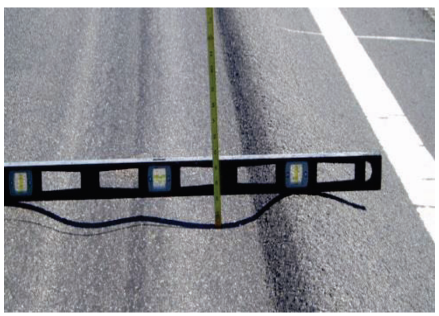
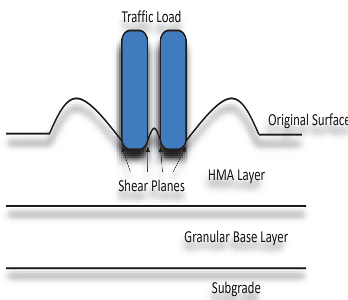
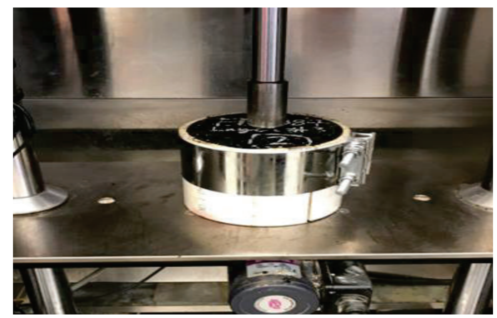
Project 5-6744-01

Implementation of the HMA Shear Test for Routine Mix-Design and Screening

The SPST

by
LUBINDA, ABU, TITO, AND SANG

Cedar Park | August 22 2018

Presentation Outline

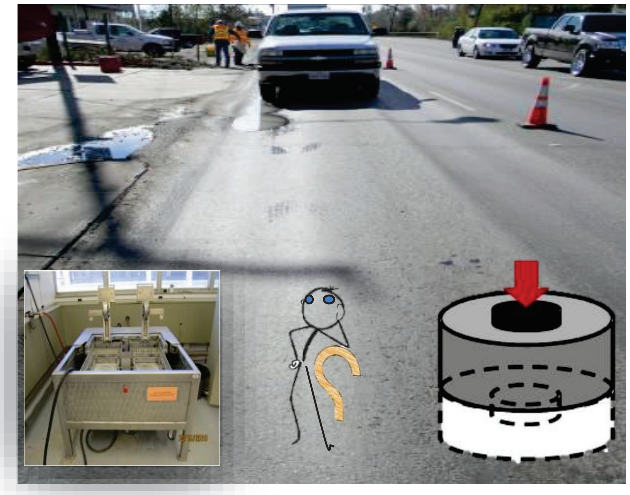
1) Introduction

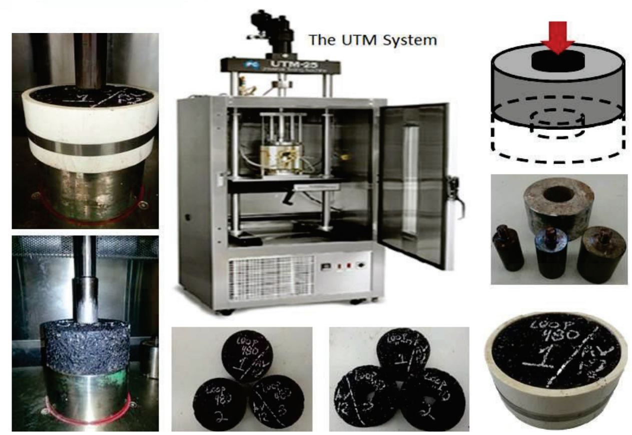
2) Task timeline and deliverables

3) Work completed to date

4) Summary and conclusions

5) Comments, discussions, and contributions





Introduction

- Project details
- Problem statement
- Technical objectives
- Work plans and research tasks
- Product deliverables

Project Details

- Three-year implementation project
- Aug. 2015 – Aug. 2018

TxDOT PMC

- Kevin Pete (PM)
- Travis Patton
- Gisel Carrasco
- Ryan Barborak

TTI Research Team

- Lubinda F. Walubita (PI)
- Abu N. M. Faruk
- Tito Nyamuhokya
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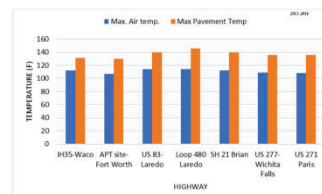
- Adrianus Prakoso

Problem Statement

1) Rutting/PD continues to be a PVMNT failure mode of concern even for mixes that pass the HWTT in the lab

2) Prevalence of shear failures



   - Slow moving traffic, urban stop-go sections, highway intersections
   - Prolonged high temperatures
   - Heavy traffic loading (e.g., oil activities)
   - Low PG asphalt binder grades

3) Findings from TxDOT project 0-6744 can improve laboratory screening procedures to better simulate field conditions
   - Modified HWTT parameters to better suit filed conditions (elevated test temperature, slower wheel speed, etc.)
   - Validation and implementation of new supplementary HMA shear test: SPST

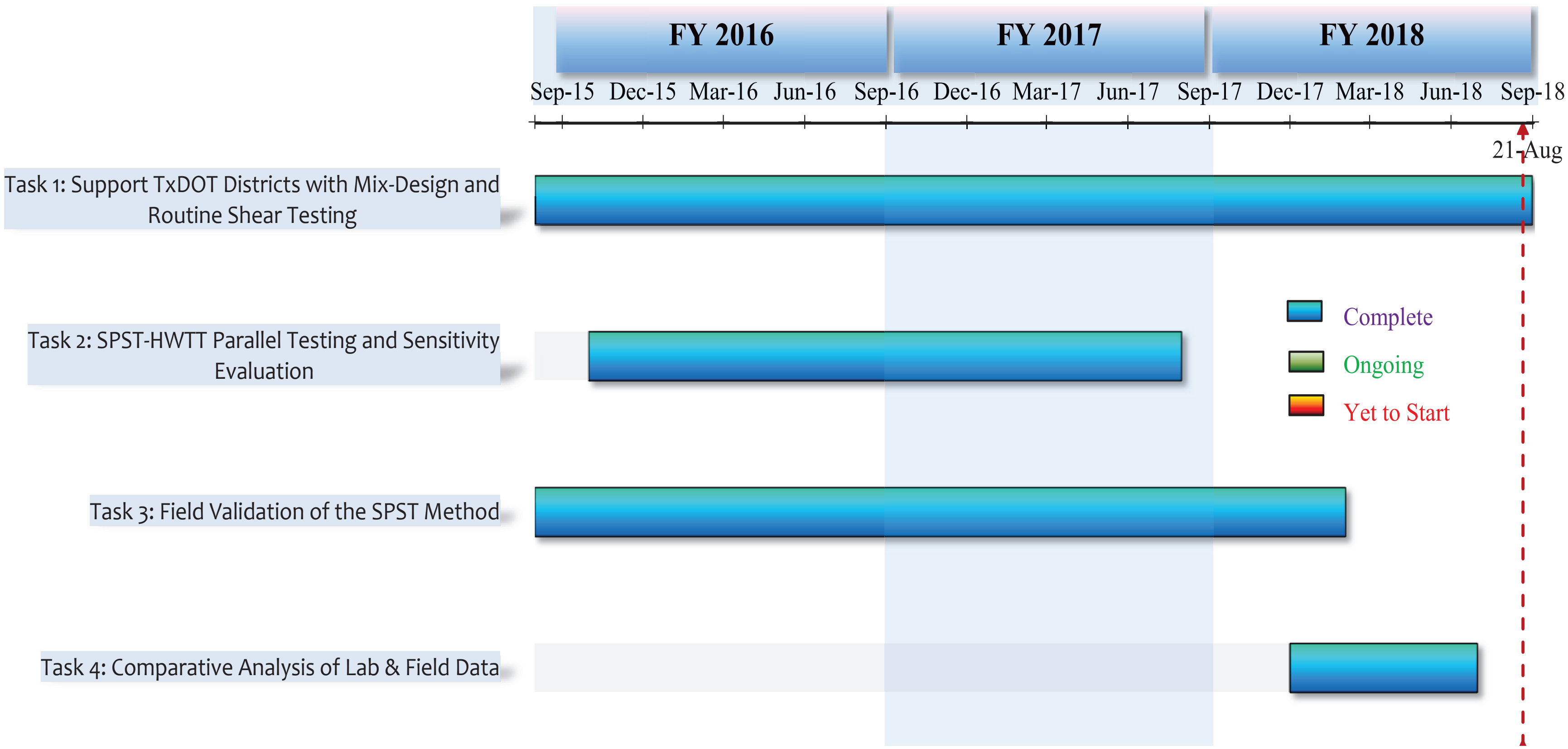
Technical Objectives

1) To assist the TxDOT districts with their routine mix-design screening and HMA shear strength testing.

