AMRL Research Status

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AASHTO Materials Reference Laboratory
HSOM Meeting, Aug. 2008

AMRL Research Program Mission

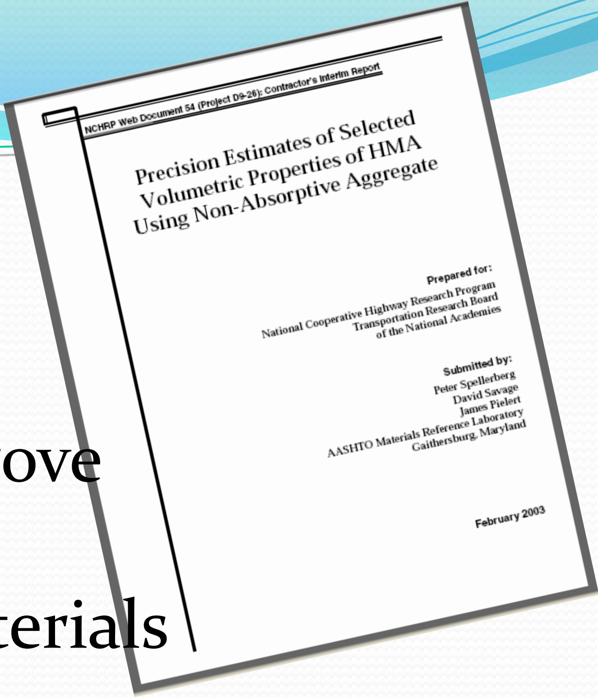
Meet the Research and Standards

Needs of the AASHTO Member States

Outline

- Accomplished work
- Current research activities
- Future research plans

NCHRP 9-26
Background



- A multi-phase research project to improve estimates of precision in AASHTO test methods for various pavement materials
- NCHRP Reports available online:
  - Phase 1, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w54.pdf
  - Phase 2, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w66.pdf
  - Phase 3, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w71.pdf
  - Phase 4, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w109.pdf
  - Phase 5, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w114.pdf

NCHRP 9-26(4)

"Precision Estimates for Selected Volumetric Properties of HMA Using Absorptive Aggregate"

Phase 4 Components

- Interlaboratory Study (ILS):
  - provided estimates of precision for various test methods associated with HMA mix design when absorptive aggregate are used.

- Aging Time Experiment :
  - Determined the effects of aging time on volumetric properties of mixtures containing absorptive aggregate
  - Provided appropriate aging time for mixtures with absorptive aggregate.

Proposed Precision Estimates

Determined estimates of precision… when HMA designs contain absorptive aggregates:

- T 312, "Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor"
- T 166, "Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens"
- T 209 (D 2041), "Theoretical Maximum Specific Gravity and Density of Hot-Mix Asphalt Paving Mixtures"
- T 331 (D 6752), "Bulk Specific Gravity and Density of Compacted Asphalt Mixtures Using Automatic Vacuum Sealing Method"

Proposed Addition to AASHTO R30

- Change in % air voids and % absorbed asphalt of mixtures with absorptive aggregates could become physically significant after 4 hours of aging
- Therefore, short term oven aging of mixtures with absorptive aggregate was proposed to be 4 hrs.

NCHRP 9-26(5)

Precision Estimates for AASHTO T269 Determined Using AMRL Proficiency Sample Data

Phase 5 Objective

Update precision estimates for AASHTO T269, "Percent Air Voids in Compacted Dense and Open Asphalt Mixtures" using data from the AMRL Proficiency Sample Program (PSP)

Proposed Precision Statement for T 269, G_{mb} measured using T166

Test and Type Index	Standard Deviation (1S Limit)	Acceptable Range of Two Results (D2S Limit)
Single Operator Precision:		
AASHTO T245[b]	0.47	1.33
AASHTO T247	0.54	1.52
ASTM D4013	0.42	1.42
AASHTO T312	0.54	1.53
Multi-laboratory Precision:		
AASHTO T245[b]	1.07	3.02
AASHTO T247	1.30	3.67
ASTM D4013	1.50	4.25
AASHTO T312	0.95	2.87

Proposed Precision Statement for T 269, G_{mb} measured using T 331

Test and Type Index	Standard Deviation (1S Limit)	Acceptable Range of Two Results (D2S Limit)
Single Operator Precision:		
AASHTO T245[b]	0.48	1.35
AASHTO T312	0.46	1.31
Multi-laboratory Precision:		
AASHTO T245[b]	0.84	2.38
AASHTO T312	0.90	2.54

NCHRP 9-26A

"Interlaboratory Studies and Data Mining to Collect Data for the Preparation of Precision Statements"

Objective of NCHRP 9-26 (A)

Develop, verify, or update precision estimates for several AASHTO test methods selected by AASHTO Highway Subcommittee on Materials (HSOM) on broad range of highway materials including soil, aggregate, asphalt binder, asphalt mixture, hydraulic cement, and cement concrete

Test Methods in NCHRP 9-26 (A)

- AASHTO T 22, “Compressive Strength of Cylindrical Specimens”
- AASHTO T 104, “Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate”
- AASHTO T 105, “Chemical Analysis of Hydraulic Cement”
- AASHTO T 186, “Early Stiffening of Hydraulic Cement (Paste Method)”
- AASHTO T 154, “Time of Setting of Hydraulic Cement Paste by Gilmore Needles”
- AASHTO T 180, “Moisture-Density Relations of Soil Using a 4.54-kg. (10-lb.) Hammer and a 457-mm (18-in.) Drop”
- AASHTO T 265, “Laboratory Determination of Moisture Content of Soils”
- AASHTO T 267, ”Determination of Organic Content in Soils by Loss on Ignition”
- AASHTO T 148, “Measuring the length of Drilled Concrete Cores”
- AASHTO T 242, “Frictional Properties of Paved Surfaces Using a Full-Scale Tire”
- AASHTO T 283, “Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage”

NCHRP 9-26(A) Data Mining

- Using AMRL and CCRL Proficiency Sample Data, and states' Friction data from Texas Transportation Institute (TTI) and Transportation Research Center (TRC), precision estimates for the following test methods are being developed:
  - AASHTO T 104,
  - AASHTO T 22, AASHTO T 186, AASHTO T 154
  - AASHTO T 105
  - AASHTO T 242
- Draft reports on precision estimates were reviewed by the panel and comments are being addressed

9-26(A) Interlaboratory Studies

- AASHTO T 180
  - four materials , three replicates were prepared and shipped to the participating labs (17 state and 18 private labs)
- AASHTO T 265
  - Same materials as for T 180 will be sent to the labs
- AASHTO T 267
  - Three materials, three percentages of organic material , three replicates were prepared and sent to 30 laboratories
  - Test results are being received at the present
- AASHTO T 283

AASHTO T 283 ILS

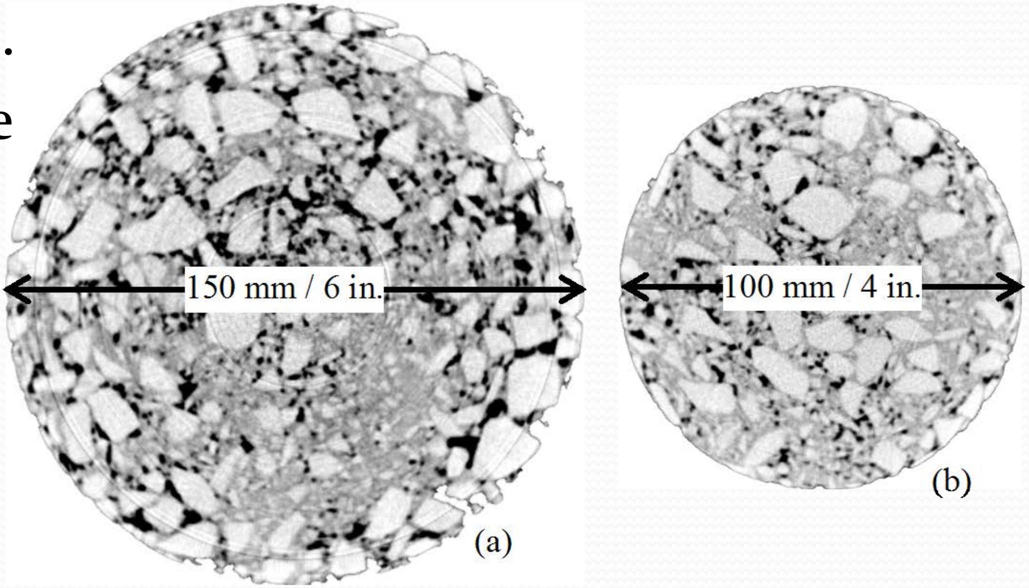
- 60 laboratories are participating -35 will test gyratory and 25 will test Marshall specimens
- Despite its popularity, T 283 is known to be very variable and sometimes provides erroneous results.
- Within the NCHRP 9-26A project, in addition to determining the variability of the test,
    - Reasons of the possible discrepancies of the test will be investigated
    - Recommendations towards its improvement will be made

AASHTO T 283 ILS, Preliminary Study

- Two mixtures with known low and high levels of moisture susceptibility were selected
- Sandstone aggregate from MD as moisture susceptible & Limestone mixture from PA as moisture resistant
- Study was conducted at TFHRC
- Purpose of the preliminary study was to :
  - Evaluate performance of the two mixtures,
  - Investigate effect of compaction and specimen size on the test results.
  - Use specimens' images for finite element analysis

AASHTO T 283 ILS, Preliminary Study (2)

- 6 Superpave gyratory and 6 Marshall specimens were compacted for each mixture.
- A total of 24 specimens were mixed, cured, compacted, conditioned, and tested according to T283 .
- Compacted specimens were scanned using X-ray computed tomography



Experimental Results, Sandstone

- Both Marshall and gyratory compacted specimens of the sandstone mixture, which was expected to be moisture susceptible, passed the test with very high wet/dry tensile strength ratio (TSR).
- Average TSR of the Marshall compacted specimens was 0.91 and the average TSR of the gyratory compacted specimen was 0.95.
- No visual stripping was observed for any of the sandstone specimens.

