Evaluation of Hot Mix Asphalt (HMA) Mixtures with High content of Recycled Materials Using the AMPT Cyclic Fatigue Test (Part A)

Mobile Asphalt Testing Trailer - Field Project WI14100

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Asphalt Mixture Expert Task Group
September 16, 2015

Outline

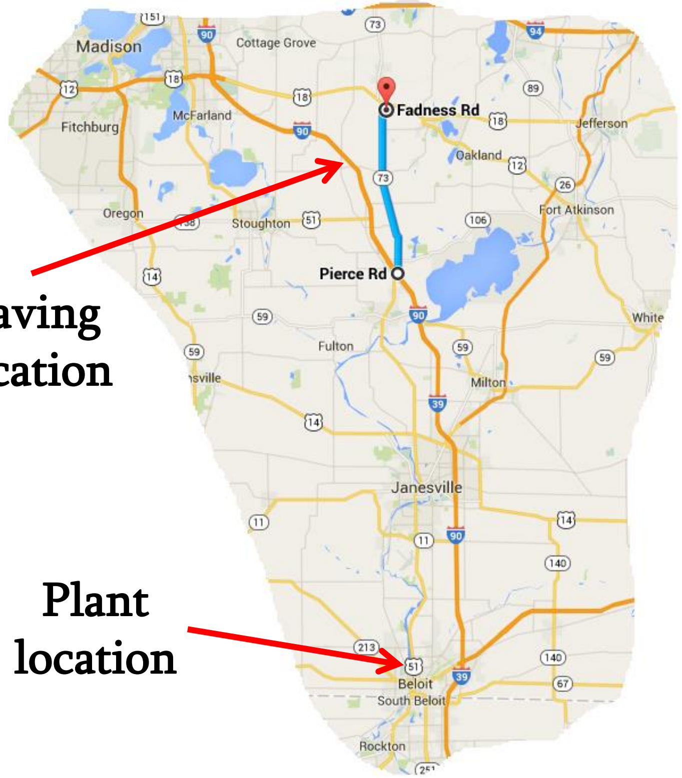
- Project information
- Materials
- Mix designs
- Volumetric testing
- Performance testing
  - Complex Modulus (E*)
  - Flow Number (FN)
  - AMPT Cyclic Fatigue
- Summary of findings
- Work in progress
- Questions & comments

Project Information

- **Project objective:**
  - Assessing the feasibility of increasing the content of recycled materials in HMA mixtures, without deteriorating the performance properties of the mixes
- **Project scope:**
  - Production of HMA mixes with various content of recycled materials:
    - ✓ Recycled Asphalt Pavement (RAP): 13 to 40 percent of total mix
    - ✓ Recycled Asphalt Shingles (RAS): 3 to 6 percent of total mix
  - Laboratory testing
    - ✓ Gradation of extracted binders
    - ✓ Superpave volumetric testing of mixtures
    - ✓ Performance testing of mixtures

Project Information

- Project issued by:
  - Wisconsin Department of Transportation (WisDOT)
- Project location:
  - STH-73: Pierce Rd (Edgerton,) to Fadness Rd (Deerfield)
- Pavement structures:
  - Base layer (NMAS 19 mm)
  - Surface layer (NMAS 12.5 mm)
  - 1-3 ESALs x 10^6
  - N_{design} = 75 gyrations



Paving location

Plant location

Materials

- **Binder**
  - PG 52-34 (Interstate Asphalt)
  - PG 58-28 (BP Products North America)
  - PG 58-34 (Flint Hills Resources Pine Bend, LLC)
- **Additives/Modifiers**
  - SonneWarmix (Sonneborn Refined Products)
  - SBS (Flint Hills Resources Pine Bend, LLC)
- **Aggregate stockpiles**
  - 1/2" RAP
  - RAS
  - Blend Sand (BS)
  - Washed Manufactured Sand (WMS)
  - 3/4" Stone
  - 5/8" Stone

Materials

- Aggregates

3/4" Stone

5/8" Stone

Blend Sand (BS)

Washed Manufactured Sand (WMS)

Materials

- RAP

RAP stockpile
(1/2” RAP Townline Pit – 52400-26)

Materials

- RAS

RAS stockpile

(RAS - SouthWind, South Beloit, IL)

Mix Designs

- Proposed mixes

Surface layer (NMAS 12.5 mm)

Mix 9	Mix 9.5	Mix 10	Mix 12	Mix 13
RAP = 32%	RAP = 32%	RAP = 32%	RAP = 13%	RAP = 13%
RAS = 5%	RAS = 5%	RAS = 5%	RAS = 3%	RAS = 3%
RBR = 0.50	RBR = 0.50	RBR = 0.50	RBR = 0.25	RBR = 0.25
PG 58-28	PG 58-28	PG 52-34	PG 58-28	PG 52-34
VA = 3.5 %	VA = 3.5 %	VA = 3.5 %	VA = 3.5 %	VA = 4.0 %
Pb = 2.7 %	Pb = 2.7 %	Pb = 2.7 %	Pb = 4.0 %	Pb = 4.0 %
No additive	SBS polymer	No additive	No additive	No additive

Base layer (NMAS 19.0 mm)

Mix 1	Mix 2	Mix 4	Mix 5	Mix 6	Mix 7	Mix 8
RAP = 40%	RAP = 40%	RAP = 33%	RAP = 33%	RAP = 33%	RAP = 14%	RAP = 14%
RAS = 6%	RAS = 6%	RAS = 4%	RAS = 4%	RAS = 4%	RAS = 4%	RAS = 4%
RBR = 0.65	RBR = 0.65	RBR = 0.50	RBR = 0.50	RBR = 0.50	RBR = 0.35	RBR = 0.35
PG 58-28	PG 52-34	PG 58-28	PG 52-34	PG 58-28	PG 58-28	PG 52-34
VA = 3.5%	VA = 3.5%	VA = 3.5 %	VA = 3.5 %	VA = 3.5 %	VA = 4.0 %	VA = 4.0 %
Pb = 1.62%	Pb = 1.62%	Pb = 2.45 %	Pb = 2.45 %	Pb = 2.45 %	Pb = 3.0 %	Pb = 3.0 %
No additive	No additive	No additive	No additive	SonneWarmix(2)	No additive	No additive

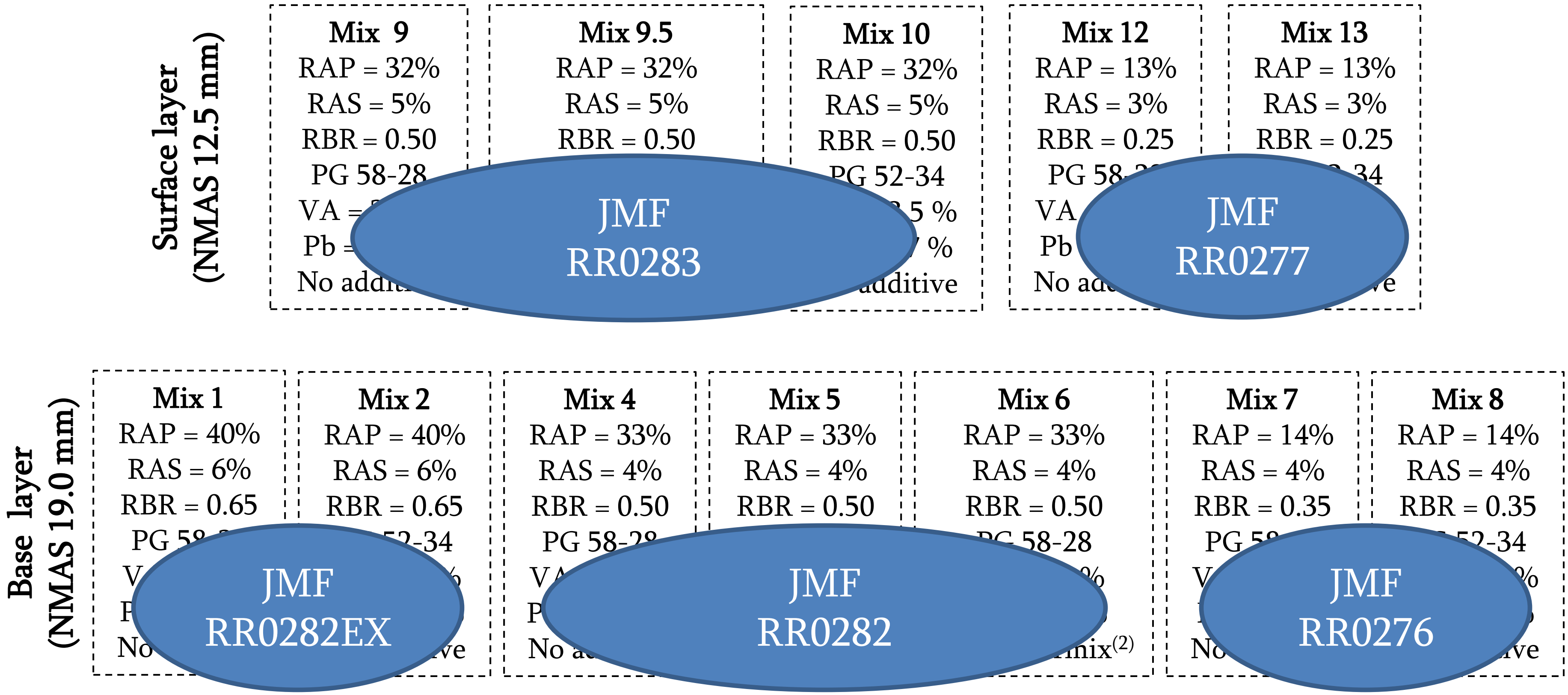
Notes:

