PRESENTATION FOR NEW BINDER TESTS AND SPECIFICATION CHANGE WORKSHOP

by

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Project 0-6674
Project Title: Improving Fracture Resistance Measurement in Asphalt Binder Specification with Verification on Asphalt Mixtures Cracking Performance

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and the
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TEXAS A&M TRANSPORTATION INSTITUTE
College Station, Texas 77843-3135

Project 0-6674, Improving Fracture Resistance Measurement in Asphalt Binder Specification with Verification on Asphalt Mixture Cracking Performance

P2: Presentation for New Binder Tests and Specification Change Workshop

The research team of the Texas A&M Transportation Institute (TTI) developed and taught a new asphalt binder test workshop, which was held at the Cedar Park branch of the Texas Department of Transportation (TxDOT) on June 18, 2014. The focus of the workshop was to identify a simple, practical fatigue type of test for asphalt binders, since the cracking issue is the most critical problem pavement engineers are facing every day. It was found that the linear amplitude sweep (LAS) test is a very promising fracture test for evaluating fatigue cracking resistance of asphalt binders at intermediate temperature. Both laboratory mixture tests and field test sections have been employed to validate this binder fatigue cracking test. The mixture fracture test results showed that the LAS test has a reasonable correlation with the Overlay test, which is the standard mixture test for cracking resistance of asphalt mixtures in Texas. Field test sections are still being monitored, and the field observation will be critical for the final validation of the LAS test. The workshop presentation is presented.

TxDOT Project 0-6674

Improving Fracture Resistance Measurement in Asphalt Binder Specification with Verification on Asphalt Mixtures Cracking Performance

Workshop

PM: Darrin Jensen

PMC: Jerry Peterson, Stacey Young, Gisel Carrasco, Dar-Hao Chen

Texas A&M Transportation Institute

Fujie Zhou and Sheng Hu

Cedar Park, TxDOT; June 18, 2014

Outline

- Overview (objectives and task by task review)
- Binder fracture tests
- Mixture tests (binder fracture vs. mix fracture)
- Field test sections
- Performance of field test sections: predicted vs. observed
- Asphalt overlay performance simulations
- Statewide catalogue of recommended binder types
- Life cycling cost analysis
- What's next

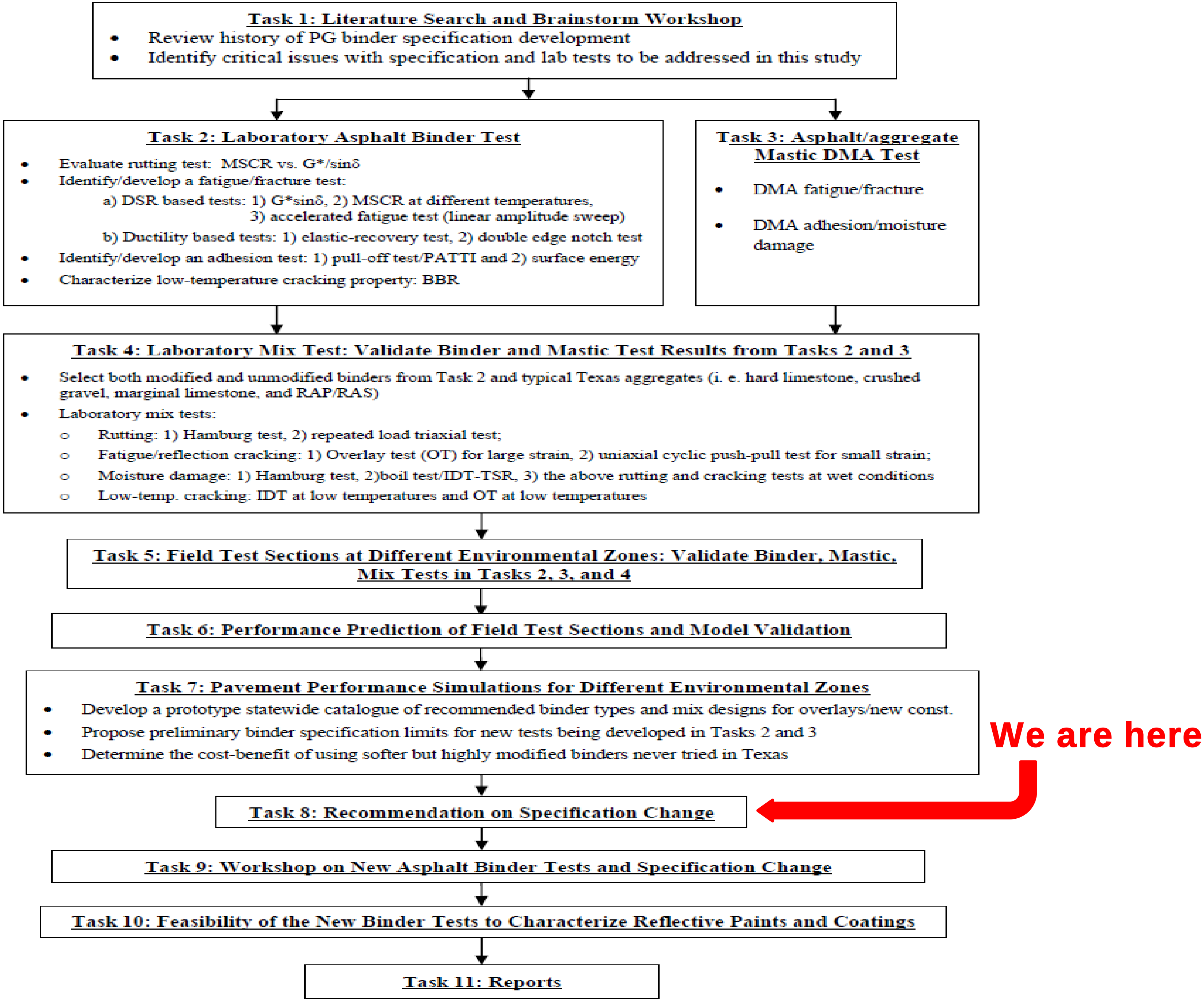
Overview

- Background:
  - Texas mixes are prone to cracking
  - Multiple Stress Creep Recovery (**MSCR**)
    - A new test procedure
    - Benefit to soft binders
    - Recovery for identifying polymers
  - MnRoad mixes with soft binders

- Objectives
  - Evaluate MSCR: Jnr, Recovery, Repeatability
  - Identify binder fracture/fatigue tests
  - Investigate soft binders: cost and benefit

Task by Task Review

- Task 1: Literature Search and Brainstorm Workshop (Done)
- Task 2: Laboratory Asphalt Binder Test (**Done**)
- Task 3: Asphalt/Aggregate Mastic DMA Test (**Done**)
- Task 4: Laboratory Mix Test: Validate Binder and Mastic Test Results from Tasks 2 and 3 (**Done**)
- Task 5: Field Test Sections at Different Environmental Zones: Validate Binder, Mastic, Mix Tests in Tasks 2, 3, and 4 (**Done**)
- Task 6: Performance Prediction of Field Test Sections and Model Validation (**Done**)
- Task 7: Pavement Performance Simulations for Different Environmental Zones (**Done**)
- Task 8: Recommendation on Specification Change (**Ongoing**)
- Task 9: Workshop on New Asphalt Binder Tests and Specification Change (**Ongoing**)
- Task 10: Reports (**R1 submitted, R2D later**)


Task 1: Literature Search and Brainstorm Workshop
• Review history of PG binder specification development
• Identify critical issues with specification and lab tests to be addressed in this study
Task 2: Laboratory Asphalt Binder Test
• Evaluate rutting test: MSCR vs. G*/sinδ
• Identify/develop a fatigue/fracture test:
a) DSR based tests: 1) G*sinδ, 2) MSCR at different temperatures, 3) accelerated fatigue test (linear amplitude sweep)
b) Ductility based tests: 1) elastic-recovery test, 2) double edge notch test
• Identify/develop an adhesion test: 1) pull-off test/PATTI and 2) surface energy
• Characterize low-temperature cracking property: BBR
Task 3: Asphalt/aggregate Mastic DMA Test
• DMA fatigue/fracture
• DMA adhesion/moisture damage
Task 4: Laboratory Mix Test: Validate Binder and Mastic Test Results from Tasks 2 and 3
• Select both modified and unmodified binders from Task 2 and typical Texas aggregates (i. e. hard limestone, crushed gravel, marginal limestone, and RAP/RAS)
• Laboratory mix tests:
o Rutting: 1) Hamburg test, 2) repeated load triaxial test;
o Fatigue/reflection cracking: 1) Overlay test (OT) for large strain, 2) uniaxial cyclic push-pull test for small strain;
o Moisture damage: 1) Hamburg test, 2)boil test/IDT-TSR, 3) the above rutting and cracking tests at wet conditions
o Low-temp. cracking: IDT at low temperatures and OT at low temperatures
Task 5: Field Test Sections at Different Environmental Zones: Validate Binder, Mastic, Mix Tests in Tasks 2, 3, and 4
Task 6: Performance Prediction of Field Test Sections and Model Validation
Task 7: Pavement Performance Simulations for Different Environmental Zones
• Develop a prototype statewide catalogue of recommended binder types and mix designs for overlays/new const.
• Propose preliminary binder specification limits for new tests being developed in Tasks 2 and 3
• Determine the cost-benefit of using softer but highly modified binders never tried in Texas
We are here
Task 8: Recommendation on Specification Change
Task 9: Workshop on New Asphalt Binder Tests and Specification Change
Task 10: Feasibility of the New Binder Tests to Characterize Reflective Paints and Coatings
Task 11: Reports

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- Overview (objectives and task by task review)
- Binder tests
  - MSCR-rutting test
  - Fracture test
- Mixture test (binder fracture vs. mix fracture)
- Field test sections
- Performance of field test sections: predicted vs. observed
- Asphalt overlay performance simulations
- Statewide catalogue of recommended binder types
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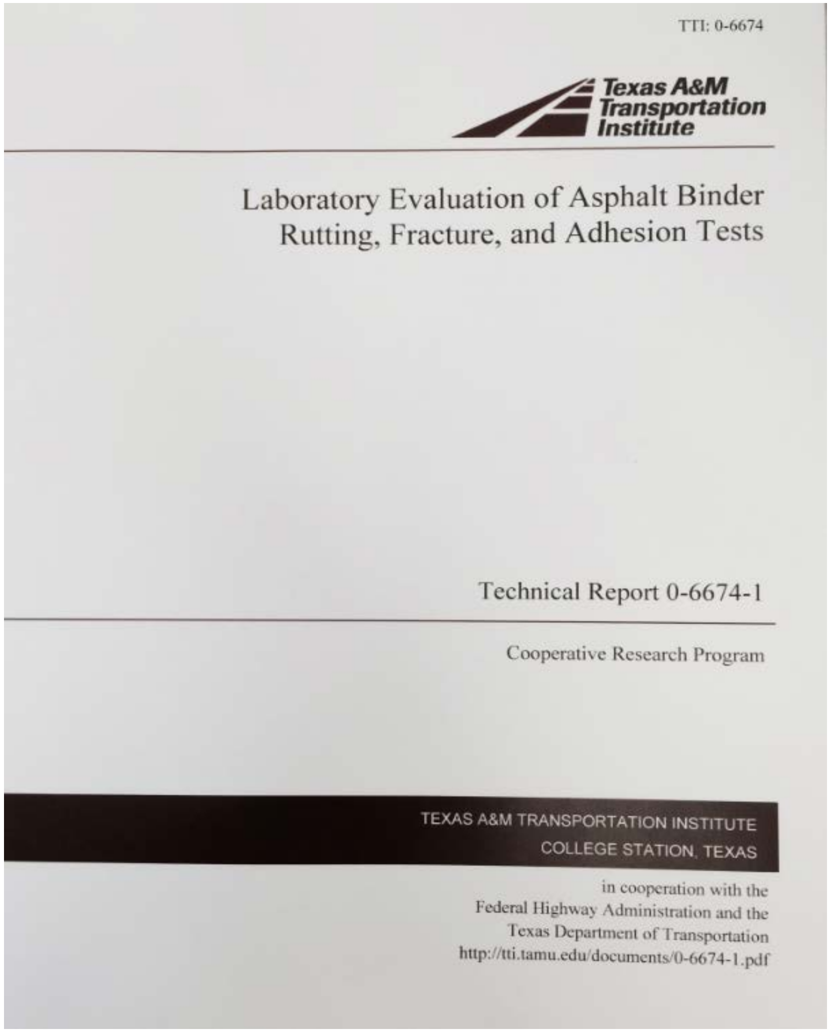
Asphalt Binder Tests

A variety of asphalt binder tests have been performed under this project. All the lab results have been documented in report Tx-0-6674-1.