2) To conduct a pilot implementation of the findings of project 0-6744 through assisting the districts with their routine HMA mix-designs and mix screening using the proposed SPST and modified HWTT protocols.

3) To verify and refine the proposed test procedures with field performance data from in-service highway test sections.

Research Tasks and Timeline



Product Deliverables

Product Deliverables

Work Completed to Date

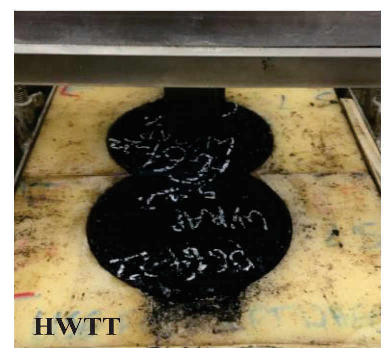
- Task 1: TxDOT district routine HMA shear testing
- Task 2: SPST-HWTT parallel testing
- Task 3: Field validation study
- Task 4: Comparative analysis of lab and field data

HMA Specimen Fabrication

- Used both plant and lab prepared mixtures for SPST and HWTT
- HMA mixture types
  - Fine-graded (crack attenuating mix [CAM] and type F)
  - Dense-graded (type C and type D)
  - Coarse-graded (type B)
  - Permeable friction course (PFC)
- HMA specimens
  - Typical HWTT; 6-inch in diameter and 2.5-inch thick
  - 7±1% air voids (20±2% air void for PFC)
  - Molded by Superpave Gyratory Compactor (SGC)

SP

HWTT



SPST

HMA Specimen Fabrication

- HMA Mixing & Compaction Temperatures Mixture
  - 2 hr @ mixing and 2 hr @ compaction
  - For pre-mixed HMA (i.e., plant mixtures), and extra 1.5 hr oven aging @ 275°F to soften and spread the mixtures.

Asphalt-Binder PG Grade	Mixing Temperature	Molding/Compaction Temperature
PG 64-22	290 °F (143 °C)	250 °F (121 °C)
PG 70-22	300 °F (149 °C)	275 °F (135°C)
PG 76-22	325 °F (163 °C)	300 °F (149 °C)

- Limit Oxidation Effect
  - Specimen tested within 5 days after molding
  - For any testing delay, specimens kept under 0°C prior to testing

Experimental Matrix

HMA Type	NMAS	PG grade	Asphalt-Binder %	RAP%	Hwy/ Lab	HWTT 50 °C	HWTT 60 °C	SPST 50 °C	SPST 60 °C
Type B	3/4	64-22	4.7	21.9	IH 35	✓	✓	✓	✓
Type C	3/8	70-22	5.2	20	Loop 480	✓	✓	✓	✓
Type C	3/8	64-22	4.8	20	SH 21	✓	✓	✓	✓
Type D	3/8	70-22	5.3	16	FM 2100	✓	✓	✓	✓
CAM	#4	76-22	7.0	0	SH 121	✓	✓	✓	✓
PFC	1/2	76-22	6.0	FC=.3%	US 271	✓	✓	✓	✓
Type D	3/8	64-22	5.2	20	US 59	✓	✓	✓	✓
Type C	3/8	64-22	4.8	20	US 83	✓	✓	✓	✓
Type D	3/8	64-22	5.3	15	US 82	✓	✓	✓	✓
Type F	3/8	76-22	7.4	0	US 271	✓	✓	✓	✓
Type B	3/4	64-22	5.0	15	APT	✓	✓	✓	✓
Type C	1/2	70-22	5.2	0	FM 1887	✓	✓	✓	✓
Type C	3/8	64-22	4.7	0	Lab	✓	✓	✓	✓
Type C	3/8	64-22	5.2	0	Lab	✓	✓	✓	✓
Type C	3/8	64-22	5.7	0	Lab	✓	✓	✓	✓
Type C	3/8	70-22	4.7	0	Lab	✓	✓	✓	✓
Type C	3/8	70-22	5.2	0	Lab	✓	✓	✓	✓
Type C	3/8	70-22	5.7	0	Lab	✓	✓	✓	✓
Type C	3/8	76-22	4.7	0	Lab	✓	✓	✓	✓
Type C	3/8	76-22	5.2	0	Lab	✓	✓	✓	✓
Type C	3/8	76-22	5.7	0	Lab	✓	✓	✓	✓
Type C	3/8	64-22	5.2	15	Lab	✓	✓	✓	✓
Type C	3/8	64-22	5.2	20	Lab	✓	✓	✓	✓
Type C	3/8	64-22	5.2	25	Lab	✓	✓	✓	✓
Type D	3/8	64-22	4.5	0	Lab	✓	✓	✓	✓
Type D	3/8	64-22	5.0	0	Lab	✓	✓	✓	✓
Type D	3/8	64-22	5.5	0	Lab	✓	✓	✓	✓
Type D	3/8	70-22	4.5	0	Lab	✓	✓	✓	✓
Type D	3/8	70-22	5.0	0	Lab	✓	✓	✓	✓
Type D	3/8	70-22	5.5	0	Lab	✓	✓	✓	✓
Type D	3/8	76-22	4.5	0	Lab	✓	✓	✓	✓
Type D	3/8	76-22	5.0	0	Lab	✓	✓	✓	✓
Type D	3/8	76-22	5.5	0	Lab	✓	✓	✓	✓

Legend: Hwy = Highway for plant-mix materials sampled from the field; Lab = laboratory prepared mixes; N/A = Not Applicable; FC = Fiber Content; ✓= test performed for a given mix at different temperatures

The Simple Punching Shear Test (SPST)

- Performed on a UTM (or other loading frame with environmental chamber)
- Follows the SPST protocol developed in the TxDOT project 0-6744
- Test to failure takes less than 20 min.

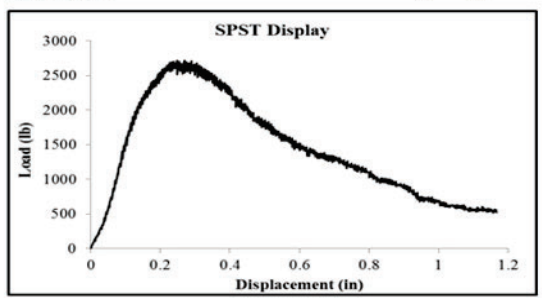
1. Specimen and base

2. Specimen on the base

3. Specimen-base aligning

4. Securing collar-strap

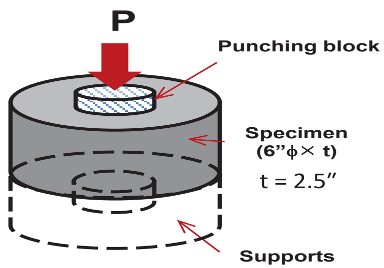
5. Loading



6. Real time data display

7. Specimen after test

The SPST Test Parameters

#	Item	Description
1	Schematic	
2	Test objective	Characterization of HMA shear resistance properties
3	Specimen dimension	2.5" (63.5 mm) thick × 6.0" (152.4 mm) ϕ
4	Loading mode	Monotonic axial compressive loading. Displacement controlled (axial continuously increasing displacement)
5	Sitting load	8 lbs (0.036 kN) or sitting stress of 0.29 psi (2 kPa)
6	Loading rate (mm/s)	0.2 mm/s (0.50 in/min)
7	Specimen confinement	Yes (20 psi)
8	Loading head diameter	1.5" (38.1 mm) dimeter
9	Test temperatures	50 ± 2°C (122°F) and 60 ± 2°C (140°F)
10	Data capturing frequency	Every 0.10 second (except temperature; at least every 5 seconds)
11	Test termination	2.49" (63.2 mm) vertical RAM movement
12	Total test time	≤ 10 minutes
13	Measured parameters	Temperature, time, load, & shear deformations
14	Number of specimen replicates per test condition	≥3
15	Target specimen air voids	7 ± 1% for all HMA mixes, except PFC mixes at 20 ± 2%.
16	Specimen temperature conditioning time	≤ 3 hrs (it is recommended to monitor the temperature from a thermocouple wire inserted inside a dummy specimen that is also placed in the same temperature chamber as the test specimens)