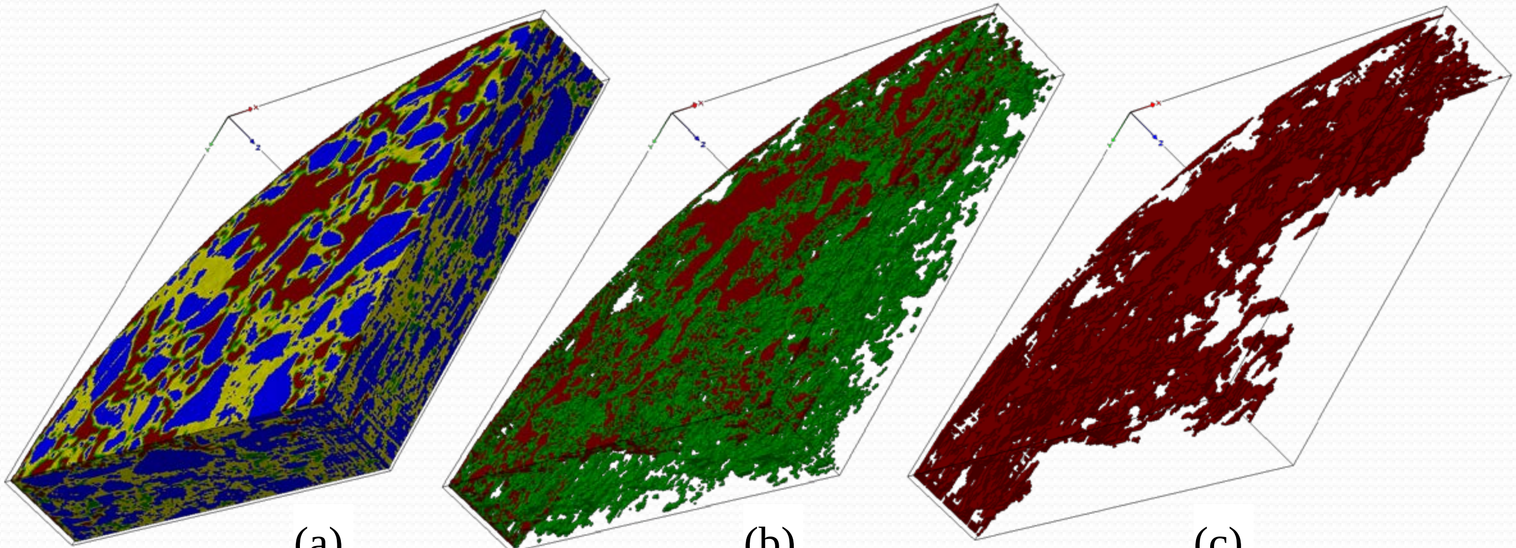
Experimental Results, Limestone

- Gyratory specimens' TSR was high value of 1.06, stating that the conditioning of the specimens had no effect on the tensile strength of the material.
- The TSR value of the Marshall compacted specimens was, however, unexpectedly low with a TSR of 0.82.
- The Marshall compacted samples also showed a significant amount of visual stripping.

Investigating Cause of Variability

To find explanation of the results,

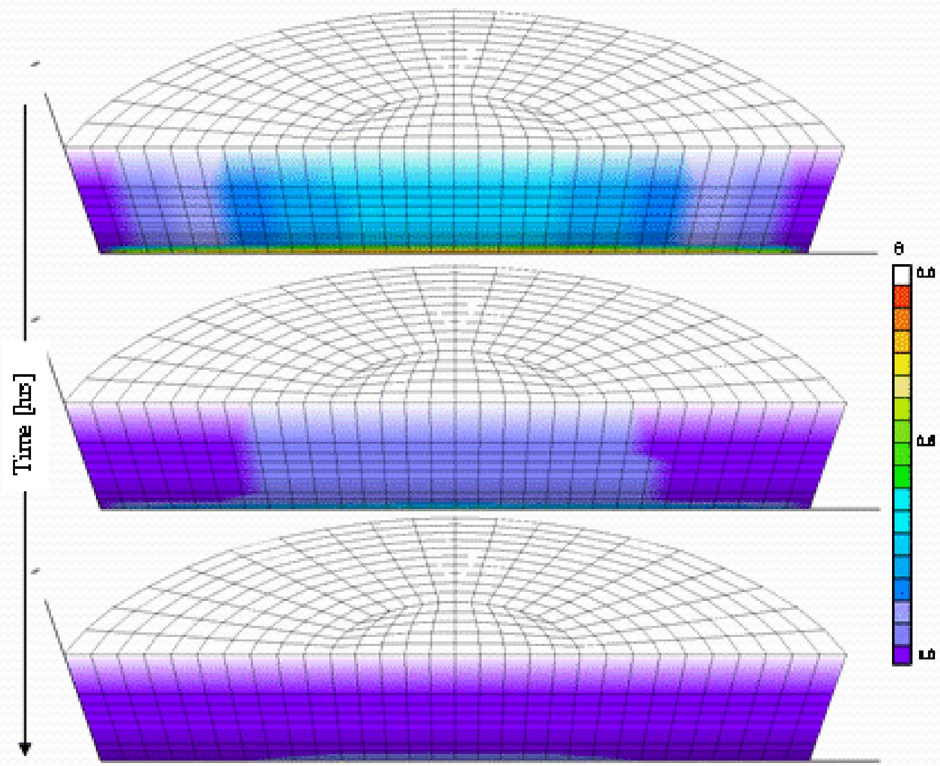
- Finite element analyses were used to simulate moisture infiltration in T 283 conditioning procedure.
- Distribution of the pore-space within the samples and in periphery of the samples were analyzed



(a) (b) (c)

AASHTO T 283 ILS, Finite Element Analysis

In collaboration with Group of Mechanics of Infrastructure Materials at Delft University of Technology (TU Delft), Moisture infiltration patterns for the two specimen sizes were via micro-scale finite element analyses using CAPA-3D finite element system



Finite Element Mesh

For the finite element meshes, the pixel-based 2D scans were assembled into a 3D voxel-based mesh of the mixture.

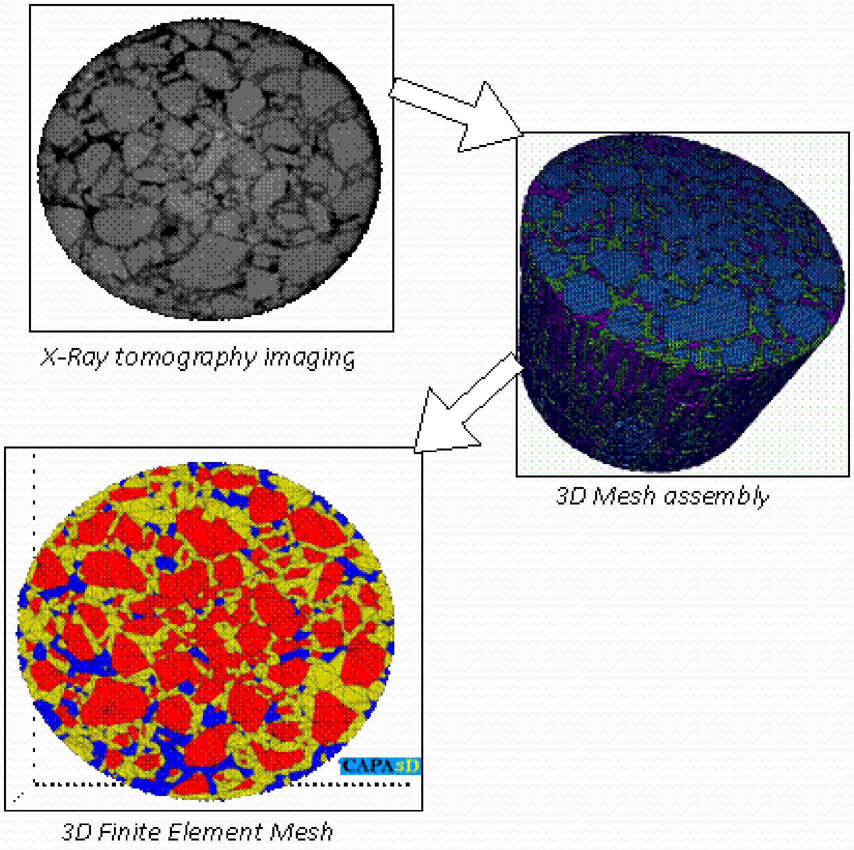
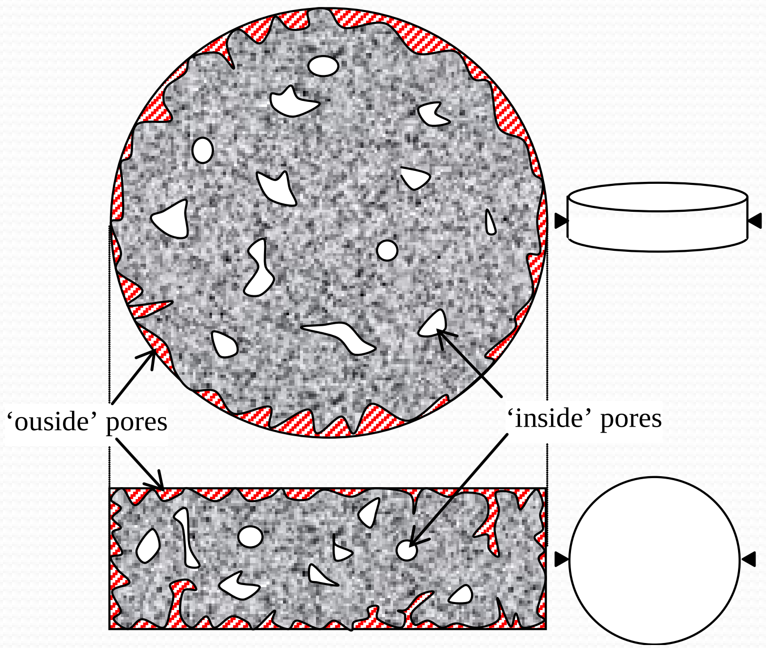


