Sampling Of Bituminous Materials

NDDOT 1 - Sampling Of Bituminous Materials

- Emulsion Sample:
- Two ***<u>one-half gallon</u>*** plastic containers
  - This will be a change to the printed version of NDDOT 1



Common Terminology

Asphalt Paving Terminology

- Lot - one day's placement of pavement, one paver width wide (410.05 C.1)
- Sublot - 2,000 foot portion of lot
  - If a partial sublot at the end of the day's production is less than 1,000, The Engineer will include it in the last complete sublot.
  - The Engineer will consider a partial sublot greater than 1,000 feet a separate sublot.

- For all worksheets or forms:
  - **Sign**
  - **Date**

  If any corrections or change are made – sign/date – or make notation on electronic forms

Table of Contents
Asphalt Test Procedures
Chapter 6

NDDOT 1 - SAMPLING OF BITUMINOUS MATERIALS

Conduct these procedures according to the standards defined by the NDDOT.

SCOPE

The following sampling and testing procedures are for emulsified asphalt materials, performance graded asphalt cement, asphalt cutbacks, and crack and joint sealants.

REFERENCED DOCUMENTS

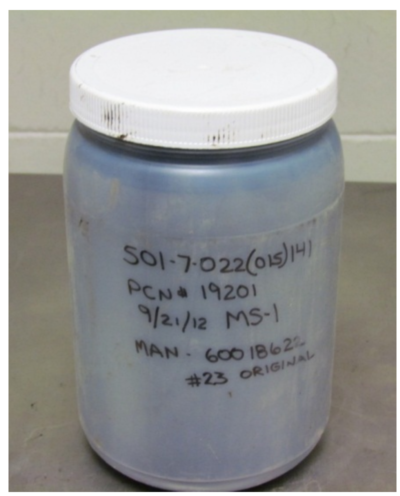
AASHTO M 81, Cutback Asphalt (Rapid-Curing Type)
AASHTO M 82, Cutback Asphalt (Medium-Curing Type)
AASHTO M 320, Performance-Graded Asphalt Binder
AASHTO M 324, Joint and Crack Sealants, Hot Applied, for Concrete and Asphalt Pavement

APPARATUS

One gallon plastic, wide-mouth jar with a plastic cap with liner
One liter metal, screw-top containers
Manufacturer's original unopened container, either two 30-lb single sample boxes or one 55-lb double sample box.

PROCEDURE

EMULSIFIED ASPHALT:



The following is a description of the NDDOT's procedure for sampling and testing emulsified asphalt materials in the Districts and Materials and Research Laboratory.

A sample is defined as two one-gallon plastic containers filled with the material to be tested. One gallon is tested as the original sample and the second gallon is used as a check if the original fails.

District Sampling and Testing:

- The District samples each truck load delivered to the project.
- Each sample will be retained until all testing is completed.
- The District labs test the Saybolt viscosity and sieve on one sample from the first truck load delivered to the project and then one random sample from the next four trucks delivered. The testing rate then goes to two random samples from each additional five truck lot, or fraction of a five

truck lot.

- For CRS-2P emulsions the sampling rate will remain at one sample from each truck load delivered to the project. The sieve and Saybolt viscosity will not be tested unless the Engineer determines that there is a consistency problem with the emulsion.
- For all emulsions, one sample is randomly selected from the first and second halves of the project and sent to the Materials and Research Laboratory for assurance testing.
- Samples should be submitted in a timely manner because there is a time frame in which testing can be done.
- Label each sample container with the following information.
  - Project number
  - PCN number
  - Date sampled
  - Field sample number
  - Manifest number
  - Manufacturer
  - Grade of emulsion
  - Original or check

Materials and Research Laboratory Testing:

- The Materials and Research Laboratory tests the random sample from both halves of the project. If the samples pass, the entire project is accepted with no further testing.
- If one sample passes from either half of the project then that half is accepted with no further testing.
- If one sample fails, then all samples from that half of the project are submitted to the Materials and Research Laboratory for testing.
- The Materials and Research Laboratory will inform the District when sample submittal is required due to failing tests.
- The Materials and Research Laboratory will then test samples around the one that does not pass to determine a failing lot size. For example, there are four loads of emulsion delivered during the first half of a project and five loads for the second half of the project. The District submits Sample 3 from both halves of the project. Sample 3 from the first half passes and all material from the first half is accepted with no further testing. Sample 3 from the second half fails so the Materials and Research Laboratory will test Samples 2 and 4. If Sample 2 passes, Sample 1 is accepted with no further testing. If sample 4 fails, sample 5 is tested. If Sample 5 passes, the failing lot size is made up of loads 3 and 4. See table below:

First Half of Project				Second Half of Project				
Sample 1	Sample 2	Sample 3	Sample 4	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5

PERFORMANCE GRADED ASPHALT CEMENT:

The following is a description of the NDDOT′s procedure for sampling and testing performance-graded (PG) asphalt cement in the Districts and Materials and Research Laboratory.

A sample is defined as two one-liter metal, screw top containers filled with the material to be tested. One liter is tested as the original sample and the second liter is used as a check if the original fails.

District Sampling and Testing:

- NDDOT project personnel will observe the Contractor obtain samples from material delivered to the job site.
- The sampling rate will be a minimum of one sample for every 250 tons for each supplier and grade of asphalt cement, or fraction thereof.
- The sample shall be taken randomly within each 250 tons of material.
- A sample will consist of taking two one-liter samples from the designated transport.
- Both samples will be sent to the NDDOT Materials and Research Laboratory.
- Label each sample can with the following information.
    - Project number
    - PCN number
    - Date sampled
    - Field sample number
    - Manifest number
    - Manufacturer
    - Grade of asphalt
    - Original or check
- Extra samples are also obtained as directed by the Engineer when necessary.

Materials and Research Laboratory Testing:

- The Materials and Research Laboratory will randomly test one sample from each lot of four delivered.
- The testing will be the full battery of tests required by M 320.

ASPHALT CUTBACKS:

The following is a description of the NDDOT′s procedure for sampling and testing cutback asphalt in the Districts and Materials and Research Laboratory.

A sample is defined as two one-liter metal, screw top containers filled with the material to be tested. One liter is tested as the original sample and the second liter is used as a check if the original fails.

- NDDOT project personnel will observe the Contractor obtain samples from material delivered to the job site.
- Obtain two one-liter samples of cutback from each load delivered to the project**.**

- Submit one sample to the Materials and Research Laboratory and keep one in the field for a check sample.
- Label each sample can with the following information.
  - Project number
  - PCN number
  - Date sampled
  - Field sample number
  - Manifest number
  - Manufacturer
  - Type of cutback asphalt
  - Original or check
- Extra samples are also obtained as directed by the Engineer when necessary.

Materials and Research Laboratory Testing:

- The Materials and Research Laboratory will test each sample delivered from the project.
- The testing will be the full battery of tests required by M 81 and M 82 for the type of cutback delivered.

CRACK AND JOINT SEALANT:

The following is a description of the NDDOT′s procedure for sampling and testing crack and joint sealant material in the Districts and Materials and Research Laboratory.

District Sampling and Testing:

- The District will sample each lot of crack and joint sealer delivered to the project.
- The sample will consist of two boxes if the material is delivered in 30-lb single sample boxes.
- The sample will consist of one box if the material is delivered in 55-lb double sample boxes.
- All crack and joint sealers shall be submitted in the manufacturer's original unopened container.
- Completely fill out crack and joint sealer sample card and submit it with

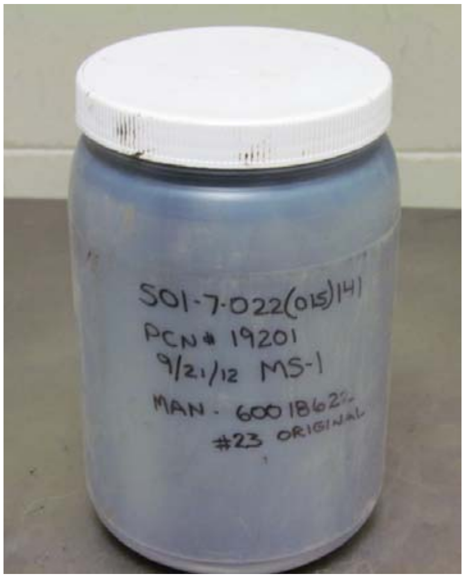
the sample.

Materials and Research Laboratory Testing:

- The Materials and Research Laboratory will test one sample brick from material delivered from the project.
- The testing will be the full battery of tests required by M 324 for the type of material delivered.

Asphalt Sample Containers

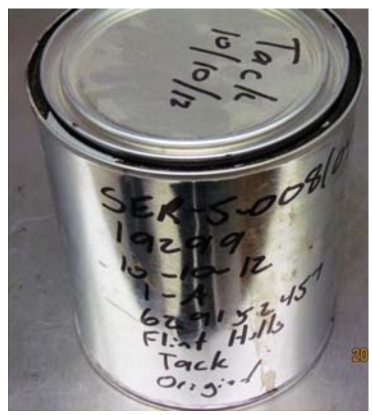
Properly Labeled Emulsion Sample



Improperly Labeled Emulsion Sample

Improper Sample Cans for PG Asphalt

Improper Emulsion Sample Container



Unacceptable PG Asphalt Sample

Proper PG Asphalt Sample

NDDOT 2 - CONTRACTOR CORING

Conduct this procedure according to the standard defined by the NDDOT.

SCOPE

The following sampling procedure is for obtaining asphalt roadway cores.

REFERENCED DOCUMENTS

AASHTO T 166, Bulk Specific Gravity of Compacted Hot-Mix Asphalt Using Saturated Surface-Dry Specimens

APPARATUS

Coring machine
Masonry saw

PROCEDURE

The diameter of the asphalt cores can be either 4" or 6". The cores are obtained by the Contractor, under the observation of the Engineer. The Engineer will compute and mark the locations to be cored using random numbers to determine station and offset from the edge of the pavement. The Engineer will adjust core locations that fall within one foot of the pavement edge or select a new random location that establishes a core location within the test area. The cores are to be taken at least 6" apart but no more than one foot apart and on a longitudinal plane.

Take asphalt cores through the full depth of the asphalt pavement. The core bit must be at right angles to the pavement surface to ensure that the resultant core is reasonably straight. Do not force the core bit through the pavement as this results in rough, uneven cores which precludes certain testing. Exercise care when removing the core from the pavement to prevent distorting or cracking.

After removing the core, fill the hole in the pavement with mix and tamp to a density close to that of the surrounding pavement.

Remove the pavement lift of interest from the core by wet sawing with a masonry saw. Transport the cores to the laboratory for mat density testing. Conduct testing according to T 166.

NDDOT 5 - SAMPLING AND SPLITTING
FIELD VERIFICATION
HOT MIX ASPHALT (HMA) SAMPLES

Conduct this procedure according to the standard defined by the NDDOT.

SCOPE

This procedure is used to obtain samples of hot mix asphalt from behind the paver. The material is then used to run AASHTO T 245 for Marshall plugs, AASHTO T 209 for the Rice test, or AASHTO T 312 for Superpave gyratory compaction.

REFERENCED DOCUMENTS

AASHTO T 209, Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt
AASHTO T 245, Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus
AASHTO T 312, Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

APPARATUS

Shovel - flat bottom, square-edge
Pails
Insulated container
Scoop - flat bottom, square-edge
Trowel

PROCEDURE

SAMPLING:

Obtain a hot mix asphalt sample of approximately 72 lbs (33 kg) from behind the paver. If the sample is for a Marshall project you will only need approximately 50 lbs (23 kg) of hot mix asphalt.

The location the sample is collected is

determined randomly by a DOT employee. The sample may be obtained by Contractor's personnel under observation of DOT personnel.

Take one bucket full of material from the asphalt windrow in front of the paver. This material will be used to fill the hole created when obtaining the sample from behind the paver.

Mark out an area that is large enough to provide the required size sample. Use the shovel and take the sample a minimum of one foot from the edge of the pavement. Be careful to avoid including material from the subgrade or base.

Place the sample in the pails. Place the pails in an insulated container and cover to retain as much heat as possible for the transport to the field lab. A DOT representative will transport the sample to the field or testing lab.

SPLITTING:

At the field lab place the entire sample on a level surface or in a pan and re-mix with the scoop. Carefully flatten to a uniform thickness and divide the flattened mass into four equal quarters using a trowel.

For the Marshall specimens a portion from each of three quarters will be used. The fourth quarter will be used for running the theoretical maximum specific gravity, or Rice test.

For Superpave projects use one quarter for the Rice test and the opposite quarter for one gyratory specimen. A second gyratory specimen can be made from either one of the remaining two quarters.

Place any unused portion of the hot mix asphalt sample into a container and save it for further testing if needed.

Discard the unused portion when all testing on the original sample is complete.

TABLE OF RANDOM NUMBERS

0.10	0.09	0.73	0.25	0.33	0.76	0.52	0.01	0.35	0.86	0.34	0.67	0.35	0.48	0.76	0.80	0.95	0.90	0.91	0.17
0.37	0.54	0.20	0.48	0.05	0.64	0.89	0.47	0.42	0.96	0.24	0.80	0.52	0.40	0.37	0.20	0.63	0.61	0.04	0.02
0.08	0.42	0.26	0.89	0.53	0.19	0.64	0.50	0.93	0.03	0.23	0.20	0.90	0.25	0.60	0.15	0.95	0.33	0.47	0.64
0.99	0.01	0.90	0.25	0.29	0.09	0.37	0.67	0.07	0.15	0.38	0.31	0.13	0.11	0.65	0.88	0.67	0.67	0.43	0.97
0.12	0.80	0.79	0.99	0.70	0.80	0.15	0.73	0.61	0.47	0.64	0.03	0.23	0.66	0.53	0.98	0.95	0.11	0.68	0.77
0.66	0.06	0.57	0.47	0.17	0.34	0.07	0.27	0.68	0.50	0.36	0.69	0.73	0.61	0.70	0.65	0.81	0.33	0.98	0.85
0.31	0.06	0.01	0.08	0.05	0.45	0.57	0.18	0.24	0.06	0.35	0.30	0.34	0.26	0.14	0.86	0.79	0.90	0.74	0.39
0.85	0.26	0.97	0.76	0.02	0.02	0.05	0.16	0.56	0.92	0.68	0.66	0.57	0.48	0.18	0.73	0.05	0.38	0.52	0.47
0.63	0.57	0.33	0.21	0.35	0.05	0.32	0.54	0.70	0.48	0.90	0.55	0.35	0.75	0.48	0.28	0.46	0.82	0.87	0.09
0.73	0.79	0.64	0.57	0.53	0.03	0.52	0.96	0.47	0.78	0.35	0.80	0.83	0.42	0.82	0.60	0.93	0.52	0.03	0.44
0.98	0.52	0.01	0.77	0.67	0.14	0.90	0.56	0.86	0.07	0.22	0.10	0.94	0.05	0.58	0.60	0.97	0.09	0.34	0.33
0.11	0.80	0.50	0.54	0.31	0.39	0.80	0.82	0.77	0.32	0.50	0.72	0.56	0.82	0.48	0.29	0.40	0.52	0.42	0.01
0.83	0.45	0.29	0.96	0.34	0.06	0.28	0.89	0.80	0.83	0.13	0.74	0.67	0.00	0.78	0.18	0.47	0.54	0.06	0.10
0.88	0.68	0.54	0.02	0.00	0.86	0.50	0.75	0.84	0.01	0.36	0.76	0.66	0.79	0.51	0.90	0.36	0.47	0.64	0.93
0.99	0.59	0.46	0.73	0.48	0.87	0.51	0.76	0.49	0.69	0.91	0.82	0.60	0.89	0.28	0.93	0.78	0.56	0.13	0.68
0.65	0.48	0.11	0.76	0.74	0.17	0.46	0.85	0.09	0.50	0.58	0.04	0.77	0.69	0.74	0.73	0.03	0.95	0.71	0.86
0.80	0.12	0.43	0.56	0.35	0.17	0.72	0.70	0.80	0.15	0.45	0.31	0.82	0.23	0.74	0.21	0.11	0.57	0.82	0.53
0.74	0.35	0.09	0.98	0.17	0.77	0.40	0.27	0.72	0.14	0.43	0.23	0.60	0.02	0.10	0.45	0.52	0.16	0.42	0.37
0.69	0.91	0.62	0.68	0.03	0.66	0.25	0.22	0.91	0.48	0.36	0.93	0.68	0.72	0.03	0.76	0.62	0.11	0.39	0.90
0.09	0.89	0.32	0.05	0.05	0.14	0.22	0.56	0.85	0.14	0.46	0.42	0.75	0.67	0.88	0.96	0.29	0.77	0.88	0.22
0.91	0.49	0.91	0.45	0.23	0.68	0.47	0.92	0.76	0.86	0.46	0.16	0.28	0.35	0.54	0.94	0.75	0.08	0.99	0.23
0.80	0.33	0.69	0.45	0.98	0.26	0.94	0.03	0.68	0.58	0.70	0.29	0.73	0.41	0.35	0.53	0.14	0.03	0.33	0.40
0.44	0.10	0.48	0.19	0.49	0.85	0.15	0.74	0.79	0.54	0.32	0.97	0.92	0.65	0.75	0.57	0.60	0.04	0.08	0.81
0.12	0.55	0.07	0.37	0.42	0.11	0.10	0.00	0.20	0.40	0.12	0.86	0.07	0.46	0.97	0.96	0.64	0.48	0.94	0.39
0.63	0.60	0.64	0.93	0.29	0.16	0.50	0.53	0.44	0.84	0.40	0.21	0.95	0.25	0.63	0.43	0.65	0.17	0.70	0.82
0.61	0.19	0.69	0.04	0.46	0.26	0.45	0.74	0.77	0.74	0.51	0.92	0.43	0.37	0.29	0.65	0.39	0.45	0.95	0.93
0.15	0.47	0.44	0.52	0.66	0.95	0.27	0.07	0.99	0.53	0.59	0.36	0.78	0.38	0.48	0.82	0.39	0.61	0.01	0.18
0.94	0.55	0.72	0.85	0.73	0.67	0.89	0.75	0.43	0.87	0.54	0.62	0.24	0.44	0.31	0.91	0.19	0.04	0.25	0.92
0.42	0.48	0.11	0.62	0.13	0.97	0.34	0.40	0.87	0.21	0.16	0.86	0.84	0.87	0.67	0.03	0.07	0.11	0.20	0.59
0.23	0.52	0.37	0.83	0.17	0.73	0.20	0.88	0.98	0.37	0.68	0.93	0.59	0.14	0.16	0.26	0.25	0.22	0.96	0.63
0.04	0.49	0.35	0.24	0.94	0.75	0.24	0.63	0.38	0.24	0.45	0.86	0.25	0.10	0.25	0.61	0.96	0.27	0.93	0.35
0.00	0.54	0.99	0.76	0.54	0.64	0.05	0.18	0.81	0.59	0.96	0.11	0.96	0.38	0.96	0.54	0.69	0.28	0.23	0.91
0.35	0.96	0.31	0.53	0.07	0.26	0.89	0.80	0.93	0.54	0.33	0.35	0.13	0.54	0.62	0.77	0.97	0.45	0.00	0.24
0.59	0.80	0.80	0.83	0.91	0.45	0.42	0.72	0.68	0.42	0.83	0.60	0.94	0.97	0.00	0.13	0.02	0.12	0.48	0.92
0.46	0.05	0.88	0.52	0.36	0.01	0.39	0.00	0.22	0.86	0.77	0.28	0.14	0.40	0.77	0.93	0.91	0.08	0.36	0.47
0.32	0.17	0.90	0.05	0.97	0.87	0.37	0.92	0.52	0.41	0.05	0.56	0.70	0.70	0.07	0.86	0.74	0.31	0.71	0.57
0.69	0.23	0.46	0.14	0.06	0.20	0.11	0.74	0.52	0.04	0.15	0.95	0.66	0.00	0.00	0.18	0.74	0.39	0.24	0.23
0.19	0.56	0.54	0.14	0.30	0.01	0.75	0.87	0.53	0.79	0.40	0.41	0.92	0.15	0.85	0.66	0.67	0.43	0.68	0.06
0.45	0.15	0.51	0.49	0.38	0.19	0.47	0.60	0.72	0.46	0.43	0.66	0.79	0.45	0.43	0.59	0.04	0.79	0.00	0.33
0.94	0.86	0.43	0.19	0.94	0.36	0.16	0.81	0.08	0.51	0.34	0.88	0.88	0.15	0.53	0.01	0.54	0.03	0.54	0.56
0.98	0.08	0.62	0.48	0.26	0.45	0.24	0.02	0.84	0.04	0.44	0.99	0.90	0.88	0.96	0.39	0.09	0.47	0.34	0.07
0.33	0.18	0.51	0.62	0.32	0.41	0.94	0.15	0.09	0.49	0.89	0.43	0.54	0.85	0.81	0.88	0.69	0.54	0.19	0.94
0.80	0.95	0.10	0.04	0.06	0.96	0.38	0.27	0.07	0.74	0.20	0.15	0.12	0.33	0.87	0.45	0.01	0.62	0.52	0.98
0.79	0.75	0.24	0.91	0.40	0.71	0.96	0.12	0.82	0.96	0.69	0.86	0.10	0.25	0.91	0.74	0.85	0.22	0.05	0.39
0.18	0.63	0.33	0.25	0.37	0.98	0.14	0.50	0.65	0.71	0.31	0.01	0.02	0.46	0.74	0.05	0.45	0.56	0.14	0.27
0.74	0.02	0.94	0.39	0.02	0.77	0.55	0.73	0.22	0.70	0.97	0.79	0.01	0.71	0.19	0.52	0.52	0.75	0.80	0.21
0.54	0.17	0.84	0.56	0.11	0.80	0.99	0.33	0.71	0.43	0.05	0.33	0.51	0.29	0.69	0.56	0.12	0.71	0.92	0.55
0.11	0.66	0.44	0.98	0.83	0.52	0.07	0.98	0.48	0.27	0.59	0.38	0.17	0.15	0.39	0.09	0.97	0.33	0.34	0.40
0.48	0.32	0.47	0.79	0.28	0.31	0.24	0.96	0.47	0.10	0.02	0.29	0.53	0.68	0.70	0.32	0.30	0.75	0.75	0.46
0.69	0.07	0.49	0.41	0.38	0.87	0.63	0.79	0.19	0.76	0.35	0.58	0.40	0.44	0.01	0.10	0.51	0.82	0.16	0.15

AASHTO T 166 - BULK SPECIFIC GRAVITY OF COMPACTED ASPHALT MIXTURES USING SATURATED SURFACE-DRY SPECIMENS

Conduct this procedure according to AASHTO T 166, NDDOT Modified.