Pass-Fail Criteria	Shear Strength
At 50 °C	≥300 psi
At 60 °C	≥200 psi

Hamburg Wheel Tracking Test (HWTT)

- TxDOT uses HWTT (Tex-242-F) to screen HMA mixtures susceptible to rutting
- Takes about 7 hr to complete standard 20,000 loading cycles

Hamburg Wheel Tracking Test (HWTT)

- For each test, a pair per HMA mix-design per temperature was used
- Example of the HWTT rut data report (US 83 at 50°C)

Number of Wheel Pass	HWTT Rut Depth (mm)	
	Left Wheel	Right Wheel
5,000	2.24	2.66
10,000	3.77	4.32
15,000	5.88	6.32
20,000	8.85	9.94

The SPST and HWTT Outputs

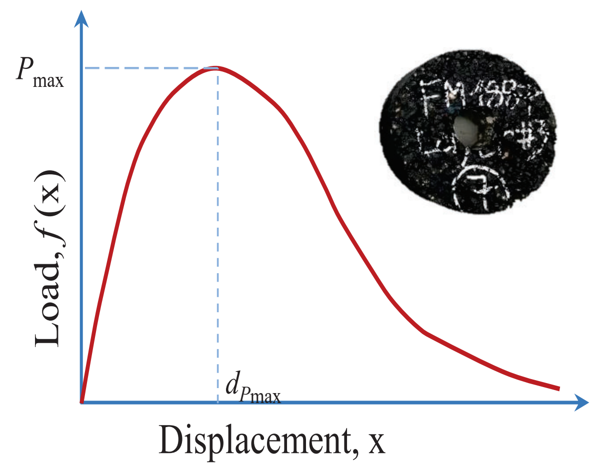
❑ SPST Primary output

- Shear strength (τ), shear strain (γ), and shear modulus (G)

$$\gamma = \frac{\text{Displacement @ Peak load}}{\text{Sample thickness}}$$

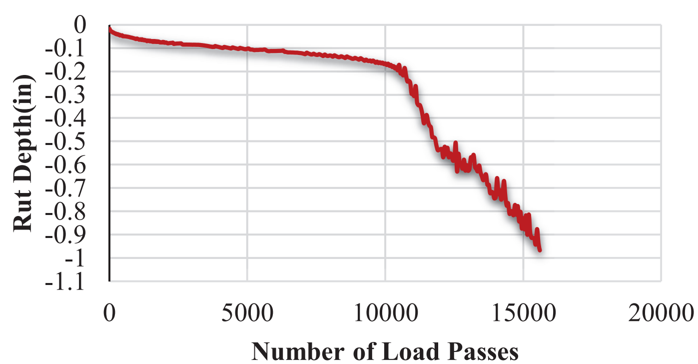
$$\tau = \frac{\text{Peak load}}{\text{x-area}}$$

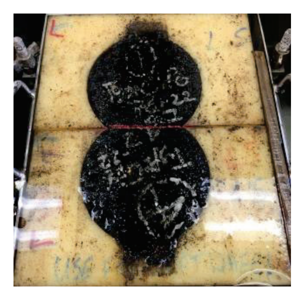
$$G = \frac{\tau}{\gamma}$$



❑ HWTT Primary Output

- Rut depth





Task 1: Routine HMA Shear Testing

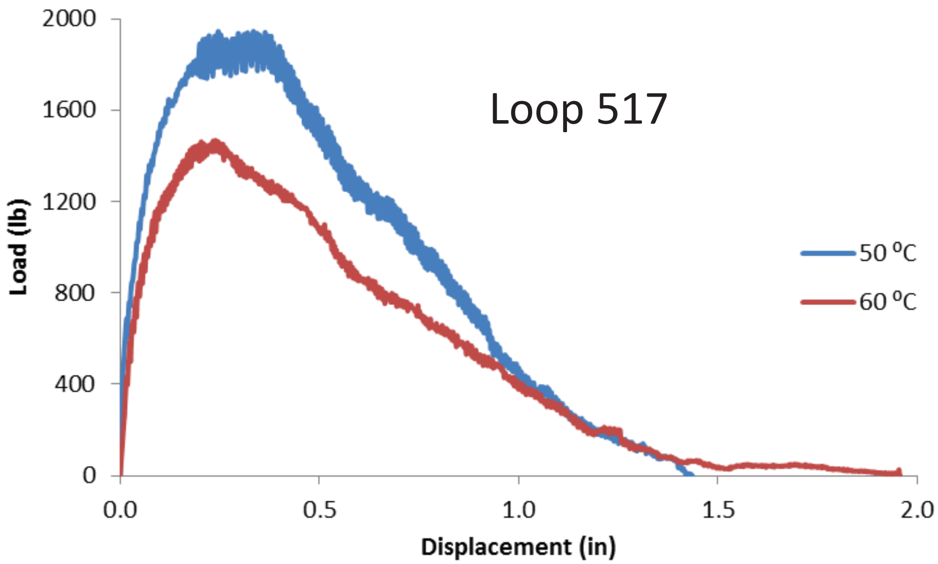
Support the TxDOT Districts with Mix-Design = RD, ATL, PHR, and BRY

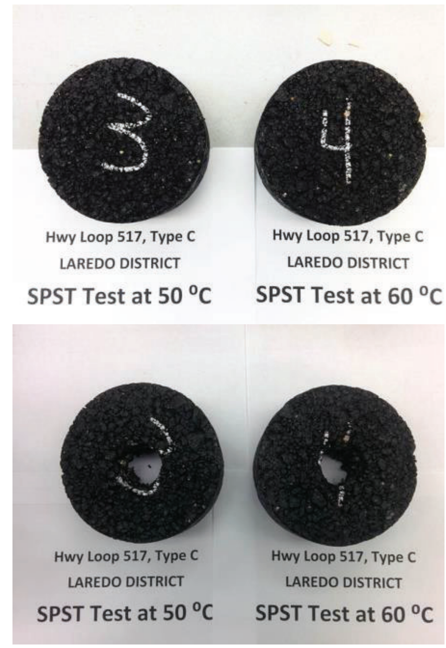
Mix ID	Hwy	Mix	HWTT rut depth at LRD lab (mm)		SPST shear strength (psi)	
			@ 10k passes	@ 15k passes	@ 50 °C	@ 60 °C
LRD-1	Loop 517	Type C	5.14	7.02	247.48	186.87
LRD-2	FM 1472	Type C	5.07	9.74	275.16	193.75
LRD-3	FM 1472	Type D	4.54	9.45	286.73	201.20
LRD-4	-	Type B	2.15	6.31	327.15	253.37
LRD-5	-	Type D (PG 70-22)	4.36	5.00	322.92	238.47

Mix ID	Hwy	Mix	HWTT rut depth after 20k passes (mm)		SPST shear strength (psi)	
			@ 50 °C	@ 60 °C	@ 50 °C	@ 60 °C
ATL	-	Type C	4.34	12.5 @ 10,050	196.73	151.23
PHR	-	Type D	3.85	12.5 @ 8700	281.83	-
PHR	-	Type C	3.28	11.09	301.87	203.16
BRY	-	Type D	7.01	12.34	311.02	198.76

Task 1: Routine HMA Shear Testing

Support the TxDOT Districts with Mix-Designs = LRD (Type D)