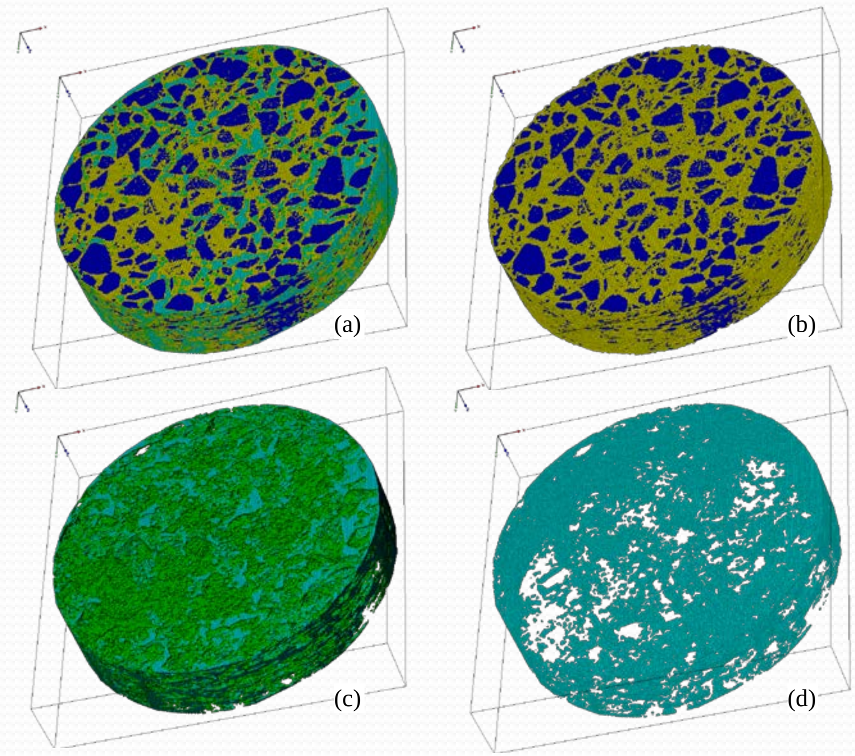
Image Analysis of Air Void Distributions

- Both inside and outside porosity of the tested specimens was calculated, in which a perfect cylindrical shape of the specimen was assumed.
- From the calculated inside and outside porosities, it was seen that the target (inside) porosity of 7 % ±0.5 was reasonably well met.



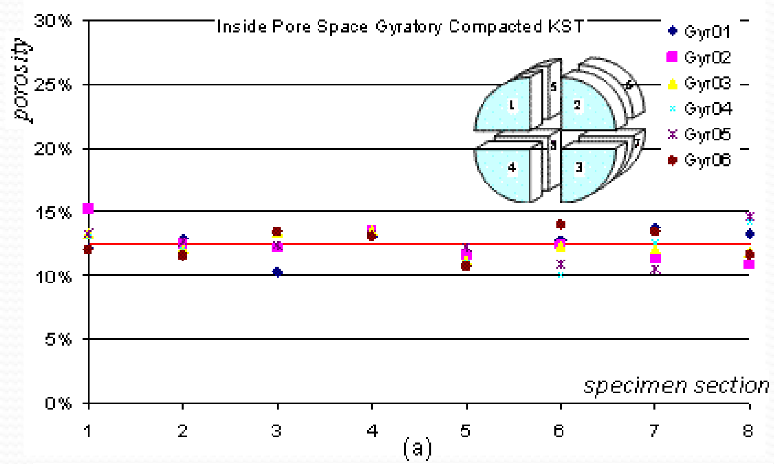
Outside Pore Distribution

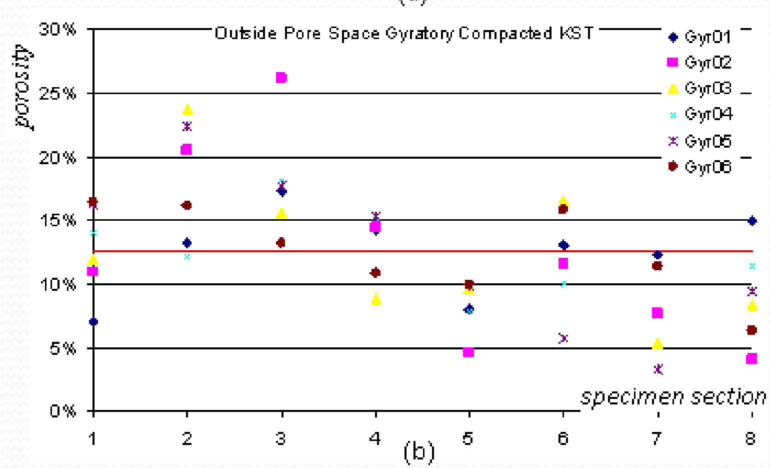
- Gyratory specimens have an additional 23% and the Marshall have an additional 45% of outside pore space
- Indicates that Marshall specimens may have relatively more access to moisture during conditioning times and could reach higher moisture concentrations.



Inside Pore Distribution

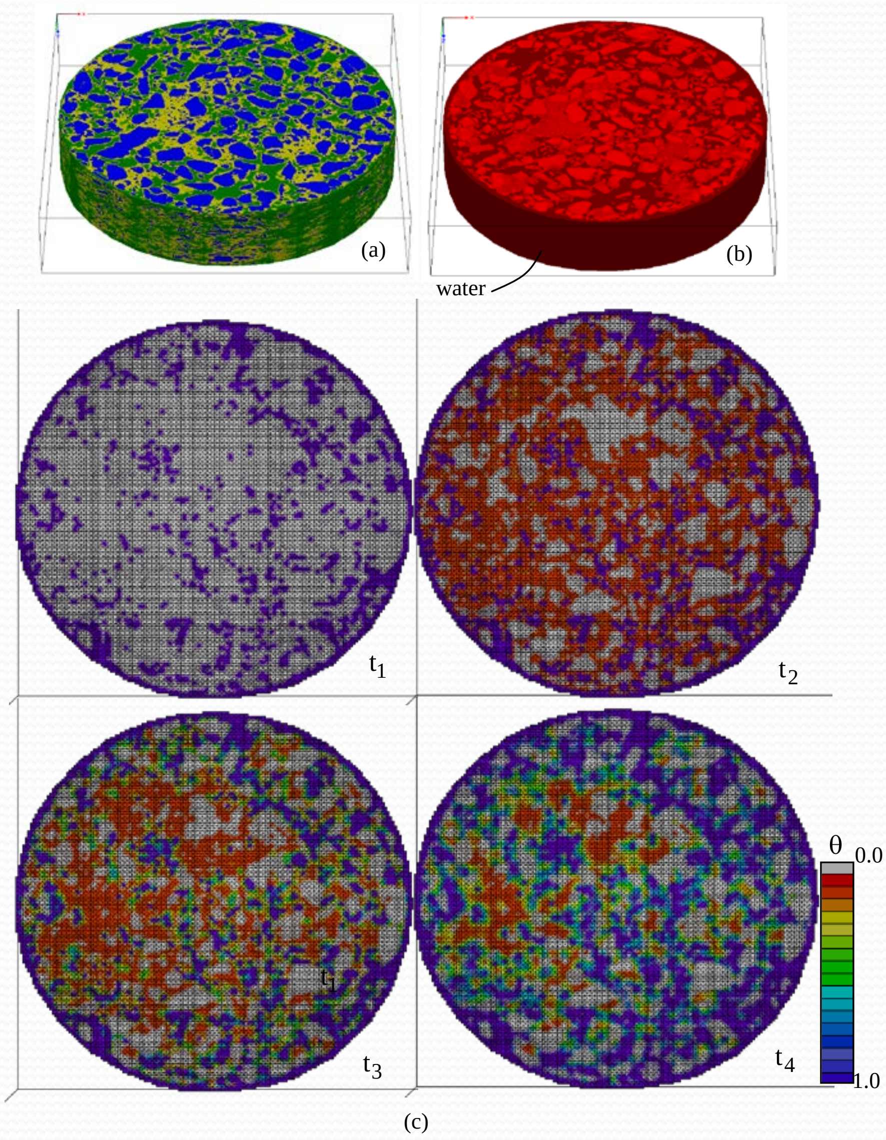
- Gyratory compaction creates a rather well distributed pore-space, with a maximum variation of 2.5% from the mean.
- Marshall compaction creates a less dispersed inside pore-space and tends to create clusters of air-voids.





Moisture Infiltration Simulation

- In gyratory specimens moisture distributes itself relatively uniform over the specimen.
- For KST Marshall a relatively large amount of moisture reached the center of the core.
- This could explain why the Marshall compacted KST specimens had an unexpected low TSR.