TTI: 0-6674

Texas A&M Transportation Institute

Laboratory Evaluation of Asphalt Binder Rutting, Fracture, and Adhesion Tests

Technical Report 0-6674-1

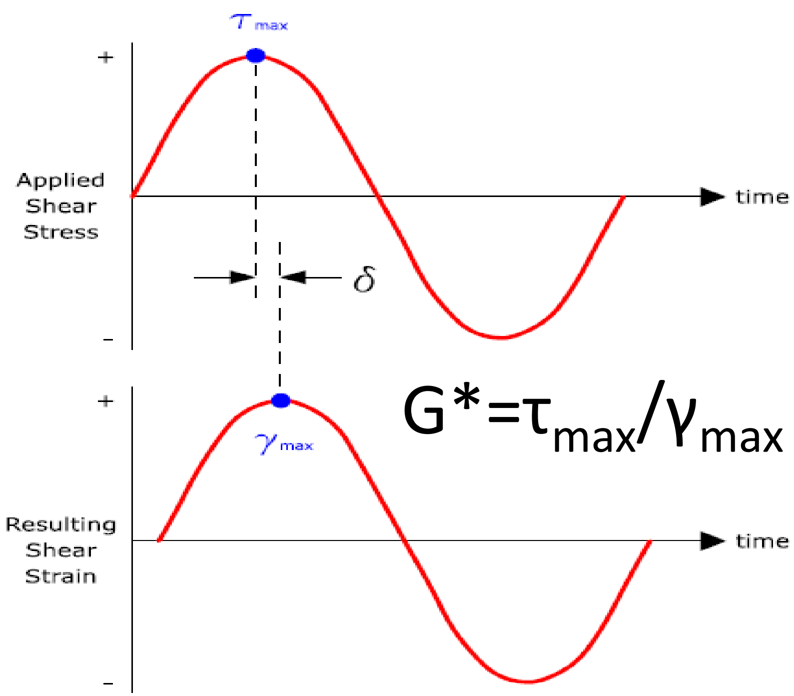
Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS

in cooperation with the
Federal Highway Administration and the
Texas Department of Transportation
http://tti.tamu.edu/documents/0-6674-1.pdf

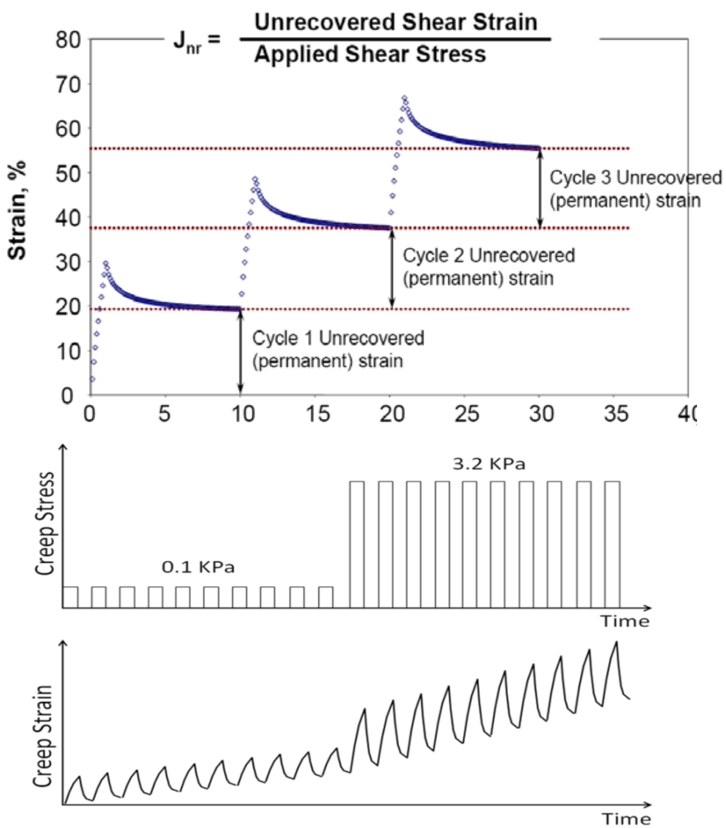
G*/sinδ vs. MSCR

- Existing: G*/sinδ
  - Small strain/stiffness
  - No damage



$G^*=\tau_{max}/\gamma_{max}$

- MSCR: Jnr; Recovery
  - Permanent strain

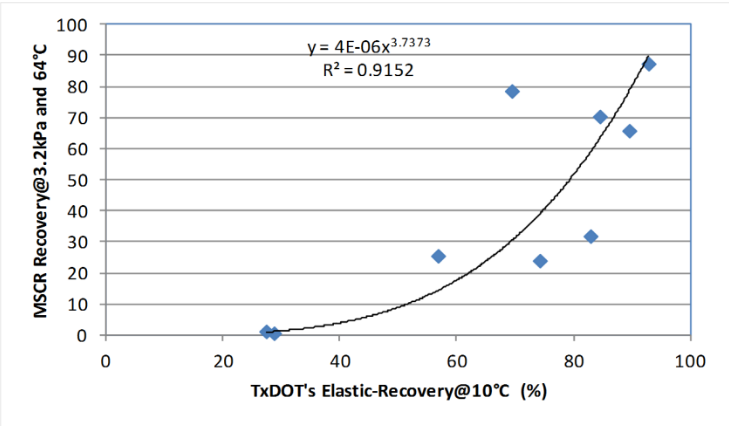


TxDOT Viewpoint on MSCR-Jerry

- Partial implementation: Replacing elastic-recov.
- Full implementation: Jnr-later
- Test temp.=64^{o}C
  - PG76 → PG64-“V”
  - PG70 → PG64-“H”
  - PG64 → PG64-“S”

TTI's Concerns on MSCR Specification

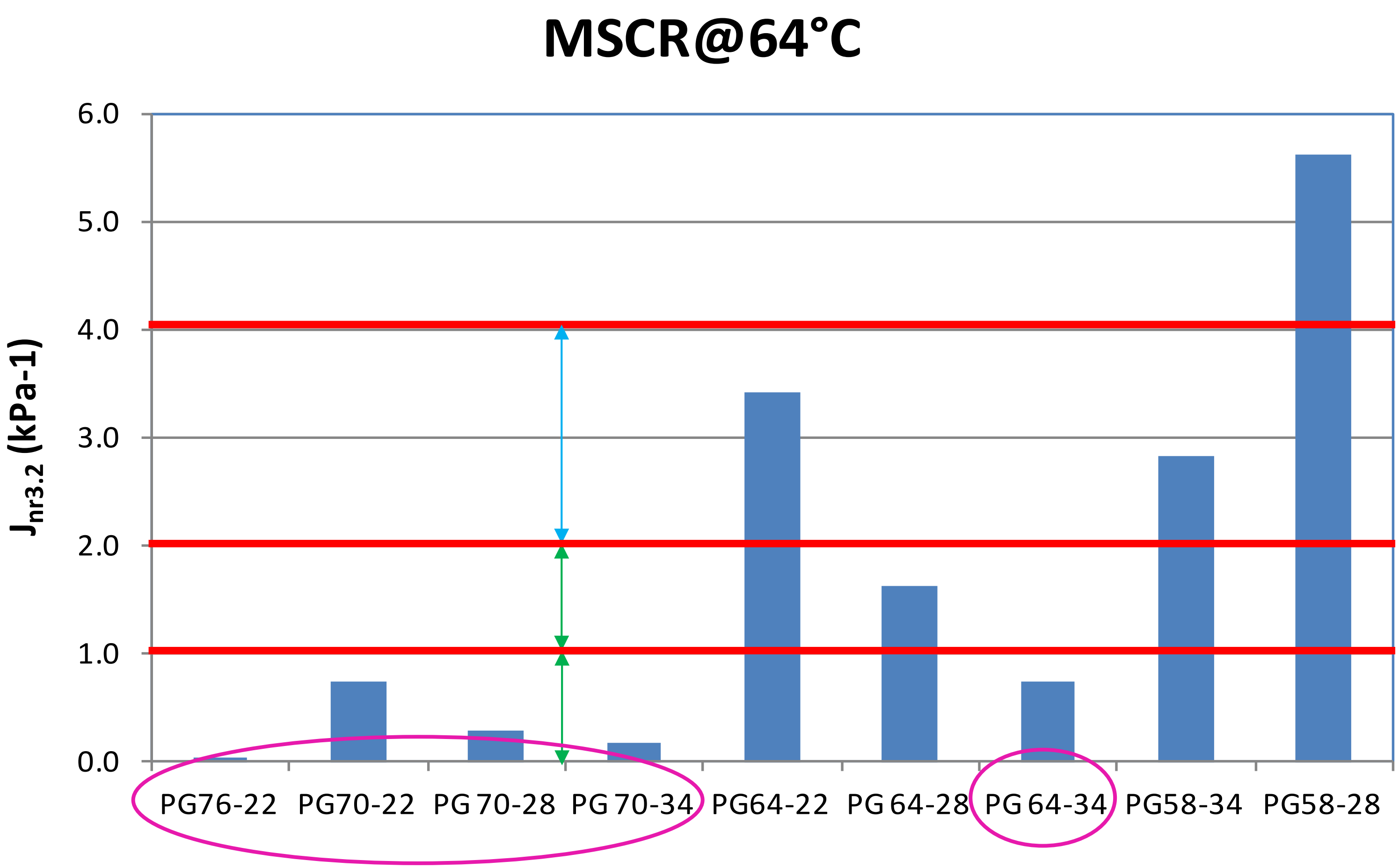
- Partial implementation: Replacing elastic-recov.
  - Potential problem with RAP/RAS binder



- MSCR specification
  - May overestimate elastic-recovery to less rutting
    - Jnr vs. G*/sin δ
    - Jnr vs. Hamburg test results

TTI's Concerns on MSCR Specification

- Nine asphalt binders: Jnr vs. G*/sin δ



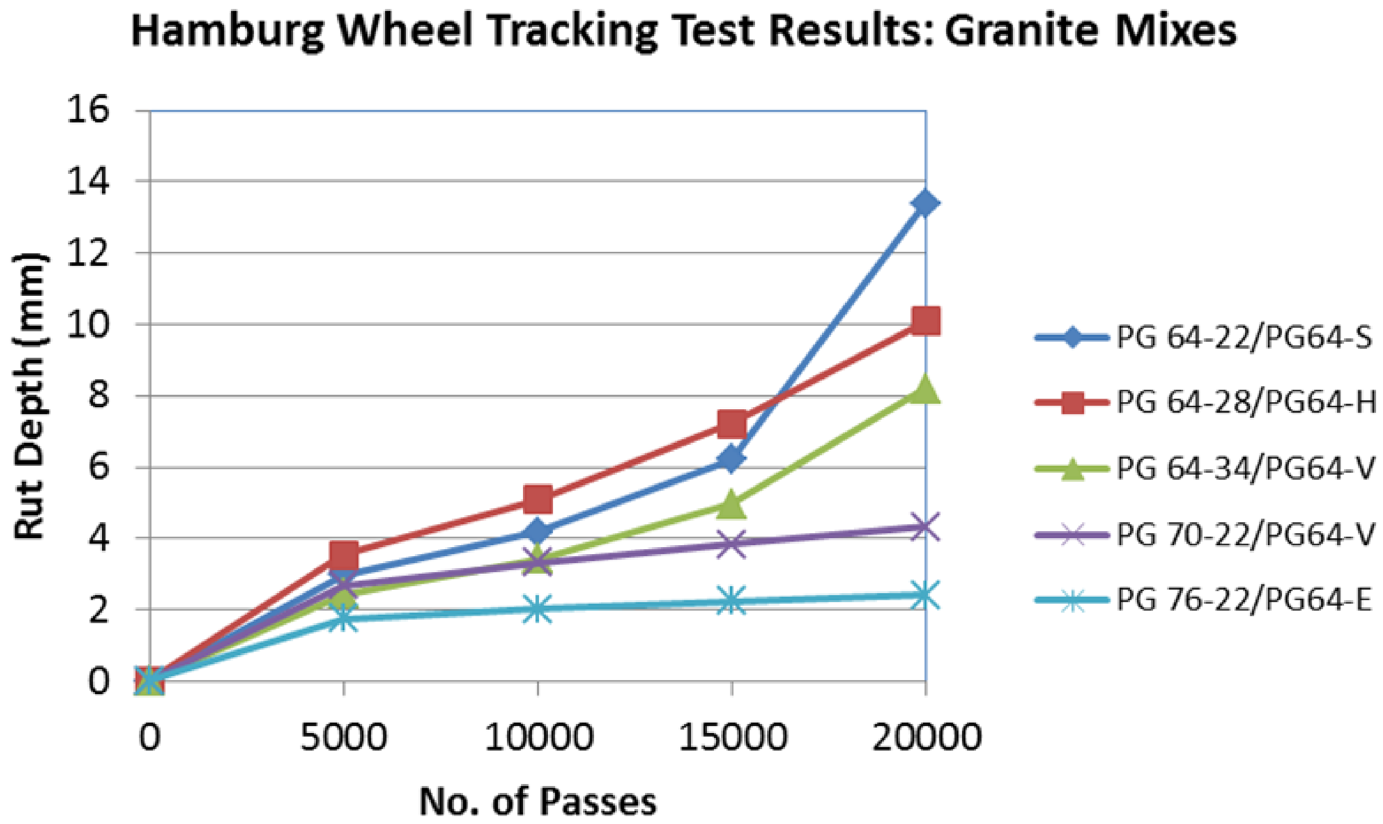
TTI's Concerns on MSCR Specification

Jnr vs. Hamburg Mixture Test

- 3 mixes
  - Superpave-D
    - OAC=5.5%@4%AV
    - Granite aggregates
  - Dense-graded Type D
    - OAC=4.8%
    - Limestone aggregates
  - Dense-graded Type D
    - OAC=4.6%
    - Crushed gravel
- 5 asphalt binders
  - PG76-22-$Jnr_{3.2}$=0.03=PG64-E
  - PG70-22-$Jnr_{3.2}$=0.73=PG64-V
  - PG64-22-$Jnr_{3.2}$=3.42=PG64-S
  - PG64-28-$Jnr_{3.2}$=1.69=PG64-H
  - PG64-34-$Jnr_{3.2}$=0.73=PG64-V