The standard test procedure specifies for cores to be immersed for 4±1 minutes. The NDDOT modification is to immerse cores for 3 to 3½ minutes.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

The following describes "Method A".

SCOPE

This test procedure determines the bulk specific gravity of specimens of compacted asphalt mixtures.

REFERENCED DOCUMENTS

AASHTO T 275, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens
AASHTO T 331, Bulk Specific Gravity and Density of Hot Mix Asphalt Using Automatic Vacuum Sealing Method

APPARATUS

Balance, readable to 0.1% of the sample weight
Suspension apparatus
Water bath with overflow outlet
Damp towel

TEST SPECIMEN

Test specimens may be either laboratory molded or cores taken from HMA pavements. They shall be free from foreign material such as seal coat, tack coat, or foundation material. Layers may be separated by sawing or other suitable means with care taken not to damage the specimen. Laboratory molded specimens may be cooled by a fan.

PROCEDURE

Record all weights to the nearest 0.1 g.

Dry the specimens to constant weight.

Samples saturated with water shall be initially dried overnight at 125±5°F (52±3°C) then weighed at two-hour intervals. Recently molded laboratory specimens which have not been exposed to moisture do not require drying.

Cool the specimens to 77±9°F (25±5°C) and weigh each specimen. Record this mass as specimen in air.

Immerse each specimen in water at 77±1.8°F (25±1°C) suspended beneath a balance for a period of 3 to 3½ minutes. Record this mass as specimen in water.

Remove the specimen from the water and surface dry by blotting with a damp towel. Weigh the mass as quickly as possible and record as surface-dry specimen in air.

CALCULATIONS

To calculate the bulk specific gravity, use the following formula:

Bulk Specific Gravity (G_{mb}) = [A/(B - C)]

A = Weight in grams of the specimen in air
B = Weight in grams, surface dry
C = Weight in grams, in water

Report the bulk specific gravity to the nearest 0.001.

The bulk specific gravity may be used to calculate the unit weight of the specimens by multiplying by 62.4. The results are in lbs/cu.ft.

Calculate the percent of water absorbed by the specimen (on a volume basis) as follows:

Percent of water absorbed by volume = [(B - A)/(B - C)] x 100

If the percent of water absorbed by the specimen exceeds 2%, use AASHTO T 275 or T 331 to determine the bulk specific gravity.

NOTES

Constant weight is defined as when further drying does not change the weight by more than 0.05% at two-hour intervals.

Terry cloth has been found to work well for an absorbent cloth. Damp is considered to be when no water can be wrung from the towel.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

AASHTO T 209 - THEORETICAL MAXIMUM SPECIFIC GRAVITY AND DENSITY OF HOT MIX ASPHALT

Conduct this procedure according to AASHTO T 209, NDDOT Modified.

The standard test procedure specifies flasks are agitated for 15±2 minutes and after agitation the flasks are immersed in water for 10±1 minutes. The NDDOT modification is to agitate for 15 minutes ± 30 seconds and after agitation the flasks are immersed in water for 10 minutes ± 30 seconds.

The standard test procedure allows for a wetting agent such as Aerosol OT to facilitate the release of entrapped air. NDDOT does not allow any wetting agent.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

SCOPE

This test determines the theoretical maximum specific gravity and density of uncompacted bituminous paving mixtures at 77°F (25°C).

REFERENCED DOCUMENTS

NDDOT 5, Sampling and Splitting Field Verification Hot Mix Asphalt (HMA) Samples

APPARATUS

Vacuum container
Volumetric flasks,* two at 2000 mL each
Vacuum gage, capable of measuring 30 mm Hg (4 kPa)
Vacuum pump, capable of evacuating air from flask to pressure of 30 mm Hg (4 kPa)
Thermometers
Water bath
Orbital shaker
Pan
Glass cover plate
Balance

*****Flasks shall be sufficiently strong to withstand a partial vacuum and shall have a cover fitted with a rubber stopper with a hose connection. A smooth piece of fine wire mesh covering the hose opening will minimize the possibility of loss of fine material. The top surfaces of the flasks shall be smooth and substantially plane.

TEST SPECIMEN

Material used for this test procedure may be obtained from behind the paver as outlined in NDDOT 5, or from laboratory prepared samples. An approximate 2000 g sample of hot mix asphalt is needed.

PROCEDURE

Weigh and record all masses to the nearest tenth of a gram on SFN 7925 or SFN 50289.

Cure laboratory prepared samples in an oven at 275±9°F (135±5°C) for a minimum of 2 hours or until constant** mass is achieved.

Paving mixtures that have not been prepared in a laboratory with oven-dried aggregates shall be dried to constant** mass at a temperature of 221±9°F (105±5°C).

**Constant is defined as when mass repeats within 0.1%.

Determine the weight of each flask full of distilled water, with a matching glass plate, at a temperature of 77±1°F (25±0.5°C).

To obtain the weight, overfill the flask so the water is convexed above the brim. Then slide the cover plate over the brim of the flask. The flask should be free of any air bubbles. Dry the outside. Weigh and record.

Spread in a large pan. Cool to room temperature. While this mixture is cooling, periodically, carefully separate the particles so that clumps of the fine aggregate portion are no larger than 1/4" (6.3 mm).

Place the flask on a scale and tare the scale. Place half of the hot mix asphalt sample in the flask and weigh. After recording weight, add sufficient distilled water that is at approximately 77°F to cover the sample completely. Repeat this process with the remaining half of the material using the second flask.

Remove entrapped air by subjecting the contents of both flasks to a partial vacuum of 30 mm Hg (4 kPa). Maintain the partial vacuum and agitate the containers and contents with an orbital shaker that is set at 225 to 250 rpm with a 3/4" throw for 15 minutes ± 30 seconds.

Note: Problems have been encountered with some mixes clumping and forming a mass instead of freely moving particles during the 15-minute agitation period. If this happens, it is probable that all the entrapped air will not be removed. (This is more likely to happen when the sample is not adequately cooled before putting it in the flasks). The mix will have to be broken up before agitation continues. This can be done by:

- Shutting off the vacuum to the flask, while keeping the vacuum pump running.
- Maintain all hose connections.
- Vigorously hand shake the flask until the sample is free moving.
- Take care so vacuum is not lost to the flask.
- Return the flask to the shaker and turn on the vacuum to the flask.
- Do not stop the timer through this procedure.

After removing from orbital shaker, release the vacuum by increasing the pressure at a rate not to exceed 60 mm Hg (8 kPa) per second. Remove flasks from shaker. Fill flasks *(slightly overfill)* with distilled water that is at a temperature of 77±1°F (25±0.5°C). Place in a water bath at a temperature of 77±2°F (25±1°C) for 10 minutes ± 30 seconds.

Remove from water bath, slide the glass cover plate over the flask, and remove from the bath. Dry the outside. Weigh and record.

<u>Flask Calibration</u>

Determine the weight of each flask full of distilled water, with a matching glass plate, at a temperature of 77±1°F (25±0.5°C).

To obtain the weight, overfill the flask so the water is convexed above the brim. Then slide the cover plate over the brim of the flask. The flask should be free of any air bubbles. Dry the outside. Weigh and record.

CALCULATIONS

The theoretical maximum specific gravity weight in air is calculated as follows:

Theoretical Maximum Specific Gravity = A/(A + D – E)

A = mass of oven-dry sample in air
D = mass of container filled with water at 77°F (25°C)
E = mass of container filled with sample and water at 77°F (25°C)

The difference in maximum specific gravity results of two properly conducted tests on the same sample shall not exceed 0.011. Use the average of the results from the two flasks of the passing test for the final maximum specific gravity.

If the difference exceeds 0.011, rerun the test.

NOTES

The specified cure time in the oven is a minimum of two hours for laboratory prepared specimens only. Plant produced materials should not be cured since absorption takes place during production.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

AASHTO T 245 - RESISTANCE TO PLASTIC FLOW OF BITUMINOUS MIXTURES USING MARSHALL APPARATUS

Conduct this procedure according to AASHTO T 245.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification details.

SCOPE

This procedure is used to prepare cylindrical specimens of bituminous paving mixture loaded on the lateral surface by means of a Marshall apparatus.

REFERENCED DOCUMENTS

NDDOT 5, Sampling and Splitting Field Verification Hot Mix Asphalt (HMA) Samples

APPARATUS

- Mold cylinders, base plate and extension collars
- Triple compaction hammer and apparatus
- Compaction pedestal
- Extrusion jack
- Oven or hot plate
- Fan (optional)
- Balance
- Paper disks
- Spoons
- Spatula
- Colored grease pencil
- Pans
- Mixing Bowl
- Mechanical mixing apparatus
- Thermometers
- Gloves
- Breaking head
- Marshall Stability machine
- Water bath

TEST SPECIMEN

Material used to prepare at least three specimens may be obtained from behind the paver as outlined in NDDOT 5.

PROCEDURE

Heat the sample in an oven to 270±5°F.

Heat the molds and hammer faces to a temperature between 200 to 300°F (93 to 149°C). Once heated, the hammer may be placed in a sand bath or on a hot plate to maintain the temperature.

Enough material shall be used that will result in a compacted specimen 2.5±0.05" (63.5±1.27 mm) in height. This will take approximately 1200 g.

Assemble the mold and collar on the base plate. Place the assembled mold on a scale and place a paper disk in the bottom of the mold. Add approximately 1200 g of mix into the mold.

Position the mold assembly on the mold holder of the triple Marshall Mix compaction machine. Using a heated spatula, spade around the outer perimeter of the mold 15 times. Then spade the interior portion of the mix 10 times.

Form the top of the mix into a smooth, slightly-rounded mound. Place a paper disk on the top of the mix.

Repeat the same steps for the two remaining molds.

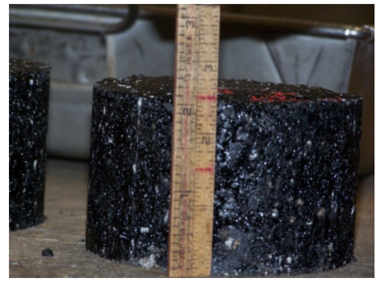
Position and attach the Marshall hammers. Verify that the machine counter is set for the correct number of blows required by the mix design. This may be either 50 or 75 blows with the compaction hammer having a free fall of 18". Push the start button on the counter and wait for the machine to complete its blows.

Remove the base plate and collar. Turn the molds over and reassemble the mold with the base plate and collar. Apply the same number of compaction blows as on the reverse side.

When the compaction blows are complete, remove the hammers from the apparatus. Take the molds off the bases and remove the paper disks. Keep the last side compacted facing up.

Mark the specimens on the last side compacted at each asphalt content with a colored grease pencil. As an example, mark them 5-A, 5-B, or 5-C.

Position the mold in the extrusion jack. With the last side pounded facing up, remove the specimen from the mold and set it aside on a smooth, flat surface at room temperature overnight. A fan can be used for rapid cooling if necessary.



TESTING FLOW AND STABILITY OF A SPECIMEN

If the specimens are to be tested for plastic flow, place the specimens in a water bath 30 to 40 minutes or in an oven for 2 hours. Maintain the bath or oven at 140±1.8°F (60±1°C).

The testing head apparatus temperature shall be between 70 to 100°F (21.1 to 37.8°C).

Guide rods shall be thoroughly clean and lubricated so that the upper test head slides freely over them.

Remove the specimen from the water bath or oven and place in the lower segment of the breaking head. Place the upper segment of the breaking head on the specimen and insert assembly into the compression machine. Adjust the measuring dial to zero in the proving ring to measure maximum load and place the flow meter dial on a guide rod to measure flow.

Apply the load to the specimen with a constant rate of movement for the testing machine head of 2" (50.8 mm) per minute until the maximum load is reached. When applying load hold when maximum load is reached, obtain the dial reading in the proving ring and remove the flow meter dial from its location. Record both values.

The elapsed time for the test from removal of the test specimen from the water bath to the maximum load determination shall not exceed 30 seconds.

CALCULATIONS

To determine the stability of the specimen, the dial reading is converted to a maximum load by a chart supplied with the compression machine.

When core specimens vary from the 2.5" depth, a correction factor must be applied to the maximum load.

To determine stability, use the following formula:

Stability = Maximum Load x Correction Factor

Stability is recorded to the nearest whole number.

Flow is a direct reading of the flow meter dial and recorded to 0.01".

Correction factors are found in the following table.

CORRECTION FACTOR TABLE

Volume of Specimen (cm^3)	Thickness of Specimen (in.)	mm	Correlation Ratio	Volume of Specimen (cm^3)	Thickness of Specimen (in.)	mm	Correlation Ratio
200 to 213	1	25.4	5.56	406 to 420	2	50.8	1.47
214 to 225	1 1/16	27.0	5.00	421 to 431	2 1/16	52.4	1.39
226 to 237	1 1/8	28.6	4.55	432 to 443	2 1/8	54.0	1.32
238 to 250	1 3/16	30.2	4.17	444 to 456	2 3/16	55.6	1.25
251 to 264	1 1/4	31.8	3.85	457 to 470	2 1/4	57.2	1.19
265 to 276	1 5/16	33.3	3.57	471 to 482	2 5/16	58.7	1.14
277 to 289	1 3/8	34.9	3.33	483 to 495	2 3/8	60.3	1.09
290 to 301	1 7/16	36.5	3.03	496 to 508	2 7/16	61.9	1.04
302 to 316	1 1/2	38.1	2.78	509 to 522	2 1/2	63.5	1.00
317 to 328	1 9/16	39.7	2.50	523 to 535	2 9/16	65.1	0.96
329 to 340	1 5/8	41.3	2.27	536 to 546	2 5/8	66.7	0.93
341 to 353	1 11/16	42.9	2.08	547 to 559	2 11/16	68.3	0.89
354 to 367	1 3/4	44.4	1.92	560 to 573	2 3/4	69.9	0.86
368 to 379	1 13/16	46.0	1.79	574 to 585	2 13/16	71.4	0.83
380 to 392	1 7/8	47.6	1.67	586 to 598	2 7/8	73.0	0.81
393 to 405	1 15/16	49.2	1.56	599 to 610	2 15/16	74.6	0.78
				611 to 625	3	76.2	0.76

NOTES

Put the compaction hammers on the Marshall machine by attaching them to the pins at the top of the pedestal. There is a hook on one side of the hammer. This hook must be attached to the chain drive on the machine to maintain the proper sequence.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

AASHTO T 312 - PREPARING AND DETERMINING DENSITY OF HOT MIX ASPHALT (HMA) SPECIMENS BY MEANS OF THE SUPERPAVE GYRATORY COMPACTOR

Conduct this procedure according to AASHTO T 312.

Consult the current edition of AASHTO for procedure in its entirety and equipment specification and details.

SCOPE

This test is used to prepare specimens for determining the mechanical and volumetric properties of Hot Mix Asphalt (HMA) using the Superpave gyratory compactor. The specimens simulate the density, aggregate orientation, and structural characteristics obtained in the actual roadway when proper construction procedure is used in the placement paving mix.

REFERENCED DOCUMENTS

NDDOT 5, Sampling and Splitting Field Verification Hot Mix Asphalt (HMA) Samples

APPARATUS

Gyratory Compactor
Molds
Thermometers
Paper disks
Oven
Spoon
Pans
Funnel
Fan
Balance
Extrusion jack

TEST SPECIMEN

Material used to prepare at least three specimens is obtained from behind the paver as outlined in NDDOT 5.

PROCEDURE:

Mixture Preparation:

Immediately prior to the time the HMA is ready for compaction, turn on the power to your compactor for the warm up period recommended by the manufacturer.

Next, verify the settings on the compactor, and if you are using a computer to record your data, enter your header information.

The mold, base plate, and funnel should be preheated in an oven at 200 to 300°F (93 to 149°C) for 30 to 60 minutes. This will prevent the asphalt mix from sticking to molds during the compaction process and sticking in the funnel during sample preparation.

Heat the asphalt mixture in an oven at 270±5°F (132±3°C).

Compaction Procedure:

When the asphalt mixture reaches 270±5°F (132±3°C), remove the heated mold and base plate from the oven and place a paper disk in the bottom of the mold.

Mix the entire sample, approximately 4700 g, to be compacted with a heated spoon and then carefully put the sample in a funnel. With the funnel, place all the mixture into the mold in one lift.

With a heated spoon or spatula level the mix in the mold and place a paper disk on the top. Load the mold into the compactor and center the loading ram.

Set the pressure, angle setting, and gyrations per minute. Push the start button on the compactor and wait for the compaction process to finish.

When completed, retract the loading ram and remove the mold assembly from the compactor.

The specimens can be removed immediately from the mold after compaction for most HMA mixes. In order to insure the specimen does not get damaged, a cooling period of 5 to 10 minutes

in front of a fan may be necessary.

Remove the specimen with an extrusion jack. Remove the paper disks from the top and bottom of the specimen.

Procedures for "Pine" brand portable gyratory compactors vary from the procedure listed above.

Place the mold in the machine using the mold tongs, rotating clockwise to the stops before starting the test. If it is in the correct position, you will be able to see a mold pin in the middle of the retainer cylinder port.

Place the base plate in the mold, beveled side facing down, place paper filter on top, place the funnel on top of mold and pour mix into mold.

Place second filter paper on leveled mix then second base plate beveled side up.

Before closing the compaction chamber, make certain the ram is fully retracted and the gyratory head is parked. Close the machine and clamp it into place.
Set the pressure, angle setting, and gyrations per minute. Push the start button on the compactor and wait for the compaction process to finish.

When the compaction process is complete, the gyratory head and hydraulics automatically shut off. At this point the specimen may be extruded from the mold.

The funnel cap is used to hold the mold down in the compaction chamber as the ram pushes the specimen out of the mold. Press the UNLOAD function key twice. The ram pushes the specimen up and out of the mold. Press the Reverse function key to assure that the gyratory head is parked properly. Remove top paper, carefully unclamp and remove the funnel cap. Move the specimen to a nearby flat surface and remove bottom paper. Press the RESET button to lower the ram.

NOTES

Before testing, the gyratory compactor should be calibrated periodically for pressure, height, angle, and rotation to make sure compactor is within specifications.

CALIBRATION

A calibration check of the equipment should be performed annually as a minimum, or whenever damage or repair occurs.

optimum 6.5% AC

TROXLER 4140 Gyratory Compactor

Sample ID: 6.5-A   Time: 11:03   Date: 8/22/01

Serial Number: 185
Pressure: 600 KPa

	1	2	3	4	5	6	7	8	9	10
0	136.3	134.2	132.4	130.9	129.9	128.8	128.1	127.4	126.8	126.3
10	125.8	125.3	124.9	124.6	124.2	123.9	123.6	123.3	123.1	122.8
20	122.6	122.4	122.1	121.9	121.8	121.6	121.4	121.2	121.1	120.9
30	120.8	120.6	120.5	120.4	120.2	120.1	120.0	119.9	119.8	119.6
40	119.5	119.4	119.3	119.2	119.1	119.0	119.0	118.9	118.8	118.7
50	118.6	118.5	118.5	118.4	118.3	118.2	118.1	118.1	118.0	117.9
60	117.9	117.8	117.8	117.7	117.6	117.6	117.5	117.5	117.4	117.3
70	117.3	117.2	117.2	117.1	117.1	117.0	117.0	116.9	116.9	116.8
80	116.8	116.7	116.7	116.6	116.6	116.6	116.5	116.5	116.4	116.4
90	116.4	116.3	116.3	116.2	116.2	116.2	116.1	116.1	116.1	116.0
100	116.0	116.0	115.9	115.9	115.9	115.8	115.8	115.8	115.7	115.7
110	115.7	115.6	115.6	115.6	115.5					

DEFINITIONS

Aggregate		
Term	**Identifier**	**Definition**
Absorption		The capacity of an aggregate to absorb water (or asphalt).
Specific Gravity		The ratio between the weight of a given volume of aggregate and the weight of an equal volume of water.
Bulk Specific Gravity	G_{sb}	The ratio of the oven dry weight in air of a unit volume of a permeable material (including both permeable and impermeable voids normal for the material) to the unit weight of an equal volume of water at a stated temperature.
Apparent Specific Gravity	G_{sa}	The ratio of the oven dry weight in air of a unit volume of an impermeable material to the weight of an equal volume of water at a stated temperature.
Asphalt		
Air Voids	P_a or V_a	The total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as a percent of the bulk volume of the compacted paving mixture.
Voids in Mineral Aggregate	VMA	The volume of inter-angular void space between the aggregate particles of a compacted paving mixture that includes the air voids and the volume of the asphalt not absorbed into the aggregate.
Voids Filled with Asphalt	VFA	The percent of the volume of the Voids in Mineral Aggregate (VMA) that is filled with asphalt cement.
Effective Specific Gravity of Aggregate	G_{se}	The ratio of the oven dry weight in air of a unit volume of permeable material (excluding voids permeable to asphalt) to the weight of an equal volume of water at a stated temperature.
Bulk Specific Gravity of Compacted Mixture	G_{mb}	The ratio of the weight in air of a unit volume of compacted specimen of hot mix asphalt (including permeable voids) to the weight of an equal volume of water at a stated temperature.