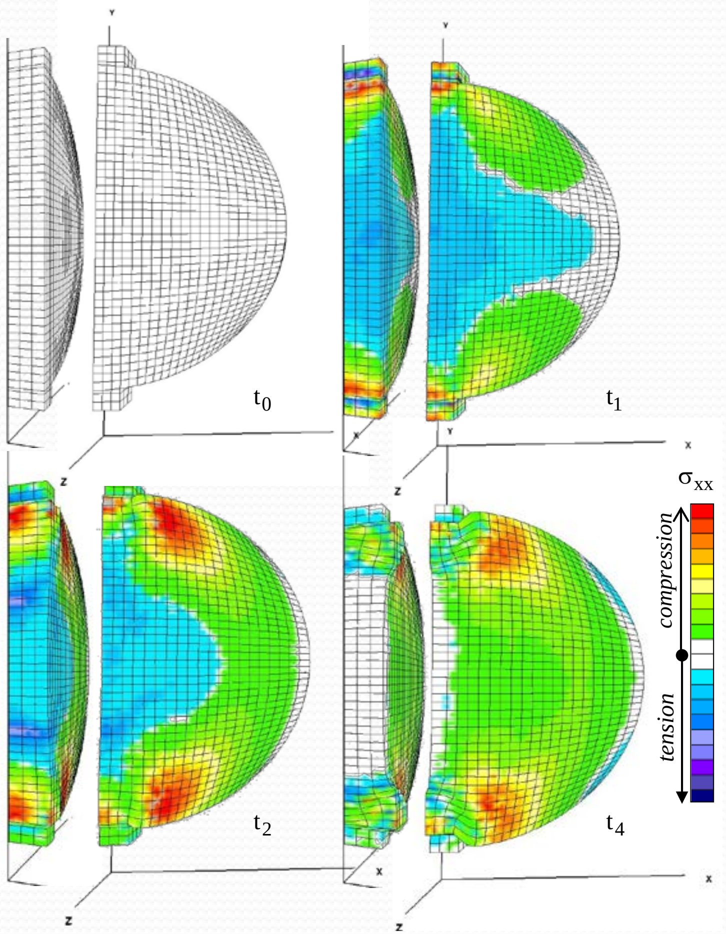


Conclusion of the Simulation

- TSR specimens are exposed to large variations of the moisture conditioning of the samples, even when the moisture conditioning protocol is kept the same.
- Depending on the distribution of the inside pore-space, the added 'moisture accessibility' of the specimen due to increased outside-porosity, and the connectivity of the inside pores within the sample, large differences can be expected when comparing the results of the TSR test.

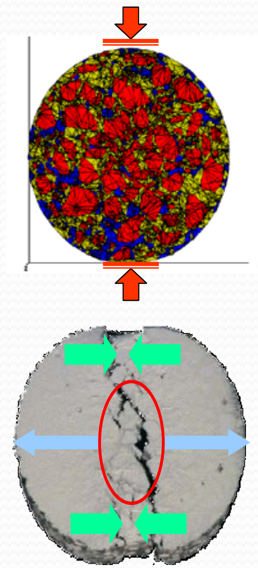
Future Simulation Work

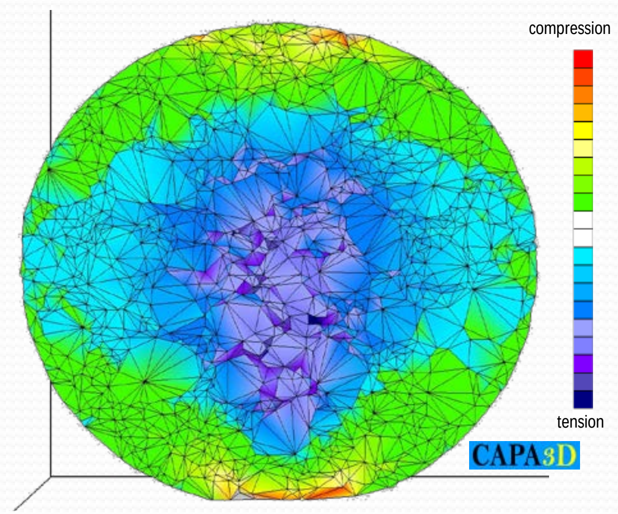
- Finite element meshes will be exposed to the same moisture conditioning and temperature cycling as in T283
- Will include mechanical loading to simulate the material response



Future Simulation Work, Cont.

- For accurate mechanical computational analyses, the mechanical triaxial response of the material components (mastic) must be determined.
- Tensile and compressive response of the mix under various strain rates should be measured separately.





NCHRP 20-7

Development of a Test Method for Optical Sizing and Roundness Determination of Glass Beads Utilized in Traffic Markings

Measurement Methods

Developed interlaboratory precision and bias testing to include measurements from different methods

- Two computerized optical equipment
- ASTM 1155 and ASTM 1214
- Microscope
- X-ray micro-computed tomography

Interlaboratory Study

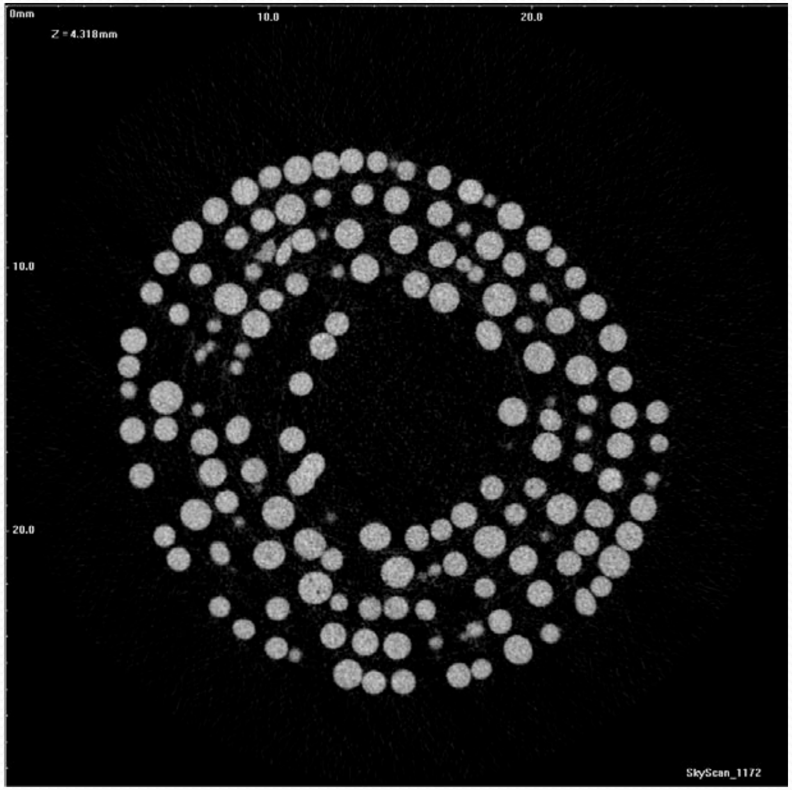
- Prepared three replicates of 4 different blends of glass beads
  - Each blend has different gradation and percent roundness
  - Total of 360 samples prepared
- 30 laboratories are participating:
  - 10 using computerized method
  - 19 follow ASTM methods
  - 1 lab uses microscope
- NIST provides the ground-truth measurements for comparison using X-ray micro tomography

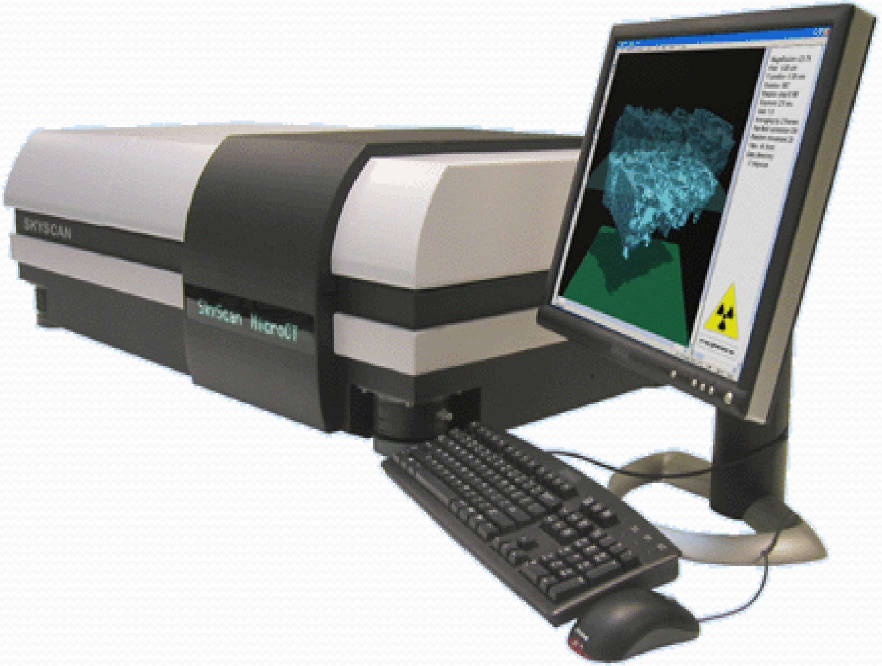
Laboratory Measurements of parameters

- Instructions to the laboratories were prepared with the help of the equipment manufacturers
- Multiple shape parameters were asked to be measured by the labs with computerized equipment
- NIST uses spherical harmonic mathematical analysis of volume, surface area, mean curvature, length-width-thickness for multiple shape parameters