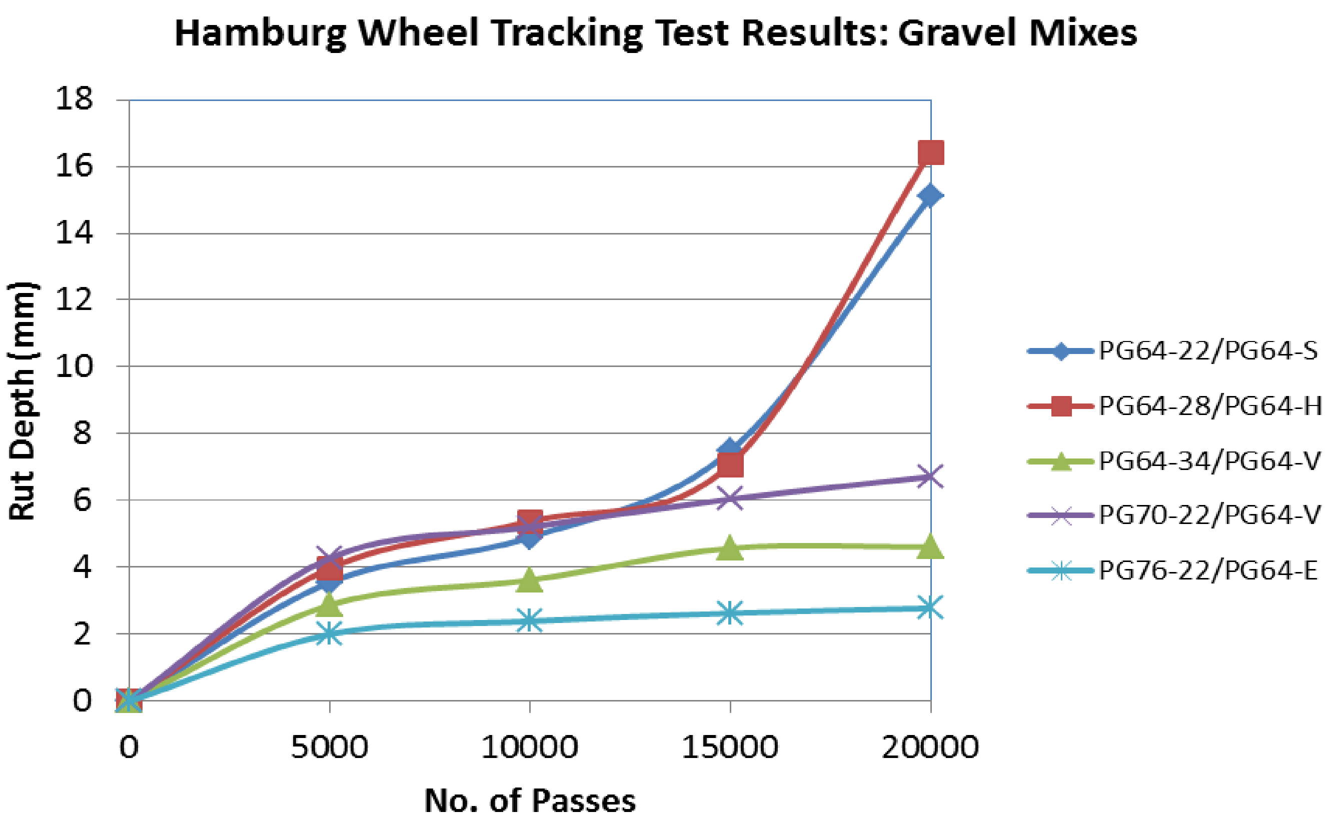
TTI's Concerns on MSCR Specification

Jnr vs. Hamburg Mixture Test



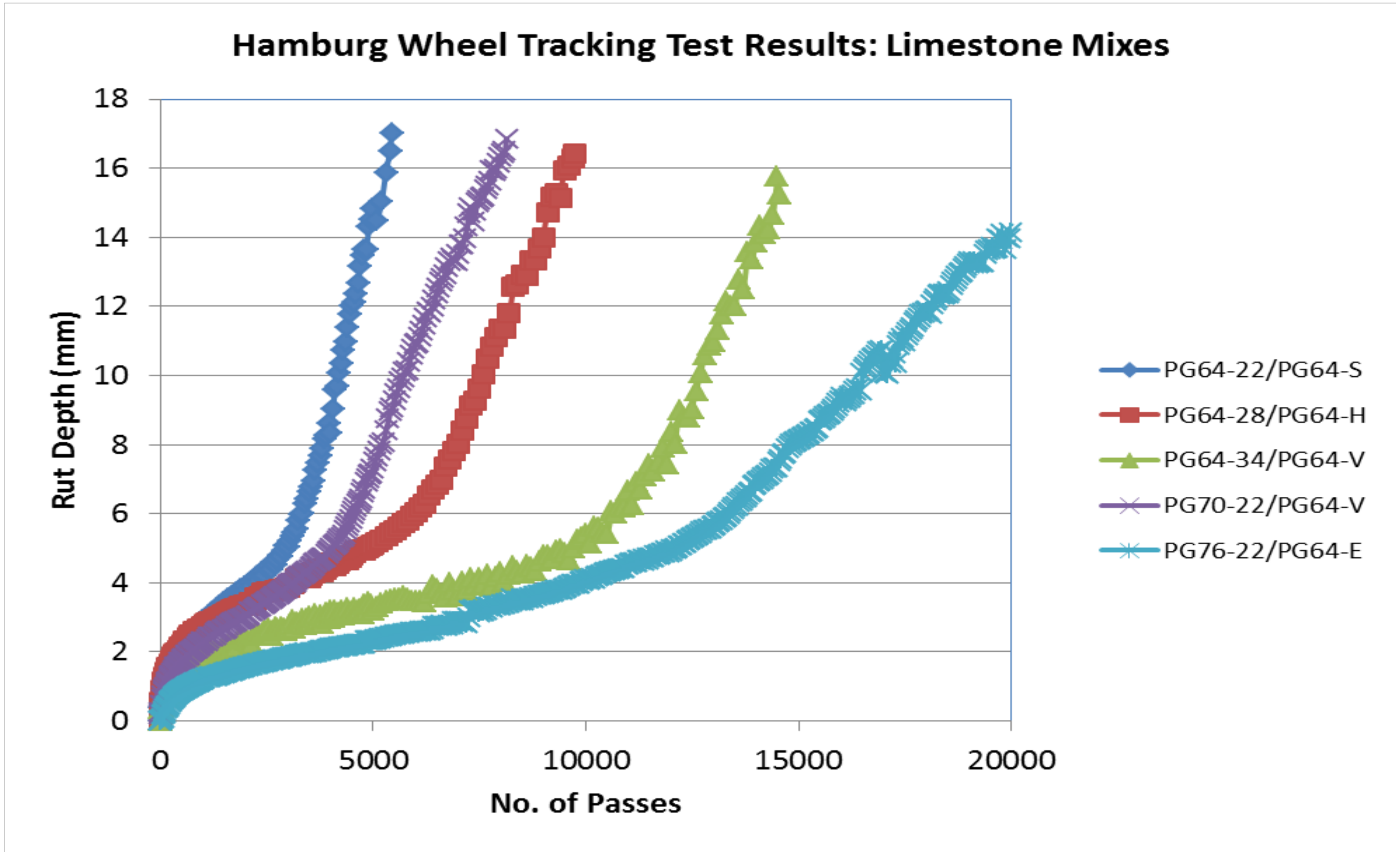
TTI's concerns on MSCR specification

Jnr vs. Hamburg mixture test



TTI's Concerns on MSCR Specification

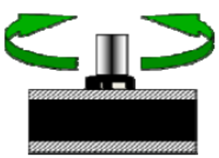
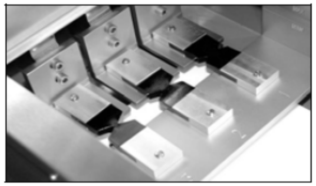
Jnr vs. Hamburg Mixture Test



MSCR-Jnr vs. G*/sinδ

- Current Jnr criteria will allow using soft binders (i.e., PG64-28, PG64-34) to be used for very high traffic roads, which jeopardizes rutting problem.
- MSCR-Jnr criteria need further refinement.
- Right now, it is better to keep current PG system until more field data are available! (**Field test sections on this issue**).

Binder Fracture/Fatigue Tests

Item	G* Test	MSCR Test	Time Sweep Test	Linear Amplitude Sweep Test	Elastic Recovery Test	Double Edge Notch Tension test	DMA Mortar Test
Test method	AASHTO T 315	AASHTO TP 70	NCHRP 9-10 (*2*)	Bahia et al. (*7, 8, 9*)	AASHTO T301 ASTM D6084	Ontario Ministry of Transportation Test Method LS-299	Kim et al. (*12*)
Parameter	G*sinδ	Recovery (%)	Fatigue life	Fatigue lives at different strain levels	Elastic recovery (%)	Critical tip opening displacement (CTOD)	Fatigue life
Specimen aging condition	PAV	RTFO	RTFO PAV	RTFO/PAV	RTFO	PAV	Not well defined
Test equipment	DSR				Ductility test machine	Ductility test machine with capability of measuring the force and displacement	Advanced DSR
Test specimen	Asphalt binder only and easy to prepare 				Asphalt binder only and easy to prepare 	Asphalt binder only and easy to prepare 	Asphalt binder + fine aggregates and much longer time to prepare 
Loading mode	Shear				Tension		Shear
Beyond LVE range	No	Yes	Yes	Yes	Yes	Yes	Yes
Correlation with field fatigue distress	Lots of concerns	To be determined	To be determined	Preliminarily validated with LTPP sections	Used for decades	Validated with FHWA-APT fatigue test sections	To be determined

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  - Binder fracture vs. mix fracture
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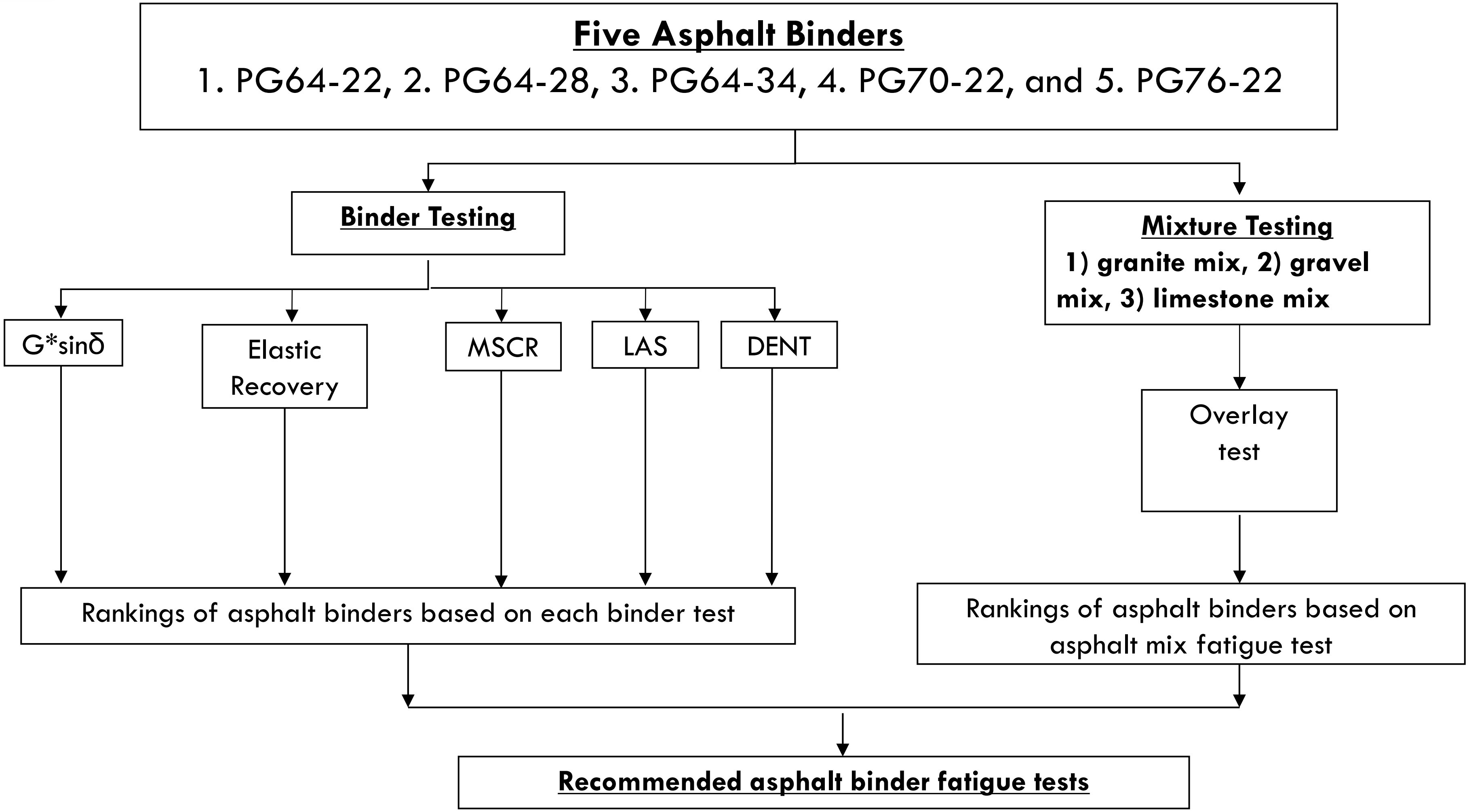
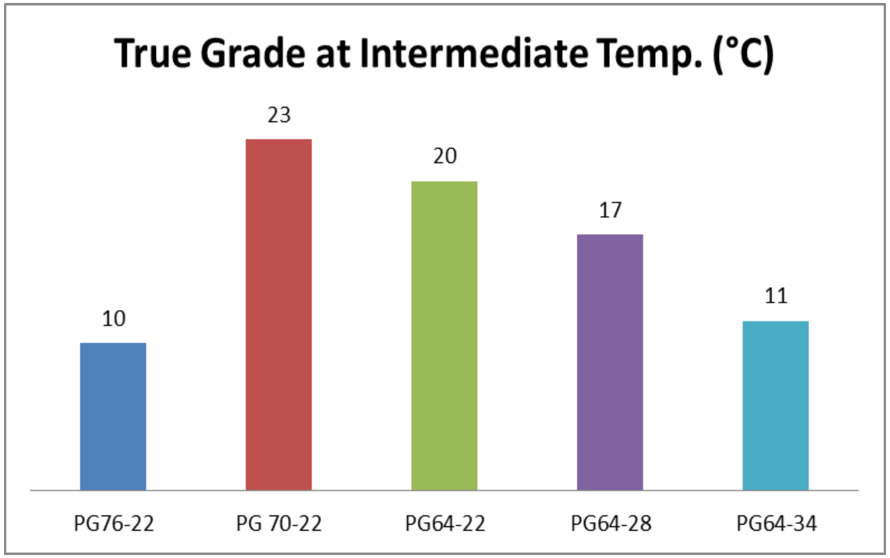
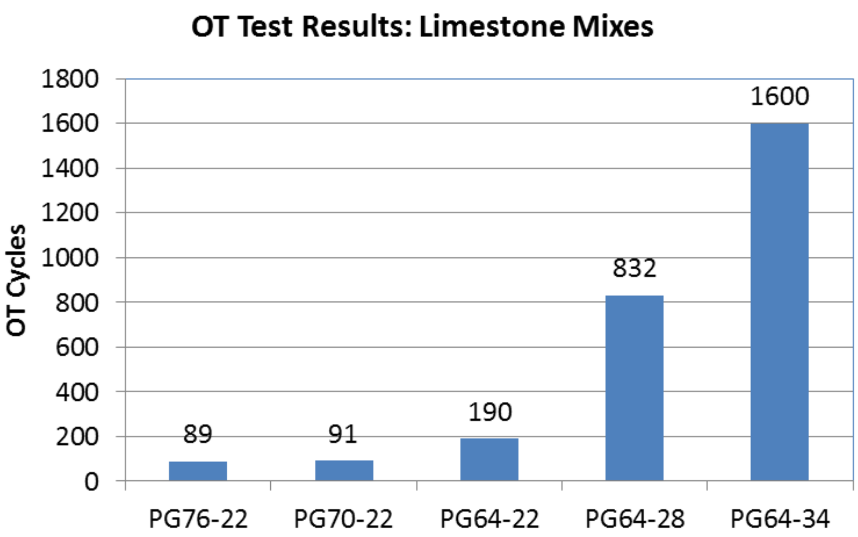
Experimental Test Plan