Asphalt		
Term	**Identifier**	**Definition**
Theoretical Maximum Specific Gravity (Rice Test)	G_{mm}	The ratio of the weight in air of a unit volume of an uncompacted HMA to the weight of an equal volume of water at a stated temperature.
Effective Asphalt Content	P_{be}	The total asphalt content of HMA less the portion of asphalt binder that is absorbed by the aggregate particles; expressed as a percentage of the total weight of the compacted paving mixture.
Volume of Absorbed Asphalt	V_{ba}	The volume of asphalt binder that has been absorbed into the pores of the aggregate.
Gradation		The distribution of particle sizes expressed as a percent of the total weight of the sample.
Marshall Flow		The vertical deformation of the sample measured from the start of loading to the point at which stability begins to decrease, measured in 1/100 of an inch.
Marshall Stability		The maximum load carried by a compacted specimen tested at 140°F at a loading rate of 2 inches per minute.

AGGREGATES

Combining Aggregate Specific Gravities

$$Gsb = \frac{P1 + P2 + \cdots + Pn}{\frac{P1}{G1} + \frac{P2}{G2} \ldots + \frac{Pn}{Gn}}$$

G_{sb} = specific gravity for the total aggregate
P_1, P_2, P_n = individual percentages by weight of aggregate
G_1, G_2, G_n = individual bulk specific gravities of aggregate

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Fine Aggregate Specific Gravity, *(AASHTO T 84)*

$$Bulk\ Specific\ Gravity\ (Gsb) = \frac{A}{B + 500 - C}$$

$$Apparent\ Specific\ Gravity\ (Gsa) = \frac{A}{B + A - C}$$

$$Absorption = \left(\frac{500 - A}{A}\right) X\ 100$$

A = Weight of oven dry sample
B = Weight of flask, cover plate, and water to top of flask
C = Weight of flask, cover plate, sample and water to top of flask
500 g = Weight of saturated surface dry sample in air

Coarse Aggregate Specific Gravity, *(AASHTO T 85)*

$$Bulk\ Specific\ Gravity\ (Gsb) = \frac{A}{B - C}$$

$$Apparent\ Specific\ Gravity\ (Gsa) = \frac{A}{A - C}$$

$$Absorption\ \left(\frac{B - A}{A}\right) X\ 100$$

A = Weight of oven dry sample in air
B = Weight of saturated surface dry sample in air
C = Weight of saturated sample in water

ASPHALT MIXTURES

Effective Specific Gravity of Aggregate

$$Gse = \frac{Pmm - Pb}{\frac{Pmm}{Gmm} - \frac{Pb}{Gb}}$$

G_{se} = effective specific gravity of aggregate (stone)
G_{mm} = theoretical maximum specific gravity of paving mixture (no air voids)
P_{mm} = percent by weight of total loose mixture = 100
P_b = asphalt (binder) content at which test was performed, percent by total weight of mixture
G_b = specific gravity of asphalt (binder)

$$Agg\ Mixture\ Effective\ Specific\ Gravity\ (Gse) = \frac{100 - \%\ AC}{\frac{100}{Max\ Sp.Gr\ Mix} - \frac{\%\ AC}{Sp.Gr\ of\ AC}}$$

(Theoretical) Maximum Specific Gravity *(RICE Test AASHTO T 209)*

$$Gmm = \frac{Pmm}{\frac{Ps}{Gse} + \frac{Pb}{Gb}}$$

G_{mm} = theoretical maximum specific gravity of paving mixture (no air voids)
P_{mm} = percent by weight of total loose mixture = 100
P_s = aggregate (stone) content, percent by total weight of mixture
P_b = asphalt (binder) content at which test was performed, percent by total weight of mixture
G_{se} = effective specific gravity of aggregate
G_b = specific gravity of asphalt (binder)

$$Maximum\ Specific\ Gravity\ (Gmm) = \left(\frac{100}{\frac{\%\ Agg}{Eff\ Sp.Gr\ of\ Aggr} + \frac{\%\ AC}{Sp.Gr\ of\ AC}}\right)$$

Bulk Specific Gravity – of compacted HMA (*AASHTO T 166*)

$G_{mb} = \frac{A}{B-C}$

G_{mb} = Bulk Specific Gravity

A = mass of dry specimen (in air)
B = mass of surface-dry specimen in air, g
C = mass of specimen in water, g

Unit Weight/Mix Density of Asphalt Mix = G_{mb} X 62.4

Asphalt Absorption

$$Pba = 100\ X\ \left(\frac{Gse - Gsb}{Gsb\ X\ Gse}\right) X\ Gb$$

P_{ba} = absorbed asphalt (binder), percent by weight of aggregate
G_{se} = effective specific gravity of aggregate (stone)
G_{sb} = bulk specific gravity of aggregate (stone)
G_b = specific gravity of asphalt (binder)

$$Asphalt\ Absorption\ (Pba) = 100\ X\ \left(\frac{Eff.Sp.Gr.Aggr\ - Bulk\ Sp.Gr.Aggr\ Blend}{Eff.Sp.Gr.Aggr\ X\ Bulk\ Sp.Gr\ Aggr\ Blend}\right) X\ Sp.Gr\ of\ AC$$

Effective Asphalt Content of HMA Mixture

$$Pbe = Pb - \left(\frac{Pba}{100}\ X\ Ps\right)$$

P_{be} = effective asphalt content, percent by total weight of mixture
P_b = asphalt content, percent by total weight of mixture
P_{ba} = absorbed asphalt, percent by weight of aggregate
P_s = aggregate (stone) content, percent by total weight of mixture

$$Effective\ Asphalt\ Content\ (Pbe) = \%\ AC - \left(\frac{\%\ Absorbed\ AC\ by\ Wt\ Aggr.}{100}\right) X\ \%\ Aggr$$

Percent VMA in Compacted HMA Mixture

$$VMA = 100 - \left(\frac{Gmb\ X\ Ps}{Gsb}\right)$$

VMA = voids in mineral aggregate, percent bulk volume
G_{sb} = bulk specific gravity of total aggregate
G_{mb} = bulk specific gravity of compacted mixture
P_s = aggregate (stone) content, percent by total weight of mixture

$$Percent\ VMA = 100 - \left(\frac{Bulk\ Sp.Gr.Mix\ X\ \%\ Aggr}{Bulk\ Sp.Gr.Agg\ Blend}\right)$$

Percent Air Voids

$$Va = 100\ X\ \left(\frac{Gmm - Gmb}{Gmm}\right)$$

V_a = air voids in compacted HMA mixture, percent of total volume
G_{mm} = theoretical maximum specific gravity of paving mixture (Rice test – no air voids)
G_{mb} = bulk specific gravity of compacted mixture

$$Percent\ Air\ Voids\ (Va) = 100\ x\ \left(\frac{Theor\ Max.Sp.Gr.Mix - Bulk\ Sp.Gr.Mix}{Theor.Max.Sp.Gr.Mix}\right)$$

Voids Filled With Asphalt

$$VFA = \frac{VMA - Air\ Voids}{VMA}\ X\ 100$$

VFA = Voids Filled with Asphalt, percent of VMA
VMA = Voids in mineral aggregate, percent bulk volume
Corrected Air Voids = air voids in compacted HMA mixture, percent of total volume

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Dust to Asphalt

$$Dust\ to\ Asphalt\ Ratio = \frac{\%\ Passing\ No.200}{Pbe}\ Where$$

$$Eff.AC = \%\ AC - \left(\frac{\%\ Absorbed\ AC\ by\ Wt\ of\ Agg}{100}\right)\ X\ \%\ Agg\ in\ Mix$$

% A.C. from Mix Design at 4% air voids

% Passing No. 200 = Aggregate content passing no. 200 sieve, percent of aggregate weight
P_{be} = effective asphalt content, percent by total weight of mixture
These values are taken from the mix design, at the design asphalt content value.

Mix Design – Batching Aggregates and Liquid Asphalt

Determining asphalt content with given mass of aggregate, and given mass of asphalt.

$$Percent\ AC = \left(\frac{Weight\ of\ Asphalt}{Weight\ of\ Aggregate + Weight\ of\ Asphalt}\right)100$$

Determining weight of asphalt cement needed for a target AC content.

$$Weight\ of\ Asphalt\ Cement = \left[\frac{weight\ of\ aggregate}{100 - Target\ AC\ Content} X\ 100\right] - Wt\ aggregate$$

SUMMARY OF DEFINITIONS AND CONVENTIONS

NAMING CONVENTIONS

G_{sb}

volumetric property → G; material → s; type → b

volumetric property	material	type
		b = bulk
G = specific gravity	s = stone	e = effective
V = volume	b = binder	m = maximum theoretical
P = percent	m = mix	a = apparent (for G) or
	a = air	a = absorbed (for V and P)

DEFINITIONS

G = specific gravity
G_b = specific gravity of binder
G_{sb} = bulk specific gravity of aggregate
G_{se} = effective specific gravity of aggregate
G_{sa} = apparent specific gravity of aggregate
G_{mb} = bulk specific gravity of mix
G_{mm} = maximum theoretical specific gravity of mix

V = volume
V_a = volume of air voids
V_{ba} = volume of binder absorbed
V_{be} = volume of effective binder

P = percent
P_a = percent air
P_s = percent stone (100 - P_b)
P_b = percent binder
P_{ba} = percent binder absorbed
P_{be} = percent effective binder
$P_{0.075}$ = percent passing 0.075 sieve

SECTION 408

SUPERPAVE (SPV)

408 SPV DESCRIPTION

This work consists of constructing one or more courses of bituminous pavement on a prepared foundation. The bituminous pavement will be a mixture of aggregate, filler if required, and bitumen. The Contractor shall be responsible for providing an aggregate that meets the mix design properties that are specified.

There are two 408 sections in the "Field Sampling and Testing Manual." Section 408 Hot Bituminous Pavement and Section 408 Superpave. Use the section requirements for the class of material specified in the plans.

408.1 SPV ACCEPTANCE SAMPLES AND TESTS DURING AGGREGATE PRODUCTION

Contractor Testing: The Contractor obtains and splits aggregate samples according to AASHTO T 2, "Sampling of Aggregates," and AASHTO T 248, "Reducing Samples of Aggregate to Testing Size," respectively. A minimum of one sieve analysis test is required for each 1,000 tons of aggregate produced for the first 10,000 tons. Sieve analysis is conducted according to AASHTO T 27, "Sieve Analysis of Fine and Coarse Aggregate," and AASHTO T 11, "Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing." After 10,000 tons is produced the testing frequency for aggregate gradation is a minimum of one test per 2,000 tons of aggregate produced. Compute the results on SFN 9987, "Aggregate Sample Worksheet."

During aggregate production fine aggregate angularity testing is required and is conducted according to AASHTO T 304, "Uncompacted Void Content of Fine Aggregate." The testing frequency for the fine aggregate angularity will be the average of three random samples from the first 5,000 tons of material produced from each stockpile. The fine aggregate angularity from each stockpile will be combined to determine the final blend results.

The Contractor will provide the Engineer with a 165-lb sample from each stockpile for the mix design. Aggregate samples are submitted 30 days prior to production. Samples are submitted to the District Materials Laboratory for a NDDOT developed mix design or a verification of a Contractor developed mix design. See Appendix 400-B, "Verification of Contractor Mix Design."

The Superpave volumetric mix design is done according to NDDOT Standard Specifications, Section 410 under "Construction Requirements."

District Laboratory Testing: As soon as the Contractor determines the aggregate is representative and prior to the initial mix design, it is recommended the district laboratory test each aggregate stockpile during the first week of aggregate production to determine the bulk (dry) and apparent specific gravity and the percent water absorption by dry weight of aggregate. Testing should be conducted according to AASHTO T 84, “Specific Gravity and Absorption of Fine Aggregate,” and AASHTO T 85, “Specific Gravity and Absorption of Coarse Aggregate.” One test is performed for each 10,000 ton of each aggregate component produced. The individual specific gravity values determined by the Contractor and the district laboratory should correlate within 0.040.

408.2 SPV ACCEPTANCE SAMPLES AND TESTS DURING MIX PRODUCTION

Field Laboratory Testing – Aggregate: The Contractor performs two moisture tests on the aggregate blend the first day and a minimum of one per day thereafter. Testing is conducted according to AASHTO T 255, “Total Evaporable Moisture Content of Aggregate by Drying.” More tests are required after a rain as determined by the Engineer.

The Engineer or Representative submits one composite aggregate sample, obtained by the Contractor during the beginning of aggregate stockpiling, to the District Materials Coordinator. The District Materials Coordinator sends the sample to the Materials and Research Laboratory to determine the L.A. abrasion loss percentage according to AASHTO T 96, “Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.”

On each hot bituminous pavement project the Contractor, under the observation of the Engineer or Representative and at random times as determined by the Engineer, shall obtain one aggregate sample from the cold feed belt for each 1,500 ton of mix produced with a minimum of one sample per day. The sample is obtained and split according to AASHTO T 2, “Sampling of Aggregates,” and AASHTO T 248, “Reducing Samples of Aggregate to Testing Size,” respectively. A sieve analysis is conducted according to AASHTO T 27, “Sieve Analysis of Fine and Coarse Aggregates,” and AASHTO T 11, “Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing.” Compute the results on SFN 9987, “Aggregate Sample Worksheet,” and enter the results on SFN 18552, “Daily Report – Hot Bituminous Pavement – Quality Control (Penalty Assessed).” The summary of results is to be reported on SFN 10072, “Aggregate Quality Test Summary.”

The Contractor, under the observation of the Engineer or Representative, shall obtain from the cold feed belt from each lot of 10,000 tons of aggregate produced, aggregate samples before the addition of bitumen into the mix. The aggregate samples are tested according to AASHTO T 304, “Uncompacted Void Content of Fine Aggregate”; AASHTO T 113, “Lightweight Pieces in Aggregate”; ASTM D 4791, “Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregates”; NDDOT 4, “Percentage of Fractured

Particles in Coarse Aggregate"; and AASHTO T 176, "Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test."

The lightweight pieces of aggregate, coarse aggregate, angularity, and flat and elongated pieces of the aggregate are determined by the average of test results from three random samples obtained from the cold feed belt from each lot of 10,000 tons produced, or fraction thereof.

The testing frequency for the fine aggregate angularity and clay content will be the average of three random samples from the first 10,000 tons of material produced from each stockpile. The fine aggregate angularity and clay content from each stockpile will be combined to determine the final blend results. The samples are tested and the material accepted if the average of three samples meets the specified requirements. If each of the samples is within the specified limits, test only one of the three samples from each subsequent lot.

If at any time the sample tested does not meet the specified requirements, the remaining two samples are tested. The average of the three samples is used to determine acceptance of the material. If an average of three test results is used to determine the acceptance for a lot, then each subsequent lot shall have all three samples tested. However, the testing can be reduced once again to only one test per subsequent lot after a lot has all three samples within the specified limits.

Field Laboratory Testing – HMA: The Contractor obtains mix samples from behind the paver according to NDDOT 5, "Sampling and Splitting Field Verification Hot Mix Asphalt (HMA) Samples." Mix samples are obtained at random times as determined by the Engineer and at the same time an aggregate sample is obtained for sieve analysis. See Appendix 400-B, "Verification of Contractor Mix Designs."

The Contractor compacts two gyratory specimens from each sample obtained according to AASHTO T 312, "Preparing and Determining the Density of the HMA Specimens by Means of the Superpave Gyratory Compactor."
The Contractor determines the densities of the field gyratory plugs according to AASHTO T 166, "Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens," and AASHTO T 209, "Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures." The results are recorded onto SFN 50289, "Maximum Density Worksheet."

The Contractor, under the observation of the Engineer or Representative, obtains two pavement cores in each sublot adjacent to each other and at random locations as determined by the Engineer. Cores are obtained according to NDDOT 2, "Contractor Coring," and given to the Engineer immediately after they are obtained for density determination. Density testing is conducted according to AASHTO T 166, "Bulk Specific Gravity of Compacted Bituminous Mixtures Using

Saturated Surface Dry Specimens." The average of the two cores is used to determine the density of the sublot. The results are recorded onto SFN 59132, "Density Pay Factor."

Each sublot will be one paver lift wide (excluding the shoulders) by 2,000 feet long and of the depth specified for the pavement. If the partial sublot remaining at the end of the production day is 1,000 feet in length or greater, it will be considered a separate sublot. If it is less than 1,000 feet long it will be included in the last complete sublot. If the total day's production is less than 2,000 feet long and one paver width wide that production is considered a lot. The average density of the mainline pavement placed each production day will be the average of the densities of all that day's sublots.

Field Laboratory Testing – Bitumen: The Contractor obtains bitumen samples according to NDDOT 1, "Sampling of Bituminous Materials."

Materials and Research Laboratory Testing: Determine L.A. abrasion loss percentage according to AASHTO T 96, "Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the L.A. Machine," on a composite aggregate sample obtained during the beginning of aggregate stockpiling.

408.3 SPV ASSURANCE SAMPLES AND TESTS

District Laboratory Testing: The Contractor, under the observation of the Engineer or Representative, obtains and splits one aggregate sample according to AASHTO T 2, "Sampling of Aggregates" and AASHTO T 248, "Reducing Samples of Aggregate to Testing Size," respectively. The District Materials Coordinator runs a sieve analysis according to AASHTO T 27, "Sieve Analysis of Fine and Coarse Aggregate," and AASHTO T 11, "Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing." Physical properties of the sample are determined for each 10,000 tons of mix produced according to NDDOT 4, "Percentage of Fractured Particles in Coarse Aggregate"; AASHTO T 90, "Determining the Plastic Limit and Plasticity Index of Soils"; and AASHTO T 113, "Lightweight Pieces in Aggregate." Compute the results on SFN 9987, "Aggregate Sample Worksheet."

Materials and Research Laboratory Testing: The Contractor, under the observation of the Engineer or Representative, obtains for sieve analysis, one aggregate sample for each 10 miles in length, or fraction thereof. Samples are submitted to the Materials and Research Laboratory by the District Materials Coordinator. The sieve analysis is conducted according to AASHTO T 27, "Sieve Analysis of Fine and Coarse Aggregate," and AASHTO T 11, "Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing." Compute the results on SFN 9987, "Aggregate Sample Worksheet."

408.4 VERIFICATION SAMPLES AND TESTS (NHS PROJECTS ONLY) SPV

A second field laboratory is required on all NHS projects.

Field Laboratory Testing: The Engineer will conduct verification tests on independent samples.

The Contractor, under the observation of the Engineer or Representative, shall obtain samples from the cold feed belt, bitumen tank, and obtain cores.

The Engineer obtains HMA samples from behind the paver according to NDDOT 5, "Sampling and Splitting Field Verification Hot Mix Asphalt (HMA) Samples," and NDDOT 2, "Contractor Coring."

A sieve analysis is conducted on the sample according to AASHTO T 27, "Sieve Analysis of Fine and Coarse Aggregates," and AASHTO T 11, "Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing." Physical properties are determined for each 10,000 tons of mix produced according to NDDOT 4, "Percentage of Fractured Particles in Coarse Aggregate"; AASHTO T 90, "Determining the Plastic Limit and Plasticity Index of Soils"; and AASHTO T 113, "Lightweight Pieces in Aggregate." Compute the results on SFN 9987, "Aggregate Sample Worksheet."

Compact two gyratory specimens from the sample according to AASHTO T 312, "Preparing and Determining the Density of the HMA Specimens by Means of the Superpave Gyratory Compactor." Determine the densities of the field Marshall plugs according to AASHTO T 166, "Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface Dry Specimens," and AASHTO T 209, "Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures." Record the results on SFN 50289, "Maximum Density Worksheet."

The results of the acceptance and verification tests will correlate within acceptable tolerances given in the following table.

5/8" and No. 4 sieve	± 7%
No. 30 sieve	± 5%
No. 200 sieve	± 2.5%
Air Voids	± 2.0%
Maximum Specific Gravity	± 0.035

Included with Superpave projects:

Fine Aggregate Angularity	± 3%
Flat and Elongated Pieces	± 3%
Clay Content	± 7%

District Laboratory Testing: The Contractor, under the observation of the Engineer or Representative, obtains one full depth core for depth determination according to NDDOT 2, “Contractor Coring.” Cores are obtained after the final lift is placed and at one random location per mile as determined by the Engineer. Width measurements are to be taken at the same location where the core is obtained.