(1) RBR = recycled binder ratio

(2) SonneWarmix additive used for rejuvenation purpose only

Mix Designs

- Proposed mixes



Surface layer (NMAS 12.5 mm)

Mix 9
RAP = 32%
RAS = 5%
RBR = 0.50
PG 58-28
VA =
Pb =
No addi

Mix 9.5
RAP = 32%
RAS = 5%
RBR = 0.50

Mix 10
RAP = 32%
RAS = 5%
RBR = 0.50
PG 52-34
5 %
%
additive

Mix 12
RAP = 13%
RAS = 3%
RBR = 0.25
PG 58-
VA
Pb
No ad

Mix 13
RAP = 13%
RAS = 3%
RBR = 0.25
34
ve

JMF
RR0283

JMF
RR0277

Base layer (NMAS 19.0 mm)

Mix 1
RAP = 40%
RAS = 6%
RBR = 0.65
PG 58
V
P
No

Mix 2
RAP = 40%
RAS = 6%
RBR = 0.65
2-34
%
ve

Mix 4
RAP = 33%
RAS = 4%
RBR = 0.50
PG 58-28
VA
P
No a

Mix 5
RAP = 33%
RAS = 4%
RBR = 0.50

Mix 6
RAP = 33%
RAS = 4%
RBR = 0.50
PG 58-28
%
mix(2)

Mix 7
RAP = 14%
RAS = 4%
RBR = 0.35
PG 58
V
No

Mix 8
RAP = 14%
RAS = 4%
RBR = 0.35
2-34
%
%
ive

JMF
RR0282EX

JMF
RR0282

JMF
RR0276

Notes:
(1) RBR = recycled binder ratio
(2) SonneWarmix additive used for rejuvenation purpose only

AMPT Based Performance Testing

- **Dynamic Complex Modulus |E*| Test - stiffness**
  - Test temperatures : 4.0°C, 20.0°C, 40.0°C
  - Test frequencies : 10 Hz, 1Hz, 0.1 Hz, and 0.01 Hz (only at 40.0°C)
- **Cyclic Fatigue Test – cracking** (AASHTO TP107-14)
  - Test temperature: 15.0°C
  - Frequency: 10 Hz
  - Range of initial on-specimen strains 250-450 με
- **Flow Number (F_n) - rutting**
  - Test temperature: 50.0°C (LTTP Bind database)
  - Loading : Axial = 600 kPa; Confining pressure = 0 kPa
  - Loading mode: Pulse (0.1sec loading 0.9sec rest)
  - Termination criteria: 50000 με accumulated strain or 10000 cycles

IPC Global AMPT

Long Term Oven Conditioning of Specimens

Three different oven conditioning criteria of the compacted test specimens.

- Set 1: No oven conditioning
- Set 2: 85°C (185°F) for 5 days
- Set 3: 85°C (185°F) for 10 days

AMPT Based Performance Testing

Test	Dimensions (mm)		Long-Term Conditioning	Test Config.	Test Temp. (°C)	Test Freq. (Hz)	Rep. #	Va, %
	D (mm)	H (mm)						
F_n	100	150	None	600-00	50	Standard	4	7±0.5
	100	150	5 days @ 85° C	600-00	50	Standard	4	7±0.5
	100	150	10 days @ 85° C	600-00	50	Standard	4	7±0.5
|E*|	100	150	None		4, 20, & 40	10, 1, 0.1, 0.01*	3	7±0.5
	100	150	5 days @ 85° C		4, 20, 40	10, 1, 0.1, 0.01*	3	7±0.5
	100	150	10 days @ 85° C		4, 20, & 40	10, 1, 0.1, 0.01*	3	7±0.5
Cyclic Fatigue	100	130	None	Low ε	15	10	2	7±0.5
	100	130		Inter. ε	15	10	2	7±0.5
	100	130		High ε	15	10	2	7±0.5
	100	130	5 days @ 85° C	Low ε	15	10	2	7±0.5
	100	130		Inter. ε	15	10	2	7±0.5
	100	130		High ε	15	10	2	7±0.5
	100	130	10 days @ 85° C	Low ε	15	10	2	7±0.5
	100	130		Inter. ε	15	10	2	7±0.5
	100	130		High ε	15	10	2	7±0.5

*** Note: The DM test frequency of 0.01 was applied only at 40°C**

Background - Why FHWA has been working with the methodology

1. FHWA started working with prototype methodologies in 2005
   - Classic beam fatigue apparatus broke during early stages of polymer modified ALF mixture testing for TPF-5(019)
   - We needed to do something quick
2. Heritage and "pedigree" of the theory – aerospace industry application for solid rocket propellant
3. Vetting and peer review; "winning" candidate in NCHRP 9-19 Tasks F&G
4. Wanted a performance test that could be **defensible**, **not empirical correlations**
5. Already promoting the investment in AMPTs for the MEPDG & the AMPT can do much more than $|E^*|$

1.1 Description of the Problem

[redacted] are the prime component of [redacted] and the performance of such [redacted] influenced largely by the mechanical properties of [redacted] grains. The structural integrity of [redacted] is determined by performing stress analysis for loading and environmental conditions under which the [redacted] is likely to operate. Consequently, the accuracy of the representation of the [redacted] mechanical behavior is essential for the usefulness of stress analysis results of [redacted]

All modern [redacted] use an elastomeric binder which is filled with quite high levels of solid particles. The mechanical behavior of [redacted] is mainly determined by the polymeric nature of the binder and the binder-filler interaction. The application of a load causes irreversible microstructural changes referred to as damage. They mainly consist of broken molecular chains and interfacial debonding, also called dewetting, that result in the formation of microvoids at or near the interface of the particles and surrounding matrix. Under these influences [redacted] exhibit very complicated behavior including features associated with time and rate effects, temperature and superimposed pressure dependence, large deformations and large strains, stress softening during cyclic loading, called Mullins' effect, and transition from incompressible to compressible behavior…

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…sounds a lot like asphalt?…

1.1 Description of the Problem

Solid propellants are the prime component of solid rocket motors and the performance of such motors is influenced largely by the mechanical properties of propellant grains. The structural integrity of a rocket motor is determined by performing stress analysis for loading and environmental conditions under which the motor is likely to operate. Consequently, the accuracy of the representation of the solid propellant mechanical behavior is essential for the usefulness of stress analysis results of solid rocket motors.

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CONSTITUTIVE EQUATIONS FOR SOLID PROPELLANTS
Sebnem Ozupek - PhD Dissertation UT-Austin 1997

Some more on solid rocket propellant

Castable composite solid rocket motors were invented by John Whiteside "Jack" Parsons at Caltech in ***1942*** when he replaced double base propellant with ***roofing asphalt and potassium perchlorate***. […] Charles Bartley, employed at JPL (Caltech), ***substituted curable synthetic rubber for the gooey asphalt***, creating a flexible but geometrically stable load-bearing propellant grain that bonded securely to the motor casing. This made possible much larger solid rocket motors. Atlantic Research Corporation significantly boosted composite propellant in 1954 by increasing the amount of ***powdered aluminum in the propellant to as much as 20%.***

