COMMITTEE ON MATERIALS & PAVEMENTS

2018 Annual Meeting – Cincinnati, OH
Wednesday, August 8th, 2018
3:15 – 5:00 PM EST

TECHNICAL SUBCOMMITTEE 2d
Proportioning of Asphalt – Aggregate Mixtures

I. **Call to Order and Opening Remarks**
   A. Brief summary of activities *(to ensure all attendees up to speed)*

II. **Roll Call** States present: AL, AK, AZ, AR, CO, CT, DE, DC, FL, ID, IL, KS, KY, ME, MD, MN, MS, MO, MT, NV, OH, OK, OR, PA, TN, TX, UT, VT, WA, WI, WY, ONT

III. **Approval of Technical Subcommittee Minutes** (Attachment #1) Motion – MD, second - ME

IV. **Old Business**
   A. COMP Ballot Items
      i. No outstanding items. Will review 2017 COMP items. (Attachment #1)
   B. TS Ballots
      i. No TS ballots
   C. Task Force Reports
      i. No Task Force Reports
   D. T 312 – "if required" language
      i. Apologies for not taking care of this sooner. Suggested language to resolve confusion (Attachment #2) This issue came to us from AASHTO re:source. Motion to move suggested wording to COMP ballot: MN, second – CT.

V. **New Business**
   A. Research Proposals
      i. "Laboratory Aging Protocols for Assessing the Cracking Resistance of Asphalt Mixtures" (Attachment #4) Randy West spoke about this. One member supported this as a research topic.
      ii. "Development of a Targeted Mixture Test for Asphalt Concrete Pavement Top-Down Cracking Evaluation" (Attachment #3) There wasn't any interest expressed in supporting this as a research topic.
   B. AASHTO Technical Service Programs Items None.
   C. NCHRP Issues None.
   D. Correspondence, calls, meetings
      i. Questions on T 322 LVDT requirements (p. 3 of 6)
      ii. M 323 Table 7, footnote d (pp. 4-5 of 6)
      iii. Interpolating a 75-gyration mix design from a 100-gyration design (p. 6 of 6) The group felt this wouldn't be acceptable.
   E. Presentation by Industry/Academia

i. Maine's experience with small specimens in the AMPT – Derek Nener-Plante, Maine DOT
ii. Evaluation of Asphaltic Materials/Asphalt Mastic Using the DSR – Dr. Haleh Azari, Pavement Systems, LLC
iii. Low temperature testing in the DSR/Top Down Cracking evaluation – Dr. Yong-Rak Kim, University of Nebraska - Google survey: https://goo.gl/forms/JeOYz1a1TfoBhIcF2

F. Proposed New Standards
   i. M.I.S.T. (Attachment #5) Will send to Technical Subcommittee ballot.
   ii. AMPT Small Specimen Fabrication (Attachment #6) Send to concurrent ballot: motion – OH, second - ME
   iii. AMPT Small Specimen Modulus (Attachment #7) Send to concurrent ballot: motion – OH, second - ME
   iv. Cyclic fatigue Send to concurrent ballot: motion – OH, second - ME
G. Proposed New Task Forces None.
H. Standards Requiring Reconfirmation
   i. R 30
   ii. R 68
   iii. T 167
   iv. T 245
   v. T 246
   vi. T 247
   vii. T 340
   viii. T 342
I. COMP Ballot Items (including any ASTM changes/equivalencies/harmonization)

VI. Open Discussion

VII. **Adjourn** 5:00 p.m., no motions made to adjourn.

URL: http://portal.transportation.org/sites/som
Name: Andrew B Cooper
E-Mail Address: andrew@cooper.co.uk

I'd like to speak with the person responsible for the AASHTO T322 standard. The description of the LVDT mounting system is very tight. It seems that issues with this LVDT configuration breaking have been reported by users. It seems we are looking for performed based approach in mix design, but the standards are tight as opposed to giving manufacturers an opportunity to develop more user friendly. If the standard is exactly followed expensive LVDTs can easily be broken.
Thanks
Andrew

Oak,

We found that we could only buy from one source and they are manufactured in China. The standard Western transducer manufacturers don't produce units which meet the specific dimensions required in the standard. The issue we have found with these LVDTs is the wires are extremely thin, as you can see in the enclosed image. Consequently they are very delicate. Additionally the nature of the test and the LVDT configuration can result in LVDT failure along with the specimen failure. The argument that the test has been used without complaint for 10 years is a strong one. We just wonder whether a more robust system could be employed which would meet the measurement requirements of the test. Or maybe some people are using standard LVDTs?

Oak,

I hope you're doing well.

I believe I ran across an issue in M 323-17, Table 7 in regards to footnote *d*. It appears this has been an issue since the M 323-12 was published.

PennDOT is implementing a Superpave 4.75 mm mixture to replace an old Marshall Method fine aggregate mixture. When reviewing M 323-17, Table 7 for the 4.75 mm NMAS requirements, the location of reference "*d*" in Table 7 did not seem to coincide with the text of footnote *d* below the table. The actual text of footnote *d* indicates "*For 4.75-mm nominal maximum size mixtures, the relative density (as a percent of the theoretical maximum specific gravity) shall be within the range of 94.0 to 96.0 percent.*" In comparing the existing location of "*d*" in Table 7 versus the actual text of footnote *d*, it causes some confusion. Especially for how the text in footnote *d* is to be used regarding the Design ESALs in the first column. By the existing location of "*d*" in Table 7, the footnote text would only be applicable for <0.3 Design ESALs. Typically, the footnote text includes the specific Design ESALs that the footnote text applies to.

In looking back, I saw that the M 323 4.75 mm NMAS requirements were significantly revised in M 323-12. So, I went back to the 2011 SOM TS-2d Minutes and Ballot Package. On PDF page 26 of 67 of the 2011 SOM TS-2d ballot package (1st screen snip-it shown below), it shows M 323, Table 6 (Table 7 in M 323-17) and the proposed revisions to Table 6. The proposed new location of "*d*" in Table 6 is in the Relative Density and Ndesign column for the <u>first four</u> Design ESALs (<0.3 Design ESALs to 10 to < 30 Design ESALs). These locations for "*d*" make much more sense and better coincide with the actual text of footnote *d* below the table. In the proposed ballot item (1st screen snip-it below), the existing "*d*" in Table 6, which is located in the column for VFA and for only the first Design ESALs (<0.3), the "*d*" is proposed to be deleted (i.e., strikethrough font).

I'm not sure what ballot comments were received during the 2011 SOM TS-2d ballot item for M 323 or what transpired during the technical review prior to publishing M 323-12, but I believe the proposed relocation of "*d*" in Table 6, from the VFA column (first Design ESAL range) to the Relative Density, Ndesign column (first four Design ESAL ranges) somehow got overlooked or changed prior to publishing as compared to what was actually balloted in the 2011 SOM TS-2d ballot package.

I strongly believe that the M 323-17, Table 7, has an incorrect location for "*d*" in the VFA column and for the first Design ESALs row and it causes some confusion. I believe "*d*" should be moved from the VFA column (first ESAL Range) to the Relative Density and Ndesign column for the <u>first four</u> Design ESAL ranges as was balloted during the 2011 SOM TS-2d ballot.

<u>M 323, 2011 SOM TS-2d Ballot Item</u>:

maximum number of gyrations are specified in R 35.

Table 6—Superpave HMA Design Requirements

Design ESALs[a] (Million)	Required Relative Density, Percent of Theoretical Maximum Specific Gravity: $N_{initial}$	N_{design}	N_{max}	Voids in the Mineral Aggregate (VMA), Percent Minimum — Nominal Maximum Aggregate Size, mm: 37.5	25.0	19.0	12.5	9.5	4.75	Voids Filled with Asphalt (VFA) Range,[b] Percent	Dust-to-Binder Ratio Range[c]
<0.3	≤91.5	96.0[d]	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	70–80[d,e]	0.6–1.2
0.3 to <3	≤90.5	96.0[d]	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–78[e]	0.6–1.2
3 to <10	≤89.0	96.0[d]	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–75[e,f,g]	0.6–1.2
10 to <30	≤89.0	96.0[d]	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–75[e,f,g]	0.6–1.2
≥30	≤89.0	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–75[e,g]	0.6–1.2

[a] Design ESALs are the anticipated project traffic level expected on the design lane over a 20-year period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 years.

[b] For 37.5-mm nominal maximum size mixtures, the specified lower limit of the VFA range shall be 64 percent for all design traffic levels.

[c] For 4.75-mm nominal maximum size mixtures, the dust-to-binder ratio shall be ~~0.9~~1.0 to 2.0, for design traffic levels <3 million ESALs, and 1.5 to 2.0 for design traffic levels ≥3 million ESALs.

[d] For 4.75-mm nominal maximum size mixtures, the relative density (as a percent of the theoretical maximum specific gravity) shall be within the range of 94.0 to 96.0 percent.

[e] For design traffic levels <0.3 million ESALs, 25.0-mm nominal maximum size mixtures, the specified lower limit of the VFA range shall be 67 percent, and for 4.75-mm nominal maximum size mixtures, the specified VFA range shall be 67 to 79 percent. ~~for design traffic levels <0.3 million ESALs.~~

[f] For design traffic levels >0.3 million ESALs, 4.75-mm nominal maximum size mixtures, the specified VFA range shall be 66 to 77 percent.

[g] For design traffic levels ~~>~~≥3 million ESALs, 9.5-mm nominal maximum size mixtures, the specified VFA range shall be 73 to 76 percent, ~~and for 4.75-mm nominal maximum size mixtures shall be 75 to 78 percent.~~

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M 323-17, Table 7:

Table 7—Superpave Asphalt Mixture Design Requirements

Design ESALs,[a] million	Required Relative Density, Percent of Theoretical Maximum Specific Gravity: $N_{initial}$	N_{design}	N_{max}	Voids in the Mineral Aggregate (VMA), % Minimum — Nominal Maximum Aggregate Size, mm: 37.5	25.0	19.0	12.5	9.5	4.75	Voids Filled with Asphalt (VFA) Range,[b] %	Dust-to-Binder Ratio Range[c]
<0.3	≤91.5	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	70–80[d,e]	0.6–1.2
0.3 to <3	≤90.5	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–78[f]	0.6–1.2
3 to <10	≤89.0	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–75[e,f,g]	0.6–1.2
10 to <30	≤89.0	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–75[e,f,g]	0.6–1.2
≥30	≤89.0	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–75[g]	0.6–1.2

[a] Design ESALs are the anticipated project traffic level expected on the design lane over a 20-yr period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 yr.

[b] For 37.5-mm nominal maximum size mixtures, the specified lower limit of the VFA range shall be 64 percent for all design traffic levels.

[c] For 4.75-mm nominal maximum size mixtures, the dust-to-binder ratio shall be 1.0 to 2.0, for design traffic levels <3 million ESALs, and 1.5 to 2.0 for design traffic levels ≥3 million ESALs.

[d] For 4.75-mm nominal maximum size mixtures, the relative density (as a percent of the theoretical maximum specific gravity) shall be within the range of 94.0 to 96.0 percent.

[e] For design traffic levels <0.3 million ESALs, and for 25.0-mm nominal maximum size mixtures, the specified lower limit of the VFA range shall be 67 percent, and for 4.75-mm nominal maximum size mixtures, the specified VFA range shall be 67 to 79 percent.

[f] For design traffic levels >0.3 million ESALs, and for 4.75-mm nominal maximum size mixtures, the specified VFA range shall be 66 to 77 percent.

[g] For design traffic levels ≥3 million ESALs, and for 9.5-mm nominal maximum size mixtures, the specified VFA range shall be 73 to 76 percent.

Tim.

Timothy L. Ramirez, P.E. | Engineer of Tests
PA Department of Transportation | Bureau of Project Delivery |
Construction and Materials Division | Laboratory Testing Section
81 Lab Lane | Harrisburg PA 17110-2543
Phone: 717.783.6602 | Fax: 717.783.5955
www.PennDOT.gov

Spoke with Joe DeVol of Washington DOT at the ETG meeting about the possibility of interpolating binder content for a 75 gyration design based on a 100 gyration test so a state or contractor could have two mixes from a single test.

Recommendations for Revisions to Criteria for the Design of 4.75 mm Mixtures

Randy C. West
National Center for Asphalt Technology

Background

The 4.75 mm mix design criteria were added to AASHTO specifications in 2004 based on a limited NCAT study with laboratory fabricated gradations and the experience of a few states with similar mixtures. However, many mix designers had difficulty developing suitable mix designs with those original 4.75 mm criteria. NCAT then completed Pooled Fund Study 930-615P aimed at revising the mix design specifications for 4.75 mm NMAS mixtures. This document summarizes the recommended changes to the AASHTO M323 standard that resulted from that study. For more detailed information, please see NCAT Report 10-04 available at www.ncat.us.

Although 4.75 mm mixtures have been used in a variety of pavement applications, their primary use has been for surface courses on low traffic volume roadways and thin overlays. With greater attention to pavement preservation in recent years, thin overlays with 4.75 mm mixtures have several key advantages. These mixes are typically placed ¾ to one inch thick, have excellent workability and provide good joints. Compared to other pavement preservation options, thin overlays can improve pavement smoothness and reduce tire-pavement noise. In many parts of the US, an excess of crushed fine aggregates exist. One of the original motivations for the development of 4.75 mm mixtures was to provide an economic opportunity for using these surplus stockpiles of fine aggregates. However, most mix design trials with high percentages of these materials resulted in very high VMAs and consequently high asphalt contents to achieve the design air void content of 4.0 percent. Therefore, some early attempts to use 4.75 mm mixtures had rutting problems and/or were not considered economical as binder prices escalated.

Summary of Recommended Changes

There are five areas in M323 that are recommended to be revised for 4.75 mm mix designs:

1. Reduction of the maximum percent passing the 1.18 mm sieve and increase the maximum percent passing the 0.075 mm sieve
2. Adding a fine aggregate angularity requirement for the lowest traffic category, and increasing the requirement for 0.3 to 3.0 million ESALs
3. Allowing a design air void content range of 4.0 to 6.0 percent
4. Adjusting the Voids Filled with Asphalt (VFA) criteria
5. Increasing the minimum dust-to-binder ratio

Most of these recommended changes are intended to improve the resistance of 4.75 mm mixtures to permanent deformation without sacrificing pavement durability or the economic advantage of using locally available materials in thin-lift applications.

Recommended Revision to Gradation Control Point

Shown below is Table 3 from M323 with the recommended revision to reduce the maximum percent passing the 1.18 mm sieve from 60 to 55, and to increase the maximum percent passing the 0.075 mm sieve from 12 to 13. In the pooled fund study, 4.75 mm mixtures with gradations approaching 60 percent on the 1.18 mm sieve were prone to excessive VMA and poor rutting resistance. Allowing a slightly higher dust content is the most sensible way to reduce the VMA of a mix design.

Table 1~~3~~—Aggregate Gradation Control Points

Sieve Size	Nominal Maximum Aggregate Size—Control Points (Percent Passing) 37.5 mm Min	37.5 mm Max	25.0 mm Min	25.0 mm Max	19.0 mm Min	19.0 mm Max	12.5 mm Min	12.5 mm Max	9.5 mm Min	9.5 mm Max	4.75 mm Min	4.75 mm Max
50.0 mm	100	—	—	—	—	—	—	—	—	—	—	—
37.5 mm	90	100	100	—	—	—	—	—	—	—	—	—
25.0 mm	—	90	90	100	100	—	—	—	—	—	—	—
19.0 mm	—	—	—	90	90	100	100	—	—	—	—	—
12.5 mm	—	—	—	—	—	90	90	100	100	—	100	—
9.5 mm	—	—	—	—	—	—	—	90	90	100	95	100
4.75 mm	—	—	—	—	—	—	—	—	—	90	90	100
2.36 mm	15	41	19	45	23	49	28	58	32	67	—	—
1.18 mm	—	—	—	—	—	—	—	—	—	—	30	~~60~~55
0.075 mm	0	6	1	7	2	8	2	10	2	10	6	~~12~~13

Recommended Revision to the Fine Aggregate Angularity Requirement for 4.75 mm Mixes
Table 5 from M323 is shown below with a footnote added to implement a minimum fine aggregate angularity criterion of 40 for the lowest traffic category and to increase the criterion from 40 to 45 for the next lowest traffic category for 4.75 mm mixtures used in layers within 100 mm of the pavement surface. These changes are also recommended to improve the deformation resistance of 4.75 mm mixtures.

Table 2~~5~~—Superpave Aggregate Consensus Property Requirements

Design ESALs[a] (Million)	Fractured Faces, Coarse Aggregate,[c] Percent Minimum — Depth from Surface ≤ 100 mm	Fractured Faces — > 100 mm	Uncompacted Void Content of Fine Aggregate, Percent Minimum — Depth from Surface ≤ 100 mm	Uncompacted Void Content — > 100 mm	Sand Equivalent, Percent Minimum	Flat and Elongated,[c] Percent Maximum
<0.3	55/—	—/—	—[d]	—	40	—
0.3 to <3	75/—	50/—	40[d]	40	40	10
3 to <10	85/80[b]	60/—	45	40	45	10
10 to <30	95/90	80/75	45	40	45	10
≥30	100/100	100/100	45	45	50	10

[a] The anticipated project traffic level expected on the design lane over a 20-year period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 years.

[b] 85/80 denotes that 85 percent of the coarse aggregate has one fractured face and 80 percent has two or more fractured faces.

[c] This criterion does not apply to 4.75-mm nominal maximum size mixtures.

[d] For 4.75 mm mixtures designed for traffic levels below 0.3 million ESALs, the minimum Uncompacted Void Content for is 40, and for traffic levels equal to or above 0.3 million ESALs, the minimum Uncompacted Void Content for is 45.

Recommended Revisions to Volumetric Criteria for 4.75 mm NMAS Mix Designs
To summarize the recommended changes to the current volumetric requirements, let us begin by reviewing Table 6 from AASHTO M323, shown below:

Table 3~~6~~— Current Superpave HMA Design Requirements

Design ESALs[a] (Million)	Required Relative Density, Percent of Theoretical Maximum Specific Gravity: $N_{initial}$	N_{design}	N_{max}	Voids in the Mineral Aggregate (VMA), Percent Minimum — Nominal Maximum Aggregate Size, mm: 37.5	25.0	19.0	12.5	9.5	4.75	Voids Filled with Asphalt (VFA) Range,[b] Percent	Dust-to-Binder Ratio Range[c]
<0.3	≤91.5	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	70–80[d]	0.6–1.2
0.3 to <3	≤90.5	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–78	0.6–1.2
3 to <10	≤89.0	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–75[e]	0.6–1.2
10 to <30	≤89.0	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–75[e]	0.6–1.2
≥30	≤89.0	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–75[e]	0.6–1.2

[a] Design ESALs are the anticipated project traffic level expected on the design lane over a 20-year period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 years.

[b] For 37.5-mm nominal maximum size mixtures, the specified lower limit of the VFA range shall be 64 percent for all design traffic levels.

[c] For 4.75-mm nominal maximum size mixtures, the dust-to-binder ratio shall be 0.9 to 2.0.

[d] For 25.0-mm nominal maximum size mixtures, the specified lower limit of the VFA range shall be 67 percent for design traffic levels <0.3 million ESALs.

[e] For design traffic levels > 3 million ESALs, 9.5-mm nominal maximum size mixtures, the specified VFA range shall be 73 to 76 percent and for 4.75-mm nominal maximum size mixtures shall be 75 to 78 percent.

The Table below is another way of presenting the same criteria, except with a minimum and maximum volume of effective binder rather than minimum criteria for VMA and a range for VFA. The Vbe range is a simpler concept to teach new technicians, since a minimum volume of effective asphalt is more intuitively related to mix durability and a maximum volume of effective asphalt can be easily understood to avoid an over-asphalted, unstable mix.

Table 4~~6~~—Superpave HMA Design Requirements, Same Criteria Except Vbe Range Rather than VMA & VFA

Design ESALs[a] (Million)	Required Relative Density, Percent of Theoretical Maximum Specific Gravity: $N_{initial}$	N_{design}	Volume of Effective Binder Range, Percent — Nominal Maximum Aggregate Size, mm: 37.5	25.0	19.0	12.5	9.5	4.75	Dust-to-Binder Ratio Range[c]
<0.3	≤91.5	96.0	7.4 -16.0	8.1-16.0	9.3-16.0	10.0-16.0	11.0-16.0	12.0-16.0	0.6–1.2
0.3 to <3	≤90.5	96.0	7.4 -16.0	8.0-14.2	9.0-14.2	10.0-14.2	11.0-14.2	12.0-14.2	0.6–1.2
3 to <10	≤89.0	96.0	7.4 -16.0	8.0-12.0	9.0-12.0	10.0-12.0	11.0-12.7	12.0-14.2	0.6–1.2
10 to <30	≤89.0	96.0	7.4 -16.0	8.0-12.0	9.0-12.0	10.0-12.0	11.0-12.7	12.0-14.2	0.6–1.2
≥30	≤89.0	96.0	7.4 -16.0	8.0-12.0	9.0-12.0	10.0-12.0	11.0-12.7	12.0-14.2	0.6–1.2

[a] Design ESALs are the anticipated project traffic level expected on the design lane over a 20-year period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 years.

[c] For 4.75-mm nominal maximum size mixtures, the dust-to-binder ratio shall be 0.9 to 2.0.

Note that since the volumetric criteria (and current Ndesign table) are exactly the same for the traffic levels of 3 to 10 million ESALs and 10 to 30 million ESALs, these rows can be combined for a slightly more streamlined table, as shown below.

Table ~~5~~6—Superpave HMA Design Requirements, Combined 3 to 10 and 10 to 30 since all criteria were the same

Design ESALs[a] (Million)	Required Relative Density, Percent of Theoretical Maximum Specific Gravity		Volume of Effective Binder Range, Percent						Dust-to-Binder Ratio Range[c]
			Nominal Maximum Aggregate Size, mm						
	$N_{initial}$	N_{design}	37.5	25.0	19.0	12.5	9.5	4.75	
<0.3	≤91.5	96.0	7.4 -16.0	8.1-16.0	9.3-16.0	10.0-16.0	11.0-16.0	12.0-16.0	0.6–1.2
0.3 to <3	≤90.5	96.0	7.4 -16.0	8.0-14.2	9.0-14.2	10.0-14.2	11.0-14.2	12.0-14.2	0.6–1.2
3 to <30	≤89.0	96.0	7.4 -16.0	8.0-12.0	9.0-12.0	10.0-12.0	11.0-12.7	12.0-14.2	0.6–1.2
≥30	≤89.0	96.0	7.4 -16.0	8.0-12.0	9.0-12.0	10.0-12.0	11.0-12.7	12.0-14.2	0.6–1.2

[a] Design ESALs are the anticipated project traffic level expected on the design lane over a 20-year period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 years.

[c] For 4.75-mm nominal maximum size mixtures, the dust-to-binder ratio shall be 0.9 to 2.0.

The following table shows NCAT's recommended volumetric changes for the design of 4.75 mm NMAS mixtures. Footnote "*b*" was added to permit the design air void content to range between 4.0 and 6.0%, or using the current convention, 94.0 to 96.0% of Gmm. Footnote "c" was revised to increase the minimum dust-to-binder ratio to 1.0 for the lower two traffic levels and to 1.5 for traffic levels equal to or above 3 million ESALs. Changes were also recommended in the Vbe criteria for 4.75 mm mix designs. A comparison of Table 3 and Table 4; the same Vbe criteria are recommended for the lower traffic levels, and the Vbe recommended for the traffic range of 3 to 30 million ESALs is reduced. Note that at this time, 4.75 mm mixtures are not recommended (as surface layers) for pavements with design traffic above 30 million ESALs due to unknown friction properties for high speed, high traffic roadways.

Table 6—Superpave HMA Design Requirements

Design ESALs[a] (Million)	Required Relative Density, Percent of Theoretical Maximum Specific Gravity		Volume of Effective Binder Range, Percent						Dust-to-Binder Ratio Range[c]
			Nominal Maximum Aggregate Size, mm						
	$N_{initial}$	N_{design}	37.5	25.0	19.0	12.5	9.5	4.75	
<0.3	≤91.5	96.0[b]	7.4 -16.0	8.1-16.0	9.3-16.0	10.0-16.0	11.0-16.0	12.0-15.0	0.6–1.2
0.3 to <3	≤90.5	96.0[b]	7.4 -16.0	8.0-14.2	9.0-14.2	10.0-14.2	11.0-14.2	12.0-15.0	0.6–1.2
3 to <30	≤89.0	96.0[b]	7.4 -16.0	8.0-12.0	9.0-12.0	10.0-12.0	11.0-12.7	11.5-13.5	0.6–1.2
≥30	≤89.0	96.0	7.4 -16.0	8.0-12.0	9.0-12.0	10.0-12.0	11.0-12.7		0.6–1.2

[a] Design ESALs are the anticipated project traffic level expected on the design lane over a 20-year period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 years.

[b] For 4.75-mm nominal maximum size mixtures, the relative density (as a percent of the maximum theoretical specific gravity) shall be within the range of 94.0 to 96.0.

[c] For 4.75-mm nominal maximum size mixtures, the dust-to-binder ratio shall be ~~0.9~~ 1.0 to 2.0 for design traffic levels <3 million ESALs, and 1.5 to 2.0 for design traffic levels ≥3 million ESALs.

Realizing that substituting Vbe criteria for the well established VMA and VFA criteria would not likely be well received by most practicing asphalt technologies, the VMA and VFA criteria are recommended with a few additional footnotes pertaining to VFA criteria for 4.75 mm mixtures.

Table 7~~6~~—Superpave HMA Design Requirements with Recommended Revisions for 4.75 mm NMAS mixtures

Design ESALs[a] (Million)	Required Relative Density, Percent of Theoretical Maximum Specific Gravity $N_{initial}$	N_{design}	N_{max}	Voids in the Mineral Aggregate (VMA), Percent Minimum — Nominal Maximum Aggregate Size, mm 37.5	25.0	19.0	12.5	9.5	4.75	Voids Filled with Asphalt (VFA) Range,[b] Percent	Dust-to-Binder Ratio Range[c]
<0.3	≤91.5	96.0[d]	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	70–80[~~d~~e]	0.6–1.2
0.3 to <3	≤90.5	96.0[d]	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–78[f]	0.6–1.2
3 to <10	≤89.0	96.0[d]	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–75[~~e~~f,g]	0.6–1.2
10 to <30	≤89.0	96.0[d]	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–75[~~e~~f,g]	0.6–1.2
≥30	≤89.0	96.0	≤98.0	11.0	12.0	13.0	14.0	15.0	16.0	65–75[~~e~~g]	0.6–1.2

[a] Design ESALs are the anticipated project traffic level expected on the design lane over a 20-year period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 years.

[b] For 37.5-mm nominal maximum size mixtures, the specified lower limit of the VFA range shall be 64 percent for all design traffic levels.

[c] For 4.75-mm nominal maximum size mixtures, the dust-to-binder ratio shall be ~~0.9~~1.0 to 2.0 for design traffic levels <3 million ESALs, and 1.5 to 2.0 for design traffic levels ≥3 million ESALs.

[d] For 4.75-mm nominal maximum size mixtures, the relative density (as a percent of the maximum theoretical specific gravity) shall be within the range of 94.0 to 96.0

[e] For design traffic levels <0.3 million ESALs, 25.0-mm nominal maximum size mixtures, the specified lower limit of the VFA range shall be 67 percent ~~for design traffic levels <0.3 million ESALs~~., and 4.75-mm nominal maximum size mixtures, the specified VFA range shall be 67 to 79.

[f] For design traffic levels ≥0.3 million ESALS, 4.75 mm nominal maximum size mixtures, the specified VFA range shall be 66 to 77.

[g~~e~~] For design traffic levels > 3 million ESALs, 9.5-mm nominal maximum size mixtures, the specified VFA range shall be 73 to 76 percent and for 4.75-mm nominal maximum size mixtures shall be 75 to 78 percent.

Additional Notes Regarding the Design and Construction of 4.75 mm Mixtures

In addition to the recommendations to refine the mix design criteria for 4.75 mm mixtures, there are several other research findings recommendations worth noting.

First, because 4.75 mm mixtures are often placed on existing surfaces with irregular profiles and grades, thicknesses of the mix are variable with an average thickness of less than one inch. Consequently, in-place density tests with gauges or cores) are not reliable and should not be used for acceptance and pay determinations. Fortunately, because of the fine gradations used with most 4.75 mm mixtures, the layers remain practically impermeable at in place densities as low as 88% of Gmm.

Second, the use of fine fractionated RAP is encouraged in 4.75 mm mixtures. Fine fractionated RAP typically has a higher asphalt content which can help reduce the virgin asphalt content and improve the economic viability of 4.75 mm mixes. The stiffer RAP binder and the high P0.075 mm content of the RAP will also help stiffen the 4.75 mm mix to improve its resistance to rutting and shoving.

Finally, a caution is given with regard to friction. Fine-graded 4.75 mm mixtures will have low macrotexture and could provide a skid hazard when used on high-speed roadways. Since friction is influenced by aggregate characteristics, pavement geometry, texture, and the presence of water, agencies are encouraged to closely monitor skid resistance of 4.75 mm mix surface layers on roadways with speed limits greater than 40 mph.

COMMITTEE ON MATERIALS AND PAVEMENTS

2018 Mid-Year Webinar
Thursday, February 1st, 2018
Noon – 2:00 PM MST

TECHNICAL SUBCOMMITTEE 2d
Proportioning of Asphalt – Aggregate Mixtures

I. **Call to Order and Opening Remarks** North Dakota is no longer a member of this Technical Subcommittee

II. **Roll Call (Voting Members – Page 7.)** AZ, AR, CA, CO, CT, ID, KS, KY, MO, MT, NV, OH, OK, RI, TN, UT, WA, WI, WY – Greg Milburn/Vice Chair

III. **Approval of Technical Section Minutes from 2017 SOM Annual Meeting in Phoenix, AZ** Motion: WI, second: MO

IV. **Old Business**
A. 2017 Concurrent Ballot Items

Item Number:	**28**		
Description:	Concurrent ballot item to revise TP 124, Determining the Fracture Potential of Asphalt Mixtures Using the Flexibility Index Test (FIT). Substantial revisions. See Pages 3-7 and 11-14 of the minutes and pages 35-57.		
Decisions:	Affirmative: 30 of 34 Negative: 0 of 34 No Vote: 4 of 34		
Agency (Individual Name)	**Comments**	**Decision**	**Response Attachment**
Florida Department of Transportation (Timothy J. Ruelke) (timothy.ruelke@dot.state.fl.us)	We still feel samples from cores with one cut face and one compacted face should be identified as such in the test report. Chair Action: This was addressed in section **13. REPORT** of the balloted method. Section 13.1.3 states "The number of cut faces for each specimen tested, if pavement cores were used." Move to publication.	Affirmative	

Item Number:	**29**
Description:	Concurrent ballot item to adopt a new provisional standard, Mix Design of Cold Recycled Mixtures Using Foamed Asphalt. See Pages 8 and 20-30 of the minutes and pages 58-61.
Decisions:	Affirmative: 30 of 34 Negative: 0 of 34 No Vote: 4 of 34

Item Number:	**30**
Description:	Concurrent ballot item to adopt a new provisional standard, Optimum Asphalt Content of Cold Recycled Mixtures Using Foamed Asphalt. See Pages 8 and 20-30 of the minutes and pages 62-69.
Decisions:	Affirmative: 30 of 34

	Negative: 0 of 34 No Vote: 4 of 34

Agency (Individual Name)	Comments	Decision	Response Attachment
Missouri Department of Transportation (Brett Steven Trautman) (brett.trautman@modot.mo.gov)	Affirmative vote with an editorial comment: 1) In Sections 3.2 and 3.3, believe the word "planning" is misspelled. Both sections currently show, "cold planning machine". Recommend changing to "cold planing machine". Chair Action: Make editorial changes. Missouri had the same comment on both item #29 and #30. Changes will be made.	Affirmative	

B. 2017 COMP Ballot Items

Item Number:	**31**
Description:	COMP ballot item to revise TP 107, Determining the Damage Characteristic Curve and Failure Criterion Using the Asphalt Mixture Performance Tester (AMPT) Cyclic Fatigue Tests. See Pages 2,3 and 10 of the minutes and pages 70-128.
Decisions:	Affirmative: 48 of 52 Negative: 0 of 52 No Vote: 4 of 52

Agency (Individual Name)	Comments	Decision	Response Attachment
Pennsylvania Department of Transportation (Timothy L Ramirez) (tramirez@pa.gov)	Editorial comments: 1) In Section 11.2, 2nd line, suggest revising from "of materials' " to "a material's ". 2) In Section 11.18, 2nd line, text is "at least 50 samples per second", but in the 8th line, text is "at least 50 specimens per second". Shouldn't similar text be used in both locations? 3) In Section 11.19, 4th line, suggest revising from "damage characteristic (C versus S curve) curve" to "damage characteristic (C versus S) curve" or "damage characteristic curve (C versus S curve)". 4) In Section 11.20, 2nd line, revise from "(in microstrain)for" to "(in microstrain) for" [i.e. add space between ")" and "for"]. Chair Action: Make editorial changes. Changes will be made.		
Oregon Department of Transportation (Greg Frank Stellmach) (greg.f.stellmach@odot.state.or.us)	In spite of the following comments, I vote yes on the proposed standard as written. The following comments are only for consideration in further development of the standard - I would recommend that in Section 1.2 the dimension be given as 1.0" rather than 0.98". Section 2.1 - PP 60 should be changed to say R 83. PP 61 should be changed to say R 84. TP 79 should be changed to say T378. Note 2 in Section 6.4 and Note 3 in Section 9.1 need to be renumbered. Section 9.1 - Change reference PP 60 to R 83. Note 4 in Section 11.8 and Note 5 in Section 11.13 need to be renumbered. Section 11.13 and Section 11.15 - Change reference TP 79 to T 378. Note 7 has a reference to Table 3, but I think the reference is supposed to be Table 2 Section 11.18 - Is the change of the last sentence to "...50 specimens per second..." appropriate? At the beginning of Section 11.18 it refers to "...at least 50 samples per second." I think that these two phrases are supposed to read the same, whichever way (samples/specimens) is more appropriate. Section 12.2 - Change reference PP 61 to R 84. Section 12.4 - Equation 3 - Should refer to "max E' " Section 12.4 - Equation 6 and Equation 12 are the same equation. Note 6 in Section 12.18, Note 7 in Section 12.19, Note 8 in Section 12.20, and Note 9 in Section 12.24 need to be renumbered. Section 12.33 - There seems to be a grammatical problem "... pseudo secant modulus from for each step..." Section X1.6 - Change reference TP 79 to T 378. Chair Action: Make editorial changes Changes will be made.	Affirmative	

Illinois Department of Transportation (Brian Pfeifer) (brian.pfeifer@illinois.gov)	Section 1.2, how is success defined? It may be more appropriate to state that NMAS greater than or equal to 25.0 mm may experience repeatability issues. Section 3, recommend defining steady state Table 1 load range, shouldn't the range specify a maximum value only?. Currently the seating load in 11.7 is less than the minimum load range in Table 1. Section 10, consider stating a required steel putty strength to better define where the point of full cure occurs. Section 12.4, do VMA and VFA percentages come from mix design or actual test specimens? Section X2, references NCHRP IDEA research. Consider include recommendations from Project 181 final report Chair Action: Refer these comments to author even though this was submitted by ILDOT. Proceed with publishing. Editorial changes will be made, Oak will contact Illinois about their questions.	Affirmative	
Missouri Department of Transportation (Brett Steven Trautman) (brett.trautman@modot.mo.gov)	Affirmative vote with a comment: 1) Section 11.18, the second sentence, it refers to loading at a rate of "at least 50 samples per second". The last sentence in Section 11.18 refers to "50 specimens per second". The wording should be consistent throughout the specification. Recommend using the word "specimen". Chair Action: Agreed. The terminology used elsewhere "asphalt mixtures" will be used. Editorial changes will be made, Oak will contact Illinois about their questions.	Affirmative	

Item Number:	**32**
Description:	COMP Ballot item to adopt a new provisional standard, Determining the Dynamic Modulus for Asphalt Concrete Using the Indirect Tension Test. See Pages 8-9, 18-20, and 31-34 of the minutes and pages 129-148.
Decisions:	Affirmative: 48 of 52 Negative: 0 of 52 No Vote: 4 of 52

Agency (Individual Name)	Comments	Decision	Response Attachment
Oregon Department of Transportation (Greg Frank Stellmach) (greg.f.stellmach@odot.state.or.us)	Section 1.1, and Section 4.1 - Consider using the same language as the title "indirect tension test" to be more consistent. Figure 3 - Dimension of the steel rod on the bottom plate may be inaccurate. Seems like the dimensions of the steel rod in the top left corner should be the same as the steel rod in the bottom right. Section 9.2.1 - Misspelling "gage points" in the third sentence. Table 5 â€“ Misspelling "Loose gage point" after "Standard Error > 10%". Misspelling "Move gage points" after "Uniformity > 30%". Chair Action: Make editorial changes. Gage is not necessarily misspelled. Oak will look to Publications to see if there is a standard spelling.	Affirmative	
Illinois Department of Transportation (Brian Pfeifer) (brian.pfeifer@illinois.gov)	Section 1.1, consider adding the word "up" between "sizes" and "to" Note 3, consider adding year of publication to Kim, et al Chair Action: Make editorial changes. Changes will be made.	Affirmative	
Missouri Department of Transportation (Brett Steven Trautman) (brett.trautman@modot.mo.gov)	Affirmative vote with a comment: 1) Is it necessary to insert the word "concrete" after the word "asphalt" in the title and the scope? Most specifications that have switched from "HMA" to be inclusive of warm mix asphalt have just used the word "asphalt". 2) Section 4.2 has a reference to "HMA" instead of "asphalt". Chair Action: See action for same comment above. "Asphalt Mixtures" is the term being used now.	Affirmative	

Item Number:	**33**
Description:	COMP Ballot item to adopt a new provisional standard, Preparation of Indirect Tension Performance Test Specimens. See Pages 8-9, 18-20, and 31-34 of the minutes and pages 149-160.
Decisions:	Affirmative: 48 of 52 Negative: 0 of 52

	No Vote: 4 of 52		
Agency (Individual Name)	**Comments**	**Decision**	**Response Attachment**
Oregon Department of Transportation (Greg Frank Stellmach) (greg.f.stellmach@odot.state.or.us)	Section 2.1 and Note 2 - PP 60 should be changed to say R 83. Section 2.2, Section 3.2, and Section 9.2 - Was there any discussion about using AASHTO R 67 instead of ASTM D 5361 as the procedure for taking asphalt cores? Oak believes we should be referencing the appropriate AASHTO standards, if they exist. Section 6.1, Note 2, Section 9.1, and Section 10.5.1 - I think that there is some confusion between these four references. Section 6.1 indicates the SGC should be able to make specimens a minimum of 150 mm. Section 10.5.1 says that the specimen should be cut into 2 pieces with thickness 38 to 50 mm. Note 2 says that the specimen height should be based on AASHTO PP60-14 (R 83). R 83 describes cutting the test specimen into 3 pieces. Section 9.1 says to prepare 2 gyratory specimens to produce 4 test specimens. It seems unclear whether or not the specimen is supposed to be cut into 2 pieces or 3. Specimens should be cut into two pieces as directed in section 6.1. Reference to R83 has to do with the uniformity of the specimen and how a lab can evaluate their chosen height to ensure it provides a uniform specimen. Section 10.1.2 - PP 60 should be changed to say R 83. It doesn't look like there was an "Appendix A" in either PP 60 or R 83. Note 2 and Note 4 - It doesn't look like there was an "Appendix B" in either PP 60 or R 83. Appendices are lettered X1 & X2, as opposed to A & B. Table 1 - Is the Thickness Specification appropriate? It is hard to read with the edits left on, but I thought that it was supposed to say " 38 to 50 mm". Should this table look more like Table 1 from R 83? It seems like the term used should be "height" rather than "thickness". Should the standard deviation of the diameter be listed as < 0.5 mm like it does in R 83? Is the standard deviation of the diameter necessary since 10.5.3.1 doesn't list it as a requirement for rejection? Section 2.2 - ASTM D3549 could be deleted since the references to it have been deleted. Section 10.5.3.1 â€“ Should check this again to make sure it says what it needs to say. As edited it seems to say that only one diameter measurement is supposed to be taken since the requirements of D 3549 were deleted. If only one measurement is taken, there is no reason to refer to the "average diameter" since there wouldnâ€™t be an average. Do they want to reject specimens that exceed the standard deviation of diameter. If they want to reject this should be stated. Section 10.5.3.2 â€“ Should check this again to make sure it says what it needs to say. The height is measured to the nearest 0.25 mm, but the standard deviation is supposed to be less than 0.25 mm. Iâ€™m not sure how easy it is to achieve a standard deviation that is the unit that you are measuring with. Not sure that the sentence "Reject specimens not meeting average and standard deviationâ€¦" is clear enough. In Table 1 average diameter is the only average listed, but I think in this section it is actually referring to "average thickness/height". The last sentence in this section about reporting average diameter and thickness doesnâ€™t completely make sense since this section is only about measuring the thickness. This section should probably have a "Record the average thickness" statement comparable to Section 10.5.3.1. Chair Action: Make editorial comments, refer dimensional questions to author for clarification. Changes will be made.	Affirmative	
Illinois Department of Transportation (Brian Pfeifer) (brian.pfeifer@illinois.gov)	Section 3.1, consider changing "minimal" to "minimum" Chair Action: I will consider it.	Affirmative	

Item Number:	**34**
Description:	COMP Ballot item to adopt a new provisional standard, Developing Dynamic Modulus Master Curves for Asphalt Concrete Using the Indirect Tension Test. See Pages 8-9, 18-20, and 31-34 of the minutes and pages 161-169.
Decisions:	Affirmative: 48 of 52

	Negative: 0 of 52 No Vote: 4 of 52

Agency (Individual Name)	Comments	Decision	Response Attachment
Oregon Department of Transportation (Greg Frank Stellmach) (greg.f.stellmach@odot.state.or.us)	Section 3.2 - Do they need to add the definition of Poisson's effect that was added to the Preparation of IDT Specimens procedure? Section 10.2.1 - Should say "Select the Reference Temperature" Chair Action: Make editorial changes and add Poisson's effect to Terminology section. Changes will be made.	Affirmative	
Illinois Department of Transportation (Brian Pfeifer) (brian.pfeifer@illinois.gov)	Section 9.1.2, are VMA and VFA from mix design or from actual test specimens? Section 10.1.1, references MEPDG, but other areas reference Pavement ME Chair Action: Make editorial changes. Refer questions to author. Oak will ask the author about this.	Affirmative	
Missouri Department of Transportation (Brett Steven Trautman) (brett.trautman@modot.mo.gov)	Affirmative vote with a comment: 1) Recommend removing the word "concrete" from behind the word "asphalt" where the words "hot mix" were removed. Need to be consistent throughout the specification and to be consistent with other AASHTO asphalt specification. Chair Action: See action for same comment above. "Asphalt Mixtures" will be used.	Affirmative	

C. Reconfirmation Ballot (All reconfirmed) All affirmative votes, no negatives, no comments. All will be reconfirmed.
   i. T 283
   ii. MP 23
   iii. PP 77
   iv. TP 108
   v. TP 125

D. Task Force Reports?
   i. No current task forces.

V. New Business

A. Research Proposals

B. ~~AMRL~~ AASHTO re:source/CCRL - Observations from Assessments?
   i. T 312 – "if required" language regarding top plates in SGC's. Email from Sonya Puterbaugh indicates this is still an issue so I will work on some clarifying language. "If required" appears in sections 9.1 and 9.2; language was the result of the original manufacturing of gyratory compactors; when different models came out, with ram on the bottom, the "if required" language came into play because the first devices had the ram on the top; Oak will try to develop some short and sweet language to clarify the requirement, such as "Heat the compaction surfaces of molds and base plates in accordance with manufacturer's recommendations"; need to be mindful that manufacturer's recommendations may not be available in all cases; this should be an editorial change since it's just for clarification purposes; Oak will be in touch with proposed language in the next couple of weeks

C. NCHRP Issues None mentioned.

D. Correspondence, calls, meetings None.

E. Proposed Revisions to Standards None.

F. Proposed New Task Forces None.

G. ETG Update Matt Corrigan was unable to make the meeting today. The work on M323 is still ongoing.

VI. Open Discussion

Randy West spoke on the NAPA mix design initiative. Many in the group chimed in on the topic.

VII. Adjourn Motion:

OH, second: WA. Meeting adjourned at 2:00 p.m.EST

From: Metcalfe, Ross (Oak) [mailto:rmetcalfe@mt.gov]
Sent: Thursday, September 22, 2016 3:19 PM
To: SOM_TS2d@aashto.org; Georgene
Cc: Evan Rothblatt; Katheryn Malusky @ Work
Subject: AASHTO T 312

All,

Apologies for the earlier mail, I hit send to fast. I'm writing to you all today to seek assistance on a question about the subject test method. I received a query asking for clarification on sections 9.1 and 9.2 of T 312. Specifically the reference to "(if required)" :

9.1. When the compaction temperature is achieved, remove the heated mold, base plate, and upper plate (if required) from the oven. Place the base plate and a paper disk in the bottom of the mold.

9.2. Place the mixture into the mold in one lift. Care should be taken to avoid segregation in the mold. After all the mix is in the mold, level the mix, and place another paper disk and upper plate (if required) on top of the leveled material.

There appears to be some confusion about what the "if required" is in reference too. The question comes from the interpretation that this is at the agency's request, i.e. if the Agency requires the upper plate or not.

My thought is this is referring to the fact that not all Superpave Gyratory Compactor manufacturers use a "top plate". As an example, Pine Instrument Company's AFG2 model uses what they refer to as a "mold top" which isn't a plate at all that is rotated into position and is secured by a tab/slot mechanism. Another example would be the Troxler Model 4140 which uses a mold and a "puck."

I haven't been able to trace the history of T 312 back past a few years and this is in all the versions. I see that Bob Lutz from AASHTO RE:source has already replied stating that my interpretation is correct. Is everyone else in agreement?

Thank you for your time and attention,

Ross "Oak" Metcalfe, P.E.
Testing Engineer/Physical Test Section Supervisor
Materials Bureau
406-444-9201
rmetcalfe@mt.gov

Name	Email Address	State	Designation	Member Type	Present
Metcalfe, Ross Oak	rmetcalfe@mt.gov	Montana	Chair	Voting	
Milburn, Greg	greg.milburn@wyo.gov	Wyoming	Vice Chair	Voting	
Blackburn, Lyndi D	blackburnl@dot.state.al.us	Alabama	Member	Voting	
San Angelo, P.E., Michael	michael.sanangelo@alaska.gov	Alaska	Member	Voting	
Burch, Paul	pburch@azdot.gov	Arizona	Member	Voting	
Benson, Michael C	michael.benson@arkansashighways.com	Arkansas	Member	Voting	
Schiebel, Bill R	bill.schiebel@state.co.us	Colorado	Member	Voting	
Lauzon, Robert G	robert.lauzon@ct.gov	Connecticut	Member	Voting	
Pinkerton, Jennifer M	Jennifer.Pinkerton@state.de.us	Delaware	Member	Voting	
Khan, Wasi U	wasi.khan@dc.gov	District of Columbia	Member	Voting	
Ruelke, Timothy J.	timothy.ruelke@dot.state.fl.us	Florida	Member	Voting	
Shishido, Eric	eric.shishido@hawaii.gov	Hawaii	Member	Voting	
Santi, Michael J	mike.santi@itd.idaho.gov	Idaho	Member	Voting	
Pfeifer, Brian	brian.pfeifer@illinois.gov	Illinois	Member	Voting	
Leibrock, Christopher	christopher.leibrock@ks.gov	Kansas	Member	Voting	
Myers, Allen H	allen.myers@ky.gov	Kentucky	Member	Voting	
Bradbury, Richard L	Richard.Bradbury@maine.gov	Maine	Member	Voting	
Barot, Sejal	sbarot@sha.state.md.us	Maryland	Member	Voting	
Grieco, John E	john.grieco@state.ma.us	Massachusetts	Member	Voting	
Turgeon, Curt	curt.turgeon@state.mn.us	Minnesota	Member	Voting	
Trautman, Brett Steven	brett.trautman@modot.mo.gov	Missouri	Member	Voting	
Tedford, Darin P	dtedford@dot.state.nv.us	Nevada	Member	Voting	
Boisvert, Denis M.	Denis.Boisvert@dot.nh.gov	New Hampshire	Member	Voting	
~~Horner, Ron~~	~~rhorner@nd.gov~~	~~North Dakota~~	~~Member~~	~~Voting~~	
Biehl, Eric R	eric.biehl@dot.ohio.gov	Ohio	Member	Voting	
Seiter, Scott	sseiter@odot.org	Oklahoma	Member	Voting	
Parker, Sean	Sean.P.Parker@odot.state.or.us	Oregon	Member	Voting	
Ramirez, Timothy	tramirez@pa.gov	Pennsylvania	Member	Voting	
Byrne, Michael P	michael.byrne@dot.ri.gov	Rhode Island	Member	Voting	
Feller, Joe J.	joe.feller@state.sd.us	South Dakota	Member	Voting	
Egan, Brian	brian.egan@tn.gov	Tennessee	Member	Voting	
Hazlett, Darren	darren.hazlett@txdot.gov	Texas	Member	Voting	
Andrus, Scott S	scottandrus@utah.gov	Utah	Member	Voting	
Gagulic, Mladen	mladen.gagulic@vermont.gov	Vermont	Member	Voting	
Williams, Kurt R	willikr@wsdot.wa.gov	Washington	Member	Voting	
Paye, Barry C	barry.paye@dot.wi.gov	Wisconsin	Member	Voting	
Lane, Becca	Becca.Lane@ontario.ca	Ontario	Associate Member	Voting	

8.1.6 Place the compaction mold(s) ~~and base plate(s)~~ in an oven at the required compaction temperature for a minimum of 30 min prior to the estimated beginning of compaction (during the time the mixture is being conditioned in accordance with R 30). Place any additional compaction surfaces, such as base plates and upper plates, into the oven with and for the same time frame as the molds, according to the manufacturer's instructions.