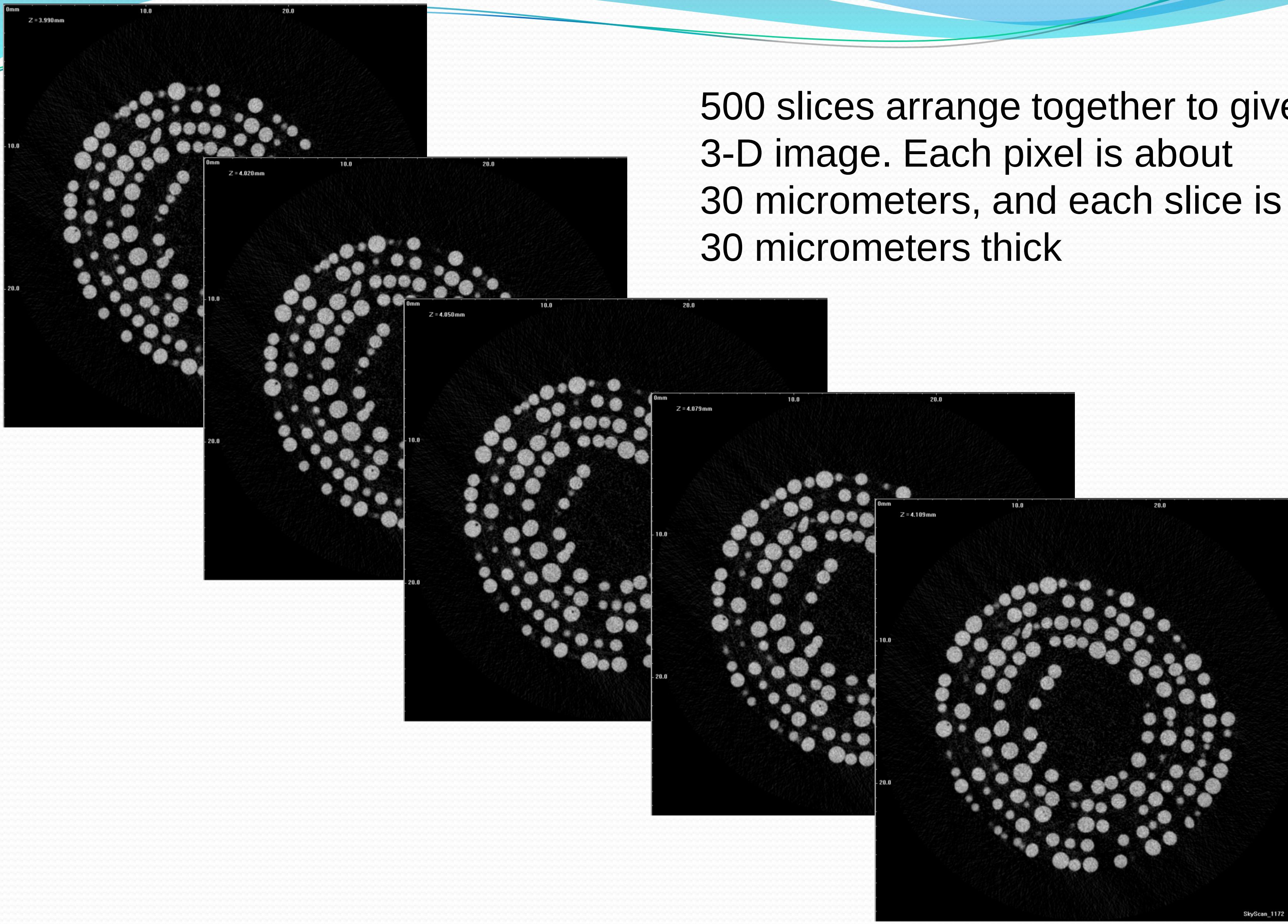
NIST X-ray CT Scans

One sample - sprinkled glass beads on contact paper then rolled into a tube

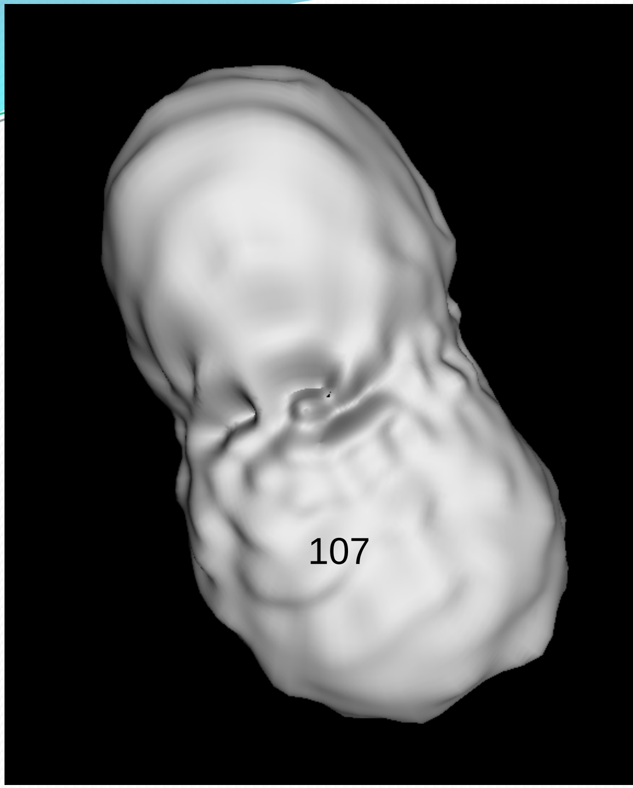


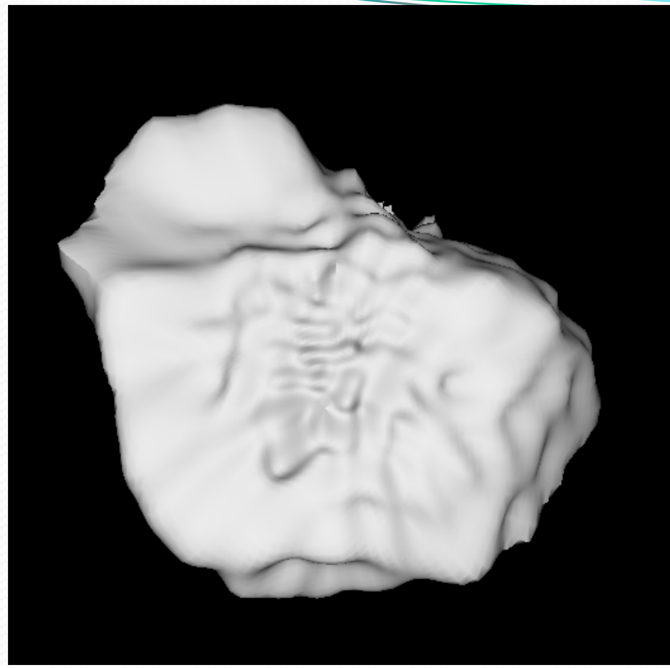


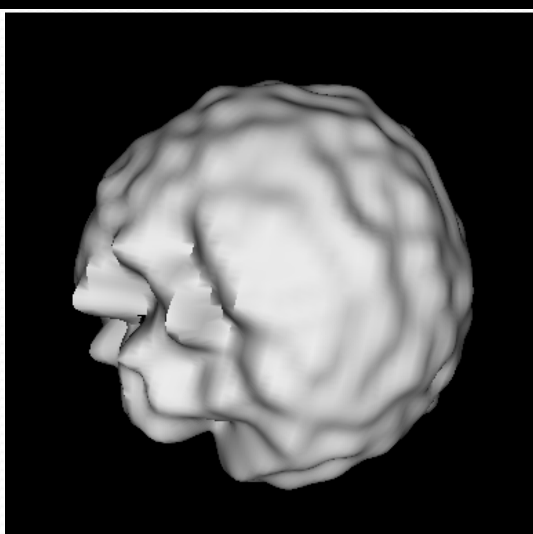
500 slices arrange together to give 3-D image. Each pixel is about 30 micrometers, and each slice is 30 micrometers thick

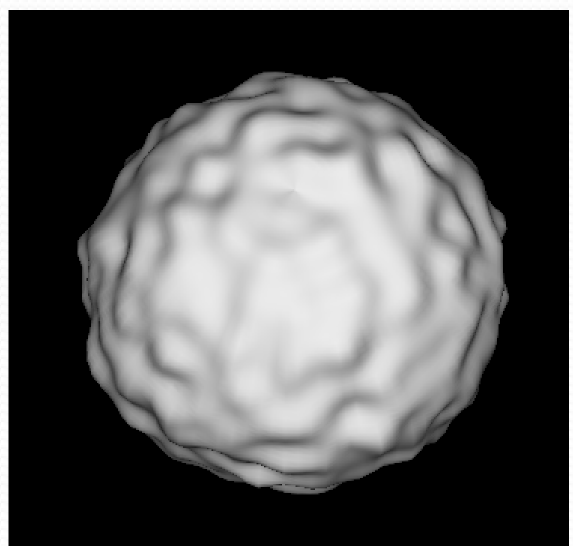


Non-round









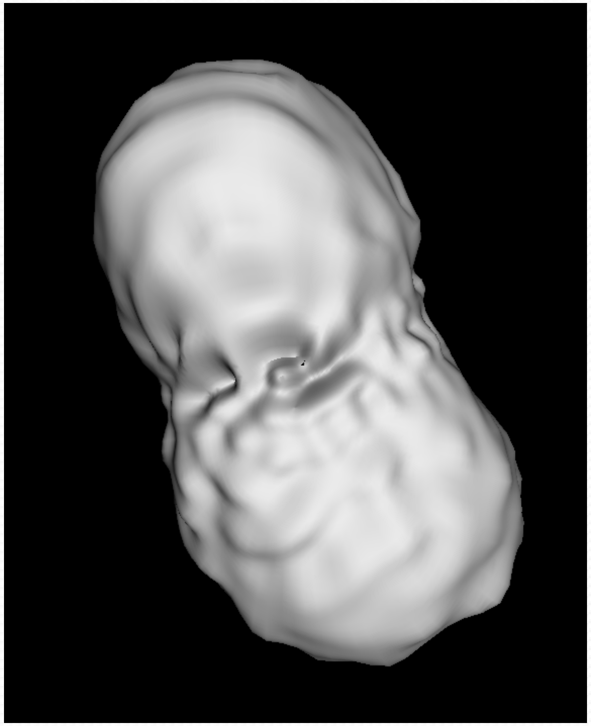
Round

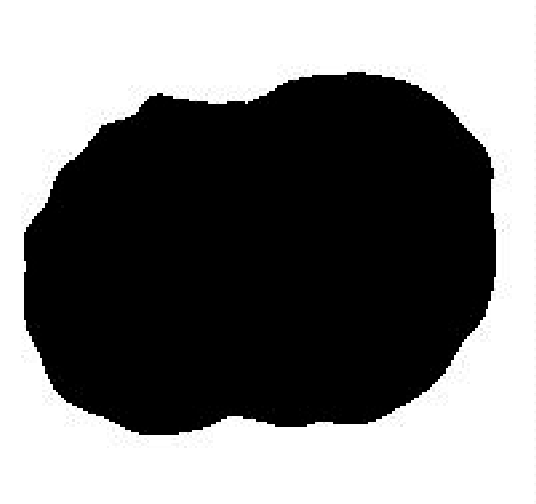
Status of NIST X-Ray CT Analysis

- Size distribution analysis is completed
- The shape information are being processed
- 2-D projection analysis will also be conducted to compare to 2-D optical results from the labs and to 3-D measures.