https://en.wikipedia.org/wiki/Solid-fuel_rocket

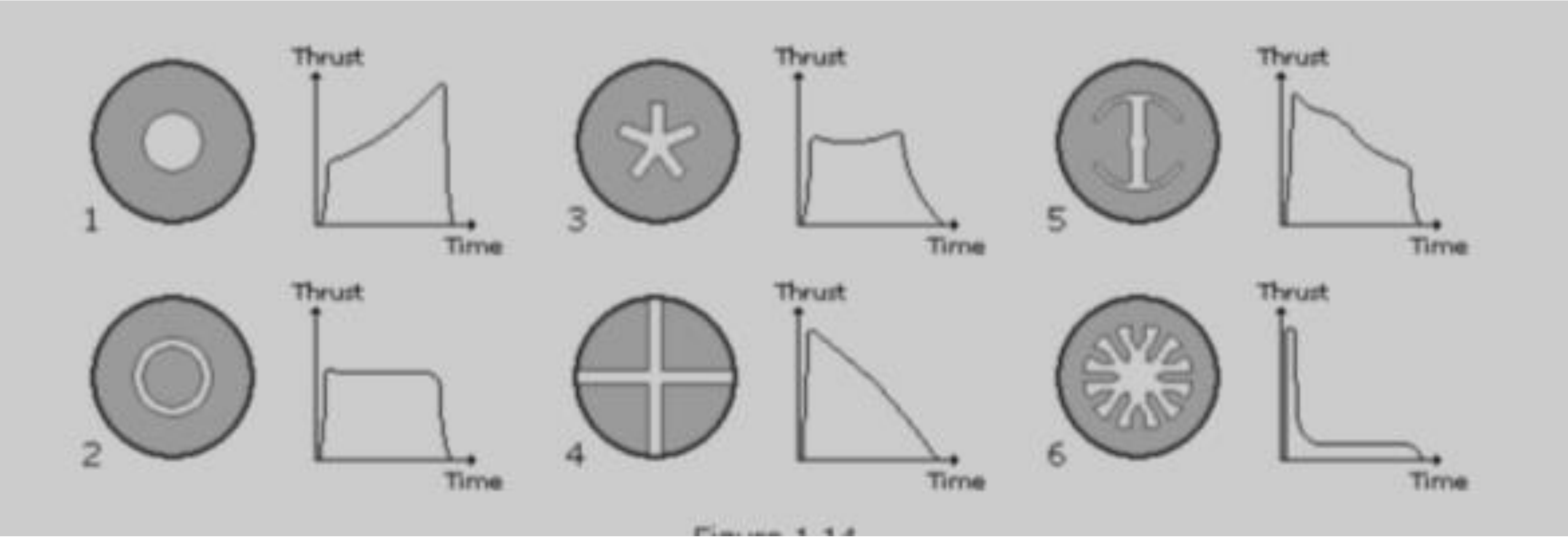
http://www.wired.com/2011/12/to-build-a-diy-spacecraft-is-a-daunting-task/

http://www.nasa.gov/mission_pages/shuttle/behindscenes/srb_inspection-gallery.html

Some more on solid rocket propellant

Common modes of failure in solid rocket motors include *fracture of the grain*, failure of case bonding, and air pockets in the grain. All of these produce an instantaneous increase in burn surface area and a corresponding increase in exhaust gas and pressure, which may rupture the casing.

https://en.wikipedia.org/wiki/Solid-fuel_rocket



http://www.braeunig.us/space/propuls.htm

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The Rocket: Solid and Liquid Propellant Motors

Space and Missile Systems Center Los Angeles AFB

Application of Schapery's Theory of Viscoelastic Fracture to Solid Propellant

S. R. Swanson*
University of Utah, Salt Lake City, Utah

The analysis of time-dependent crack propagation in viscoelastic materials in general, and solid propellants in particular, has been hampered by the difficulty of the mathematical analysis of a cracked viscoelastic material. The viscoelastic solution to the singular line crack has not provided a realistic fracture criterion, whereas various approximations to this problem have compared more favorably with experiments. However, it is difficult to assess the generality of the approximations involved. Recently, Schapery has generalized the Barenblatt model to the viscoelastic case and thus developed a model that appears to be consistent with both theory and experiment. The objective of the present work was to obtain a detailed comparison of this model with laboratory results available in the literature on a PBAN solid propellant. The results of the comparison are extremely good over a wide range of variables. A time-dependent fracture energy is found to result which can be incorporated readily into the theory.

Introduction

IT is well known that cracks in viscoelastic solid-propellant rocket motor grains may initiate and propagate under various environmental loadings. The consequences of crack propagation during firing of the propellant grain depend critically on the time required for crack propagation compared with the burning rate, as burning can modify the geometry of the crack or flaw. Slowly propagating or stationary cracks thus may be removed essentially by burning, whereas more rapidly propagating cracks may become more severe as the crack deepens, and pressure may build up in the crack.

Viscoelastic crack propagation has been studied by a number of investigators,[1-10] and the results have been developed concerning the time dependence of the initiation of crack propagation and the subsequent velocity of crack propagation. Although the work cited has been a generalization of the classic elastic crack instability analysis, certain physically or mathematically based approximations necessarily have been made because of the complexity of the viscoelastic stress analysis of the crack geometry.

The exact solution to the problem of a line crack in a linearly viscoelastic material has been presented recently by Graham[11] and subsequently corroborated by Nuismer[12] using the usual thermodynamic power balance for fracture. The result of this solution is that the fracture criterion is given by

$$\sigma_0(t_f) = [2\gamma_c/\pi D_g a_0]^{1/2} \qquad (1)$$

which is Eq. (11) by Nuismer.[12] It is seen that this is identical to the classic Griffith solution except that the elastic modulus is replaced by the reciprocal of the glassy creep compliance. A second feature of the preceding solution is that no information is given about crack propagation velocities; the criterion applies only to the initiation of cracking.

As pointed out by Nuismer, the foregoing result is physically unappealing in that it appears to be only an upper bound on the fracture stress. No information is available from this result about time-dependent fracture at lower stress levels or crack velocities. Thus the exact solution to the singular viscoelastic line crack problem does not give a realistic fracture criterion, and as discussed by Nuismer, raises question about the validity of the results obtained by the various approximate theories.

Knauss[13,14] has pointed out, however, that a length parameter not present in the singular line crack problem is necessary to introduce time or velocity effects into the viscoelastic fracture analysis. Thus an approximate solution that incorporates a failure zone length, as developed by Knauss,[5,8] may capture more of the physical features of the real case than does the singular line crack, even though an approximate stress analysis was employed.

A way out of this dilema has been developed recently by Schapery.[15,16] Schapery has generalized the Barenblatt model[17] for elastic fracture to the linear viscoelastic case. In Schapery's model (as in the Barenblatt model), a small "cohesive" zone is assumed to exist at the tip of the crack which exerts tractions on the crack faces. The singularity in stress at the crack tip due to these cohesive forces is equated to the negative of the singularity in stress at the crack tip due to the external applied loads, so that the resulting stress is everywhere finite. Schapery calculates the work done on the cohesive zone by the surrounding linear viscoelastic material and equates this to the fracture energy. Schapery develops the equation for crack velocity as

$$C_v(\bar{t}_\alpha) = 8\Gamma/K_I{}^2 \qquad (2)$$

where C_v is related to the creep compliance, Γ is surface energy, and K_I is the opening mode stress intensity factor. The term $\bar{t}_\alpha$ can be viewed as the time required for the crack to traverse the cohesive zone at the crack tip. For a one- or two-term power law representation of C_v, this equation can be solved explicitly for the crack velocity as

$$\dot{a} = \left[\frac{C_I \lambda_n \Pi^n}{\Gamma \sigma_m{}^{2n} I_I{}^{2n} 2^{1+n}}\right]^{1/n} K_I{}^{2[1+(1/n)]} \qquad (3)$$

where C_v has been taken as $C_v = C_I t^n$. C_v is related approximately to the creep compliance $D(t)$ by $C_v(t) = 4(1-\nu^2)D(t)$. The terms in brackets are constants or material parameters developed by Schapery. If the fracture energy Γ is a constant, the propagation law is of the form

$$\dot{a} = A\,K_I{}^{2[1+(1/n)]} = A\,K_I{}^q \qquad (4)$$

Received Aug. 22, 1975; revision received Jan. 5, 1976. This work was supported in part by Hercules Incorporated. Discussions with J. J. Anderson, S. C. Beckwith, and R. A. Schapery were very helpful.

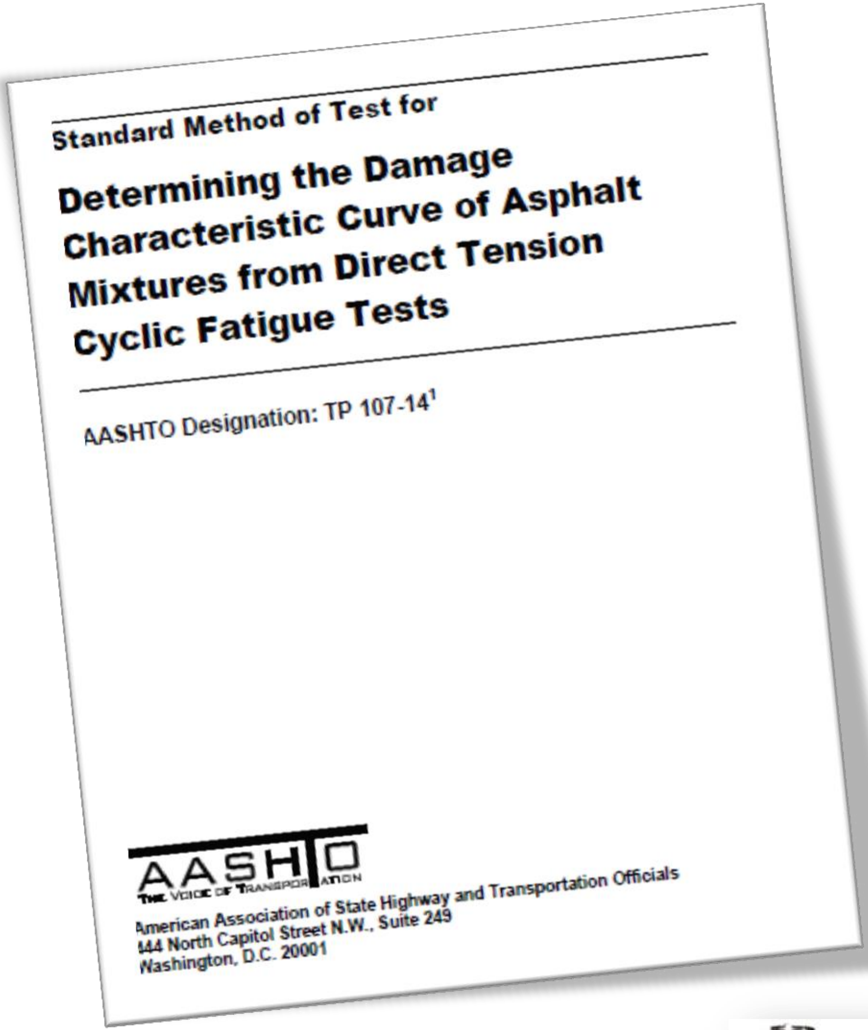
Index category: Solid and Hybrid Rocket Engines.