8.2.1 Place the compaction mold(s) ~~and base plate(s)~~ in an oven at the required compaction temperature (see section 8.1.7.1). Place any additional compaction surfaces, such as base plates and upper plates, into the oven with and for the same time frame as the molds, according to the manufacturer's instructions.

9.1 When the compaction temperature is achieved, remove the heated mold~~, base plate, and upper plate (if required)~~ and any compaction surfaces from 8.1.6 or 8.2.1from the oven. Place the base plate and a paper disk in the bottom of the mold.

9.2 Place the mixture into the mold in one lift. Care should be taken to avoid segregation in the mold. After all the mix is in the mold, level the mix, and place another paper disk ~~and upper plate (if required)~~ on top of the leveled material. Complete any remaining mold assembly, load the mold into the compactor, and center the loading ram according to the manufacturer's instructions.

~~9.3 Load the charged mold into the compactor, and center the loading ram.~~

9.~~4~~3 Apply a pressure of 600 ± 18 kPa on the specimen.

Title	Laboratory Aging Protocols for Assessing the Cracking Resistance of Asphalt Mixtures
Background / Description	Cracking is a primary form of asphalt pavement distress often controlling the service lives of highway projects. Cracking of surface layers is significantly affected by aging of the asphalt binder over time. However, asphalt binders age at different rates depending on their chemical composition, climate, and depth in the pavement structure. Several research studies have been critical of the current long-term aging protocol in AASHTO R30 that recommends aging compacted specimens for 5 days at 95°C prior to mixture performance testing. The ongoing NCHRP 9-54 project has recommended loose mix aging at 95°C for a period of time based on climate, depth, and years of service. For surface layers with four years of service, aging time using this protocol ranges from 72 to 120 hours for most of the continental U.S. Although the loose mix aging protocol seems to be a better approach to simulate the long-term aging of asphalt mixtures, the recommended times are not practical for use in routine projects. The selection of 95°C for oven aging was based on laboratory test results showing that aging at 135°C reduces the dynamic modulus and fatigue resistance of asphalt mixtures, and literature that indicates chemical changes occurring in some binders at temperatures above 100°C due to disruption of polar molecular associations and sulfoxide decomposition. However, it is important to mention that the sensitivity of sulfoxides to thermal decomposition is not identical for all asphalt binders. Furthermore, existing literature recognizes the importance of asphalt component compatibility (i.e., dispersion of micellar components) on its oxidative age hardening behavior. Certain asphalt binders are more chemically reactive and less susceptible to aging due to a greater extent of solubilization and/or dispersion of the oxidation products. These findings are of major importance to asphalt oxidative age hardening and highlight the risk of using loose mix aging at 95°C to simulate field aging because asphalt binders have different chemical compositions and physicochemical states (i.e., degree of molecular association and immobilization). In addition, the NCHRP 9-54 project only evaluated three asphalt binders with different chemistries (i.e., one binder with low sulfur content, one binder with high sulfur content, and one polymer modified binder) in the experiment to select the laboratory aging temperature, which is not sufficient to reach a comprehensive conclusion considering the wide variety of aging behaviors of asphalt binders from different crude sources and refining processes. It is worth noting that some asphalt binders may not exhibit significantly different aging behavior

	over a fairly wide temperature range, while others exhibit significant differences. For assessing the cracking resistance of asphalt mixtures as part of mix design and during mixture production, the goal of the laboratory aging should be to simulate properties that exist in-situ when cracking begins to develop. Therefore, accelerated oxidative aging in laboratory always involves a tradeoff when considering the potential adverse effects caused by the selected testing conditions. Moreover, it is important to consider that the oxidation process can only explain part of the changes observed in the rheological properties of asphalts, since it is the interactions of some oxidation products with each other and with other polar groups in asphalt that lead to large changes in physical properties and affect the overall pavement service life. In this situation, the binder oxidation kinetics may not be fully simulated at either lower or higher aging temperatures and some sacrifice of precision may be acceptable in the interest of expediency.
Objective	To develop practical protocols for laboratory aging of asphalt mixtures to prepare specimens for cracking tests used for mix design and quality assurance testing that considers the location of asphalt mixtures in the pavement structure and the amount of time in service at which cracking is likely to initiate.
Potential Benefits	Improved methods are needed to properly assess the cracking resistance of asphalt mixtures as their component materials become more complex and innovative modifiers are introduced. A critical step toward implementation of better methods for the design and field acceptance of asphalt mixtures is the preparation of specimens to represent the conditions at which distresses begin to develop.
Related Research	NCHRP Report 815 confirmed that two hours of loose mixture conditioning at the anticipated compaction temperature was appropriate for simulating the effects of plant mixing and storage to the point of loading in haul trucks. The study also concluded that the long-term aging protocol per AASHTO R30 was only able to simulate two or three years of field aging. Research studies by the University of New Mexico and Mississippi State University concluded that the long-term aging protocol per AASHTO R30 was representative of no more than one year of field aging. NCHRP Report 871 recommended loose mix aging at 95°C and developed a series of laboratory aging duration maps to match 4, 8, and 16 years of field aging at various depths below the pavement surface.

Proposed Tasks	1. Review literature and survey industry and state highway agencies to identify specific materials with a range of aging susceptibilities. Identify existing pavements with appropriate service life from a wide range of geographic areas. Pavements must have as-produced material available and pavement distress data at regular intervals. Candidate project sites may include the LTPP program, MnROAD, NCAT test track, and other field sections documented in published research studies. 2. Leverage existing research to propose alternative mixture aging protocols based on asphalt binder tests to assess changes in both chemical and rheological properties from in-situ and accelerated laboratory aging as well as practical mixture tests to assess the potential for all modes of cracking. To better understand factors that may affect aging, procedures considered in the research plan may include: (a) loose mix aging over a wide range of temperatures from 95 to 135°C, and (b) weathering systems that simulate cyclic actions of thermal oxidation, ultraviolet radiation, and moisture infiltration and diffusion. 3. Develop and execute an experimental plan to develop or validate relationships between in-situ aging and laboratory aging protocols. 4. Develop appropriate mixture aging protocols in the format of an AASHTO standard practice for mixtures used in different layers of a pavement structure. 5. Assess risks associated with the use of the proposed accelerated aging protocols as part of mix design approval and quality assurance.
Implementation	The anticipated product from this research is a draft mixture aging protocol following an AASHTO standard practice format. The users of this product will be highway agencies who specify performance tests for mix design and quality assurance and contractors engaged in the design and construction of asphalt pavements. The likelihood of successful implementation will depend on the practicality of how well the protocol can be used in routine testing.
Relevance	Aging is a primary factor in the cracking resistance of asphalt pavements. As asphalt binder markets continue to change, more recycled products are incorporated into mixtures, and new additives are introduced, it becomes more critical to consider aging within mix design and quality assurance testing. Therefore, a practical aging protocol is needed for preparing mixture samples for routine testing and analysis.
Estimated Funding	$800,000
Estimated Research Period	36 Months

RNS Developer	Randy West (westran@auburn.edu), Andrew Hanz, Fan Yin, and Raquel Moraes
Source Info:	• Kim, Y.R., S. Underwood, and M.J. Farrar (2017) NCHRP Report 871 Pre-Publication Draft, Long-Term Aging of Asphalt Mixtures for Performance Testing and Prediction, The National Academies of Science, Engineering, and Medicine. • Newcomb, D. et al (2016) NCHRP Report 815 Short-Term Laboratory Conditioning of Asphalt Mixtures, The National Academies of Science, Engineering, and Medicine. • Chen, C. et al (2018) Selecting a Laboratory Loose Mix Aging Protocol for the NCAT Top-Down Cracking Experiment, accepted for publication in Transportation Research Record. • Islam, M. R., Hossain, M. I., & Tarefder, R. A. (2015). A study of asphalt aging using Indirect Tensile Strength test. Construction and Building Materials, 95, 218-223. • Howard, I. L., & Doyle, J. D. (2015). Durability Indexes via Cantabro Testing for Unaged, Laboratory-Conditioned, and One-Year Outdoor-Aged Asphalt Concrete. In Transportation Research Board 94th Annual Meeting (No. 15-1366).
Date Developed:	March 9, 2018

Title:

Development of a Targeted Mixture Test for Asphalt Concrete Pavement Top-Down Cracking Evaluation

Background (Research Needs):

Top-down cracking (TDC) is a major form of pavement distress and is currently considered in the Pavement ME Design process; however, the predictions are based upon experiments where the mechanism of failure is not reflective of those mechanisms occurring in TDC (e.g., bending beam fatigue tests). These mechanisms have not been shown to accurately reflect the nature of the TDC, which is strongly related to interactions of mixture properties, pavement structures, and loading-environmental conditions. The structural-material interactions that lead to TDC are not the same as those leading to bottom-up fatigue cracking. Using test results that do not explicitly recognize this difference subsequently introduces bias in TDC predictions. Improper predictions/identification of TDC may lead to improper maintenance and rehabilitation decisions that ultimately increase agency costs. A clear knowledge gap that remains unsolved (or will still be unsolved at the completion of ongoing efforts) is a test method that can accurately incorporate the structural-material interactions occurring in TDC. Such a method should directly relate to the relevant distress and assess key properties such that mixtures can be screened for susceptibility to TDC and the resulting properties can be used in pavement design-analysis process.

The goal of this research is to develop/improve a test method suitable for better identifying the key properties related to TDC based upon the findings from relevant studies including NCHRP 1-42, 1-42A, and 1-52. The test method should consider the following: the unique structural and loading factors that lead to TDC, mixed-mode cracking, temperature-dependent behavior, rate-dependent cracking, role of oxidative aging, healing, and interactions among the constituents in the mixtures. The resulting test should be a structurally informed method for assessing TDC potential of asphalt mixtures that is amenable to both structures (e.g., pavement analysis/design) and mixtures (e.g., balanced mix design).

Related Research:

Over the past several decades, many regional (state-level and pooled-fund studies), national (several NCHRP projects such as 1-41, 1-42, 1-42A, 1-52, 9-19, 9-30A, 9-57), and international attempts have been made to improve the characterization of asphalt mixtures and pavements based on more use of mechanistic approaches. These efforts have resulted in a suite of tests capable of evaluating the key pavement distresses (i.e., rutting, fatigue cracking, and thermal cracking), but as of yet no similar method to specifically evaluate TDC exists. With respect to TDC though, projects 1-42 and 1-42A proposed potential mechanisms responsible for TDC and verified the potential for these mechanisms and other structural factors through pavement performance modeling. NCHRP 1-52, which has recently been completed, is building upon these efforts to develop a calibrated, validated mechanistic-empirical (ME) model to incorporate into the Pavement ME Design procedures. The National Center for Asphalt Technology (NCAT) have also operated test tracks since 2015 to better understand interactions between pavement TDC and material characteristics. The various efforts clearly demonstrate that TDC is recognized as a primary contributor to the degradation of asphalt pavements.

Fatigue cracking and thermal cracking can be related to TDC, but the role of structure subjected to loading-environmental conditions quite differ. As a result, a test protocol to specifically evaluate mixtures for pavement TDC does not exist. It is also well known that the fatigue cracking (both top-down and bottom-up) at intermediate service temperatures is sensitive to loading rates, temperatures, and aging due to material viscoelasticity, with most fractures occurring under a combination of opening and shearing displacement (so-called mixed-mode fracture). Accurate characterization and understanding of the rate- and mode-sensitive cracking phenomenon with environmental conditions has not been fully surmounted in asphalt pavement community, in spite of its significance and physical observation. This research is therefore strongly related to many other pre-existing and on-going studies but is clearly distinguished from those with specific targets to develop/improve a test method suitable for identifying the key properties related to TDC in pavements. The work may also relate to and build upon research conducted in NCHRP 9-52 and 9-54, since TDC is closely related to oxidation induced stiffening and embrittlement of surface layers. For the same reason, it may also relate to work conducted in NCHRP 9-44A, which integrated healing into the fatigue endurance limit prediction process.

Objective:
The objective of this research is to provide researchers and practitioners with a simple, yet fundamental, mechanics-based test method that can be used in routine characterization of TDC resistance of asphalt mixtures.

Proposed Tasks:
1. Evaluate the current tests and relevant methods for characterizing the fracture of asphalt mixtures. Efforts in this task should coordinate closely with NCHRP 9-57 and 9-57A to eliminate substantial overlap where possible.
2. Identify the core mixture properties (such as fracture properties) and their relation to structural-environmental factors related to TDC resistance. Efforts in this task will target to incorporate with the most-recent ME pavement design approaches.
3. Develop, modify (where possible), and/or advance (where needed) a test method suitable for identifying the core properties related to TDC in pavements. Efforts in this task will consider the inherent nature of TDC including the unique structural and loading factors that lead to TDC, mixed-mode cracking, temperature-dependent behavior, rate-dependent cracking, role of oxidative aging, healing, and interactions among the constituents in the mixtures.
4. Validate the test method to eventually propose (or recommend) a protocol that highway engineers will use to evaluate mixtures.
5. Develop a Draft AASHTO specification for the proposed method, circulate to ETG's, etc. for comment, and revise.

Potential Benefits:
This project will result in a test method that is practically implementable and properly addresses TDC behavior of asphalt mixtures in pavements. Moreover, outcomes of this project can bring substantial cost savings by permitting better selection of materials to significantly mitigate TDC. This can lead to better selection of paving materials and improved integration of the material and structural design processes against TDC, which current practices, including those outlined in the Pavement ME Design system, are limited.

Implementation:
The results of this research will be used by highway agencies, asphalt mixture designers, and asphalt paving contractors to produce more durable, longer-lasting asphalt mixtures and pavements. Implementation will require proposers to develop explanatory videos of the test methods as well as a draft AASHTO-ready standard. The standard should be reviewed and commented on by the mixture ETG. Based on the timing of the research project ETG review may have to occur in a follow-on activity. Champions will be needed to move forward with a ruggedness study and inter-laboratory study of the resultant test method.

Relevance:
Pavement TDC is a major pavement distress that must be managed and corrected by agencies. Many efforts by NCHRP and others have resulted in laboratory test methods targeting bottom-up fatigue cracking and thermal cracking. The bottom-up fatigue cracking and thermal cracking can be related to TDC, but the role of structure and materials subjected to loading-environmental conditions quite differ. As a result, a test method to specifically evaluate mixtures for pavement TDC does not exist. This research will result in a test method that can be used by agencies, asphalt contractors, and material designers to implement materials that better resist TDC. The primary research outcome (a test method) can be adopted by agencies for many practical activities related to material screening, pavement analysis/design, and balanced mix design approaches.

Proposed Funding and Period:
600~750K for 3 years

Standard Method of Test for

Moisture Sensitivity Using Hydrostatic Pore Pressure to Determine Cohesion and Adhesion Strength of Compacted Asphalt Mixture Specimens

AASHTO Designation: TP xxx-yy[1]
Release: Group n (Month yyyy)

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

Standard Method of Test for

Moisture Sensitivity Using Hydrostatic Pore Pressure to Determine Cohesion and Adhesion Strength of Compacted Asphalt Mixture Specimens

AASHTO Designation: TP xxx-yy
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1. SCOPE

1.1. This test method includes procedures for preparing compacted asphalt mixture specimens, exposing the specimens to prolonged exposure to moisture and hydrostatic pore pressure inside an enclosed chamber and testing the effect of water on the indirect tensile strength and swell of the specimens.

1.2. Units—The values stated in either SI units or U.S. Customary units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3. This standard may involve hazardous materials, operations, and equipment. It does not purport to address all of the safety concerns 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.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- R 47, Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size
- R 68, Preparation of Asphalt Mixtures by Means of the Marshall Apparatus
- R 79, Vacuum Drying Compacted Asphalt Specimens
- T 166, Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures
- T 168, (D979) Sampling Bituminous Paving Mixtures
- T 209, Theoretical Maximum Specific Gravity (G_{mm}) and Density of Hot Mix Asphalt (HMA)
- T 247, Preparation of Bituminous Mixture Test Specimens by Means of California Kneading Compactor
- T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- T 283, Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage
- T 312, Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor
- T 331, Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Automatic Vacuum Sealing Method

2.2. *ASTM Standards:*

- D3549 Thickness or Height of Compacted Bituminous Paving Mixture Specimens
- D4867 Test Method for Effect of Moisture on Asphalt Concrete Paving Mixtures
- D6857 Test Method for Maximum Specific Gravity and Density of Bituminous Paving Mixtures Using Automatic Vacuum Sealing Method

3. SUMMARY OF TEST METHOD

3.1. Asphalt mixture specimens are prepared using the methods described in R 68, T 247 or T 312. The bulk specific gravity (density) of each specimen is measured using T 166 or T 331. A subset of specimens is moisture conditioned by exposing them to moisture at high temperature for 20 hours to test for adhesion strength and then using cyclically increasing and decreasing hydrostatic pore pressure to test for cohesion strength. After conditioning, the density of each specimen is measured and compared to the density obtained prior to conditioning to determine the swell or density change of the specimen. Then, the indirect tensile strength is measured for each conditioned and unconditioned specimen. The tensile strength ratio for these specimens is calculated to evaluate the effect of moisture damage on the mixture specimens. Finally, a visual or surface evaluation of moisture damage is performed. The extended exposure to moisture at high temperature and cyclic pressure helps in determining moisture damage susceptibility of the specimens from both adhesion and cohesion failures that can occur in the field.

4. SIGNIFICANCE AND USE

4.1. This test method provides an accelerated conditioning method for moisture exposure that can cause adhesive and cohesive strength failures in asphalt mixtures. The mixture response to moisture exposure is amplified by using high temperature and cyclic hydrostatic loading. The system described in the apparatus section is capable of operating at higher than normal temperatures and creating hydrostatic pore pressure within a compacted asphalt mixture to achieve an acceleration of the effects that a mixture would experience over time from traffic at normal temperatures and moisture conditions. The accelerated conditioning in this method is intended to simulate the stresses induced in a wet pavement by a passing vehicle tire.

4.2. The factors that influence the potential for moisture damage to occur in asphalt mix include aggregate mineralogy, mixture air voids, water, cyclic applied stress, and elevated temperature. This test method provides a method and apparatus that is capable of producing three of these factors: water, stress, and high temperature.

4.3. Specimens conditioned in this test method are evaluated using the tensile strength ratio, percentage of swell, visual inspection and surface evaluation of stripped aggregates

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5. APPARATUS[1]

5.1. Equipment for compacting specimens according to R 68, T 247, or T 312

5.2. Balance in accordance with M 231.

5.3. Water bath capable of maintaining a temperature of 25 ± 1°C [77 ± 2°F].

[1] The sole source of supply of the apparatus known to the committee at this time is InstroTek, Inc., 5908 Triangle Drive, Raleigh, N.C. If you are aware of alternative suppliers, please provide this information to AASHTO. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

5.4. System (schematic shown in Fig. 1) having a pressure chamber and capable of applying cyclic hydrostatic pressure to condition specimens. The system shall be capable of conditioning a total of three 100 mm [4 in.] in diameter and 63.5 ± 2.5 mm [2.5 ± 0.10 in.] high specimens or two 150 mm [6 in.] in diameter and 95 ± 5 mm [3.75 ± 0.20 in.] high specimens. The system shall be capable of applying cyclic hydrostatic pressure with a peak pressure within ±30 kPa [±4 psi] of the pressure set point and a pressure duration of 2.0 +/- 1.0 s at or above one-half of the maximum peak pressure.

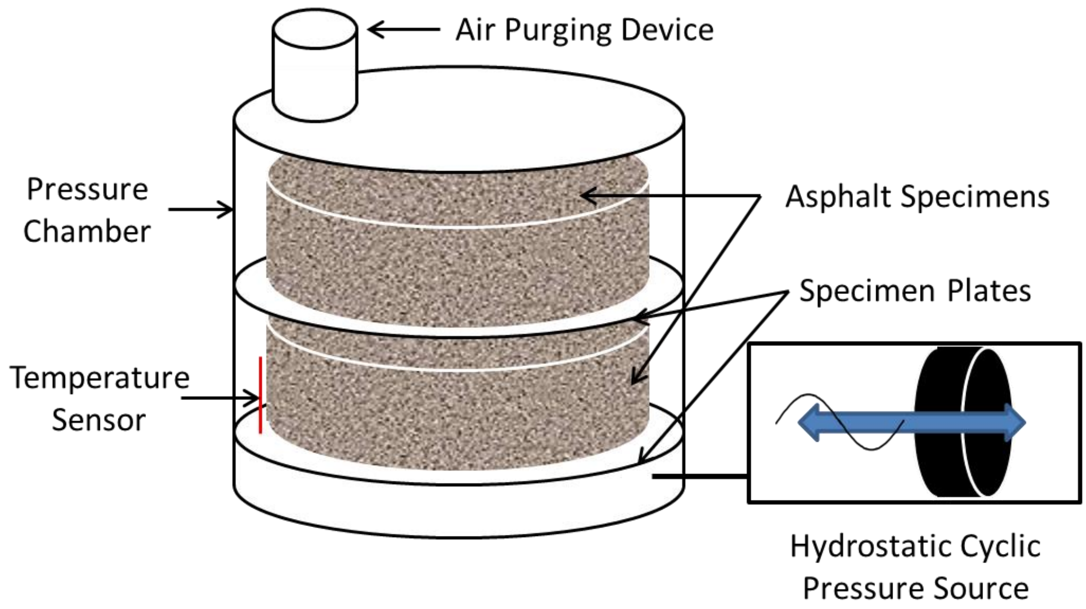

Figure 1 – Moisture Conditioning System

5.4.1. The pressure chamber shall be capable of withstanding pressures of up to 485 kPa [70 psi].

5.4.2. The system shall be capable of producing and controlling cyclic pressures within the pressure chamber between 200 and 420 kPa [30 to 50 psi] with measurements accurate to within ±30 kPa [±4 psi].

5.4.3. The system shall be capable of heating the water and controlling the temperature between 30 and 70°C [86 to 158°F] with measurements accurate to within ±1°C [±2°F] for a predetermined period of time. Then, it shall automatically start the cyclic hydrostatic pressure conditioning.

5.4.4. The system shall be equipped with the ability to automatically purge and remove air from the pressure chamber, and then replace the accessible air void spaces with water.

5.4.5. The system shall have plates and spacers to prevent a specimen from resting on another specimen during conditioning.

5.5. One or more containers sufficient in size to hold water and specimen(s) at 25 ±1°C [77 ±2°F] to perform T 166 or T 331.

5.6. Water bath capable of controlling the temperature of water between 30 and 60°C and maintaining the desired temperature within ±1°C [±2°F]. The temperature of the water bath must be verified by an external thermometer.

5.7. A device that supports the specimen to prevent damage to the hot specimen while transferring the specimen from the water bath and placing it into the pressure chamber.

5.8. Thermometric device to measure the temperature of the water bath in Section 5.6. Use the thermometric device with a minimum accuracy of 0.5°C [1.0°F].

6. PREPARATION OF LABORATORY-MIXED, LABORATORY-COMPACTED SPECIMENS

6.1. Make at least six 100 mm [4 in.] diameter specimens or at least four 150 mm [6 in.] diameter specimens.

6.2. Use specimens that are 100 mm [4 in.] in diameter and 63.5 ± 2.5 mm [2.5 ± 0.10 in.] high or 150 mm [6 in.] in diameter and 95 ± 5 mm [3.75 ± 0.20 in.] high. If aggregate larger than 25 mm [1.0 in.] is present in the mixture, use specimens 150 mm [6 in.] in diameter.

6.3. Follow the procedures in R 68 or T 312 to prepare and condition each asphalt mixture sample. If preparing a multi-specimen batch, split the batch into single-specimen quantities before placing the mixture in the oven.

6.4. Compact the specimens using one of the following methods: R 68, T 247, or T 312. Compact the specimens to 7.0 ± 0.5 percent air voids.

6.5. Extract the specimen from the mold and cool to room temperature.

7. PREPARATION OF FIELD-MIXED, LABORATORY-COMPACTED SPECIMENS

7.1. Obtain a sample from the field in accordance with T 168. Reduce the sample in accordance with R 47.

7.2. Make at least six 100 mm [4 in.] diameter specimens or at least four 150 mm [6 in.] diameter specimens. Use specimens that are 100 mm [4 in.] in diameter and 63.5 ± 2.5 mm [2.5 ± 0.10 in.] high or 150 mm [6 in.] in diameter and 95 ± 5 mm [3.75 ± 0.2 in.] high. If aggregate larger than 25 mm [1.0 in.] is present in the mixture, use specimens 150 mm [6 in.] in diameter.

Note 1— The user is cautioned that the specimen diameter has been determined to influence both the tensile strength and the tensile strength ratio. The tensile strength and the tensile strength ratio values may be different for 150 mm [6 in.] specimens compared to 100 mm [4 in.] specimens.

7.3. Compact the specimens in accordance with Section 6.4. If compacting to a target percent air void to match compaction at the time of construction, all individual samples conditioned shall not be more than ± 0.5 % different from the target percent air void.

8. DENSITY, THICKNESS AND GROUPING OF SPECIMENS

8.1. Record the specimen thickness (t) in accordance with D3549.

8.2. Record the nominal diameter of each specimen.

8.3. Determine the theoretical maximum specific gravity of each specimen using T 209 or D6857. Determine the bulk specific gravity of each specimen (Gmb) using T 166 or T 331.

8.4. Calculate the percent air voids using T 269.

8.5. Separate the specimens into two subsets, of at least two specimens of 150 mm [6.0 in.] in diameter or three specimens of 100 mm [4.0 in.] in diameter for each subset, so that the average air voids of the two subsets

are approximately equal. One subset will be conditioned using the apparatus in Section 5.4 and the other subset will not be conditioned before testing according to T 283.

9. CONDITIONING PROCEDURE

9.1. For mixtures containing PG high temperature grades higher than 60, the conditioning temperature is 60°C [140°F]. For mixtures with PG high temperature grades less than 60 and all Warm Mix Asphalt (WMA) mixtures, the conditioning temperature is 50°C [122°F].

9.2. The pressure chamber of the system or an external water bath system can be used to perform the non-cyclic conditioning. Set the temperature controller to the temperature required in Section 9.1.

9.3. Perform the hot water conditioning.

9.3.1. Using an external water bath -

9.3.1.1. Place the specimens on transfer devices and insert them into the water bath.

9.3.1.2. Condition the specimens for 20 hours ± 15 minutes at the conditioning temperature required in Section 9.1. The temperature should be controlled to within ±1°C [± 2°F].

9.3.2. Using the pressure chamber of the system -

9.3.2.1. Place the specimens into the chamber and fill the chamber with water according to the manufacture's recommendations.

9.3.2.2. Start the system according to the manufacture's recommendations. The system should heat the water to the conditioning temperature and maintain the temperature to within ±1°C [± 2°F] for 20 hours ± 15 minutes.

9.4. Prepare specimens for the cyclic hydrostatic pressure conditioning.

9.4.1. Using an external water bath -

9.4.1.1. Before moving the specimens into the pressure chamber of the system, pour hot water from the water bath into the pressure chamber. Follow manufacturer's recommendations for filling the pressure chamber with hot water.

9.4.1.2. Place the specimens in the pressure chamber using the transfer device according to the manufacturer's recommendations and fill with sufficient water at 35 to 60°C [95 to 150°F] to cover the specimens.

Note 2 — The specimens can be easily deformed at elevated test temperatures. Use extreme care when moving the specimens from the water bath to the pressure chamber.

9.4.2. If using the pressure chamber to perform the hot water conditioning, the samples will remain in the pressure chamber and the system will automatically start the cyclic hydrostatic pressure conditioning.

9.5. Perform the cyclic hydrostatic pressure conditioning by exposing the specimens to 3500 cycles of hydrostatic pressure with a peak pressure of 275 kPa [40 psi] while maintaining the conditioning temperature.

9.6. When the cyclic hydrostatic pressure conditioning is completed, the drain valve should open and allow all water to drain.

9.7. Pour sufficient tap water, 10 to 27°C [50 to 80°F], in the pressure chamber to cover the specimens. Allow for the specimens to cool for at least 2 minutes after submersion with tap water. This will help reduce the specimens' temperature and to ensure the specimens do not fall apart during removal from the chamber.

9.8. Carefully remove the specimens from the pressure chamber and place the specimens in a water container capable of maintaining a temperature of 25 ± 1°C [77 ± 2°F] for 2 h to 3 h. Specimens shall not be stacked directly on top of each other at any time during or after the conditioning process

10. TESTING PROCEDURE

10.1. Measure the bulk specific gravity (Gmb_{final}) of the specimen after conditioning according to T 166 or T 331. If using T 331, dry the sample to constant weight according to R79.

10.1.1. Use the same dry weight as the one used to determine the initial bulk specific gravity.

10.1.2. Measure the required weights to determine the bulk specific gravity according to T 166 or T 331.

10.2. Use T 283 to measure the indirect tensile (IDT) strength of both the dry and wet subsets of specimens.

10.3. Record the visual moisture damage according to T 283.

11. CALCULATIONS

11.1. Calculate the indirect tensile (IDT) strength of each specimen using test method T 283.

11.2. Calculate the tensile (IDT) strength ratio of the average of each subset using test method T 283.

11.3. Calculate the percent change in bulk specific gravity of the specimen after conditioning compared to before conditioning as follows:

$$Gmb\ Swell\ (\%) = \frac{Gmb - Gmb_{final}}{Gmb} * 100 \qquad (1)$$

where:

$Gmb\ Swell$ – percentage change in bulk specific gravity of specimen (%)

Gmb – bulk specific gravity before conditioning

Gmb_{final} – bulk specific gravity after conditioning.

12. REPORT

12.1. Report the following information:

12.1.1. Type of samples tested (laboratory-mixed, laboratory-compacted or plant-mixed, laboratory compacted) and description of mixture (such as nominal maximum aggregate size, gradation, binder type).

12.1.2. The measured height and nominal diameter of each specimen, to the nearest 1 mm.

12.1.3. Test temperature, to the nearest 1°C [2°F].

12.1.4. Maximum indirect tensile (IDT) load of each specimen, to the nearest 50 N [10 lbs.]

12.1.5. Average air voids of each subset.

12.1.6. The IDT strength of each of the replicate specimens and the average IDT strength for the set of specimens, to the nearest 5 kPa [1 psi].

12.1.7. Report the tensile strength ratio (TSR), to the nearest 0.01.

12.1.8. The Gmb swell of each of the replicate specimens and the average swell for the set of specimens, to the nearest 0.1%.

12.1.9. Report the visual moisture damage rating (Scale of “0” to “5” with “%” being the most stripped).

13. PRECISION AND BIAS

13.1. The within-laboratory single-user repeatability standard deviation for the indirect strength test for a conditioned sample has been determined to be 77 kPa [11 psi]. This standard deviation was calculated from 9 mixtures from North Carolina. The mixtures included nominal maximum sized aggregate (NMSA) between 9.5 and 25 mm [3/8 and 1 inch] for low, moderate, and high traffic pavements. The between-laboratory reproducibility of this test method is being determined and will be available before January 2021. Therefore, this Standard should not be used for acceptance or rejection of materials for purchasing purposes.

13.2. The within-laboratory repeatability standard deviation for the percentage density change has been determined to be 0.2% based on the same mixtures described in Section 13.1. The between-laboratory reproducibility of this test method is being determined and will be available before January 2021. Therefore, this Standard should not be used for acceptance or rejection of materials for purchasing purposes.

14. KEYWORDS

14.1. antistripping additives; asphalt concrete paving mixtures; cyclic stress; moisture; moisture conditioning; pore pressure; tensile strength; water

Executive Summary for Proposed Small Specimen Standards

Three standards are proposed to facilitate measuring dynamic modulus and fatigue cracking properties on small, cylindrical test specimens that are 38-mm in diameter: (1) Preparation of Small Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor (SGC) and Field Cores; (2) Determining the Dynamic Modulus for Asphalt Mixtures Using Small Specimens in the Asphalt Mixture Performance Tester (AMPT); and (3) Determining the Damage Characteristic Curve and Failure Criterion Using Small Specimens in the AMPT Cyclic Fatigue Test.

The small specimen geometry in the proposed standards enables the testing of as-built pavement layers. Field core testing will enable performance-based quality acceptance and forensic investigations of asphalt mixture properties of individual pavement layers throughout a pavement's service life. The small specimen geometry also offers a significant opportunity to improve laboratory testing efficiency. Four small specimens can be extracted from a single SGC sample, greatly improving the efficiency of laboratory-fabricated specimen testing. In addition, the small specimen size reduces time requirements for thermal equilibration, improving testing efficiency in both dynamic modulus and cyclic fatigue testing. Cyclic fatigue testing efficiency is further improved with the use of small specimens by the use of quick setting epoxy, which cannot be used for large specimens (i.e., 100-mm diameter) due to larger loads required for testing large specimens than those required for small specimens. The proposed small specimen fabrication, dynamic modulus test, and cyclic fatigue test standards closely follow AASHTO R83, AASHTO T378, and AASHTO TP107, respectively, with the appropriate modifications for small specimen testing. It is worth noting that the proposed small specimen cyclic fatigue test standard includes a strain selection procedure, which has been improved from that in TP107, to help ensure that fatigue failure occurs within the desired timeframe. In addition, both the proposed small specimen dynamic modulus and cyclic fatigue test standards include improved and simplified guidance for test temperature selection and conditioning time compared to the companion large specimen standards.

The proposed small specimen standards were developed based on the results of the recently completed NCHRP N-181 project combined with the FHWA's extensive experience with small specimen testing. The goal of the NCHRP IDEA N-181 project was to enable widespread use of small specimen geometries in AMPT testing. To best meet this goal, a rigorous assessment of specimen geometry effects was first conducted to identify the material types and testing conditions where the small specimen geometries yield representative results. A comparison between the AMPT dynamic modulus and cyclic fatigue test results of small specimens and large specimens was conducted using five mixtures with nominal maximum aggregate size (NMAS) values ranging from 9.5 mm to 25.0 mm to rigorously evaluate specimen geometry effects. It was found that four small specimens with relatively uniform air void content can be vertically-extracted from the inner 100 mm of SGC samples. The results demonstrated that the dynamic modulus and phase angle mastercurves acquired from the large and small specimen geometries are statistically equivalent at the temperatures outlined in AASHTO R 84. At higher temperatures, the small specimen dynamic modulus values are higher and the phase angle values were lower than those of the large specimens. The cyclic fatigue test results of large and small specimens were in good agreement. The specimen-to-specimen variability of the large and small specimen dynamic modulus and cyclic fatigue results are comparable. Recent experience with additional mixtures suggests a potential increase in variability with 25.0-mm NMAS mixtures

and therefore, the proposed standards are limited to mixtures with NMAS values less than or equal to 19.0 mm; the applicability of the small specimen geometry to 25.0-mm NMAS mixtures is currently under investigation.

Standard Method of Practice for

Preparation of Small Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor (SGC) and Field Cores

AASHTO Designation: PP XX-XX

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

Standard Method of Test for

Preparation of Small Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor (SGC) or Field Cores

AASHTO Designation: PP XX-XX

1. SCOPE

1.1. This practice covers the use of a Superpave gyratory compactor (SGC) or field cores to prepare 38-mm (1.50 in.) diameter by 110-mm (4.33 in.) height performance test specimens for use in a variety of axial compression and tension performance tests. This practice is intended for dense-graded asphalt mixtures with nominal maximum aggregate sizes up to 19.0 mm (0.98 in.).

1.2. *This standard may involve hazardous material, operations, and equipment. This standard does not purport to address all safety problems associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- R 30, Mixture Conditioning of Hot Mix Asphalt
- R 83, Preparation of Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor (SGC)
- T 166, Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface Dry Specimens
- T 209, Theoretical Maximum Specific Gravity (G_{mm}) and Density of Hot Mix Asphalt (HMA)
- T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- T 312, Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor
- T 331, Bulk Specific Gravity (G_{mb}) and Density of Compacted Asphalt Mixtures Using Automatic Vacuum Sealing Method
- T 342, Determining the Dynamic Modulus of Hot Mix Asphalt (HMA)
- TP XX, Determining the Dynamic Modulus for Asphalt Mixtures Using Small Specimens in the Asphalt Mixture Performance Tester (AMPT)
- TP XX, Determining the Damage Characteristic Curve and Analysis Parameters Using Small Specimens in the Asphalt Mixture Performance Tester (AMPT) Cyclic Fatigue Test

2.2. *ASTM Standard*:

- D3549/D3549M, Standard Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens

2.3. *Other Document*:

- NCDOT Report FHWA/NC/2010-01, *Investigation of Primary Causes of Fatigue Cracking in Asphalt Pavement in North Carolina*, March 2015.

3. TERMINOLOGY

3.1. *SGC specimen*—a 150-mm (5.91 in.)diameter by 180-mm (7.09 in.)tall (minimum) cylindrical specimen prepared in an SGC meeting the requirements of T 312.

3.2. *test specimen*—a 38-mm (1.50 in.) diameter by 110-mm (4.33 in.) tall cylindrical specimen cored and sawed from an SGC specimen.

3.3. *end perpendicularity*—the degree to which an end surface departs from being perpendicular to the axis of the cylindrical test specimen. This configuration is measured using a precision square with the beam touching the cylinder parallel to its axis and the blade touching the highest point on the end of the cylinder. The distance between the blade of the square and the lowest point on the end of the cylinder is checked with 1.0-mm (0.04 in.) diameter wire or feeler gauges.

3.4. *end flatness*—maximum departure of the test specimen end from a plane. This dimension is checked using a straightedge and 0.5-mm (0.20 in.) diameter wire or feeler gauges.

4. SUMMARY OF PRACTICE

4.1. This practice presents methods for extracting 38-mm (1.50 in.) diameter by 110-mm (4.33 in.) tall cylindrical 38-mm (1.50 in.) test specimens from SGC specimens and field cores for use in a variety of axial compression and tension performance tests.

5. SIGNIFICANCE AND USE

5.1. This practice should be used to prepare 38-mm (1.50 in.) test specimens for TP XX and TP XX.

5.2. This practice may also be used to prepare 38-mm (1.50 in.) test specimens for other tests requiring 38-mm (1.50 in.) diameter by 110-mm (4.33 in.) height cylindrical test specimens.

6. APPARATUS

6.1. *Superpave Gyratory Compactor*—Meeting the requirements of T 312 and capable of preparing 150-mm (5.91 in.) diameter SGC specimens that are a height of at least 180 mm (7.09 in.).

6.2. *Mixture Preparation Equipment*—Balances, ovens, thermometers, mixer, pans, and other miscellaneous equipment needed to prepare SGC specimens in accordance with T 312, perform bulk specific gravity (G_{mb}) measurements in accordance with T 166, and perform maximum specific gravity (G_{mm}) measurements in accordance with T 209.

6.3. *Core Drill*—An air- or water-cooled, diamond-bit core drill capable of cutting cores to a nominal diameter of 38-mm (1.50 in.) and meeting the dimensional requirements of Section 9.4.4. The core drill shall be equipped with a fixture for holding the SGC specimens or field cores from which the test specimens are being extracted.

Note 1—Core drills with fixed and adjustable rotational speed have been used successfully to prepare test specimens meeting the dimensional tolerances given in Section 9.4.4. Rotational speeds from 450 to 750 rpm have been used.

Note 2—Core drills with automatic and manual feed rate have been used successfully to prepare test specimens meeting the dimensional tolerances given in Section 9.4.4.

6.4. *Masonry Saw*—An air- or water-cooled, diamond-bladed masonry saw capable of cutting test specimens to a nominal length of 110 mm (4.33 in.) and meeting the tolerances for end perpendicularity and end flatness given in Section 9.4.4.

Note 3—Heavy duty tile saws with good stability have been found effective for sawing 38-mm (1.50 in.) diameter specimens. Larger masonry saws may be used, provided the test specimens meet the dimensional tolerances. Saws require a fixture to securely hold the specimen during sawing and to control the feed rate.

6.5. *Square*—Precision square with 101.6 mm (4in.) beam and 152.4 mm (6in.) blade, McMaster Carr Catalog Number 2278A14 or equivalent.

6.6. *1.0-mm (0.39 in.) Diameter Carbon Steel Wire*—1mm (0.39 in.) diameter carbon steel wire, McMaster Carr Catalog Number 8907K42 or equivalent.

6.7. *0.5-mm (0.02 in.) Diameter Carbon Steel Wire*—0.5-mm (0.02 in.) diameter carbon steel wire, McMaster Carr Catalog Number 8907K21 or equivalent.

6.8. *Feeler Gauges*—Tapered-leaf feeler gauges in 0.05-mm (0.002 in.) increments.

6.9. *Metal Ruler*—Capable of measuring 150-mm (5.91 in.) long (nominal) specimens to the nearest 1 mm (0.39 in.).

6.10. *Calipers*—Capable of measuring 38-mm (1.50 in.) diameter (nominal) specimens to the nearest 0.1 mm (0.004 in.).

6.11. *Spatula*—Stainless steel spatula with blade approximately 254-mm (10 in.) long and 38-mm (1.50 in.) wide, McMaster Carr Catalog Number 3660A16 or equivalent.

7. HAZARDS

7.1. This practice and associated standards involve handling of hot asphalt binder, aggregates, and asphalt mixtures. It also includes the use of sawing and coring machinery. Use standard safety precautions, equipment, clothing, and personal protection equipment when handling hot materials and operating machinery.

8. STANDARDIZATION

8.1. Items associated with this practice that require calibration or verification are included in the AASHTO standards referenced in Section 2. Refer to the pertinent section of the referenced standards for information concerning calibration or verification.

9. PROCEDURE A – FABRICATION FROM SGC SPECIMENS

9.1. *Asphalt Mixture Preparation:*

9.1.1. Prepare asphalt mixture for each SGC specimen in accordance with T 312 and prepare a companion mixture sample for determining theoretical maximum specific gravity (G_{mm}) in accordance with T 209.

9.1.2. The mass of asphalt mixture needed for each SGC specimen will depend on the SGC specimen height, the G_{mm} of the mixture, the nominal maximum aggregate size, gradation (coarse or fine), and target air void content of the test specimens.

Note 4—Appendix X1 describes one procedure for determining the mass of asphalt mixture required to reach a specified test specimen target air void content.

9.1.3. Perform conditioning on the asphalt mixture for the test specimens and companion G_{mm} sample in accordance with R 30.

9.2. *SGC Specimen Compaction:*

9.2.1. Compact the SGC specimens to a height of 180 mm (7.09 in.) or higher, in accordance with T 312, carefully following the exceptions noted in 9.2.2 and 9.2.3.

9.2.2. Pour the mixture into the center of the mold to minimize air void variation between samples. Pouring material down the sides of the mold will result in lower air voids on that side of the mold.

9.2.3. Charge the mold in two equal lifts. After each lift, use the spatula to scrape the walls of the mold, inserting the spatula 8-10 times around the circumference of the mold. Insert the spatula into the center of the mixture 10-12 times in an evenly distributed pattern. Insert the spatula as far as possible into the mixture without damaging aggregates.

9.3. *SGC Specimen Density and Air Voids (Optional):*

9.3.1. Determine the G_{mm} of the asphalt mixture in accordance with T 209. If long-term conditioning has been used, determine the G_{mm} on the long-term-conditioned loose asphalt mixture. Record the G_{mm} of the mixture.

9.3.2. Determine G_{mb} of the SGC specimen in accordance with T 166 or T 331. Record the G_{mb} of the SGC specimen.

9.3.3. Compute the air void content of the SGC specimen in accordance with T 269. Record the air void content of the SGC specimen.

Note 5—Section 9.3 is optional because acceptance of the test specimen for mechanical property testing is based on the air void content of the test specimen, not the SGC specimen. However, monitoring SGC specimen density can identify improperly prepared specimens early in the specimen fabrication process. Information on SGC specimen air voids and test specimen air voids will also assist the laboratory in establishing potentially more precise methods than Appendix X1 for preparing test specimens to a target air void content.

9.4. *Test Specimen Preparation:*

9.4.1. Mark the SGC specimen by marking the location(s) where the cores will be taken. All cores must be taken within the center 100-mm (3.94 in.) diameter of the gyratory specimen. Four (4) test specimens can be cored from one SGC specimen, as shown in Figure 1.

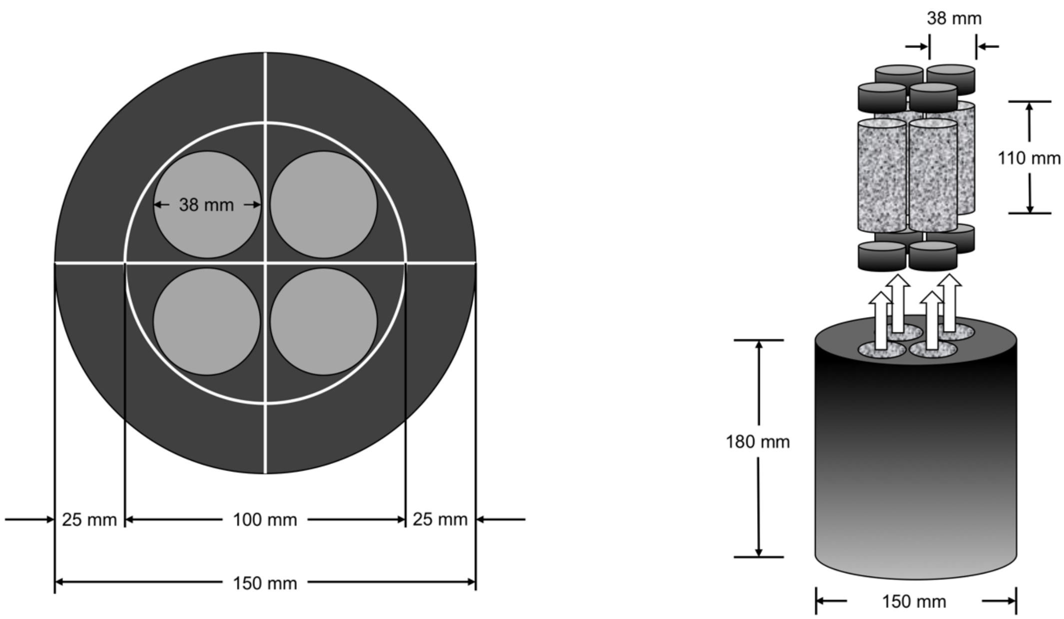

Figure 1—Graphics of coring from an SGC specimen

9.4.2. Core a test specimen with a nominal diameter of 38 mm (1.50 in.) from the SGC specimen. Both the SGC specimen and the coring equipment shall be adequately secured and supported to ensure that the resulting core is cylindrical with smooth, parallel sides, and meet the tolerances on test specimen diameter given in Table 1.

9.4.3. Saw both ends of the core to remove equivalent material from both ends to obtain a test specimen of a nominal height of 110 mm (4.33 in.). Both the core and the saw shall be adequately secured and supported to ensure that the resulting test specimen meets the tolerances given in Table 1 for height, end flatness, and end perpendicularity.