If a NHS system project, submit a copy of SFN 13889, “Project Records Samples/Tests Report,” to the FHWA at the completion of the project for compliance purposes.

408.5 SPV INDEPENDENT ASSURANCE (IA) SAMPLES AND TESTS (NHS PROJECTS ONLY)

The Contractor obtains and splits for the Engineer one aggregate sample according to AASHTO T 2, “Sampling of Aggregate,” and AASHTO T 248, “Reducing Samples of Aggregate to Testing Size,” respectively. The Engineer submits the sample to the District Materials Coordinator to conduct IA tests.

IA testing on split samples will be done once during the first ten tests required of the Contractor. The IA sample will be further split for testing by the verification tester. If the initial IA test is acceptable, then one more IA test is required on a split sample at the approximate midpoint of the project and again near the end of the project.

The IA tests run by the Contractor can be used for acceptance.

If the initial IA testing is not within specified tolerances, additional samples will be immediately obtained for testing, equipment will be checked, and testing procedures will be reviewed. This will continue until the differences are resolved. The additional IA tests will be performed by the IA tester and the other lab (QC or QA) that is not within the specified tolerance.

Results from the QC and IA testing will correlate within acceptable tolerances given in the following table.

5/8" - No. 4 sieve	± 5%
No. 30 sieve	± 3%
No. 200 sieve	± 1.5%
Fractured Faces	± 5%
Air Voids	± 1.0%
Maximum Specific Gravity	± 0.020
Lightweight pieces of aggregate	± 1%
Aggregate Bulk Sp Gr (dry), each fraction	± 0.040
Aggregate Apparent Sp Gr, each fraction	± 0.040
Fine Aggregate Angularity	± 2.5%
Flat and Elongated Pieces	± 2.5%
Clay Content	± 5.0%

Dispute Resolution: If the cause of disagreement between the quality assurance and quality control results cannot be determined, the dispute resolution process will be implemented. See Appendix 400-A, "Quality Control Program," for dispute resolution.

District Laboratory Testing: The Contractor, under the observation of the Engineer or Representative, is to provide one full depth core according to NDDOT 2, "Contractor Coring," for depth determination. A core is obtained at one random location per mile as determined by the Engineer. The core will be obtained after the final lift is placed. Width measurements are to be taken at the same location that the core is obtained. The Engineer tests the cores according to AASHTO T 166, "Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface Dry Specimens."

If a NHS system project, submit a copy of SFN 13889, "Project Records Samples/Tests Report," to the FHWA at the completion of the project for compliance purposes.

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SECTION 409

HOT BITUMINOUS PAVEMENT FOR QUALITY CONTROL/QUALITY ASSURANCE (QC/QA) PROJECTS

409 DESCRIPTION

This work consists of constructing one or more courses of bituminous pavement on a prepared surface for Quality Control/Quality Assurance (QC/QA) projects. The Contractor is responsible for process control and performs the necessary testing to control the quality of the work.

409.1 SAMPLES AND TESTS DURING AGGREGATE PRODUCTION

Contractor Testing: The Contractor obtains and splits aggregate samples according to AASHTO T 2, “Sampling of Aggregates,” and AASHTO T 248, “Reducing Samples of Aggregate to Testing Size,” respectively. The aggregate will be tested for gradation according to AASHTO T 27, “Sieve Analysis of Fine and Coarse Aggregate,” and AASHTO T 11, “Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing.” The physical properties will be determined according to AASHTO T 90, “Determining the Plastic Limit and Plasticity Index of Soils”; NDDOT 4, “Percentage of Fractured Particles in Coarse Aggregate”; and AASHTO T 113, “Lightweight Pieces in Aggregate.” Compute the results on SFN 9987, “Aggregate Sample Worksheet.”

The testing frequency for gradation will be one test per 1,000 tons of material produced for each aggregate stockpile. The testing frequency for the plastic index, fractured faces, and lightweight pieces of aggregate will be the average of three random composite samples from the first 5,000 tons of material produced.

If all three samples pass, the testing frequency will change to one of three samples tested for each 10,000 tons of material produced.

If a sample fails, the remaining two samples will be tested and averaged for acceptance of that lot. The testing frequency will then revert to the average of three tests per 5,000 tons until all three samples pass, then one of three samples will be tested for each 10,000 tons.

During the first week of aggregate production for each class of aggregate and as soon as the Contractor determines the aggregate is representative, prior to the initial mix design, the Contractor will obtain a 90-lb sample of each aggregate component according to AASHTO T 2, “Sampling of Aggregates.” The Contractor splits the samples according to AASHTO T 248, “Reducing Samples of Aggregate to Testing Size.” One-half of each aggregate sample will be submitted to the Engineer for testing. The Contractor and the Engineer will test the samples to determine the bulk (dry) and apparent specific gravity and the percent water absorption by dry weight of aggregate. The testing will be completed according to AASHTO T 84, “Specific Gravity and Absorption of Fine Aggregate,” and AASHTO T 85, “Specific Gravity and Absorption of Coarse Aggregate.” One test will be performed for each 10,000 ton of each aggregate component produced. A minimum of two tests will be required for each aggregate component. Testing will begin within two working days of sampling.

After 10,000 tons of material is produced, the Contractor will develop a preliminary mix design and submit the results to the department. This mix design is for informational purposes to assure the Contractor has produced material that meets specifications. See Appendix 400-B, “Verification of Contractor Mix Designs.”

After 10,000 tons of material is produced, the Contractor will provide the Engineer with an aggregate sample representing each stockpile for a mix design. The total weight of the combined sample will be about 150 lbs. The Contractor will also provide eight one-liter cans of performance-graded (PG) asphalt to be used on the project. This sample is to be submitted to the District Materials Laboratory for either a NDDOT developed mix design or a Contractor developed mix design. The mix design sample is to be submitted at least seven days prior to mix production.

District Laboratory Testing: During the first week of aggregate production the Contractor, under the observation of the Engineer or Representative, will obtain and split aggregate samples according to AASHTO T 2, “Sampling of Aggregates,” and AASHTO T 248, “Reducing Samples of Aggregate to Testing Size,” respectively. The District Lab will test each aggregate stockpile to determine the bulk (dry) and apparent specific gravity and the percent water absorption by dry weight of aggregate. The testing will be completed according to AASHTO T 84, “Specific Gravity and Absorption of Fine Aggregate,” and AASHTO T 85, “Specific Gravity and Absorption of Coarse Aggregate.” One test will be performed for each 10,000 ton of each aggregate component produced. A minimum of two tests will be required for each aggregate component.

Materials and Research Laboratory Testing: For projects not on the NHS system, a composite aggregate sample is obtained by the Engineer during the beginning of aggregate stockpiling for the District Materials Coordinator. The District Materials Coordinator sends the sample to the Materials and Research Laboratory to determine L.A. abrasion loss percentage according to AASHTO T 96, “Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the L.A. Machine.” Materials and Research personnel or a Representative designated by the Materials and Research Division will obtain L.A. samples on NHS projects.

409.2 QUALITY CONTROL (QC) SAMPLES AND TESTS DURING MIX PRODUCTION

QC will be the responsibility of the Contractor.

The Contractor will be required to perform random sampling and testing on the aggregate and bituminous mix as the mix is produced and placed on the roadway. Samples will be obtained according to NDDOT 5, “Sampling and Splitting Field Verification Hot Mix Asphalt (HMA) Samples,” and AASHTO T 2, “Sampling of Aggregates.” The aggregate sample will be split according to AASHTO T 248, “Reducing Samples of Aggregate to Testing Size.” Sieve analysis will be conducted according to AASHTO T 27, “Sieve Analysis of Fine and Coarse Aggregate,” and AASHTO T 11, “Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing.” The physical properties are determined according to AASHTO T 90, “Determining the Plastic Limit and Plasticity Index of Soils”; NDDOT 4, “Percentage of Fractured Particles in Coarse Aggregate”; and AASHTO T 113, “Lightweight Pieces in Aggregate.”

QC Aggregate: The Contractor shall perform two moisture tests according to AASHTO T 255, “Total Evaporable Moisture Content of Aggregate by Drying,” on aggregate the first day and a minimum of one per day thereafter. More tests are required after a rain as determined by the Engineer.

Aggregate will be sampled and tested in lot sizes equal to the number of tons placed each production day. The aggregate gradation specified will be the basis of acceptance.

The Contractor shall obtain all aggregate samples at random times as determined by the Contractor. The Contractor will obtain one aggregate sample for each 1,500 ton of mix produced. The samples are obtained from the cold feed belt according to AASHTO T 2, “Sampling of Aggregate” and split according to AASHTO T 248, “Reducing Samples of Aggregate to Testing Size.” The two representative samples are numbered and bagged. The untested half of the sample will be retained by the Engineer for 24 hours after the test results are made known to the Contractor. Either party may request that the second half of the sample be tested within this 24-hour timeframe. The test results from this retest shall replace the test values of the initial test.

The Contractor shall obtain aggregate samples before the addition of bitumen into the mix. Samples are obtained and split according to AASHTO T 2, “Sampling of Aggregates,” and AASHTO T 248, “Reducing Samples of Aggregate to Testing Size,” respectively. The samples are tested according to AASHTO T 113, “Lightweight Pieces in Aggregate”; AASHTO T 90, “Determining Plastic Limit and Plastic Index of Soils”; NDDOT 4, “Percentage of Fractured Particles in Coarse Aggregate”; and AASHTO T 96, “Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the L.A. Machine.”

The shale content and plasticity index of the aggregate are determined by the average of test results from three random samples obtained from the cold feed belt from each lot of 10,000 tons produced, or fraction thereof. The samples are tested and the material accepted if the average of three samples meets the specified requirements. If each of the samples is within the specified limits test only one of the three samples from each subsequent lot. If at any time the sample tested does not meet the specified requirements the remaining two samples are tested. The average of the three samples is used to determine acceptance of the material. If an average of three test results is used to determine the acceptance for a lot, then each subsequent lot shall have all three samples tested. However, the testing can be reduced once again to only one test per subsequent lot after a lot has all three samples within the specified limits.

The percentage of fractured faces for coarse aggregate is determined by the average of test results from three random samples obtained from the cold feed belt from each lot of 10,000 tons of bituminous mixture produced. The samples are tested and the material accepted if the average of three samples meets the specified requirements. If each of the samples is within the specified limits, test only one of the three samples from each subsequent lot. If at any time the sample tested does not meet the specified requirements the remaining two samples are tested.

QC HMA: The Contractor obtains mix samples from behind the paver at random times as specified by the Engineer. A mix sample is obtained each time an aggregate sample is obtained for sieve analysis. The sample is obtained according to NDDOT 5, “Sampling and Splitting Field Verification Hot Mix Asphalt (HMA) Samples.” See Appendix 400-B, “Verification of Contractor Mix Designs.”

The Contractor compacts three Marshall specimens according to AASHTO T 245, “Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus.” With each sample obtained the Contractor determines the field Marshall density according to AASHTO T 166, “Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens,” and the maximum theoretical density according to AASHTO T 209, “Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures.” The results are recorded on SFN 50289, “Maximum Density Worksheet.”

QC Bitumen: The Contractor will make random checks of the asphalt content each time a gradation test is obtained. The random checks will be based on readings from the totalizers for the aggregate and the bitumen. Record on SFN 18552, “Daily Report-Hot Bituminous Pavement-Quality Control.”

409.3 QUALITY ASSURANCE (QA) SAMPLES AND TESTS

District Field Laboratory Testing: The Engineer or Representative will conduct QA tests on independent samples in the field laboratory.

The Contractor, under the observation of the Engineer or Representative, shall obtain samples from the cold feed belt, bitumen tank, and obtain cores. Samples are obtained according to AASHTO T 2, “Sampling of Aggregates,” and NDDOT 2, “Contractor Coring.”

The Engineer or Representative shall obtain samples from behind the paver according to NDDOT 5 “Sampling and Splitting Field Verification Hot Mix Asphalt (HMA) Samples.”

The samples will be tested according to AASHTO T 113, “Lightweight Pieces in Aggregate”; AASHTO T 90, “Determining Plastic Limit and Plastic Index of Soils”; NDDOT 4, “Percentage of Fractured Particles in Coarse Aggregate”; AASHTO T 166, “Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens”; and AASHTO T 209, “Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures.”

The Engineer will test at an increased rate during the first lot of production to determine the accuracy of the quality control testing. The Engineer will test a minimum of four tests for the Contractor’s first ten tests and then 10% or greater of the frequency required for the Contractor’s QC testing.

Results from the QC and QA testing will correlate within acceptable tolerances given in the following table.

5/8" and No. 4 sieve	± 7%
No. 30 sieve	± 5%
No. 200 sieve	± 2.5%
Plastic Index	± 4%
Lightweight Pieces	± 3%
Fractured Faces	± 5%
Bulk Specific Gravity (Mix)	± 0.040
Maximum Specific Gravity	± 0.035

The Engineer or Representative will read random checks for asphalt content on a daily basis and record on SFN 18674, “Asphalt Content & Virgin Aggregate Determination.”

The Contractor obtains two pavement cores in each sublot. Cores are obtained at random locations as determined by the Engineer and according to NDDOT 2, “Contractor Coring.” The cores are given to the Engineer for density determination. The cores are obtained adjacent to each other and the average of the two cores is used to determine the density of the sublot. The results are recorded on SFN 59132, “Density Pay Factor.”

Each sublot will be one paver-lift wide (excluding the shoulders) by 2,000 feet long and by the depth specified for the pavement. If the partial sublot remaining at the end of the production day is 1,000 feet in length or greater it will be considered a separate sublot. If it is less than 1,000 feet long it will be included in the last complete sublot. If the total day's production is less than 2,000 feet long and one paver width wide that production is considered a lot. The average density of the mainline pavement placed each production day will be the average of the densities of all that day's sublots.

409.4 INDEPENDENT ASSURANCE (IA) SAMPLES AND TESTS

District Laboratory Testing: The District Materials Coordinator conducts IA tests on split samples obtained by the Contractor.

Samples are obtained by the Contractor, under the observation of the District Materials Coordinator, according to AASHTO T 2, "Sampling of Aggregate," and split according to AASHTO T 248, "Reducing Samples of Aggregate to Testing Size."

The IA tests run by the Contractor can be used for acceptance.

IA testing on split samples will be done once during the first ten tests required of the Contractor. The IA sample will be further split for testing by the QA tester.

If the initial IA testing is acceptable, then one more IA test is required on a split sample at the approximate mid-point of the project and again near the end of the project.

If the initial IA testing is not within specified tolerances, additional samples will be immediately obtained for testing, equipment will be checked, and testing procedures will be reviewed. This will continue until the differences are resolved. The additional IA testing will be performed by the IA tester and the other lab (QC or verification) that is not within the specified tolerance.

Results from the QC, QA, and IA testing will correlate within acceptable tolerances given in the following table.

5/8" - No. 4 sieve	± 5%
No. 30 sieve	± 3%
No. 200 sieve	± 1.5%
Plastic Index	± 2%
Fractured Faces	± 5%
Air Voids	± 1.0%
Maximum Specific Gravity	± 0.020
Lightweight Pieces of Aggregate	± 1%
Aggregate Bulk Sp Gr (dry), each fraction	± 0.040
Aggregate Apparent Sp Gr, each fraction	± 0.040

Dispute Resolution: If the cause of disagreement between the verification and quality control results cannot be determined, the dispute resolution process will be implemented. See Appendix 400-A, “Quality Control Program,” for dispute resolution.

Width and Depth Checks: The Contractor, under the observation of the Engineer or Representative, is to provide one full depth core for depth determination. The core will be obtained from one random location per mile as determined by the Engineer or Representative and after the final lift is placed. The core is obtained according to NDDOT 2, “Contractor Coring.” The Engineer or Representative takes the width measurements at the same location where the core is obtained.

If a NHS system project, submit a copy of SFN 13889, “Project Records Samples/Tests Report,” to the FHWA at the completion of the project for compliance purposes.

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SECTION 410

HOT BITUMINOUS PAVEMENT
SUPERPAVE VOLUMETRIC MIX DESIGN
FOR QUALITY CONTROL/QUALITY ASSURANCE (QC/QA)

410 DESCRIPTION

This work consists of constructing one or more courses of bituminous pavement on a prepared surface for QC/QA projects. The Contractor is responsible for process control and performs the necessary testing to control the quality of the work.

410.1 QUALITY CONTROL (QC) SAMPLES AND TESTS DURING AGGREGATE PRODUCTION

Contractor Field Laboratory Testing: During aggregate production the Contractor obtains and splits aggregate samples according to AASHTO T 2, “Sampling of Aggregates,” and AASHTO T 248, “Reducing Samples of Aggregate to Testing Size,” respectively. The aggregate will be tested for gradation according to AASHTO T 27, “Sieve Analysis of Fine and Coarse Aggregate;” and AASHTO T 11, “Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing.” The physical properties will be determined according to AASHTO T 304, “Uncompacted Void Content of Fine Aggregate”; AASHTO T 113, “Lightweight Pieces in Aggregate”; ASTM D 4791, “Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate”; NDDOT 4, “Percentage of Fractured Particles in Coarse Aggregate”; and AASHTO T 176, “Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test.” Compute the results on SFN 9987, “Aggregate Sample Worksheet.”

The testing frequency for gradation will be one test per 1,000 tons of material produced for each aggregate stockpile. The testing frequency for lightweight pieces of aggregate, flat and elongated pieces, and coarse aggregate angularity will be the average of three random composite samples from the first 5,000 tons of material produced.

The testing frequency for the fine aggregate angularity and clay content will be the average of three random samples from the first 5,000 tons of material produced from each stockpile. The fine aggregate angularity and clay content from each stockpile will be combined to determine the final blend results. If all three samples pass, the testing frequency will change to one of three samples tested for each 10,000 tons of material produced.

If a sample fails the remaining two samples will be tested and averaged for acceptance of that lot. The testing frequency will then revert to the average of three tests per 5,000 tons until all three samples pass, then one of three samples will be tested for each 10,000 tons.

During the first week of aggregate production for each class of aggregate and as soon as the Contractor determines the aggregate is representative, prior to the initial mix design, the Contractor, under the observation of the Engineer or Representative, will obtain a 90-lb. sample of each aggregate component. The Contractor obtains and splits the samples according to AASHTO T 2, "Sampling of Aggregates," and AASHTO T 248, "Reducing Samples of Aggregate to Testing Size," respectively. One-half of each aggregate sample will be submitted to the Engineer for testing. The Contractor and the Engineer will test the samples to determine the bulk (dry) and apparent specific gravity and the percent water absorption by dry weight of aggregate. The testing will be completed according to AASHTO T 84, "Specific Gravity and Absorption of Fine Aggregate," and AASHTO T 85, "Specific Gravity and Absorption of Coarse Aggregate." One test will be performed for each 10,000 ton of each aggregate component produced. A minimum of two tests will be required for each aggregate component. Testing will begin within two working days of sampling.

After 10,000 tons of material is produced, the Contractor will develop a preliminary Superpave gyratory mix design and submit the results to the District Materials Coordinator or Representative. This mix design is for informational purposes to assure the Contractor has produced specified material. See Appendix 400-B, "Verification of Contractor Mix Designs."

District Laboratory Testing: The Contractor, under the observation of the Engineer or Representative, will obtain these samples, split them, and submit them to the District Materials Coordinator.

During the first week of aggregate production the district laboratory will test each aggregate stockpile to determine the bulk (dry) and apparent specific gravity and the percent water absorption by dry weight of aggregate. The testing will be completed according to AASHTO T 84, "Specific Gravity and Absorption of Fine Aggregate;" and AASHTO T 85, "Specific Gravity and Absorption of Coarse Aggregate." One test will be performed for each 10,000 ton of each aggregate component produced. A minimum of two tests will be required for each aggregate component.

Materials and Research Laboratory Testing: Determine L.A. abrasion loss percentage according to AASHTO T 96, "Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine," on a composite aggregate sample obtained during the beginning of aggregate stockpiling. Materials and Research personnel or a Representative designated by the Materials and Research Division will obtain L.A. samples on NHS projects.

410.2 QUALITY CONTROL (QC) SAMPLES AND TESTS DURING MIX PRODUCTION

QC will be the responsibility of the Contractor.

During production of the bituminous mix, the Contractor will be required to perform random sampling and testing on the aggregate and bituminous mix as the mix is being produced and placed on the roadway.

QC Aggregate: Perform two moisture tests according to AASHTO T 255, "Total Evaporable Moisture Content of Aggregate by Drying," on aggregate the first day and a minimum of one per day thereafter. More tests are required after a rain as determined by the Engineer.

Aggregate will be sampled and tested in lot sizes equal to the number of tons placed each production day. The aggregate gradation specified will be the basis of acceptance.

The Contractor will obtain one aggregate sample from the cold feed belt for each 1,500 ton of mix produced. Aggregate samples are obtained at random times according to AASHTO T 2, "Sampling of Aggregates." The sample is split into two representative samples according to AASHTO T 248, "Reducing Samples of Aggregate to Testing Size." The samples will be numbered and bagged by the Contractor, under the observation of the Engineer or Representative. The untested half of the sample will be retained by the Contractor for 24 hours after the test results are made known to the Engineer. Either party may request that the second half of the sample be tested within this 24-hour time frame. The test results from this retest shall replace the test values of the initial test.