*Research Associate Professor, Department of Mechanical Engineering; also Consultant, Hercules Incorporated.

S. R. SWANSON. "*Application of Schapery's Theory of Viscoelastic Fracture to Solid Propellant*" Journal of Spacecraft and Rockets, Vol. 13, No. 9 (*1976*), pp. 528-533.

Richard Schapery's theories provided the foundation for asphalt viscoelastic continuum damage (VECD) using AMPT cyclic fatigue, all beginning with:

Kim, Y.R., Little, D.N.: One-dimensional constitutive modeling of asphalt concrete. ASCE J. Eng. Mech. 116(4), 751–772 (1990)



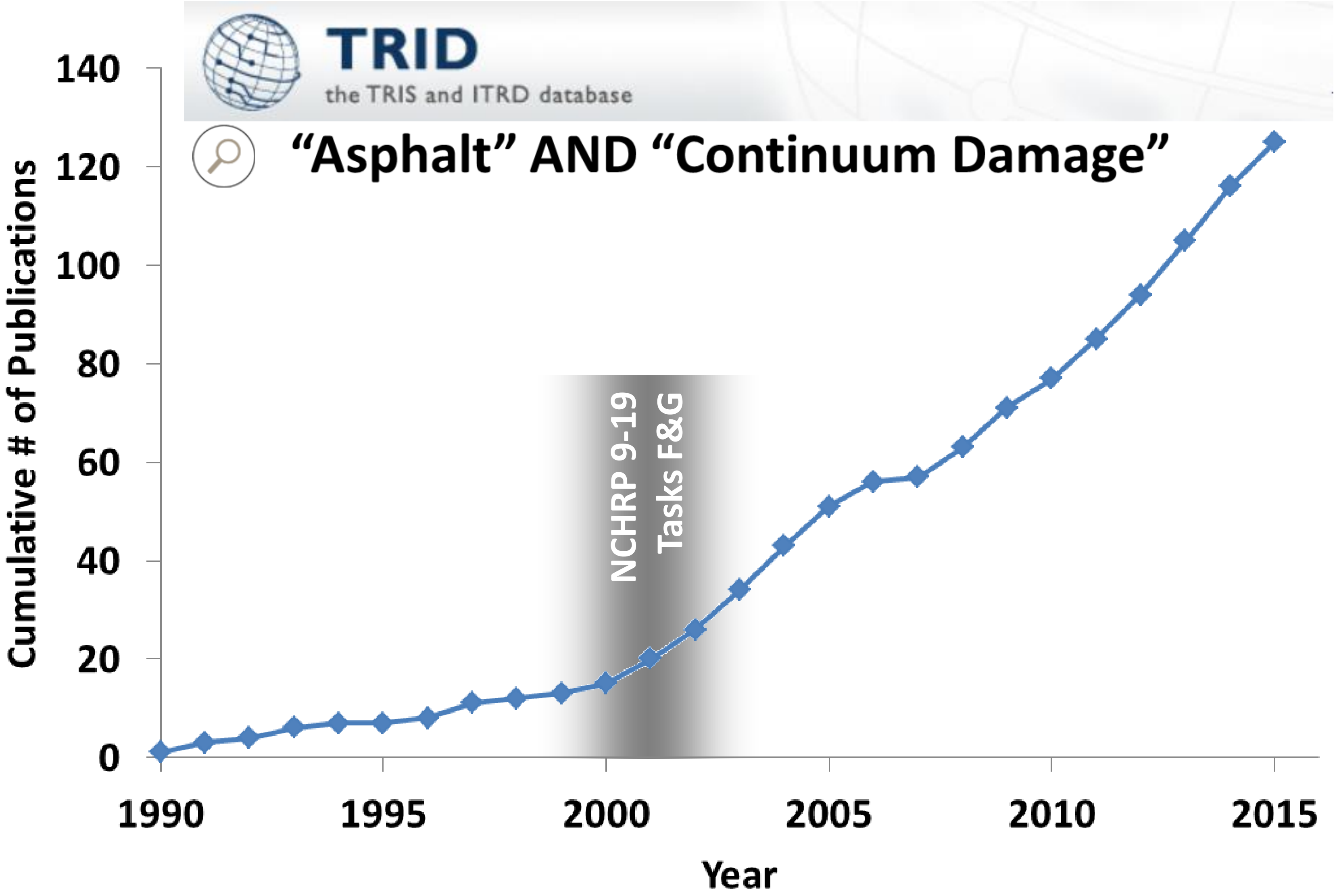
Standard Method of Test for

Determining the Damage Characteristic Curve of Asphalt Mixtures from Direct Tension Cyclic Fatigue Tests

AASHTO Designation: TP 107-14[1]

AASHTO
THE VOICE OF TRANSPORTATION
American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

This is not a 'Johnny-come-lately' methodology!



Background - Why FHWA has been working with the methodology

6. Unified/common AMPT equipment specification criteria
   - Custom MTS or UTM machines which differ greatly from institution to institution
7. Unified/common compaction control with SGC
   - Density uncertainty with slab compactors
   - Slab compactors vary greatly by design; vibratory, plate-kneading, tamping or shear box
   - Less material, less waste, easier handling
8. ***Extended time-temperature superposition !!!!!***
   - Discovered during NCHRP 9-19 Tasks F&G
   - Shift factors for |E*| vs. Temperature are the same for explaining fatigue damage vs. Temperature
   - Less Testing!

Background - Why FHWA has been working with the methodology

9. Certainty in the stress–strain state within the test specimen
    - Uniaxial stress state is uniform not like a bending/flexural stress which is different everywhere
    - Strains are measured on the specimen rather than a beam deflection, avoiding end effects and other artifacts
10. The test tells you a lot about your mix
    - Response under different strains: STRUCTURE/TRAFFIC
    - Response under different load rates: TRAFFIC
    - Response under different temperature: SEASONAL
    - More information gained than from a single test at a single rate/temperature
11. **Connect mix design and construction by means of distress and performance prediction** (i.e. not just a pass/fail)

Performance Testing

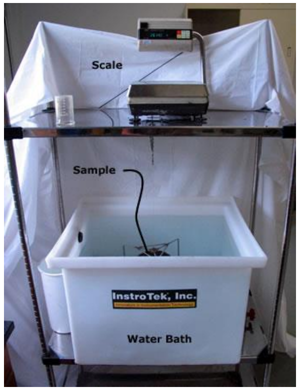
- Fabrication of test specimens
  - Loose mixture sampled from haul trucks and compacted w/o reheating: Plant Mixed Lab Compacted (PMLC)