Note 6—With most equipment, it is better to perform the coring before the sawing. However, these operations may be performed in either order as long as the dimensional tolerances in Table 1 are satisfied.

9.4.4. 38-mm (1.50 in.) test specimens shall meet the dimensional tolerances given in Table 1.

Table 1—Test Specimen Dimensional Tolerances

Item	Specification	Method Reference
Average diameter	36 to 40 mm (1.42 to 1.57 in.)	9.4.4.1
Standard deviation of diameter	≤0.5 mm (0.20 in.)	9.4.4.1
Height	107.5 to 112.5 mm (4.23 to 4.43 in.)	9.4.4.2
End flatness	≤0.5 mm (0.20 in.)	9.4.4.3
End perpendicularity	≤1.0 mm (0.40 in.)	9.4.4.4

9.4.4.1. Using calipers, measure the diameter at the center and third points of the test specimen along axes that are 90 degrees apart. Record each of the six measurements to the nearest 0.1 mm (0.004 in.). Calculate the average and the standard deviation of the six measurements. Reject test specimens not meeting the average and the standard deviation requirements given in Table 1. The average diameter, reported to the nearest 0.1 mm (0.004 in.), shall be used in all material property calculations.

9.4.4.2. Measure the height of the test specimen in accordance with ASTM D3549/D3549M. Reject test specimens with an average height outside the height tolerance listed in Table 1. Record the average height.

9.4.4.3. Using the blade of the precision square as a straightedge, check the flatness of each end at three locations approximately 120 degrees apart. At each location, place the blade of the precision square across the diameter of the test specimens as shown in Figure 2, and check the maximum departure of the test specimen from the blade using the 0.5-mm (0.20 in.) diameter carbon steel wire or feeler gauge. Reject test specimens if the 0.5-mm (0.20 in.) diameter carbon steel wire fits between the blade and the test specimen at any location.

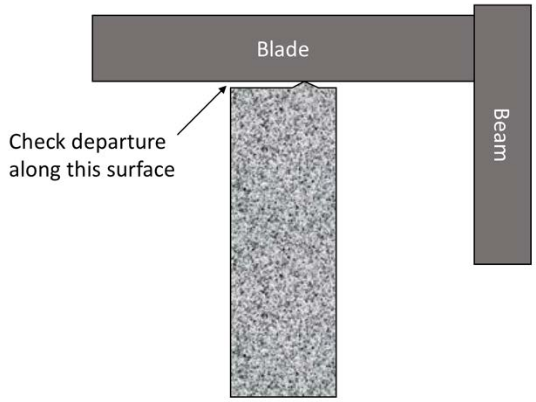

Figure 2—Graphic of end flatness measurement

9.4.4.4. Check the perpendicularity of each end of the test specimen using the precision square and the 1.0 mm (0.40 in.) carbon steel wire at two locations approximately 90 degrees apart. Place the precision square on a table with the beam in contact with the table and the blade extending vertically. Place the long axis of the test specimen on the beam such that the blade is in contact with the end of the test specimen as shown in Figure 3. Check the maximum departure of the test specimen from the blade using the 1.0-mm (0.40 in.) diameter carbon steel wire or feeler gauge. Reject test specimens if the 1.0-mm (0.40 in.) diameter carbon steel wire fits between the blade and the test specimen at any location.

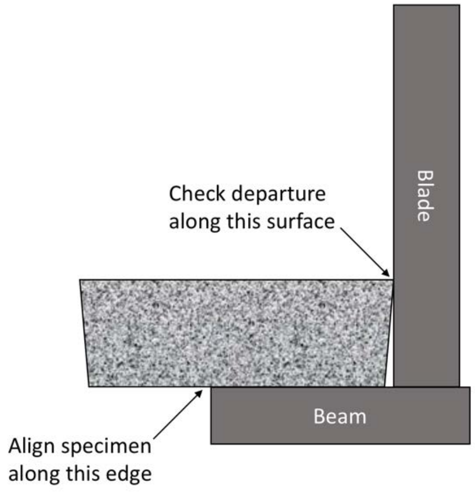

Figure 3—Graphic of end perpendicularity measurement

9.5. *Test Specimen Density and Air Voids:*

9.5.1. Determine the G_{mm} of the asphalt mixture in accordance with T 209. If long-term conditioning has been used, determine the G_{mm} on the long-term-conditioned loose asphalt mixture. Record the G_{mm} of the mixture.

9.5.2. Determine the G_{mb} of the test specimen in accordance with T 166 or T 331. Record the G_{mb} of the test specimen.

Note 7—When using T 166 and wet-coring and sawing methods are used, measure the immersed mass, followed by the surface-dry mass followed by the dry mass, to minimize drying time and expedite the test specimen fabrication process.

9.5.3. Compute the air void content of the test specimen in accordance with T 269. Record the air void content of the test specimen.

9.6. *Test Specimen Storage:*

9.6.1. Mark the test specimen with a unique identification number.

9.6.2. Store the test specimen, until tested, on its end on a flat shelf in a room with the temperature controlled between 15 and 27ºC (59 and 81°F).

Note 8—Definitive research concerning the effects of test specimen aging on various mechanical property tests has not been completed. Some users enclose specimens in plastic wrap, or minimize specimen storage time to two weeks, or both.

10. PROCEDURE B – FABRICATION FROM FIELD CORES

10.1. *Field Core Preparation:*

10.1.1. Obtain sufficient 150-mm (5.91 in.) diameter field cores for all testing and additional cores to provide sufficient material to conduct the maximum specific gravity (G_{mm}) test in accordance with T 209.

10.1.2. Mark the direction of traffic on the end surface of the field core before coring. If the traffic direction is not marked on the field core, evaluate and select the most probable direction of traffic.

Note 9—Possible indications of the direction of traffic on an unmarked field core include directional compaction marks, lane markings, surface wear patterns, or milling grooves. If traffic direction is not apparent, note the issue, select a direction and continue.

10.1.3. Reduce the size of the field core, if needed, using the saw to make a field core geometry which can be held stable by the fixture for subsequent small-scale test specimen coring and is suitable for extracting one or more small-scale test specimens perpendicular to the direction of traffic. Before cutting, mark the direction of traffic on all sections of the field core.

10.2. *Test Specimen Preparation:*

10.2.1. Prepare the field core by marking where the cores will be taken. Two (2) diameter test specimens can be cored perpendicular to the direction of traffic from one (1) 150-mm (5.91 in.) diameter field core, as shown in Figure 4.

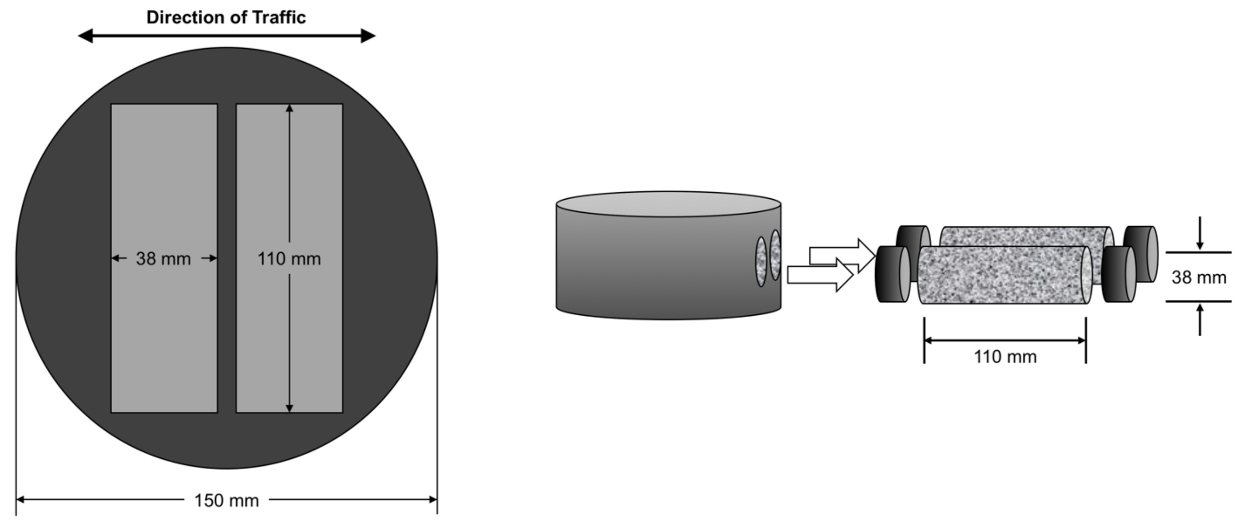

Figure 4—Graphics of 38-mm (1.50 in.) test specimens cored from a 150-mm (5.91 in.) diameter field core

10.2.2. Core small-scale test specimens with a nominal diameter of 38 mm horizontally from the field core. Both the field core and the coring equipment shall be adequately secured and supported to ensure that the resulting small-scale test specimen core is cylindrical with smooth, parallel sides and meet the tolerances on test specimen diameter given in Table 1.

10.2.3. Saw both ends of the small-scale test specimen core to remove equivalent material from both ends to obtain a 38-mm (1.50 in.) test specimen of a nominal height of 110 mm (4.33 in.). Both the small-scale test specimen core and the saw shall be adequately secured and supported to ensure that the resulting 38-mm (1.50 in.) test specimen meets the tolerances given in Table 1 for height, end flatness, and end perpendicularity.

Note 10—With most equipment, it is better to perform the coring before the sawing. However, these operations may be performed in either order as long as the dimensional tolerances in Table 2 are satisfied.

10.2.4. 38-mm (1.50 in.) test specimens shall meet the dimensional tolerances given in Table 1.

10.3. *38-mm (1.50 in.) Test Specimen Density and Air Voids:*

10.3.1. Procure sufficient material from separate field cores to determine the G_{mm} of the asphalt mixture in accordance with T 209. Determine the G_{mm} of the asphalt mixture in accordance with T 209.

10.3.2. Determine G_{mb} of the 38-mm (1.50 in.) test specimen in accordance with T 166. Record the G_{mb} of the 38-mm (1.50 in.) test specimen.

Note 11—When wet-coring and sawing methods are used, measure the immersed mass, followed by the surface-dry mass followed by the dry mass, to minimize drying time and expedite the specimen fabrication process.

10.3.3. Compute the air void content of the 38-mm (1.50 in.) test specimen in accordance with T 269. Record the air void content of the 38-mm (1.50 in.) test specimen

10.4. *Test Specimen Storage:*

10.4.1. Mark the test specimen with a unique identification number.

10.4.2. Store the test specimen, until tested, on its end on a flat shelf in a room with the temperature controlled between 15 and 27ºC (59 and 81°F).

Note 12—Definitive research concerning the effects of test specimen aging on various mechanical property tests has not been completed. Some users enclose specimens in plastic wrap, or minimize specimen storage time to two weeks, or both.

11. REPORTING

11.1. *Report the following information:*

11.1.1. Unique test specimen identification number;

11.1.2. Mixture design data including design compaction level and air void content, asphalt binder type and grade, binder content, binder specific gravities, aggregate types and specific gravities, aggregate consensus properties, and G_{mm};

11.1.3. Type of conditioning used;

11.1.4. G_{mm} for the conditioned specimens;

11.1.5. SGC specimen target height (optional);

11.1.6. SGC specimen G_{mb} (optional);

11.1.7. SGC specimen air void content (optional);

11.1.8. Test specimen average height;

11.1.9. Test specimen average diameter;

11.1.10. Test specimen G_{mb};

11.1.11. Test specimen air void content;

11.1.12. Test specimen end flatness for each end;

11.1.13. Test specimen end perpendicularity for each end; and

11.1.14. Remarks concerning deviations from this standard practice.

12. KEYWORDS

12.1. Gyratory compaction; performance test specimens, 38-mm (1.50 in.) test specimen, small scale, AMPT, asphalt mixture performance tester

APPENDIXES

(Nonmandatory Information)

X1. METHOD FOR ACHIEVING A TARGET AIR VOID CONTENT

X1.1. *Purpose:*

X1.1.1. This appendix presents a procedure for estimating the mass of asphalt mixture required to produce 38-mm test specimens at a target air void content. It was developed to avoid compacting repeat trial specimens. A trial and error method which may use less material is available in R 83 Appendix X1.

X1.1.2. This procedure can be used with either plant-produced or laboratory-prepared asphalt mixtures.

X1.2. *Summary:*

X1.2.1. An estimate of the mass of mixture required is made knowing the maximum specific gravity of the mixture, G_{mm}, and the volume of the SGC specimen.

X1.2.2. Three trial SGC specimens are compacted in the SGC to the target height, one at the target mass and the other two at the target mass ±100 grams (3.53 oz.). 100-mm (3.94 in.) diameter by 150-mm (5.91 in.) height trial specimens are cored and sawed from the center of each of the SGC specimens.

Note X1—If companion testing on large specimens will not be performed, it is acceptable to saw the trial specimens to a height of 110 mm (4.33 in.).

X1.2.3. The air void contents of the 100-mm (3.94 in.) diameter by 150-mm (5.91 in.) height trial specimens are measured and used to develop a relationship between SGC specimen mass and trial 100-mm (3.94 in.) diameter by 150-mm (5.91 in.) height test specimen air voids.

X1.3. *Procedure:*

X1.3.1. Measure the maximum specific gravity, G_{mm}, of the mixture in accordance with T 209.

X1.3.2. Calculate the mass of the mixture required for a SGC specimen of target height, H, using Equation X1.1:

$$Mass = \left[\frac{100-(Va_t+F)}{100}\right] * G_{mm} * 176.7147 * H \qquad (X1.1)$$

where:

$Mass$ = estimated mass of mixture to prepare a test specimen to the target air voids, g

Va_t = target air void content for the test specimen, percent by volume

G_{mm} = maximum specific gravity for the mixture

H = height of the SGC specimen, cm

F = air void adjustment factor: 1.0 for fine-graded; 1.5 for coarse-graded

X1.3.3. Using the estimated mass from Equation X1.1, prepare three trial SGC specimens at the target mass and ±100 grams (3.53 oz.). Core and saw 100-mm (3.94 in.) diameter by 150-mm (5.91 in.) height trial specimens from each of the SGC specimens.
Note X2—If companion testing on large specimens will not be performed, it is acceptable to saw the trial specimens to a height of 110 mm (4.33 in.).

X1.3.4. Measure the bulk specific gravity of the 100-mm (3.94 in.) diameter by 150-mm (5.91 in.) height trial specimens and calculate the air void content of the 100-mm (3.94 in.) diameter by 150-mm (5.91 in.) height trial specimens in accordance with Section 9.5.

X1.3.5. Prepare a plot of the SGC specimen mass against the trial specimen air void content. Fit a line to the three points as shown in Figure X1.1.

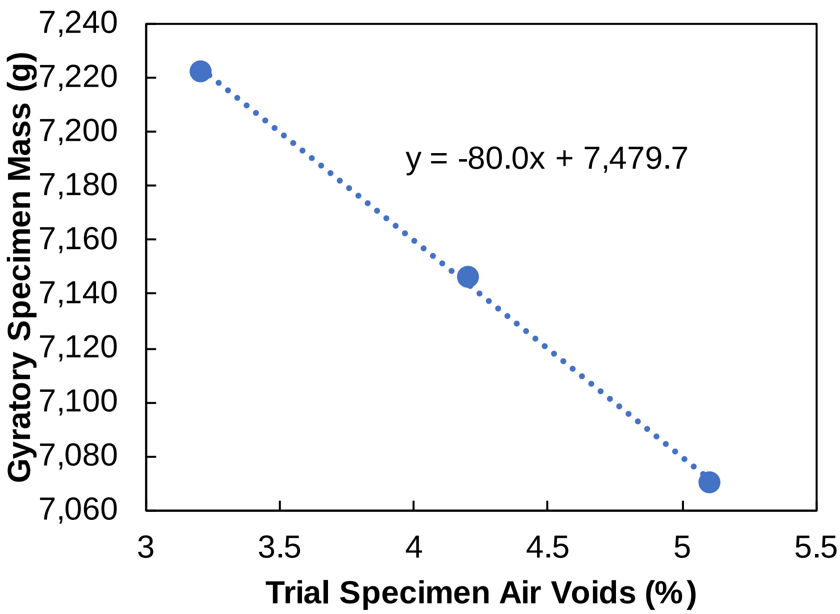

Figure X1.1-Example of Air Void Relationship Plot with Fitted Line and Equation

X1.3.6. Use the fitted line to determine the mass needed for the specific target air voids.

X1.3.7. This procedure does require three trial specimens to avoid the repeat compaction which may be needed in a trial-and-error procedure.

Standard Method of Test for

Determining the Dynamic Modulus for Asphalt Mixtures Using Small Specimens in the Asphalt Mixture Performance Tester (AMPT)

AASHTO Designation: TP XX-XX

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

Standard Method of Test for

Determining the Dynamic Modulus for Asphalt Mixtures Using Small Specimens in the Asphalt Mixture Performance Tester (AMPT)

AASHTO Designation: TP XX-XX

1. SCOPE

1.1. This standard describes test methods for measuring the dynamic modulus for asphalt mixtures using the Asphalt Mixture Performance Tester (AMPT). This practice is intended for dense-graded mixtures with nominal-maximum aggregate sizes up to 19.0 mm.

1.2. *This standard may involve hazardous material, operations, and equipment. This standard does not purport to address all safety problems associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- PP XX, Preparation of Small Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor (SGC) or Field Cores
- T 378, Determining the Dynamic Modulus and Flow Number for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)
- R 84, Developing Dynamic Modulus Master Curves for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)
- R 62, Developing Dynamic Modulus Master Curves for Asphalt Mixtures

2.2. *Other Documents*:

- NCHRP Report 629, *Equipment Specifications for the Simple Performance Test System, Appendix E*, October 16, 2007
- VTRC Report 15-R26, *Asphalt Mixture Performance Characterization Using Small-Scale Cylindrical Specimens*, June 2015

3. TERMINOLOGY

3.1. *dynamic modulus*, |E*|—the absolute value of the complex modulus calculated by dividing the peak-to-peak stress by the peak-to-peak strain for a material subjected to a sinusoidal loading.

3.2. *phase angle*, δ—the angle in degrees between a sinusoidally applied stress and the resulting strain in a controlled stress test.

3.3. *test specimen*—a 38-mm (1.50 in.) diameter by 110-mm (4.33 in.) tall cylindrical specimen cored and sawed from either an SGC specimen or field core.

4. SUMMARY OF METHOD

4.1. This test method describes the procedure for measuring the dynamic modulus of asphalt mixtures. A test specimen at a specific test temperature is subjected to a controlled sinusoidal (haversine) compressive stress of various frequencies. The applied stresses and resulting axial strains are measured as a function of time and used to calculate the dynamic modulus and phase angle.

5. SIGNIFICANCE AND USE

5.1. The dynamic modulus is a performance-related property that can be used for mixture evaluation and for characterizing the stiffness of HMA for mechanistic-empirical pavement design.

6. APPARATUS

6.1. *Specimen Fabrication Equipment*—For fabricating dynamic modulus test specimens as described in PP XX.

6.2. *Dynamic Modulus Test System*—Meeting the requirements of the equipment specification for the Simple Performance Test (SPT) System, Version 3.0, except for the following provisions: in the referenced equipment specification, Sections 10.7 and 11.3 shall require a temperature sensor range of 0 to 75°C (32 to 167°F) and Section 11.1 shall require a temperature control range from 4 to 70°C (39 to 158°F).

6.3. *38-mm Specimen Dynamic Modulus Platens*—Platens meeting the requirements of the equipment specification for the Simple Performance Test (SPT) system, Version 3.0, except the following provisions: the lower platen loading surface diameter and the upper platen diameter shall be not less than 42 mm and not more than 45 mm.

6.4. *Conditioning Chamber*—An environmental chamber for conditioning the test specimens to the desired testing temperature. The environmental chamber shall be capable of controlling the temperature of the specimen over a temperature range from 4 to 70°C (39 to 158°F) to an accuracy of ±0.5°C (0.9°F). The chamber shall be large enough to accommodate the number of specimens to be tested plus a “dummy” specimen with a temperature sensor mounted in the center for temperature verification.

6.5. *PTFE Sheet*—0.25 mm (0.01 in.) thick, to be used as a friction reducer between the specimen and the loading platens in the dynamic modulus test.

Note 1—Greased double latex type friction reducers are not recommended for small specimen testing due to the specimens occasionally sliding out from between the loading platens, which damages the specimen and may damage the testing equipment.

7. HAZARDS

7.1. This practice and associated standards involve handling of hot asphalt binder, aggregates, and asphalt mixtures. It also includes the use of sawing and coring machinery and servo-hydraulic testing equipment. Use standard safety precautions, equipment, clothing, and personal protection equipment when handling hot materials and operating machinery.

8. STANDARDIZATION

8.1. *Verification with Proving Ring*:

8.1.1. Verify the normal operation of the AMPT weekly or at the beginning of a new testing program using the manufacturer-provided proving ring and following the proving ring manufacturer's use instructions. Perform a dynamic modulus test on the proving ring using a target strain of 100 microstrain at 1.0 Hz. The dynamic modulus of the proving ring should be within ±3 percent of the value obtained on the proving ring for the same testing conditions during the last calibration.

8.2. *Calibration:*

8.2.1. The following systems on the AMPT shall be calibrated annually, when the AMPT system is moved, or when any of its components are changed:

- Load Measuring System
- Actuator Displacement Measuring System
- Specimen-Mounted Deformation Measuring System
- Confining Pressure Measuring System
- Temperature Measuring System

Methods for calibration of each of these systems are included in Annex A.

9. PROCEDURE

9.1. *Test Specimen Fabrication:*

9.1.1. Testing shall be performed on 38-mm (1.50 in.) diameter by 110-mm (4.33 in.) tall test specimens fabricated in accordance with PP XX.

9.1.2. Prepare three test specimens at the target air void content ±0.5 percent and with the aging condition in accordance with PP XX.

9.2. *Test Specimen Instrumentation (Standard Glued-Gauge-Point System):*

9.2.1. Attach the gauge points to the test specimen in accordance with the manufacturer's instructions.

9.2.2. Confirm that the gauge length is 70 mm ± 1 mm (2.76 in. ± 0.04 in.), measured center-to-center of the gauge points.

9.3. *Loading Platens and End-Friction Reducers:*

9.3.1. For the dynamic modulus test, the top platen shall be free to rotate.

9.3.2. PTFE end-friction reducers are made from 0.25-mm (0.01 in.) thick PTFE sheet, cut to a size slightly larger than the specimen diameter.

9.4. *Procedure:*

9.4.1. Place the test specimens to be tested in the environmental chamber with the "dummy" specimen and monitor the temperature of the "dummy" specimen to determine when testing can begin.

9.4.2. Place platens and friction reducers inside the testing chamber. Turn on the AMPT, set the temperature control to the desired testing temperature, and allow the testing chamber to equilibrate at the testing temperature for at least 1 h.

9.4.3. When the “dummy” specimen and the testing chamber reach the target temperature, open the testing chamber. Remove a test specimen from the conditioning chamber and quickly place it in the testing chamber.

9.4.4. Assemble the specimen to be tested with platens in the following order from bottom to top: bottom loading platen, bottom friction reducer, test specimen, top friction reducer, and top loading platen.

9.4.5. Install the specimen-mounted deformation-measuring system on the gauge points per the manufacturer’s instructions. Ensure that the deformation-measuring system is within its calibrated range. Ensure that the top loading platen is free to rotate during loading.

9.4.6. Close the testing chamber and allow the chamber temperature to return to the testing temperature.

9.4.7. Procedures in Sections 9.4.3 through 9.4.6, including the return of the test chamber to the target temperature, shall be completed in 5 min.

9.4.8. Enter the required identification and control information into the dynamic modulus test software. Test temperatures and loading frequencies should be in accordance with Table 1.

Note 2—Users should consult with equipment manufacturers to determine if adjustments are needed to AMPT control systems in order to conduct this test (i.e., running a servo-hydraulic system on low pressure versus high pressure).

Table 1— Recommended Testing Temperatures and Loading Frequencies

PG 58-XX and Softer		PG 64-XX and Stiffer	
Temperature, °C	Loading Frequencies, Hz	Temperature, °C	Loading Frequencies, Hz
4	10, 1, 0.1	4	10, 1, 0.1
20	10, 1, 0.1	20	10, 1, 0.1
35	10, 1, 0.1	40	10, 1, 0.1

9.4.9. Measure the dynamic modulus and phase angle of each test specimen. Begin testing at the lowest temperature and highest frequency. Test all frequencies in descending order before moving to the next highest temperature.

9.4.10. Follow the software prompts to begin the test. The AMPT will automatically unload when the test is complete and will display the test data and data quality indicators.

9.4.11. Review the data quality indicators as discussed in Section 9.5. Retest 38-mm (1.50 in.) test specimens with data quality indicators above the values specified in Section 9.5.

9.4.12. Once acceptable data have been collected, open the test chamber and remove the tested specimen.

9.4.13. Repeat procedures in Sections 9.4.3 through 9.4.12 for the remaining test specimens.

9.5. *Computations and Data Quality:*

9.5.1. The calculation of dynamic modulus, phase angle, and the data quality indicators is performed automatically by the AMPT software.

9.5.2. Accept only test data meeting the data quality statistics given in Table 2. Repeat tests as necessary to obtain test data meeting the data quality statistics requirements. Table 3 summarizes actions that can be taken to improve the data quality statistic.

Table 2—Data Quality Statistics Requirements

Data Quality Statistic	Limit
Deformation drift	In direction of applied load
Peak-to-peak strain	50 to 75 µstrain
Load standard error	10%
Deformation standard error	10%
Deformation uniformity	30%
Phase uniformity	3°

Note 3—The data quality statistics in Table 2 are reported by the AMPT. If a dynamic modulus test system other than the AMPT is used, refer to the equipment specification on for the Simple Performance Test (SPT) System, Version 3.0, for algorithms for the computation of dynamic modulus, phase angle, and data quality statistics.

Table 3—Data Quality Statistics Requirements

Item	Cause	Possible Solutions
Deformation drift not in direction of applied load	Gauge points are moving apart	Reduce LVDT spring force. Add compensation springs. Reduce test temperature.
Peak-to-peak strain too high	Load level too high	Reduce load level.
Peak-to-peak strain too low	Load level too low	Increase load level.
Load standard error >10%	Applied load not sinusoidal	Adjust tuning of hydraulics.
Deformation standard error >10%	1. Deformation not sinusoidal 2. Loose gauge point 3. Excessive noise on deformation signals 4. Damaged LVDT	1. Adjust tuning of hydraulics. 2. Check gauge points. Reinstall if loose. 3. Check wiring of deformation sensors. 4. Replace LVDT.
Deformation uniformity >30%	1. Eccentric loading 2. Loose gauge point 3. Sample ends not parallel 4. Poor gauge point placement 5. Non-uniform air void distribution	1. Ensure specimen is properly aligned. 2. Check gauge points. Reinstall if loose. 3. Check parallelism of sample ends. Mill ends if out of tolerance. 4. Check for specimen non-uniformity (segregation, air voids). Move gauge points. 5. Ensure test specimens are cored from the middle of the gyratory specimen.
Phase uniformity >3°	1. Eccentric loading 2. Loose gauge point 3. Poor gauge point placement 4. Damaged LVDT	1. Ensure specimen is properly aligned. 2. Check gauge points. Reinstall if loose. 3. Check for specimen non-uniformity (segregation, air voids). Move gauge points. 4. Replace LVDT.

9.6. *Reporting:*

9.6.1. For each test specimen tested, report the following:

9.6.1.1. Test temperature,

9.6.1.2. Test frequency,

9.6.1.3. Confining stress level,

9.6.1.4. Dynamic modulus,

9.6.1.5. Phase angle, and

9.6.1.6. Data quality statistics.

9.6.2. Attach the AMPT dynamic modulus test summary report for each test specimen tested.

10. KEYWORDS

10.1. AMPT; dynamic modulus; phase angle.

ANNEX A – PROCEDURES FOR CALIBRATING THE AMPT

(Mandatory Information)

A1. PURPOSE

A1.1. This Annex presents procedures for calibrating the measuring systems on the AMPT.

A2. SUMMARY

A2.1. The following components of the AMPT are calibrated using the procedures contained in this Annex:

- Load Measuring System
- Actuator Displacement Measuring System
- Specimen-Mounted Deformation Measuring System
- Confining Pressure Measuring System
- Temperature Measuring System

A3. REFERENCED STANDARDS

A3.1. *ASTM Standards*:

- D5720, Standard Practice for Static Calibration of Electronic Transducer-Based Pressure Measurement Systems for Geotechnical Purposes
- D6027, Standard Test Method for Calibrating Linear Displacement Transducers for Geotechnical Purposes (withdrawn 2013)
- E4, Standard Practices for Force Verification of Testing Machines
- E74, Standard Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines
- E83, Standard Practice for Verification and Classification of Extensometer Systems

A4. PROCEDURE

A4.1. *Load Measuring System Calibration*:

A4.1.1. The load measuring system shall have a maximum error of 1 percent of the indicated value over the range of 0.12 kN (25 lb) to 13.5 kN (3.0 kips) when verified in accordance with ASTM E4.

A4.1.2. The resolution of the load measuring system shall comply with the requirements of ASTM E4.

A4.1.3. Perform load measuring system verification in accordance with ASTM E4.

A4.1.4. All calibration load cells used for the load calibration shall be certified according to ASTM E74 and shall not be used below their Class A loading limits.

A4.1.5. When performing the load verification, apply at least two verification runs of at least five loads throughout the range selected.

A4.1.6. If the initial verification loads are within ±1 percent of the reading, these values can be applied as the as-found values, and the second set of verification forces can be used as the final values. Record return-to-zero values for each set of verification loads.

A4.1.7. If the initial verification loads are out of tolerance, calibration adjustments shall be made according to the manufacturer’s specifications until the values are established within the ASTM E4 recommendations. Two applications of verification loads shall then be applied to determine the acceptance criteria for repeatability according to ASTM E4.

A4.1.8. At no time will correction factors be applied to corrected values that do not meet the accuracy requirements of ASTM E4.

A4.2. *Actuator Displacement and Specimen-Mounted Deformation Measuring Systems Calibration*:

A4.2.1. The actuator displacement measuring system shall have a minimum resolution of 0.0025 mm (0.0001 in.).

A4.2.2. The actuator displacement measuring system shall have a maximum error of 0.03 mm (0.001 in.) over the 12-mm (0.47-in.) range when verified in accordance with ASTM D6027.

A4.2.3. The specimen-mounted deformation measuring system shall have a minimum resolution of 0.0002 mm (7.8 μin.).

A4.2.4. The specimen-mounted deformation measuring system shall have a maximum error of 0.0025 mm (0.0001 in.) over the 1-mm (0.04-in.) range when verified in accordance with ASTM D6027.

A4.2.5. Perform verification of the actuator displacement and specimen-mounted deformation measuring systems in accordance with ASTM D6027.

A4.2.6. The micrometer used shall conform to the requirements of ASTM E83.

A4.2.7. When performing verification of the actuator displacement and specimen-mounted deformation measuring systems, each transducer and associated electronics must be verified individually throughout its intended range of use.

A4.2.8. Mount the appropriate transducer in the micrometer stand and align it to prevent errors caused by angular application of measurements.

A4.2.9. Apply at least five verification measurements to the transducer throughout its range. Rezero and repeat the verification measurements to determine repeatability.

A4.2.10. If the readings of the first verification do not meet the specified error tolerance, perform calibration adjustments according to manufacturer's specifications and repeat the applications of measurement to satisfy the error tolerances.

A4.3. *Confining Pressure Measuring System Calibration*:

A4.3.1. The confining pressure measuring system shall have a minimum resolution of 0.5 kPa (0.07 psi).

A4.3.2. The confining pressure measuring system shall have a maximum error of 1 percent of the indicated value over the range of 35 kPa (5 psi) to 210 kPa (30 psi) when verified in accordance with ASTM D5720.

A4.3.3. Perform verification of the confining pressure measuring system in accordance with ASTM D5720.

A4.3.4. All calibrated pressure standards shall meet the requirements of ASTM D5720.

A4.3.5. Attach the pressure transducer to the pressure standardizing device.

A4.3.6. Apply at least five verification pressures to the device throughout its range and record each value. Determine if the verification readings fall within ±1 percent of the value applied.

A4.3.7. If the readings are within tolerance, apply a second set of readings to determine repeatability. Record the return-to-zero values for each set of verification pressures.

A4.3.8. If the readings are out of tolerance, adjust the device according to the manufacturer's specifications and repeat the dual applications of pressure as described above to complete verification.

A4.4. *Temperature Measuring System Calibration*:

A4.4.1. The temperature measuring system shall be readable and accurate to the nearest 0.25°C (0.5°F).

A4.4.2. Verification of the temperature measuring system shall be performed using an NIST-traceable reference thermal detector that is readable and accurate to 0.1°C (0.2°F).

A4.4.3. A rubber band or O-ring will be used to fasten the reference thermal detector to the system temperature sensor.

A4.4.4. Comparisons of the temperature from the reference thermal detector and the system temperature sensor shall be made at six temperatures over the operating range of the environmental chamber.

A4.4.5. Once equilibrium is obtained at each temperature setting, record the temperature of the reference thermal detector and the system temperature sensor.

A4.4.6. If the readings are out of the specified tolerance, adjust the device according to the manufacturer's specifications and repeat the measurements as described above to complete verification.

A4.5. *Dynamic Performance Verification*:

A4.5.1. The verification of the dynamic performance of the equipment shall be performed after calibration of the system.

A4.5.2. The dynamic performance verification shall be performed using the verification device provided with the system by the manufacturer.

A4.5.3. First, measure and record the modulus of the verification device for a diameter of 100 mm (4 in.) under static loading conditions using applied stresses of 65, 575, 1100, and 1600 kPa (10, 85, 160, and 230 psi).

A4.5.4. Then, use the verification device to simulate the dynamic modulus test conditions. Measure the dynamic modulus of the verification for a diameter of 100 mm (4 in.) using applied stresses of 65, 575, 1100, and 1600 kPa (10, 85, 160, and 230 psi) at frequencies of 0.1, 1, and 10 Hz (a total of 12 measurements).

A4.5.5. The 12 moduli from the dynamic loading shall be within ±2 percent of that value obtained for the same stress level from the static measurement. The 12 phase angles from the dynamic loading shall be less than ±1 degree.

APPENDIXES

(Nonmandatory Information)

X1. USE OF ALTERNATIVE SMALL SPECIMEN GEOMETRIES AND FABRICATION PROCEDURES

X1.1. *Alternative small specimen geometries*—Test specimens of geometries other than the 38-mm (1.50 in.) diameter test specimen specified can be obtained from constructed pavement layers to measure the dynamic modulus for use in applications such as forensic investigations and field monitoring of test sections. Test specimens with a 50 mm diameter can be used where there are concerns about the use of 38-mm diameter test specimens. Prismatic specimens 25 mm by 50 mm by 110 mm have also been evaluated for thinner construction lifts.

X1.2. *Alternative small specimen geometries test equipment*—The same gauge points, same gauge length, and same on-specimen deformation sensors are used. Alternate end plates should be designed or procured to match the alternative specimen geometry. Alternate end friction reducers should be fabricated to match the alternative specimen geometry.

X1.3. *Horizontal coring of test specimens from SGC specimens*—Small test specimens for dynamic modulus testing can be cored horizontally from SGC specimens. These test specimens shall not be used in TP XX (fatigue) due to regions of high air voids at the sample ends which cause irregular failure and incomplete fatigue characterization. For more information on horizontal coring of small test specimens, see VTRC Report 15-R26.

Standard Method of Test for

Determining the Damage Characteristic Curve and Failure Criterion Using Small Specimens in the Asphalt Mixture Performance Tester (AMPT) Cyclic Fatigue Test

AASHTO Designation: TP XX-XX

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

Standard Method of Test for

Determining the Damage Characteristic Curve and Failure Criterion Using Small Specimens in the Asphalt Mixture Performance Tester (AMPT) Cyclic Fatigue Test

AASHTO Designation: TP XX-XX

1. SCOPE

1.1. This test method covers procedures for preparing and testing both laboratory-compacted and field-cored asphalt mixture specimens to determine the damage characteristic curve and fatigue analysis parameters via the direct tension cyclic fatigue test using the Asphalt Mixture Performance Tester (AMPT).

1.2. This standard is intended for dense-graded mixtures with nominal maximum aggregate size up to 19.0 mm (0.98 in.). Mixtures with a nominal maximum aggregate size greater than 19.0 mm (0.98 in.) should be tested following TP 107.

1.3. *This standard may involve hazardous material, operations, and equipment. This standard does not purport to address all safety problems associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- R 84, Developing Dynamic Modulus Master Curves for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)
- PP XX, Preparation of Small Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor (SGC) and Field Cores
- R 30, Mixture Conditioning of Hot Mix Asphalt (HMA)
- R 62, Developing Dynamic Modulus Master Curves for Asphalt Mixtures
- T 378, Determining the Dynamic Modulus and Flow Number for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)
- TP 107, Determining the Damage Characteristic Curve of Asphalt Mixtures from Direct Tension Cyclic Fatigue Tests
- TP XX, Determining the Dynamic Modulus for Asphalt Mixtures Using Small Specimens in the Asphalt Mixture Performance Tester (AMPT)

2.2. *ASTM Standards*:

- E 4, Standard Practices for Force Verification of Testing Machines

2.3. *Other Documents*:

- Li, X. and Gibson, N.H. "Using Small Specimens for AMPT Dynamic Modulus and Fatigue Tests," Asphalt Paving Technology, Journal of the Association of Asphalt Paving Technologists, Vol. 82, pp. 579-615, 2013.
- NCHRP Report 629, *Equipment Specifications for the Simple Performance Test System, Appendix E*, October 16, 2007.
- FHWA Report, *Development of Asphalt Mixture Performance Related Specifications, Final Report of Project DTFH61-08-H-00005*, In Press, 2017.

3. TERMINOLOGY

3.1. *test specimen*—a 38-mm (1.50 in.) diameter by 110-mm (4.33 in.) tall cylindrical specimen cored and sawed from either an SGC specimen or field core.

3.2. *end failure*—specimen failure in which the macrocrack develops outside the range of one or more axial deformation sensors. Several example end failure locations are shown in Figure 1.

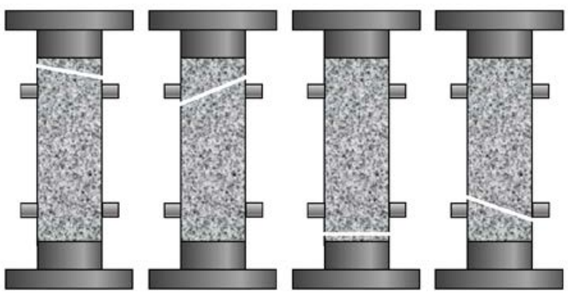

Figure 1—Example End Failure Locations

3.3. *middle failure*—specimen failure in which the macrocrack develops within the range of all axial deformation sensors. Several example middle failure locations are shown in Figure 2.

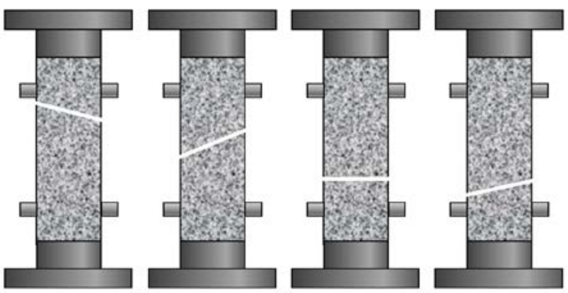

Figure 2—Example Middle Failure Locations

3.4. *complex modulus* (E^*)—a complex number that defines the relationship between stress and strain for a linear viscoelastic material.

3.5. *dynamic modulus* ($|E^*|$)—the norm of the E^*, which is calculated by dividing the peak-to-peak stress by the peak-to-peak axial strain measured during the steady-state period.

3.6. *phase angle* (φ)—the angle, expressed in degrees, between an applied sinusoidal stress and the resulting sinusoidal strain measured during the steady-state period.

3.7. *relaxation modulus* ($E(t)$)—the quotient of the stress response of a material with time to a constant step amplitude of strain.

3.8. *alpha term (α)*—value corresponding to the slope of the relaxation modulus master curve which is used in the accumulation of damage with time.

3.9. *dynamic modulus ratio (DMR)*—the ratio between the dynamic modulus fingerprint and the dynamic modulus value from a master curve construction, both evaluated at the same temperature and frequency condition. This value is also used to characterize specimen-to-specimen variability.

3.10. *pseudo strain* (ε_R)—a quantity that is similar to strain but does not include time effects. Pseudo strain is calculated by solving the convolution integral of the strain and $E(t)$.

3.11. *pseudo secant modulus* (C)—the secant modulus in stress–pseudo strain space.

3.12. *cyclic pseudo secant modulus* (C^*)—the secant modulus in stress–pseudo strain space for a single cycle. This pseudo modulus differs from C because it is computed using a steady-state assumption and is used only with cycle-based data.

3.13. *damage* (S)—the internal state variable that quantifies microstructural changes in asphalt concrete.

3.14. *damage characteristic curve* (*C versus S curve*)—the curve formed when plotting the damage on the x-axis and the pseudo secant modulus on the y-axis. It defines the unique relationship between the structural integrity and amount of damage in a given mixture.

3.15. *failure cycle* (N_f)—the cycle in which the measured phase angle drops sharply after a stable increase during cyclic loading.

3.16. *fatigue analysis coefficients (k_1, k_2, k_3)*—fitting coefficients to describe the classical stress (or strain) versus cycles to failure relationship.

3.17. *pseudo energy-based fatigue failure criterion (D^R)*—the slope of the linear relationship between sum of (1-C) up to failure and the number of cycles to

failure. The physical meaning is the average loss of integrity of the material during the fatigue loading.

4. SUMMARY OF METHOD

4.1. An actuator displacement-controlled repeated cyclic loading is applied to an asphalt mixture test specimen until failure. The applied stress and on-specimen axial strain response are measured and used to calculate the necessary quantities. The analysis of this test procedure requires dynamic modulus data conducted in accordance with TP XX or T 378. The relationship between the damage (*S*) and the pseudo secant modulus (*C*) is determined and expressed as the damage characteristic curve. It is important to recognize that this document pertains to direct tension testing in an AMPT. Test procedures will differ if using other machinery and it is recommended that more specialized procedures be developed for these loading machines.

5. SIGNIFICANCE AND USE

5.1. The damage characteristic curve represents the fundamental relationship between damage and material integrity for asphalt mixtures. This property is independent of temperature, frequency, and mode of loading. Combined with the linear viscoelastic properties, the damage characteristic curve can be used to analyze asphalt mixture fatigue characteristics.

5.2. Damage characteristic curves can also be combined with additional fatigue parameters and pavement response models to predict the fatigue behavior of in-service asphalt mixtures.

6. APPARATUS

6.1. *Asphalt Mixture Performance Tester*—An AMPT or other system meeting or exceeding the requirements of Equipment Specifications for the Simple Performance Test System, NCHRP Report 629, Appendix E, with the additional capability to conduct direct tension testing, as shown in Figure 3.

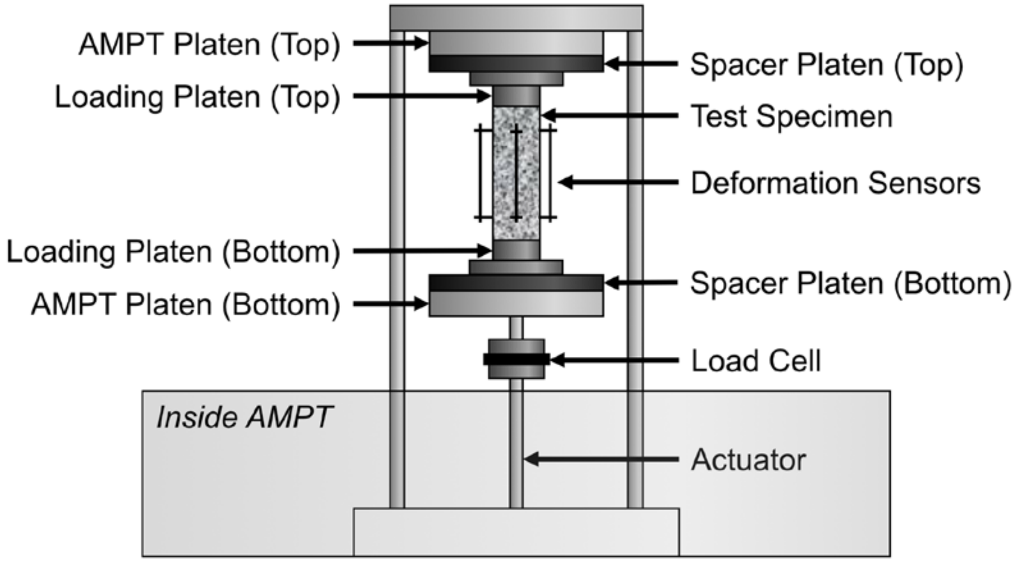

Figure 3—General Schematic of Direct Tension Test Setup

6.2. *External Conditioning Chamber (optional)*— An environmental chamber for conditioning the test specimens to the desired testing temperature. The chamber shall be capable of controlling the temperature of the test specimen over a temperature range of 5 to 25°C (41 to 77°F) to within ±0.5°C (±1°F). The chamber shall be large enough to accommodate at least a single test specimen and a "dummy" specimen with a thermocouple or other calibrated temperature-measuring device mounted at the center for temperature verification.

6.3. *Axial Deformation Measurement System*—Axial deformations shall be measured in the middle 70 mm (2.76 in.) of the test specimen using sensors mounted between gauge points that are glued to the test specimen. The deformations shall be measured at three locations 120 degrees apart, or four locations 90 degrees apart.

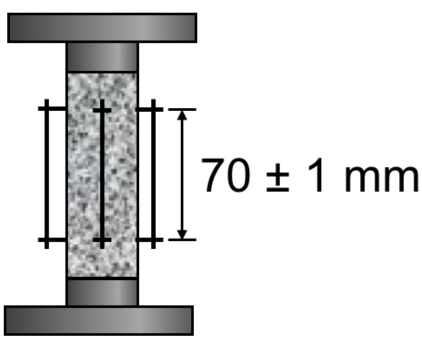

Figure 4—General Schematic of Gauge Points (Not to Scale)

6.4. *Loading Platens*—Are adhered to the top and bottom of the specimen to transfer the load from the testing machine to the specimen. The diameter of the loading platens shall be 38±1 mm (1.50±0.04 in.). These platens should be made of

hardened or plated steel, or anodized high strength aluminum. Materials that have linear elastic modulus properties and hardness properties lower than that of 6061-T6 aluminum shall not be used. The face of each loading platen shall be grooved to provide better adhesion between the epoxy adhesive and plate. The top loading platen shall be designed so that it can be mated to the test machine without inducing any loading eccentricity. May be called end plates or end platens colloquially.

6.5. *Ball Bearing (optional)* —Users may place a ball bearing in the dent of the upper loading platen or spacer platen in an attempt to account for loading eccentricity. Extra care should be taken using the ball bearing because if the screws are not tightened evenly around then excessive tensile stresses will develop on one side of the test specimen due to an induced loading eccentricity.

6.6. *Loading Platen Gluing Apparatus*—Used for gluing the loading platens to the test specimen with epoxy adhesive. The device should ensure that the loading platens and test specimen are all centered, that the two loading platens are held parallel, and that the test specimen is standing perpendicular to the loading platens. The weight resting on the test specimen during curing of the adhesive shall not exceed 0.02 kN (4.5 lb).

Figure 5—Loading Platen Gluing Apparatus

6.7. *Spacer Platens (optional)*—May be required to attach the test specimen to the AMPT due to the small test specimen size.

6.8. *Epoxy adhesive*—Is required to affix the loading platens to the test specimen. The epoxy adhesive must be capable of maintaining adhesion between metal and asphalt concrete under cyclic tension loading.

Note 1—Devcon 10240 Plastic Steel 5 Minute Putty has been used successfully (McMaster Carr Catalog Number 74575A63).

7. HAZARDS

7.1. Use standard laboratory safety precautions, equipment, and personal protection equipment when preparing and testing asphalt mixture specimens.

8. TESTING EQUIPMENT CALIBRATION

8.1. The guidelines provided in T 378 shall be followed to ensure that the test equipment and on-specimen measurement devices are properly calibrated.