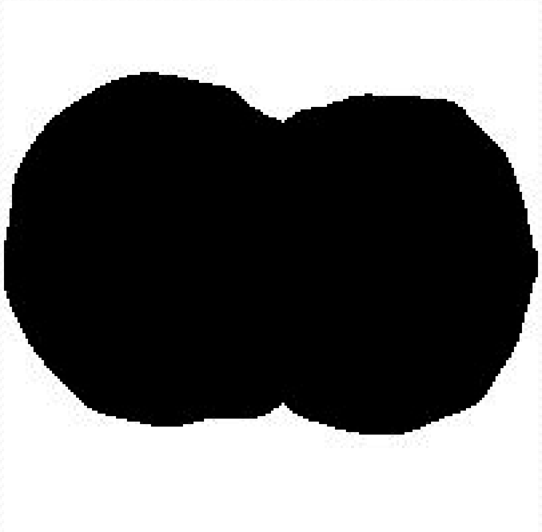
Sieve size (μm)	Mass % retained (sieve)	Mass % retained (CT)
1400	0-5	0.0
1180	5-15	26.4
1000	55-70	52.1
850	10-35	21.0
710	0-3	0.5
600	0-2	0.0

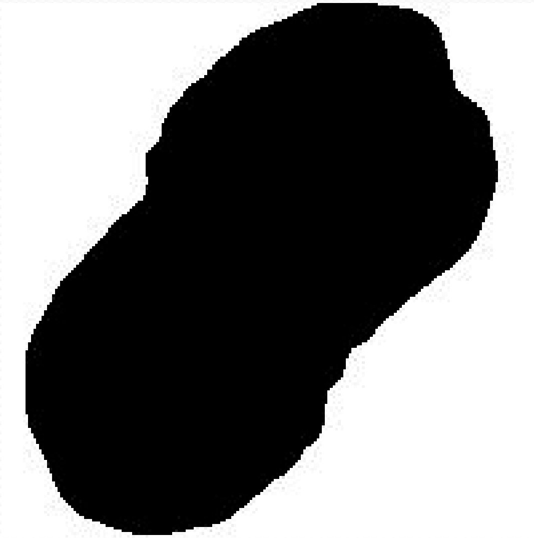
2-D Projections of 3-D image





Three orthogonal projections





More on NCHRP 9-26A

Proposals to NCHRP 9-26A

- As part of 9-26A, AMRL was encouraged by the panel to propose research studies for improvement of the standard test methods in relation to the existing 9-26 tasks.
- AMRL submitted two proposal for 9-26 panel consideration:
  - Developing performance models based on direct measurement of hydraulic cement phase composition
  - Purchase of Asphalt Mixture Performance Testing (AMPT) System for participating in FHWA pooled fund study and other asphalt mixture research studies

Designation: C 1365 – 06

Recently adopted XRD Standard Test
- a direct measure of phase concentrations

Standard Test Method for Determination of the Proportion of Phases in Portland Cement and Portland-Cement Clinker Using X-Ray Powder Diffraction Analysis[1]

This standard is issued under the fixed designation C 1365; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers direct determination of the proportion by mass of individual phases in portland cement or portland-cement clinker using quantitative X-ray (QXRD) analysis. The following phases are covered by this standard: alite (tricalcium silicate), belite (dicalcium silicate), aluminate (tricalcium aluminate), ferrite (tetracalcium aluminoferrite), periclase (magnesium oxide), gypsum (calcium sulfate dihydrate), bassanite (calcium sulfate hemihydrate), anhydrite (calcium sulfate), and calcite (calcium carbonate).

1.2 This test method specifies certain general aspects of the analytical procedure, but does not specify detailed aspects. Recommended procedures are described, but not specified. Regardless of the procedure selected, the user shall demonstrate by analysis of certified reference materials (CRM's) that the particular analytical procedure selected for this purpose qualifies (that is, provides acceptable precision and bias) (see Note 1). The recommended procedures are ones used in the round-robin analyses to determine the precision levels of this test method.

NOTE 1—A similar approach was used in the performance requirements for alternative methods for chemical analysis in Test Methods C 114.

1.3 The values stated in SI units shall be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazards, see Section 9.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 114 Test Methods for Chemical Analysis of Hydraulic Cement
C 150 Specification for Portland Cement
C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement
C 219 Terminology Relating to Hydraulic Cement
C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions are in accordance with Terminology C 219.*

3.2 *Phases* (**1**):[3]

3.2.1 *alite, n*—tricalcium silicate (C_3S)[4] modified in composition and crystal structure by incorporation of foreign ions; occurs typically between 30 to 70 % (by mass) of the portland-cement clinker; and is normally either the M_1 or M_3 crystal polymorph, each of which is monoclinic.

3.2.2 *alkali sulfates, n*—arcanite (K_2SO_4) may accommodate Na^+, $Ca2^+$, and CO_3 in solid solution, aphthitalite ($(K_{4-x}Na_x)SO_4$ with x usually 1 but up to 3), calcium langbeinite ($K_2Ca_2[SO_4]_3$) may occur in clinkers high in K_2O, and thenardite (Na_2SO_4) in clinkers with high Na/K ratios (**1**).

3.2.3 *aluminate, n*—tricalcium aluminate (C_3A) modified in composition and sometimes in crystal structure by incorporation of a substantial proportion of foreign ions; occurs as 2 to 15 % (by mass) of the portland-cement clinker; is normally cubic when relatively pure and orthorhombic or monoclinic when in solid solution with significant amounts of sodium (**2**).

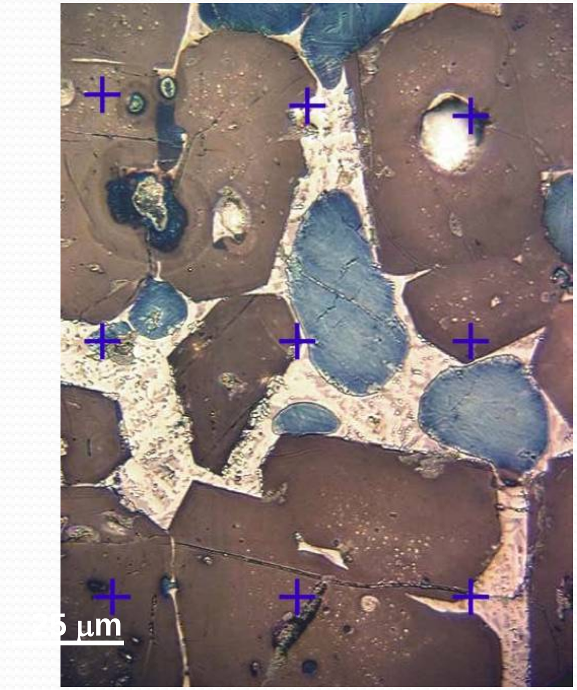
3.2.4 *anhydrite, n*—calcium sulfate ($C\bar{S}$) and is orthorhombic (see Note 2).

A Bogue calculation provides an estimate of the four primary constituents of a cement, whereas an XRD analysis may include each of the 10 - 14 phases that may be in a cement !

- –Alite
- –Belite
- –Ferrite
- –Aluminate
  - –cubic
  - –orthohombic
- –Periclase
- –Aphthitolite
- –Thenardite
- –Arcanite
- –Anhydrite
- –Bassanite
- –Gypsum
- –Free Lime

Components of XRD Study

- Measurement of CCRL cement phase composition using XRD
- Utilizing performance data from the CCRL proficiency testing program and conducting additional in-house testing to explore relationships between cement phase composition and performance.
- Applying advanced statistical data exploration methods to develop cement property - performance relationships.

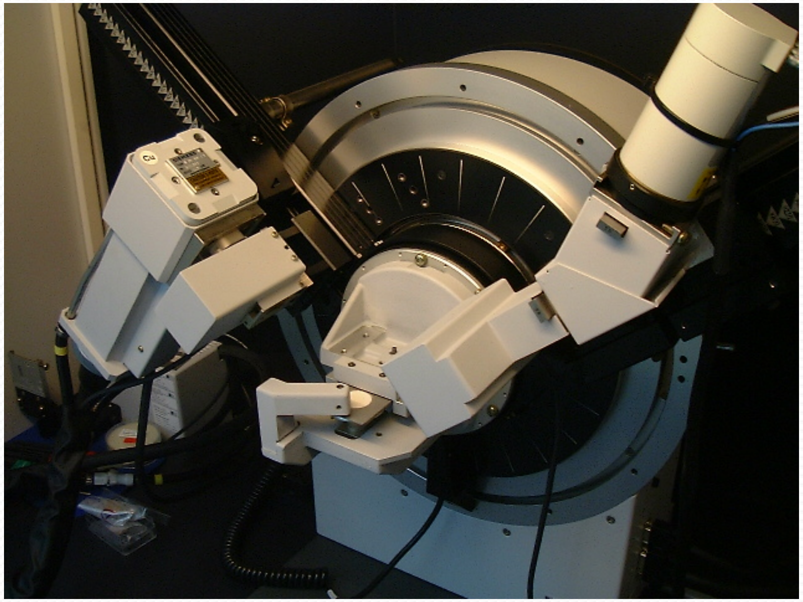


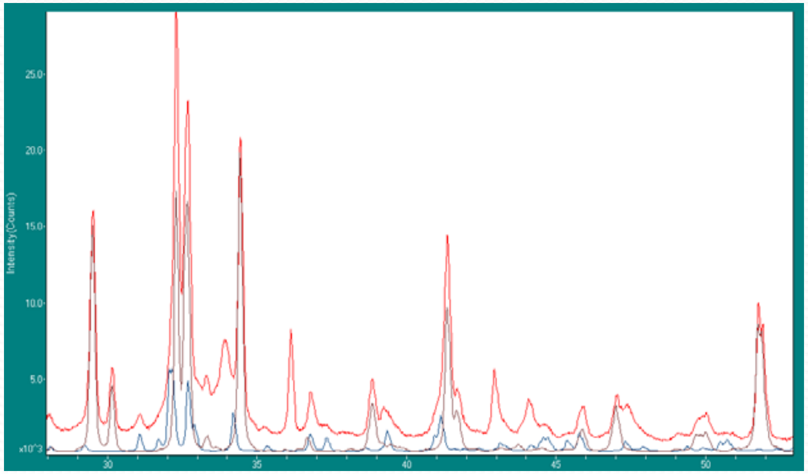
Cement clinker is a complex, multi-phase material comprised of calcium silicates, calcium aluminates, calcium alumino-ferrites, alkali sulfates, magnesium and calcium oxides and voids.