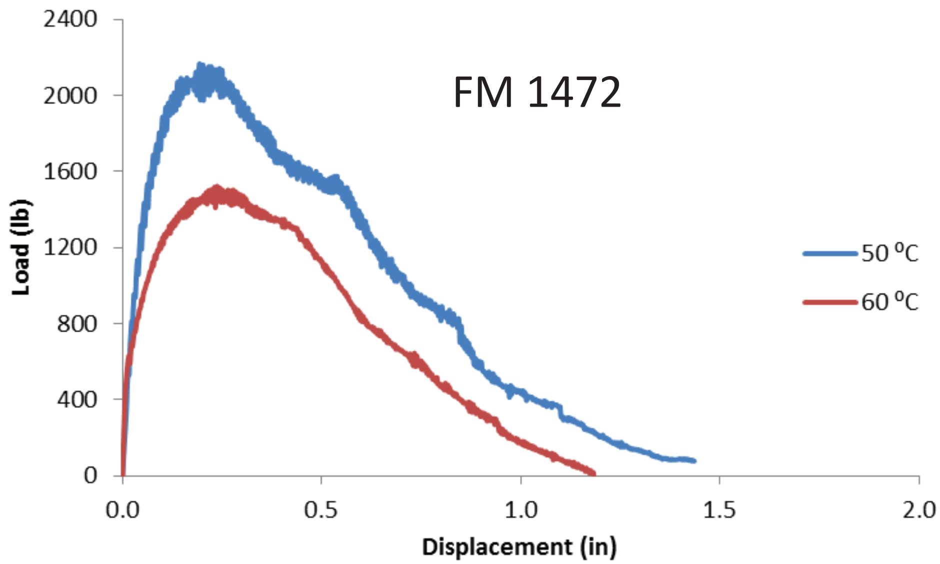


Sample #	Test temp.	Shear Strength (psi)	Shear Strain (in/in)	Shear Mod. (ksi)	SSE (kJ/m^2)
S# 3	50 °C	247.48	0.134	1.85	30.9
S# 4	60 °C	186.87	0.096	1.95	23.37

Passing Criteria	Shear Strength	SSE
At 50 °C	≥300 psi	≥25 kJ/m^2
At 60 °C	≥200 psi	≥17 kJ/m^2

Task 1: Routine HMA Shear Testing

Support the TxDOT Districts with Mix-Designs = LRD (Type C)



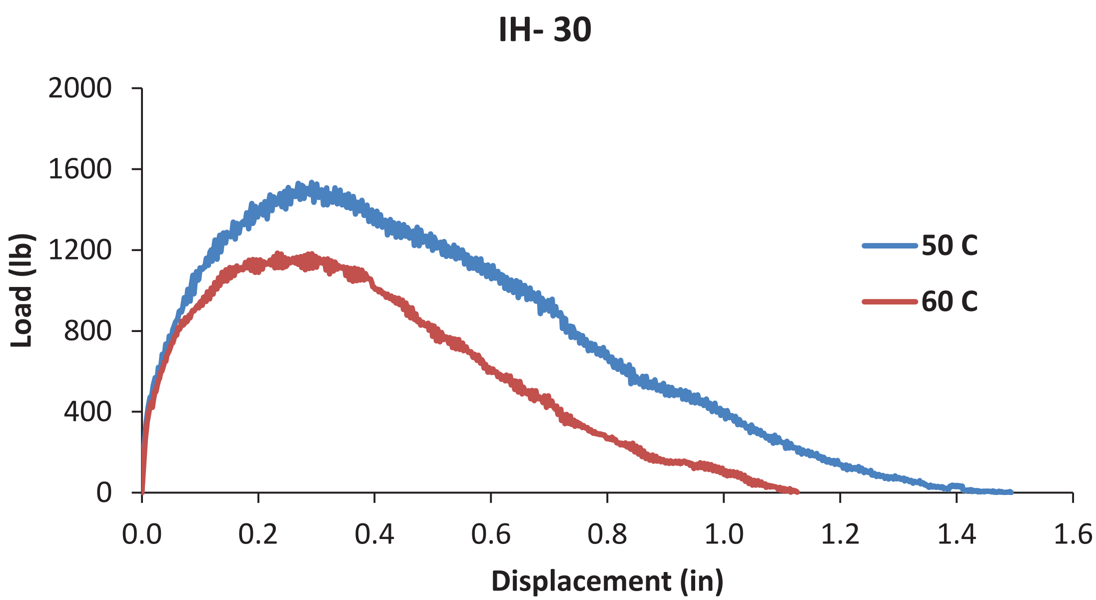
Tested at 50 °C   Tested at 60 °C

Sample #	Test temp.	Shear Strength (psi)	Shear Strain (in/in)	Shear Mod. (ksi)	SSE (kJ/m^2)
S# 1	50 °C	275.16	0.077	3.55	32.62
S# 2	60 °C	193.75	0.095	2.04	21.04

Passing Criteria	Shear Strength	SSE
At 50 °C	≥300 psi	≥25 kJ/m^2
At 60 °C	≥200 psi	≥17 kJ/m^2

Task 1: Routine HMA Shear Testing

Support the TxDOT Districts with Mix-Design = ATL (Type D)



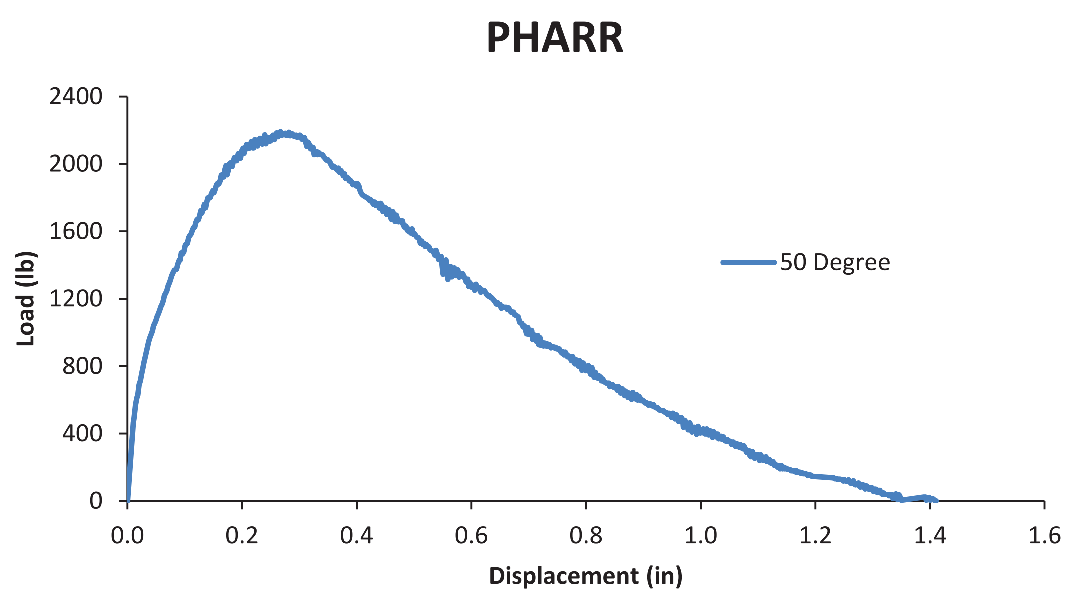
Tested at 50 °C and 60 °C

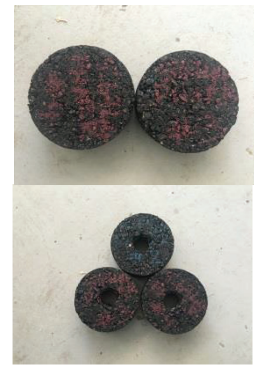
Sample #	Test temp.	Shear Strength (psi)	Shear Strain (in/in)	Shear Mod. (ksi)	SSE (kJ/m^2)
S# 1	50 °C	205.46	0.115	1.79	22.09
S# 2	60 °C	188.01	0.120	1.56	18.37

Passing Criteria	Shear Strength	SSE
At 50 °C	≥300 psi	≥25 kJ/m^2
At 60 °C	≥200 psi	≥17 kJ/m^2

Task 1: Routine HMA Shear Testing

Support the TxDOT Districts with Mix-Designs = PHR (Type C)