SGC Specimens
150 mm x 180 mm

Coring
100 mm x 180 mm

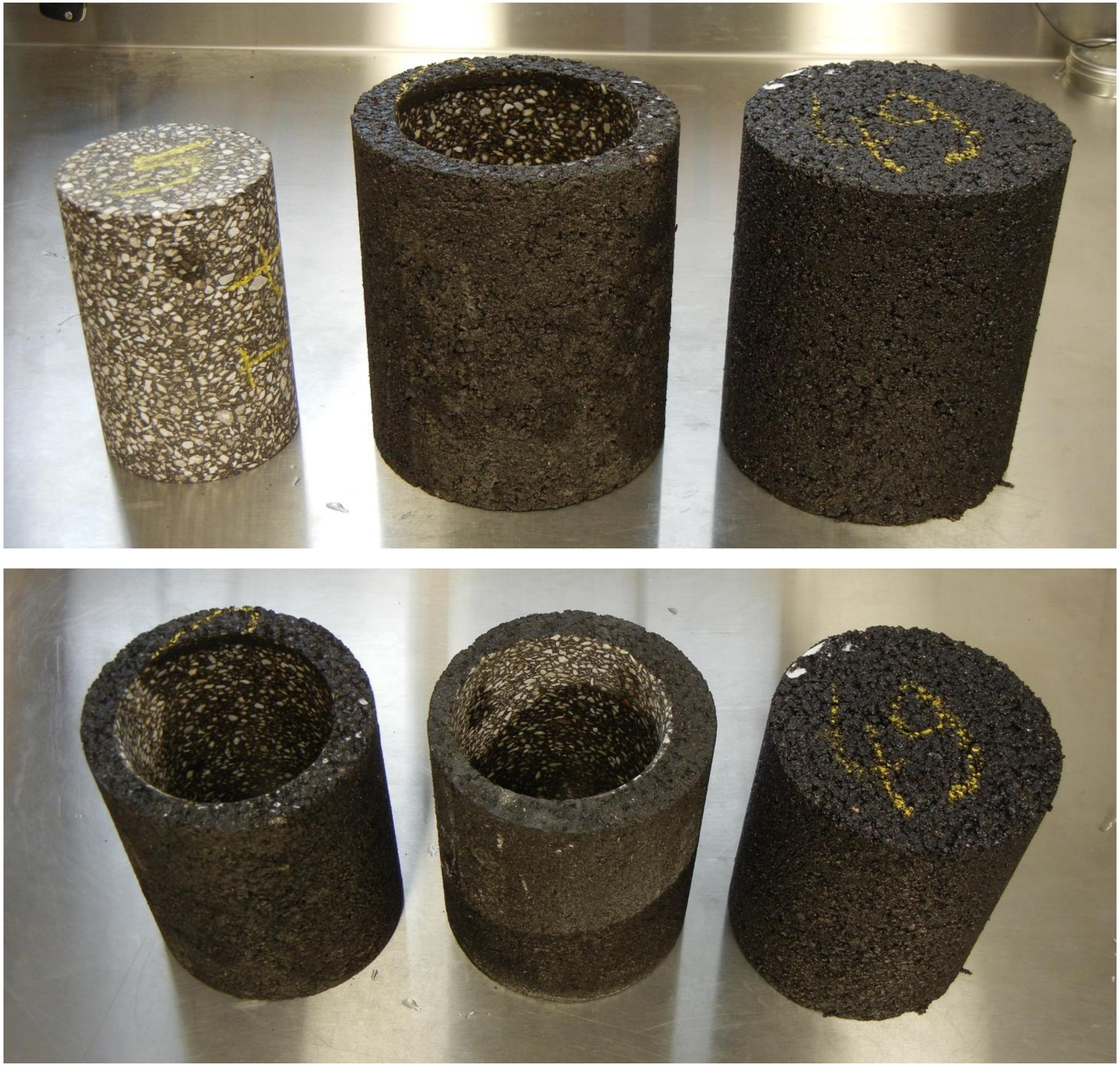
Trimming
100 mm x 150 mm
(E^* and F_n)

100 mm x 130 mm
(cyclic fatigue)



Percent air void on final test specimens
7.0 ± 0.5 %

Specimen Prep - Coring

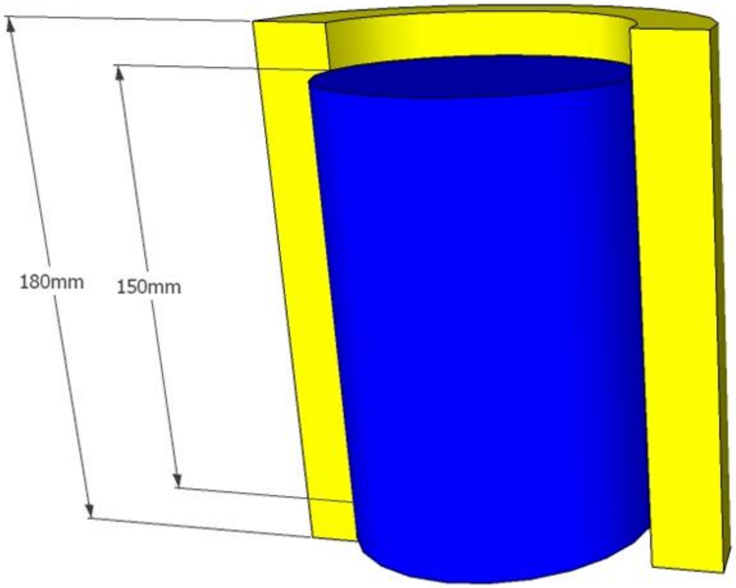


Specimen Prep - Coring

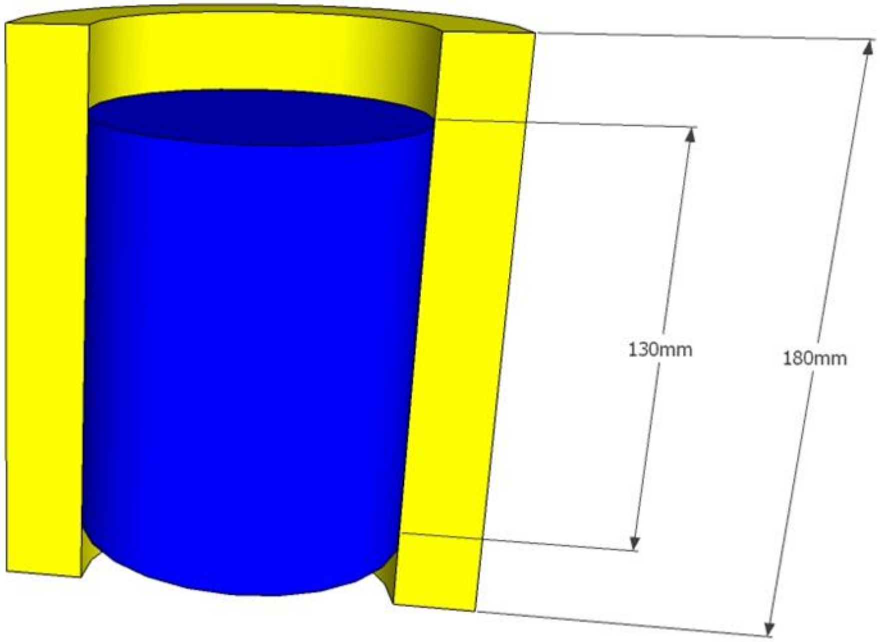
Specimen Prep - Coring

Specimen Prep - Compaction Height

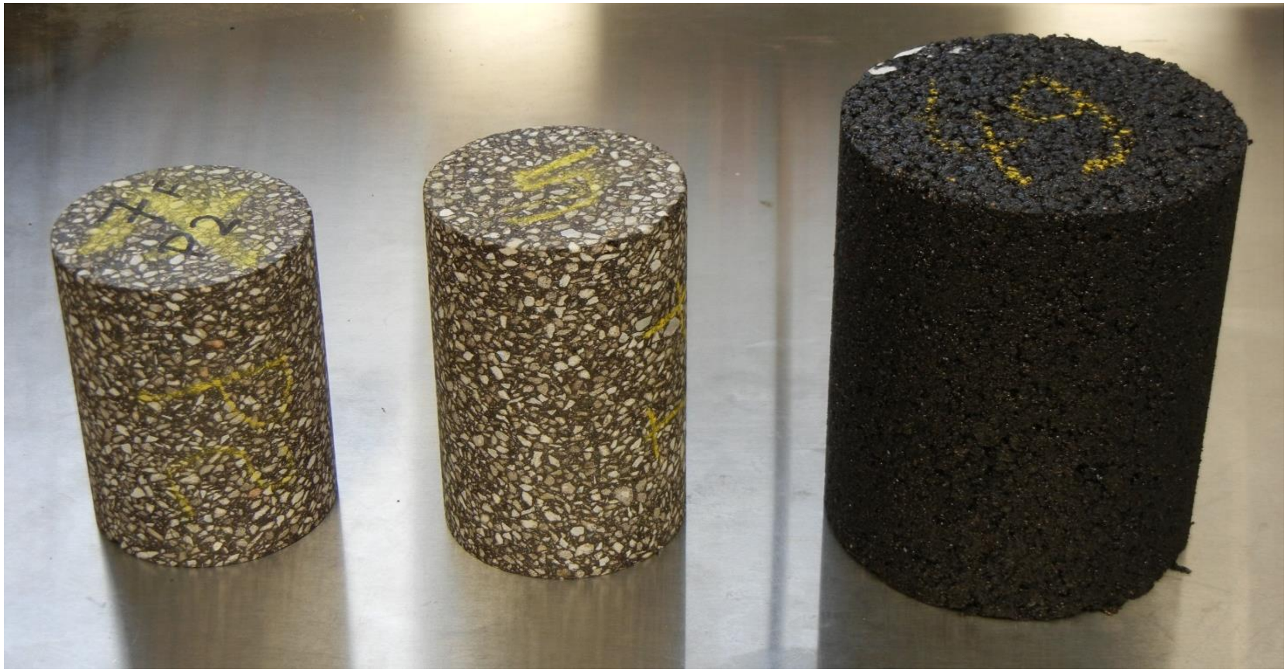
- Best Results for middle failure, experience-based
- Both E* and Cyclic Fatigue minimum 180mm SGC
- Cut more material away for Cyclic Fatigue
- Do not make a shorter SGC for Cyclic Fatigue