The Contractor shall obtain aggregate samples before the addition of the bitumen into the mix. The aggregate samples will be tested according to AASHTO T 304, "Uncompacted Void Content of Fine Aggregate"; AASHTO T 113, "Lightweight Pieces in Aggregate"; ASTM D 4791, "Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate"; AASHTO T 176, "Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test"; NDDOT 4, "Percentage of Fractured Particles in Coarse Aggregate"; and AASHTO T 96, "Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine."

The shale content and clay content of the aggregate are determined by the average of test results from three random samples obtained from the cold feed belt from each lot of 10,000 tons produced, or fraction thereof. The samples are tested and the material accepted if the average of three samples meets the specified requirements. If each of the samples is within the specified limits test only one of the three samples from each subsequent lot. If at any time the sample tested does not meet the specified requirements the remaining two samples are tested. The average of the three samples is used to determine acceptance of the material. If an average of three test results is used to determine the acceptance for a lot, then each subsequent lot shall have all three samples tested. However, the testing can be reduced once again to only one test per subsequent lot after a lot has all three samples within the specified limits.

The percentage of fractured faces for coarse aggregate is determined by the average of test results from three random samples obtained from the cold feed belt from each lot of 10,000 tons of bituminous mixture produced. The samples are tested and the material accepted if the average of three samples meets the specified requirements. If each of the samples is within the specified limits test only one of the three samples from each subsequent lot. If at any time the sample tested does not meet the specified requirements the remaining two samples are tested. The average of the three samples is used to determine acceptance of the material. If an average of three test results is used to determine the acceptance for a lot then each subsequent lot shall have all three samples tested. However, the testing can be reduced once again to only one test per subsequent lot after a lot has all three samples within the specified limits.

QC HMA: The Contractor obtains mix samples from behind the paver according to NDDOT 5, “Sampling and Splitting Field Verification Hot Mix Asphalt (HMA) Samples.” Samples are obtained at random times and random locations as specified by the Engineer. A mix sample is obtained each time an aggregate sample is obtained for sieve analysis.

The Contractor shall compact two gyratory specimens from each sample obtained according to AASHTO T 312, “Preparing and Determining the Density of the HMA Specimens by Means of the Superpave Gyratory Compactor.”

The Contractor shall determine the field density from the specimens according to AASHTO T 166, “Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens,” and maximum theoretical density according to AASHTO T 209, “Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures.” The results are recorded on SFN 50289, “Maximum Density Worksheet.”

Each sublot will be one paver-lift wide (excluding the shoulders) by 2,000 feet long and of the depth specified for the pavement. If the partial sublot remaining at the end of the production day is 1,000 feet in length or greater it will be considered a separate sublot. If it is less than 1,000 feet long it will be included in the last complete sublot. If the total day’s production is less than 2,000 feet long and one paver-width wide that production is considered a lot. The average density of the mainline pavement placed each production day will be the average of the densities of all that day’s sublots.

QC Bitumen: The Contractor, under the observation of the Engineer or Representative, will make random checks of the asphalt content each time a gradation test is performed. The random checks will be based on readings from the totalizers for the aggregate and the bitumen. Record on SFN 18552, “Daily Report-Hot Bituminous Pavement-Quality Control (No Penalty).”

410.3 QUALITY ASSURANCE SAMPLES AND TESTS

District Field Laboratory Testing: The Engineer will conduct QA tests on independent samples in the field lab.

The Contractor, under the observation of the Engineer or Representative, shall obtain samples from the cold feed belt, bitumen tank, and obtain cores. Samples are obtained according to AASHTO T 2, “Sampling of Aggregates,” and NDDOT 2, “Contractor Coring.”

The Engineer or Representative shall obtain samples from behind the paver according to NDDOT 5 “Sampling and Splitting Field Verification Hot Mix Asphalt (HMA) Samples.”

The Engineer will test at an increased rate during the first lot of production to determine the accuracy of the quality control testing. The Engineer will test at a minimum of four tests for the Contractor’s first ten tests and then 10% or greater of the frequency required for the Contractor’s QC testing.

The Contractor, under the observation of the Engineer or Representative, obtains two pavement cores in each sublot adjacent to each other and at random locations as determined by the Engineer. Cores are obtained according to NDDOT 2, “Contractor Coring.” Cores are given to the Engineer for density determination. Density tests are conducted according to AASHTO T 166, “Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface Dry Specimens.” The average of the two cores is used to determine the density of the sublot. The results are recorded onto SFN 59132, “Density Pay Factor.”

Results from the QC and QA testing will correlate within acceptable tolerances given in the following table:

5/8" and No. 4 sieve	± 7%
No. 30 sieve	± 5%
No. 200 sieve	± 2.5%
Lightweight Pieces	± 3%
Fractured Faces	± 5%
Bulk Specific Gravity (Mix)	± 0.040
Maximum Specific Gravity	± 0.035
Fine Aggregate Angularity	± 3%
Flat and Elongated Pieces	± 3%
Clay Content	± 7%

The Contractor, under the observation of the Engineer or Representative, will make checks for asphalt content each time a gradation test is performed.

District Laboratory Testing: The Contractor, under the observation of the Engineer or Representative, is to provide to the Engineer one full depth core for depth determination. The cores are obtained according to NDDOT 2, "Contractor Coring," at one random location per mile as determined by the Engineer and after the final lift is placed. Width measurements are to be taken at the same location that the cores are obtained. The Engineer tests the cores according to AASHTO T 166, "Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface Dry Specimens."

If a NHS system project, submit a copy of SFN 13889, "Project Records Samples/Tests Report," to the FHWA at the completion of the project for compliance purposes.

410.4 INDEPENDENT ASSURANCE (IA) SAMPLES AND TESTS

District Laboratory Testing: The District Materials Coordinator conducts IA tests on split samples obtained by the Contractor.

Samples are obtained by the Contractor, under the observation of the District Materials Coordinator, according to AASHTO T 2, "Sampling of Aggregate," and split according to AASHTO T 248, "Reducing Samples of Aggregate to Testing Size."

The IA tests run by the Contractor can be used for acceptance.

IA testing on split samples will be done once during the first ten tests required of the Contractor. The IA sample will be further split for testing by the verification tester. If the initial IA test is acceptable, then one more IA test is required on a split sample at the approximate midpoint of the project and again near the end of the project.

If the initial IA testing is not within specified tolerances, additional samples will be immediately obtained for testing, equipment will be checked, and test procedures will be reviewed. This will continue until the differences are resolved. The additional IA testing will be performed by the IA tester and the other lab (QC or QA) that is not within the specified tolerance.

Results from the QC and IA testing will correlate within acceptable tolerances given in the table on page 7:

5/8" - No. 4 sieve	± 5%
No. 30 sieve	± 3%
No. 200 sieve	± 1.5%
Fractured Faces	± 5%
Air Voids	± 1.0%
Maximum Specific Gravity	± 0.020
Lightweight pieces of aggregate	± 1%
Aggregate Bulk Sp Gr (dry), each fraction	± 0.040
Aggregate Apparent Sp Gr, each fraction	± 0.040
Fine Aggregate Angularity	± 2.5%
Flat and Elongated Pieces	± 2.5%
Clay Content	± 5.0%

Dispute Resolution: If the cause of disagreement between the QA and QC results cannot be determined the dispute resolution process will be implemented. See Appendix 400-A, "Quality Control Program," for dispute resolution.

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APPENDIX 400-A

QUALITY CONTROL PROGRAM

400-A-1 MATERIAL ACCEPTANCE

Materials will be accepted in one of three ways.

A. Certification

By certification as defined in the NDDOT's "Standard Specifications for Road and Bridge Construction."

B. Testing

1. Acceptance based on testing performed by the NDDOT.

2. The frequency for this testing is defined in the NDDOT's "Field Sampling and Testing Manual."

C. Quality Control/Quality Assurance (QC/QA)

1. Acceptance by Quality Control/Quality Assurance (QC/QA).

2. A QC/QA program is made up of the following sections:

   a. Acceptance based on Contractor quality control testing as specified in the project contract documents.

   b. Validation based on verification testing performed by the NDDOT, or its Representative.

   c. Independent assurance.

   d. Dispute resolution, if required.

400-A-2 QUALITY ASSURANCE PROGRAM

A. QC Sampling and Testing

QC testing is performed by the Contractor for material acceptance. The frequency and specific location in the construction process at which QC sampling and testing is to be accomplished will be outlined in the contract documents.

The Contractor's QC program will be conducted by certified personnel as outlined in the applicable NDDOT's Certification Program.

QC samples will be split under the observation of the NDDOT, or its Representative. One quarter of the split QC sample will be retained by the verification testing lab.

Results from the QC and verification testing will correlate within acceptable tolerances given in the following table.

Tolerances between QC and Verification Test Results:

5/8" and No. 4 sieve	± 7%
No. 30 sieve	± 5%
No. 200 sieve	± 2.5%
Plastic Index	± 4%
Lightweight Pieces	± 3%
Fractured Faces	± 5%
Bulk Specific Gravity (Mix)	± 0.040
Maximum Specific Gravity	± 0.035

Included with Superpave projects:

Fine Aggregate Angularity	± 3%
Flat and Elongated Pieces	± 3%
Clay Content	± 7%

In addition, data from the QC and verification testing will be compared using statistical analysis. The F test will be used to compare the standard deviations. The t test will be used to compare the mean values. The data sets must pass both of these tests to be acceptable. Until more data is collected and the NDDOT feels comfortable with the F and t acceptance criteria, the F and t statistical analysis will be used for informational purposes only.

If the results of the NDDOT's verification sampling and testing program do not agree with the QC sampling and testing as performed by the Contractor, the NDDOT, or its Representative, will conduct a review of the quality control and verification procedures, calculations, and equipment to determine the cause of disagreement. If the QC and Verification test results do not agree then the QC samples retained by the verification lab will also be tested. The test results from the QC samples will then be used in determining the acceptance of the material.

B. Verification Sampling and Testing

Verification tests on independent samples are required to confirm the quality of the product and will be accomplished in the following manner:

1. The specific test properties required are outlined in the contract documents provided for the project.

2. The NDDOT, or its Representative, will conduct verification tests on samples taken independent of the Contractor's quality control testing.

3. Samples are obtained by the NDDOT, or its Representative, from a location selected at any point in the process, independent of the Contractor's QC program. These samples may be split by the NDDOT, or its Representative, for testing by the Contractor. The Contractor may not use this test for acceptance. The frequency of verification testing will be four tests for the Contractor's first ten tests and then 10% or greater of the frequency required for the Contractor's QC testing. The results of verification testing will be made available to the Contractor.

4. The NDDOT's verification program will be conducted by certified personnel as outlined in the applicable NDDOT's Certification Program.

5. The NDDOT, or its Representative, will observe the Contractor split QC samples and will take possession of one quarter of the split QC sample. This sample will be retained until verification testing confirms the validity of the QC testing.

C. Independent Assurance (IA) Program

Independent Assurance (IA) testing is required to assure that personnel and equipment are capable of performing tests properly. IA will be accomplished by the following means:

1. The NDDOT, or its Representative, may conduct IA tests on split samples taken by the Contractor, the NDDOT, or its Representative. IA testing on split samples will be done once during the first ten tests required of the Contractor to ensure accuracy of the QC testing. The IA sample will be further split for testing by the Verification Tester. This will be used to ensure the accuracy of the verification testing. The specific test parameters and tolerance limits for comparison of test results will be outlined in the QC/QA specifications found in Section 409 and 410 of NDDOT's "Standard Specifications for Road and Bridge Construction."

   a. Acceptable Initial IA Test.

      If the initial IA test is acceptable, then one more IA test is required on a split sample at the approximate mid-point of the project and again near the end of the project.

   b. Unacceptable Initial IA Test.

      If the initial IA test is not within specified tolerances, additional samples will be immediately obtained for testing, equipment checks will be conducted, and testing procedures will be reviewed. This will continue until the differences are resolved. The additional IA tests will be performed by the Independent

Assurance Tester and the other lab (QC or Verification) that is not within the specified tolerance.

2. The NDDOT, or its Representative, will periodically observe tests performed by the Contractor and the Verification Tester.

3. The NDDOT, or its Representative, will ensure that testing personnel are qualified as outlined in the applicable NDDOT Certification Program.

4. Periodically, the NDDOT, or its Representative, will evaluate testing equipment by one or more of the following means:

   a. Calibration checks. Equipment calibration checks will be done at the start of the project and again at the approximate mid-point of the project.

   b. Split samples.

   c. Proficiency samples.

5. Should the difference between the QC, Verification, or IA Tester's split or proficiency sample results be greater than specified, the Engineer will investigate the reason for the difference.

   a. The investigation may include testing by the NDDOT, or its Representative, of any remaining split samples.

   b. The investigation may also include review and observation of the Contractor or Verification Tester's sampling and testing procedures and equipment.

6. Progress samples must be sent to the Materials and Research Laboratory according to the Section 408 frequency guide.

7. The portion of the IA sample run by the Contractor can be used as the Contractor's QC acceptance sample for that lot if the requirements in Appendix 400-A-2 A are met.

D. Dispute Resolution Program

If the cause of disagreement between the verification and QC results cannot be determined, a dispute resolution process will be implemented. The material remaining from retained samples will be sent to the NDDOT Materials and Research Laboratory. The Materials and Research Laboratory will investigate testing and sampling procedures, plus review equipment used. The results from the NDDOT Materials and Research Laboratory will be considered final.

E. Project Basis

The Independent Assurance (IA) program will be in effect for each project. With this approach, the NDDOT is not required to supply the FHWA with an annual report summarizing the IA program but IA testing will be required on each project.

F. Materials Certification Letter

The materials certification letter shall be submitted for each construction project that is subject to the FHWA construction oversight activities. This can be combined with the "District's Project Acceptance Letter" sent to FHWA at the end of a project.

The following letter is a guide for materials certification by the NDDOT District Materials Coordinators.

Date______________________________________

Project Number ________________________________

This is to certify that:

The results of the tests used in the acceptance program indicate that the materials incorporated in the construction work, and the construction operations controlled by sampling and testing, were in conformity with the approved plans and specifications.

Exceptions to the plans and specifications are explained on the back (or on attached sheet).

____
NDDOT District Materials Coordinator

400-A-3 SAMPLING AND TESTING FREQUENCY GUIDE

Specification Item Number 409

Independent Assurance (IA) Testing	Verification Testing
IA testing is done by the District Materials Coordinator or as directed by the Materials and Research Division. IA testing on split samples will be done once during the first ten tests required of the Contractor to ensure accuracy of the QC and verification testing. If the initial IA testing is acceptable, then one more IA test is required on a split sample at the approximate mid-point of the project and again near the end of the project. If the initial IA test is not within specified tolerances, then testing will be performed on additional samples immediately obtained after the initial IA test, equipment checks will be conducted, and testing procedures reviewed. Equipment calibration checks will be done at the start of the project and again at the approximate mid-point of the project. The IA tests run by the Contractor can be used for acceptance.	Verification testing is done by the NDDOT or its Representative's field laboratory. The verification tester cannot be the same laboratory used for IA testing. Verification testing will take place at a rate of four tests for the Contractor's first ten and then 10% of the testing required for the Contractor's QC program. Independent samples (IA) are obtained by the NDDOT, or its Representative. A Contractor split sample is not allowed for verification test samples. Where safety is a concern, the Contractor will collect verification samples, under the observation of the Engineer, but the samples will still be independent of the Contractor's QC program. These include belt samples, cores, and bituminous samples. The NDDOT, or its Representative, will observe the Contractor split QC samples and will take possession of one quarter of the split QC sample. This sample will be retained until verification testing confirms the validity of the QC testing.

APPENDIX 400-B

VERIFICATION OF CONTRACTOR MIX DESIGNS

A Contractor mix design will be specified in the plans for a 408, 409 or 410 HMA project. The following Plan Note will be used:

> "The mix design will be a laboratory mix design determined by the Contractor and approved by the NDDOT. The mix design will be developed according to NDDOT mix design procedures and will meet the requirements of Section 408, 409, or 410 of the NDDOT Standard Specifications. The mix design will be developed using the aggregate source and asphalt cement that is to be used on the project."

400-B-1 CONTRACTOR REQUIREMENTS FOR VERIFICATION

After 10,000 tons of material is produced and uniform production of each aggregate component is assured, the Contractor shall produce a mix design or series of mix designs until one is developed meeting all requirements specified.

The Contractor shall submit the completed mix design, including all test data, to the appropriate District Materials Laboratory. The mix design report shall be submitted in a NDDOT approved computer format, or using the appropriate State forms for mix designs.

The Contractor shall submit the following materials for mix design verification testing:

1. During aggregate production, the Contractor will supply the district with a 90-lb sample from each aggregate component to determine the physical properties, bulk (dry) and apparent specific gravity, and the percent water absorption by dry weight of the aggregate.

2. An aggregate sample representing each stockpile used for the Contractor mix design. The combined sample will be approximately 150 lbs for either a Marshall or Superpave project. The target value on each sieve for the mix design shall be the average of production samples multiplied by the percentage of material used in the blend proportion. The blended sample will be used for the verification mix design if the gradations obtained from the blended sample are within the tolerances listed in the following table when compared to the target values.

Marshall or Superpave Projects:

5/8" - No. 4 sieve	± 5%
#30 sieve	± 3%
#200 sieve	± 1.5%

3. Eight one-quart cans of PG asphalt. The PG asphalt will be the same type and grade as specified on the plans and from the supplier that will be used on the project. When two types of PG asphalt are specified, the Contractor can supply either type but it must be the same type used for the original mix design.

4. Approximately 30 lbs of loose asphaltic concrete mix prepared at the optimum asphalt content recommended by the mix design.

5. The mix design Job Mix Formula (JMF) submitted by the Contractor will contain the following elements:

   a. The percentage of aggregate passing each of the specified sieves.
   b. The percent asphalt cement to be added to the mixture.
   c. The target air voids will be 4%.
   d. The maximum specific gravity of the mixture obtained in the laboratory.
   e. The bulk specific gravity of the mixture obtained in the laboratory.
   f. The percent VMA of the mixture obtained in the laboratory.
   g. The stability and flow of the mix (Marshall only).
   h. Calculated film thickness (microns).
   i. Calculated dust/asphalt ratio.
   j. $\%G_{mm}$ @ N_{ini} (Superpave only).
   k. $\%G_{mm}$ @ N_{max} (Superpave only).

400-B-2 DISTRICT MATERIALS LABORATORY REQUIREMENTS FOR VERIFICATION

The district will verify the physical properties, the bulk (dry) and apparent specific gravity, and the percent water absorption by dry weight of the aggregate from samples supplied by the Contractor during aggregate production.

The district will verify the Contractor mix design by any or all of the following procedures:

1. A full mix design utilizing the virgin aggregate and blend supplied by the Contractor.

2. HMA specimens developed at the Contractor mix design optimum asphalt content, and made up of the virgin aggregate and blend supplied by the Contractor.

3. HMA specimens developed from loose asphaltic concrete mix prepared at the optimum asphalt content recommended by the Contractor mix design.

4. Historic data from past projects utilizing the same aggregate source.

The Contractor's mix design will be approved if the district's verification testing confirms that the Contractor's mix design results are within the tolerances shown in the following table:

Acceptable Tolerance for Contractor Mix Design Verification

Marshall Projects:

Plastic Index	± 2%
Fractured Faces	± 5%
Lightweight Pieces of Aggregate	± 1%
Aggregate Bulk SpGr (dry), each fraction	± 0.040
Aggregate Apparent SpGr, each fraction	± 0.040
Air Voids	± 1.0%
Maximum SpGr	± 0.030

Superpave Projects:

Fractured Faces	± 5%
Lightweight Pieces of Aggregate	± 1%
Aggregate Bulk SpGr (dry), each fraction	± 0.040
Aggregate Apparent SpGr, each fraction	± 0.040
Fine Aggregate Angularity	± 1%
Flat and Elongated Pieces	± 1%
Clay Content	± 5%
Air Voids	± 1.0%
Maximum SpGr	± 0.030

If the Contractor's mix design is not approved, the Contractor shall submit another mix design. An approved mix design will be required prior to beginning production of hot bituminous pavement.

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APPENDIX 400-C

NDDOT TESTING TOLERANCE, RESOLUTION PROCEDURE AND MODIFICATIONS FOR TEST PROCEDURES

400-C-1 ALLOWABLE TOLERANCE

Allowable tolerance from split companion sample, between Contractor (or representative) and NDDOT test results:

G_{sb} (aggregate bulk specific gravity individual component) = 0.040

If the contractor's test results meet tolerance as verified by the NDDOT testing, the contractor's specific gravity numbers will be used to calculate the mix design properties.

400-C-2 RESOLUTION PROCEDURE

Resolution procedure when tolerance is not met:

1. Obtain a second split companion sample. Prior to testing this new sample, review with contractor and agency lab the procedures and testing practices to insure consistent methods are used. If the contractor's specific gravity numbers are within tolerance as verified by the NDDOT testing, use the contractor's numbers to calculate the mix design properties.

2. When a second sample fails to meet allowable tolerance procedures, obtain another sample large enough to be a split companion with a third party. The third party will be the NDDOT Materials and Research Lab. The final three tests of the third sample will be analyzed according to the precision statement set forth in AASHTO T 84 and T 85. The average of the acceptable tests from the final set will be used to determine the mix design properties.