Tested at 50 °C

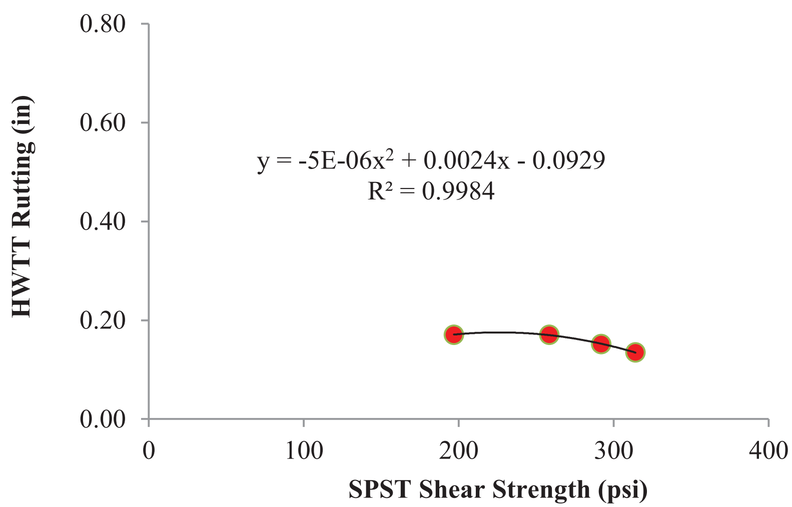
Sample #	Test temp.	Shear Strength (psi)	Shear Strain (in/in)	Shear Mod. (ksi)	SSE (kJ/m²)
S# 1	50 °C	301.87	0.107	2.742	23.259
S# 2	60 °C	203.16			

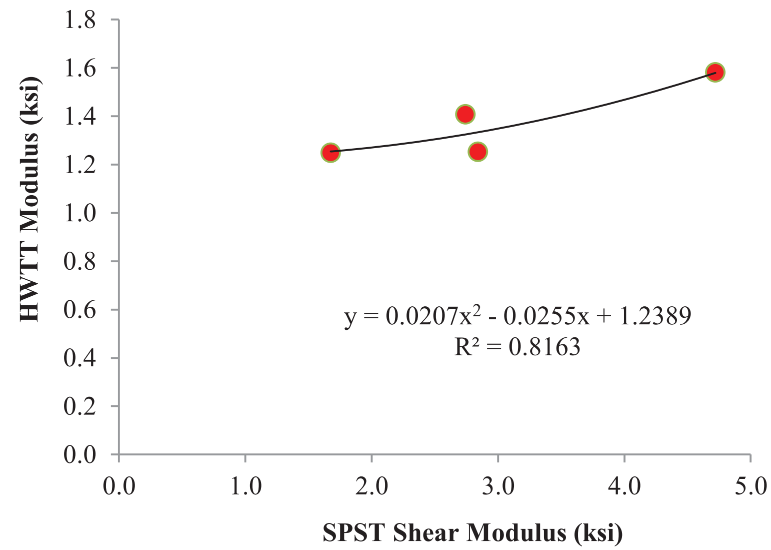
Passing Criteria	Shear Strength
At 50 °C	≥300 psi
At 60 °C	≥200 psi

Lubinda

Task 2: SPST-HWTT Parallel Testing

Correlation graphs

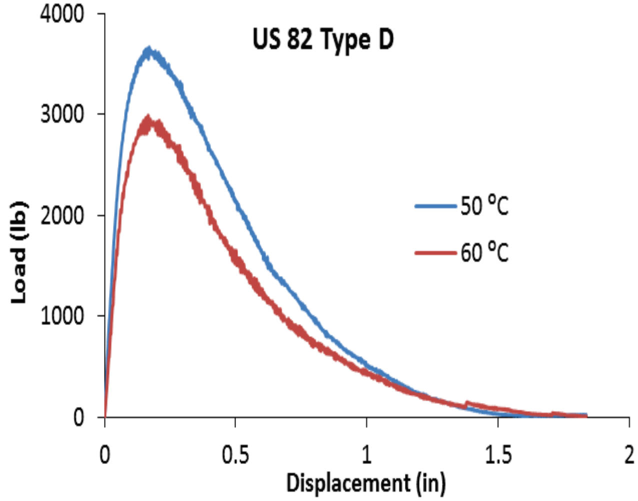




Task 2: SPST-HWTT Parallel Testing

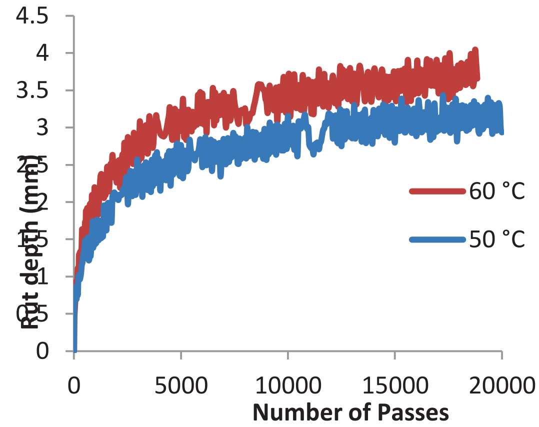
Comparison of Test Results

SPST results



Sample ID	Shear Strength (psi)		Shear Strain (in/in)		Shear Mod. (ksi)		SSE (kJ/m²)	
	50 °C	60 °C	50 °C	60 °C	50 °C	60 °C	50 °C	60 °C
S #1	325	259	0.074	0.072	4.38	3.61	34.74	25.79
S #2	324	239	0.060	0.067	5.36	3.60	32.99	25.29
S #3	292	269	0.066	0.066	4.40	4.05	27.34	23.54
Average	314	256	0.067	0.068	4.72	3.75	31.69	24.87
COV	5.96%	5.93%	10.22%	4.43%	11.90%	6.85%	12.21%	4.74%

HWTT results



Rut_{max} (mm)		Failure Cycles N_d		Rut_{Δ} (mm)		Shape Factor, SF	
50 °C	60 °C	50 °C	60 °C	50 °C	60 °C	50 °C	60 °C
3.43	4.04	20000	20000	2.71	3.23	1.577	1.599

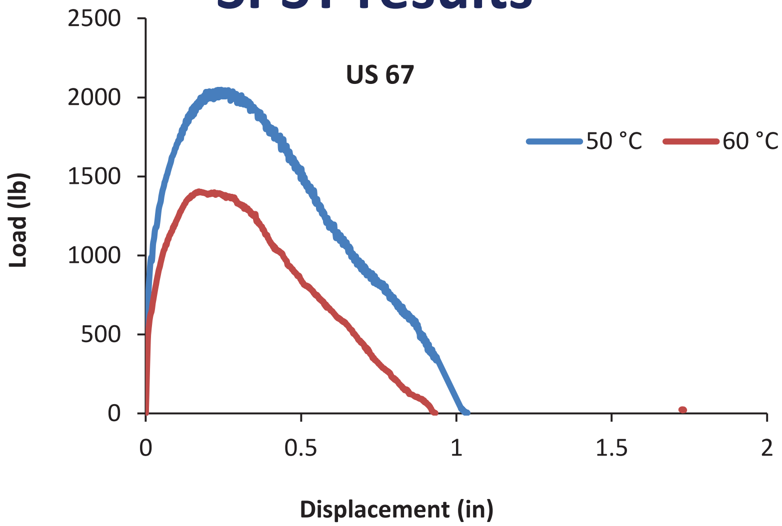
Paris Type D

Texas A&M Transportation Institute

Task 2: SPST-HWTT Parallel Testing

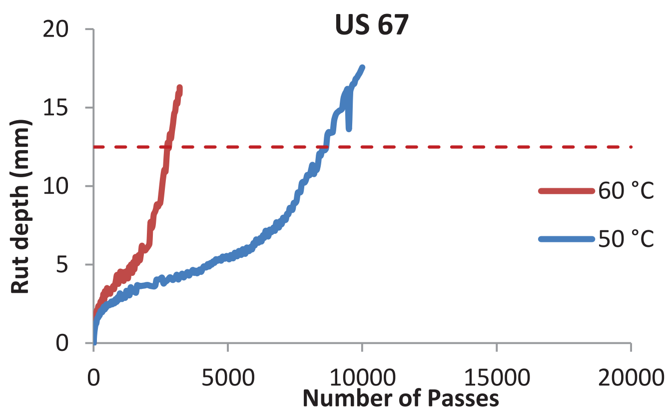
Comparison of Test Results

SPST results



Sample ID	Shear Strngth (psi)		Shear Strain (in/in)		Shear Mod. (ksi)		SSE (kJ/m²)	
	50 °C	60 °C	50 °C	60 °C	50 °C	60 °C	50 °C	60 °C
S#1	298	214	0.10	0.07	2.78	3.12	19.29	11.56
S#2	298	145	0.09	0.11	3.22	1.30	14.76	6.98
Avg	298	179	0.10	0.09	3.00	2.21	17.03	9.27
COV	*0.2%*	*27.4%*	*8.8%*	*33.2%*	*10.4%*	*57.9%*	*18.8%*	*34.9%*