Binder Fracture Test

G*/sin δ vs. OT Cycles

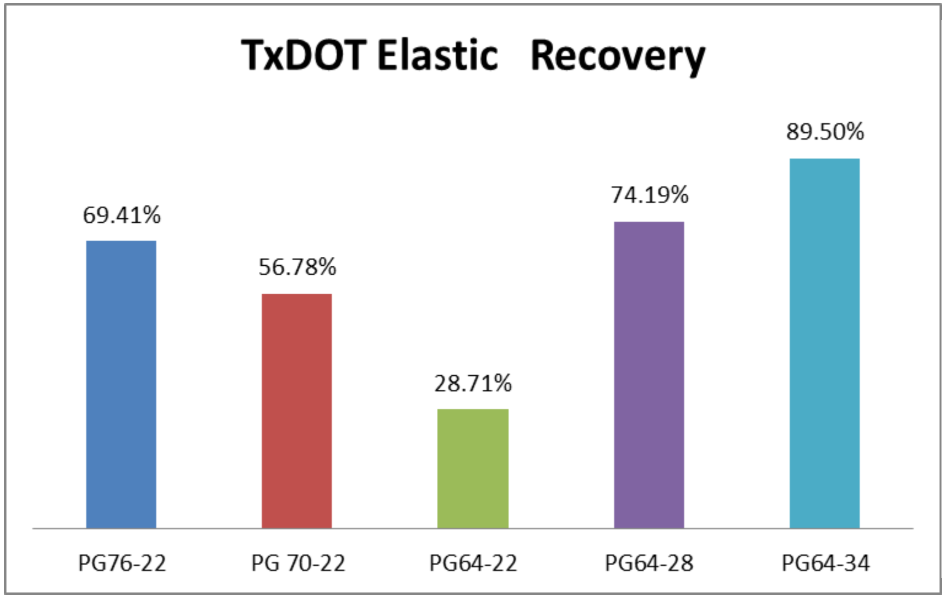


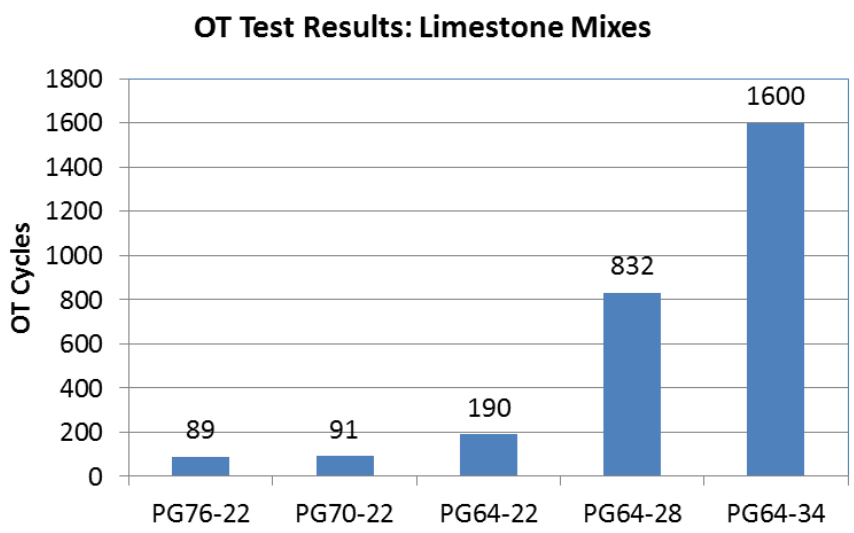


Except PG76-22, the lower intermediate temperature, the higher OT cycles.

Binder Fracture Test

TxDOT's Elastic Recovery vs. OT Cycles

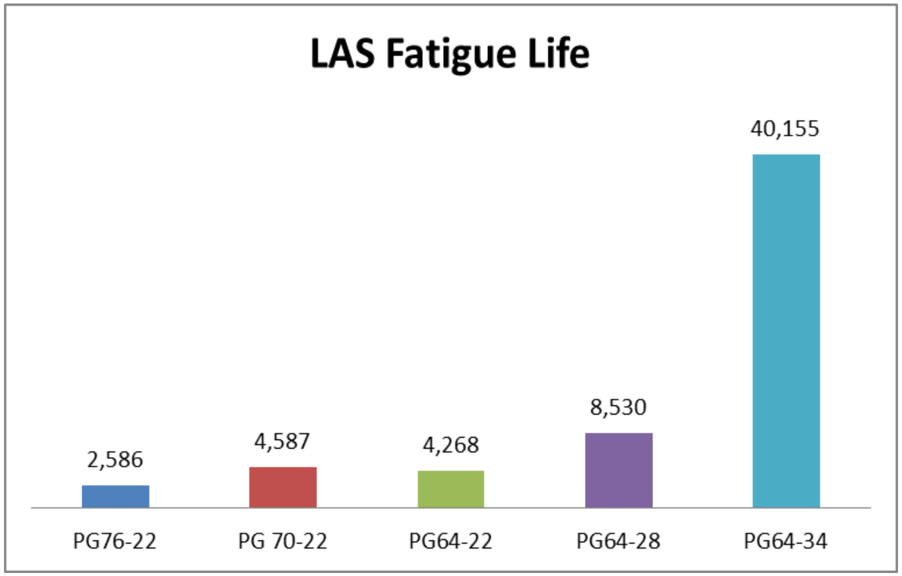


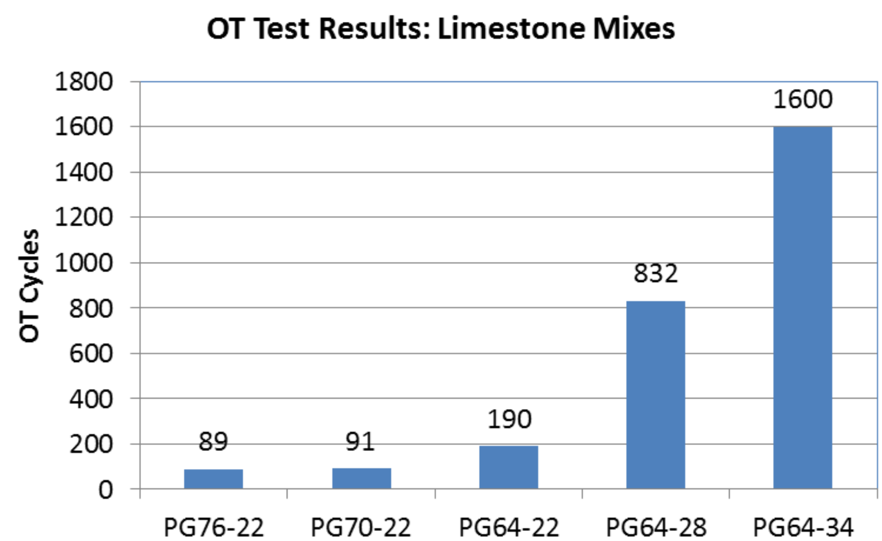


There is no good relationship between TxDOT's elastic recovery vs. OT cycles. Note that TxDOT's elastic recovery test was run at 50°F (10°C).

Binder Fracture Test

LAS vs. OT Cycles

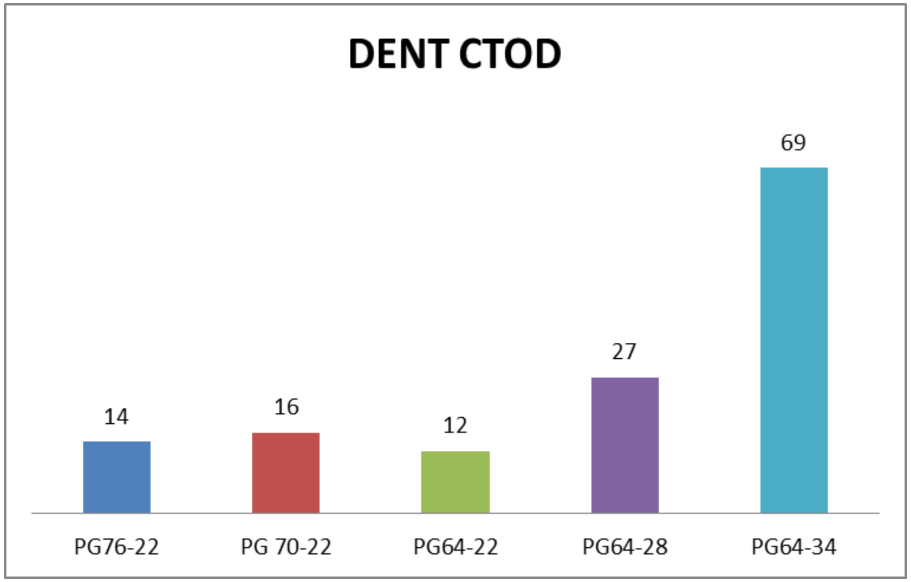


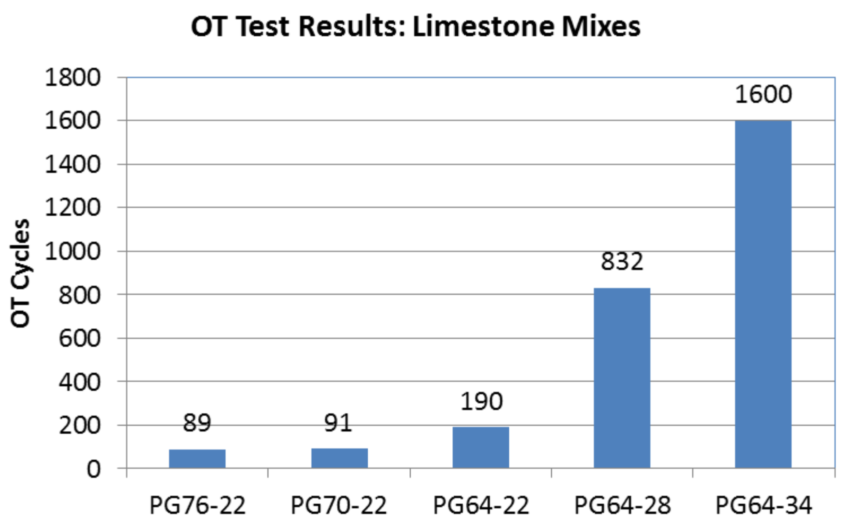


Basically, LAS test results have similar rankings as the OT cycles. LAS test is a very promising test for these five binders.

Binder Fracture Test

DENT (CTOD) vs. OT Cycles





DENT-CTOD cannot differentiate PG76-22, PG70-22, and PG64-22.

Binder Fracture Test

- No perfect binder fracture test is found so far.
- The Linear Amplitude Sweep (LAS) test showed a very good correlation with OT cycles.
- Field validation is needed for the LAS test.