|E*| Specimen



Cyclic Fatigue Specimen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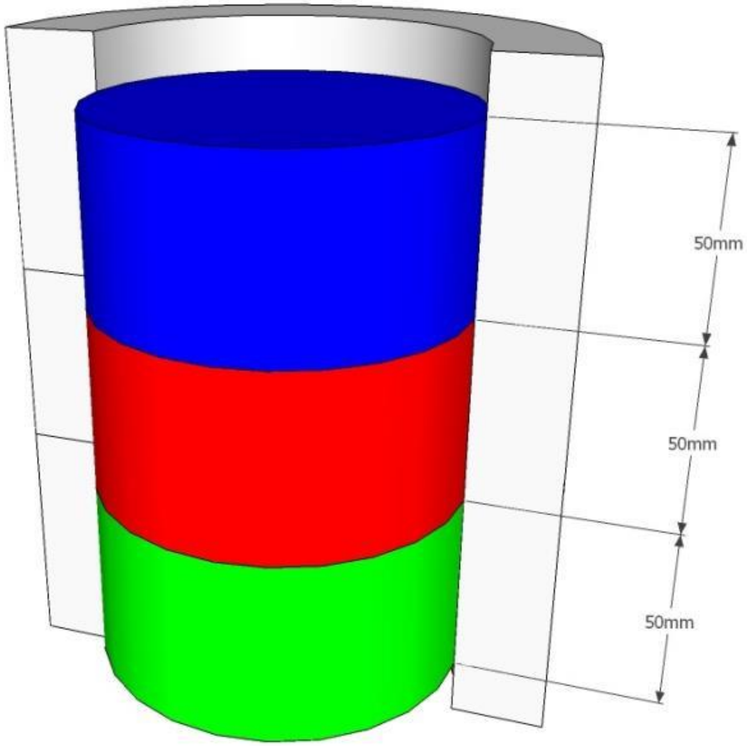
AASHTO PP 60

Preparation of Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor



- X2.2.3. A statistical hypothesis test is conducted to determine the significance of the difference in the mean G_{mb} of the top and bottom slices relative to the middle third.

- For the sample sizes specified, the absolute value of the test statistic must be less than 2.78 to conclude that the G_{mb} of the top and middle slices are equal.

Gage Points and Gluing

Gage Points and Gluing

- Glue
  - Epoxy for each of 6 gage points (such as Devcon 14240 - 5 Minute® Epoxy Gel)
  - non-migrating (no sag) gel adhesive which makes it ideal for use on vertical surfaces
  - working time 4-7 min. @ 72°F
  - fixture time 10-15 min. @ 72°F
  - functional Cure 1.5 hr. @ 72°F

Platens and Gluing

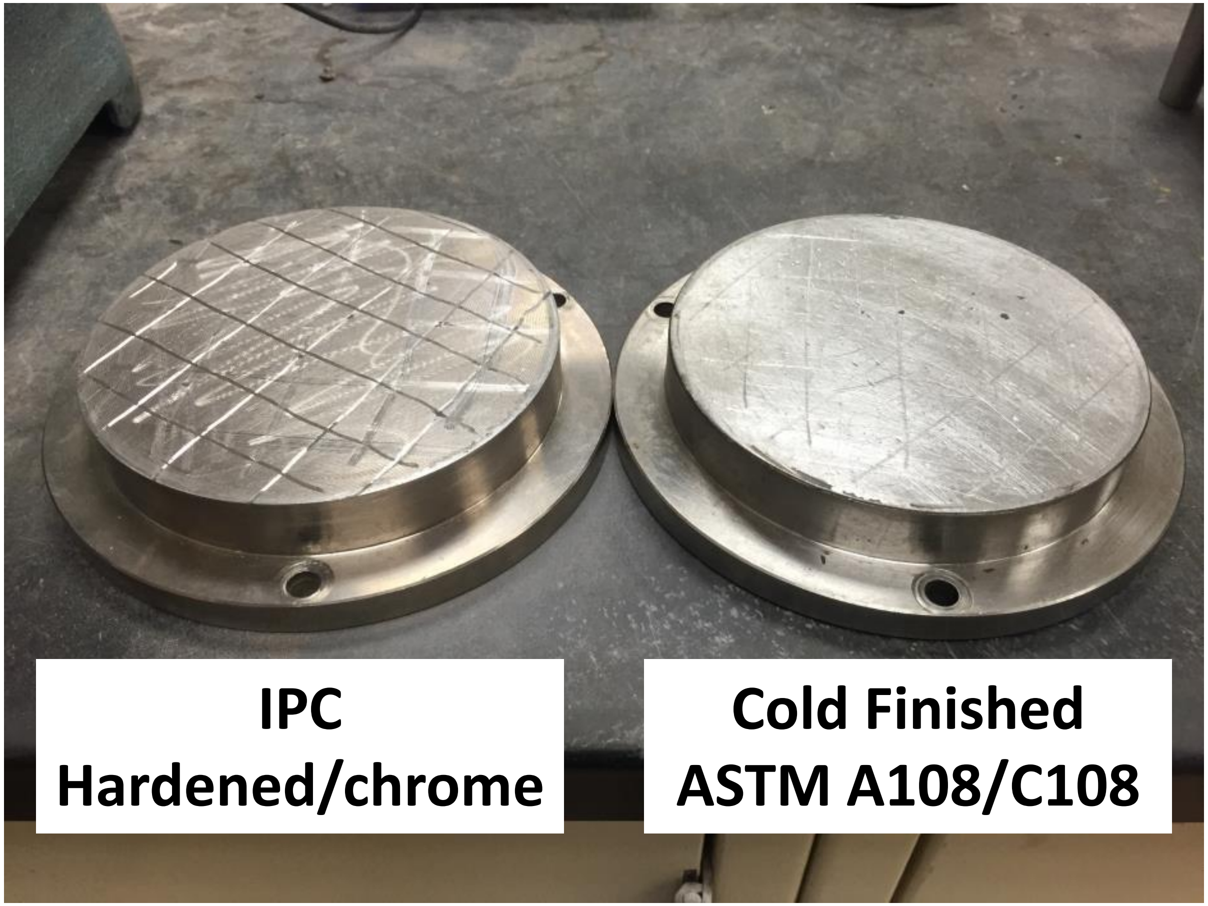
Platens and Gluing

Platens and Gluing

- Platen Metal
  - Made our own before “official” ones were available
  - **Cold finished steel, ASTM A108/C1018**
  - “Better” bond than hardened/chrome steel
  - Scuffing with 80-grit sandpaper
  - Final acetone cleaning
  - Grooves not necessary

Platens and Gluing

- Platen Metal



IPC
Hardened/chrome

Cold Finished
ASTM A108/C108

Platens and Gluing

- Platen Metal

Platens and Gluing

- Glue
  - Heavily oozing, sloppy glue is not ideal or necessary
  - Trim the glue - like a DSR
  - You need about 15 g of “plastic steel” epoxy for each side (such as Devcon 10120); 30 g total
  - fully cures in 16 hours @ 70°F