HWTT results



Rut_{max} (mm)		Failure Cycles N_d		Rut_{Δ} (mm)		Shape Factor, SF	
50 °C	60 °C	50 °C	60 °C	50 °C	60 °C	50 °C	60 °C
12.5	12.5	8655	2803	5.63	5.55	0.901	0.88

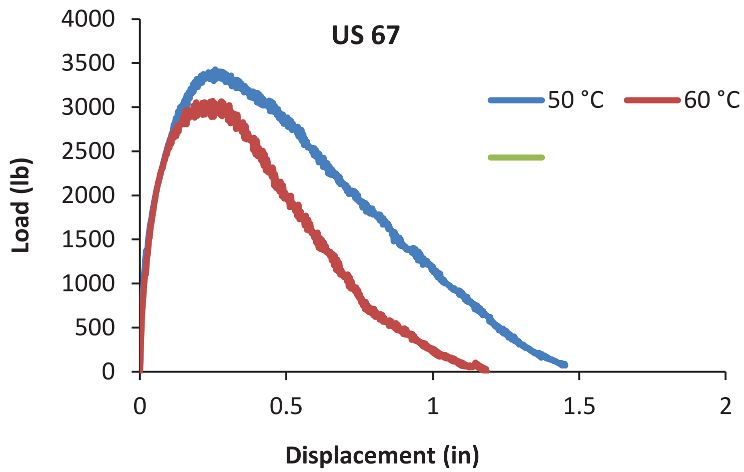
<u>Atlanta Type D</u>

Texas A&M Transportation Institute

Task 2: SPST-HWTT Parallel Testing

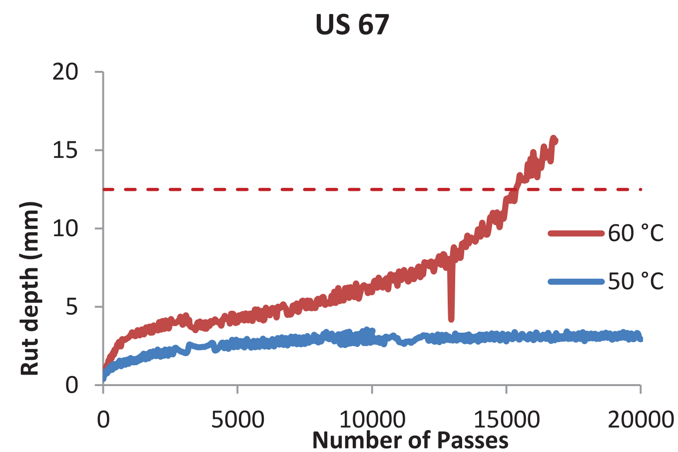
Comparison of Test Results

SPST results



Sample ID	Shear Strngth (psi)		Shear Strain (in/in)		Shear Mod. (ksi)		SSE (kJ/m^2)	
	50 °C	60 °C	50 °C	60 °C	50 °C	60 °C	50 °C	60 °C
S#1	468	332.93	0.109	0.077	4.28	4.3	50.5	21.7
S#2	410	455.94	0.103	0.11	3.98	4.3	54.09	31.4
Avg	439	394	0.106	0.092	4.135	4.307	52.307	26.541
COV	*9.4%*	*22.1%*	*4.3%*	*23.2%*	*5.1%*	*1.2%*	*4.8%*	*25.7%*

HWTT results



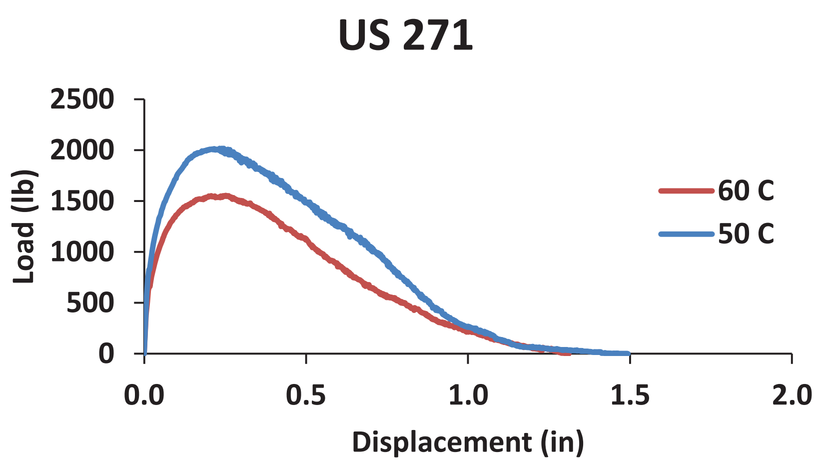
Rut_{max} (mm)		Failure Cycles N_d		Rut_{Δ} (mm)		Shape Factor, SF	
50 °C	60 °C	50 °C	60 °C	50 °C	60 °C	50 °C	60 °C
3.56	12.5	20000	15631	2.76	5.78	1.551	0.926

Atlanta Type B

Task 2: SPST-HWTT Parallel Testing

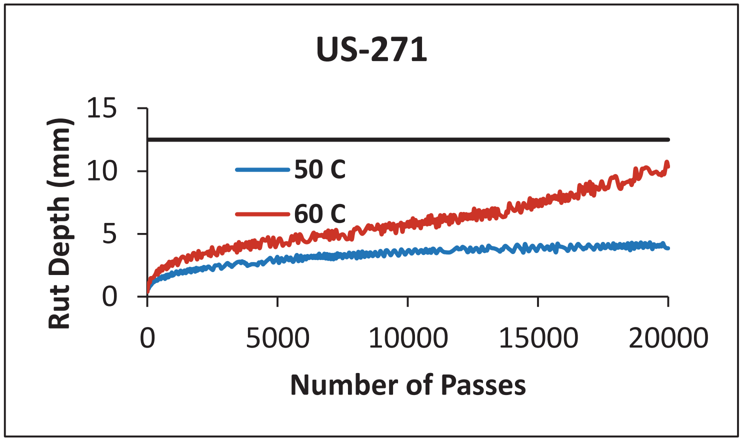
Comparison of Test Results

SPST results



Sample ID	Shear Strngth (psi)		Shear Strain (in/in)		Shear Mod. (ksi)		SSE (kJ/m2)	
	50	60	50	60	50	60	50	60
S #1	237	201	0.08	0.08	3.04	2.42	24.86	18.31
S #2	280	199	0.10	0.10	2.84	1.98	20.65	14.40
Average	258	200	0.09	0.09	2.94	2.20	22.76	16.35
COV	3.50	0.01	0.00	0.00	0.01	0.05	0.39	0.47

HWTT results



Rut_{max} (mm)		Failure Cycles N_d		Rut_{Δ} (mm)		Shape Factor, SF	
50 °C	60 °C	50 °C	60 °C	50 °C	60 °C	50 °C	60 °C
4.33	10.74	20000	20000	3.31	5.94	1.529	1.106