Cements additionally contain calcium sulfates, calcium sulfate hydrates and possibly calcium carbonates, slag, and fly ash

X-Ray Powder Diffraction

- Improving relationships between cement phase composition and performance, e.g. the AASHTO heat index formula, using more accurate XRD measurements
- Incorporating these findings in AASHTO standards and test methods (e.g. M 85).





Equipment Purchase

- A complete set of Superpave asphalt mixture performance testing equipment was purchased through NCHRP 9-26A project:
  - Servo-hydraulic loading system known as Superpave performance Tester,
  - Environmental chamber
  - Servopac gyratory compactor
  - Two pieces of equipment for sawing and coring asphalt mixture specimens
  - CoreDry for quick drying of the cut and cored samples.

Laboratory Space and Support Staff

- Two Laboratory spaces are being transferred to AMRL by NIST for establishing asphalt mixture performance testing
- A full time technician is planned to be hired to run the laboratory
- With the establishment of this laboratory, AMRL will be fully equipped for mechanical testing of asphalt mixtures

NCHRP 9-35

Improved Test Methods for Specific Gravity and Absorption of Coarse and Fine Aggregate

Project Explanations

- Project was awarded March 09
- In collaboration with NCAT and NIST
- NCAT is selecting the promising test methods for measuring specific gravity of fine, coarse, and blended aggregates
- AMRL will plan and conduct the ruggedness testing of the selected tests (January 09)
- NIST and NCAT will also conduct ruggedness testing in their laboratories

Thank you!

Questions?

ILS Problem Statement

Superpave hot-mix asphalt mix designs rely on the volumetric properties of HMA. The ILS in Phase 1 of 9-26 provided estimates of precision for various test methods associated with HMA mix design when non-absorptive aggregates are used. This ILS is a repetition of that ILS using absorptive aggregates.

ILS Materials

- Aggregates: two sources of absorptive aggregate
  - Source 1: Bulk Specific Gravity = 2.349, Percent Absorption = 5.3%
  - Source 2: Bulk Specific Gravity = 2.440, Percent Absorption = 4.5%
- Gradations: two nominal maximum aggregate sizes
  - 9.5 mm & 19.0 mm
- Asphalt Binder: PG 64-22
- Resulted in four mixtures

Participants

27 laboratories

- 22 DOTs
- 1 FHWA
- 2 Contractors
- 1 Research/Training
- 1 AMRL

Instructions to Laboratories- Rice Specimens

- Heat at 105 ± 5°C
- Perform Maximum Specific Gravity once on each specimen according to D2041-03a
- Use either the weighing-in-air method or the weighing-in-water method
- Follow instructions in Section 11 for dry back

Analysis of ILS Data

- Outliers were eliminated from analysis by following the procedures described in ASTM E691, "Standard Practice for Conducting an Interlaboratory study to Determine the Precision of a Test Method."
- Repeatability (S_r) and reproducibility (S_R) estimates of precision were computed according to ASTM E691
- F-test used to examine the significance of difference in precision estimates for volumetric properties of different mixtures and different tests methods

Precision Estimates of G_{mm} (D 2041)

- Precision estimates for G_{mm} of finer and coarser mixtures were not significantly different
- Difference between precision estimates of G_{mm} of mixtures with absorptive aggregates and mixtures with non-absorptive aggregates were significant
- Separate precision estimates for mixtures with absorptive and with non-absorptive aggregate is recommended

Property	Mix	Phase 4 (Absorptive Aggregate)				Phase 1 (Non-Absorptive Aggregate)			
		Repeatability		Reproducibility		Repeatability		Reproducibility	
		1S(Sr)	D2S	1S (SR)	D2S	1S (Sr)	D2S	1S (SR)	D2S
G_{mm} (D 2041)	Finer	0.004	0.011	0.009	0.024	0.002	0.006	0.004	0.011
	Coarser	0.005	0.015	0.011	0.030	0.002	0.006	0.003	0.008
	Comb.	0.005	0.014	0.010	0.028	0.002	0.006	0.004	0.011

Proposed Precision Statement for D 2041/T 209

Maximum Specific Gravity of Mixtures

Test and Type Index	Standard Deviation (1S Limit)	Acceptable Range of Two Results (D2S Limit)
Single Operator Precision:		
Aggregate with less than 1.5% absorption	0.002 (0.004)	0.006 (0.011)
Aggregate with 4% to 5% absorption	0.005 (0.006)	0.014 (0.018)
Multilaboratory Precision:		
Aggregate with less than 1.5% absorption	0.004 (0.006)	0.011 (0.018)
Aggregate with 4% to 5% absorption	0.010 (0.019)	0.028 (0.055)

Precision Estimates- T166

- Precision estimates of G_{mb} of finer and coarser mixtures with absorptive aggregates were not significantly different
- Repeatability Precisions of G_{mb} of finer and coarser mixtures with non-absorptive aggregates were significantly different
- Combined G_{mb} precision of mixtures with absorptive aggregates were not significantly different from G_{mb} of either fine or coarse mixture with non-absorptive aggregates

Property	Mix	Phase 4 (Absorptive Aggregate)				Phase 1 (Non-Absorptive Aggregate)			
		Repeatability		Reproducibility		Repeatability		Reproducibility	
		1S(Sr)	D2S	1S (SR)	D2S	1S (Sr)	D2S	1S (SR)	D2S
G_{mb} (T166)	Finer	0.011	0.030	0.018	0.051	0.008	0.023	0.015	0.042
	Coarser	0.010	0.029	0.016	0.046	0.013	0.037	0.014	0.040
	Comb.	0.011	0.030	0.017	0.048			0.015	0.042

Precision Statement for T 166

Bulk Specific Gravity of Mixtures using SSD

Test and Type Index	Standard Deviation (1S Limit)	Acceptable Range of Two Results (D2S Limit)
Single Operator Precision:		(0.02)
Aggregate with less than 1.5% absorption		
12.5-mm nominal maximum aggregate	0.008	0.023
19.0-mm nominal maximum aggregate	0.013	0.037
Aggregate with 4% to 5% absorption	0.011	0.030
Multi-laboratory Precision:	0.016	0.045

Precision Estimates- D 6752/ T331

- Precision estimates for G_{mb} of finer and coarser mixtures were not significantly different
- Precision estimates for G_{mb} of mixtures with absorptive aggregates and with non-absorptive aggregates were not significantly different

Property	Mix	Phase 4 (Absorptive Aggregate)				Phase 1 (Non-Absorptive Aggregate)			
		Repeatability		Reproducibility		Repeatability		Reproducibility	
		1S(Sr)	D2S	1S (SR)	D2S	1S (Sr)	D2S	1S (SR)	D2S
	Finer	0.012	0.033	0.020	0.058	0.011	0.031	0.019	0.054
G_{mb} (Corelok)	Coarser	0.013	0.037	0.023	0.066	0.015	0.042	0.021	0.059
	Comb.	0.012	0.035	0.022	0.062	0.013	0.037	0.020	0.057

Precision Statement for D 6752/T 331

Bulk Specific Gravity of Mixtures using Corelok

Test and Type Index	Standard Deviation (1S Limit)	Acceptable Range of Two Results (D2S Limit)
<u>Single Operator Precision:</u>	0.0124 (0.0124)*	0.035 (0.035)*
<u>Multilaboratory Precision:</u>		
Non-absorptive aggregate	0.0135*	0.038*
Aggregate with 4% to 5% absorption	0.0209	0.059

*Current precisions

Precision Estimates- T 312

- Precision estimates for relative density of finer and coarser mixtures with absorptive aggregates were not significantly different
- Precision estimates of relative density of mixtures with absorptive aggregates and mixtures with non-absorptive aggregates were significantly different

Property	Mix	Phase 4 (Absorptive Aggregate)				Phase 1 (Non-Absorptive Aggregate)			
		Repeatability		Reproducibility		Repeatability		Reproducibility	
		1S(Sr)	D2S	1S (SR)	D2S	1S (Sr)	D2S	1S (SR)	D2S
Rel. Densities @ N_{in} & N_d (T312)	Finer	0.5	1.4	0.8	2.2	0.3	0.9	0.5	1.4
	Coarser	0.6	1.7	1.0	2.8	0.5	1.4	0.6	1.7
	Comb.	0.6	1.7	0.9	2.5			0.6	1.7

Precision Statement for T 312

Relative Density @ N_{ini} and N_{des}

Test and Type Index	Standard Deviation (1S Limit)	Acceptable Range of Two Results (D2S Limit)
Single Operator Precision:		
Aggregate with less than 1.5% absorption		
12.5-mm nominal maximum aggregate	0.3	0.9
19.0-mm nominal maximum aggregate	0.5	1.4
Aggregate with 4% to 5% absorption	0.6	1.7
Multilaboratory Precision:		
Aggregate with less than 1.5% absorption	0.6	1.7
Aggregate with 4% to 5% absorption	0.9	2.5

Aging Time Study

Aging Time Study Problem Statement

- According to AASHTO Standard Practice R30, "Mixture Conditioning of Hot-Mix Asphalt (HMA)", mixture conditioning is designed to allow for binder absorption during the mixture design
- R30 currently specifies 2 hours for mixture conditioning of laboratory specimens prepared for volumetric mixture design

Aging Study Problem Statement, Cont.