400-C-3 FINE AND/OR COARSE SPECIFIC GRAVITY TEST DECISION

1. If 85% or more of the individual aggregate passes the 4.75 mm (No. 4) sieve, test for fine aggregate specific gravity only. Do not wash out the material passing the 0.075 mm (No. 200) sieve.

2. If less than 15% of the aggregate passes the 4.75 mm (No. 4) sieve, test for coarse aggregate specific gravity only.

3. If an individual aggregate has a value between 15 - 85% passing the 4.75 mm (No. 4) sieve, test for both coarse and fine aggregate specific gravity. Do not wash the material passing the 0.075 mm (No. 200) sieve.

4. When the fine aggregate slumps slightly (25 - 75% of the cone's upper surface area) it indicates that it has reached a surface-dry condition.

400-C-4 FINE AGGREGATE TEST MODIFICATIONS

Experience has indicated for some 9.5 mm (3/8") minus pea rock, 100% crushed fine, and other similar materials it is difficult to obtain a minus 4.75 mm (No. 4) fine aggregate specific gravity that is accurate and reproducible. Do the following when these types of material are encountered:

1. Split the materials on the 2.36 mm (No. 8) sieve instead of the 4.75 mm (No. 4) sieve.

2. Use the 15% rule described above for determining whether both the fine aggregate and coarse aggregate specific gravity need to be tested.

3. Use the pan method option described in the AASHTO T 84 test method to determine the SSD weight.

Aggregate Gradation Blending

Project:	Superpave Mix Design	Laboratory No.:	
Material:		Field Sample No.:	
Specification:		Date Received:	
Pit Location:		Date Sampled:	
Pit Owner:	Nelson	Sampled From:	
County:		Submitted By:	

Sieve Size	Nat. Fines (19.0%) Passing	A	Crshr Fine (48.0%) Passing	B	5/8 Rock (33.0%) Passing	C	Passing A+B+C	
5/8"	100.0		100.0		100.0			100
½"	100.0		100.0		84.0			90-100
3/8"	100.0		100.0		52.0			
No. 4	85.0		87.0		2.0			
No. 8	69.0		54.0		2.0			28-58
No. 16	51.0		33.0		1.3			
No. 30	31.0		20.0		1.3			
No. 50	13.0		11.0		1.3			
No. 100	8.0		8.0		1.3			
No. 200	6.0		6.4		1.3			2.0-7.0

Bulk SpG	2.490	2.626	2.627
Apparent SpG	2.707	2.765	2.778

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Combining Aggregate Blend Bulk Specific Gravities

Combined Specific Gravity $(G_{sb}) = \dfrac{P_1 + P_2 + P_3 + P_4 \ ... \ P_n}{\dfrac{P_1}{G_1} + \dfrac{P_2}{G_2} + \dfrac{P_3}{G_3} + \dfrac{P_4}{G_4} \ ... \dfrac{P_n}{G_n}}$

G_{sb} = bulk specific gravity for the total aggregate
P_1, P_2, P_3, P_n = individual percentages by weight of aggregate
G_1, G_2, G_3, G_n = individual bulk specific gravities of aggregate

Combined Bulk Specific Gravity = ________________________________

Combined Apparent Specific Gravity = _____________________________

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MAXIMUM DENSITY WORKSHEET
North Dakota Department of Transportation, Construction
SFN 50289 (Rev. 03-2003)

Project Number	Contractor	Date	Time

Test Number	Lot Number	Daily Tons	Total Tons
1	3	845	

Station	Lane	Lift
220+76	WB	Bottom

FIELD PLUGS

PLUG NO.	WEIGHT IN AIR (A)	WEIGHT IN WATER (B)	WEIGHT SAT. SURF (C)	VOLUME C-B = D (D)	BULK SP. GR. A/D = E
1	4707.9	2715.7	4708.7		
2	4708.5	2713.9	4710.5		

AVERAGE BULK SP. GR. (F) = ________________

DENSITY (F x 62.4) PCF ________________

MAXIMUM MIX DENSITY

FLASK NUMBER	5	6	
G. SAMPLE CONTAINER & SOLUTION:	3927.6	4011.1	
H. CONTAINER & SOLUTION:	3338.8	3420.8	
I. SAMPLE IN SOLUTION (G-H)			
J. SAMPLE IN AIR	1000.7	1000.7	
K. VOLUME OF VOIDLESS MIX (J-I)			
L. MEAS. MAX. SPEC GRAVITY (J/K)			
M. MAX. THEOR. DENSITY (62.4 X L)			

PERCENT AIR VOIDS

% AIR VOIDS = $\frac{L-F}{L}$ X 100 = $\left(\frac{\_\_\_\_\_ - \_\_\_\_\_}{\_\_\_\_\_}\right)$ 100 = ________% AIR VOIDS

AGGREGATE BLEND PROPORTIONS

______ ______ ______ ______

______ ______ ______ ______

______ ______ ______ ______

______ ______ ______ ______

AC CONTENT: __________

NOTES

____
Inspectors Signature

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MAXIMUM DENSITY WORKSHEET

North Dakota Department of Transportation, Construction
SFN 50289 (Rev. 03-2003)

Project Number	Contractor	Date	Time

Test Number	Lot Number	Daily Tons	Total Tons
2	3	1488	

Station	Lane	Lift
189+00	WB	middle

FIELD PLUGS

PLUG NO.	WEIGHT IN AIR (A)	WEIGHT IN WATER (B)	WEIGHT SAT. SURF (C)	VOLUME C-B = D (D)	BULK SP. GR. A/D = E
1	4717.4	2718.8	4719.0		
2	4705.5	2700.0	4711.0		

AVERAGE BULK SP. GR. (F) = ______________

DENSITY (F x 62.4) PCF ______________

MAXIMUM MIX DENSITY

FLASK NUMBER	5	6	
G. SAMPLE CONTAINER & SOLUTION:	3928.5	4013.3	
H. CONTAINER & SOLUTION:	3338.8	3424.5	
I. SAMPLE IN SOLUTION (G-H)			
J. SAMPLE IN AIR	1000.9	1000.3	
K. VOLUME OF VOIDLESS MIX (J-I)			
L. MEAS. MAX. SPEC GRAVITY (J/K)			
M. MAX. THEOR. DENSITY (62.4 X L)			

PERCENT AIR VOIDS

% AIR VOIDS = $\frac{L-F}{L}$ X 100 = $\left(\frac{\_\_\_\_\_ - \_\_\_\_\_}{\_\_\_\_\_}\right)$ 100 = ________% AIR VOIDS

AGGREGATE BLEND PROPORTIONS

______ ______ ______ ______

______ ______ ______ ______

______ ______ ______ ______

______ ______ ______ ______

AC CONTENT: __________

NOTES

Inspectors Signature

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MAXIMUM DENSITY WORKSHEET
North Dakota Department of Transportation, Construction
SFN 50289 (Rev. 03-2003)

Project Number	Contractor	Date	Time

Test Number	Lot Number	Daily Tons	Total Tons
3	3	1500	3683

Station	Lane	Lift
188+00	wb	bottom

FIELD PLUGS

PLUG NO.	WEIGHT IN AIR (A)	WEIGHT IN WATER (B)	WEIGHT SAT. SURF (C)	VOLUME C-B = D (D)	BULK SP. GR. A/D = E
1	4722.0	2725.8	4727.0		
2	4722.9	2723.9	4728.1		

AVERAGE BULK SP. GR. (F) = ______________

DENSITY (F x 62.4) PCF ______________

MAXIMUM MIX DENSITY

FLASK NUMBER	1	2	
G. SAMPLE CONTAINER & SOLUTION:	3869.8	4336.2	
H. CONTAINER & SOLUTION:	3281.4	3747.6	
I. SAMPLE IN SOLUTION (G-H)			
J. SAMPLE IN AIR	1000.2	1000.0	
K. VOLUME OF VOIDLESS MIX (J-I)			
L. MEAS. MAX. SPEC GRAVITY (J/K)			
M. MAX. THEOR. DENSITY (62.4 X L)			

PERCENT AIR VOIDS

% AIR VOIDS = $\frac{L-F}{L}$ X 100 = (________ - ________) 100 = ________% AIR VOIDS

AGGREGATE BLEND PROPORTIONS

______ ______ ______ ______

______ ______ ______ ______

______ ______ ______ ______

______ ______ ______ ______

AC CONTENT: __________

NOTES

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Inspectors Signature

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MAXIMUM DENSITY WORKSHEET

North Dakota Department of Transportation, Construction

SFN 50289 (Rev. 03-2003)

Project Number	Contractor	Date	Time
		5/13/2011	1050

Test Number	Lot Number	Daily Tons	Total Tons
1	3	609	2792

Station	Lane	Lift
	wb	bottom

FIELD PLUGS

PLUG NO.	WEIGHT IN AIR (A)	WEIGHT IN WATER (B)	WEIGHT SAT. SURF (C)	VOLUME C-B = D (D)	BULK SP. GR. A/D = E
1	4722.0	2721.9	4725.0		
2	4721.1	2724.1	4726.5		

AVERAGE BULK SP. GR. (F) = __________

DENSITY (F x 62.4) PCF __________

MAXIMUM MIX DENSITY

FLASK NUMBER	1	2	
G. SAMPLE CONTAINER & SOLUTION:	3869.8	4335.7	
H. CONTAINER & SOLUTION:	3281.4	3747.6	
I. SAMPLE IN SOLUTION (G-H)			
J. SAMPLE IN AIR	1000.2	1000.0	
K. VOLUME OF VOIDLESS MIX (J-I)			
L. MEAS. MAX. SPEC GRAVITY (J/K)			
M. MAX. THEOR. DENSITY (62.4 X L)			

PERCENT AIR VOIDS

% AIR VOIDS = $\frac{L-F}{L}$ X 100 = (______ - ______) 100 = ______% AIR VOIDS

AGGREGATE BLEND PROPORTIONS

AC CONTENT: ________

NOTES

Inspectors Signature

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Asphalt Content Determinatioins (Cutoff):

You start the day's production with a measured volume in the Plant asphalt tank of 12,400 gal. at 290-deg. F. The unit weight of the tank material is listed at 8.405 lbs./gal (60 deg. F)

You receive four loads of asphalt during the day with the following asphalt as listed on the bill of lading:

Load 1: 42,260 lbs.

Load 2: 42, 400 lbs.

Load 3: 41,850 lbs.

Load 4: 43,820 lbs.

Load 5: 44,120 lbs.

Load 6: 42,810 lbs.

At the end of the day you have a measured volume in the Plant asphalt tank of 3,400 gal. at 295 deg. F. The unit weight of the tank material is listed at 8.405 lbs./gal. (60 deg. F.)

You produced 2,720 tons of S/P FAA 42 mixture, all delivered to the project with no plant waste.

What is the asphalt content of the mixture produced?

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Given the following from:

Job Mix Formula (Mix Design)

Bulk Specific Gravity-Combined Aggregate (G_{sb}) = 2.586

COC or Bill of Lading (Asphalt Supplier)

Specific Gravity of Asphalt Cement/Binder (G_b) = 1.031

Project Daily Data (Superpave or Marshall Lot Test)

Bulk Specific Gravity of Mixture Average (G_{mb}) = 2.346 (Marshall or Gyratory)

Maximum Theoretical Specific Gravity Average (G_{mm}) = 2.468 (From Rice Test)

Gradation $P_{\#200}$ = 5.4% (From Gradation Worksheet)

Asphalt Content (P_b) = 6.0% (From Tank or AC Cutoff)

Calculate:

1) **Air Voids (V_a)**
2) **VMA (Voids in Mineral Aggregate)**
3) **Dust/Binder Ratio**
4) **VFA (Voids Filled with Asphalt)**

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Mix Testing – Bulk Specific Gravity (G_{mb}):

Marshall

You have run your Marshall plugs with field mix samples (3 ea) utilizing 1,200 grams of mix resulting in a plug height of 2-1/4".

Is this within testing tolerance?

If not, what adjustment should be made regarding specimen weight?

Superpave

You have prepared your gyratory plugs with field mix samples (2 ea) utilizing 4,650 grams of mix resulting in a plug height of 108 mm.

Is this within tolerance?

If not, what adjustment should be made regarding specimen weight?

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DETERMINING POUNDS OF BITUMEN PER GALLON

1. ____________________ X _______________ = X 8.328 (1) = ________________ lbs. (kg) of Bitumen per Gallon (L) @ temperature

   Spec. Gravity of Bitumen — Temp. Factor

2. ________________________ X ___________________ = ________________________ lbs. (kg) of Bitumen per Gallon (L) @ temperature

   Wt./Gal. (L) @ 60°F — Temp. Factor

Temp. °C	Temp. °F	Factor
107	225	0.9436
110	230	0.9419
113	235	0.9402
116	240	0.9385
118	245	0.9369
121	250	0.9352
124	255	0.9336
127	260	0.9319
129	265	0.9302
132	270	0.9286
135	275	0.9269
138	280	0.9253
141	285	0.9236
143	290	0.9220
146	295	0.9204
149	300	0.9187
152	305	0.9171
154	310	0.9154
157	315	0.9138
160	320	0.9122

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DENSITY PAY FACTOR

North Dakota Department of Transportation, Construction

SFN 59132 (06-2009)

Date Paved	Lot Number	Project Number
8/16/2011	5	Example

SPECIFIED DENSITY

MAXIMUM THEORETICAL DENSITY			SAMPLE TONS	MTD TESTS	FIELD MARSHALL PLUGS	
SUBLOT NO.	BEG TONS	RANDOM NO.			DENSITY	AIR VOIDS
1	0		265.31	150.3	144.1	4.1
2	1500		1603.16	150.0	144.9	3.5
			AVERAGE	150.2	144.5	3.8

CORE DENSITY (AVERAGE OF 2)

140.1	133.8	135.3	138.0	134.4

AVERAGE PAVEMENT DENSITY ____________ **LBS / CU. FT.**

AVERAGE PAVEMENT DENSITY (% MTD)

AVG. PAVEMENT DENSITY / MTD TEST AVG X 100 =

PAY FACTOR

TARGET DENSITY (% MTD) ____________

Inspectors Signature

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Example QC QA Test Summary

PCN: PCN 17134 & 17843 | Mix: Certified

410; FAA 43 | Mix Type: 410; FAA 43 | Gyra.: 75

Test #			1		2		3		4		5		6	
Day #			1		1		2		3		4		4	
Date 2011			8/22/11		8/22/11		8/23/11		8/24/11		8/25/11		8/25/11	
Sieve Size	JMF Limits Min.	Max.	cont.	agency	cont.	agency	cont.	agency	cont.	agency	cont.	agency	cont.	agency
1"														
mov. avg														
3/4"	100	100	100		100		100		100		100		100	
mov. avg	100	100							100		100		100	
1/2"	93	100	100		100		100		100		100		100	
mov. avg	94	100							100		100		100	
3/8"			90		91		90		90		88		87	
mov. avg									90		90		89	
#4	47	59	51		54		51		51		54		51	
mov. avg	48	58							52		52		52	
#8			33		35		34		31		34		34	
mov. avg									33		34		33	
#16			21		22		23		20		24		22	
#30	10	20	12		13		14		12		14		14	
mov. avg	11	19							13		13		14	
#50			8		8		9		7		10		9	
#100			6		7		7		6		7		7	
#200	3.8	7.0	4.6		5.5		5.1		4.4		6.0		5.4	
mov. avg	4.3	7.0							4.9		5.2		5.2	
Max mix (Gmm)			2.390		2.403		2.430		2.427		2.413		2.422	
Max mix MA (Gmm)														
Bulk Gravity (Gmb)			2.316		2.306		2.321		2.329		2.335		2.344	
Isolated Voids (%)			3.1		4.0		4.5		4.0		3.2		3.2	
Voids moving avg (%)									3.9		3.9		3.7	
AFT adj. (um)	7.5	min.	11.5		9.8		8.9		10.5		9.1		9.1	
AFT adj. moving avg (um)	8.0	min.							10.2		9.6		9.4	
AC total (%)		min.	5.8		5.8		5.8		5.9		5.9		5.9	
AC moving avg (%)		min.												
Fines/Effective oil	0.6 - 1.3		0.9		1.1		1.2		1.0		1.3		1.2	
VMA (%)			14.4		14.8		14.3		14.1		13.9		13.4	
Mix Moisture (%)	0.3	max.												
Comb. Agg. Sp.G.			2.550		2.550		2.550		2.552		2.552		2.547	
+#4 crush, 1 / 2 face (%)	85	min.	87/0				86/0		92/0					
FAA	45	min.	44.9				45.2							
-#4 Crushing calc. (%)	NA	min.												
-#4 Agg. Sp.G.			2.508		2.508		2.508		2.512		2.512		2.505	
Tonnage sampled at (random no.)			320		601		378		290		304		912	
Tonnage represented (lot size)														
Tonnage accumulated (to date total)														
Aggregate			%	SpG	%	SpG	%	SpG	%	SpG	%	SpG	%	SpG
#1 FORDVILLE FINES			27	2.450	27	2.450	27	2.450	25	2.450	25	2.450	29	2.450
#2 FORDVILLE 1/2" ROCK			36	2.625	36	2.625	36	2.625	36	2.625	36	2.625	36	2.625
#3 FORDVILLE AS/DUST				2.529		2.529		2.529		2.529		2.529		2.529
#4 FORDVILLE DUST			37	2.554	37	2.554	37	2.554	39	2.554	39	2.554	35	2.554
#5														
#6														
#7														
AC PG 58-28			5.8	1.033	5.8	1.033	5.8	1.033	5.9	1.033	5.9	1.033	5.9	1.033
Quality Control Actions, Comments and Signatures			SE = 58.7%		SE = 57.7%				Shale = 4.02%		Shale =4.86%			

Software developed by Todd Wille; SPC Engineering
(651) 653-6349 (o) (612) 250-8937 (m)