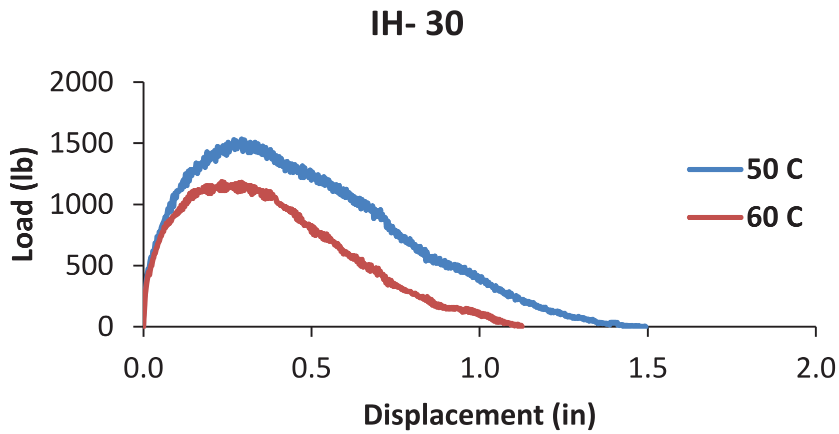
Paris US 271

Texas A&M Transportation Institute

Task 2: SPST-HWTT Parallel Testing

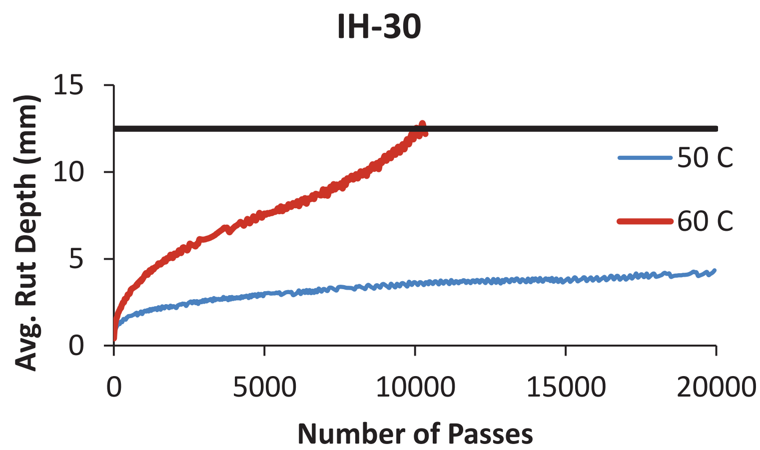
Comparison of Test Results

SPST results



Sample ID	Shear Strngth (psi)		Shear Strain (in/in)		Shear Mod. (ksi)		SSE (kJ/m2)	
	50	60	50	60	50	60	50	60
S #1	205	135	0.11	0.12	1.79	1.16	22.09	8.83
S #2	188	167	0.12	0.09	1.56	1.79	18.37	11.46
Average	197	151	0.12	0.11	1.67	1.47	20.23	10.15
COV	0.77	3.33	0.00	0.00	0.02	0.13	0.34	0.34

HWTT results



Rut_{max} (mm)		Failure Cycles N_d		Rut_{Δ} (mm)		Shape Factor, SF	
50 °C	60 °C	50 °C	60 °C	50 °C	60 °C	50 °C	60 °C
4.34	12.50	20000	10050	3.32	7.39	1.528	1.182

IH 30

Texas A&M Transportation Institute

Task 3: Field Validation of SPST

In-service Hwy Test Sections

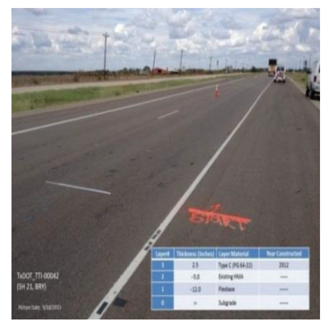
Hwy	PVMNT Type	Mix Type	Date of Construction	Climatic Region	Max PVMNT Temp.	AADTT*
US 59	Overlay-HMA-LTB	Type D	Apr '11	Wet-Cold	135.5 °F	1502
Loop 480	New Construction	Type C	Jun '12	Dry-Warm	145.5 °F	60
SH 121	Overlay-HMA-CTB	CAM	Oct '11	Wet-Cold	137.5 °F	468
SH 21	Overlay-HMA-FB	Type C	Jul '12	Wet-Warm	127.5 °F	560
IH 35	New Construction	Type B	Oct '11	Moderate	131.3 °F	53

*** AADTT = Average Annual Daily Truck Traffic**


US 59


Loop 480


SH 121


SH 21


IH 35

Task 3: Field Validation of SPST

New In-service Hwy Test Sections

Hwy	PVMNT Type	Mix Type	Date of Construction	Climatic Region	Max PVMNT Temp.	AADTT*
US 83	Overlay-HMA-PCC	Type C	Aug, 2012	Wet-Cold	104.43 °F	110
US 271	Overlay-HMA-FlexBase	Type F	Nov, 2011	Wet-Cold	77 °F	418
SH 44	Overlay-HMA-FlexBase	Type D	Jun, 2014	Moderate	87.17 °F	342
SH 304	New Construction	Type C	Oct, 2014	Moderate	93.67 °F	209