Platens and Gluing

- Glue

Platens and Gluing

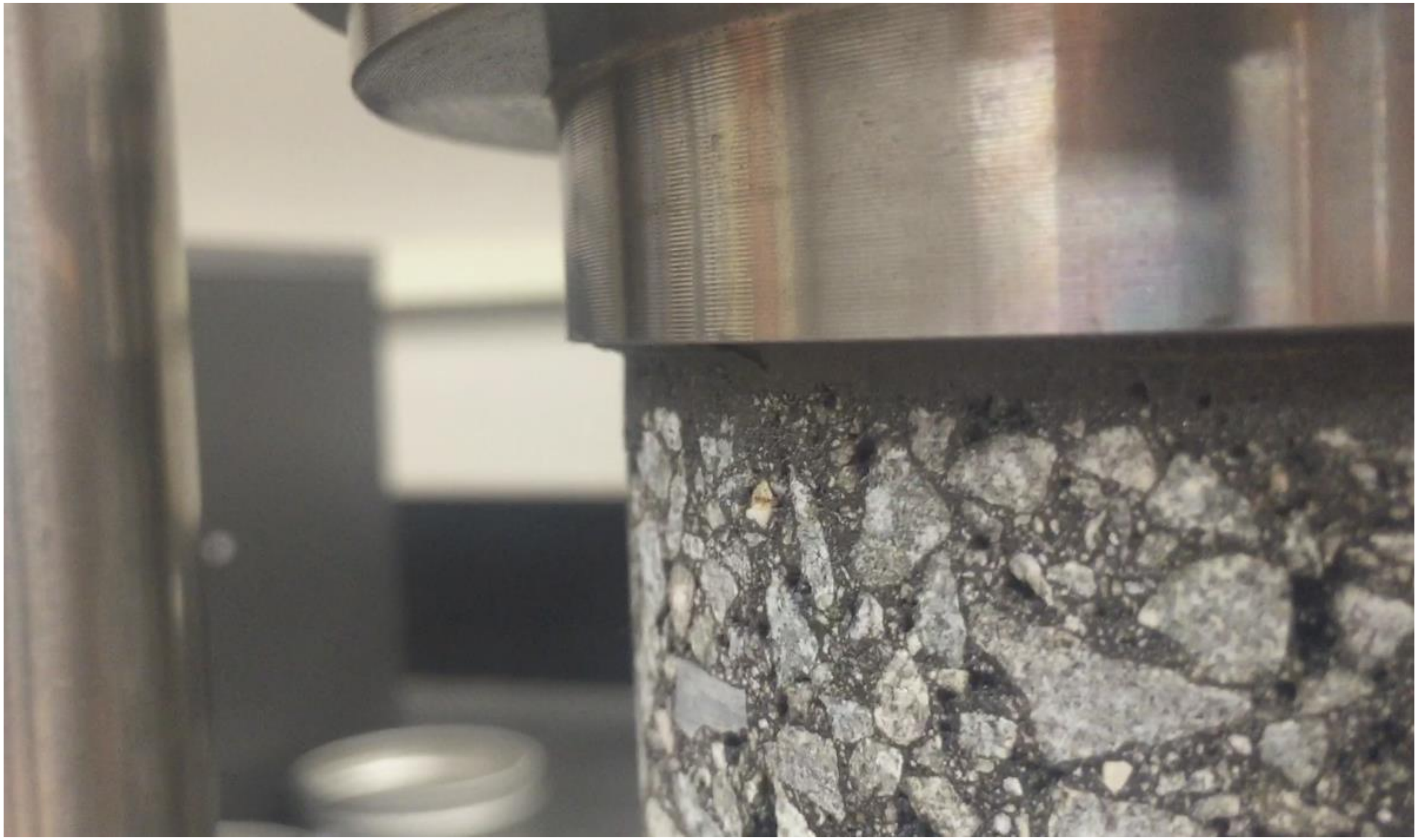
- Glue

Platens and Gluing

- Glue

Platens and Gluing

- Glue



Platens and Gluing

- It is possible to glue two (2) specimens in one (1) day with one (1) gluing jig.
- Minimum 4 hour set time
  - Overnight is better

Temperature Conditioning Options

A separate temperature controlled bath (water) used to precondition specimens before testing

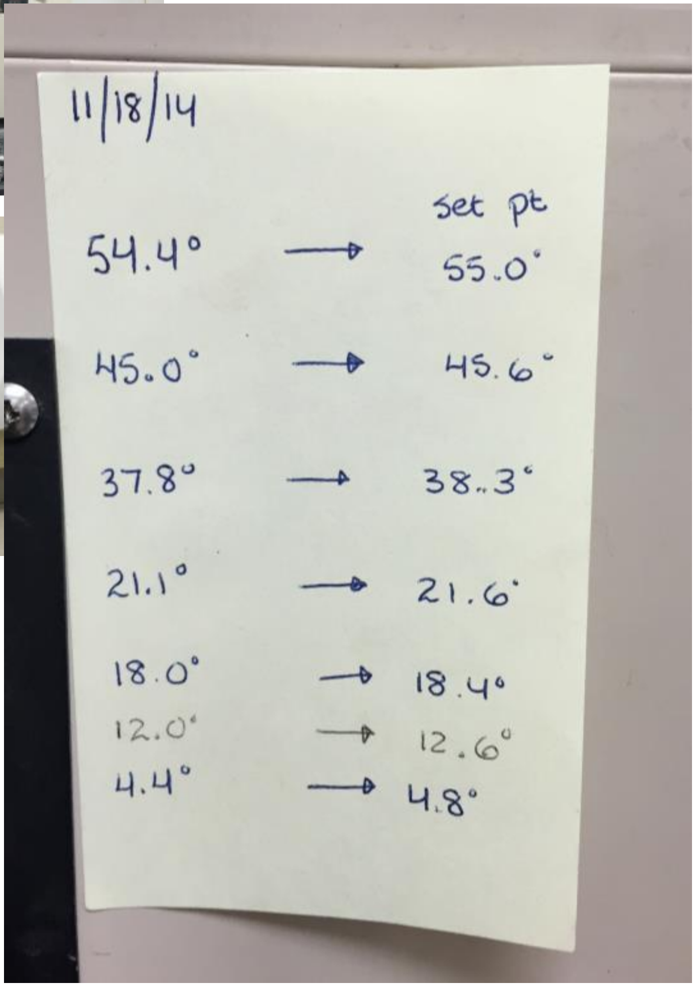
Temperature Conditioning Options

A separate environmental chamber (air) used to precondition specimens before testing

Temperature Conditioning

Condition specimens at least 3 hours and sometimes you may need to use a timer to start the chamber during the night before.

Temperature Conditioning



11/18/14

		set pt
54.4°	→	55.0°
45.0°	→	45.6°
37.8°	→	38..3°
21.1°	→	21.6°
18.0°	→	18.4°
12.0°	→	12.6°
4.4°	→	4.8°

Use a calibrated thermometer to check the embedded thermocouple in a dummy specimen to determine set-point offsets

Temperature Conditioning

Running the thermocouple wire out the seal of the AMPT chamber is not ideal because it pinches and frays the cord

Temperature Conditioning

Putting the thermocouple reader inside the chamber is "OK" but you need to ensure you have a high quality reader that has a cold junction compensation

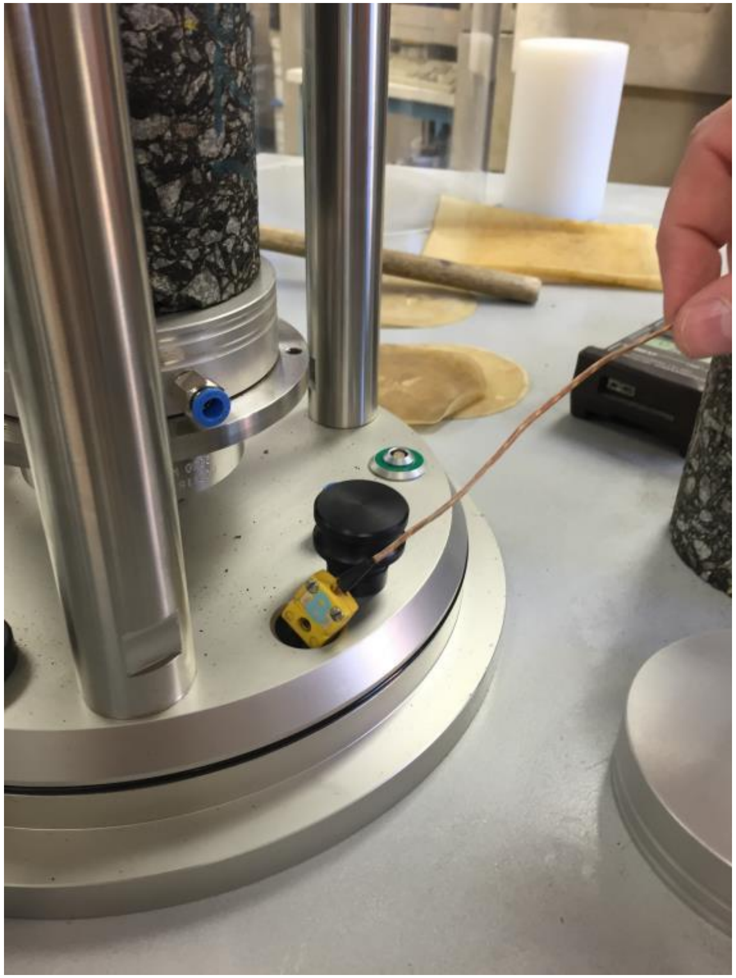
…or….

Temperature Conditioning

New-er AMPTs have a port inside the chamber….

…open up that port….

Temperature Conditioning

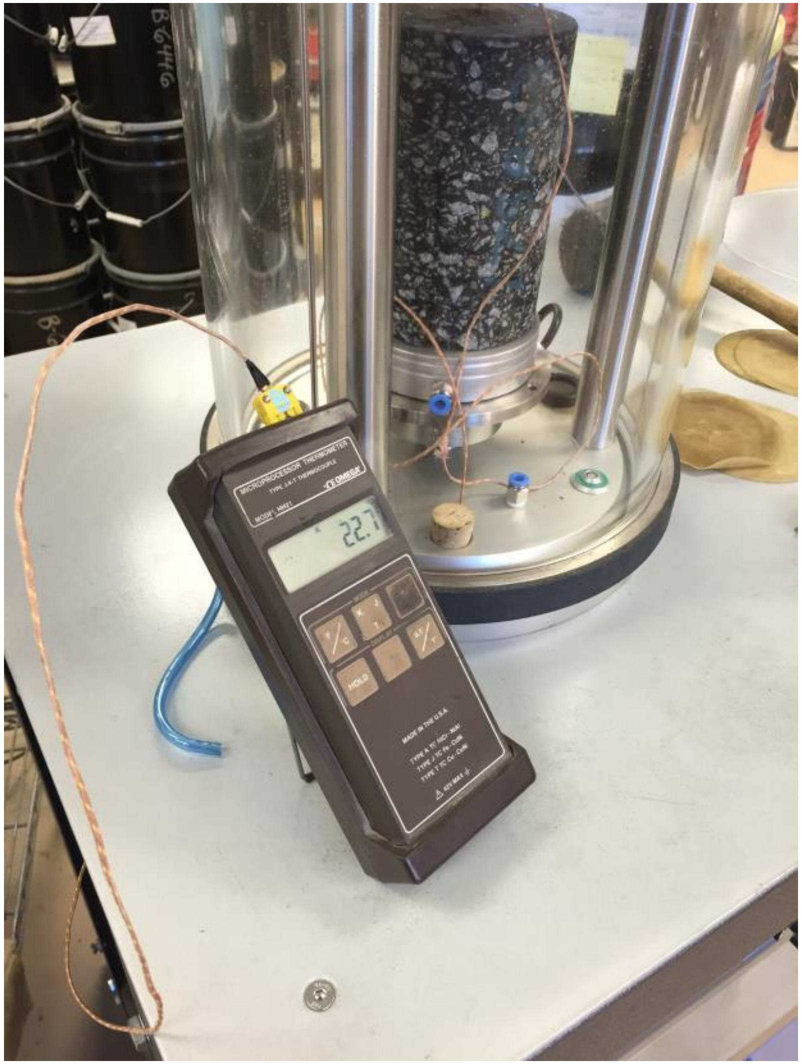


…run the dummy sample cord out through the port…

Temperature Conditioning

…and out the side of the AMPT….