Status of LAS Test

- Draft AASHTO Standard available
  - Viscoelastic continuum damage theory
  - Need further validation

Standard Method of Test for

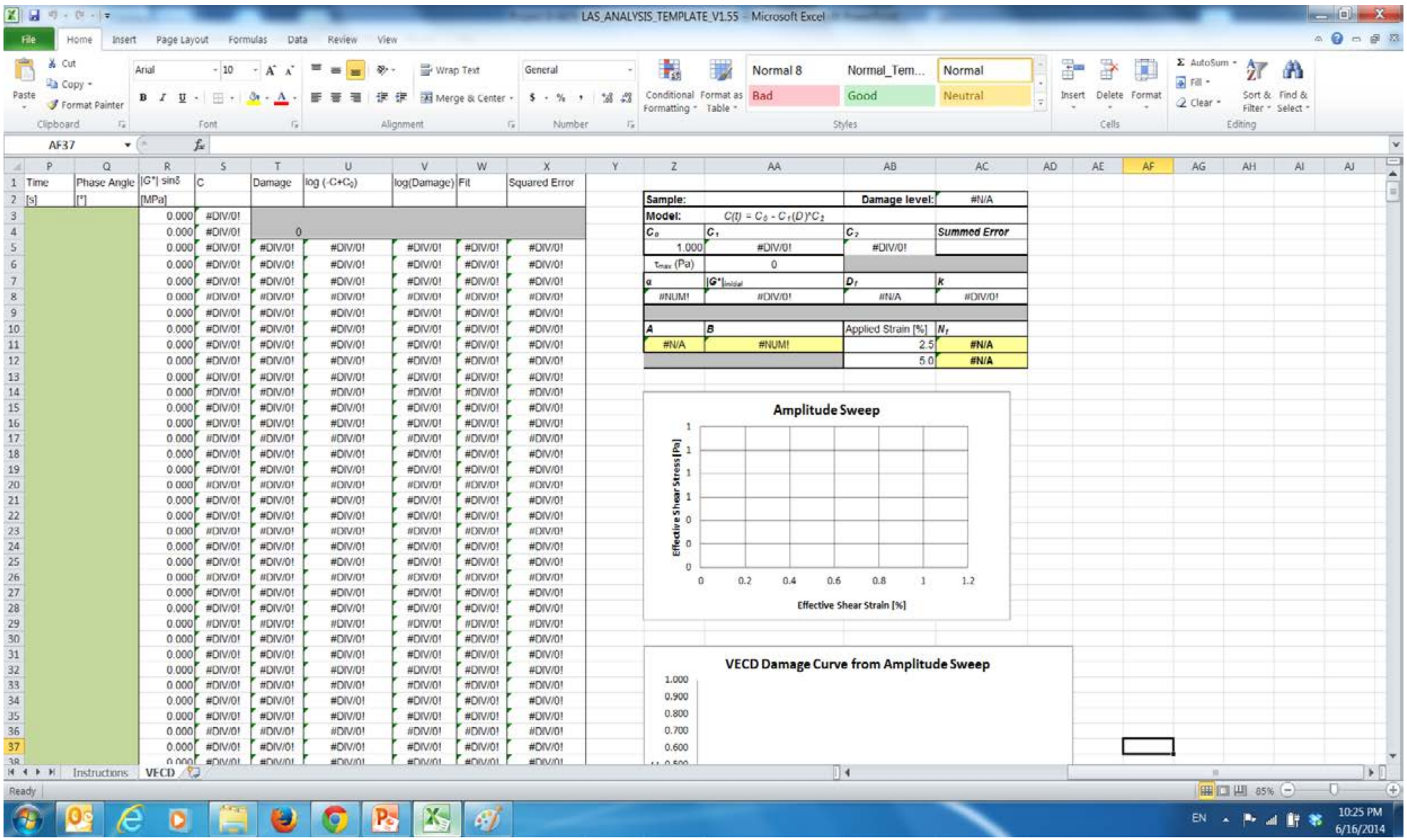
Estimating Damage Tolerance of Asphalt Binders Using the Linear Amplitude Sweep

AASHTO Designation: TP 101-14

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

Status of LAS Test

- Draft AASHTO Standard-Data Analysis Macro



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- Overview (objectives and task by task review)
- Binder test
- Mixture test (binder fracture vs. mix fracture)
- **Field test sections**
- Performance of field test sections: predicted vs. observed
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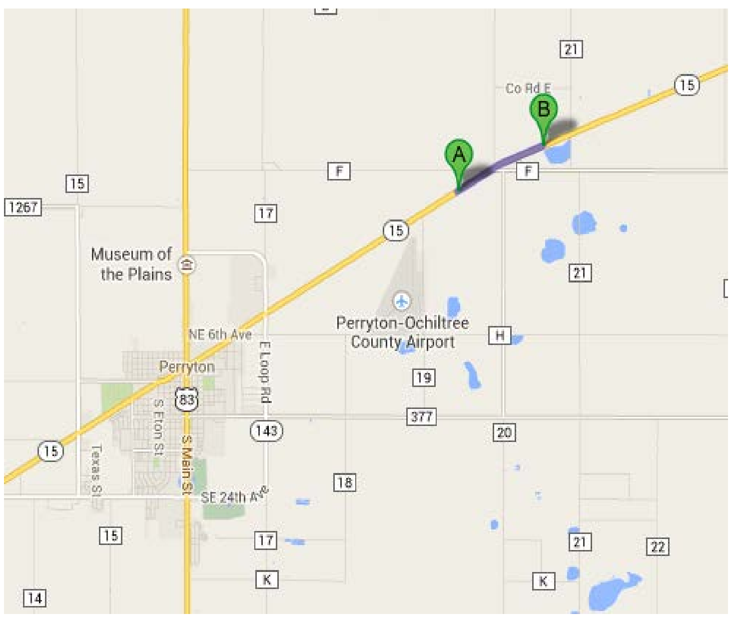
Field Test Sections

- Amarillo-SH15: 4 sections
- Childress-US62: 3 sections
- Fort Worth-Loop820: 4 sections

Objective: To evaluate the influence of different binder type, different binder content, and with/without RAP/RAS

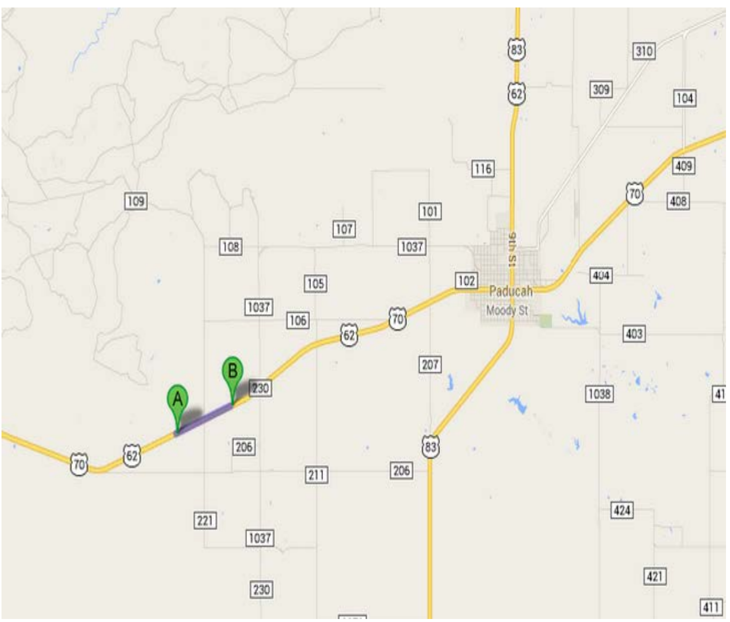
Field Test Sections – SH15

Section ID	Begin		End		Length (ft)
	Latitude	Longitude	Latitude	Longitude	
S1, PG58-28, 5.5%	36°25.887'	-100°44.277'	36°26.006'	-100°44.033'	1390
S2, PG58-28, 5.8%	36°26.040'	-100°43.966'	36°26.154'	-100°43.705'	1450
S3, PG64-34, 5.8%	36°26.201'	-100°43.560'	36°26.293'	-100°43.268'	1530
S4, PG64-34, 5.5%	36°26.328'	-100°43.155'	36°26.395'	-100°42.956'	1050



Field Test Sections – US62

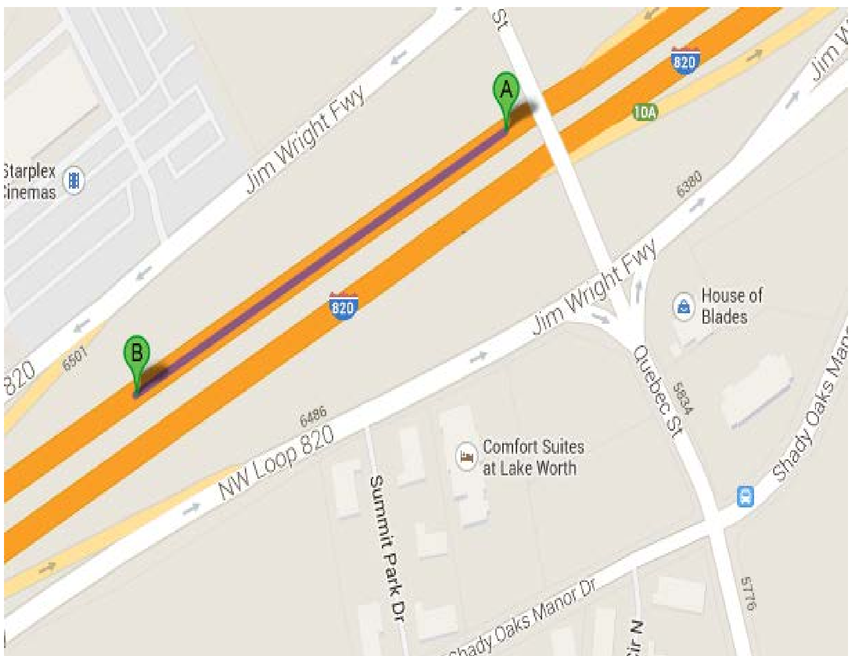
Section ID	Begin		End		Length (ft)
	Latitude	Longitude	Latitude	Longitude	
S1, PG64-34, with RAP/RAS	33°59.142'	-100°24.172'	33°59.230'	-100°23.891'	1510
S2, PG70-28, virgin mix	33°59.250'	-100°23.825'	33°59.306'	-100°23.648'	950
S3, PG70-28, with RAP/RAS	33°59.390'	-100°23.374'	33°59.430'	-100°23.248'	675

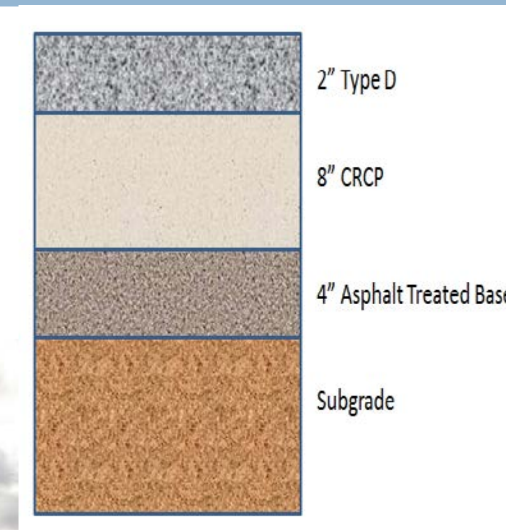


Field Test Sections – Loop820

Traffic Direction →

Section 0: control-PG64-22 13%RAP/5%RAS+ Advera additive
Section 1: APAC-PG64-22 13%RAP/5%RAS blended with Advera
Section 2: PG64-28 13%RAP/5%RAS+ Advera additive
Section 3: PG64-22+0.4% more+13%RAP/5%RAS+Advera additive





Field Test Sections – Plant Mix Sampling, Coring, and Lab Testing

For these 11 test sections, researchers:

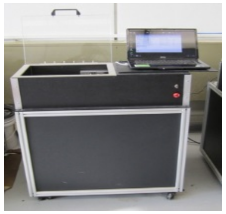
- Ran GPR test
- Monitored the construction
- Sampled at least 7 buckets of plant mix per section
- Took at least 8 field cores per section
- Fabricated lab specimens using plant mix:
  - OT test (at least 5 replicates)
  - Hamburg test (at least 2 replicates)
  - dynamic modulus test (3 replicates)
  - repeated load test (2 replicates)
- Ran the lab testing for both lab molded specimens and field cores

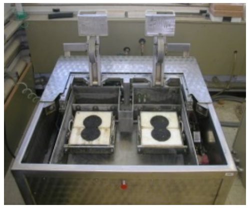

Ground Penetrating Radar


Plant Mix Sampling


Field Coring

Superpave Gyratory Compactor


Overlay Tester


Hamburg Wheel Tracking Tester


Asphalt Mixture Performance Tester

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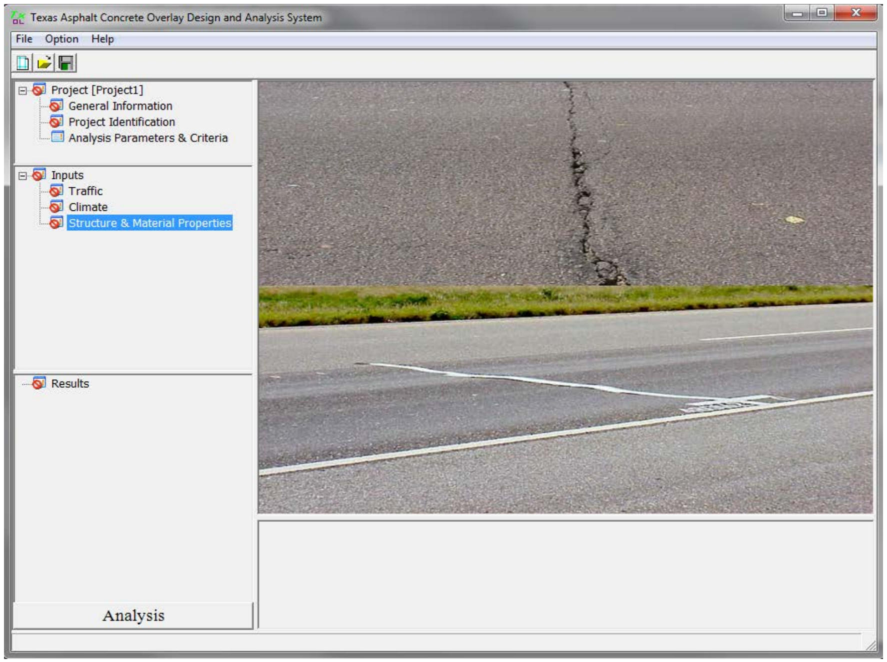
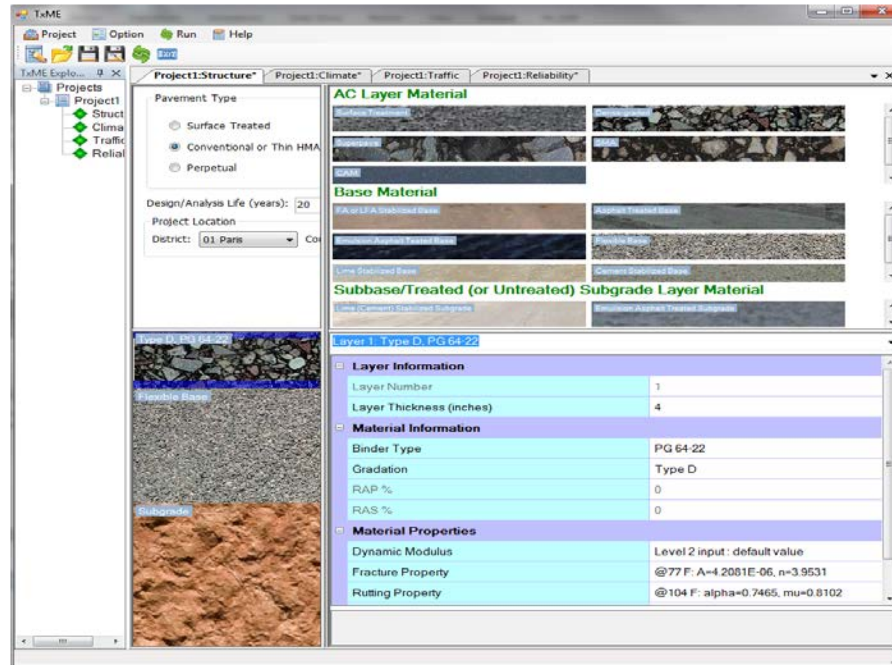
Field Test Section Performance Predictions: Software