Example QC QA Test Summary

410; FAA 43

PCN: PCN 17134 & 17843 — Mix: Certified

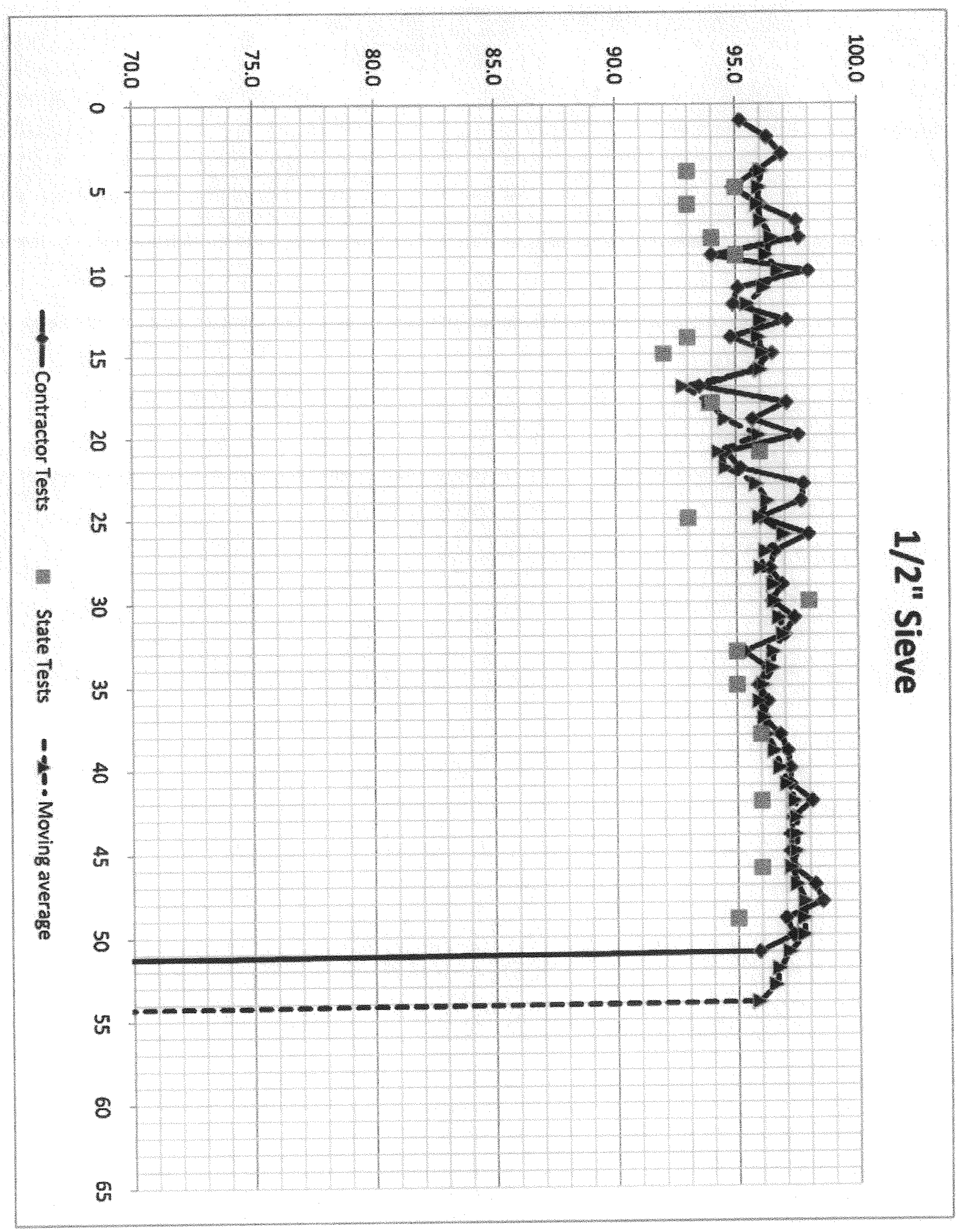
Mix Type: 410; FAA 43 — Gyra.: 75

Test #			7		8		9		10		11		12	
Day #			4		5		5		5		5		5	
Date		2011	8/25/11		8/26/11		8/26/11		8/26/11		8/26/11		8/26/11	
Sieve Size	JMF Limits Min.	Max.	cont.	agency	cont.	agency	cont.	agency	cont.	agency	cont.	agency	cont.	agency
1"														
mov. avg														
3/4"	100	100	100		100		100							
mov. avg	100	100	100		100		100							
1/2"	93	100	100		100		100							
mov. avg	94	100	100		100		100							
3/8"			86		90		89							
mov. avg			88		88		88							
#4	47	59	52		50		51							
mov. avg	48	58	52		52		51							
#8			33		34		34							
mov. avg			33		34		34							
#16			22		22		23							
#30	10	20	13		12		13							
	11	19	13		13		13							
#50			8		8		8							
#100			5		6		6							
#200	3.8	7.0	4.1		4.3		4.5							
mov. avg	4.3	7.0	5.0		5.0		4.6							
Max mix (Gmm)			2.404		2.414		2.415		0.708					
Max mix MA (Gmm)														
Bulk Gravity (Gmb)			2.332		2.332		2.331		#DIV/0!		#DIV/0!		#DIV/0!	
Isolated Voids (%)			3.0		3.4		3.5		#DIV/0!					
Voids moving avg (%)			3.4		3.2		3.3		#DIV/0!					
AFT adj. (um)	7.5	min.	11.4		10.5		10.3							
AFT adj. moving avg (um)	8.0	min.	10.0		10.0		10.3							
AC total (%)		min.	5.8		5.8		5.8		5.8		5.8		5.8	
AC moving avg (%)		min.												
Fines/Effective oil	0.6 - 1.3		0.9		0.9		1.0							
VMA (%)			13.8		13.8		13.8		#DIV/0!		#DIV/0!		#DIV/0!	
Mix Moisture (%)	0.3	max.												
Comb. Agg. Sp.G.			2.547		2.547		2.547		2.547		2.547		2.547	
+#4 crush, 1 / 2 face (%)	85	min.												
FAA	45	min.												
-#4 Crushing calc. (%)	NA	min.												
-#4 Agg. Sp.G.			2.505		2.505		2.505		2.505		2.505		2.505	
Tonnage sampled at (random no.)			1473		512		1374							
Tonnage represented (lot size)														
Tonnage accumulated (to date total)														
Aggregate			%	SpG	%	SpG	%	SpG	%	SpG	%	SpG	%	SpG
#1	FORDVILLE FINES		29	2.450	29	2.450	29	2.450	29	2.450	29	2.450	29	2.450
#2	FORDVILLE 1/2" ROCK		36	2.625	36	2.625	36	2.625	36	2.625	36	2.625	36	2.625
#3	FORDVILLE AS/DUST			2.529		2.529		2.529		2.529		2.529		2.529
#4	FORDVILLE DUST		35	2.554	35	2.554	35	2.554	35	2.554	35	2.554	35	2.554
#5														
#6														
#7														
AC	PG 58-28		5.9	1.033	5.9	1.033	5.9	1.033	5.9	1.033	5.8	1.033	5.8	1.033

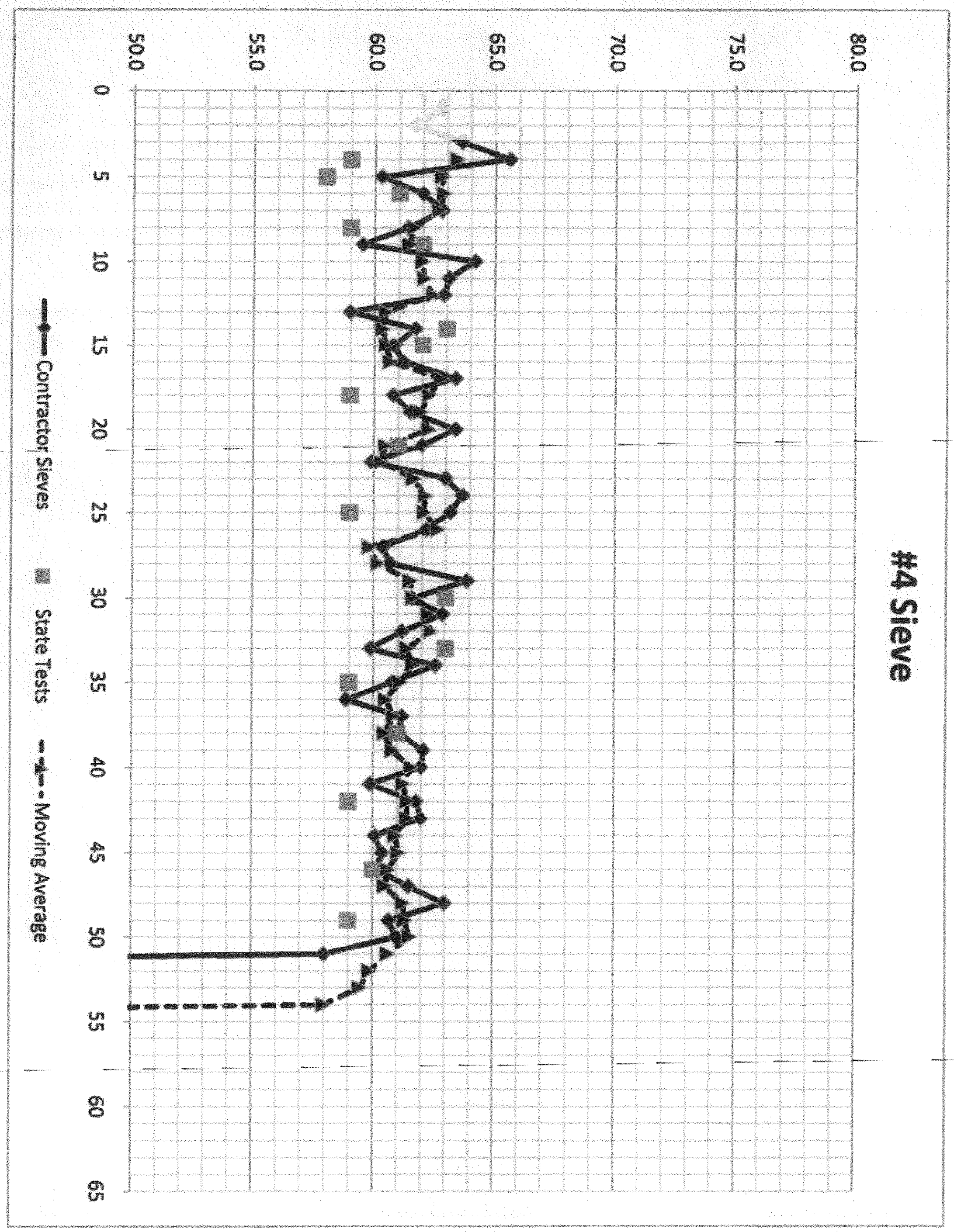
Quality Control Actions, Comments and Signatures

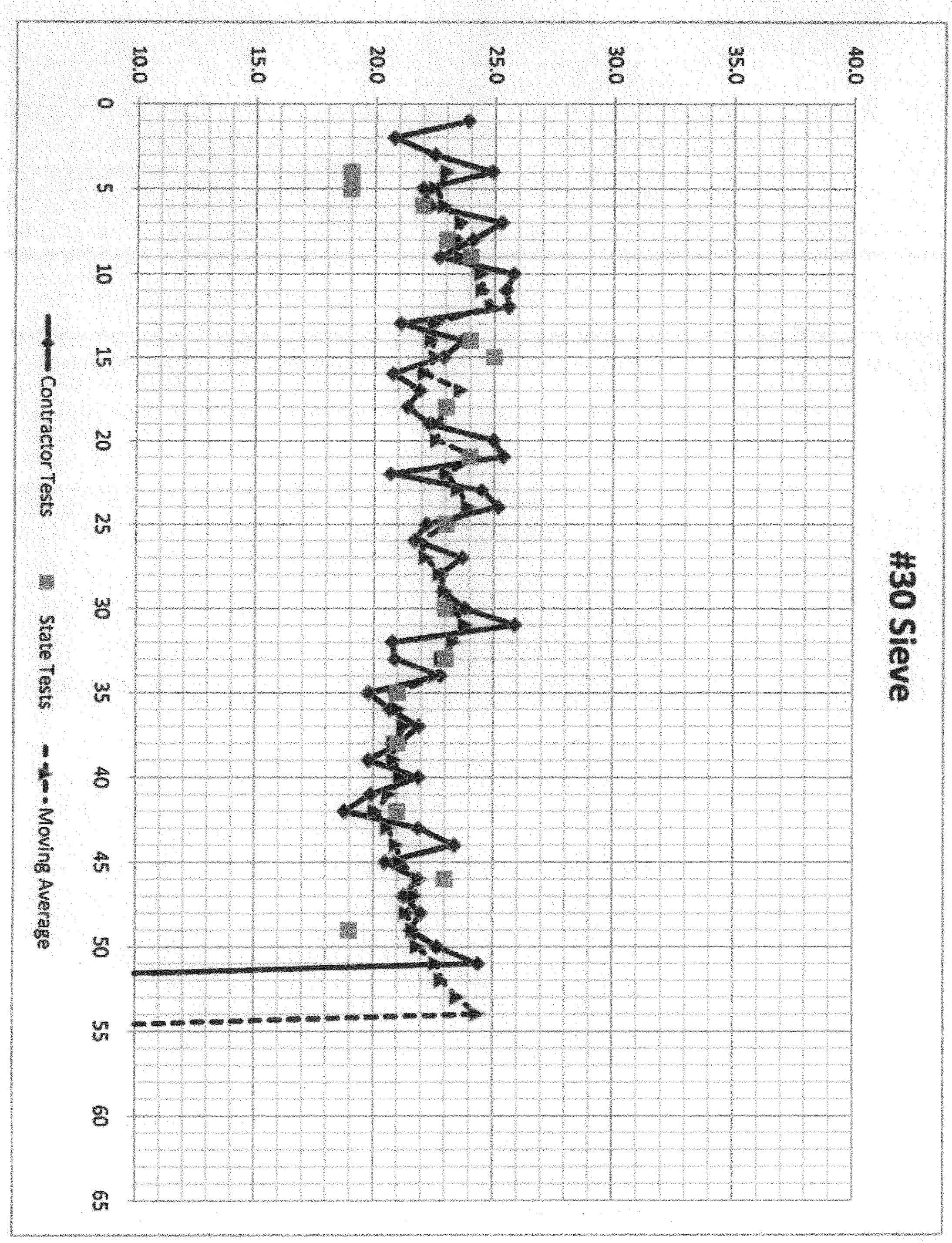
Shale = 4.65%

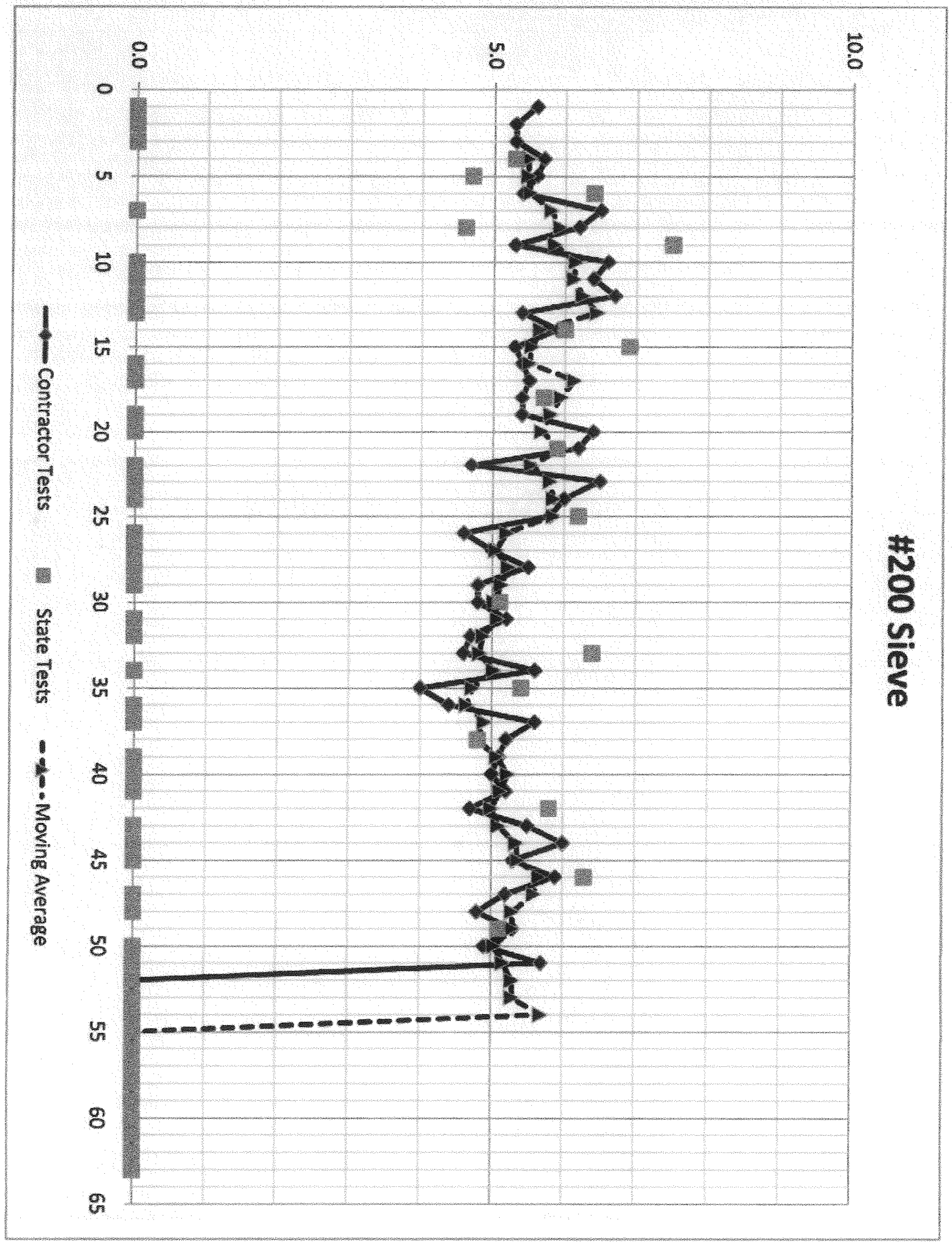
Software developed by Todd Wille; SPC Engineering
(651) 653-6349 (o) (612) 250-8937 (m)


1/2" Sieve
100.0
95.0
90.0
85.0
80.0
75.0
70.0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Contractor Tests
State Tests
Moving average

DCN: 17538


#4 Sieve
80.0
75.0
70.0
65.0
60.0
55.0
50.0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Contractor Sieves
State Tests
Moving Average


#30 Sieve
40.0
35.0
30.0
25.0
20.0
15.0
10.0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Contractor Tests
State Tests
Moving Average


#200 Sieve
0.0
5.0
10.0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Contractor Tests
State Tests
Moving Average

HOT MIX DESIGN DATA - SUPERPAVE

5/5/10

Lab. No.			
Location	I-94	Project Specification	Section 410
Project	Superpave	Type of AC (top lift)	64-28
		Type of AC (bot lift)	64-28
District	Mix Tester Class	Letting Date	
County	KIDDER	Plus #4 (%)	41.4
Date	5/5/10	Minus #4 (%)	58.6
Pit Owner(s)	Nelson		
		Gyratory Compactive Effort	
Pit #1 Location	NE1/4 12-139-71	Ninitial	7
Pit #2 Location		Ndesign	75
Pit #3 Location		Nmaximum	115

Mix Properties at Recommended Asphalt Content

	Mix Design	Specification
Optimum AC (%)	5.5	
Density (pcf)	147.7	
Air Voids (%)	4.0	4.0 TARGET
VMA (%)	14.0	14.0
VFA (%)	70.6	65-75
%Gmm @ Ninitial	87.7	89 MAX
%Gmm @ Nmaximum	97.2	98
AC Film Thickness (m)	9.5	7.5-13
Dust/Effective AC Ratio	1.1	.6-1.3
Fine Agg Angularity (%)	46.1	45 min
Sand Equivalent (%)	60.9	40 min
Coarse Agg Angularity (%)	92.9	85
Flat/Elongated Pieces (%)	0.9	10
Maximum SpG @ Ndes	2.466	
Frac. Faces Fine (%)	72.4	
Frac. Faces Course (%)	93.1	

Summary of Aggregate Characteristics from Mix Design

Gradation (% passing)	
5/8"	100.0
1/2"	94.7
3/8"	84.2
#4	58.6
#8	39.7
#16	26.0
#30	15.9
#50	8.2
#100	5.8
#200	4.6

Asphalt Absorption (%)	1.34
Water Absorption (%)	2.24
Light Wt Particles (%)	2.1
Toughness (% Loss)	

Final Aggregate Blend (%)

19	NAT FINES	MOTL
48	ASCF	MOTL
33	5/8 ROCK	MOTL

Specific Gravity Information

Bulk (Gsb)	2.599
Apparent (Gsa)	2.758
Effective (Gme)	2.691

Remarks:

Distribution:
Materials and Research
Mix Tester Class

GENERAL INFORMATION and AGGREGATE GRADATIONS/BLEND
SUPERPAVE MIX DESIGN

GENERAL INFORMATION

Enter data in shaded boxes.
Absent sieve calculator is at the bottom of the sheet.

Project:	Superpave
Location:	I-94
District:	Mix Tester Class
County:	KIDDER
Date (MM/DD/YY):	5/5/10
Lab Number:	
Type of AC (Top Lift):	64-28
Type of AC (Bot. Lift):	64-28
Letting Date:	

Pit #1 Location:	NE1/4 12-139-71
Pit #2 Location:	
Pit #3 Location:	
Pit Owner(s):	Nelson
AC Specific Gravity:	1.024
Length of Project:	10.671
Asphalt Supplier:	MURPHY
Contractor:	Central Specialties Inc

INDIVIDUAL AGGREGATE GRADATIONS

	Agg #1	Agg #2	Agg #3	Agg #4	Agg #5	Agg #6
Aggregate---> Description-->	NAT FINES MOTL	ASCF MOTL	5/8 ROCK MOTL			
If Agg. is Crushed, Enter 1	0	1	1			
Sieve Size	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing
5/8" (16mm)	100.0	100.0	100.0			
1/2" (12.5mm)	100.0	100.0	84.0			
3/8" (9.5mm)	100.0	100.0	52.0			
#4 (4.75mm)	85.0	87.0	2.0			
#8 (2.36mm)	69.0	54.0	2.0			
#16 (1.18mm)	51.0	33.0	1.3			
#30 (0.6mm)	31.0	20.0	1.3			
#50 (0.3mm)	13.0	11.0	1.3			
#100 (0.15mm)	8.0	8.0	1.3			
#200 (0.075mm)	6.0	6.4	1.3			

BLEND GRADATION

Aggregate Description	Aggregate #	Blend %	Sieve Size	Blend Gradation	Lower Control Pt	Upper Control Pt
NAT FINES	1	19	5/8"	100.0	100	100
ASCF	2	48	1/2"	94.7	90	100
5/8 ROCK	3	33	3/8"	84.2		
	4		#4	58.6		
	5		#8	39.7	28	58
	6		#16	26.0		
	Sum of % =	100	#30	15.9		
			#50	8.2		
			#100	5.8		
			#200	4.6	2	7

% Fine Aggregate Mechanically Produced (Fractured) : 72.4
% Coarse Aggregate Mechanically Produced (Fractured) : 93.1

AGGREGATE PROPERTIES

SUPERPAVE MIX DESIGN

Superpave

5/5/10

AGGREGATE PROPERTIES

	Agg #1	Agg #2	Agg #3	Agg #4	Agg #5	Agg #6
	NAT FINES	ASCF	5/8 ROCK			
Bulk SpG (Gsb)						
Coarse	2.377	2.627	2.627			
Fine	2.511	2.626	2.626			
Apparent SpG (Gsa)						
Coarse	2.727	2.778	2.778			
Fine	2.704	2.763	2.763			
Water Absorption						
Coarse	5.410	2.070	2.070			
Fine	2.840	2.150	2.150			
Combined						
Bulk SpG (Gsb)	2.490	2.626	2.627	1.000	1.000	1.000
Apparent SpG (Gsa)	2.707	2.765	2.778	1.000	1.000	1.000
Water Absorption	3.058	2.139	2.072	1.000	1.000	1.000

Aggregate	Bulk SpG (Gsb) =	2.599
Blend	Apparent SpG (Gsa)=	2.758
Properties	Water Absorption =	2.243

SUPERPAVE CONSENSUS AGGREGATE PROPERTIES

	Agg #1	Agg #2	Agg #3	Agg #4	Agg #5	Agg #6
	NAT FINES	ASCF	5/8 ROCK			
Fine Agg. Angularity						
% FAA	41.0	48.0	48.0			
Clay Content						
% Sand Equivalent	37	70	70			

Coarse Aggregate Angularity (+ No. 4 Material)