Temperature Conditioning



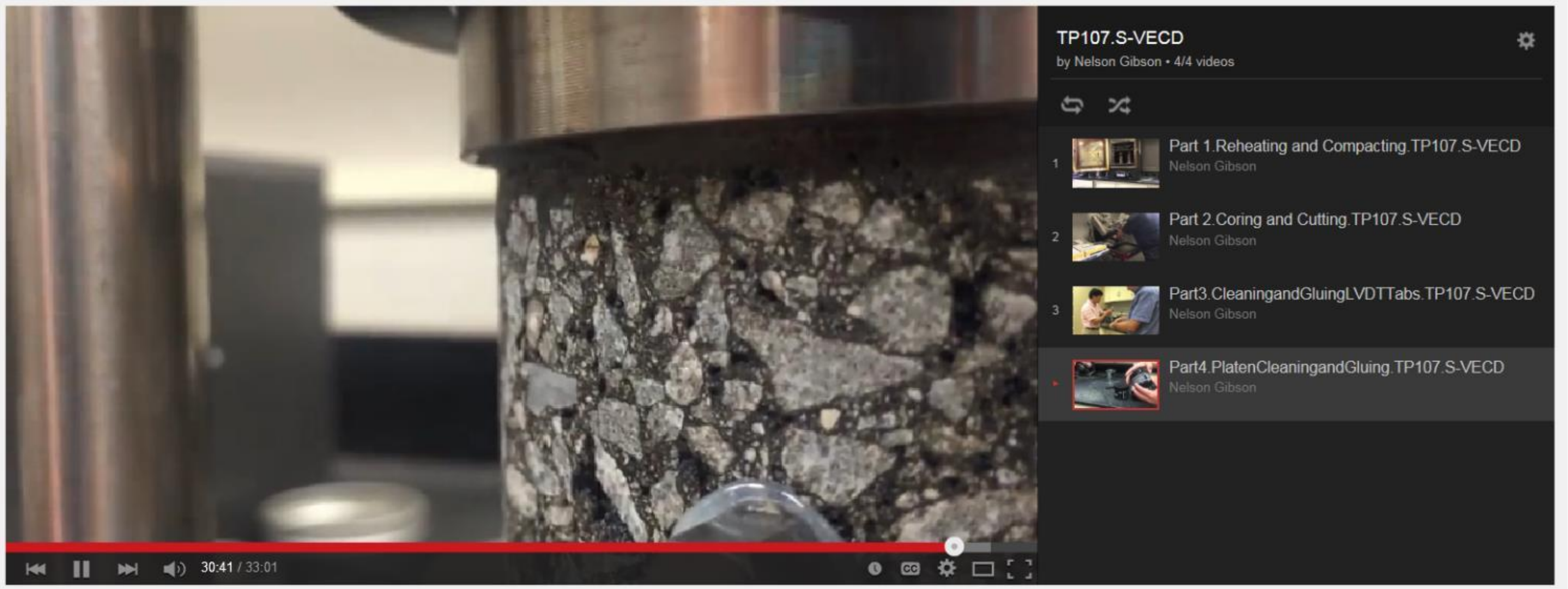
…and seal the port with a cork and you can then read the dummy specimen with confidence

TP107 Tools and Help

- FHWA Instructional Video
  - Youtube Playlist
  - Detailed, multiple parts, pick-and-choose topics
  - ***Not*** filming talented and experienced technicians,
  - Intent is to coach those familiar with an asphalt lab but haven't ran this particular test first-hand
  - Reproducibility
    - User1 Xinjun Li & User2 Nelson Gibson each will test 5 specimens duplicating each other; total of 10 fatigue specimens
    - TP107-14 requires a minimum of 3 specimens
- Guidance on choosing strain levels
  - Data driven
  - Graphical explanation of the background
  - Look-up table

FHWA Instructional Video

- https://www.youtube.com/playlist?list=PLyLypK-v8li-KjQq-Z6lmad4v2o_LcR3b



FHWA Instructional Video

- Part 1.Reheating and Compacting
- Part 2.Coring and Cutting
- Part 3.Cleaning and Gluing LVDT Tabs
- Part 4.Platen Cleaning and Gluing
- Running |E*| - See NHI Training Course
- Part 5.Choosing the Strain Level
- Part 6.Attaching Specimen and Running Test
- Part 7.Post Processing alpha-Fatigue
- Part 8.Post Processing LVECD Structural Analysis

Evaluation of Hot Mix Asphalt (HMA) Mixtures with High content of Recycled Materials Using the AMPT Cyclic Fatigue Test (Part B)

Mobile Asphalt Testing Trailer - Field Project WI14100

- Part 1.Reheating and Compacting
- Part 2.Coring and Cutting
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- Part 4.Platen Cleaning and Gluing
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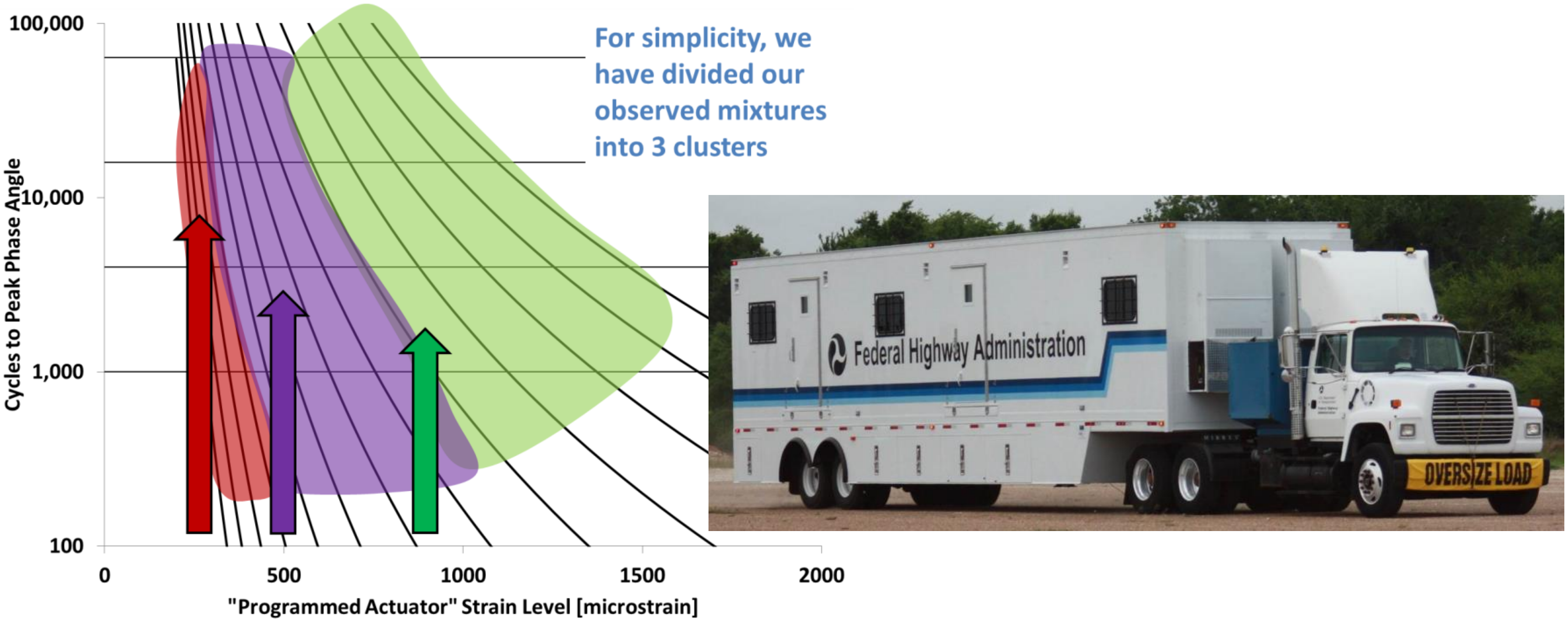
Evaluation of Hot Mix Asphalt (HMA) Mixtures with High content of Recycled Materials Using the AMPT Cyclic Fatigue Test <u>(Part B)</u>

Mobile Asphalt Testing Trailer - Field Project WI14100

… to be continued

… Spring 2016 ETG meeting



For simplicity, we have divided our observed mixtures into 3 clusters