8.2. If any of the verifications yield data that do not comply with the accuracy specified, the problem shall be corrected prior to further testing.

8.3. The hydraulic machine shall be properly tuned in displacement control mode, to enable the use of the strain selection guidance in this standard. In displacement control mode, the tuning shall be such that there is a sinusoidal actuator deformation shape and the actuator displacement returns close to the initial position on the first cycle, as this will ensure the cycles are uniform and the input strain closely matches the output strain. Consult the equipment manufacturer for guidance on the specific equipment.

9. TEST SPECIMEN MOUNTING AND INSTRUMENTATION PROCEDURE

9.1. Test specimens, 38-mm diameter by 110-mm height, shall be fabricated in accordance with PP XX.

9.2. Attach the gauge points to the test specimen in accordance with the manufacturer's instructions. Take care to avoid placing gauge points directly in-line with screw holes in the loading platens, which will be used to attach the test specimen to the testing machine.

Note 2—The same epoxy adhesive used for the loading platens has been found to be satisfactory for attaching the gauge points.

Note 3— Users may attach gauge points before or after the loading platens. However, the gluing apparatuses may require that the loading platens and gauge points are attached in a specific order.

9.3. Verify that the gauge length is 70 mm ± 1 mm, measured center to center of the gauge points.

9.4. Thoroughly clean all loading platens by first heavily brushing the face of each loading platen using either a hand operated wire brush, sandpaper, or a wire brush attached to a standard electric drill. After cleaning the loading platen, wipe the surface clean of any dust by using a towel dipped in acetone or similar solvent.

9.5. Using the same towel, but with only a small amount of solvent, wipe both ends of the test specimen clean of any residual dust.

9.6. Weigh out an appropriate amount of each part of the epoxy adhesive to adhere the loading platens and specimen to one another. The gluing process will require approximately 5 minutes, so prepare an epoxy adhesive that is appropriate for this length of working time.

Note 4—Approximately 6 grams (0.21 oz.) of the Devcon 10240 Plastic Steel 5 Minute Putty has been found to be suitable for 38-mm (1.50 in.) diameter test specimens.

9.7. Fill in any surface voids and pores in the top and bottom surfaces of the test specimen with the adhesive.

9.8. Divide the remaining adhesive in half and spread evenly between the loading platens, ensuring that the grooves are filled. Insert and secure the loading platens into the gluing jig and gently place the specimen on top of the bottom loading platen, as close as possible to the center. Engage the centering mechanism to center the test specimen on the loading platen. Lower the top plate into position, and secure if necessary. The final adhesive thickness should be approximately 1 mm (0.04 in.). Allow the epoxy adhesive to reach its initial set before moving the specimen from the jig.

9.9. Remove the test specimen from the gluing jig after initial set, taking special care to support the entire specimen from the bottom loading platen. Do not lift the specimen by the top loading platen, to ensure tension is not applied to the test specimen and epoxy adhesive.

9.10. Allow the epoxy adhesive to reach a functional cure before testing. Follow the manufacturer's recommendation to determine the time needed to reach full cure.

10. TEST INFORMATION

10.1. This test procedure is designed to first test the test specimens, at a specific temperature and frequency in oscillation (cyclic) mode to obtain linear viscoelastic fingerprints, and then at the desired frequency and temperature until failure.

10.2. A total of three acceptable tests, with specimens experiencing middle failure between 2,000 and 80,000 cycles to failure, and with a DMR between 0.9 and 1.1, are required.

10.3. The testing temperature can be selected using Table 1 or Table 2, where the specified PG of the binder material is used to determine the test temperature. Table 1 is used for PG grades developed using AASHTO M 320, or PG grades designated as “S” in AASHTO M 332. Table 2 is used for PG grades designated as “H”, “V” or “E” in AASHTO M 332. If the mixture contains recycled material and a binder with a lower (softer) PG was used in lieu of the originally specified PG, defer to the originally specified PG when selecting the testing temperature.

Note 5—The temperature used to conduct this test is selected to produce a satisfactory testing condition. The models used to analyze this test can translate satisfactory results at one temperature to a wide range of temperature conditions.

Note 6—For binders graded with a PG high temperature of 67, round down to 64 to use Table 1.

Table 1—Recommended Test Temperatures for Different Standard PG Binder Grades

PG Low Temperature, °C	Test Temperature, °C						
	PG High Temperature, °C						
	46	52	58	64	70	76	82
-10	15	18	21	21	21	21	21
-16	12	15	18	21	21	21	21
-22	9	12	15	18	21	21	21
-28	9	9	12	15	18	21	21
-34	9	9	9	12	15	18	21
-40	9	9	9	9	12	15	18
-46	9	9	9	9	9	12	15

Table 2—Recommended Test Temperatures for Different PG Binder Grades with MSCR “H”, “V”, or “E” designations

PG Low Temperature, °C	Test Temperature, °C						
	PG High Temperature, °C						
	46	52	58	64	70	76	82
-10	18	21	21	21	21	21	21
-16	15	18	21	21	21	21	21
-22	12	15	18	21	21	21	21
-28	9	12	15	18	21	21	21
-34	9	9	12	15	18	21	21
-40	9	9	9	12	15	18	21
-46	9	9	9	9	12	15	18

11. PROCEDURE

11.1. *Test Setup:*

11.1.1. Spacer platens may need to be placed between the loading platens and AMPT platens to compensate for the reduced height and diameter of the test specimens. If so, attach the spacer platens to the machine according to the manufacturer's instructions.

11.1.2. If using an external conditioning chamber to temperature-condition the specimens, continue to Section 11.1.3. If using the AMPT testing chamber to temperature-condition the specimens, skip to Section 11.1.5.

11.1.3. Insert the test specimens to be tested and the "dummy" specimen with the center-mounted temperature monitoring device into the external conditioning chamber and start the temperature control of the AMPT.

11.1.4. Allow the test specimens to reach the specified testing temperature ±0.5°C (±1°F) by monitoring the temperature of the "dummy" specimen.

11.1.5. Open the AMPT chamber and note the time.

11.1.6. Insert the test specimen into the testing machine and tighten the lower loading platen securely to the AMPT platen or spacer platen.

11.1.7. Bring the actuator into position and apply approximately 0.01 kN (2.2 lbs) of seating load. Quickly secure the top loading platen to the top AMPT platen or spacer platen, tightening screws evenly around and making sure not to overtighten any screws, which can shear the specimen.
Note 7—Shims may be placed between the top loading platen and the AMPT platen to account for any small gaps. This is done at the user's discretion. Users should use the ball bearing for test specimens which exhibit (after the seating load is applied) any gap between the loading platens and AMPT platen in excess of 1 mm (0.04 in.).

11.1.8. Reduce the load on the specimen to 0 kN ± 0.01 kN (0 lb ± 2 lb).

11.1.9. Attach the sensors to the test specimen gauge points. Position each sensor in a location along its travel range where the elongation of the test specimen will not exceed the range of the sensors as it undergoes damage, but the compression on the fingerprint can also be measured. This may not be the zero position; the exact position depends on the sensors.

11.1.10. Close the testing chamber and allow the chamber temperature to return to the testing temperature. Note the time that the chamber returns to the test temperature, and calculate the duration of time from when the chamber was opened. This period is referred to as the test setup time.

11.1.11. Determine the ambient temperature and calculate the difference between the ambient temperature and test temperature and denote as ΔT.

11.1.12. Allow the test specimen to reach the specified testing temperature ± 0.5°C (± 1°F). For most testing machines, use Table 3 to determine the minimum length of time the test specimen must condition in the AMPT chamber following setup.

11.1.12.1. If the test specimen is not conditioned in an external chamber prior to setup, use the "AMPT Condition" column.

Table 3—AMPT Conditioning Time for Different Test Setup Times

|ΔT| (°C)	AMPT Conditioning Time (hours)			
	AMPT Condition	Test Setup Time (min) after External Conditioning		
		5	10	20
15	1.50	*	1.00	1.25
14	1.50	*	1.00	1.25
13	1.50	*	1.00	1.25
12	1.25	*	1.00	1.25
11	1.25	*	1.00	1.25
10	1.25	*	1.00	1.25
9	1.25	0.75	1.00	1.00
8	1.25	0.75	1.00	1.00
7	1.25	0.75	1.00	1.00
6	1.25	0.75	1.00	1.00
5	1.00	0.75	0.75	1.00
4	1.00	0.75	0.75	1.00
3	1.00	0.50	0.75	0.75
2	1.00	0.50	0.75	0.75
1	0.75	0.25	0.50	0.50

*The test machine could not return to the test temperature in this amount of time.

11.1.13. Adjust, balance, and zero the electronic measuring system if the AMPT does not automatically adjust, balance, and zero.

11.2. *Dynamic Modulus Fingerprint Test:*

11.2.1. Input the required information for the dynamic modulus fingerprint test into the equipment control software. The fingerprint test shall be performed at a frequency of 10 Hz, at a target strain range of 50-75 microstrain, at the target test temperature, and in the tension-compression mode of loading.

Note 8—Some software may require input of an estimated dynamic modulus value to estimate the starting load amplitude. In this case, enter a value similar to the modulus obtained during frequency sweep testing (using TP XX or T 378) if available. If not available, enter a conservative (low) estimate of the dynamic modulus so that the initial load does not damage the test specimen.

11.2.2. Start the fingerprint test. The AMPT shall calculate the load level necessary to achieve 50 to 75 microstrain using the results of these first few cycles and then

apply this load level for 50 cycles. A minimum of 50 data points per cycle shall be recorded using equipment control software.

11.2.3. Compute the dynamic modulus for the last five cycles according to the method recommended in TP XX or T 378. If the peak-to-peak strain exceeds 150 microstrain, discard the test specimen.

11.2.4. The test specimen shall rest at a load of 0 kN ± 0.01 kN (0 lb ± 2 lb) for a minimum of 20 minutes following the fingerprint testing.

11.3. *Cyclic Fatigue Test:*

11.3.1. Perform a constant positive movement actuator oscillation (cyclic) fatigue experiment at a frequency of 10 Hz (e.g., a pull-pull actuator displacement test). Use a strain level that will result in a test length between 2,000 and 80,000 cycles to failure. Guidance on selecting an appropriate strain level is given in Appendix X1.

11.3.2. Allow the test to run until a clear peak in the phase angle is observed, the machine limits are reached and the test stops automatically, or the test reaches 80,000 cycles. The peak in phase angle is shown in Figure 5. If end failure occurs, the data must be discarded from analysis and the test must be repeated on a new specimen. Exclude any tests with a number of cycles to failure greater than 80,000 or less than 2,000 from analysis.

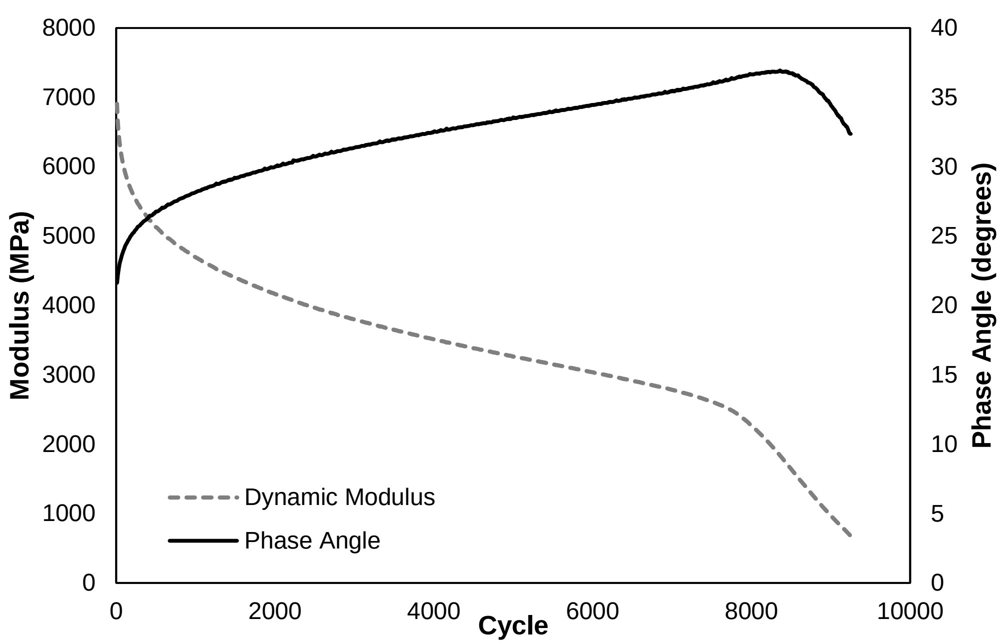

Figure 6—Dynamic Modulus and Phase Angle Changes Throughout Testing

11.4. Repeat steps in Section 11.1 through 11.3 on the remaining test specimens.

12. CALCULATIONS

12.1. This section presents the equations used to calculate the pseudo strain, pseudo secant modulus, and damage parameter for the fatigue tests. All of the calculations in this section can be automatically performed using a combination of the AMPT control software and the ALPHA-Fatigue software or the FlexMAT™ spreadsheet described in the final report for the FHWA Project DTFH61-08-H-00005.

12.2. Determine the $E(t)$ Prony coefficients from the dynamic modulus and phase angle measured using T 378 or TP XX and R 84. It is assumed that the relaxation modulus can be represented by Equation 1.

$$E(t) = E_\infty + \sum_{i=1}^{N} E_m e^{-t/\rho_m} \qquad (1)$$

where:

$E(t)$ = relaxation modulus as a function of time, t, (kPa or psi);

E_∞ = long-time equilibrium modulus, (kPa or psi);

E_m = modulus of Prony term number m, (kPa or psi);

ρ_m = relaxation time of Prony term m (s); and

N = number of Prony terms used.

12.3. Compute the storage modulus, E', for each temperature and frequency combination measured via Equation 2.

$$E' = |E^*| \times \cos\left(\frac{\theta \times \pi}{180}\right) \qquad (2)$$

where:

E' = storage modulus (kPa or psi);

$|E^*|$ = dynamic modulus determined via experiment (kPa or psi); and

θ = phase angle determined via experiment (degrees).

12.4. Optimize the coefficients in Equations 3 and 7 simultaneously. Because measured data contain some variability, a smoothing process is needed to obtain reliable coefficients.

$$\log\left(E'(\omega,T)\right) = \log\left(E'(\omega_R)\right) = \kappa + \frac{\log(\max \mathrm{E'}) - \kappa}{1+e^{\delta+\gamma\log(\omega_R)}} \qquad (3)$$

where:

$E'(\omega,T)$ = storage modulus at a particular temperature and angular frequency (kPa or psi);

$E'(\omega_R)$ = storage modulus at a particular reduced angular frequency (kPa or psi);

ω_R = reduced angular frequency, Equation 6 (rad/s);

max = defined by Equation 4; and

κ, δ, γ = fitting coefficients.

$$\max E' = P_c\left[A\left(1-\frac{VMA}{100}\right)+B\left(\frac{VFA\ x VMA}{10,000}\right)\right]+\frac{1-P_c}{\left[\frac{\left(1-\frac{VMA}{100}\right)}{A}+\frac{VMA}{B(VFA)}\right]} \tag{4}$$

where:

P_c = defined in Equation 5 (kPa or psi);

VMA = voids in mineral aggregate, %;

VFA = voids filled with asphalt, %;

A = 4,200,000 for prediction in psi or 29,000,000 for prediction in kPa; and

B = 435,000 for prediction in psi or 3,000,000 for prediction in kPa.

$$P_c = \frac{\left(20+\frac{435,000(VFA)}{VMA}\right)^{0.58}}{650+\left(\frac{435,000(VFA)}{VMA}\right)^{0.58}} \tag{5}$$

$$\omega_R = \omega * a_T \tag{6}$$

where:

a_T = time–temperature shift factor at a given temperature.

$$a_T = 10^{\alpha_1\left(T^2-T_{ref}^2\right)+\alpha_2\left(T-T_{ref}\right)} \tag{7}$$

where:

T = temperature (°C or °F);

T_{ref} = reference temperature (°C or °F); and

α_1, α_2 = fitting coefficients.

12.5. Compute the total Storage modulus according to Equation 8.

$$E' = E_\infty + \sum_{m=1}^{N}\frac{E_m\omega_R^2\rho_m^2}{\omega_R^2\rho_m^2+1} \tag{8}$$

12.6. Compute the total Loss modulus according to Equation 9.

$$E'' = \sum_{m=1}^{N}\frac{E_m\omega_R\rho_m}{\omega_R^2\rho_m^2+1} \tag{9}$$

12.7. Compute the specimen-to-specimen normalization parameter using Equation 10 and denote this parameter as the DMR (Dynamic Modulus Ratio).

$$\text{DMR} = \frac{|E^*|_{\text{fingerprint}}}{|E^*|_{LVE}} \tag{10}$$

where:

$|E^*|_{\text{fingerprint}}$ = dynamic modulus determined from Section 11.15 (kPa or psi);

$|E^*|_{LVE}$ = average representative dynamic modulus for the mixture of interest at the temperature and frequency of interest (kPa or psi), and computed by Equation 11; and

DMR = dynamic modulus ratio, which is the specimen variability compensation parameter.

$$|E^*|_{LVE} = \sqrt{\left[E_\infty + \sum_{m=1}^{N} \frac{E_m \omega_R^2 \rho_m^2}{\omega_R^2 \rho_m^2 + 1}\right]^2 + \left[\sum_{m=1}^{N} \frac{E_m \omega_R \rho_m}{\omega_R^2 \rho_m^2 + 1}\right]^2} \tag{11}$$

where:

ω = angular frequency used in the fingerprint experiment;

a_T = time–temperature shift factor for the fingerprint test temperature;

ω_R = reduced angular frequency, Equation 12, used in the fingerprint experiment; and

E_∞, E_m, ρ_m = Prony coefficient terms.

$$\omega_R = \omega * a_T \tag{12}$$

12.8. Separate the data into two parts. The first part, Dataset 1, comprises the data for the first half of the first loading path (from zero to first peak stress). The second part, Dataset 2, comprises the rest of the data.

12.9. For Dataset 1, average all sensor readings and compute the average strain for all data points.

12.10. Calculate the axial stress for each data point in Dataset 1.

12.11. Compute the reduced time for each data point in Dataset 1 using Equation 13.

$$t_R = \frac{t}{a_T} \tag{13}$$

where:

a_T = time–temperature shift factor at a given temperature;

t = time measured from the experiment (s), and

t_R = reduced time (s).

12.12. Compute the pseudo strain for each data point in Dataset 1 using the state variable formulation shown in Equation 13.

$$\varepsilon^{R(n+1)} = \frac{1}{E_R}\left[\eta_o^{n+1} + \sum_{m=1}^{N} \eta_m^{n+1}\right] \tag{14}$$

where:

$\varepsilon^{R(n+1)}$ = pseudo strain at the next time step;

E_R = reference modulus, a value of 1 should be chosen;

η = elastic component of the pseudo strain (Equation 15);

η_m = pseudo strain contribution of Prony element m (Equation 16);

n = time step used in the calculation;

ε = strain calculated for the current or subsequent time step;

Δt_R = duration of the reduced time step, $t_R^{n+1}–t_R^{n}$; and

t_R = reduced time.

$$\eta_0^{n+1} = E_\infty\left(\varepsilon^{n+1}\right) \quad (15)$$

$$\eta_m^{n+1} = e^{-\Delta t_R/\rho_m}\eta_m^n + E_m \times \rho_m\left(\frac{\varepsilon^{n+1}-\varepsilon^n}{\Delta t_R}\right)\left[1-e^{-\Delta t_R/\rho_m}\right]\ \eta_0^{n+1} = E_\infty\left(\varepsilon^{n+1}\right) \quad (16)$$

12.13. Compute the normalized pseudo secant modulus for each data point in Dataset 1 using Equation 17.

$$C = \frac{\sigma}{\varepsilon^R * DMR} \quad (17)$$

12.14. The continuum damage model power term, α, is related to the log-log slope of the relaxation modulus, $E(t)$. Its value is found numerically using the Prony series representation of the $E(t)$ in Equation 1. Determine m, the maximum value of the tangential slope of the relaxation modulus versus time relationship in log-log scale, and determine the α value using Equation 18.

$$\alpha = \frac{1}{m} + 1 \quad (18)$$

12.15. Compute the change in damage, ΔS, for each time step using Equation 19. Due to inherent electronic interference (data noise) during data acquisition, a few sequential data points may have positive ΔC values. A few of these spurious data points do not negatively affect the overall value of damage (S), but they do complicate the calculation. An efficient method that accounts for these spurious data points is the piecewise function shown in Equation 19.

$$\Delta S_i = \begin{cases} \left(-\frac{DMR}{2}\left(\varepsilon^R\right)^2\left(C_i - C_{i-1}\right)\right)^{\alpha/_{\alpha+1}}\left(\Delta t_R\right)^{1/_{\alpha+1}} & C_i \le C_{i-1} \\ 0 & C_i > C_{i-1} \end{cases} \quad (19)$$

where:

C_i = pseudo secant modulus at the current time step;

C_{i-1} = pseudo secant modulus at the previous time step;

Δt_R = change in the reduced time step; and

α = continuum damage power term related to material time dependence, Equation 18.

12.16. Determine the damage at each time step using Equation 20.

$$S_i = \sum_{i=1}^{N} \Delta S_i \tag{20}$$

where:

S_i = cumulative damage at the current time step; and

ΔS_i = incremental damage for all time steps to be summed from the initial time step, $i = 1$, to the current time step, N.

12.17. Define the damage at the final point in Dataset 1 as $S_{\text{Dataset 1}}$.

12.18. Compute the peak-to-peak strain for each sensor and each cycle in Dataset 2.

12.19. For each cycle in Dataset 2, average all sensor strains and denote this strain as the test peak-to-peak strain amplitude, ε_{pp}.

12.20. Compute the peak-to-peak stress for each cycle in Dataset 2.

12.21. Compute the phase angle for each sensor and average the values together for each cycle. Depending on the test equipment (e.g., an AMPT), phase angle may be automatically calculated per sensor and averaged.

12.22. Compute the peak-to-peak pseudo strain for each cycle in Dataset 2 using Equation 21.

$$\varepsilon_{pp}^{R} = \varepsilon_{pp} * |E^*|_{LVE} \tag{21}$$

where:

ε_{pp} = average peak-to-peak axial strain; and

ε^{R}_{pp} = peak-to-peak pseudo strain.

12.23. Compute the cyclic pseudo secant modulus for each cycle in Dataset 2 using Equation 22.

$$C^* = \frac{\sigma_{pp}}{\varepsilon_{pp}^{R} * DMR} \tag{22}$$

12.24. Compute the functional form factor, β, for each cycle in Dataset 2 using Equation 23.

$$\beta = \frac{F_{\text{peak}} + F_{\text{valley}}}{|F_{\text{peak}}| + |F_{\text{valley}}|} \tag{23}$$

where:

F_{peak} = peak axial force measured by the load transducer (kN or lb); and

F_{valley} = valley axial force measured by the load transducer (kN or lb).

12.25. Compute the tension amplitude pseudo strain for each cycle in Dataset 2 using Equation 24.

$$\varepsilon_{ta}^{R} = \frac{\beta + 1}{2}\varepsilon_{pp}^{R} \tag{24}$$

where:

$\varepsilon^{R}{}_{ta}$ = tension amplitude pseudo strain.

12.26. Compute the time within a cycle when tensile loading begins, t_b, for each cycle in Dataset 2 by using Equation 25.

$$t_b = \frac{\cos^{-1}(\beta)}{62.83} \tag{25}$$

12.27. Compute the time within a cycle when tensile loading ends, t_e, for each cycle in Dataset 2 by using Equation 26.

$$t_e = \frac{2\pi - \cos^{-1}(\beta)}{62.83} \tag{26}$$

12.28. Compute the form adjustment factor for each cycle in Dataset 2 using Equation 27. Equation 27 should be solved for each cycle, but generally β does not change significantly after the first few cycles, and a constant value may be applied after this transient period. Values of *K* have been tabulated for typical values of β and α in Table 5.

Table 4—Compiled *K* Values for Typical Material and Test Conditions

	Alpha						
Beta	4.333	4.077	3.857	3.667	3.500	3.353	3.222
–0.5	0.277	0.285	0.293	0.300	0.306	0.312	0.318
0.0	0.263	0.271	0.278	0.285	0.291	0.297	0.302
0.2	0.256	0.264	0.271	0.277	0.284	0.289	0.295
0.4	0.248	0.256	0.262	0.269	0.275	0.280	0.286
0.6	0.238	0.245	0.252	0.258	0.264	0.269	0.274
0.8	0.225	0.231	0.238	0.243	0.249	0.254	0.259
1.0	0.189	0.195	0.200	0.205	0.209	0.214	0.218

$$K = \frac{1}{t_e - t_b}\left[\left(\frac{1}{\beta+1}\right)^{2\alpha}\int_{t_b}^{t_e}\left(\beta - \cos(62.83*t)\right)^{2\alpha} dt\right] \tag{27}$$

Note 9—Equation 27 can be solved with sufficient accuracy using a suitable numerical technique with the number of time steps equal to 100.

12.29. Compute the average reduced time for each cycle in Dataset 2 using Equation 28.

$$t_R = \frac{1}{a_T}\left[\frac{N}{10}\right] \tag{28}$$

where:

N = cycle number.

12.30. Compute the change in damage, ΔS, for each cycle in the Dataset 2 using Equation 29.

Note 10—Even with data reduction, a few sequential data points may have positive ΔC values. A few of these spurious data points do not negatively affect the overall value of S, but they do complicate the calculation. An efficient method that accounts for these spurious data points is to use the piecewise function shown in Equation 23.

$$\Delta S_n = \begin{cases} \left(-\frac{DMR}{2} \left(\varepsilon_{ta}^R \right)^2 \left(C^*_n - C^*_{n-1} \right) \right)^{\alpha/\alpha+1} \left(\Delta t_R \right)^{1/\alpha+1} \left(K_1 \right)^{1/\alpha+1} & C^*_n \le C^*_{n-1} \\ 0 & C^*_n > C^*_{n-1} \end{cases} \qquad (29)$$

where:

C^*_n = the cyclic pseudo secant modulus at the current analysis cycle;

C^*_{n-1} = the cyclic pseudo secant modulus at the previous analysis cycle; and

Δt_R = the change in the average reduced time between analysis cycles.

12.31. Determine the damage at each analysis cycle using Equation 30.

$$S_n = S_{\text{dataset1}} + \sum_{n=1}^{N} \Delta S_n \qquad (30)$$

where:

S_{Dataset1} = cumulative damage value at the end of Dataset 1;

S_n = cumulative damage at the current analysis cycle; and

ΔS_n = incremental damage for all analysis cycles to be summed from the initial analysis cycle step, $n = 1$, to the current time step, N.

12.32. Combine the damage and pseudo secant modulus from each time step in the first cycle, Sections 12.13 and 12.16, with the cyclic pseudo secant moduli and damage values from Sections 12.23 and 12.31, into a single dataset.

12.33. For each mixture, determine the damage characteristic relationship by fitting one of the following equations to the plot of the pseudo secant modulus and damage from successful fatigue tests.

$$C = e^{aS^b} \text{ or} \qquad (31)$$

$$C = 1 - yS^z \qquad (32)$$

where:

a, b = the fitting coefficients for the exponential model; and

y, z = the fitting coefficients for the power model.

Note 11—The coefficients k_1, k_2, and k_3 can be fit using the N_f and ε_t for use in the AASHTOWare Pavement ME Design software with additional localized calibration coefficients.

12.34. Calculate the summation of (1-C) for each specimen.

$$Sum(1-C)=\int_0^{N_f}(1-C)\,dN \tag{33}$$

where:

N_f = cycles to failure

12.35. Determine the average reduction in pseudo secant modulus to failure by plotting the Sum(1-C) term against the number of cycles to failure for each specimen and fitting a line through the origin. The average reduction in pseudo secant modulus, D^R, is the slope of the fitted line.

13. REPORT

13.1. Report the following for each specimen tested:

13.1.1. Test temperature;

13.1.2. The fingerprint dynamic modulus, $|E^*|_{\text{fingerprint}}$;

13.1.3. DMR value; and

13.1.4. Sum(1-C) and N_f for each test specimen.

13.2. Report the following for each mixture tested:

13.2.1. The model term related to the log-log slope of the relaxation modulus master curve, α;

13.2.2. C versus S curve coefficients (a and b in Equation 31 or y and z in Equation 32); and

13.2.3. D^R for each mixture.

14. KEYWORDS

14.1. AMPT; axial deformation; complex modulus; cyclic fatigue; damage characteristic curve; direct tension; DMR; dynamic modulus; failure cycle; fingerprint; modulus; phase angle; Prony coefficients; relaxation modulus; pseudo secant modulus; pseudo strain; specimen deformation; strain.

APPENDIXES

(Nonmandatory Information)

X1. PROCEDURE FOR DETERMINING THE ON-SPECIMEN STRAIN LEVEL

X1.1. This procedure is designed to determine a target on-specimen strain level that produces test lengths between 5,000 and 40,000 cycles. The procedure is described in detail in Sections X1.3-X1.5 and shown schematically in the flow chart shown in Figure X1.

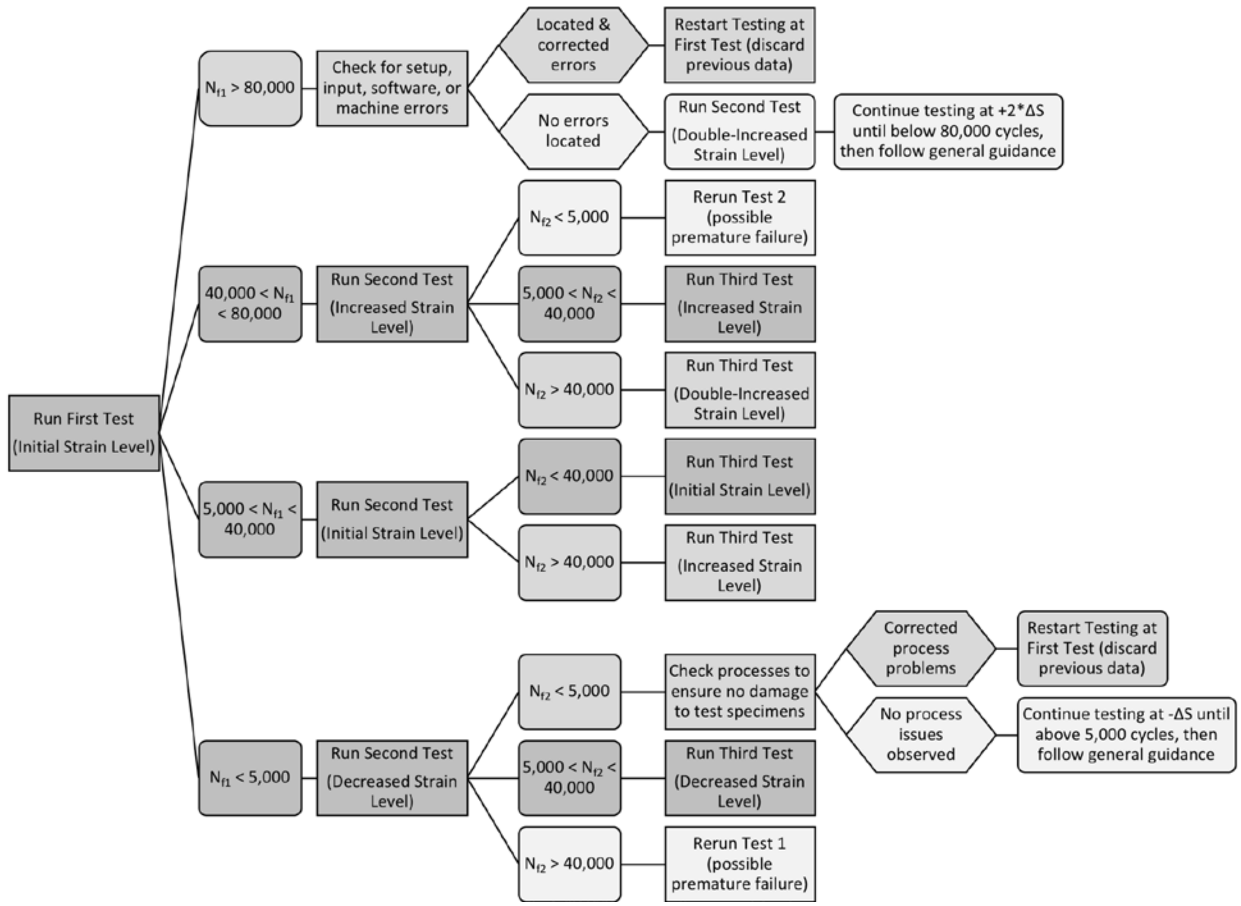

Figure X1: Diagram of the Strain Level Determination Process

X1.2. The referenced strain levels throughout the procedure can be found in Table X1. For the dynamic modulus input, use the value of $|E^*|_{LVE}$ calculated in Equation (11) based on the results of dynamic modulus testing, if available. If that value is not available, the fingerprint modulus of the first specimen may be used, however there may be discrepancy between fingerprint moduli of individual specimens due to specimen-to-specimen variability. Do not adjust the selected modulus value after the first acceptable test.

Table X1—Target On-Specimen Strain Levels

|E*| (MPa)	Initial Strain Level (microstrain)	Decreased Strain Level (microstrain)	Increased Strain Level (microstrain)	Double-Increased Strain Level (microstrain)	ΔS (microstrain)
	First test; Second test if 5,000<N_{f1}<40,000	Second test if N_{f1}<5,000	Second test if 40,000<N_{f1}<80,000	Second test if N_{f1}>80,000	Adjust repeated very short or very long tests
2500	1030	760	1300	1570	270
3000	920	690	1150	1380	230
3500	830	630	1030	1230	200
4000	760	580	940	1120	180
4500	710	550	870	1030	160
5000	660	510	810	960	150
5500	620	480	760	900	140
6000	590	460	720	850	130
6500	560	440	680	800	120
7000	530	420	640	750	110
7500	510	400	620	730	110
8000	490	390	590	690	100
8500	470	380	560	650	90
9000	450	360	540	630	90
9500	440	350	530	620	90
10000	420	340	500	580	80
10500	410	330	490	570	80
11000	400	320	480	560	80
11500	390	320	460	530	70
12000	380	310	450	520	70
12500	370	300	440	510	70
13000	360	290	430	500	70
13500	350	290	410	470	60
14000	340	280	400	460	60
14500	330	270	390	450	60
15000	330	270	390	450	60
15500	320	260	380	440	60
16000	310	260	360	410	50
16500	310	260	360	410	50
17000	300	250	350	400	50
17500	290	240	340	390	50
18000	290	240	340	390	50
18500	280	230	330	380	50
19000	280	230	330	380	50
19500	280	230	330	380	50
20000	270	230	310	350	40

X1.3. *First Test:*

X1.3.1. Run the first test at the Initial Strain Level.

X1.4. *Second Test:*

X1.4.1. If the first test yielded a number of cycles to failure between 5,000 and 40,000 cycles, run the second test at the Initial Strain Level again. If the first test yielded a number of cycles to failure between 40,000 and 80,000 cycles, run the second test at the Increased Strain Level. If the first test yielded a number of cycles to failure less than 5,000 cycles, run the second test at the Decreased Strain Level.

X1.4.2. If the first test yields a number of cycles to failure greater than 80,000 cycles, check for operator errors or machine problems (i.e., correct inputs, proper tuning, etc.). If issues are identified, correct the issues, discard the first test data, and run another test at the Initial Strain Level. If no issues are identified, run the next test at the Double-Increased Strain Level. If subsequent tests are longer than 80,000 cycles, increase the strain by $2*\Delta S$ for each subsequent test until the number of cycles to failure is less than 80,000 cycles then continue to X1.4 for subsequent tests.

X1.5. *Third and Subsequent Tests:*

X1.5.1. If the second test yields between 5,000 and 40,000 cycles to failure, continue testing at the same level as the second test for subsequent tests.

X1.5.2. If the first test yielded between 5,000 and 40,000 cycles to failure, but the second test yielded less than 5,000 cycles to failure, run the third test at the Initial Strain Level.

X1.5.3. If the first test yielded greater than 5,000 cycles to failure, and the second test yields a number of cycles to failure greater than 40,000 cycles, increase the strain level by ΔS for subsequent tests, until the number of cycles to failure is between 5,000 and 40,000.

X1.5.4. If both the first and second tests yield a number of cycles to failure less than 5,000 cycles, investigate the specimen fabrication, preparation, and installation processes to ensure the test specimens are not being damaged (e.g., test specimen carried by the top of the specimen or the top loading platen, attached to the machine unevenly, etc.). Correct any issues identified, discard previous test data, and rerun both tests. If no issues are found, reduce the strain level by ΔS for subsequent tests, until the number of cycles to failure is between 5,000 and 40,000.

X1.5.5. If the first two tests have been run at the prescribed strain levels, but one yielded a number of cycles to failure greater than 40,000 cycles and the other yielded less

than 5,000 cycles, rerun the test that yielded less than 5,000 cycles, as that is an unexpected result. If the repeated test fails before 5,000 cycles, select a strain level between the two levels previously evaluated.

X2. USE OF ALTERNATIVE SMALL SPECIMEN GEOMETRIES

X2.1. *Alternative small specimen geometries*—Test specimens of geometries other than the 38-mm (1.50 in.) test specimen specified can be obtained from constructed pavement layers to measure fatigue properties for use in applications such as forensic investigations and field monitoring of test sections. Test specimens with a 50-mm (1.97 in.) diameter can be used where there are concerns about the use of 38-mm (1.50 in.) test specimens. Prismatic specimens that are 25 mm by 50 mm by 110 mm (0.98 in. by 1.97 in. by 4.33 in.) can be used for construction lifts thinner than 38-mm (1.50 in.).

X2.2. *Alternative small specimen geometry test equipment*—The same gauge points, gauge length, and on-specimen deformation sensors as those used for 38-mm diameter cylindrical specimens are used. Alternate loading platens should be designed or procured with a gluing surface to match the alternative specimen geometry. This may require custom adapters for the AMPT equipment. Any measurement given directly in units of force (i.e., seating load for securing the specimen) should be scaled to an equal-stress condition with the 38-mm (1.50 in.) test specimens.

Executive Summary for Proposed Stress Sweep Rutting Test

Scope

The proposed stress sweep rutting (SSR) test specifications describe a test method to characterize the resistance of asphalt mixtures to rutting using the shift model. The SSR test measures the permanent strain characteristics of asphalt mixtures as a function of deviatoric stress, loading time, and temperature. SSR tests are conducted using an Asphalt Mixture Performance Tester. Results from two SSR tests at each of the high and low temperatures are used to develop the shift model. The shift model has been implemented into the pavement performance prediction program, FlexPAVE^{TM}, to predict the permanent deformation of asphalt layers under various deviatoric stress levels, loading times, and temperatures as a function of pavement depth and time. The SSR test results also can be employed as part of a performance-engineered mix design for asphalt mixtures. The proposed shift model has been used in several different projects to predict the rut depth in the asphalt layer. A comparison of simulation results with field measurements indicates that the SSR test and shift model can predict rut depths in the field very well. Figure 1 presents a comparison of rut depth measurements and FlexPAVE^{TM} predictions for the National Center for Asphalt Technology (NCAT) project.

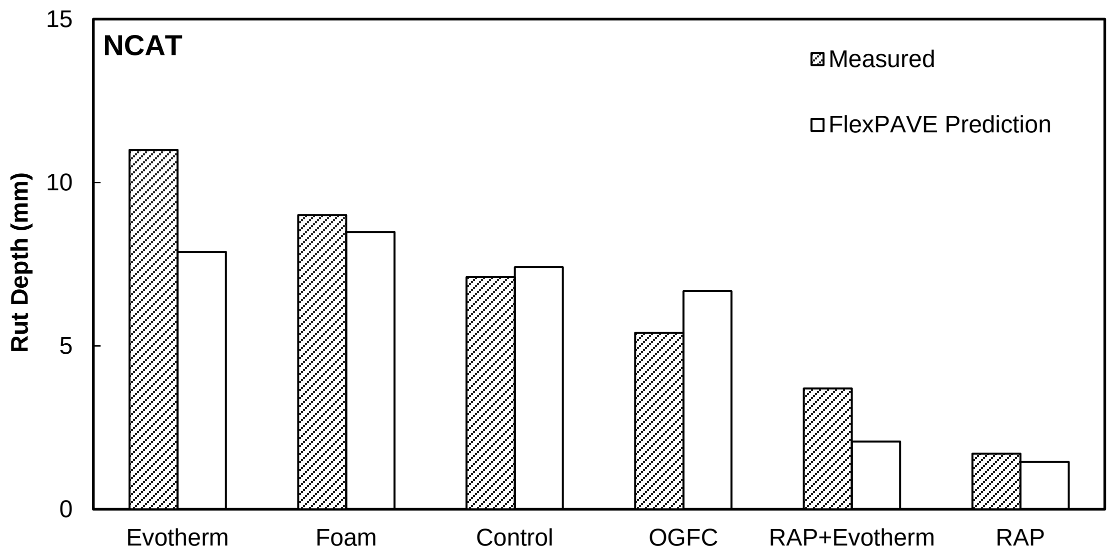

Figure 1 Comparison of rut depth measurements and FlexPAVE^{TM} predictions

Test Descriptions

Tests shall be performed using 100-mm (4-in.) diameter by 150-mm (6-in.) tall specimens fabricated in accordance with AASHTO R 83. This standard is applicable to laboratory-prepared specimens of asphalt mixtures with a nominal maximum aggregate size that is less than or equal to 37.5 mm (1.5 in.).

At least two replicate specimens shall be tested at each low and high temperature. The two test temperatures (low and high) shall be selected based on LTPPBind V. 3.1 software.

Constant confining pressure of 10 psi should be applied during the test. Vertical loading is applied for 600 cycles at three deviatoric stress levels for each of the two temperatures: 70, 100, and 130 psi for the low temperature (T_L) and 100, 70, and 130 psi for the high temperature (T_H). The load pulse is 0.4 s for each cycle. The rest periods are 1.6 s for T_L and 3.6 s for T_H.

The main reason to select different orders of deviatoric stresses between two temperatures is to reduce the number of test specimens and testing time. In the shift model, the *reference curve* is needed, which is defined as the permanent strain growth of asphalt mixture under cyclic loading of 100 psi deviatoric stress and 10 psi confining pressure at T_H. This relationship can be obtained by running triaxial repeated load permanent deformation test; however, it would require 2-3 specimens and tests in addition to the four tests at the two test temperatures. It was found that running the 100 psi loading block first at T_H would be sufficient to obtain the reference curve from the loading block. This reversal of 70 psi and 100 psi loading blocks reduces the required number of tests from six to four without losing the strengths of the shift model.

The permanent axial deformation that occurs at each load cycle is measured using actuator displacement, so this test protocol does not require on-specimen LVDTs.

Permanent Strain Shift Model Description

The coefficients in the shift model are ε_0, N_I, β, p_1, p_2, d_1, and d_2.

Once the model coefficients from the SSR test results are known, the permanent strain can be predicted using the following equations at a certain load cycle under specific temperature (T) and vertical stress (σ_v) conditions.

$$\varepsilon_{vp} = \frac{\varepsilon_0 \times N_{red}}{\left(N_I + N_{red}\right)^{\beta}}$$

$$a_{\sigma_v} = (d_1 \times T + d_2) \times (\log(\sigma_v / P_a) - 0.877)$$

$$a_{\xi_p} = p_1 \times log\left(\xi_p\right) + p_2$$

$$a_{total} = a_{\sigma_v} + a_{\xi_p}$$

$$N_{red} = N \times 10^{a_{total}}$$

Standard Method of Test for

STRESS SWEEP RUTTING (SSR) TEST USING ASPHALT MIXTURE PERFORMANCE TESTER (AMPT)

AASHTO Designation: TP ×××-××

1 SCOPE

1.1 This standard describes a test method to characterize the resistance of asphalt mixtures to rutting using the shift model. The stress sweep rutting (SSR) tests are conducted using the Asphalt Mixture Performance Tester (AMPT).

1.2 This standard is applicable to laboratory-prepared specimens of asphalt mixtures with a nominal maximum aggregate size that is less than or equal to 37.5 mm (1.5 in.).

1.3 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to its use.

2 REFERENCED DOCUMENTS

2.1 **AASHTO Standards**

- AASHTO R 83, Fabrication of Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor (SGC)
- AASHTO T 312, Standard Method for Preparing and Determining The Density of Hot Mix Asphalt (HMA) Specimens by Means of The SHRP Gyratory Compactor
- AASHTO T 378, Standard Method of Test for Determining the Dynamic Modulus and Flow Number for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)

2.2 **Other Documents:**

- Choi, Y. and Y. R. Kim. Implementation and Verification of a Mechanistic Permanent Deformation Model (Shift Model) to Predict Rut Depths of Asphalt Pavement. *Road Materials and Pavement Design*, Vol. 15, 2014, pp. 195-218.
- Kim, D. and Y. R. Kim. Development of Stress Sweep Rutting (SSR) Test for Permanent Deformation Characterization of Asphalt Mixture. *Construction and Building Materials*, Vol. 154, 2017, pp. 373-383.
- FHWA Report, *Development of Asphalt Mixture Performance Related Specifications, Final Report of Project* DTFH61-08-H-00005, In Press, 2017.

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3 TERMINOLOGY

3.1 *Permanent strain* – the non-recovered strain in a repeated load test.

3.2 *Repeated load cycle* – loading of 0.4 second followed by a 3.6-second rest period at the high test temperature (T_H) and loading of 0.4 second followed by a 1.6-second rest period at the low test temperature (T_L).

3.3 *Loading block* – 200 repetitions of loading cycles.

3.4 *Confining pressure* – the stress applied to all surfaces in a confined test.

3.5 *Vertical stress* – the total vertical stress, including applied stress and confining pressure.

3.6 *Deviatoric stress* – the difference between the vertical stress and the confining pressure.

3.7 *Shift model* – the permanent strain model that can predict permanent strain under various load times, deviatoric stress levels, and temperatures.

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4 SUMMARY OF THE TEST METHOD

4.1 The SSR test is conducted at two test temperatures, referred to as T_H (the high temperature) and T_L (the low temperature), and under constant confining pressure of 69 kPa (10 psi), with three 200-cycle loading blocks of three deviatoric stress levels.

4.2 The load pulse is 0.4 second for each cycle. The rest period is dependent on the test temperature. The permanent axial deformation that occurs at each load cycle is measured using actuator displacement.

5 SIGNIFICANCE AND USE

5.1 The SSR test measures permanent deformation characteristics of asphalt mixtures as a function of deviatoric stress, loading time, and temperature. The results from two SSR tests at each of the high and low temperatures can be used to develop the shift model. The shift model has been implemented into the pavement performance prediction program, FlexPAVE™, to predict the permanent deformation of asphalt layers under various deviatoric stress levels, loading times, and temperatures as a function of pavement depth and time. The SSR test results also can be employed as part of a performance-engineered mix design for asphalt mixtures.

5.2 The shift model is based on the permanent deformation behavior of an asphalt mixture in the primary and secondary regions. If tertiary flow occurs during the SSR test, the applicability of the shift model to the test results depends on when the tertiary flow occurs. If the tertiary flow occurs during the first or second loading blocks, the test results should not be used to develop the shift model. If the tertiary flow occurs toward the end of the third loading block, the test results can be used to develop the shift model.

6 APPARATUS

6.1 *Specimen fabrication equipment* – equipment used to fabricate SSR test specimens as described in AASHTO R 83.

6.2 *Asphalt Mixture Performance Tester (AMPT)* – a dynamic testing apparatus that meets the requirements of *Equipment Specification for the Simple Performance Test System, Version 3.0*.

6.3 *Conditioning chamber* – an environmental chamber that is used to condition the test specimens to the desired test temperature. The environmental chamber shall be able to control the temperature of the specimen over a temperature range from 4°C to 70°C (39°F to 158°F) to an accuracy of ± 0.5°C (0.9°F). The chamber shall be large enough to accommodate at least two specimens to be tested, plus a dummy specimen with a temperature sensor mounted in the center for temperature verification.

Note 1 **-** The temperature range required for the Conditioning Chamber is a function of the anticipated test temperature. The temperature control range provided in this section is intended to be inclusive of all areas of the U.S. In many climatic regions, it may not be necessary to have equipment capable of controlling the temperature up to 70°C.

6.4 *Latex membranes* – 100-mm (4-in.) diameter by 0.3-mm (0.012-in.) thick latex membranes to be used to encase the specimen and greased double-latex friction reducers to be used between the specimen and the loading platens in SSR tests.