Nominal maximum Size	Sample Size
3/8" (9.5 mm)	200 g
½" (12.5 mm)	500 g
3/4" (19 mm)	1500 g

Wt. of Total Sample =	583.6
Wt. of Fractured Material =	541.6
Wt. of Questionable Material =	9.8
Wt. of Uncrushed Material =	37.1

Flat and Elongated Particles

Nominal maximum Size	Sample Size
3/8" (9.5 mm)	1000 g
½" (12.5 mm)	2000 g
3/4" (19 mm)	5000 g

Wt. of Total Sample =	711.9
Wt. of Material Larger then 3/8" =	267.5
Wt. of Flat and Elongated Particles =	2.4

Superpave	Fine Agg. Angularity % =	46.1
Consensus	Sand Equivalent % =	60.9
Aggregate	Coarse Agg. Angularity % =	92.9
Properties	Thin & Elongated Pieces % =	0.9

SUPERPAVE MIX DESIGN DATA

Superpave

5/5/10

Bulk Specific Gravity of the Mix (Gmb) @ Ndes

%AC Specimen#	Weight in Air	SSD Weight	Weight in Water	Volume	Gmb @Ndes	Unit Weight
4.5						
A	4733.2	4750.2	2715.6	2034.6	2.326	145.2
B	4737.4	4751.8	2718.2	2033.6	2.330	145.4
			Average =	**2034.1**	**2.328**	**145.3**
5.0						
A	4736.2	4735.2	2724.8	2010.4	2.356	147.0
B	4739.8	4749.1	2732.8	2016.3	2.351	146.7
			Average =	**2013.4**	**2.353**	**146.8**
5.5						
A	4738.2	4744.7	2742.1	2002.6	2.366	147.6
B	4741.7	4748.9	2746.4	2002.5	2.368	147.8
			Average =	**2002.6**	**2.367**	**147.7**
6.0						
A	4735.9	4739.9	2755.2	1984.7	2.386	148.9
B	4739.2	4744.6	2760.2	1984.4	2.388	149.0
			Average =	**1984.6**	**2.387**	**149.0**
A						
B						
			Average =			

Rice Test: Theoretical Maximum SpG of the Mix (Gmm) @ Ndes

	AC % =	**4.5**	AC % =	**5.0**	AC % =	**5.5**	AC % =	**6.0**	AC % =	
Flask Number	1	2	1	2	1	2	1	2	1	2
Samp., Cont. & Sol.	3374.7	3898.4	3376.4	3887.4	3371.2	3895.2	3366.2	3885.2		
Cont. & Sol. (g)	2768.3	3288.5	2768.3	3288.5	2768.3	3288.5	2768.3	3288.5		
Samp. in Air (g)	1006.9	1014.9	1016.9	1002.8	1012.9	1020.6	1009.9	1006.5		
Samp. in Sol. (g)	606.4	609.9	608.1	598.9	602.9	606.7	597.9	596.7	0	0
Vol. of Voidless Mix	400.5	405	408.8	403.9	410	413.9	412	409.8	0	0
Theoretical Max. SpG	2.514	2.506	2.488	2.483	2.470	2.466	2.451	2.456		
Difference Between Flasks	0.008 In Tolerance		0.005 In Tolerance		0.005 In Tolerance		0.005 In Tolerance			
Avg Theor. Max. SpG	2.510		2.485		2.468		2.454			
Effective SpG	2.694		2.687		2.689		2.694			
AC Absorption	1.4		1.3		1.3		1.4			

Avg Effective SpG: 2.691

Voids Analysis of the Mix @ Ndes

AC Content (%)	**4.5**	**5.0**	**5.5**	**6.0**	
Bulk Specific Gravity of the Mix (Gmb)	2.328	2.353	2.367	2.387	
Percent Aggregate	95.5	95	94.5	94	#VALUE!
Theor. Maximum SpG of Mix (Gmm)	2.510	2.485	2.468	2.454	
Air Voids, Va (%)	7.3	5.3	4.1	2.7	#VALUE!
Voids in Mineral Agg. (VMA)	14.5	14.0	14.0	13.7	#VALUE!
Voids in Mineral Agg. Filled (VFA)	49.9	62.1	70.6	80.2	#VALUE!
Asphalt Absorption (%)	1.34				

SUPERPAVE MIX DESIGN
Gyratory Compactor Information

Superpave

5/5/10

Superpave Gyratory Compaction Effort

Number of Gyrations @ $N_{initial}$:	7
Number of Gyrations @ N_{design}:	75
Number of Gyrations @ $N_{maximum}$:	115

Gyratory Plugs Compacted to Ninital and Ndesign

	AC % =	**4.5**	AC % =	**5.0**	AC % =	**5.5**	AC % =	**6.0**	AC % =	
Plug Number	1	2	1	2	1	2	1	2	1	2
Plug Weight (g)	4733.2	4737.4	4736.2	4739.8	4738.2	4741.7	4735.9	4739.2		
Plug Height @ Nini (mm)	128.2	128.6	126.9	126.3	125.1	125.9	123.2	123.5		
Plug Height @ Ndes (mm)	118.0	117.8	116.4	116.2	114.9	114.7	113.3	113.5		
% Gmm initial	85.4	85.0	86.9	87.1	88.1	87.4	89.5	89.4		
Avg. % Gmm initial	85.2		87.0		87.7		89.4			

Gyratory Plugs Compacted to Nmaximum at Design Optimum Asphalt Content

%AC @ Optimum Specimen#	Weight in Air	SSD Weight	Weight in Water	Volume	Gmb @Ndes	Unit Weight
5.5						
A	4735.1	4738.9	2760.8	1978.1	2.394	149.4
B	4732.1	4736.3	2762.8	1973.5	2.398	149.6
			Average =	**1975.8**	**2.396**	**149.497**

%Gmm at $N_{maximum}$ = 97.2

Moisture Sensitivity (Minimum Percent Strength Retention)

No data is needed to be entered here at this time.

SUPERPAVE HOT MIX DESIGN GRAPHS

Department of Transportation, Materials and Research (Rev. 5-07)

Y Scale Settings

Air Voids Vs % AC

Max Scale 8

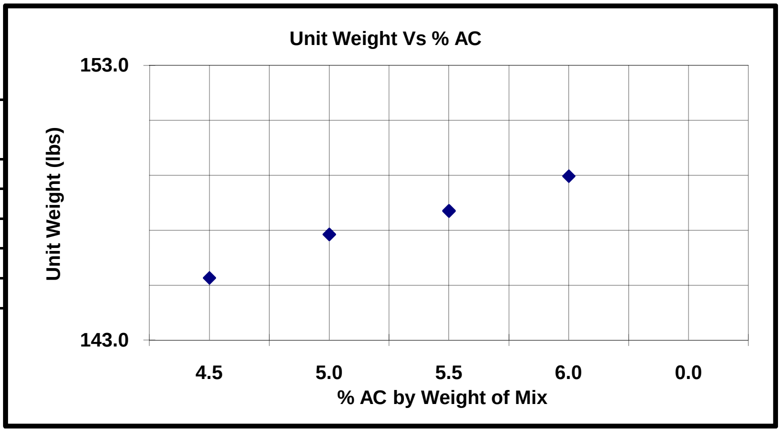
Min Scale 2

Major Unit .5

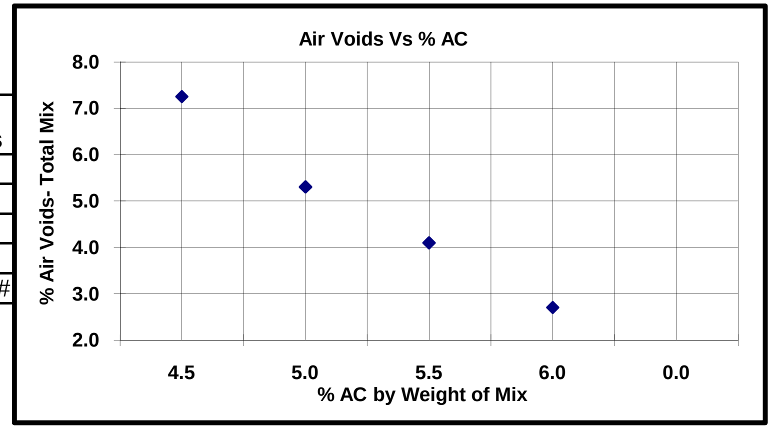
Set Scale

Clear

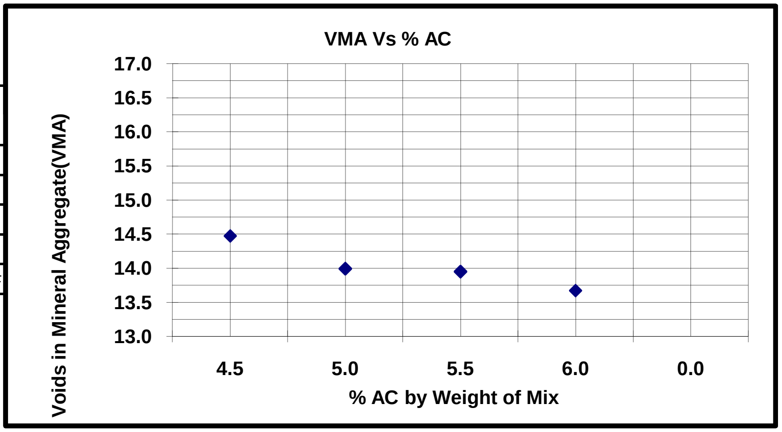
AC%	UNIT WT.
4.5	145.3
5.0	146.8
5.5	147.7
6.0	149.0
0.0	



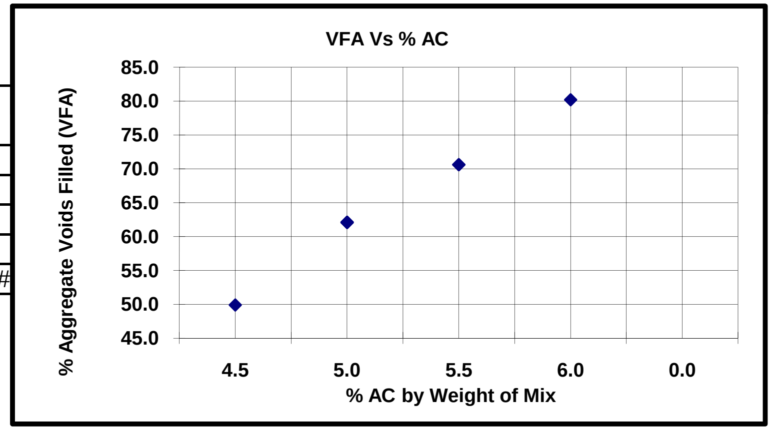
AC%	Air Voids
4.5	7.3
5.0	5.3
5.5	4.1
6.0	2.7
0.0	######



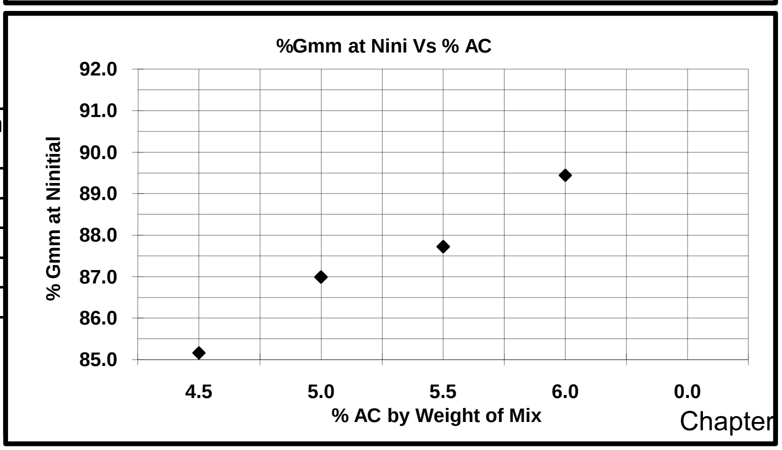
AC%	VMA
4.5	14.5
5.0	14.0
5.5	14.0
6.0	13.7
0.0	######



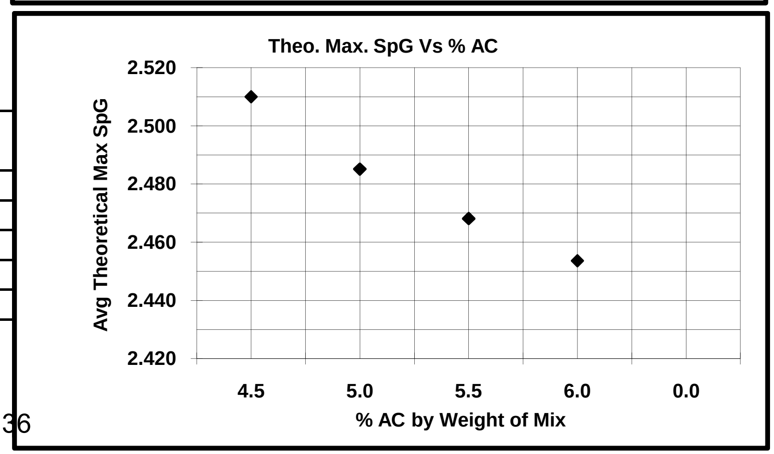
AC%	VFA
4.5	49.9
5.0	62.1
5.5	70.6
6.0	80.2
0.0	######

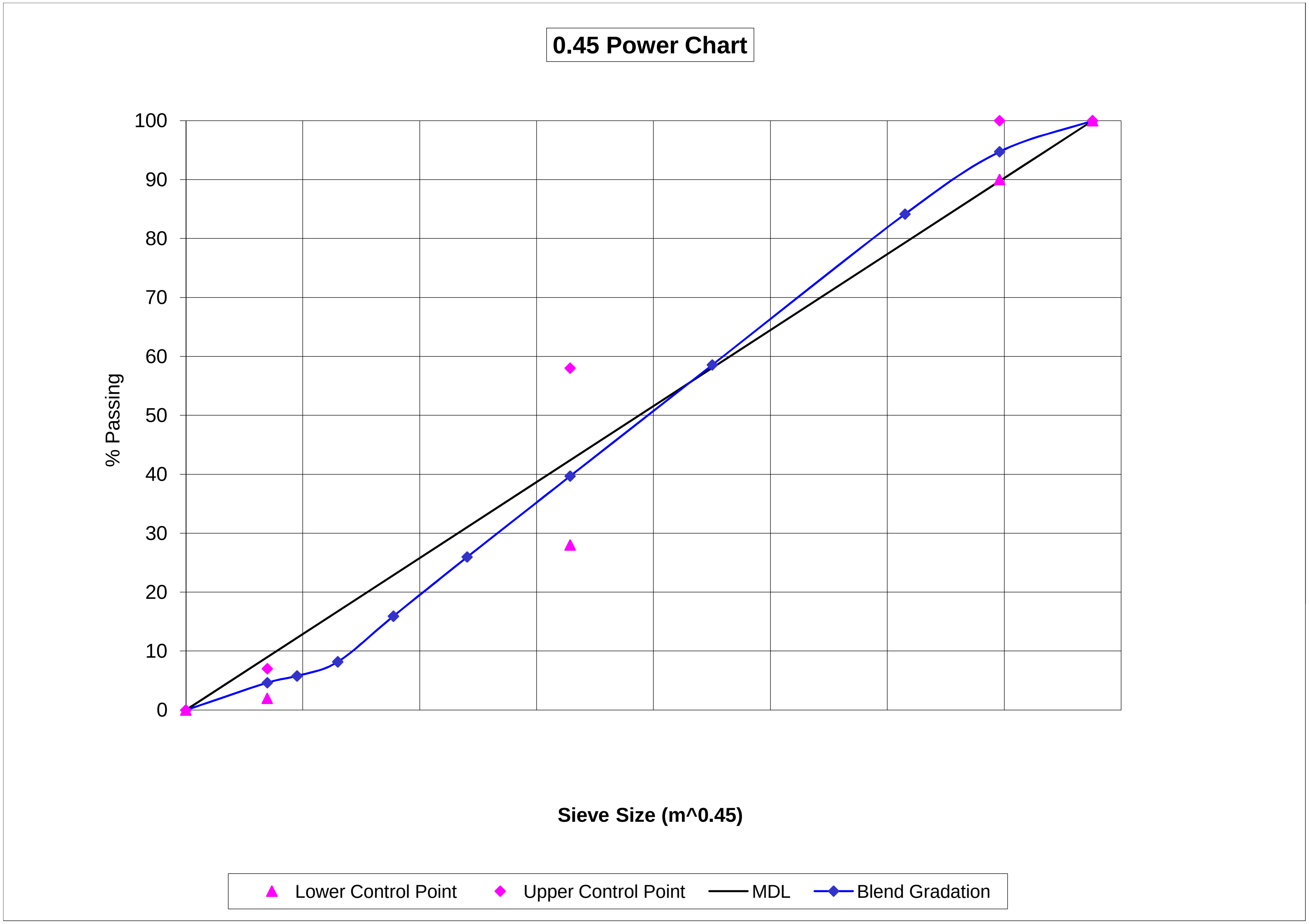


AC%	%Gmm
4.5	85.2
5.0	87.0
5.5	87.7
6.0	89.4
0.0	



AC%	Max SpG
4.5	2.510
5.0	2.485
5.5	2.468
6.0	2.454
0.0	




0.45 Power Chart
100
90
80
70
60
50
40
30
20
10
0
% Passing
Sieve Size (m^0.45)
Lower Control Point
Upper Control Point
MDL
Blend Gradation

Errors and Omissions

Did you spot an error in the book?

Which class/book: ____

Please explain what you feel should be corrected or added:

Note Paper:

Note Paper:

Contact Information

Dakota Asphalt Pavement Association

http://www.dakota-asphalt.org/

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kswedeen@dakota-asphalt.org

ND Department of Transportation

www.dot.nd.gov

Contact Information

Materials and Research Office

701-328-6900

Bituminous/Asphalt Engineer

Asphalt Mix, Liquid Asphalt
Joe Davis
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jdavis@nd.gov

Testing Lab Supervisor

Aggregates, Soil, Concrete, Field Sampling and Testing Manual
Scott Wutzke
701-328-6902
swwutzke@nd.gov

Aggregate, Asphalt, Concrete and Soils - Classes and Certification

Sharon Taylor
701-328-6937
staylor@nd.gov

Web Site for Field Sampling and Testing Manual, Classes, and Certification Status

http://www.dot.nd.gov/divisions/materials/materials.htm

Construction Office

701-328-2563

ETS – Environmental and Transportation Services (Spec Book)

701-328-2590

District Materials Coordinators

Bismarck District
Jim Glick
701-328-6927

Devils Lake District
Mike Pike
701-665-5117

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Belinda Urlacher
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Kevin Hanson
701-845-8807

Williston District
Beth Skabo
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NDDOT Technician Certification Program Performance Exams

All performance exams are completed, by appointment at the NDDOT Materials and Research office or other designated locations

It is your responsibility to be at the exam at your designated time

Performance Exam Participants

- Know which certification you are seeking
- Bring a copy of the test procedures to the exam.
- Have thorough knowledge and understanding of all test procedures in the category/group you request **before** the exam begins.
- On-the-job training is **required** before attempting a performance exam
- You will be given two chances to complete a demonstration of each test.
- If you are unable to complete the test the second time the performance exam will end at that point.
- Arrangements will need to be made to schedule another date to re-attempt the performance exam. That attempt may NOT be completed the same day.
- If the second attempt is not successful you will need to repeat the class.

You will be graded on your ability to correctly describe and/or perform all of the steps of each procedure required for the certification.

You are expected to know the steps, the test, times and temperatures.

Reference material may be used but you will not be allowed to read the entire procedure.

Note: If this is your first time completing a performance exam, or the first time in North Dakota, every state has their own variation to test procedures. You must be familiar with the North Dakota method for testing, sampling, number of samples required, modifications, etc.

North Dakota requires aggregate tests be completed during aggregate production AND during asphalt mix production. We do not use ignition ovens or extraction methods. Gradations are run in the field. You must be familiar with all methods of aggregate sampling listed in our procedure. If you typically only sample from a belt at the plant you are still required to familiarize yourself with other methods such as windrow or stockpile sampling.

QR Codes for common web links

NDDOT Field Sampling and Testing Manual

NDDOT Standard Specifications

NDDOT Forms

NDDOT Technician Registry

NDDOT Materials and Research Web Page

Dakota Asphalt Pavement Assoc.

NDDOT Tech Certification Program

Web Links – February 2014

NDDOT
https://www.dot.nd.gov/

Dakota Asphalt Pavement Association (DAPA)
www.dakota-asphalt.org

NDDOT Materials and Research Division – and Qualifying Lab Manual
http://www.dot.nd.gov/divisions/materials/materials.htm

Online Certification Registry
http://www.dot.nd.gov/dotnet/ttqp/Search.aspx

NDDOT Standard Specifications for Roads and Bridges
http://www.dot.nd.gov/dotnet/supplspecs/StandardSpecs.aspx

NDDOT Field Sampling and Testing Manual
http://www.dot.nd.gov/divisions/materials/testingmanual.htm

NDDOT Forms
http://www.dot.nd.gov/divisions/materials/testingmanual.htm

YouTube videos
http://www.dot.nd.gov/dotnet/forms/forms.aspx

Upper Great Plains Transportation Institute (UGPTI) for test modules – online learning
www.translearning.org