TxACOL – for AC overlay design and analysis

TxME – for new flexible pavement design and analysis

Field Test Section Performance Predictions – Input Parameters

Fracture Properties

Fracture Property Data

Number of Temperatures: 1

Temperature (F)	A	n
77	0.0000000970435	5.618395

Rutting Properties

Rutting Property Data

Number of Temperatures: 1

Temperature (F)	alpha	mu
104	0.6437	0.634

Dynamic Modulus

Modulus Input

Level 3 (Default Value) Level 2 (Witczak Model) Level 1 (Test Data)

Test Data

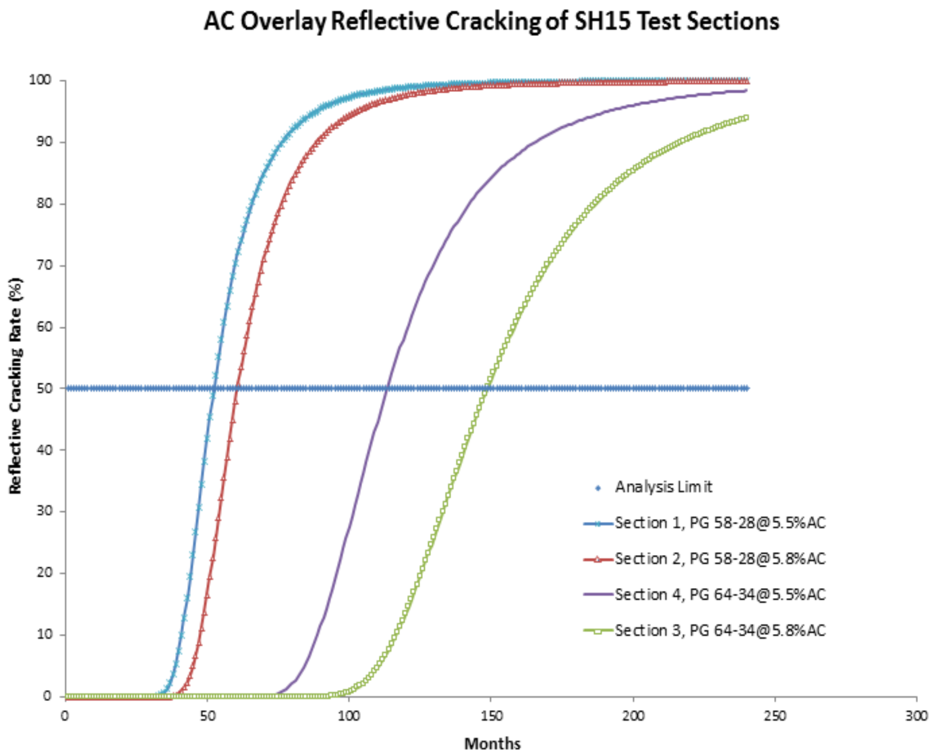
Dynamic Modulus (E*,ksi)

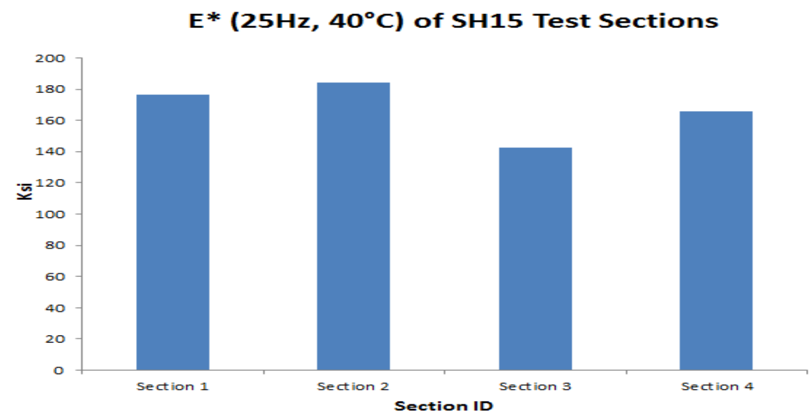
Number of Temperatures: 5 Number of frequencies: 6

Temperature (F)	Frequency (Hz)					
	25	10	5	1	0.5	0.1
14	2203.3	2119.0	2044.9	1835.1	1728.0	1442.9
40	1658.5	1494.8	1361.8	1035.5	894.5	590.0
70	784.2	613.8	497.6	281.5	213.1	105.1
100	206.3	138.9	101.4	47.6	34.4	16.7
130	40.1	26.2	19.3	10.0	7.7	4.7

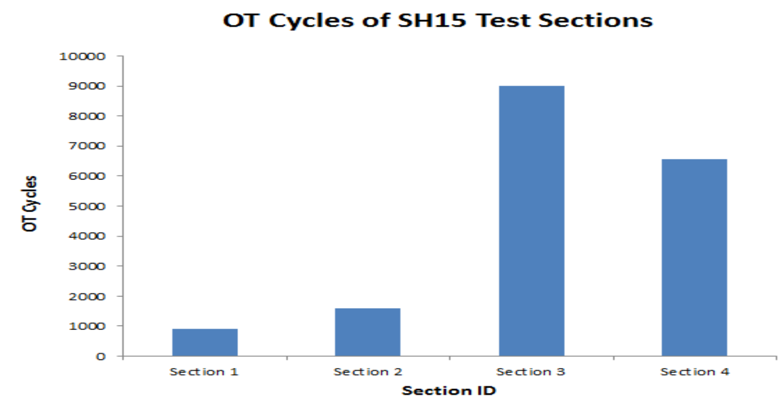
Import Export

Field Test Section Performance Predictions – SH15 Reflective Cracking





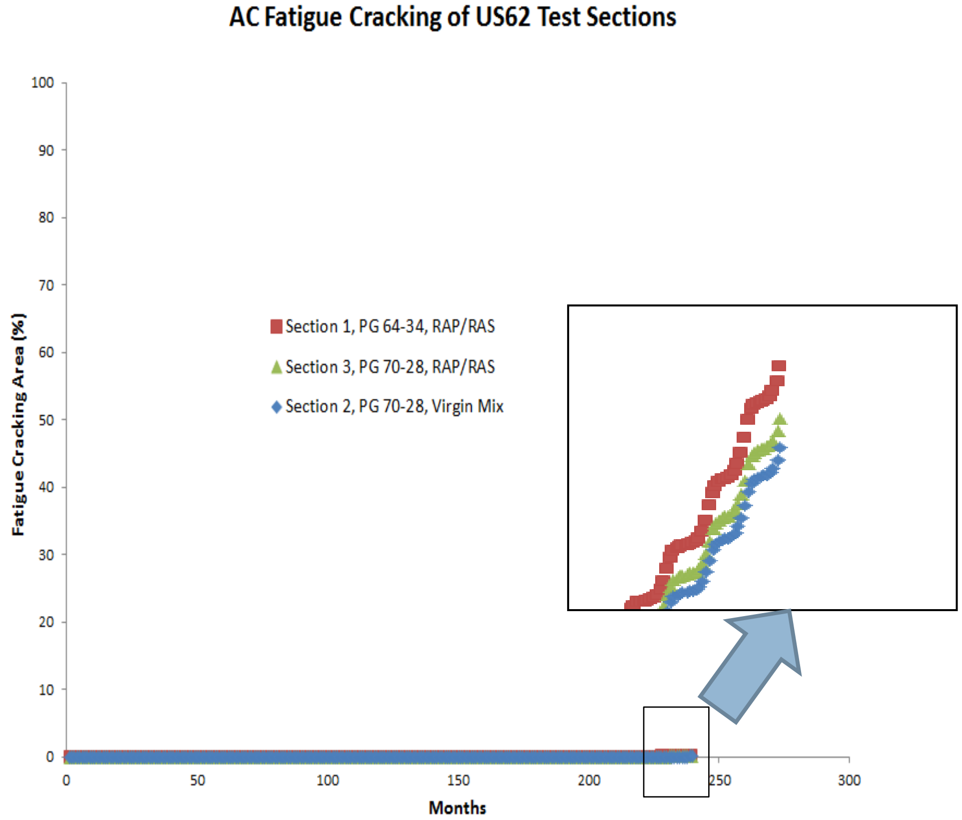
Modulus ranking (low to high):
Section 3<Section 4<Section 1<Section 2

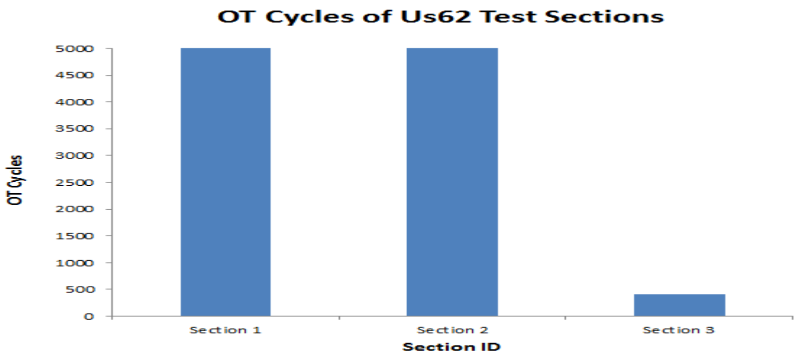


Reflective cracking resistance ranking:
Section 3>Section 4>Section 2>Section 1

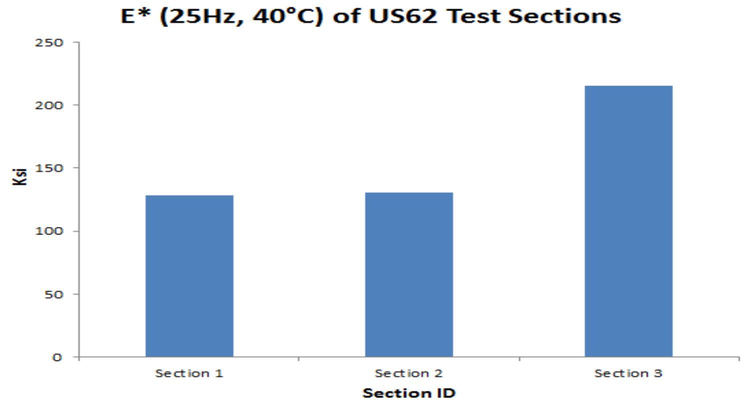
OT cycles ranking (high to low):
Section 3>Section 4>Section 2>Section 1

Field Test Section Performance Predictions – US62 Fatigue Cracking





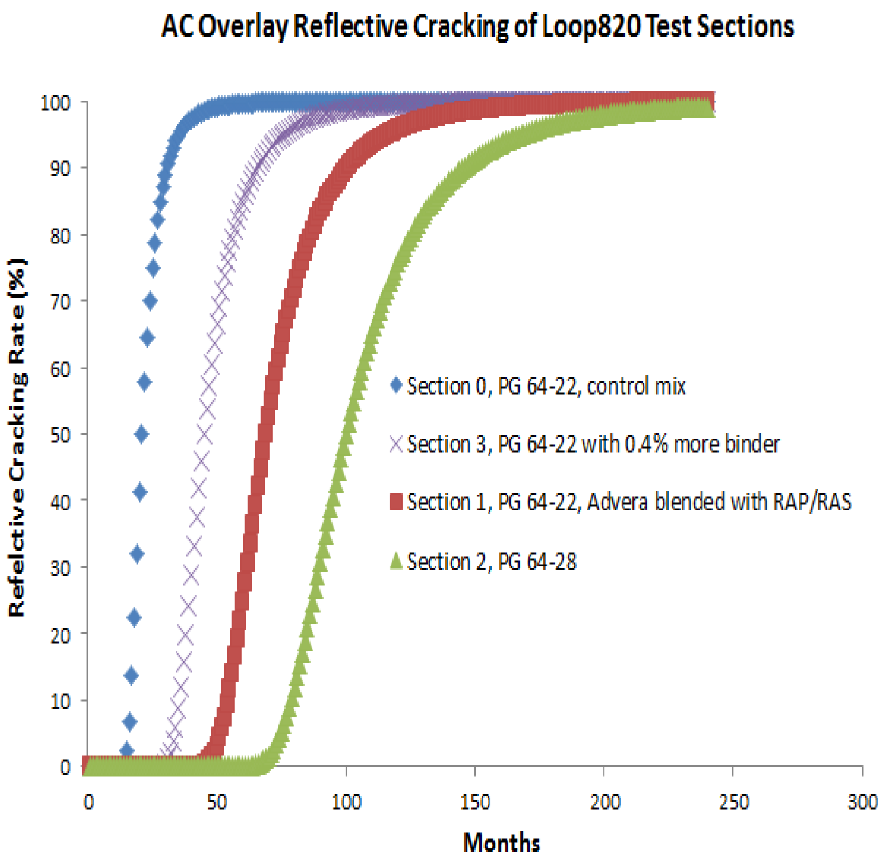
OT cycles ranking (high to low):
Section 2≥Section 1>Section 3