6.5 *Silicone grease* – Dow Corning High Vacuum Grease or equivalent to be used to fabricate the greased double-latex friction reducers.

6.6 *Balance* – a scale device that is capable of determining mass to the nearest 0.01 gram. The balance is used to determine the mass of the silicone grease for the fabrication of greased double-latex friction reducers.

7 HAZARDS

7.1 This practice and associated standards involve the handling of hot asphalt binder, aggregate, and asphalt mixtures. It also includes the use of sawing and coring machinery and servohydraulic testing equipment. Use standard safety precautions, equipment, and clothing when handling hot materials and operating machinery.

8 TESTING AND EQUIPMENT CALIBRATION

8.1 The guidelines provided in AASHTO T 378 shall be followed to ensure that all test equipment is calibrated properly.

8.2 If any of the verifications yield data that do not comply with the accuracy specified, the problem shall be corrected prior to further testing.

9 PROCEDURE

9.1 *Test Specimen Preparation*

9.1.1 Tests shall be performed using 100-mm (4-in.) diameter by 150-mm (6-in.) tall test specimens fabricated in accordance with AASHTO R83.

9.1.2 Replicates – At least two replicate specimens shall be tested for each temperature.

Note 2 – It has been found that, when the difference in the strain at the end of the test between two replicates exceeds 25%, a third replicate should be tested.

9.1.3 Prepare four test specimens at the target air void content ± 0.5 percent and with the aging condition in accordance with R 83.

Note 3 — A target air void content of 7.0 percent with tolerance of ± 0.5 percent is reasonable for a typical in-place density.

9.2 *Test Temperatures*

9.2.1 The SSR test requires two temperatures: high (T_H) and low (T_L).

9.2.2 An appropriate high temperature (T_H) can be selected based on LTPPBind at the location of interest. The T_H is calculated from the degree-days parameter for the construction site using LTPPBind v. 3.1 software and Equation (1):

$$T_H = 0.87 * \left(58 + 7 * \frac{DD}{1000} - 15 * Log\left(H + 45\right) \right) \qquad \text{Equation (1)}$$

where
T_H = high test temperature, °C,
DD = degree-days > 10°C obtained from LTPPBind v. 3.1, and
H = 0 for the surface layer and design depth to top of layer for base layers, mm.

9.2.3 The low test temperature (T_L) in degrees Celsius is selected based on Table 1 that presents recommended test temperatures based on the climatic performance grade (PG). LTPPBind v. 3.1 shall be used to obtain high and low PGs with 98% reliability for the location of interest.

Table 1—Recommended Test Temperatures for Different PG Grades

PG Low Temperature, °C	Test Temperature, °C						
	PG High Temperature, °C						
	46	52	58	64	70	76	82
-10	23	26	29	32	32	32	32
-16	20	23	26	29	32	32	32
-22	17	20	23	26	29	32	32
-28	17	17	20	23	26	29	32
-34	17	17	17	20	23	26	29
-40	17	17	17	17	20	23	26
-46	17	17	17	17	17	20	23

9.3 *Loading Platens and End-Friction Reducers*:

9.3.1 In this test, the top platen shall not be free to rotate.

9.3.2 Prepare two greased double latex end-friction reducers for each specimen that will be tested using the procedure specified in Annex A. It is recommended that new friction reducers be used for each test.

9.4 *Procedure*

9.4.1 Assemble each specimen to be tested with the platens and membrane as follows: place the bottom greased double latex friction reducer and the specimen on the bottom platen. Stretch the membrane over the specimen and bottom loading platen. Install the lower O-ring seal. Place the top greased double latex friction reducer and top platen on top of the specimen and stretch the membrane over the top platen. Install the upper O-ring seal. When performing confined tests, the specimen must be vented to atmospheric pressure through the drainage lines. Make sure that the friction reducers have holes to allow air to be vented from inside the membrane.

9.4.2 Encase the dummy specimen in a membrane.

9.4.3 Place the specimen and platen assembly in the environmental chamber with the dummy specimen and monitor the temperature of the dummy specimen to determine when testing can begin.

9.4.4 Turn on the AMPT, set the temperature control to the desired testing temperature, and allow the testing chamber to equilibrate at the testing temperature for at least 1 h.

9.4.5 When the dummy specimen and the testing chamber reach the target temperature, open the testing chamber. Remove a test specimen and platen assembly and quickly place it in the testing chamber. Properly connect the drainage lines to the loading platens so that they are vented to atmospheric pressure through the bubble chamber.

9.4.6 Place a steel ball in the sunken area in the center of the top loading platen.

9.4.7 Close the testing chamber and allow the chamber temperature to return to the testing temperature. Ensure that the top loading platen is not permitted to rotate during loading. Pressurize the test chamber. Pressurization should be complete within 10 seconds. Check the bubble chamber to make sure that air bubbles come out of the drainage lines.

Note 4 –– After pressurization, check the air bubbles for 10 to 15 seconds. A frequency of approximately 1 to 10 bubbles per second indicates proper drainage. No bubbles may indicate a blockage, and a faster rate may indicate membrane leakage.

9.4.8 The procedures described in Sections 9.4.5 and 9.4.7 to move the test specimen to the test chamber and to return the test chamber to the target temperature shall be completed within 5 minutes. Figure 1 shows a specimen that is ready for testing.

Figure 1. Installed specimen in AMPT

9.4.9 Leave the specimen at the pre-set confining pressure for one hour.

Note 5 –– The one-hour wait time is intended to give enough time to bring the test chamber temperature and the test specimen temperature (which have been affected by air temperature during pressurization) back to the target testing temperature. An experimental study should be conducted using a dummy specimen with thermocouples installed inside and on the surface of the dummy specimen using agency-specific equipment and test setup to determine the minimal time required for the specimen's temperature to reach the target test temperature.

9.4.10 Enter the required identification and control information into the software.

9.4.11 Conduct the confined cyclic compression test in three loading blocks, each with different deviatoric stress levels, with 200 load cycles for each loading block. The deviatoric stress levels for the T_H testing increments are 689 kPa, 483 kPa, and 896 kPa (100 psi, 70 psi, and 130 psi), and the stress levels for the T_L testing increments are 483 kPa, 689 kPa, and 896 kPa (70 psi, 100 psi, and 130 psi).

9.4.12 Apply loading time of 0.4 s. For rest periods, apply 1.6 s for T_L, and 3.6 s for T_H.

9.4.13 Apply confining pressure of 69 kPa (10 psi) throughout the test.

9.4.14 Apply contact stress of 6.4 kPa (0.9 psi) throughout the test. For 100-mm diameter specimens, this contact stress can be achieved by applying 0.05 kN (10 lbf).

9.4.15 Follow the software prompts to begin the test. The AMPT will automatically unload when the test reaches to 600 cycles.

9.4.16 Upon completion of the test, open the test chamber and remove the tested specimen.

9.4.17 Repeat procedures in Sections 9.4.5 through 9.4.15 for the remaining test specimens.

10 Calculations

10.1 This section presents a standard procedure for calculating the permanent strain and shift model coefficients for the SSR tests. All the calculations described in this section can be performed automatically using FlexMAT™-Rutting spreadsheet described in the FHWA report cited in Section 2.2.

10.2 The shift model is shown in Equation (2).

$$\varepsilon_{vp} = \frac{\varepsilon_0 \times N_{red}}{\left(N_I + N_{red}\right)^{\beta}} \qquad \text{Equation (2)}$$

where

$$N_{red} = A \cdot N\left(\xi_p\right)^{p_1}\left(\frac{\sigma_v}{P_a}\right)^D \text{ and } A = 10^{p_2} \cdot 10^{-0.877*D}.$$

10.3 *Construct the reference curve*. The reference curve is constructed using the total permanent strain obtained from the first loading block of the SSR test at T_H. The reference curve is modeled using Equation (3), and the coefficients ε_0, N_I, and β are obtained through numerical optimization using the measured permanent strain values and the corresponding number of cycles. This process should be done based on minimizing the error in Equation (4).

$$\varepsilon_{vp} = \frac{\varepsilon_0 \times N}{\left(N_I + N\right)^{\beta}} \qquad \text{Equation (3)}$$

where

ε_{vp} = viscoplastic strain (permanent strain),
ε_0, N_I, β = coefficients of the incremental model, and
N = number of cycles for a certain loading condition.

$$Error = \sum_{i=1}^{200}\left(\varepsilon_{vp,i,Measured} - \varepsilon_{vp,i,\Pr edicted}\right)^2 \qquad \text{Equation (4)}$$

where

$\varepsilon_{vp,\, i,\, Measured}$ = measured viscoplastic strain at i^{th} cycle at T_H, and
$\varepsilon_{vp,\, i,\, Predicted}$ = predicted viscoplastic strain at i^{th} cycle using Equation (3).

10.4 *Computing the total shift factors*. The shift factors are calculated based on the cumulative permanent strain at the last cycle of each loading block and the reference curve.

10.4.1 Find the permanent strain at the end of each loading block for each temperature.

10.4.2 For each strain level calculated in Section 10.4.1, calculate the number of cycles on the reference curve that gives the same permanent strain levels that were found in Section 10.4.1. N_{ref} should be backcalculated using Equation (5). For the backcalculation, an initial value should be selected to start the iteration. Calculate the permanent strain using Equation (5) and use $N_{ref} = 0.5$ as the first initial guess. N_{ref} is obtained through numerical optimization by comparing the measured permanent strain and the calculated permanent strain using Equation (5).

$$\varepsilon_{vp} = \frac{\varepsilon_0 \times N_{ref}}{\left(N_I + N_{ref}\right)^{\beta}} \qquad \text{Equation (5)}$$

10.4.3 Calculate ΔN_{ref} for each loading block and at each temperature using Equation (6).

$$\Delta N_{ref} = N_{ref,j} \qquad j = 1$$

Equation (6)

$$\Delta N_{ref,j} = N_{ref,j} - N_{ref,j-1} \qquad j = 2\, and\, 3$$

where

$N_{ref,j}$ = N_{ref} at j^{th} block, and

$\Delta N_{ref,j}$ = difference in N_{ref} for the j^{th} block.

10.4.4 Calculate a_{total} for each loading block and temperature using Equation (7).

$$a_{total} = log\left(\frac{\Delta N_{ref}}{200}\right)$$ Equation (7)

where
a_{total} = total shift factor.

10.4.5 Name each shift factor according to the temperature and loading block

(e.g., $a_{total,\,\mathrm{TH},\,70}$ is total shift factor at T_H for 483 kPa (70 psi) block).

10.5 *Computing the reduced load time shift factor*

10.5.1 Compute the reduced load time at T_H and T_L using Equation (8).

$$\xi_p = 0.4 \qquad \text{for } T_H,$$

Equation (8)

$$\xi_p = \frac{0.4}{a_{T_L}} \qquad \text{for } T_L,$$

where

ξ_p = reduced load time, *s*, and

a_{T_L} = time-temperature shift factor at $T_L = 10^{\left[0.0006*\left(T_L^2 - T_H^2\right) - 0.1565*\left(T_L - T_H\right)\right]}$.

10.5.2 Obtain the coefficients p_1 and p_2 using Equation (9) through Equation (12).

$$a_{\xi_{p,TH}} = a_{total,\,TH,100}$$ Equation (9)

$$a_{\xi_{p,TL}} = a_{total,TL,100} \quad \text{Equation (10)}$$

$$p_1 = \frac{a_{\xi_{p,TH}} - a_{\xi_{p,TL}}}{log\left(a_{\xi_{p,TH}}\right) - log\left(a_{\xi_{p,TL}}\right)} \quad \text{Equation (11)}$$

$$p_2 = a_{\xi_{p,TL}} - \left(\frac{a_{\xi_{p,TH}} - a_{\xi_{p,TL}}}{log\left(\xi_{p,TH}\right) - log\left(\xi_{p,TL}\right)}\right) \times log\left(\xi_{p,TL}\right) \quad \text{Equation (12)}$$

where

$a_{\xi_{p,TL}}$, $a_{\xi_{p,TH}}$ = reduced load time shift factors for T_L and T_H,

$\xi_{p,TL}, \xi_{p,TH}$ = reduced load times for T_L and T_H, *s*,

$a_{total,TL,100}$, $a_{total,TH,100}$ = total shift factors at T_L and T_H for 689 kPa (100 psi) loading block, and

p_1, p_2 = reduced load time shift factor coefficients.

10.6 *Computing the vertical stress shift factor*

10.6.1 Calculate vertical stress shift factor for three different blocks and two temperatures using Equation (13) and Equation (14).

$$a_{\sigma_v} = a_{total} - a_{\xi_p} \quad \text{Equation (13)}$$

$$a_{\xi_p} = p_1 \times log\left(\xi_p\right) + p_2 \quad \text{Equation (14)}$$

where

a_{ξ_p} = reduced load time shift factor, and

a_{σ_v} = vertical stress shift factor.

10.6.2 Name each shift factor according to the temperature and loading block (e.g., a $a_{\sigma_v,TH,70}$ is vertical stress shift factor at T_H for 483 kPa (70 psi) block).

10.6.3 Determine *D* for T_H and T_L by fitting a_{σ_v} and $\log(\sigma_v / P_a)$ to Equation (15) using linear regression fitting.

$$D = \frac{a_{\sigma_v}}{(\log(\sigma_v / P_a) - 0.877)} \quad \text{Equation (15)}$$

where

D = vertical stress shift factor coefficient,

σ_v = vertical stress, kPa, and

P_a = atmospheric pressure, 101.325 kPa. (14.696 psi)

10.6.4 Label obtained D according to the temperature (e.g., D_{TH} is vertical stress shift factor coefficient at T_H).

10.6.5 Determine d_1 and d_2 using Equation (16) and Equation (17) using linear regression fitting.

$$d_1 = \frac{D_{TH} - D_{TL}}{T_H - T_L} \quad \text{Equation (16)}$$

$$d_2 = D_{TH} - \left(\frac{D_{TH} - D_{TL}}{T_H - T_L} \right) \times T_H \quad \text{Equation (17)}$$

where

d_1, d_2 = linear coefficients, and

D_{TL}, D_{TH} = vertical stress shift factor coefficient for T_L and T_H.

Note 6 — When the shift model is applied to pavement rutting simulations that use varying temperatures, Equation (18) can yield negative D values at low temperatures. Therefore Equation (18) is valid for the temperature of interest that is greater than the averaged temperature of the high and low climatic PG temperatures ($T_{avg.\ PG}$), whereas for a temperature that is lower than or equal to $T_{avg.\ PG}$, use Equation (19). High and low climatic PG temperatures can be obtained from LTPPBind v. 3.1.

$$D = d_1 \times T + d_2 \quad \text{for } T > T_{avg.\ PG} \quad \text{Equation (18)}$$

$$D = d_1 \times T_{avg.\ PG} + d_2 \quad \text{for } T \leq T_{avg.\ PG} \quad \text{Equation (19)}$$

T = test temperature, °C, and

$T_{avg.\ PG}$ = average climatic PG temperature obtained from LTPPBind v. 3.1, °C.

11 REPORTING

11.1 Report the following:

11.1.1 Test temperature used for each replicate.

11.1.2 Average applied deviatoric stress level used for each loading block.

11.1.3 Average applied confining pressure.

11.1.4 Average permanent strain used for each test.

11.1.5 Total shift factors used for each loading block.

11.1.6 All the coefficients of the shift model: ε_0, N_I, β, p_1, p_2, d_1, and d_2.

12 KEYWORDS

Asphalt mixture, permanent strain test, stress sweep rutting (SSR) test, shift model

ANNEX A—METHOD FOR PREPARING "GREASED DOUBLE LATEX" END-FRICTION REDUCERS FOR SSR TEST

(Mandatory Information)

A1. PURPOSE

A1.1. This annex presents a procedure for fabricating greased double latex end-friction reducers for the flow number test.

A1.2. These end-friction reducers are mandatory for this test.

A2. SUMMARY

A2.1. Greased double latex end-friction reducers are fabricated by cutting two circular latex sheets from a latex membrane used for confining specimens, applying a specified mass of silicone grease evenly over one of the latex sheets, and then placing the second latex sheet over the first.

A3. PROCEDURE

A3.1. Cut a 0.3-mm-thick latex membrane along its long axis to obtain a rectangular sheet of latex. The sheet will be approximately 315 by 250 mm.

A3.2. Trace the circumference of the loading platen on the sheet of latex; then cut along the tracing to form circular latex sheets that are slightly larger than the loading platen. Four circular latex sheets are needed to fabricate friction reducers for the top and bottom of the specimen.

A3.3. Place one circular latex sheet on the balance and apply 0.25 ± 0.05 g of silicone grease onto the middle of the latex sheet.

A3.4. Spread the silicone grease evenly over the latex sheet by rubbing in a circular motion from the center to the outside of the sheet.

A3.5. Place the second circular latex sheet on top of the silicone grease.

A3.6. Cut or punch a hole through both latex sheets at the location of the vent in the loading platen.

ANNEX B—METHOD FOR PREDICTING PERMANENT STRAIN UNDER CERTAIN LOADING CONDITIONS

B1. PURPOSE

B1.1 This annex presents a procedure for calculating the permanent strain at a certain load cycle under specific temperature and vertical stress conditions.

B2. SUMMARY

B2.1. The shift model is able to predict permanent strain under different loading conditions. The predicted permanent strain after a certain number of cycles (N) can be calculated using the shift model for the specific temperature (T) and vertical stress (σ_v) of interest.

B3. PROCEDURE

B3.1. Calculate the time-temperature shift factor at T using Equation (1).

$$a_T = 10^{\left[0.0006*\left(T^2 - T_H^2\right) - 0.1565*\left(T - T_H\right)\right]}$$ Equation (1)

where
T = temperature of interest, °C,
T_H = high test temperature, °C, and
a_T = time-temperature shift factor at temperature T.

B3.2. Calculate the reduced load time using Equation (2).

$$\xi_p = \frac{t_l}{a_T}$$ Equation (2)

where

ξ_p = reduced load time, s, and
t_l = load time, s.

B3.3. Calculate the reduced load time shift factor using Equation (3).

$$a_{\xi_p} = p_1 \times log\left(\xi_p\right) + p_2 \quad \text{Equation (3)}$$

where
a_{ξ_p} = reduced load time shift factor, and
p_1, p_2 = reduced load time shift factor coefficients.

B3.4. Calculate D using Equation (4) or Equation (5).

$$D = d_1 \times T + d_2 \quad \text{for } T > T_{avg.\ PG} \quad \text{Equation (4)}$$

$$D = d_1 \times T_{avg.\ PG} + d_2 \quad \text{for } T \leq T_{avg.\ PG} \quad \text{Equation (5)}$$

where
D = vertical stress shift factor coefficient,
d_1, d_2 = linear coefficients obtained from the SSR test, and
$T_{avg.\ PG}$ = average climatic performance grade (PG) temperature obtained from LTPPBind v. 3.1, °C.

B3.5. Calculate the vertical stress shift factor using Equation (6).

$$a_{\sigma_v} = D \times (\log(\sigma_v / P_a) - 0.877) \quad \text{Equation (6)}$$

where
a_{σ_v} = vertical stress shift factor,
σ_v = vertical stress of interest, kPa, and
P_a = atmospheric pressure, 101.325 kPa (14.696 psi).

B3.6. Calculate the total shift factor using Equation (7).

$$a_{total} = a_{\sigma_v} + a_{\xi_p} \quad \text{Equation (7)}$$

where
a_{total} = total shift factor.

B3.7. Calculate N_{red} using Equation (8).

$$N_{red} = N \times 10^{a_{total}} \quad \text{Equation (8)}$$

where
N_{red} = reduced number of cycles for a certain loading condition, and
N = number of cycles of interest.

B3.8. Calculate permanent strain using Equation (9).

$$\varepsilon_{vp} = \frac{\varepsilon_0 \times N_{red}}{\left(N_I + N_{red}\right)^{\beta}} \quad \text{Equation (9)}$$

where

ε_{vp} = viscoplastic strain (permanent strain), and

$\varepsilon_0, N_I, \beta$ = coefficients of the incremental model.

Technical Subcommittee Action Required Summary—Full Standards

TS 2d

Designation No.	Title	ASTM Equiv.	Action Needed
M 323-17	Superpave Volumetric Mix Design		No
M 325-08 (2017)	Stone Matrix Asphalt (SMA)		No
R 030-02 (2015)	Mixture Conditioning of Hot Mix Asphalt (HMA)		Revise or Reconfirm
R 035-17	Superpave Volumetric Design for Asphalt Mixtures		No
R 046-08 (2017)	Designing Stone Matrix Asphalt (SMA)		No
R 062-13 (2017)	Developing Dynamic Modulus Master Curves for Asphalt Mixtures		No
R 068-15	Preparation of Asphalt Mixtures by Means of the Marshall Apparatus		Revise or Reconfirm
R 083-17	Preparation of Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor (SGC)		No
R 084-17	Developing Dynamic Modulus Master Curves for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)		No
T 167-10 (2015)	Compressive Strength of Hot Mix Asphalt		Revise or Reconfirm
T 245-15	Resistance to Plastic Flow of Asphalt Mixtures Using Marshall Apparatus		Revise or Reconfirm
T 246-10 (2015)	Resistance to Deformation and Cohesion of Hot Mix Asphalt (HMA) by Means of Hveem Apparatus	D1560-09	Revise or Reconfirm
T 247-10 (2015)	Preparation of Test Specimens of Hot Mix Asphalt (HMA) by Means of California Kneading Compactor	D1561-92	Revise or Reconfirm
T 283-14 (2018)	Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage		No
T 312-15	Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor		Revise or Reconfirm
T 320-07 (2016)	Determining the Permanent Shear Strain and Stiffness of Asphalt Mixtures Using the Superpave Shear Tester (SST)		No
T 321-17	Determining the Fatigue Life of Compacted Asphalt Mixtures Subjected to Repeated Flexural Bending		No
T 322-07 (2016)	Determining the Creep Compliance and Strength of Hot Mix Asphalt (HMA) Using the Indirect Tensile Test Device		No
T 340-10 (2015)	Determining Rutting Susceptibility of Hot Mix Asphalt (HMA) Using the Asphalt Pavement Analyzer (APA)		Revise or Reconfirm
T 342-11 (2015)	Determining Dynamic Modulus of Hot Mix Asphalt (HMA)		Revise or Reconfirm

TS 2d

Designation No.	Title	ASTM Equiv.	Action Needed
T 344-12 (2016)	Evaluation of Superpave Gyratory Compactor (SGC) Internal Angle of Gyration Using Simulated Loading	D7115-05	No
T 378-17	Determining the Dynamic Modulus and Flow Number for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)		No


EVALUATE PAVEMENT PERFORMANCE

COMP TECHNICAL SUBCOMMITTEE 2D
AUGUST 8TH, 2018

Derek Nener-Plante, M.S., P.E.

Asphalt Pavement Engineer

MaineDOT

Disclaimer / Acknowledgements

Talking Points

3

Background - MaineDOT

4

Motivation for Change

Are all mixes at the same NMAS / gyration created equal?

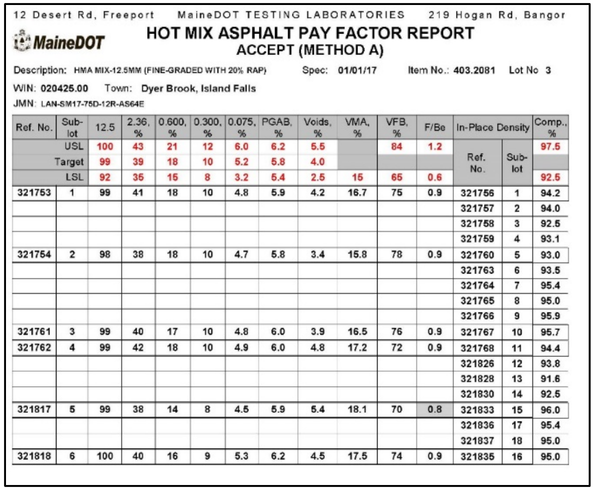
Is our current way of assessing payfactors effective?

Is 4% voids the right target for all mix designs?

Is this design optimized for payfactor or performance?

Background – HMA Process

- Crushed ledge product



12 Desert Rd, Freeport MaineDOT TESTING LABORATORIES 219 Hogan Rd, Bangor

MaineDOT

HOT MIX ASPHALT PAY FACTOR REPORT

ACCEPT (METHOD A)

Description: HMA MIX-12.5MM (FINE-GRADED WITH 20% RAP) Spec: 01/01/17 Item No.: 403.2081 Lot No 3

WIN: 020425.00 Town: Dyer Brook, Island Falls

JMN: LAN-SM17-75D-12R-AS64E

Ref. No.	Sub-lot	12.5	2.36, %	0.600, %	0.300, %	0.075, %	PGAB, %	Voids, %	VMA, %	VFB, %	F/Be	In-Place Density		Comp., %
												Ref. No.	Sub-lot	
	USL	100	43	21	12	6.0	6.2	5.5		84	1.2			97.5
	Target	99	39	18	10	5.2	5.8	4.0						
	LSL	92	35	15	8	3.2	5.4	2.5	15	65	0.6			92.5
321753	1	99	41	18	10	4.8	5.9	4.2	16.7	75	0.9	321756	1	94.2
												321757	2	94.0
												321758	3	92.5
												321759	4	93.1
321754	2	98	38	18	10	4.7	5.8	3.4	15.8	78	0.9	321760	5	93.0
												321763	6	93.5
												321764	7	95.4
												321765	8	95.0
												321766	9	95.9
321761	3	99	40	17	10	4.8	6.0	3.9	16.5	76	0.9	321767	10	95.7
321762	4	99	42	18	10	4.9	6.0	4.8	17.2	72	0.9	321768	11	94.4
												321826	12	93.8
												321828	13	91.6
												321830	14	92.5
321817	5	99	38	14	8	4.5	5.9	5.4	18.1	70	0.8	321833	15	96.0
												321836	17	95.4
												321837	18	95.0
321818	6	100	40	16	9	5.3	6.2	4.5	17.5	74	0.9	321835	16	95.0

Maine’s AMPT Objectives

- Pavement design (PavementME, FlexPave, etc.)
- Performance-Related Specification (PRS) development
- Performance-Engineered Mixture Design (PEMD)

Asphalt Mixture Performance Tester Series

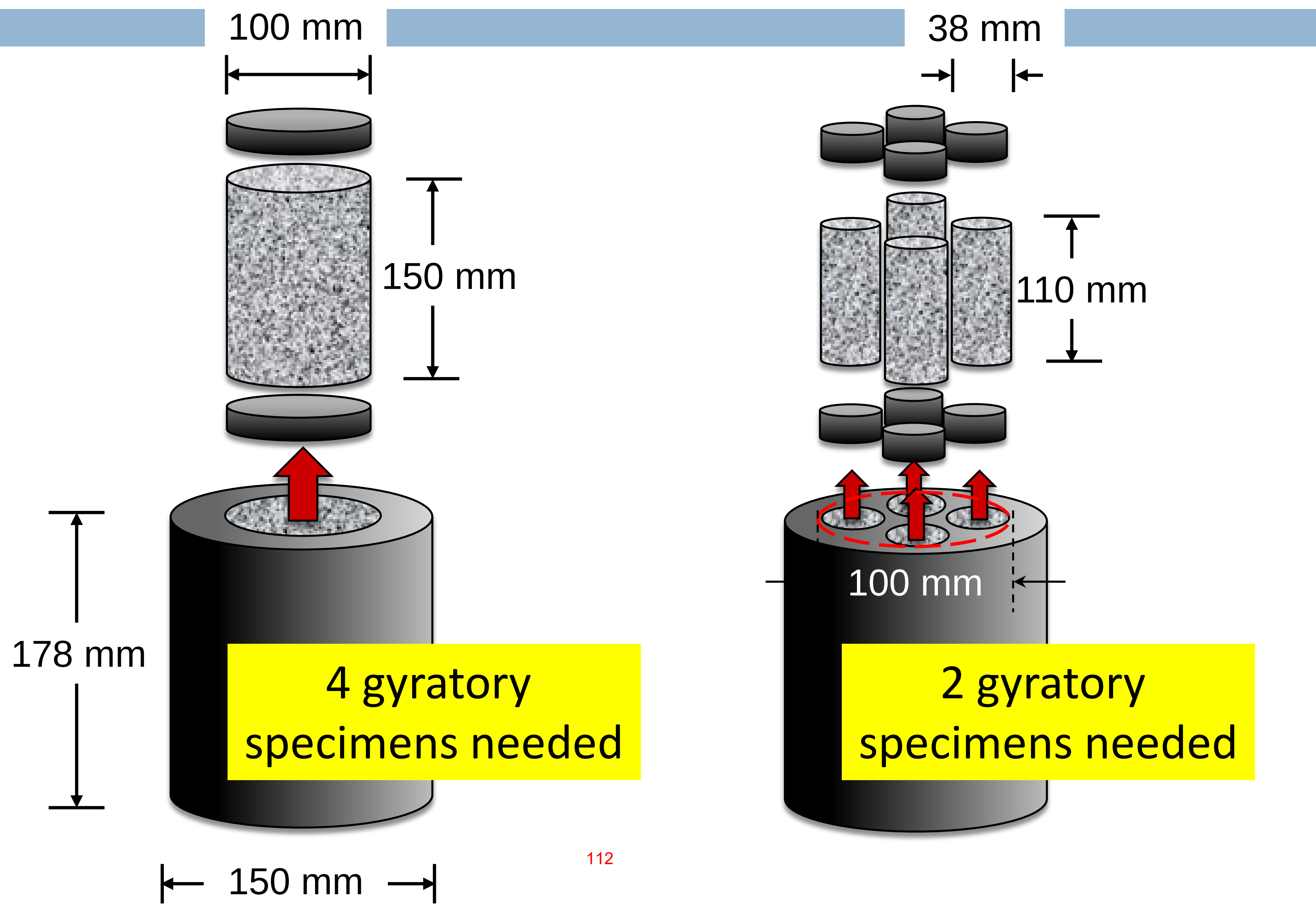
Dynamic Modulus, Cyclic Fatigue, and Stress-Sweep Rutting

AMPT Performance Test Methods

- **Modulus**
  - Axial compression dynamic modulus test (AASHTO T 378)
  - Dynamic modulus mastercurve and time-temperature shift function
- **Cracking Resistance**
  - AMPT cyclic fatigue test (AASHTO TP 107)
  - C vs. S (damage characteristic curve)
  - Energy-based failure criterion
  - Sapp cracking index parameter
- **Rutting Resistance**
  - Stress Sweep Rutting (SSR) test (spec under review by Asphalt Mixture and Construction ETG)
  - Reduced load time and stress shift factors
  - Shift model coefficients
  - Permanent strain index parameter

Rutting Test Specimen

E* and Fatigue Test Specimen



AMPT 38 mm Specimens

AMPT 38 mm Specimens

How?

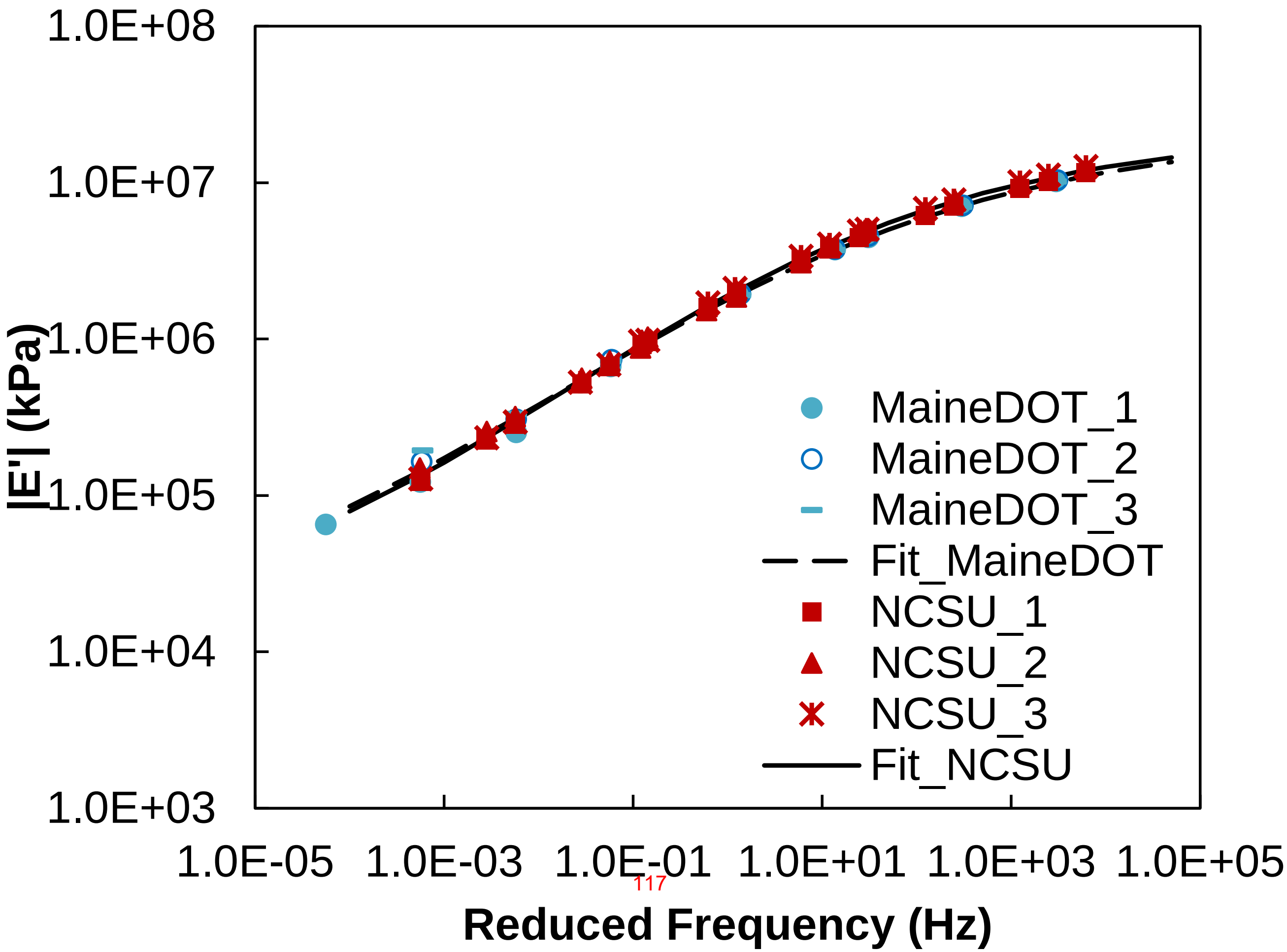
- Acquire samples of all materials in all lifts – some to be tested and some to be retained indefinitely
- Test all HMA lifts in the AMPT series
  - DM, CF, & SSR @ 5.0% air voids
  - DM @ 7.0% air voids
- Will monitor performance for years
- Will also build a library of different mixes across the state

Proficiency Tests

- First step = ensure that MaineDOT labs can perform the testing
- One large sample of plant produced mix was obtained from one truck
  - MaineDOT fabricated specimens and shipped to NCSU
  - The same mixture were tested at MaineDOT and at NCSU
  - The test results were compared

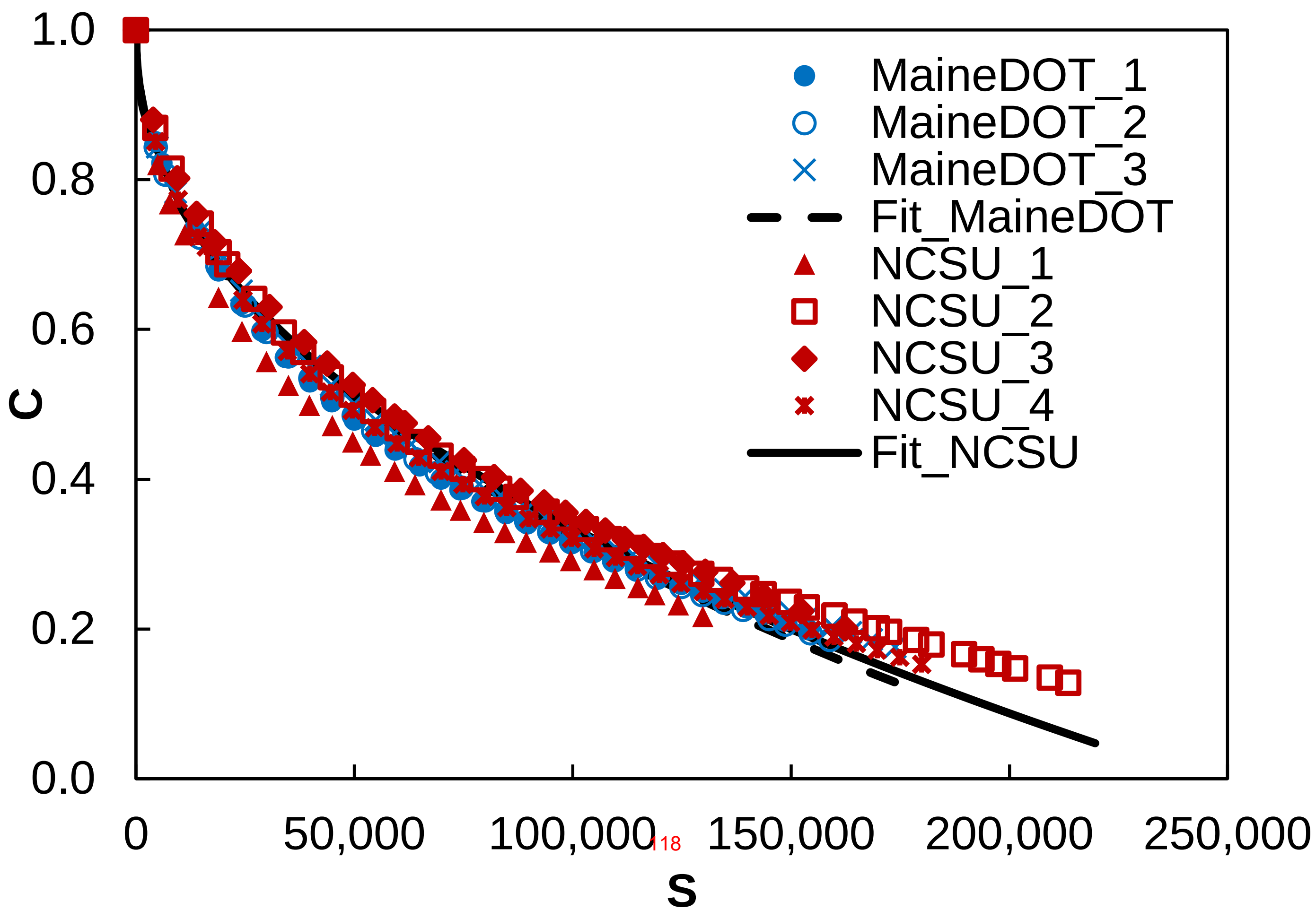
Proficiency Test Results

- Dynamic Modulus Tests



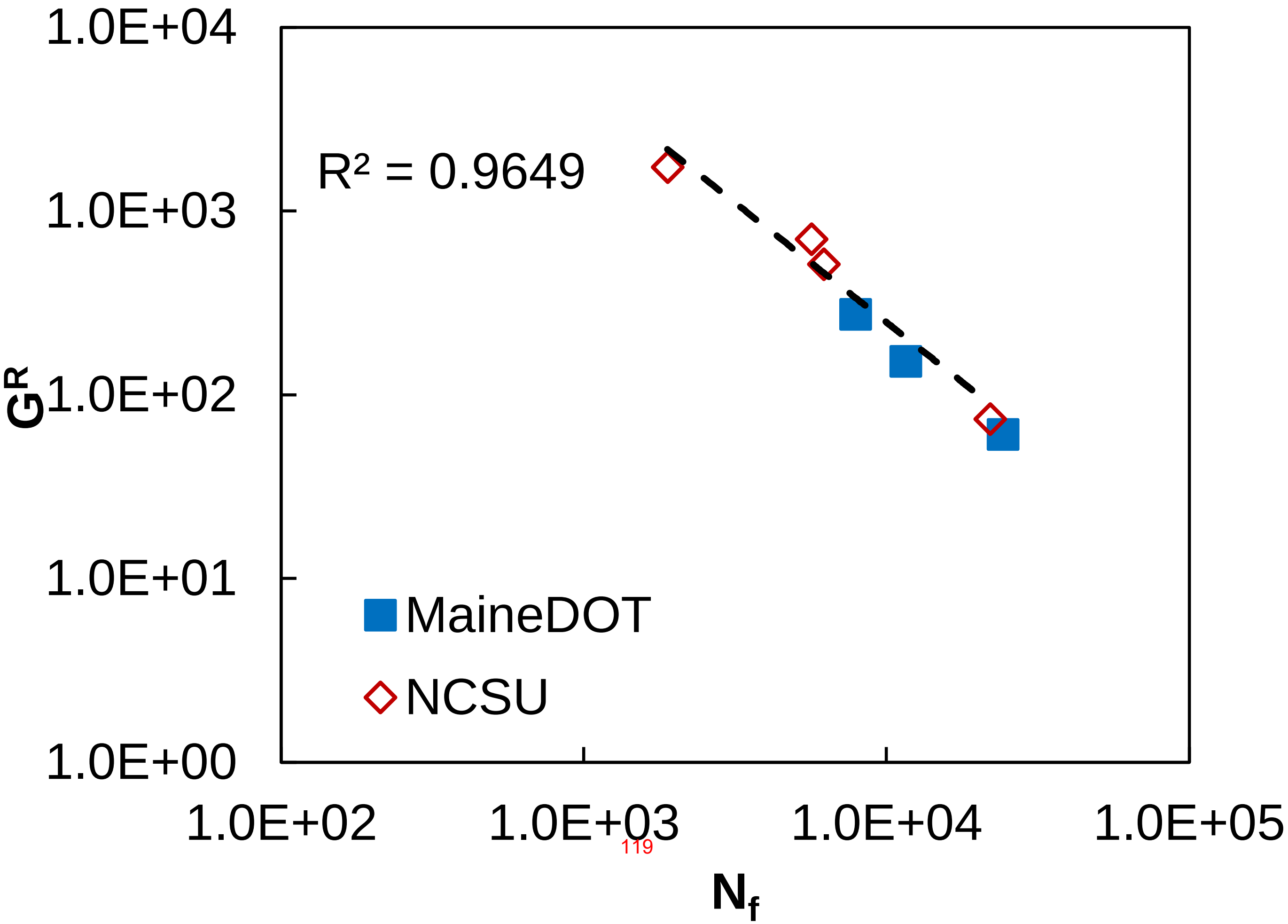
Proficiency Test Results

- Cyclic Fatigue Tests - Damage Characteristic C



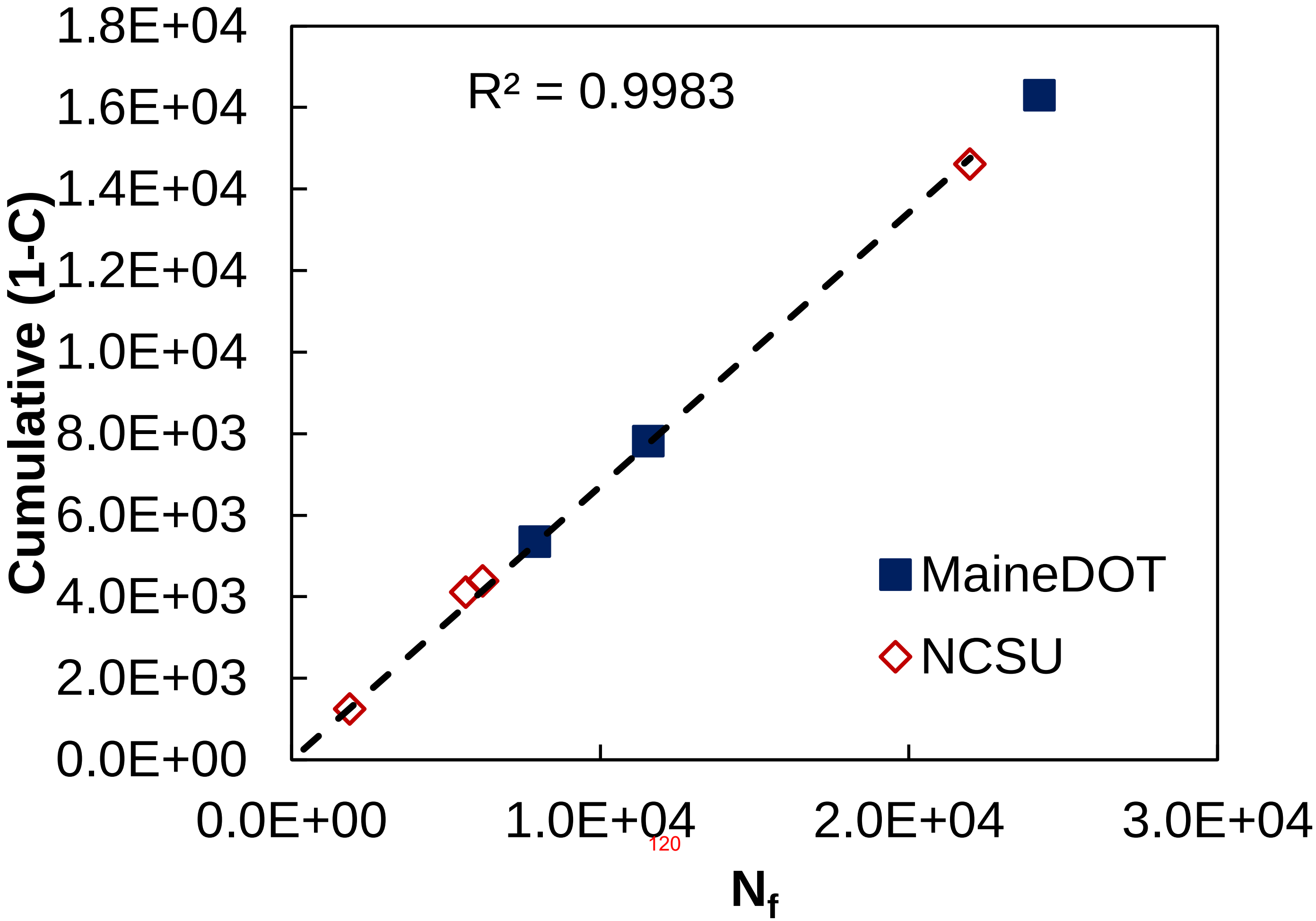
Proficiency Test Results

- Cyclic Fatigue Tests - Failure Criteria



Proficiency Test Results

- Cyclic Fatigue Tests - Failure Criteria

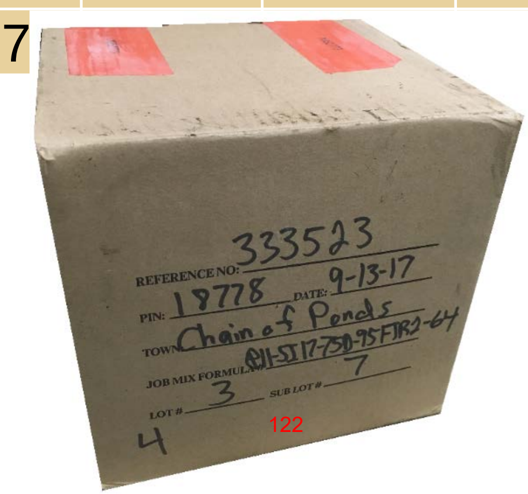


PRS Shadow Project

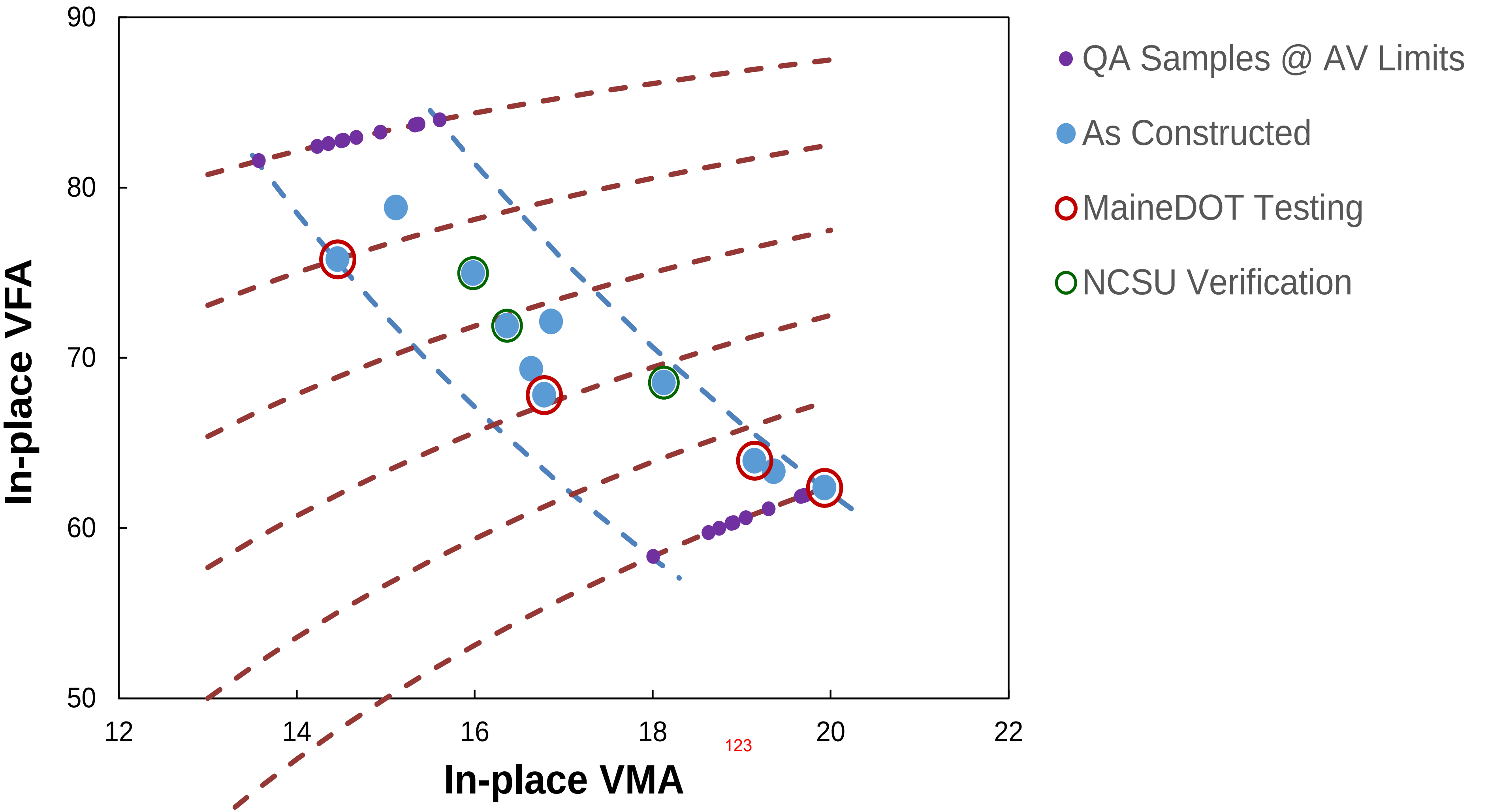
- **Objective: Use AMPT predictive models to show the impact of volumetric changes**
- 10 samples were acquired in the field from the same mix design on the same project
- Volumetric acceptance tests were performed on each
- Performance tests were conducted on 4 of the 10 samples at MaineDOT
- 3 samples were shipped to NCSU.