- 2 hours has been determined to be sufficient for mixtures with non-absorptive aggregates
- Note 1 of R30 states that absorptive aggregates may require further conditioning in order to better represent conditions during production
- R30 does not provide specific guidance when absorptive aggregates are encountered

Aging Time Study Objectives

- Determine effects of aging time on mixtures containing absorptive aggregates
- Provide guidance on appropriate aging time for the volumetric design of mixtures with absorptive aggregates

Experimental Design

Five input variables were addressed in the experiment:

- Aggregate source (Source 1, Source 2): differing levels of absorption
- Design gradations (9.5 mm, 19 mm): one 9.5-mm and one 19-mm design per source
- Aging Time (2 hr, 4 hr, 8 hr, 16 hr, 32 hr)
- Replicate (2 replicates)
- Tests (G_{mm} and G_{mb})

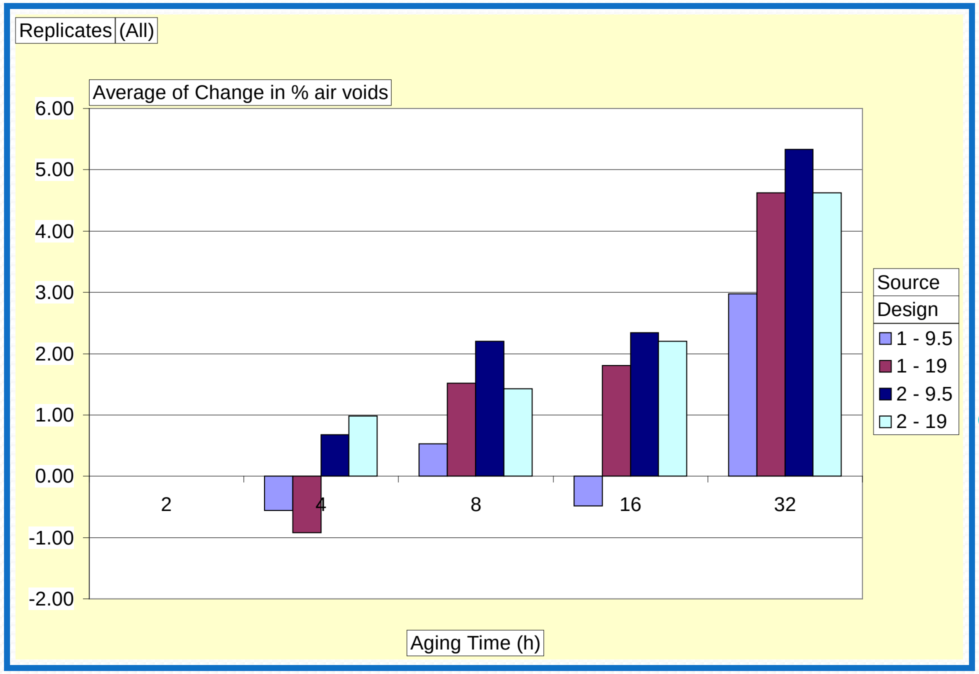
Volumetric Properties Examined

- Rice specific gravity, G_{mm}
- Bulk specific gravity, G_{mb}
- Air voids (%)
- Absorbed asphalt (%)
- Asphalt film thickness

Evaluation of the Results

- Results were evaluated based on:
  - Analysis of Variance (ANOVA) conducted on G_{mm}, G_{mb}, % air voids, and % absorbed asphalt measured from four mixtures
  - Significance of change in % air voids, % absorbed asphalt, and film thickness from practical standpoint
- Effect of aging time was best indicated by the changes in % air voids and % absorbed asphalt

Significance of Change in % Air Voids



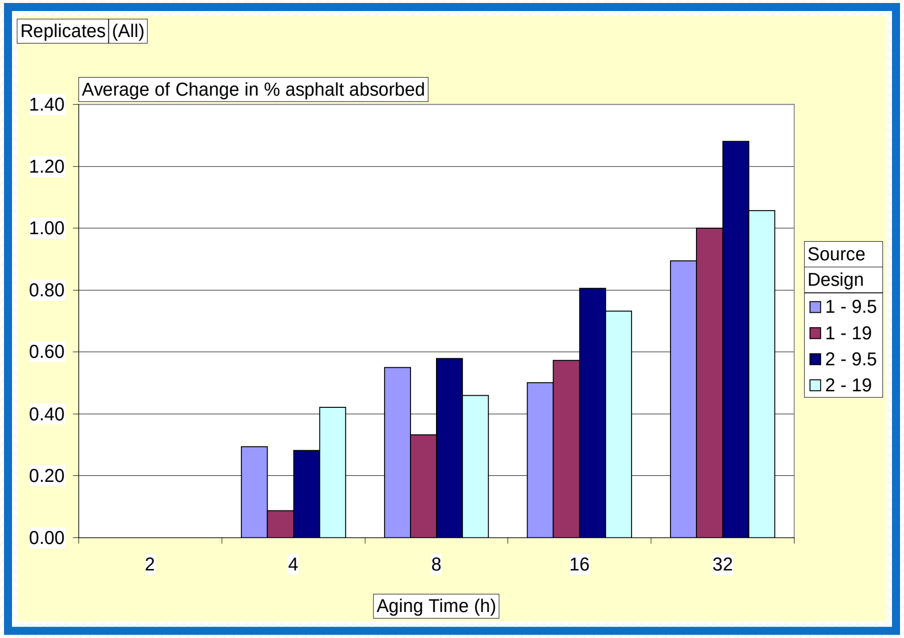
- ANOVA indicated that change in air voids of 19.5-mm mixture of Source 2 was significant between 2 to 4 hrs of aging (computed F = 12.16 vs. F_{cr}= 5.19)
- Aging of the same mixture for 4 hours resulted in an increase of 1% in air voids, which was considered significant

Laboratory aging of mixtures is suggested to be limited to 2-4 hours to retain original mix design % air voids

Implication of Increase in Air Voids

- Additional binder need to be added to reach target air voids
- Modification of mix design might not be desirable in field
  - Economical feasibility
  - Expected performance

Significance of Increase in Absorption



- ANOVA indicated that change in absorption of 9.5-mm mixture of Source 2 was significant between 2 to 4 hrs of aging (computed $F = 17.13$ vs. $F_{cr} = 5.19$)
- 19-mm mixture of Source 2 absorbed more than 0.4% asphalt after 4 hours of aging, which is considered significant

Laboratory aging of mixtures is suggested to be limited to 2-4 hours to retain original mix design asphalt content

Implication of Increase in Absorption

- More than 0.4% asphalt needs to be added to mixture to compensate for absorbed asphalt
- Might not be desirable for field:
  - Economical feasibility
  - Expected performance

Summary and Conclusions, Cont.

- Adjustment is usually in the form of addition of binder to the mixture
- Adjustment would not be economically feasible for field use of mixture
- Adjustment might create performance problems if mixtures are not intended to be stored for long period prior to compaction

Future Aging Time Study

Performance evaluation of Mixtures with Absorptive aggregates

Problem Statement for Short-Term Aging

- Aging of mixtures with absorptive aggregates has two phases:
  - absorption of asphalt into the pores of aggregates , which affect volumetrics of the mixture
  - stiffening of the binder, which change the shear strength and stiffness of the material
- Previous study aimed at determining the laboratory aging time that meets the volumetric requirements of the mixture design that is based on asphalt absorption

Problem Statement for Short-Term Aging, Cont.

- AASHTO R30 specifies 4h short-term mixture conditioning (aging) for mechanical testing
- Stiffening Effect of 4 h of aging on mixtures with absorptive aggregates is not known
  - Smaller asphalt film thickness
  - Faster stiffening process

Objectives of Short-Term Aging Study

- Examine effect of aging time on stiffening of asphalt mastic in mixtures with absorptive aggregates
- Examine effect of aging time on performance testing of asphalt mixtures with absorptive aggregates
- Determine appropriate aging time for mixtures with absorptive aggregate that are prepared for performance testing
- Smaller time intervals (1 hour) for more precise mixture conditioning (for absorption)

Approach to Short-Term Aging Study

- At various aging interval in addition to volumetric properties, the following properties of mixtures with absorptive aggregates will be measured:
  - Shear modulus of asphalt mastic using DSR
  - Dynamic modulus and flow properties using SPT
  - Asphalt film thickness using X-ray microtomography
- Correlation between measured properties will be examined
- Based on the observed changes in mechanical properties, appropriate time for short-term aging will be suggested

Compaction Methods Used

- AASHTO T245, "Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus"
- AASHTO T247, "Preparation of Test Specimens of Bituminous Mixtures by Means of California Kneading Compactor"
- AASHTO T312, "Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor"
- ASTM D4013, "Preparation of Test Specimens of Bituminous Mixtures by Means of Gyratory Shear Compactor"

Bulk Specific Gravity Measurement Methods Used

- T 166, "Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens"
- T 331, "Bulk Specific Gravity and Density of Compacted Asphalt Mixtures Using Automatic Vacuum Sealing Method"

Precision Estimates for T 269

Comp. Method	Mix	Phase 5				Current Precisions			
		Repeatability		Reproducibility		Repeatability		Reproducibility	
		1S(Sr)	D2S	1S (SR)	D2S	1S (Sr)	D2S	1S (SR)	D2S
T 166	Marshall	0.47	1.33	1.07	3.02	0.51	1.44	1.09	3.08
	Hveem	0.54	1.52	1.30	3.67				
	TX Gyr.	0.42	1.42	1.50	4.25				
	S. Gyr.	0.54	1.53	0.95	2.87				
Corelok	Marshall	0.48	1.35	0.84	2.38				
	S. Gyr.	0.46	1.31	0.90	2.54				