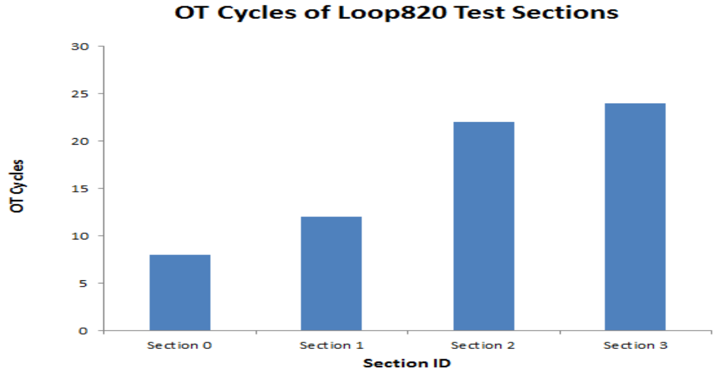
Reflective cracking resistance ranking:
Section 2>Section 3>Section 1

Modulus ranking (low to high):
Section 1<Section 2<Section 3

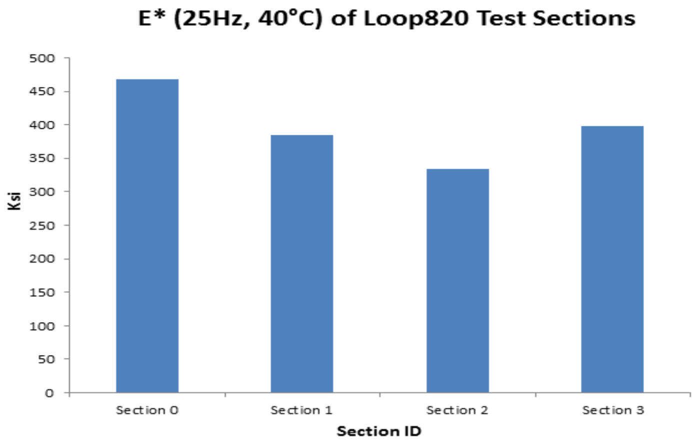
Field Test Section Performance Predictions – Loop820 Reflective Cracking



Reflective cracking resistance ranking:
Section 2>Section 1>Section 3>Section 0

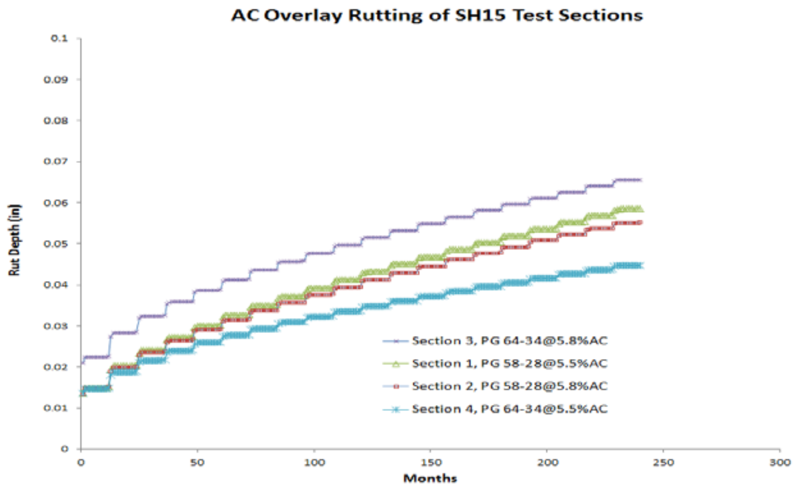


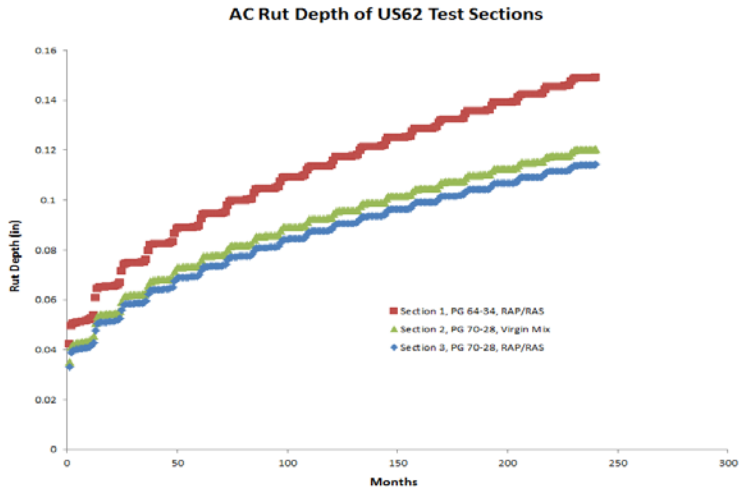
OT cycles ranking (high to low):
Section 3>Section 2>Section 1>Section 0

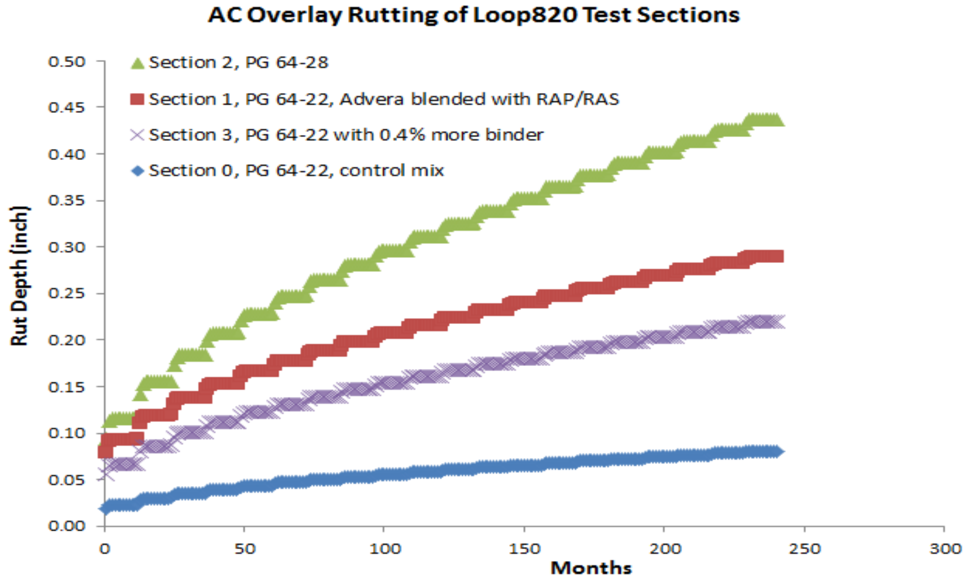


Modulus ranking (low to high):
Section 2<Section 1<Section 3<Section 0

Field Test Section Performance Predictions – AC Rutting







Field Test Sections Survey – SH15

Survey Date: 6/7/2014, 8 months after construction. No rutting or cracking observed. Some segregation area was found in Section 4.

Field Test Sections Survey – US62

Survey Date: 6/6/2014, 8 months after construction. No rutting or cracking observed.

Field Test Sections Survey – Loop820

Survey Date: 2/10/2013 and 6/12/2014, 7 and 23 months after construction. No cracking was observed.

Field Test Sections Predicted vs. Observed

- All the crack predictions during the first 2 years are close to zero or very small, which is consistent with the observation.
- Except Loop820, the predicted rut depths in the SH15 and US62 test sections are small (less than 0.1 inch), which are confirmed by the field observation. Loop820 rut depth couldn't be measured due to heavy traffic.
- The predicted performance ranking and difference among test sections are reasonable.
- The field test sections need continued monitoring to further validate the predictions.

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- Overview (objectives and task by task review)
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- Mixture test (binder fracture vs. mix fracture)
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- Performance of field test sections: predicted vs. observed
- **Asphalt overlay performance simulations**
- Statewide catalogue of recommended binder types
- Life cycling cost analysis
- What's next

Asphalt Overlay Cracking Performance Simulations – Partial Factorial Design

- Climatic Zone
  - Dry-Cold: Amarillo; Wet-Cold: Dallas; Dry-Warm: Odessa; Wet-Warm: Beaumont; Moderate: Austin
- Traffic Level
  - 3 million; 5 million; 10 million; 30 million
- Overlay Thickness
  - 2 inches; 3 inches; 4 inches
- Overlay Mixture Type
  - 15 mixes; 5 types of binders × 3 types of aggregates
- Existing Pavement Structure Type
  - Conventional Existing AC over GB; Existing JPCP over GB; Thinner Existing AC over CTB

Total Combinations: 5 Climatic Zones × 4 Traffic Levels × 3 Overlay Thicknesses × 15 Mixes × 3 Existing Pavement Structures = 2700

Asphalt Overlay Cracking Performance Simulation Results

	Environmental Zones	Existing Pavement Structures	Traffic Levels	Overlay Thicknesses	Aggregate Types	Binder Types	Mix OT Cycles	Cracking Life (Months)
1	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	LimeStone	PG64-22	190	7
2	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	LimeStone	PG64-28	832	53
3	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	LimeStone	PG64-34	1600	77
4	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	LimeStone	PG70-22	91	7
5	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	LimeStone	PG76-22	89	7
6	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Gravel	PG64-22	106	7
7	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Gravel	PG64-28	673	43
8	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Gravel	PG64-34	1400	68
9	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Gravel	PG70-22	111	7
10	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Gravel	PG76-22	55	7
11	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Granite	PG64-22	259	7
12	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Granite	PG64-28	1800	79
13	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Granite	PG64-34	5000	139
14	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Granite	PG70-22	224	8
15	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Granite	PG76-22	120	7
226	Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Thinner Existing AC over CTB	5	2	LimeStone	PG64-22	190	32
227	Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Thinner Existing AC over CTB	5	2	LimeStone	PG64-28	832	79
228	Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Thinner Existing AC over CTB	5	2	LimeStone	PG64-34	1600	114
229	Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Thinner Existing AC over CTB	5	2	LimeStone	PG70-22	91	20
230	Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Thinner Existing AC over CTB	5	2	LimeStone	PG76-22	89	20
231	Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Thinner Existing AC over CTB	5	2	Gravel	PG64-22	106	24
232	Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Thinner Existing AC over CTB	5	2	Gravel	PG64-28	673	69
233	Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Thinner Existing AC over CTB	5	2	Gravel	PG64-34	1400	104
234	Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Thinner Existing AC over CTB	5	2	Gravel	PG70-22	111	23
235	Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Thinner Existing AC over CTB	5	2	Gravel	PG76-22	55	16
236	Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Thinner Existing AC over CTB	5	2	Granite	PG64-22	259	41
237	Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Thinner Existing AC over CTB	5	2	Granite	PG64-28	1800	117
238	Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Thinner Existing AC over CTB	5	2	Granite	PG64-34	5000	196
239	Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Thinner Existing AC over CTB	5	2	Granite	PG70-22	224	33
240	Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Thinner Existing AC over CTB	5	2	Granite	PG76-22	120	23

Asphalt Overlay Cracking Performance Simulation Results Analysis

	Environmental Zones	Existing Pavement Structures	Traffic Levels	Overlay Thicknesses	Aggregate Types	Binder Types	Mix OT Cycles	Cracking Life
10	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Gravel	PG76-22	55	7
5	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	LimeStone	PG76-22	89	7
4	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	LimeStone	PG70-22	91	7
6	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Gravel	PG64-22	106	7
9	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Gravel	PG70-22	111	7
15	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Granite	PG76-22	120	7
1	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	LimeStone	PG64-22	190	7
11	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Granite	PG64-22	259	7
14	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Granite	PG70-22	224	8
7	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Gravel	PG64-28	673	43
2	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	LimeStone	PG64-28	832	53
8	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Gravel	PG64-34	1400	68
3	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	LimeStone	PG64-34	1600	77
12	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Granite	PG64-28	1800	79
13	Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	3	2	Granite	PG64-34	5000	139

Required OT number of cycles is **1097** to reach 5 years life (60 months).