Sample Volumetric Properties

	Sample ID	Air Voids	VMA	Gmb	Gmm	% Binder	In-place Density	Test AV	Status
Maine DOT	352	4.7	15.5	2.426	2.546	5.3	96.5	7.5	Done
	355	4.4	15.9	2.412	2.524	5.2	94.6	2.5	Done
	360	3.9	16.8	2.404	2.502	5.9	92.5	2.5	Done
	361	4.7	17.3	2.391	2.509	5.9	92.9	7.5	Done
NCSU	353	4.5	16.4	2.406	2.519	5.5	96.0	4	On-going
	358	4.6	16.4	2.402	2.518	5.3	95.4	4.6	On-going
	362	4.4	17[illegible]	[illegible]	[illegible]	[illegible]8	94.3	5.7	Done

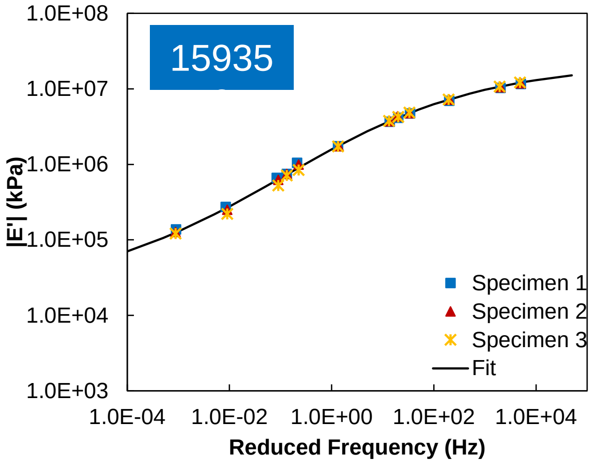


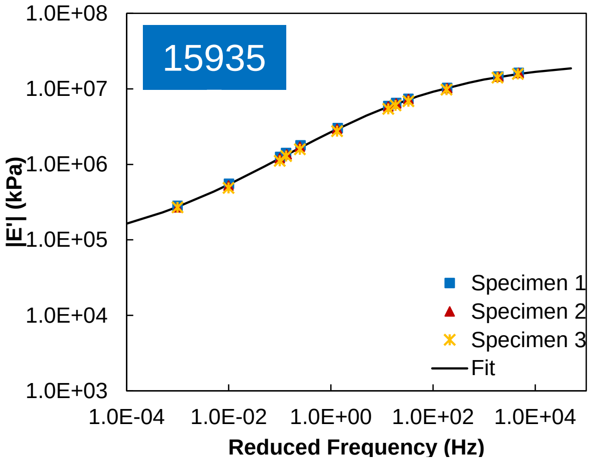
Sample Volumetric Properties

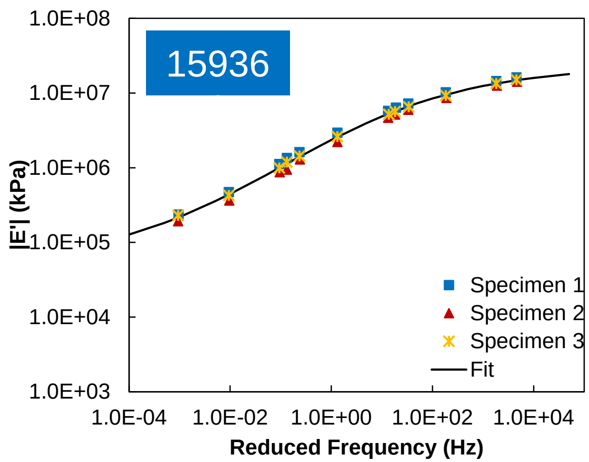


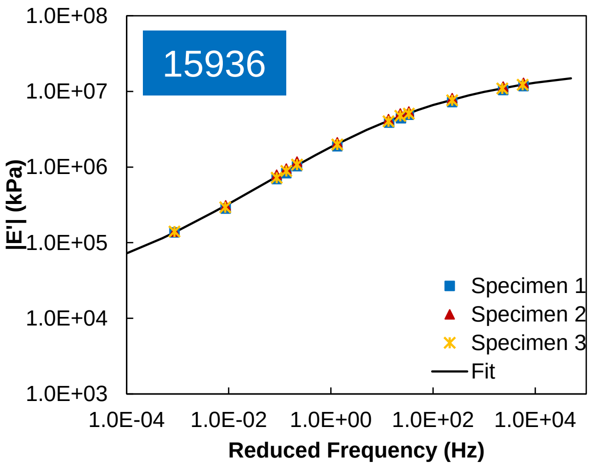
Testing Results

- Dynamic Modulus



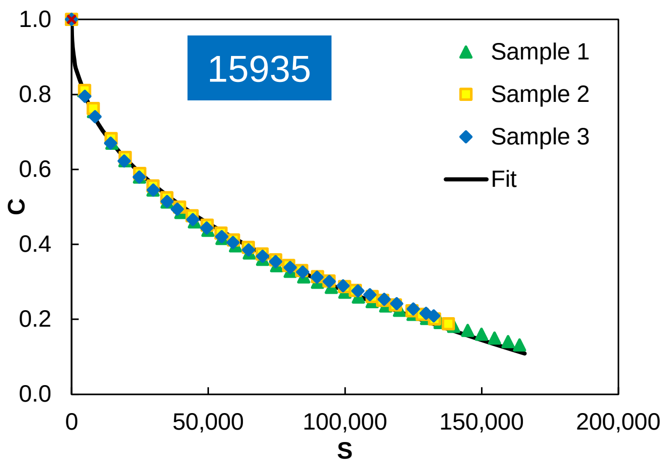


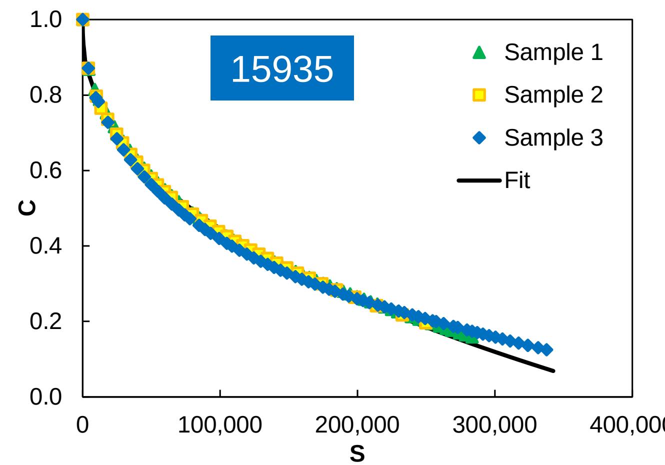


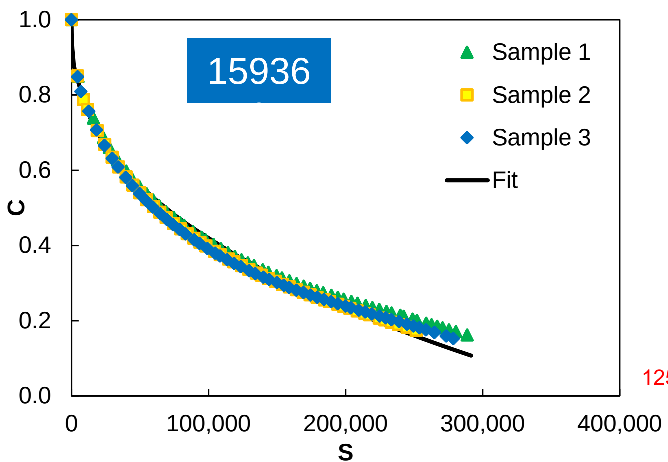


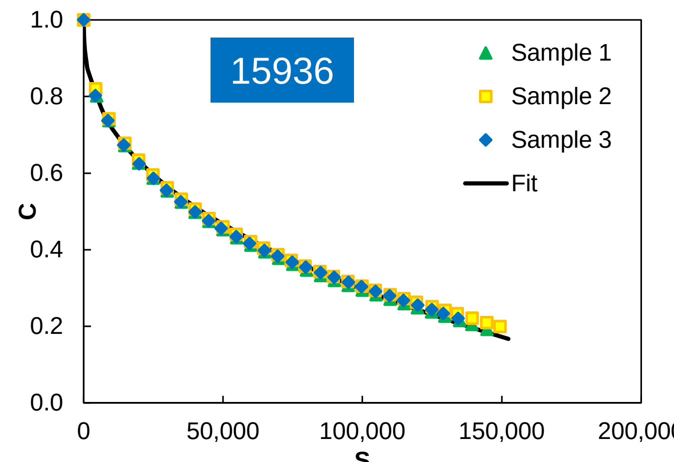
Testing Results

- Cyclic Fatigue Tests

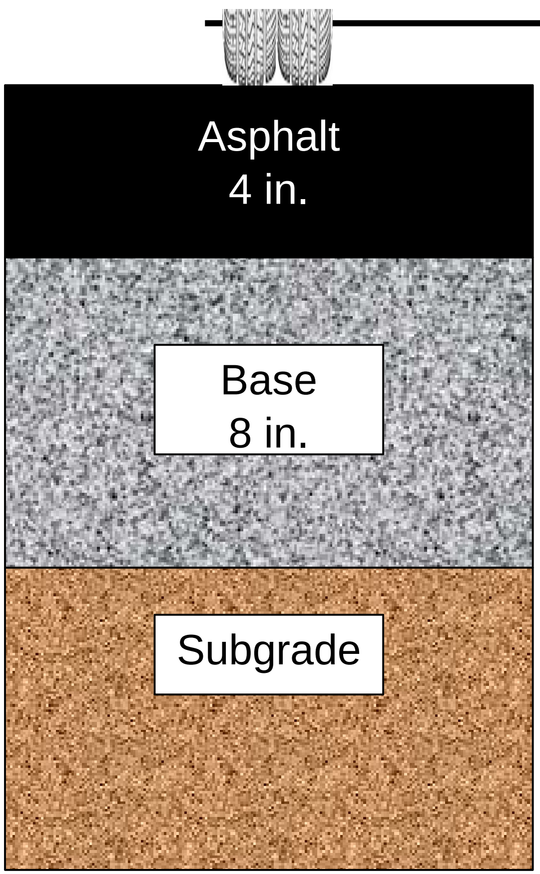


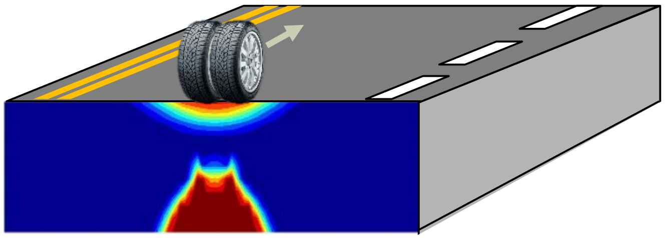




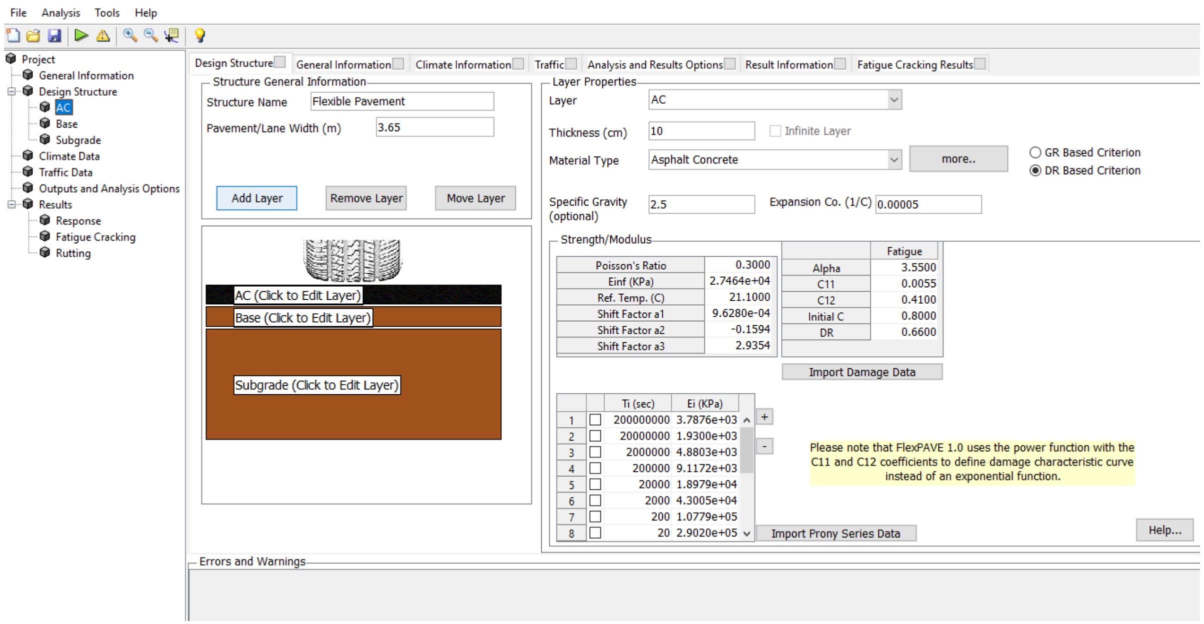


Pavement Performance Prediction

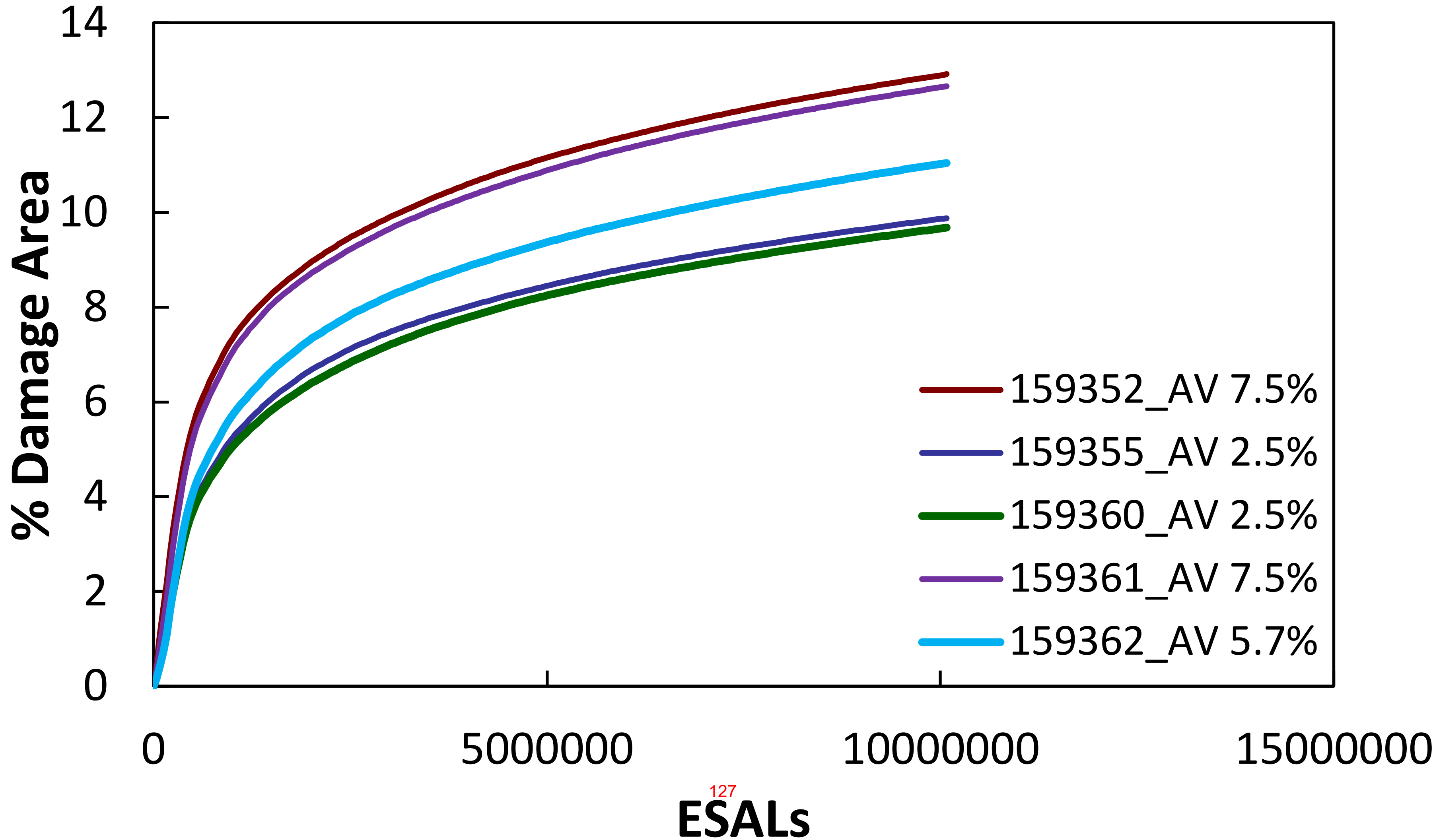




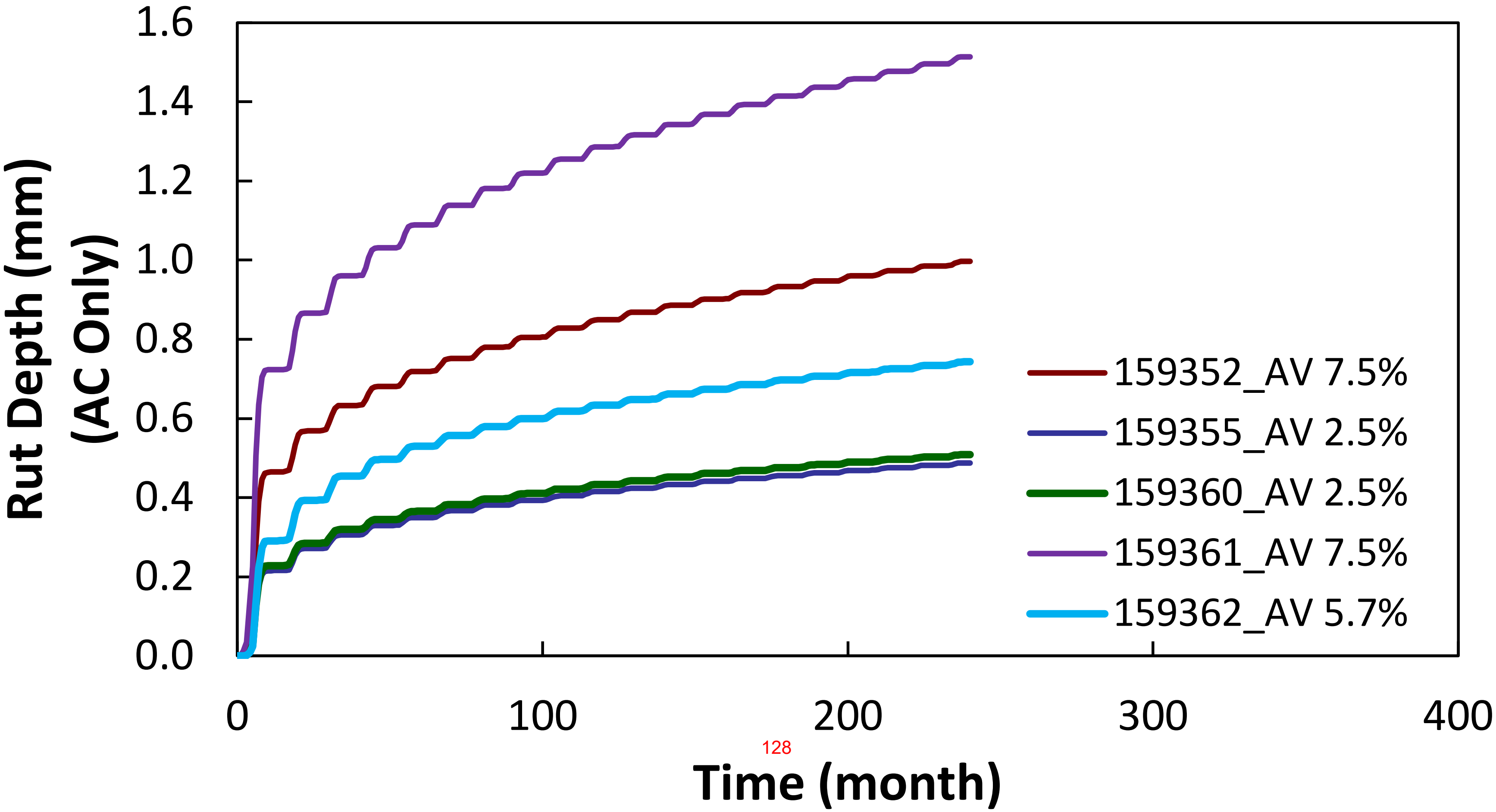
FlexPAVE™ 1.0



Fatigue Damage Prediction



Rutting Depth Prediction

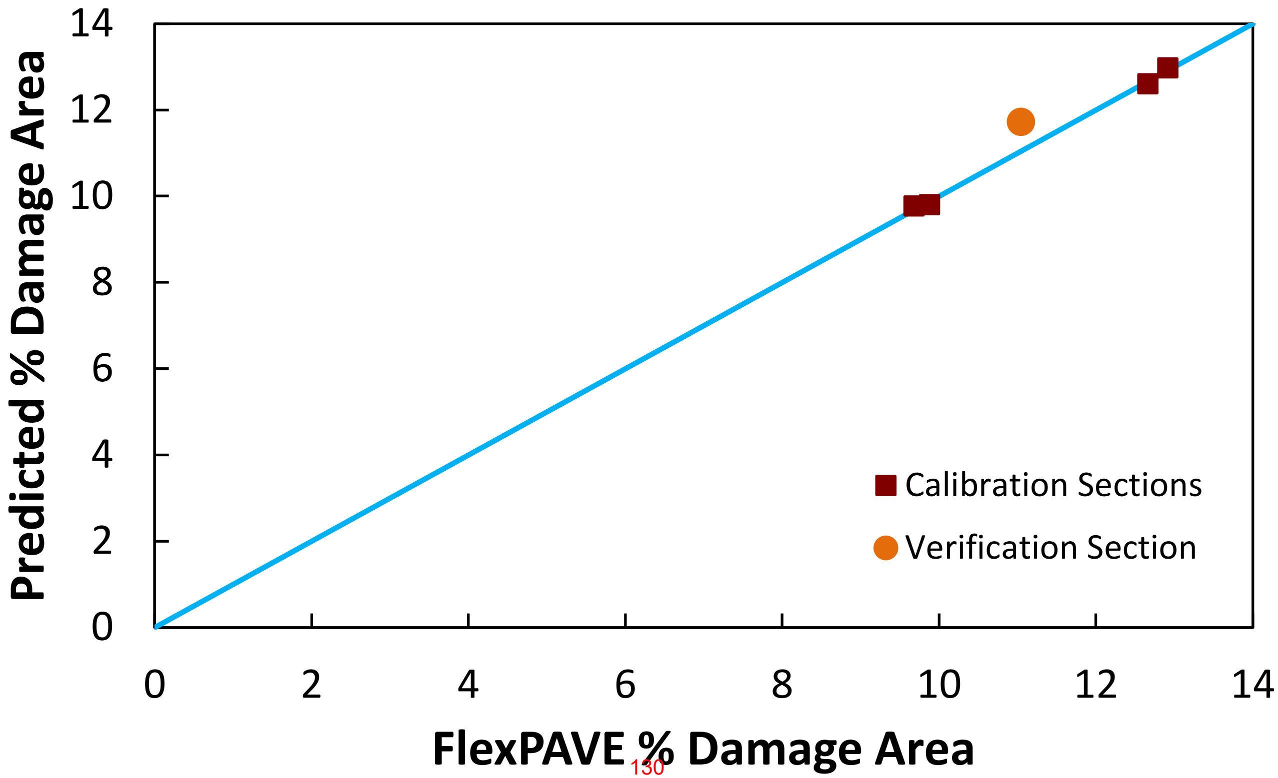


Performance-Volumetric Relationship (PVR)

- The PVR was calibrated using the performance test results generated by MaineDOT.
- PVR was used to predict performance for mixes with different volumetric properties that were tested at NCSU for verification.

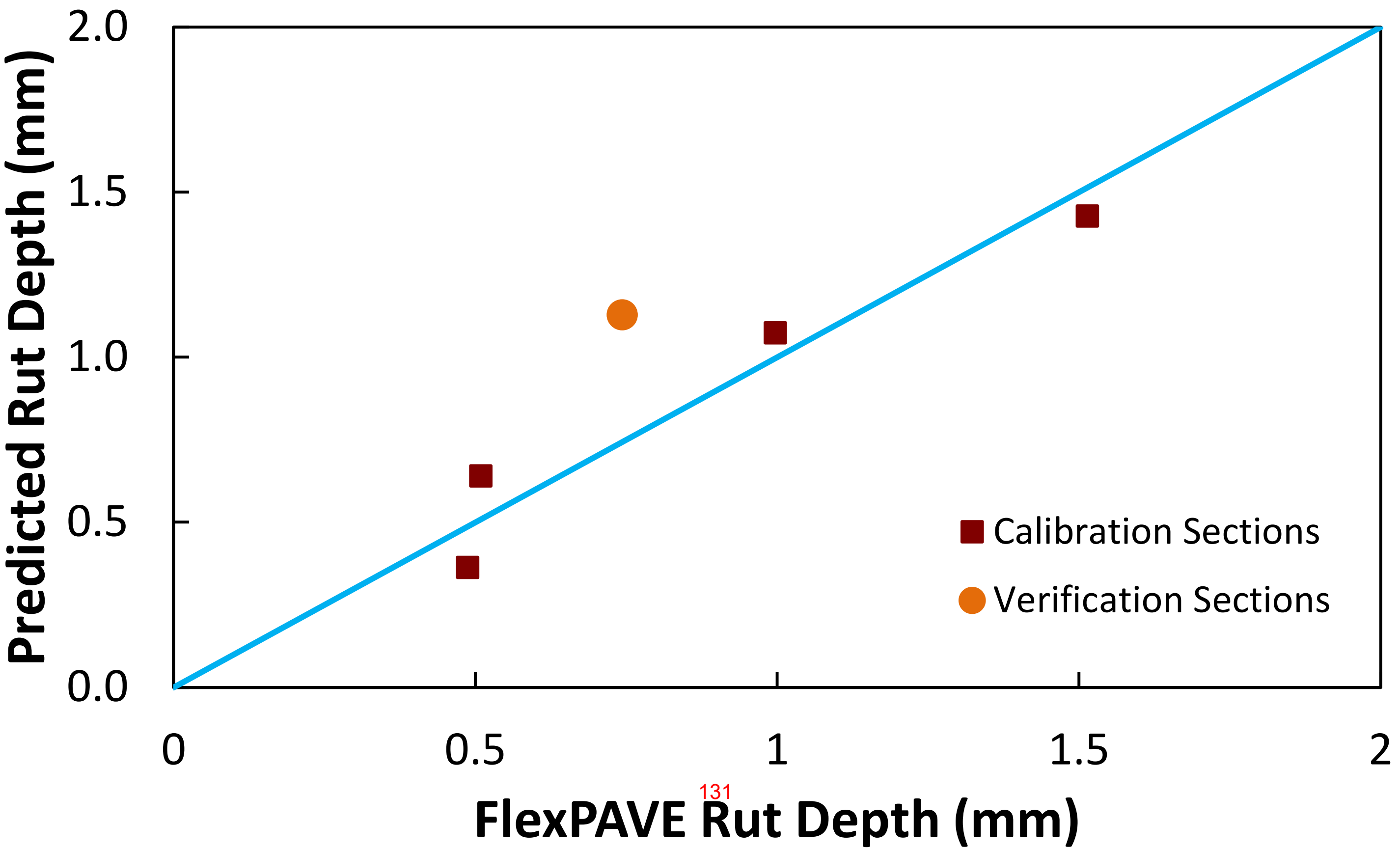
Verification of Cracking PVR

- Fatigue damage in 4-inch asphalt pavement



Verification of Rutting PVR

- Rut depth of the AC layer in the 4 inch pavement

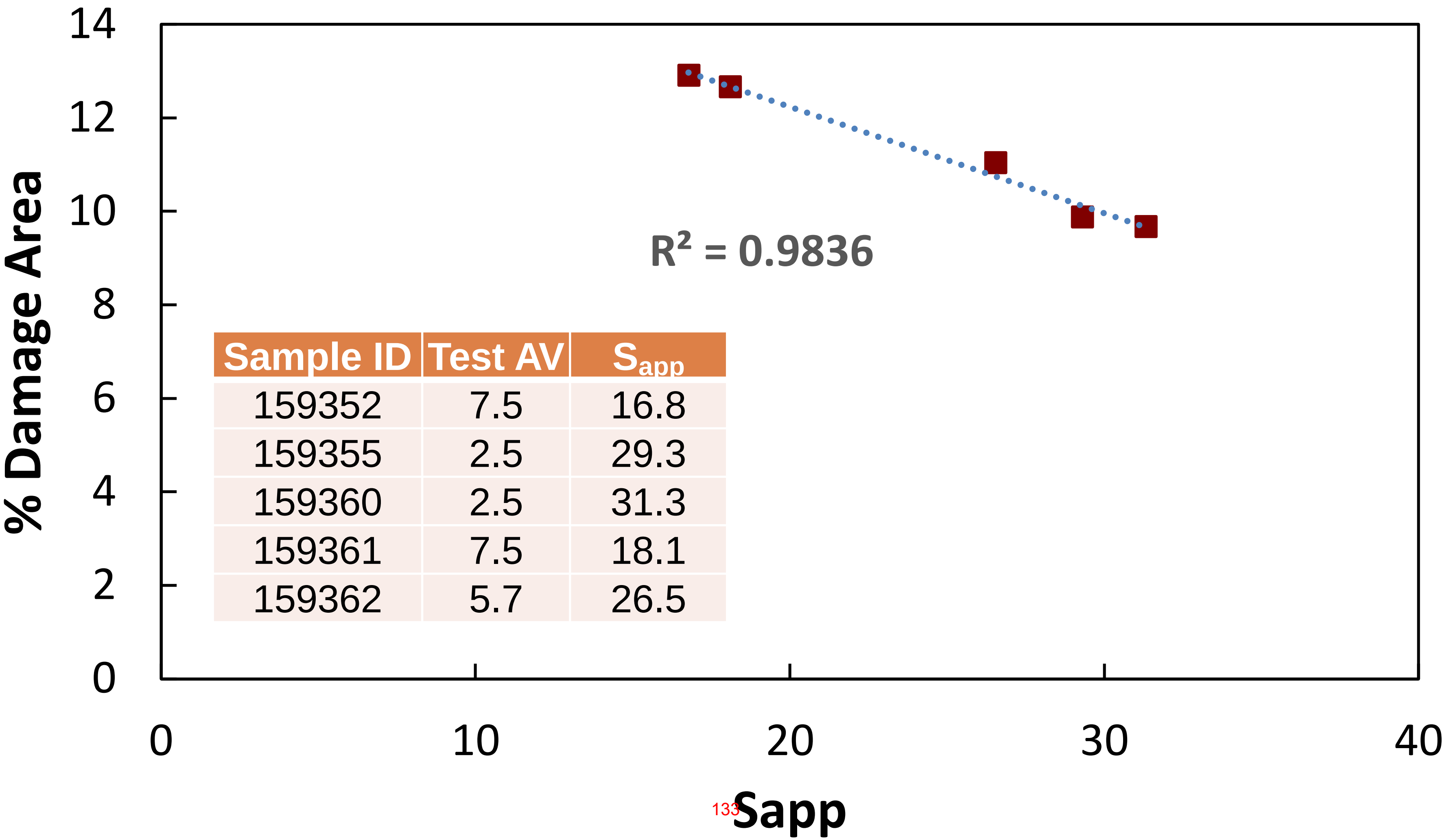


Fatigue Index Parameter

- S_{app}
  - Fatigue resistance index
  - Considers both modulus and ductility

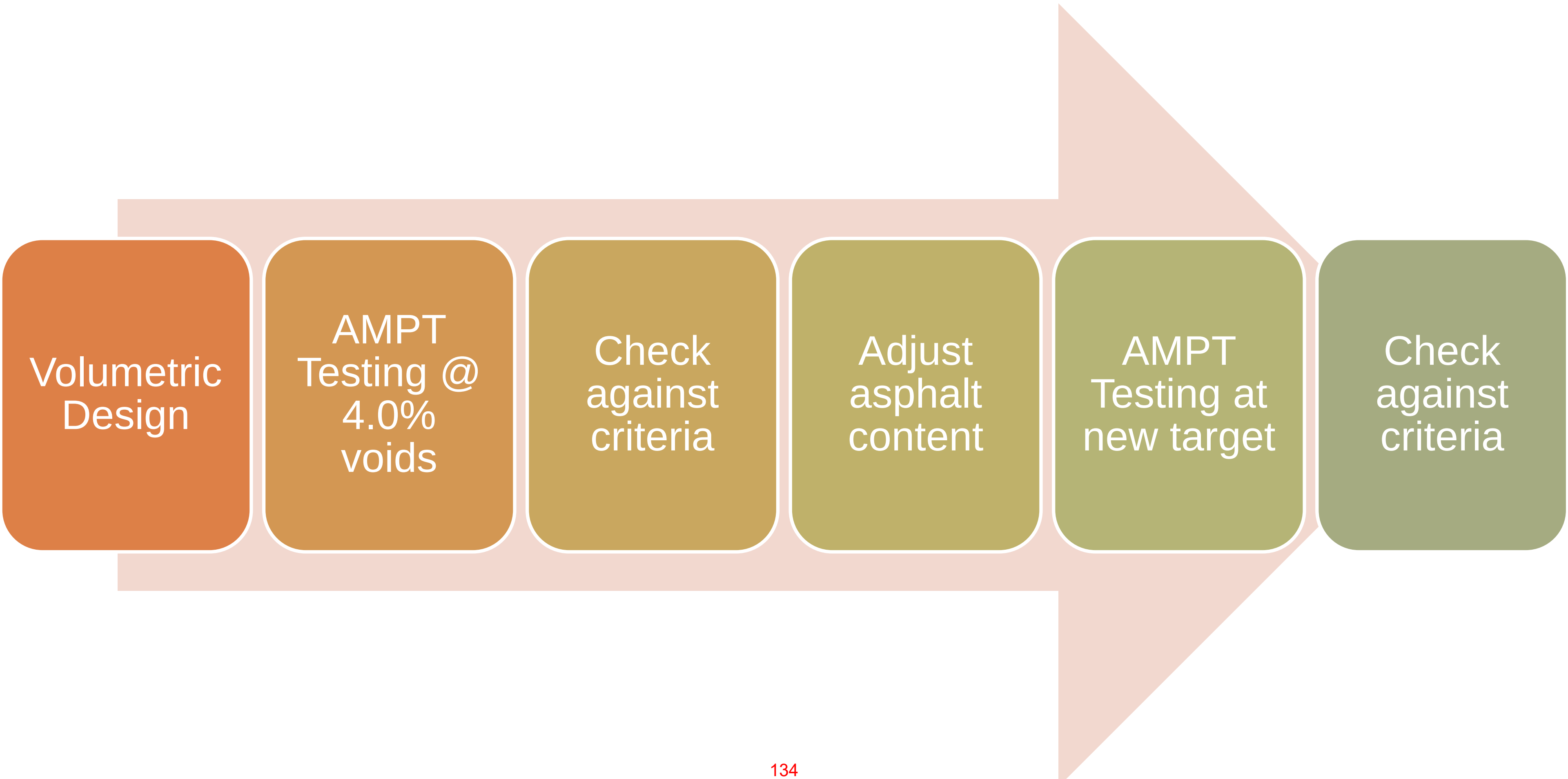
Traffic Level (million ESALs)	S_{app}	Tier	Designation
<= 3	$S_{app} <= 8$	Light	L
>3 and <=10	$8 < S_{app} <= 18$	Standard	S
>10 and <= 30	$18 < S_{app} <= 25$	Heavy	H
>30	$25 < S_{app} <= 30$	Very Heavy	V
>30 and slow traffic	$S_{app} > 30$	Extremely Heavy	E

% Damage from FlexPAVE™ vs. Sapp

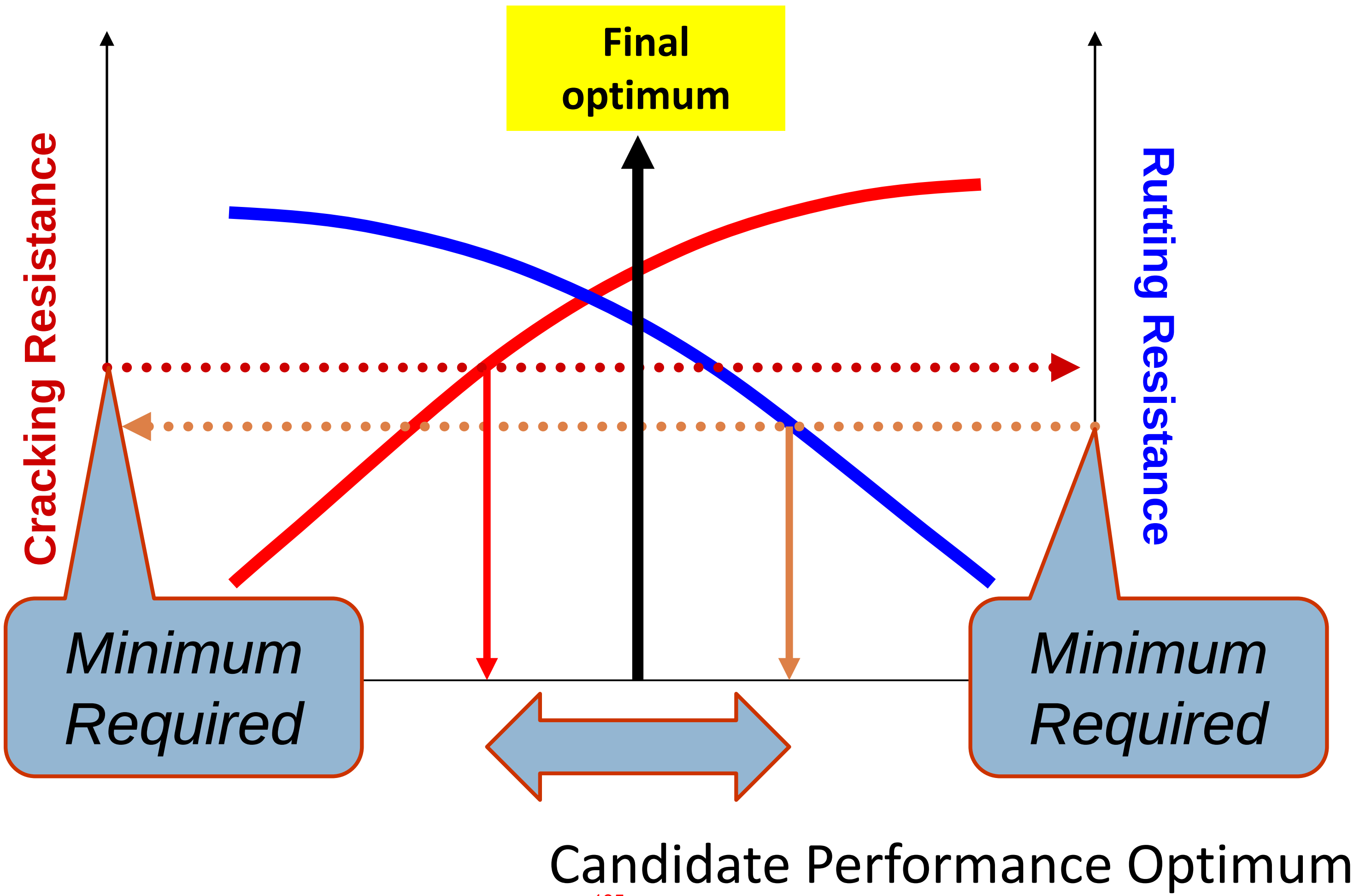


Sample ID	Test AV	S_{app}
159352	7.5	16.8
159355	2.5	29.3
159360	2.5	31.3
159361	7.5	18.1
159362	5.7	26.5

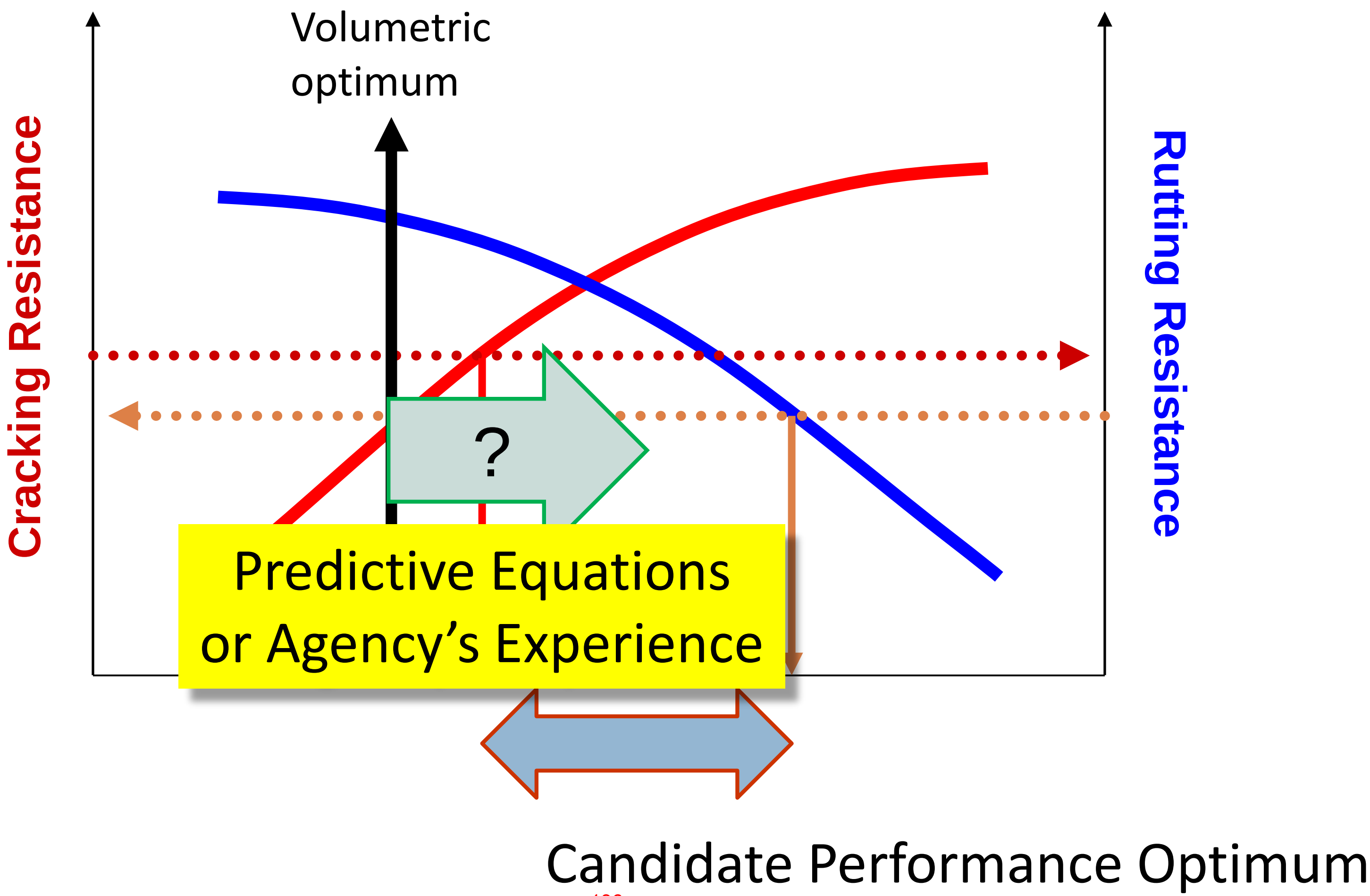
PEMD Concept



Performance-Engineered Mix Design



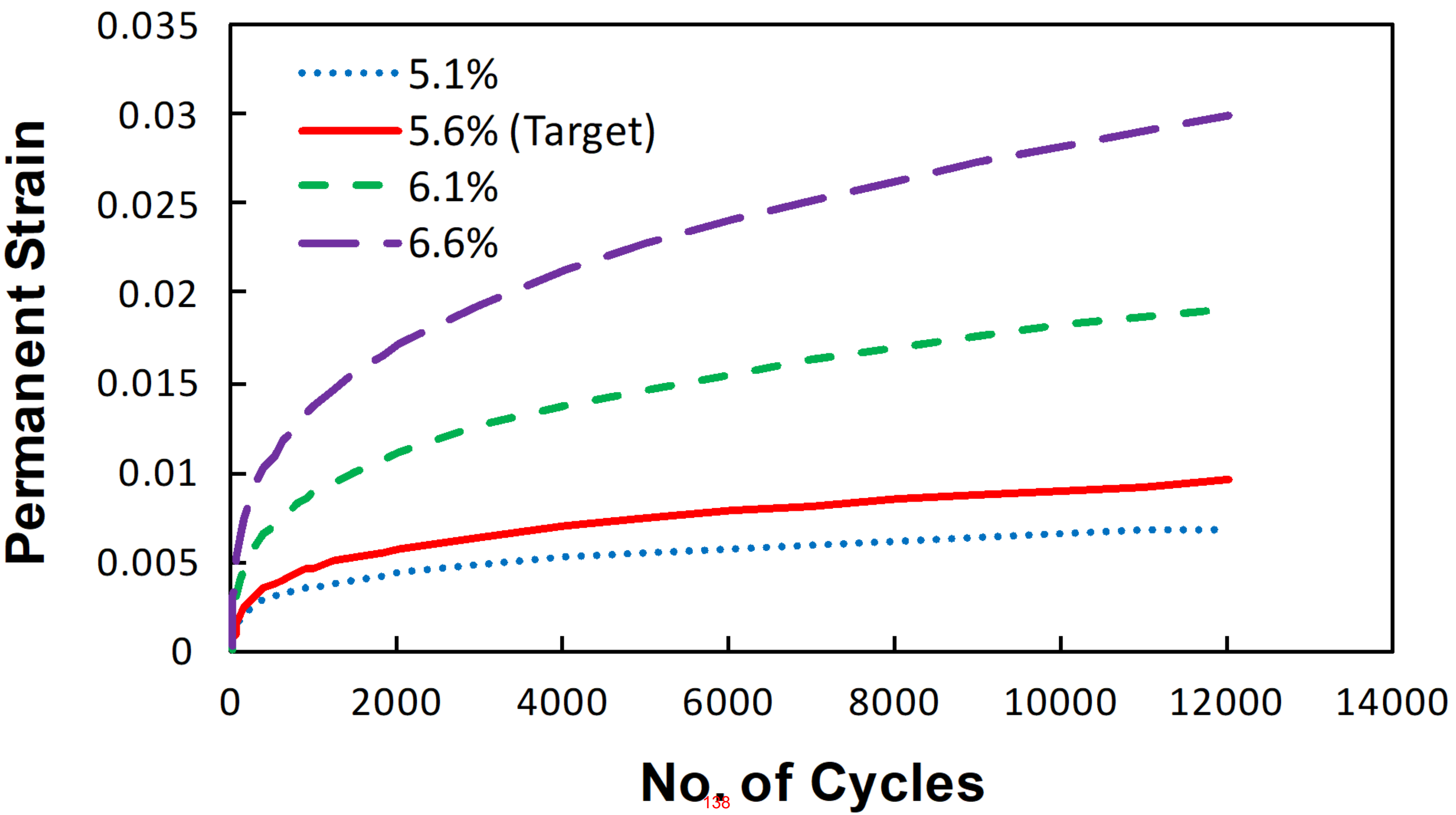
Performance-Engineered Mix Design



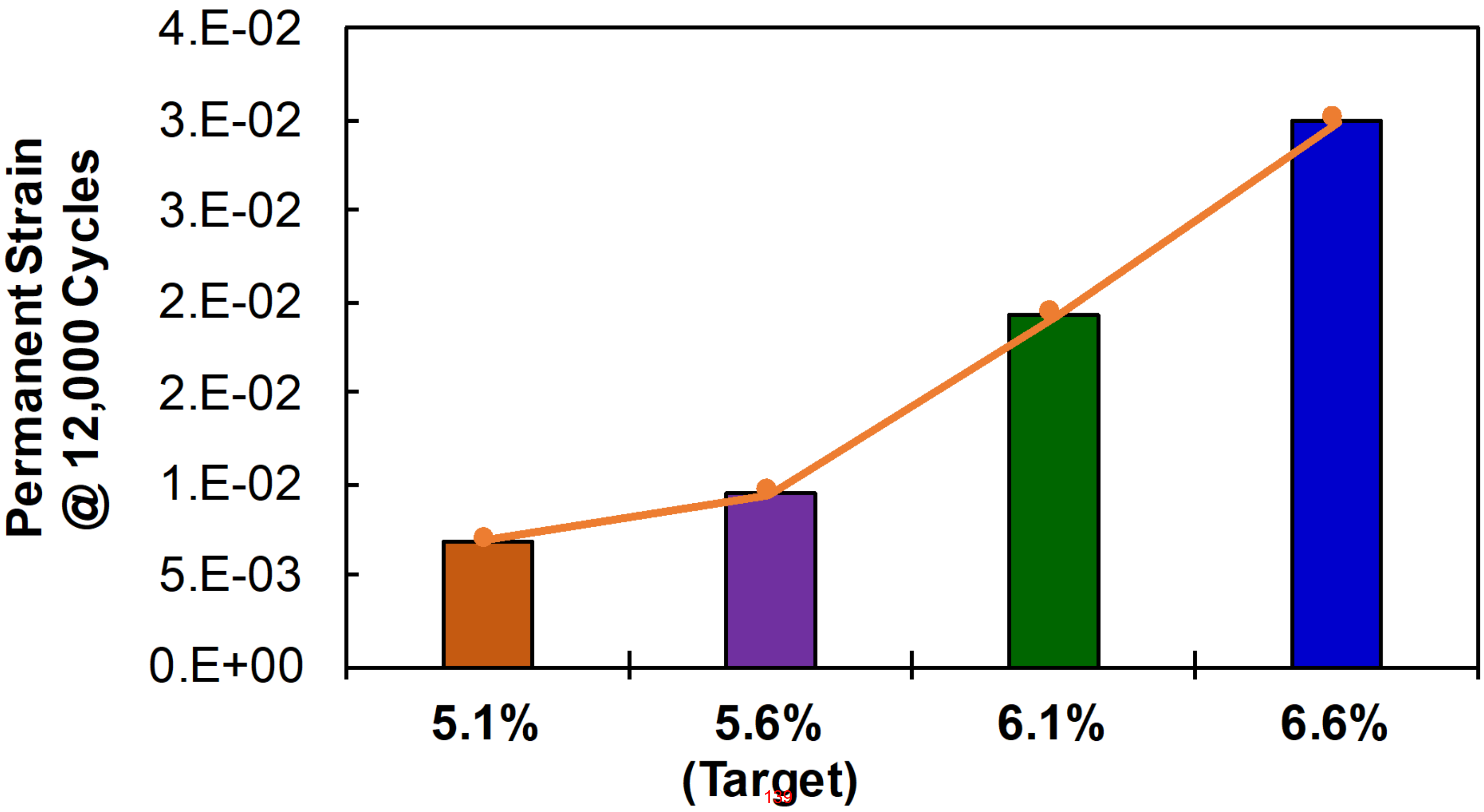
Methodology

- Target - 0.5% (5.1%)
- Target (5.6%)
- Target + 0.5% (6.1%)
- Target + 1.0% (6.6%)

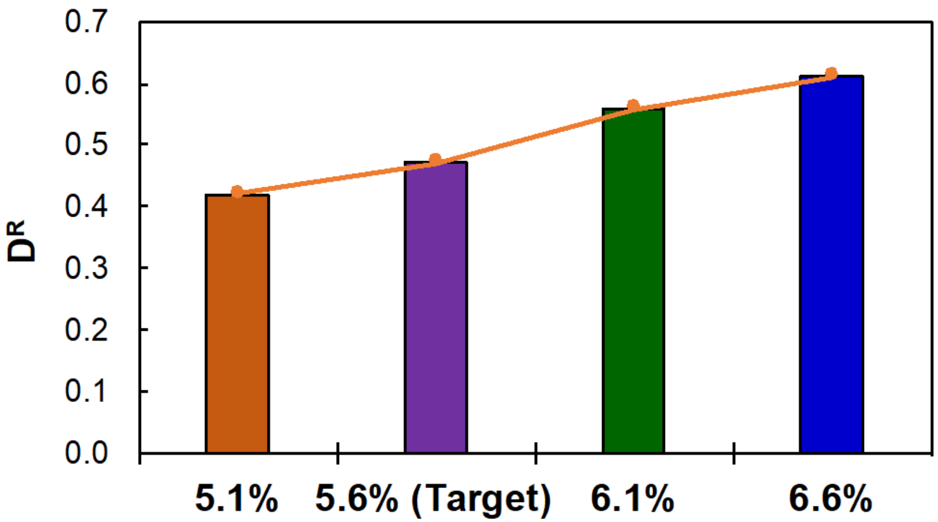
Rutting Performance



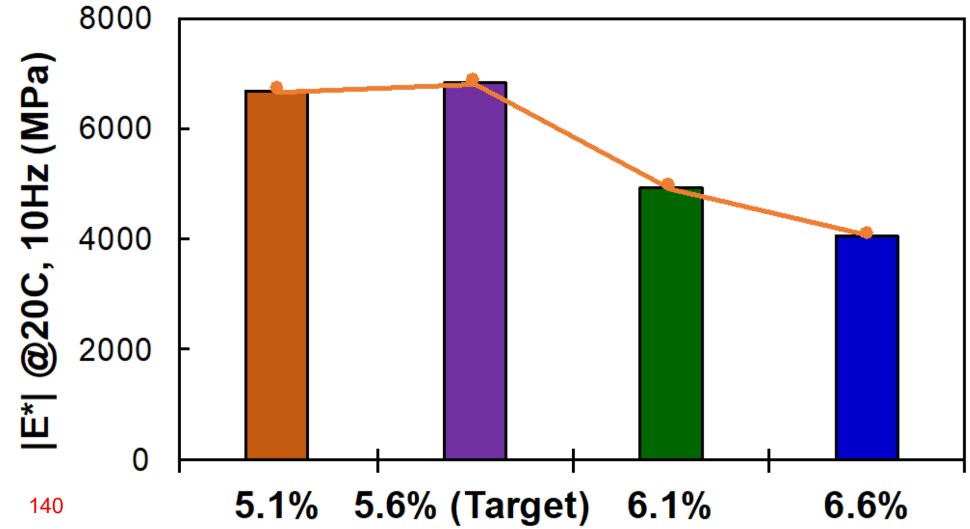
Rutting Performance



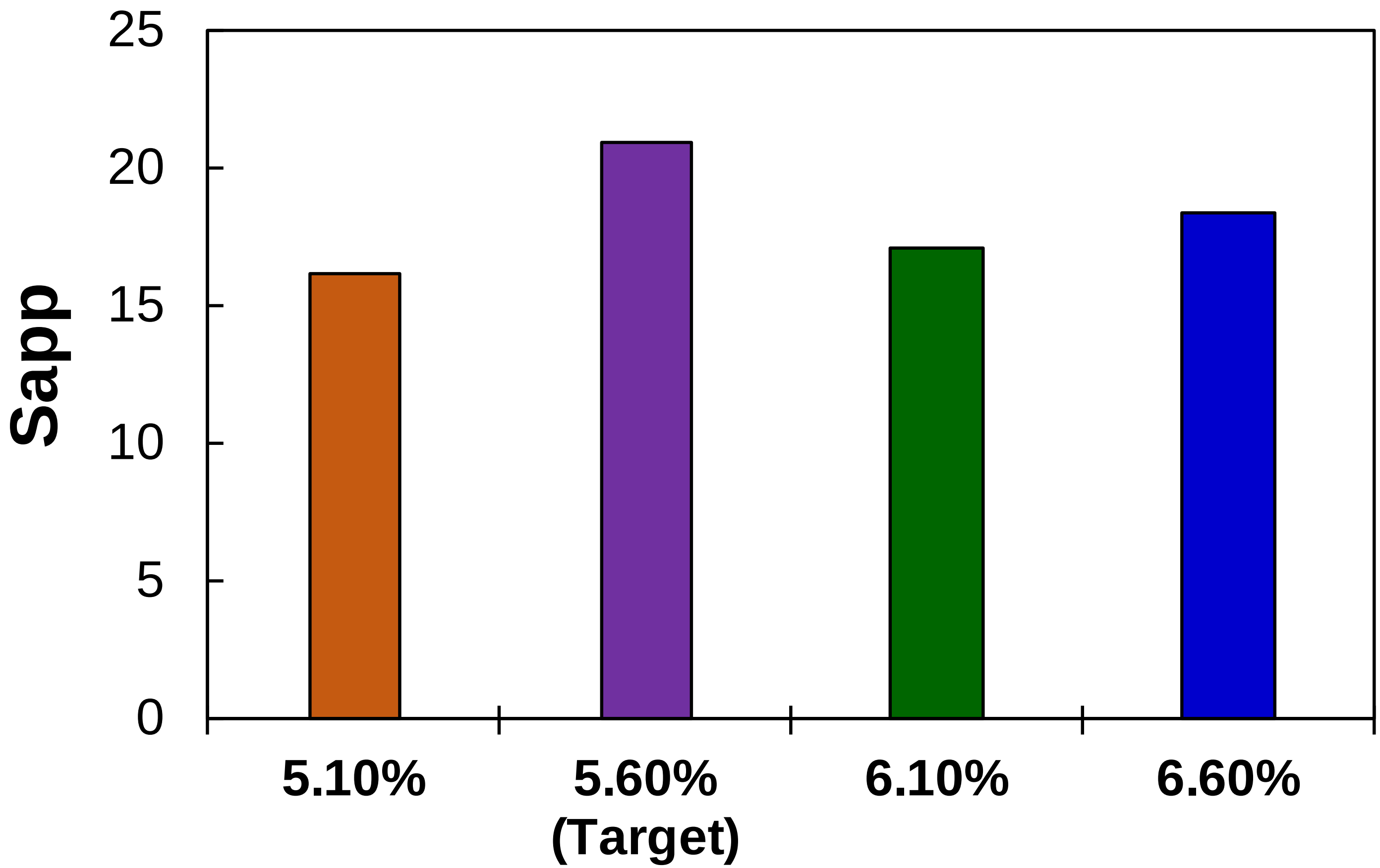
D^R Failure Criterion and Modulus



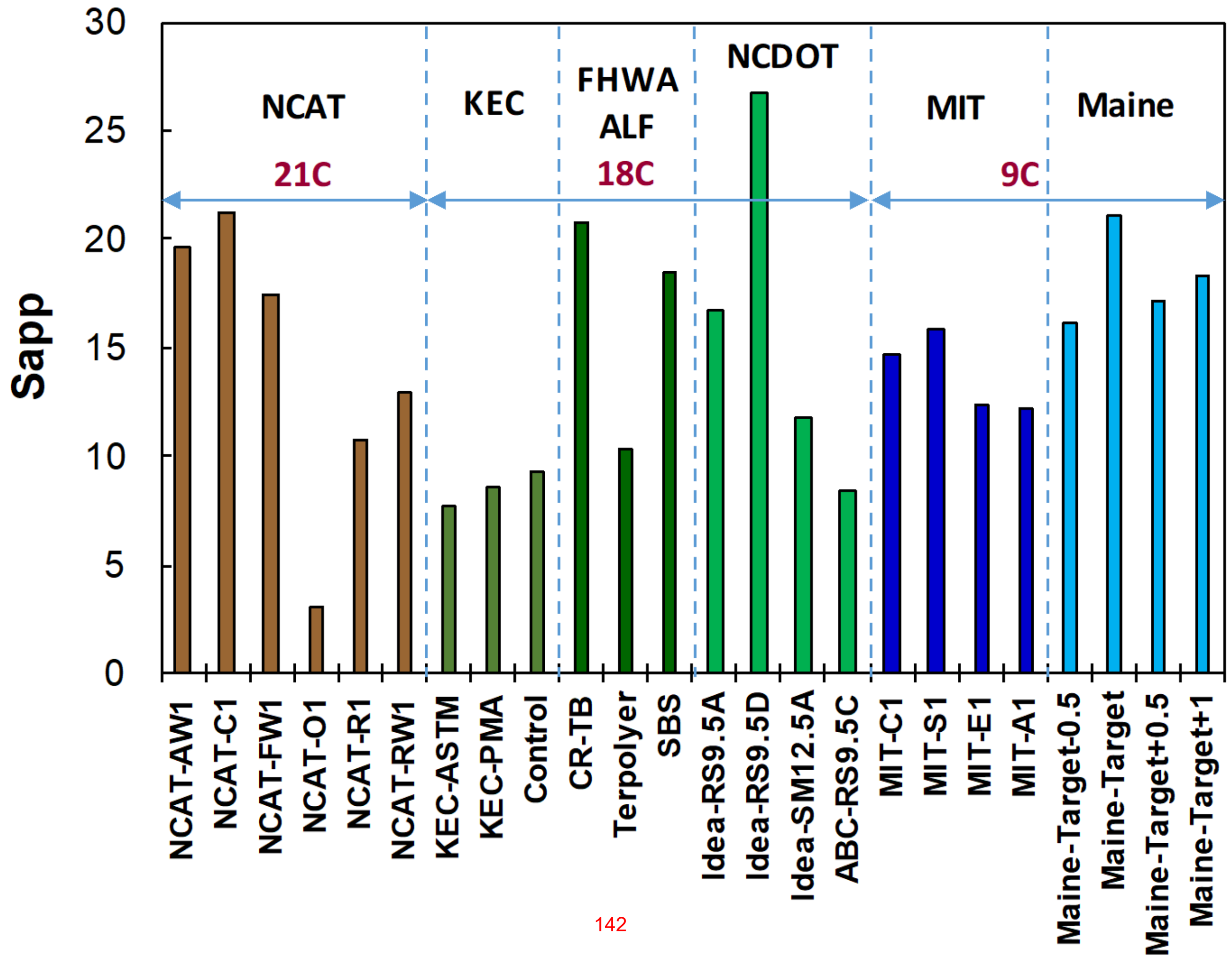
Measure of Stiffness



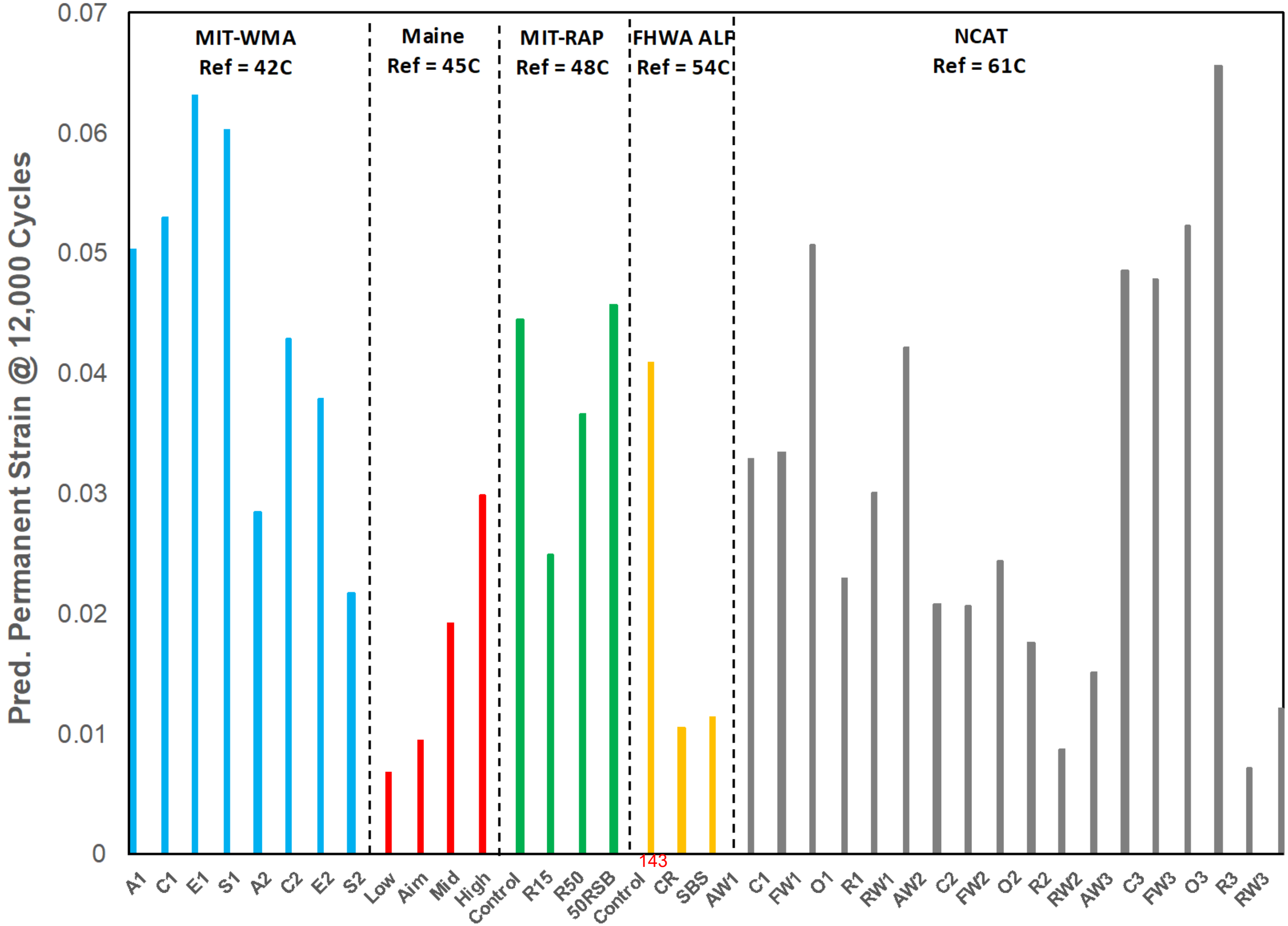
Sapp as a Fatigue Cracking Index



Fatigue Cracking Performance of Maine Mix Compared to Other Mixtures



Rutting Performance of Maine Mix Compared to Other Mixtures



PEMD Lessons Learned - Overall

AMPT Lessons Learned - Testing

43

AMPT Lessons Learned

- Selection of air void content
- Use of CoreLok for air void determination
- Sealing of samples after receipt
- Proper storage

Observations to Date

- The proficiency test results showed MaineDOT was able to perform the AMPT tests and generate high-quality data.
- The test results from the shadow mixes showed the test methods are able to predict the different pavement performance due to changes of AQC parameters.
- The performance-volumetric relationship was used to predict the pavement performance based on AQC data.
- The preliminary mix design and test confirmed the capacity of the mechanistic models and verified the original volumetric design of the mix.

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Thank you for the opportunity.

Any Questions?

Derek Nener-Plante, M.S., PE
Asphalt Pavement Engineer
Derek.Nener-Plante@maine.gov
207-215-0849

Research Thoughts Seeking Feedbacks-Comments

2018 AASHTO COMP Annual Meeting, August 2018

Yong-Rak Kim

Professor of Civil Engineering

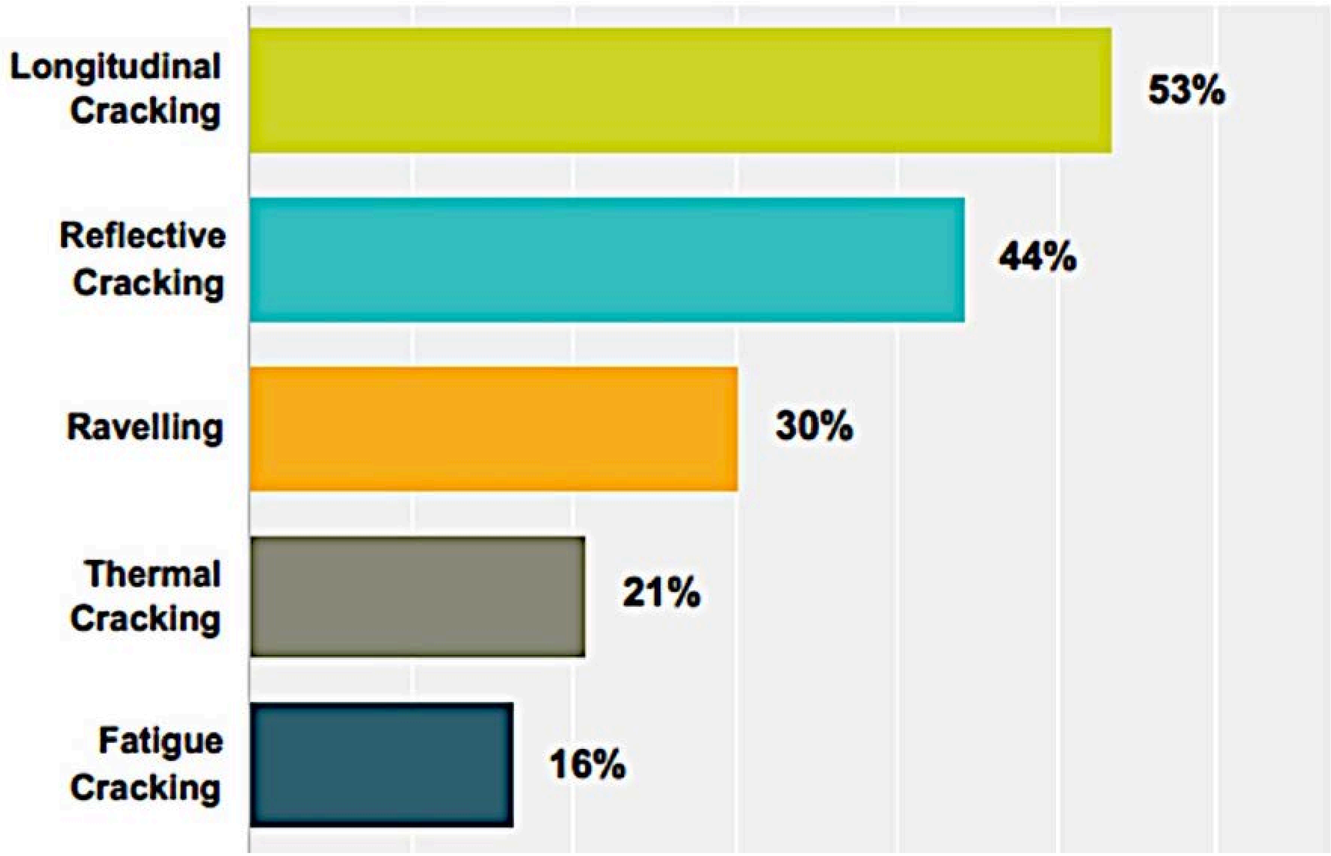
University of Nebraska, Lincoln

E-mail: yong-rak.kim@unl.edu

A Targeted Mixture Test for Asphalt Concrete Pavement Top-Down Cracking (TDC) Mitigation

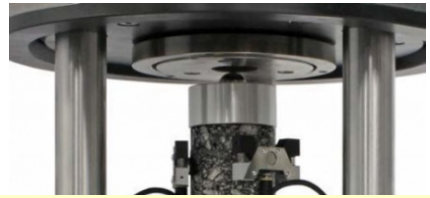
TDC: Major Form of Pavement Distress

Oldcastle Survey Q: **Within the past 5 years, what type of mix performance related distress has been most evident in your mixes?**



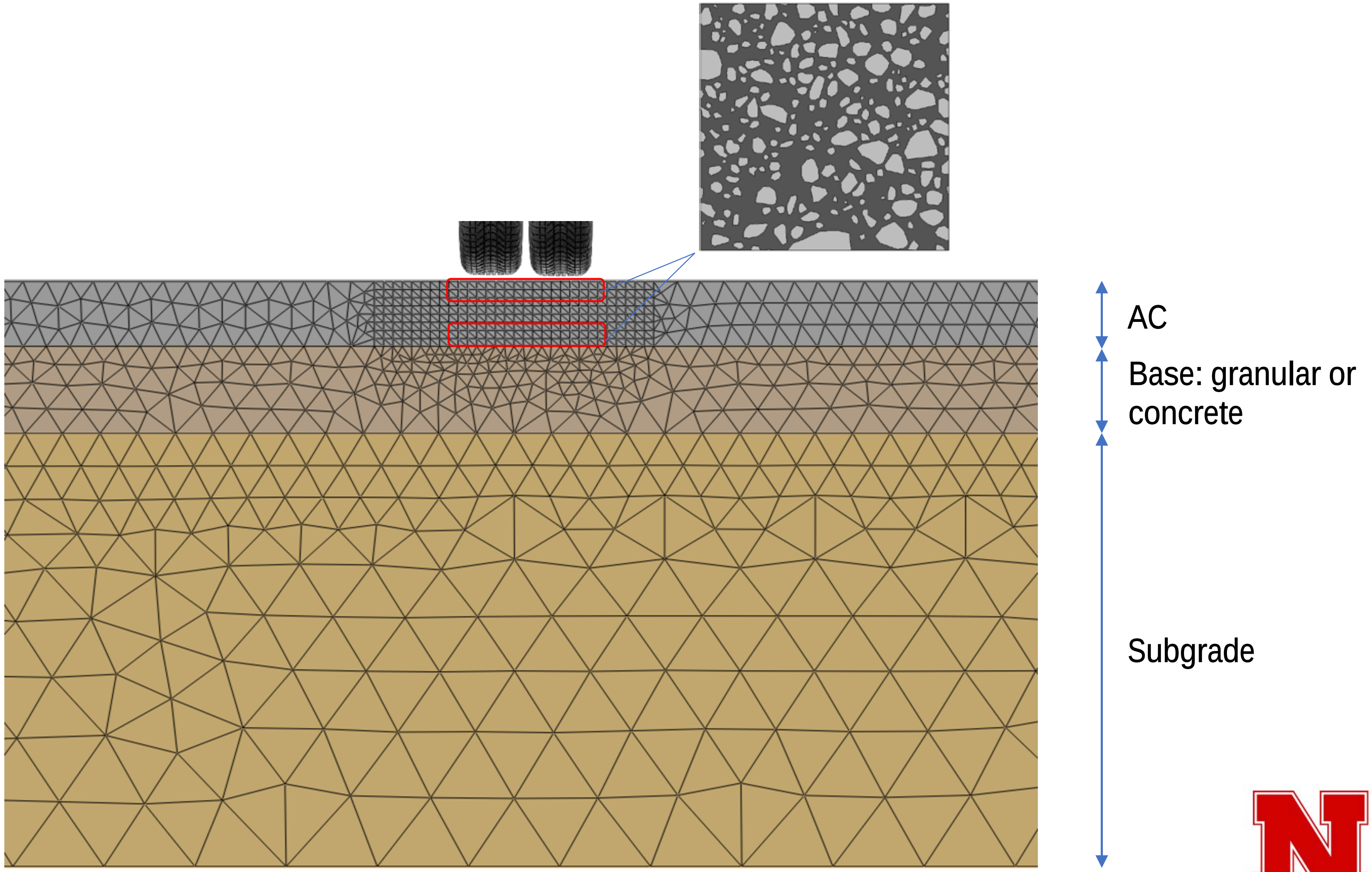
(about 40 companies responding from 30 states)

Many Tests to Evaluate Mixture Cracking

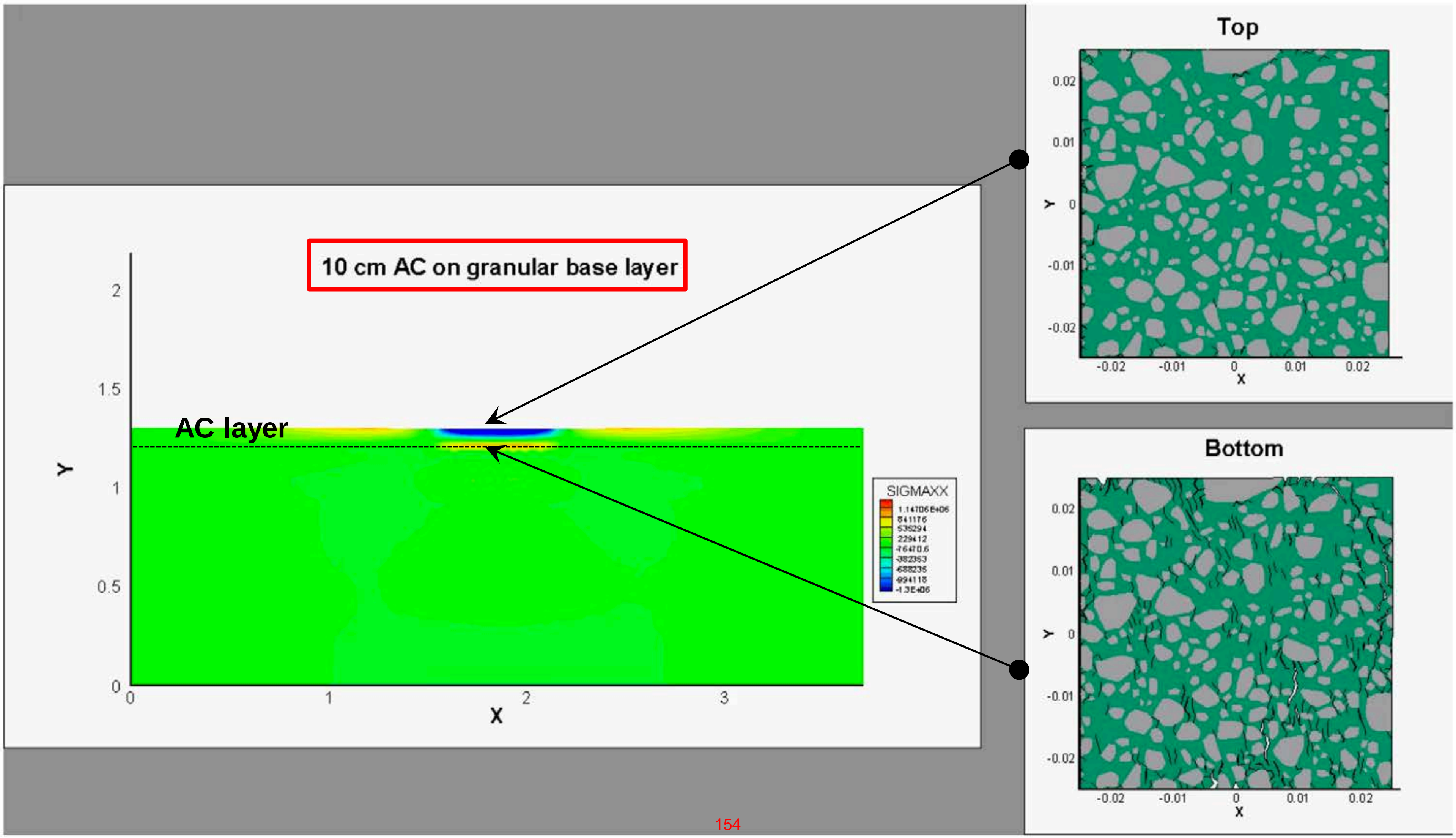


Can laboratory mixture test results predict TDC potential properly?

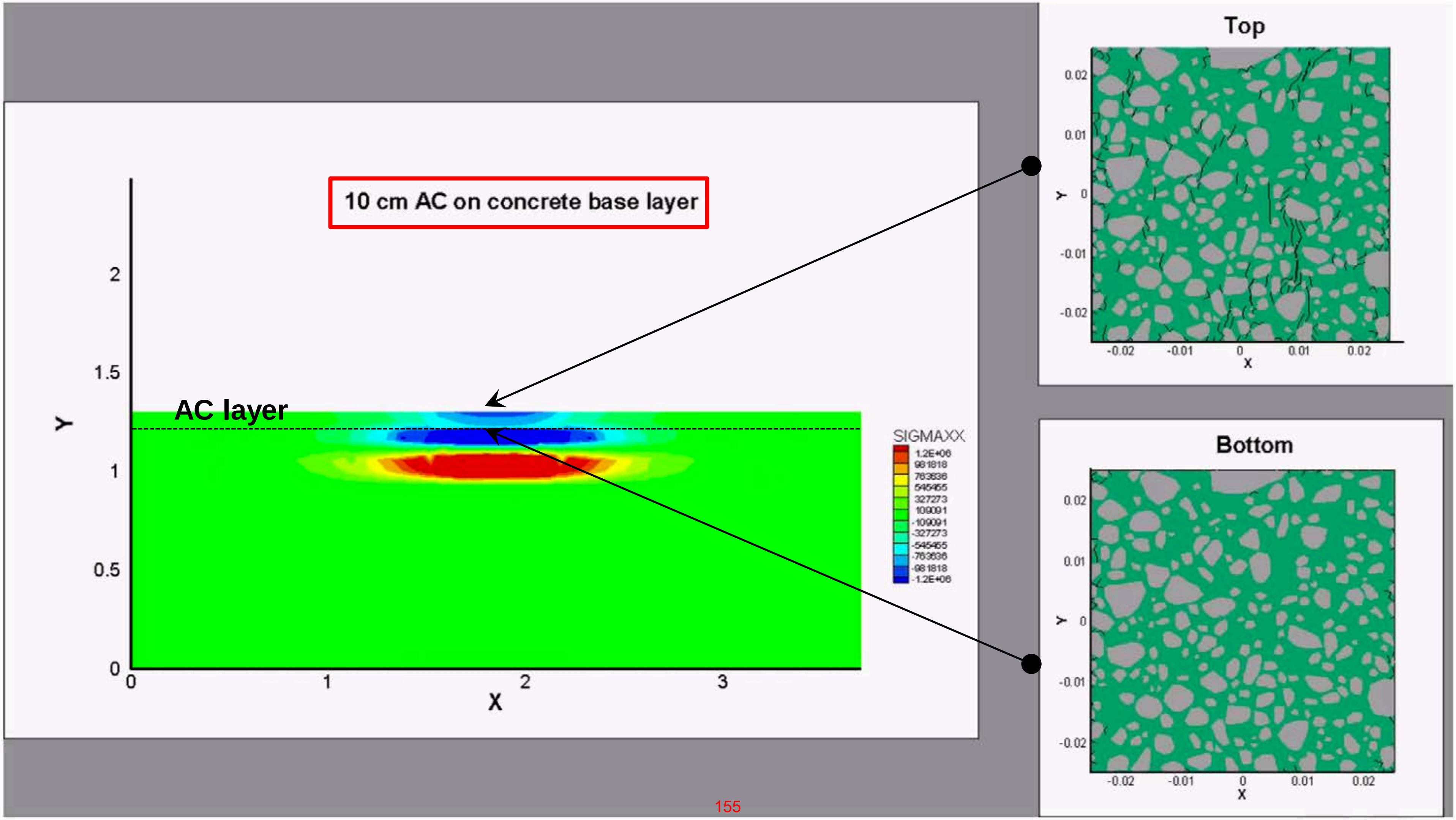
Same Mixture in Different Pavements



- The <u>structural-material interactions with environmental factors</u> that lead to TDC are not the same as those leading to other cracking (such as bottom-up).



❖ The structural-material interactions with environmental factors that lead to TDC are not the same as those leading to other cracking (such as bottom-up).



Knowledge Gap and Objective

❖ Knowledge Gap

- A test method that can accurately incorporate the structural-material interactions and loading-environmental conditions occurring in TDC does not exist.
- The test should directly relate to the relevant distress, and assess key properties such that mixtures can be screened for susceptibility to TDC and the resulting properties can be used in pavement design and mixture design.

❖ Research Objective

- The objective is to develop <u>a more TDC customized test method</u> that can incorporate the structural-material interactions and loading-environmental conditions occurring in TDC. The method can be used in routine characterization of TDC resistance of asphalt mixtures.

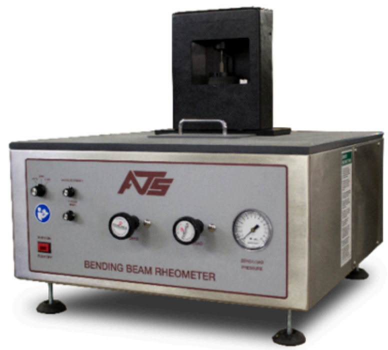
Deliverables and Significance/Benefits

- An asphalt mixture test which is amenable to material screening, mix design (e.g., balanced or performance-based), and pavement design.

- This will bring better materials-pavement engineering and cost saving.

A Test-Analysis Method for Binder Low Temperature Testing-Grading

Current Binder PG	Potential New Binder PG



PG XX-YY

Requires two separate equipment (DSR, BBR)
Takes 25 grams of binder for each BBR sample
Requires different BBR samples at different T.
Takes 4-5 hours for entire testing
Impossible for forensic study-analysis

PG XX-YY

Requires only DSR with a chiller
Takes about 1 gram of binder
Requires only 1 DSR sample for entire testing
Takes less than 2 hours for entire testing
Quite feasible for forensic study-analysis

Knowledge Gap and Objective

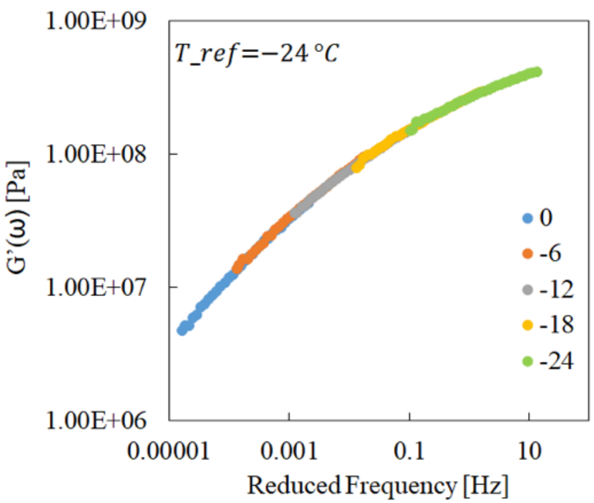
❖ Knowledge Gap

- Current standard of BBR (AASHTO T313): time-consuming and requires much binder (25 grams per testing temperature) and equipment calibration.
- Alternative test methods (e.g., ABCD, FRAAS breaking point): single critical temperature, requires additional testing device.
- WRI's 4-mm DSR: empirical correlation with data sets, database-dependent and not specific to the binder type

❖ Research Objective

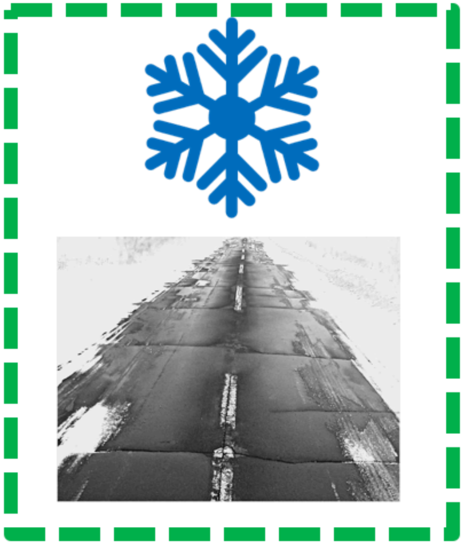
- The objective is to develop an alternative/supplemental test-analysis method for binder low temperature testing-grading only by using a DSR and mechanistic theories.

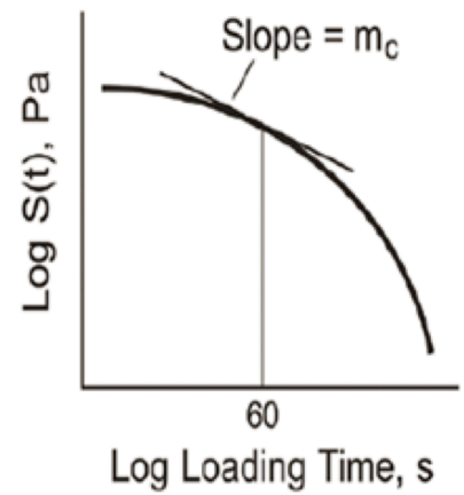
New Methodology



Frequency Sweep Test

Mechanistic Conversion from DSR Data to BBR Data





Creep Stiffness and m-value

PG XX-YY

Determination of Low Temperature PG Grade

Deliverables and Significance/Benefits

- A new standardized testing method, a user-friendly analysis module for daily practical uses, and suggested guidelines for low temperature grading of binder.

- This will bring much more efficient practices in DOTs on binder selection, testing, and grading. This will vastly reduce time-costs and enable better materials-pavement engineering.