Simulation Results Analysis Summary

Environmental Zones	Existing Pavement Structures	Required OT Cycles to reach 5 years life			
		2", 3 million:	4", 30 million:	3", 5 million:	3", 10 million:
Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Conventional Existing AC over GB	397	213	80	209
Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Conventional Existing AC over GB	164	90	31	98
Environmental Zone 3 (Wet-Cold,e.g.,Dallas)	Conventional Existing AC over GB	167	93	33	99
Environmental Zone 4 (Wet-Warm,e.g.,Beaumont)	Conventional Existing AC over GB	155	77	31	91
Environmental Zone 5 (Moderate, e.g., Austin)	Conventional Existing AC over GB	167	89	33	96
Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Existing JPCP over GB	16927	511	864	1473
Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Existing JPCP over GB	509	217	147	287
Environmental Zone 3 (Wet-Cold,e.g.,Dallas)	Existing JPCP over GB	369	201	106	242
Environmental Zone 4 (Wet-Warm,e.g.,Beaumont)	Existing JPCP over GB	240	196	80	216
Environmental Zone 5 (Moderate, e.g., Austin)	Existing JPCP over GB	287	204	90	237
Environmental Zone 1 (Dry-Cold, e.g., Amarillo)	Thinner Existing AC over CTB	1097	1743	394	737
Environmental Zone 2 (Dry-Warm, e.g., Odessa)	Thinner Existing AC over CTB	291	371	102	235
Environmental Zone 3 (Wet-Cold,e.g.,Dallas)	Thinner Existing AC over CTB	242	377	102	235
Environmental Zone 4 (Wet-Warm,e.g.,Beaumont)	Thinner Existing AC over CTB	232	263	83	167
Environmental Zone 5 (Moderate, e.g., Austin)	Thinner Existing AC over CTB	238	331	95	210

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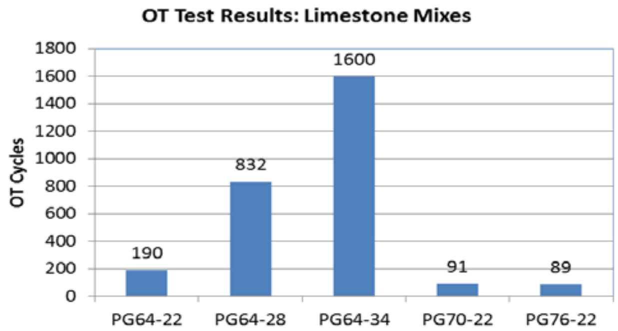
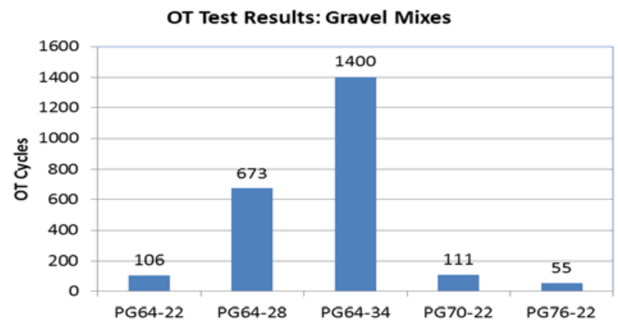
Methodology of Recommending Binder Types for Each District

- Indentify the representative climatic zone for each district
- Identify the typical aggregate type used in the district
- Determine the required OT cycles according to the existing pavement structure
- Decide which binder type can meet the requirement





Statewide Catalogue of Recommended Binder Types

Districts	Aggregate	Recommended Binder Type		
		Conventional Existing AC over GB	Existing JPCP over GB	Thinner Existing AC over CTB
01 Paris	Gravel	PG64-28	PG64-34	PG64-28
02 Fort Worth	Limestone	PG64-22 (Higher %AC) or PG64-28	PG64-34	PG64-28
03 Wichita Falls	Gravel	PG64-28	PG64-34	PG64-28
04 Amarillo	Gravel	PG64-28	PG64-34 (Higher %AC)	PG64-34
05 Lubbock	Gravel	PG64-28	PG64-34 (Higher %AC)	PG64-28 (Higher %AC) or PG64-34
06 Odessa	Gravel	PG64-28	PG64-28	PG64-28
07 San Angelo	Gravel	PG64-28	PG64-28	PG64-28
08 Abilene	Gravel	PG64-28	PG64-34 (Higher %AC)	PG64-28 (Higher %AC) or PG64-34
09 Waco	Limestone	PG64-22 (Higher %AC) or PG64-28	PG64-28	PG64-28
10 Tyler	Limestone	PG64-22 (Higher %AC) or PG64-28	PG64-34	PG64-28
11 Lufkin	Limestone	PG64-22 (Higher %AC) or PG64-28	PG64-28	PG64-28
12 Houston	Limestone	PG64-22 (Higher %AC) or PG64-28	PG64-28	PG64-28
13 Yoakum	Gravel	PG64-28	PG64-28	PG64-28
14 Austin	Limestone	PG64-22 (Higher %AC) or PG64-28	PG64-28	PG64-28
15 San Antonio	Limestone	PG64-22 (Higher %AC) or PG64-28	PG64-28	PG64-28
16 Corpus Christi	Gravel	PG64-22	PG64-22	PG64-22 (Higher %AC) or PG64-28
17 Bryan	Limestone	PG64-22 (Higher %AC) or PG64-28	PG64-28	PG64-28
18 Dallas	Limestone	PG64-22 (Higher %AC) or PG64-28	PG64-28	PG64-28
19 Atlanta	Granite	PG70-22	PG64-28	PG64-28
20 Beaumont	Granite	PG70-22	PG64-28	PG64-22 (Higher %AC) or PG64-28
21 Pharr	Gravel	PG64-22	PG64-22	PG64-22 (Higher %AC) or PG64-28
22 Laredo	Gravel	PG64-22	PG64-22	PG64-22 (Higher %AC) or PG64-28
23 Brownwood	Limestone	PG64-22 (Higher %AC) or PG64-28	PG64-28	PG64-28
24 El Paso	Limestone	PG64-22 (Higher %AC) or PG64-28	PG64-28	PG64-28
25 Childress	Gravel	PG64-28	PG64-34 (Higher %AC)	PG64-28 (Higher %AC) or PG64-34

Note: This table was developed based on virgin mix.

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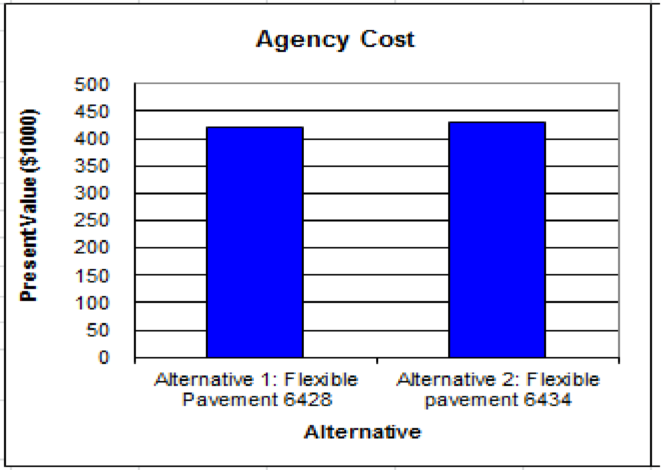
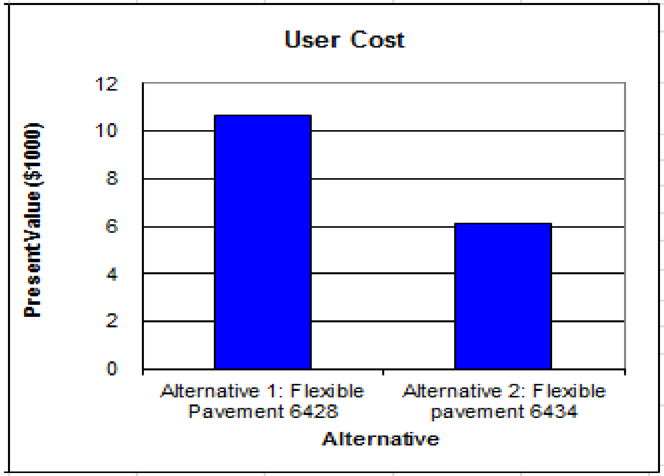
Life Cycling Cost Analysis: Amarillo

Total Cost				
	Alternative 1: Flexible Pavement 6428		Alternative 2: Flexible pavement 6434	
Total Cost	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)
Undiscounted Sum	*$184.14*	*$4.67*	*$225.29*	*$2.78*
Present Value	**$420.53**	**$10.65**	**$428.91**	**$6.12**
EUAC	$51.85	$1.31	$52.88	$0.75

Lowest Present Value Agency Cost	Alternative 1: Flexible Pavement 6428
Lowest Present Value User Cost	Alternative 2: Flexible pavement 6434

Expenditure Stream				
	Alternative 1: Flexible Pavement 6428		Alternative 2: Flexible pavement 6434	
Year	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)
2014	$558.00	$13.50	$659.00	$9.98
2015				
2016				
2017				
2018	$558.00	$14.90		
2019			$50.00	
2020				
2021			$659.00	$11.87
2022				
2023	$558.00	$16.44		
2024	($1,489.86)	($40.17)	($1,142.71)	($19.07)





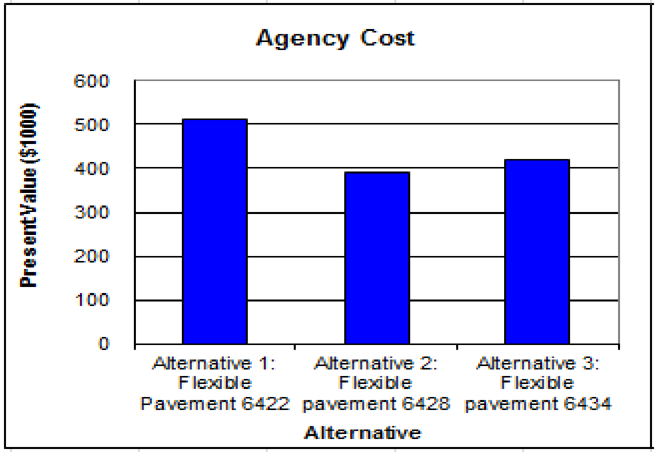
Life Cycling Cost Analysis: Austin

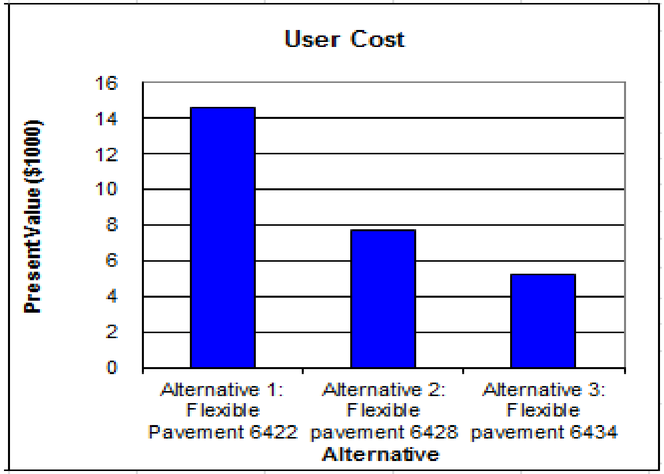
Total Cost	Alternative 1: Flexible Pavement 6422		Alternative 2: Flexible pavement 6428		Alternative 3: Flexible pavement 6434	
Total Cost	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)
Undiscounted Sum	*$243.36*	*$6.94*	*$245.08*	*$3.59*	*$258.16*	*$2.40*
Present Value	**$512.84**	**$14.57**	**$388.91**	**$7.75**	**$421.05**	**$5.24**
EUAC	$54.64	$1.55	$41.44	$0.83	$44.86	$0.56

Lowest Present Value Agency Cost	Alternative 2: Flexible pavement 6428
Lowest Present Value User Cost	Alternative 3: Flexible pavement 6434

Expenditure Stream

Year	Alternative 1: Flexible Pavement 6422		Alternative 2: Flexible pavement 6428		Alternative 3: Flexible pavement 6434	
	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)
2014	$507.00	$13.50	$558.00	$13.50	$659.00	$9.98
2015						
2016						
2017						
2018	$507.00	$14.90				
2019			$50.00		$50.00	
2020						
2021						
2022	$507.00	$16.44				
2023						
2024			$50.00		$50.00	
2025			$558.00	$17.71		
2026	($1,277.64)	($37.90)	($970.92)	($27.61)	($500.84)	($7.59)



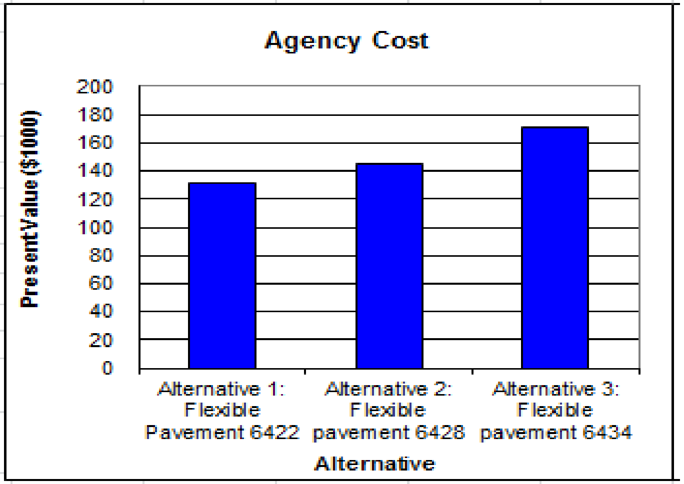


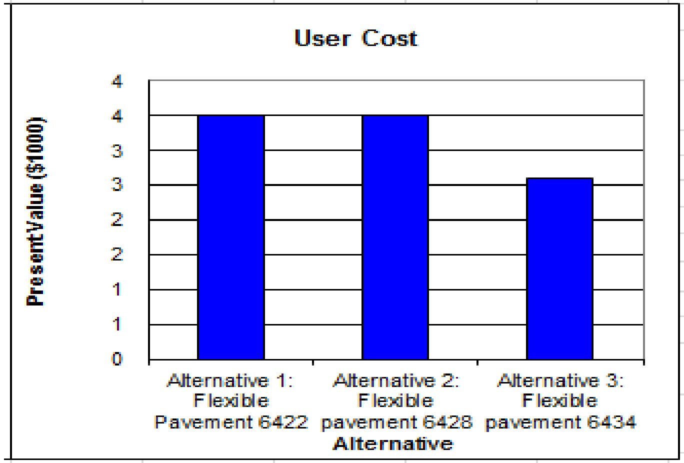
Life Cycling Cost Analysis: Pharr

Total Cost						
	Alternative 1: Flexible Pavement 6422		Alternative 2: Flexible pavement 6428		Alternative 3: Flexible pavement 6434	
Total Cost	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)
Undiscounted Sum	*$50.70*	*$1.35*	*$55.80*	*$1.35*	*$65.90*	*$1.00*
Present Value	**$131.95**	**$3.51**	**$145.23**	**$3.51**	**$171.52**	**$2.60**
EUAC	$29.64	$0.79	$32.62	$0.79	$38.53	$0.58

Lowest Present Value Agency Cost	Alternative 1: Flexible Pavement 6422
Lowest Present Value User Cost	Alternative 3: Flexible pavement 6434

Expenditure Stream						
	Alternative 1: Flexible Pavement 6422		Alternative 2: Flexible pavement 6428		Alternative 3: Flexible pavement 6434	
Year	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)	Agency Cost ($1000)	User Cost ($1000)
2014	$507.00	$13.50	$558.00	$13.50	$659.00	$9.98
2015						
2016						
2017						
2018						
2019	($456.30)	($12.15)	($502.20)	($12.15)	($593.10)	($8.98)





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What's Next

- Finish all remaining tasks
- Write final report
- Close out meeting
- Implementation plan

Thank You!!!