I need your inputs!

https://goo.gl/forms/JeOYz1a1TfoBhIcF2

Email: yong-rak.kim@unl.edu

Two New Practical Tests for Durability of Asphalt Binders

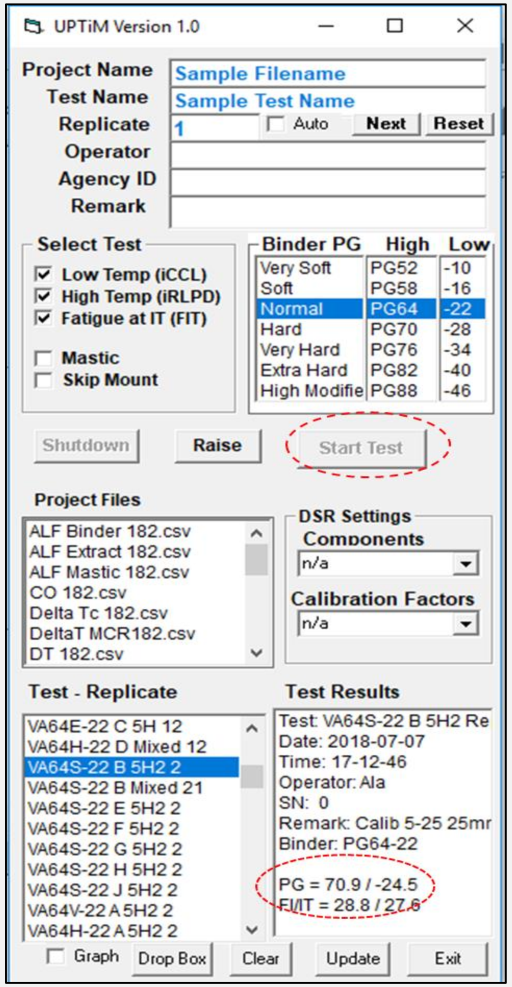
Haleh Azari, Ph.D.
Alaeddin Mohseni, Ph.D.
Pavement Systems, LLC
For AASHTO COMP Meeting ,TS 2b
Aug 7, 2018

Testing Package

Hardware/Software Tool that provides quick and reliable estimates of:

1. Low-Temperature PG and
2. Fatigue Property

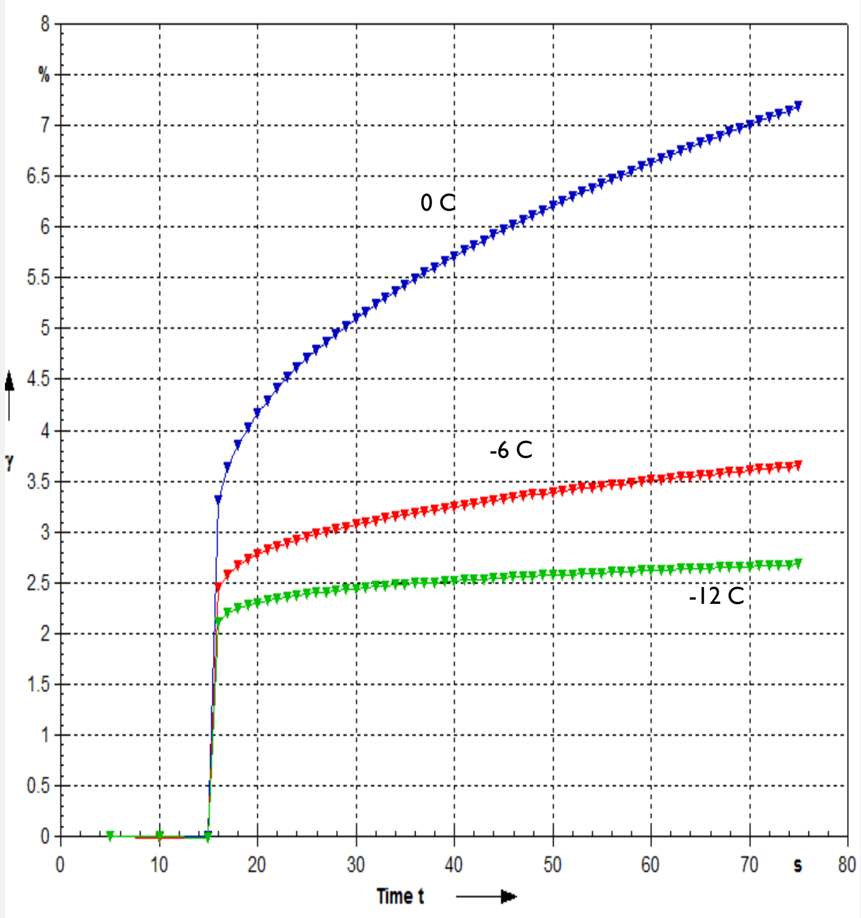
of Liquid Binder



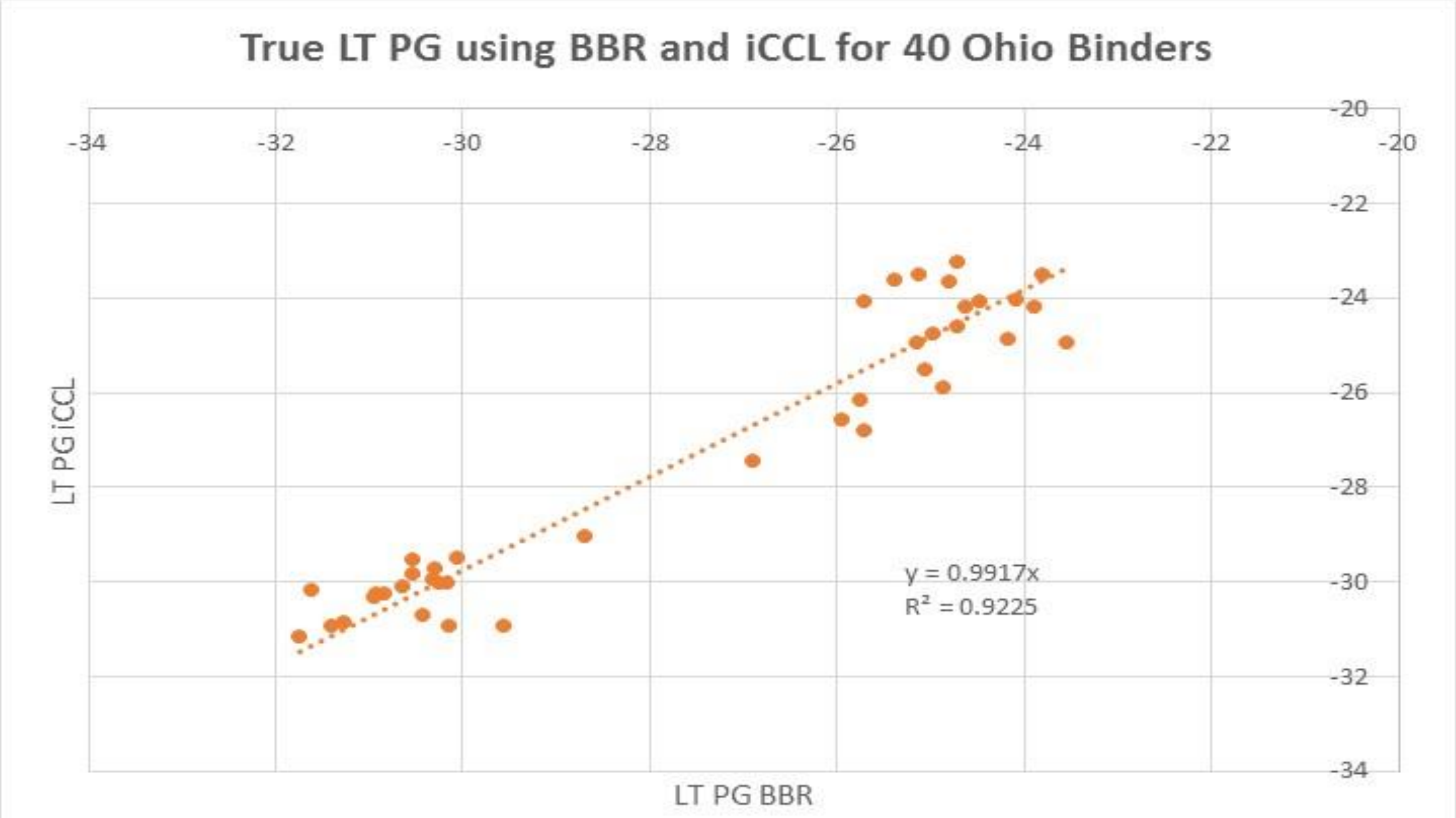
iCCL™
incremental Creep for Cracking at Low Temperature

iCCL
Creep Loading on DSR at Low Temperature

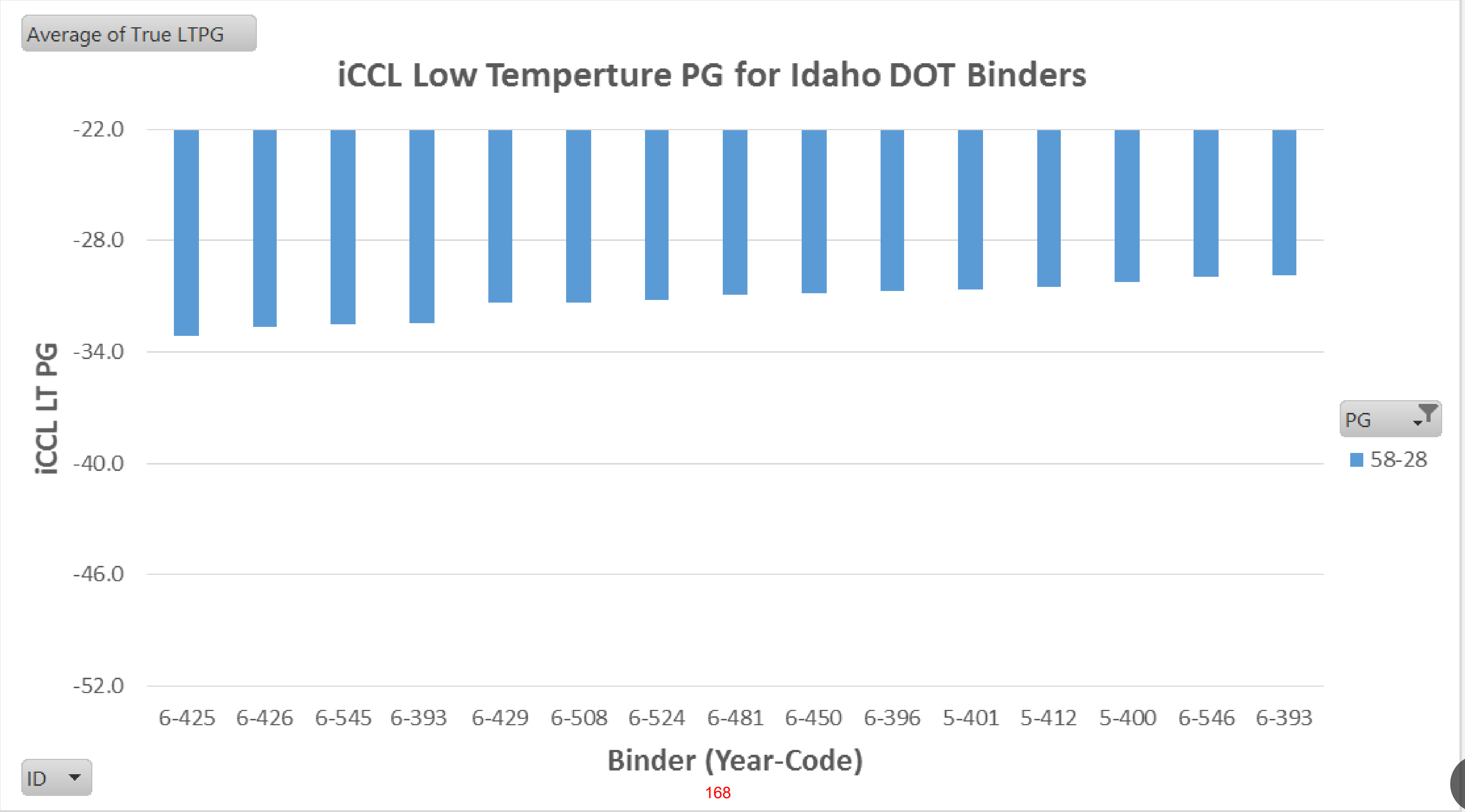
- DSR:
  - 8 mm plate, 0.5 mm Gap
- Material:
  - RTFO/PAV
- Loading:
  - Constant Creep for 60 seconds
- Low Temperature:
  - Multi Temperatures or a Fixed Subzero Temperature
- Parameters:
  - Low-Temperature PG
- Duration: 30 Minutes
- Correlated to Mixture and Composite Binder



Comparing iCCL to BBR True Grades



Example of iCCL Verification Low-Temperature PG of Idaho PG 58-28 Binders



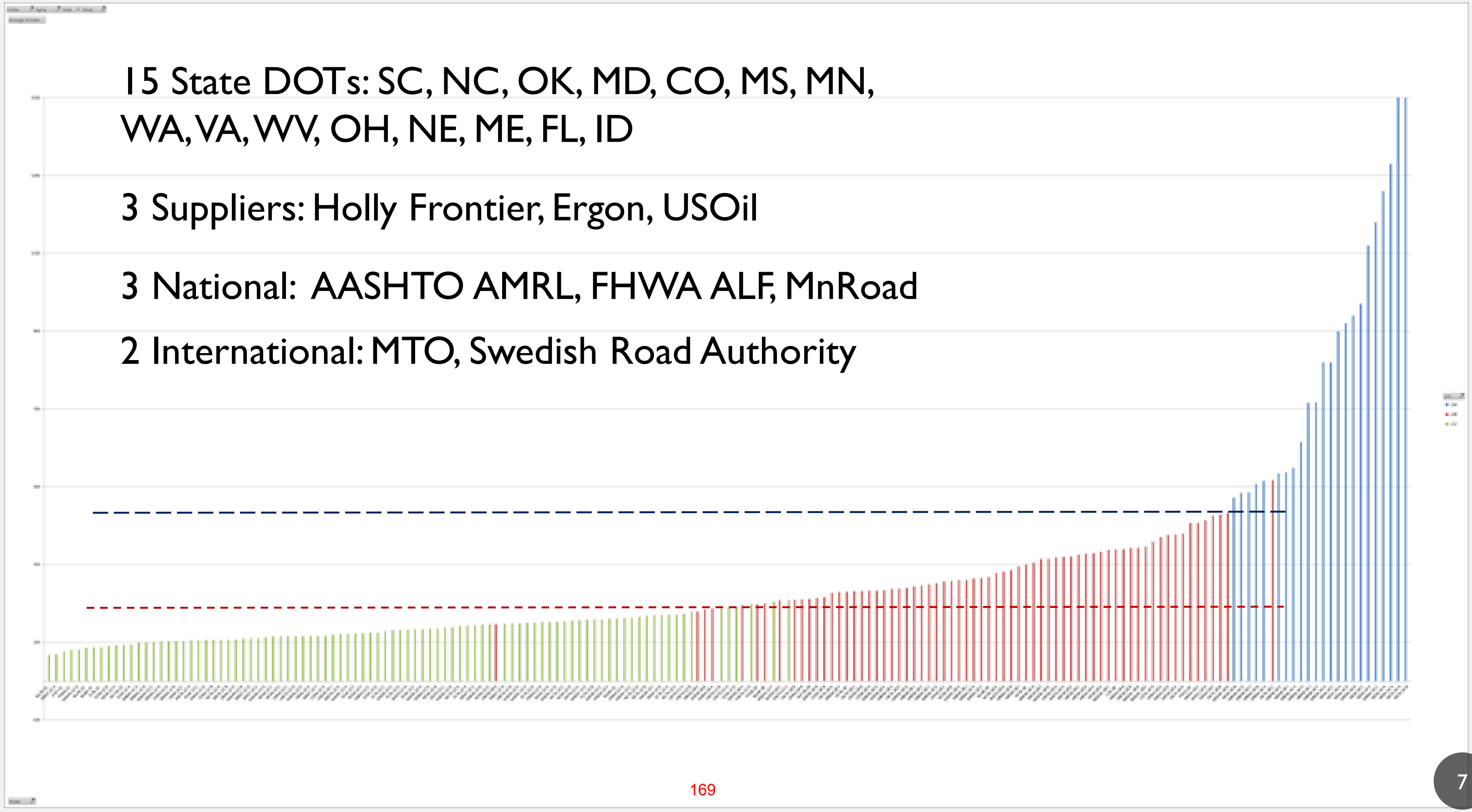
Verification of iCCL using around 500 Binders from 23 Agencies

15 State DOTs: SC, NC, OK, MD, CO, MS, MN, WA, VA, WV, OH, NE, ME, FL, ID

3 Suppliers: Holly Frontier, Ergon, USOil

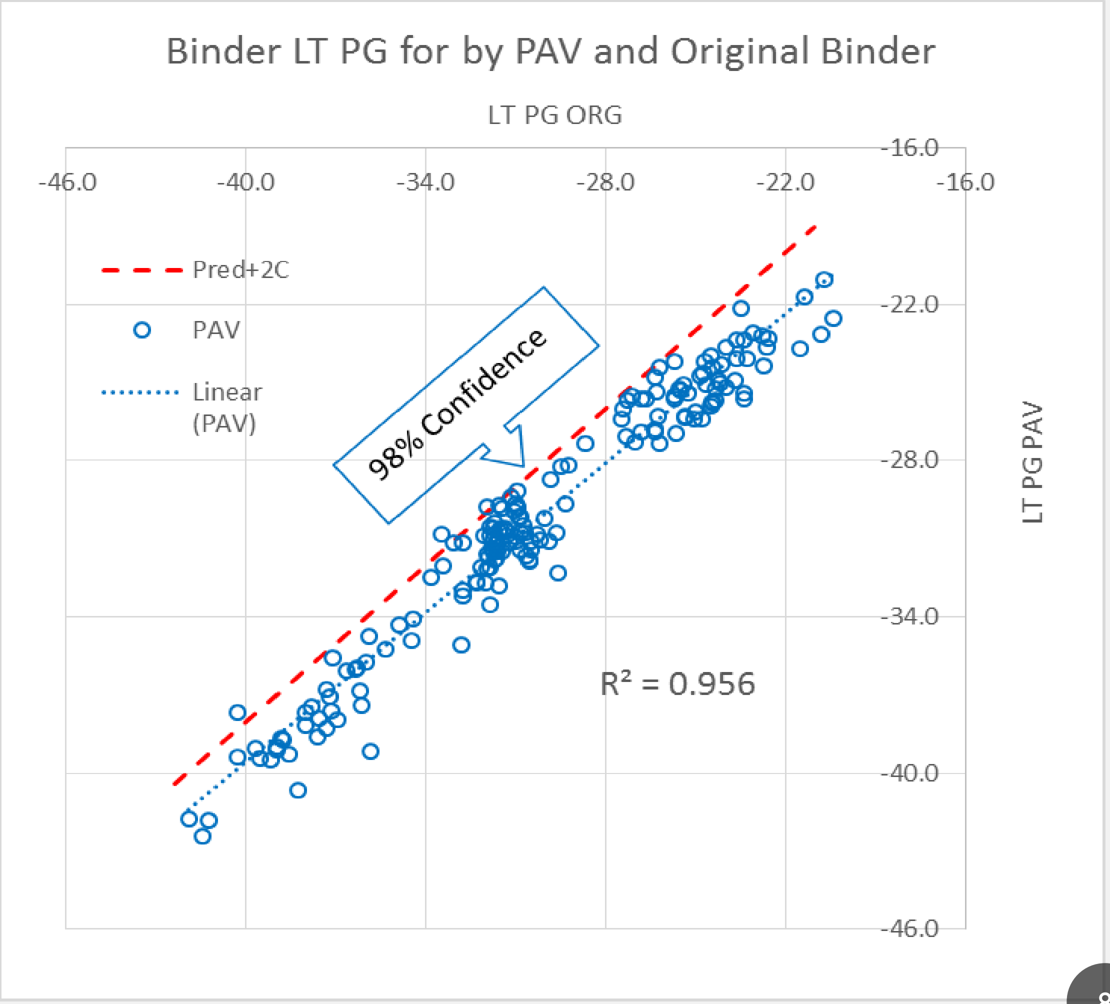
3 National: AASHTO AMRL, FHWA ALF, MnRoad

2 International: MTO, Swedish Road Authority

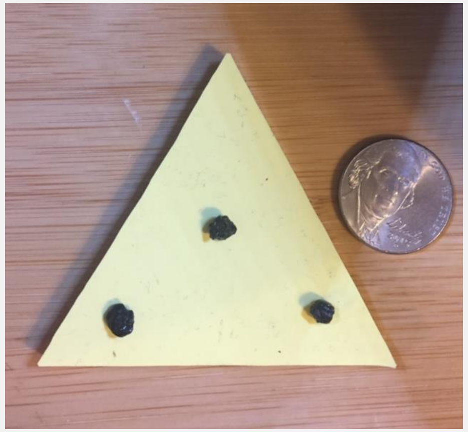


iCCL for Original Binder (ongoing)

- Model is being developed to estimate low-Temperature PG from iCCL test of original binder
- So far, 182 binders from 15 state DOTs including 23 binder grades tested
- Model Standard Error of Estimate is 1.0˚C
- 98% of LT PG estimates were within 2˚C of True PG
- Potential for quick screening



iCCL Round Robin



- A round robin study was conducted involving four laboratories:
  - Anton-Paar Graz, Austria
  - Anton-Paar Stuttgart, Germany
  - Anton-Paar USA
  - Pavement Systems LLC
- C.V. of 1.5% was reported

Comparison of iCCL™ Test with BBR

Test Features	BBR	iCCL
Sample Prep. and Testing/ Sample	One and half hours	30 minutes
True Grade	Requires Two Tests	By One Test
Technician Time/ Sample	One hour	5 minutes
Test Variability	7%	2%
Calibration Check	Every Day	Every 3 months
Use of Hazardous Liquids	Coolant	None
Testing Original Binder	N/A	Possible
Air Pressure	Yes	None
Sample Storage Limit	Two hours	None
Molding/Demolding	Required	None

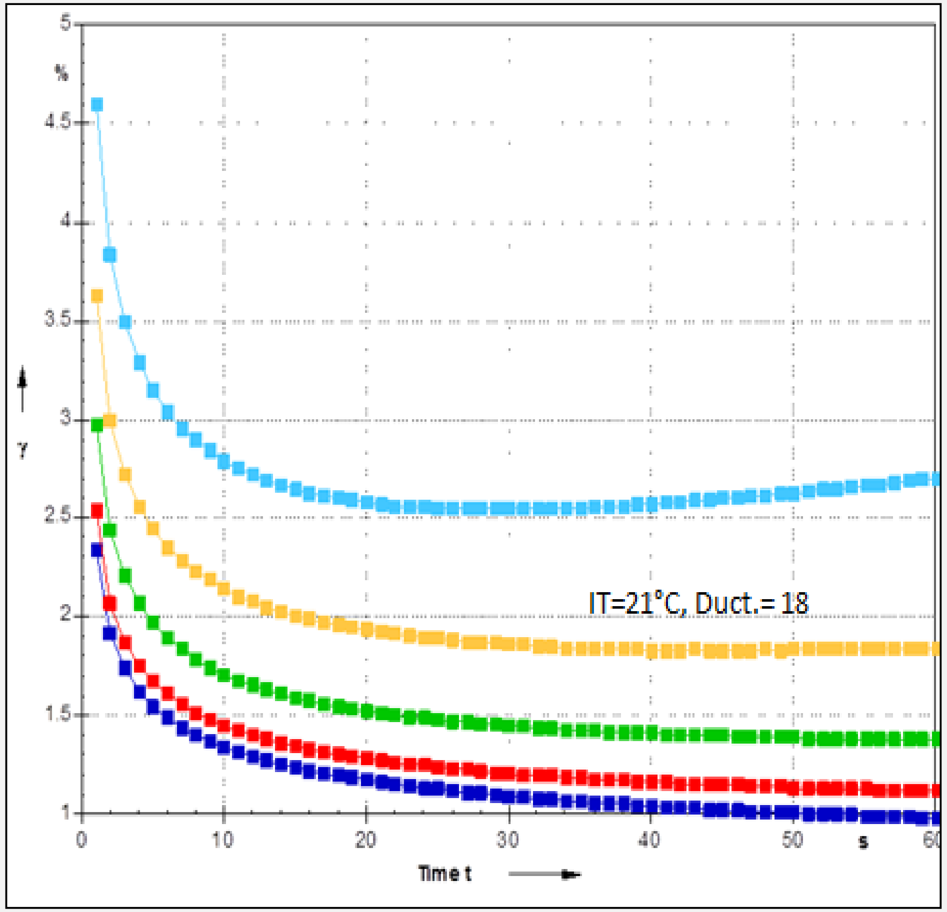
UPFiT
Fatigue Test at Intermediate Temperature

Principles of Binder Fatigue Test

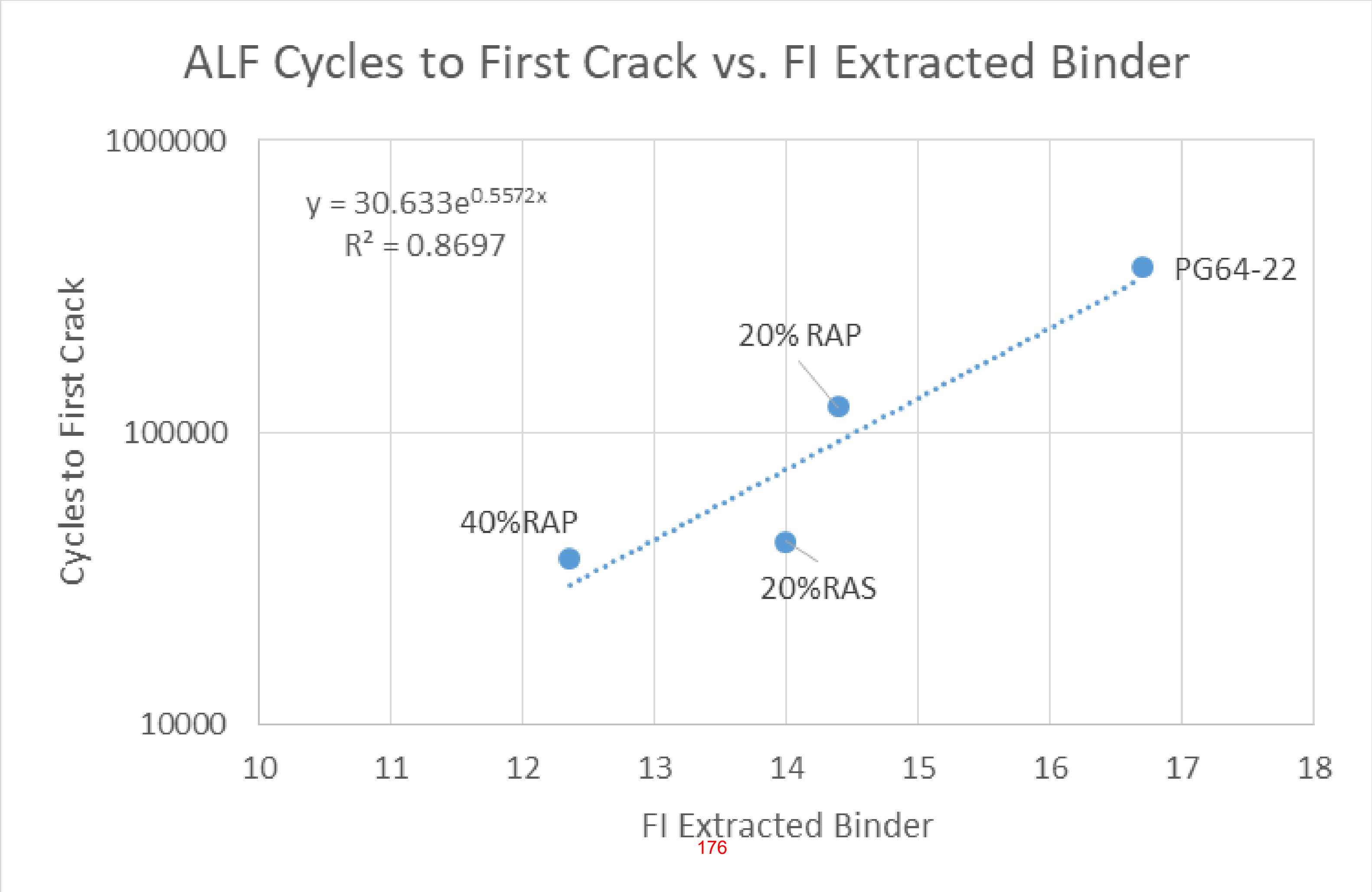
1. Fatigue Cracking means:
   - Fatigue due to Repeated Load (Not monotonic load)
   - Test should be carried to fatigue cracking
2. Loading rate should be similar to the field
3. Should include rest period
4. Damage rate should be similar to the field
5. Test should be conducted at Intermediate Temperature which is the material critical fatigue temperature

UPFiT
Repeated Load Test on DSR at Intermediate Temperature

- DSR:
  - RTFO/PAV
  - 8 mm plate, 0.5 mm Gap
- Loading:
  - 0.1 s load / 0.9 s rest
  - 60 cycles/increment
- Temperature Sweep:
  - Start at Midpoint PG,
  - Increase 1°C to reach Failure
- Parameters:
  - Fatigue Index= Permanent Strain rate at failure (m*)
  - Intermediate Temperature= Temperature at failure
- Duration: 30 Minutes
- Correlated to Elastic Recovery
- Determines Level of Modification
- Variability of test (C.V. 6%)

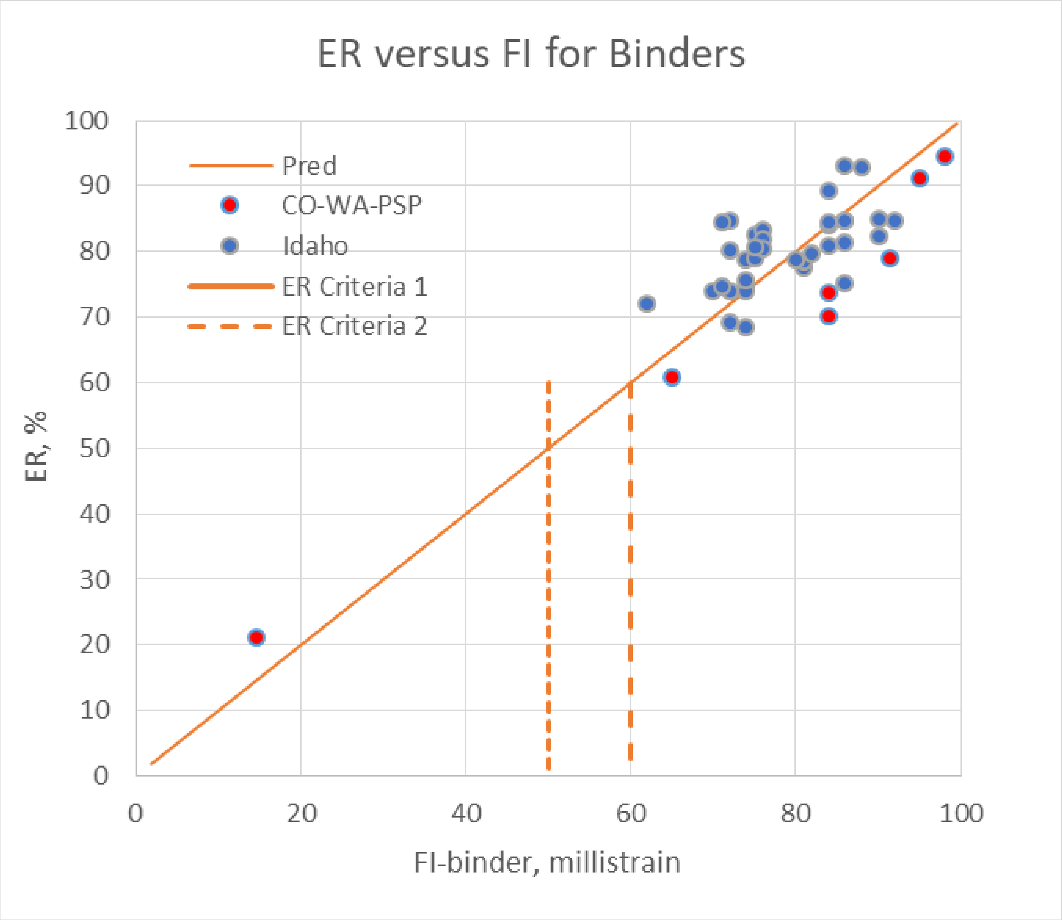


ALF Extracted Binder Fatigue Index (FI)



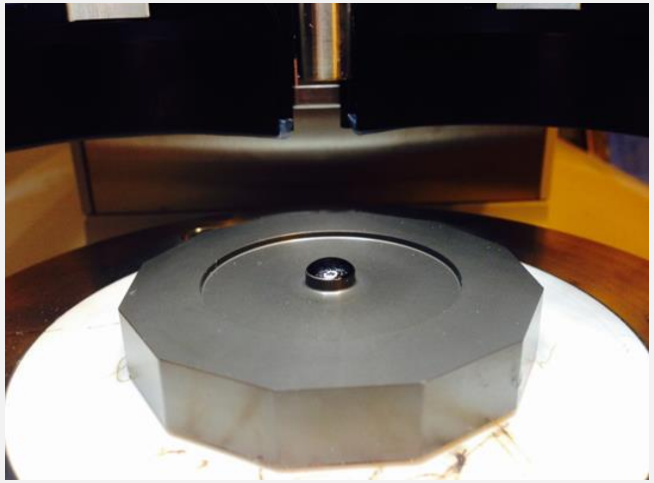
Elastic Recovery vs. Fatigue Index

- Fatigue Index (FI) has the same scale as ER (0 to 100) and has good correlation with ER
- Figure shows the fit for four sources of data:
  1. Colorado DOT binders (2)
  2. Washington State (4)
  3. AMRL Proficiency Samples (2)
  4. Idaho binders (34)
- ER and FI showed good agreement for PASS/FAIL criteria
- FI shows level of modification more accurately and precisely than ER



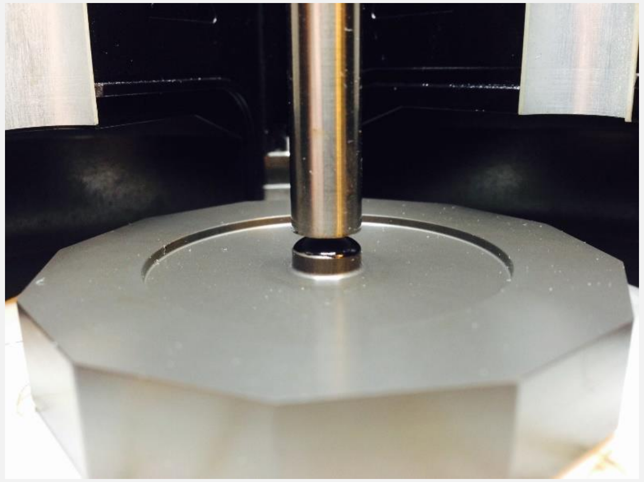
Sample Preparation and Testing

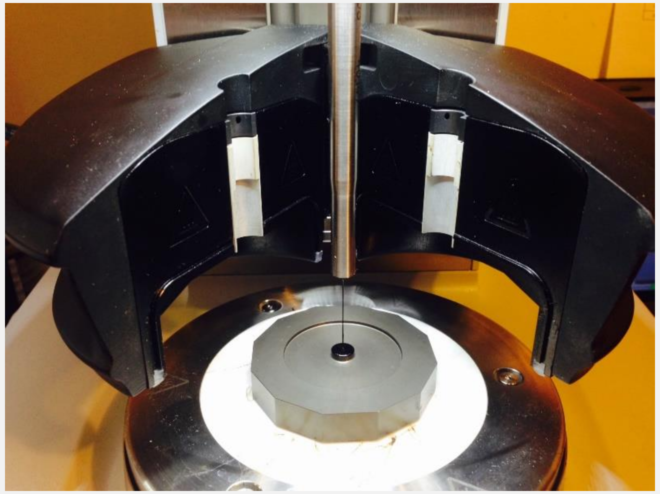
1. Open the can
2. Measure 31 mg of binder
3. Place it on the plate
4. Click on Start button
5. Get Low-Temp. PG in 30 minutes
6. Get fatigue index (Elastic Recovery) in additional 15 minutes
7. All Calculations are done by the software

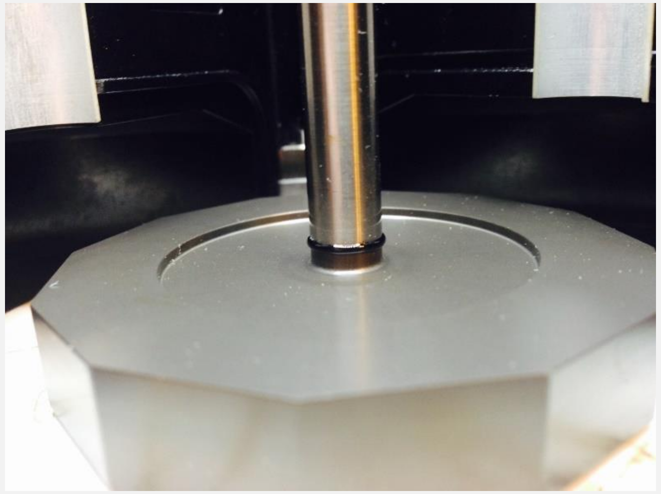


Sample Mounting & Cleaning

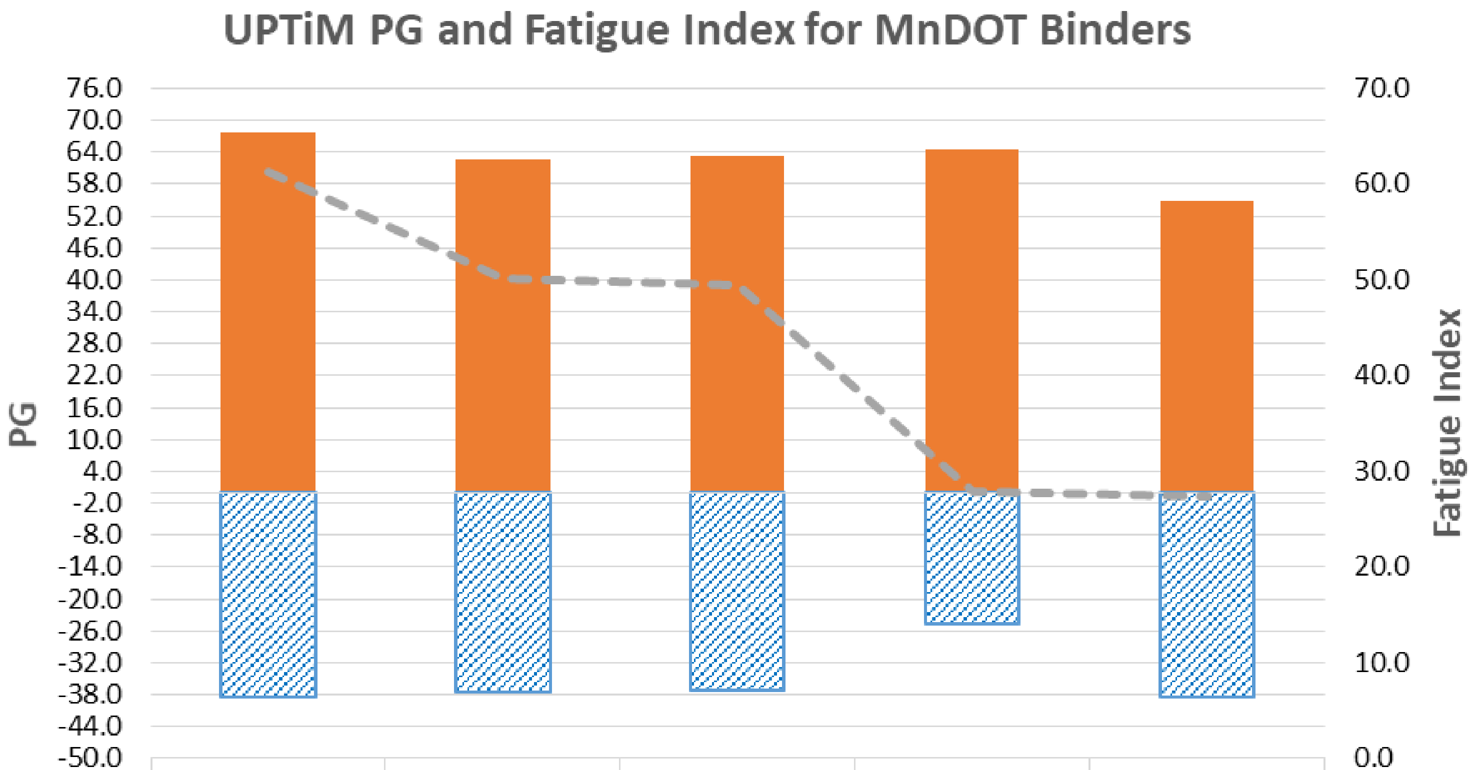
- All user has to do is to place the sample on the plate
- UPTiM® Software performs the mounting automatically, no manual trimming
- Fast and easy cleaning since sample is small, no solvent is required





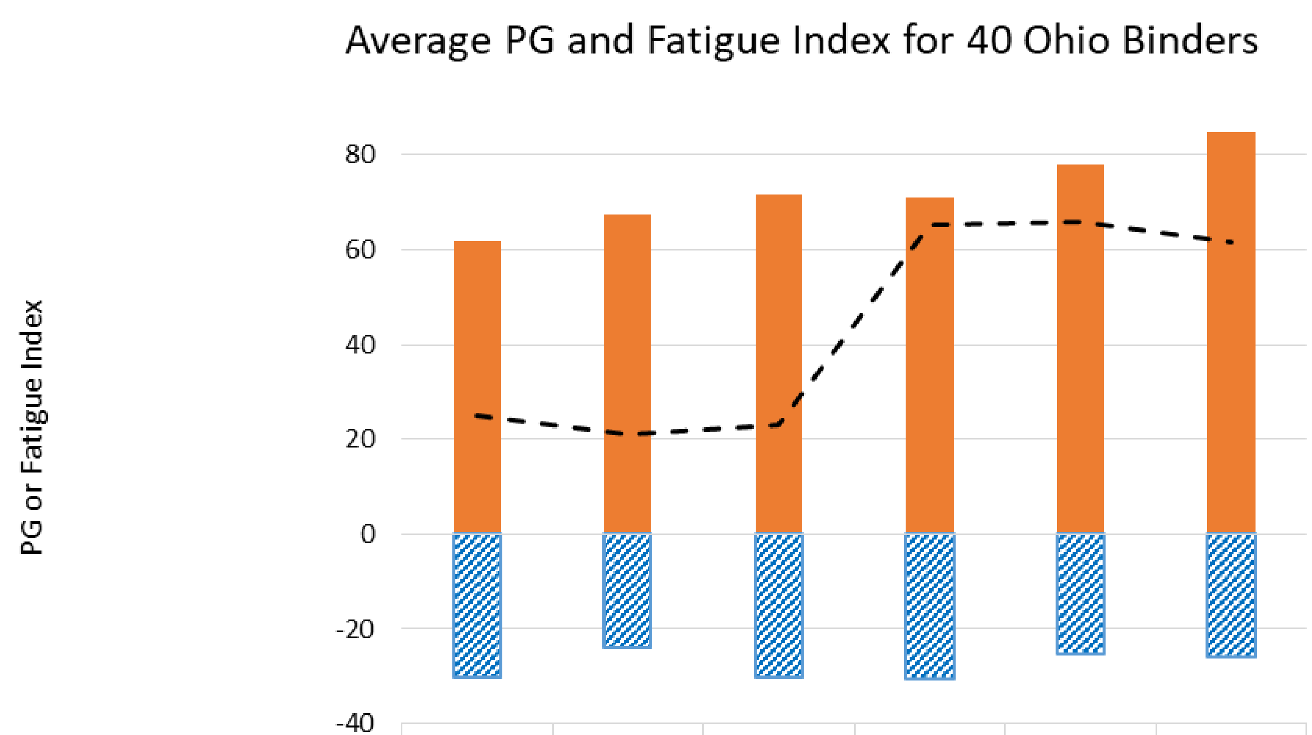


Ranking of MnRoad Binders by Fatigue Index



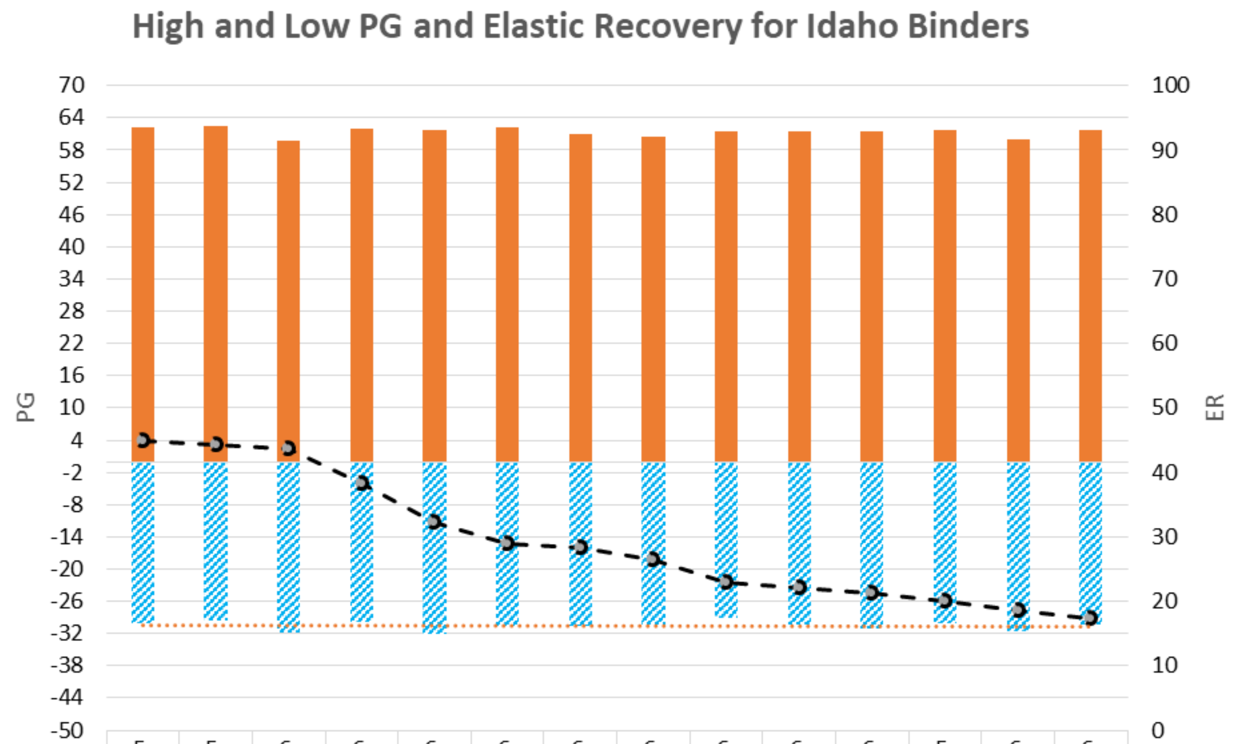
Binder	64E-34	58H-34	58H-34 AS	64S-22	52S-34
HT PG	67.7	62.6	63.3	64.6	54.9
LT PG	-38.5	-37.6	-37.3	-24.7	-38.4
Fatigue Index	61.3	50.2	49.4	27.8	27.4

Ranking of Ohio Binders by Fatigue Index (Comparison of PPA and SBS)



	Neat 58-28	Neat 64-22	PPA 64-28	SBS 64-28	SBS 70-22	SBS 76-22
Average of True HTPG	61.6	67.5	71.8	70.9	78.0	84.7
Average of LTPG	-30.2	-24.1	-30.2	-30.5	-25.4	-25.9
Average of Fatigue Index	25.0	21.0	23.1	65.3	65.9	61.5

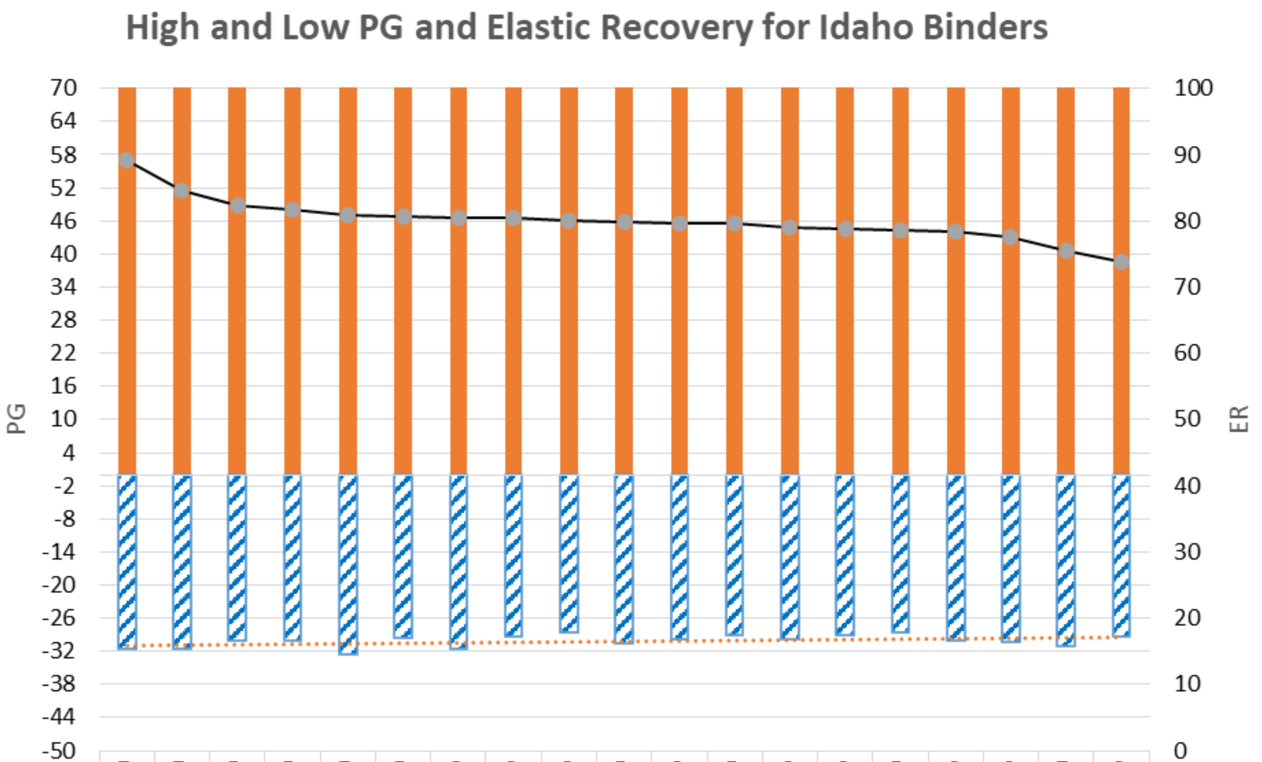
Example of Fatigue Index of Unmodified Binders Idaho PG 58-28



	5-401	5-412	6-545	6-450	6-425	6-429	6-396	6-481	6-546	6-393	6-426	5-400	6-508	6-524
Average of True HT PG - 58-28	62	62	60	62	62	62	61	61	62	62	62	62	60	62
Average of True LTPG - 58-28	-30	-30	-32	-30	-32	-31	-31	-30	-29	-30	-31	-30	-32	-30
Average of ER - 58-28	45	44	44	38	32	29	28	26	23	22	21	20	19	17

Axis Title

Example of Fatigue Index of Modified Binders Idaho PG 70-28



	7-069	7-071	5-480	5-470	7-070	5-447	6-463	6-472	6-343	5-443	6-458	5-457	6-470	6-476	5-468	6-383	6-381	7-099	6-386
Average of True HT PG - 70-28	73	74	73	73	73	73	72	72	73	72	72	73	72	73	73	72	72	72	73
Average of True LTPG - 70-28	-32	-32	-30	-30	-33	-30	-31	-29	-29	-31	-30	-29	-30	-29	-29	-30	-30	-31	-29
Average of ER - 70-28	89	85	82	82	81	81	81	80	80	80	80	80	79	79	79	78	78	76	74

Summary

- Using iCCL test, low-temperature grade of asphalt binder, identical to BBR, is determined in 30 min from RTFO/PAV with 3 time more precision than BBR
- iCCL test on original binder could provide a quick estimate of LT PG within 2 ∘C (same accuracy as BBR)
- iCCL provides the true LT grade by testing one sample
- UPFiT fatigue test is simple, fast, and reliable alternative to Elastic Recovery
- iCCL and UPFiT tests have been verified by testing hundreds of asphalt binders from 23 different agencies

Continued Verification

- Pavement Systems LLC will continue verification of iCCL and UPFiT tests
- An oz. of your PAV and original binders will help in the verification
- Please let us know if you can send us materials

U.S. Round Robin of iCCL Test

- Limited number of iCCL package (MCR 72 and software) will be available for short term loans late Fall through Winter
- Please let us know if you are interested to participate in the round robin and try iCCL to test your binders
- iCCL availability date for purchase: February 2019

Questions?

Contact:
Dr. Haleh Azari, President
Pavement Systems LLC
6105 Maiden lane
Bethesda, MD 20817
(202) 286-0148
azari@pavesys.net

www.pavesys.net