* AADTT = Average Annual Daily Truck Traffic

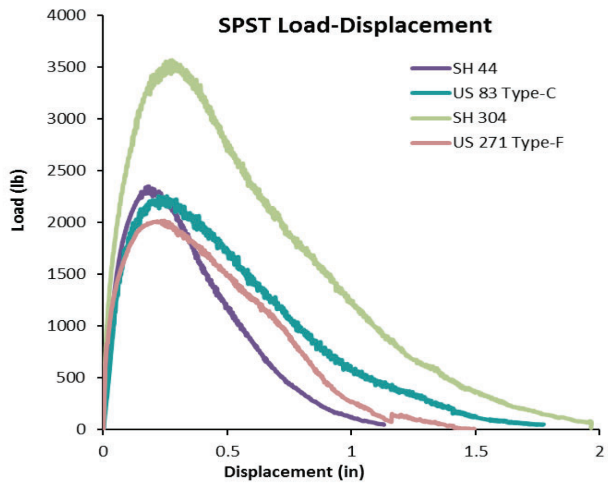
US 83

US 271

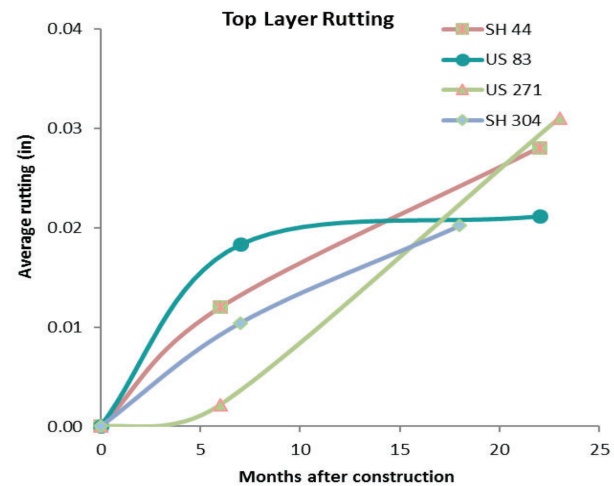
SH 44

SH 304

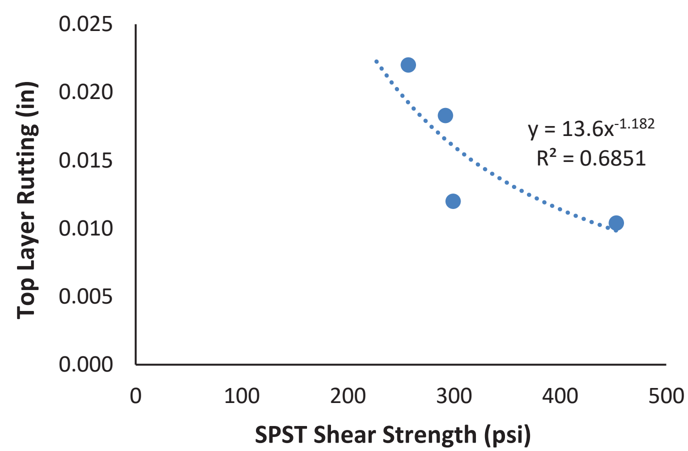
Task 3: Field Validation of SPST



SPST Load-Displacement Response of the Mixes



Field Rutting Performance of the Mixes

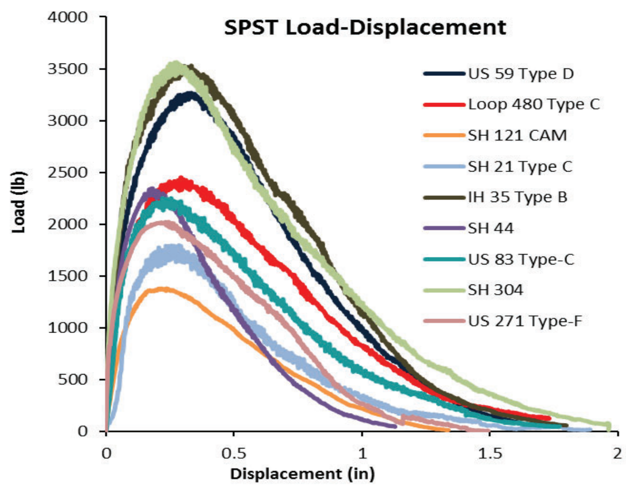


SPST-Field Performance Correlation

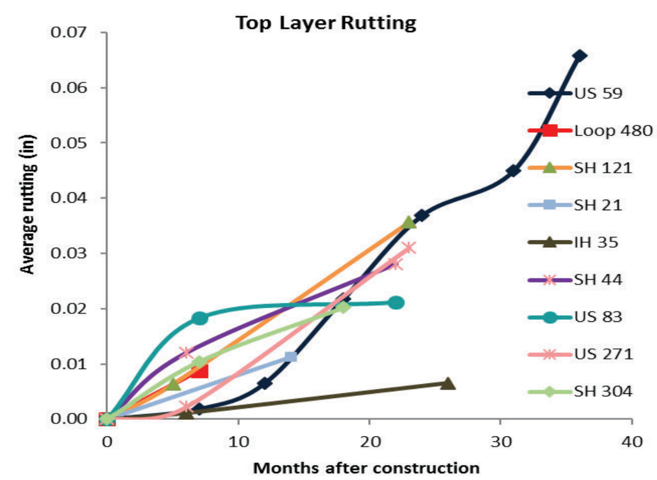
Lubinda

Task 3: Field Validation of SPST

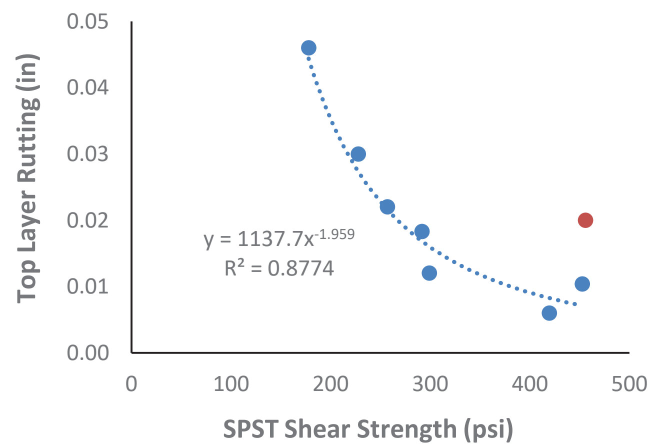
Combined



SPST Load-Displacement Response of the Mixes



Field Rutting Performance of the Mixes



SPST-Field Performance Correlation

Lubinda

Task 3: Field Validation of SPST

- Measured Total and Estimated Surface Rut Depth
  - As of 2018 none of the highways failed under rutting

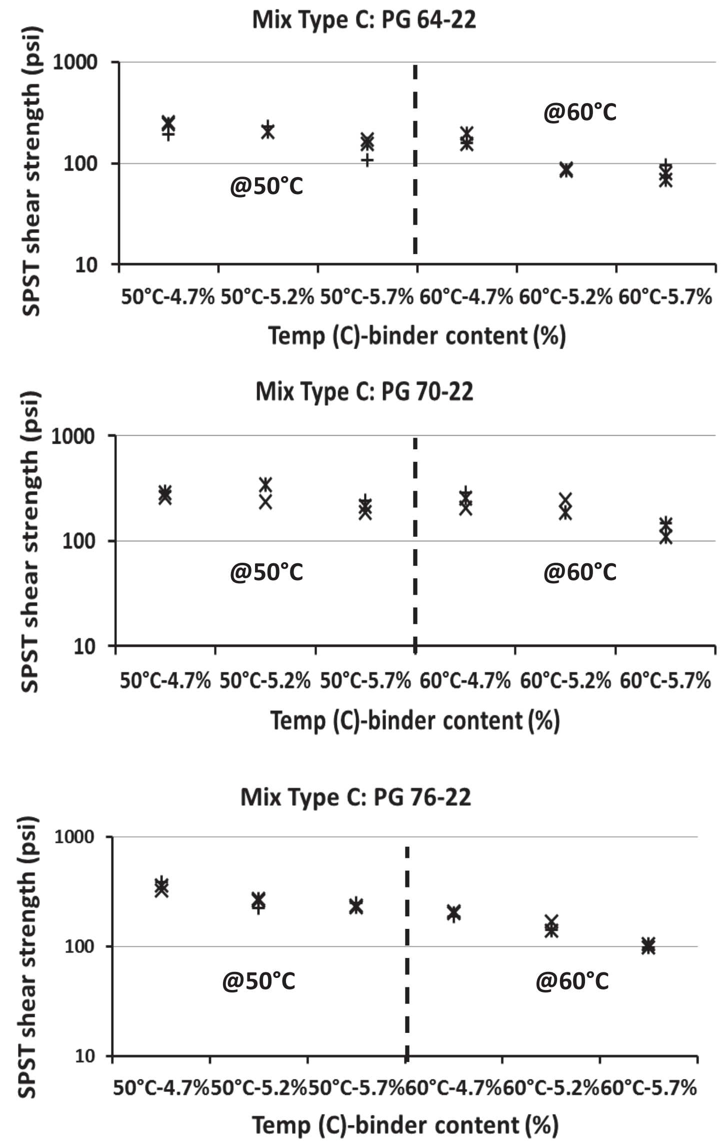
Highway	Mix Type	SPST Shear Strength (psi)	Measured Total Rut Depth (in.)	Conversion Factors from TxME	Estimated Surface Layer Rut Depth (in.)
US 59	Type D	420	0.20	0.190	0.04
LP 480	Type C	321	0.18	0.022	0.03
SH 121	CAM	178	0.11	0.818	0.09
SH 304	Type C	456	0.02	0.400	0.01
SH 21	Type C	228	0.13	0.692	0.09
US 83	Type C	292	0.11	0.547	0.06
IH 35	Type B	453	0.07	0.286	0.02
SH44	Type D	292	0.13	0.615	0.08
US271	Type F	257	0.03	1.000	0.03

@ 50 C

Task 4: Data Analysis

Sensitivity Analysis of the SPST-HWTT

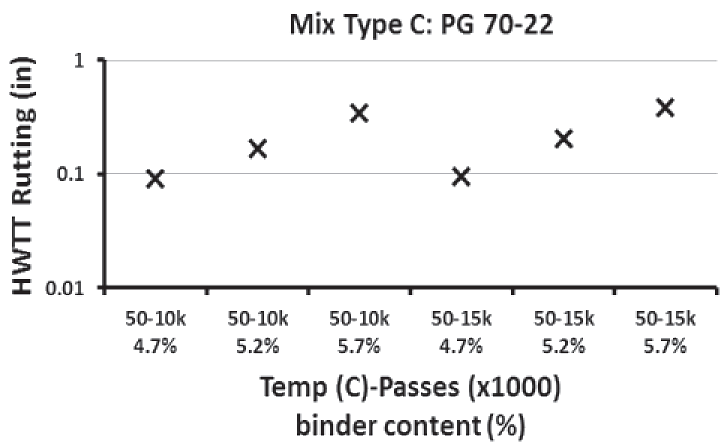
- ❑ SPST vs. Asphalt Contents
  - AC 4.7%
  - AC 5.2%
  - AC 5.7%
- ❑ Increased asphalt content has a negative effect on the SPST shear strength at 50°C and 60°C
- ❑ At the same binder content, shear strength reduce with temperature



Task 4: Data Analysis

Sensitivity Analysis of the SPST-HWTT

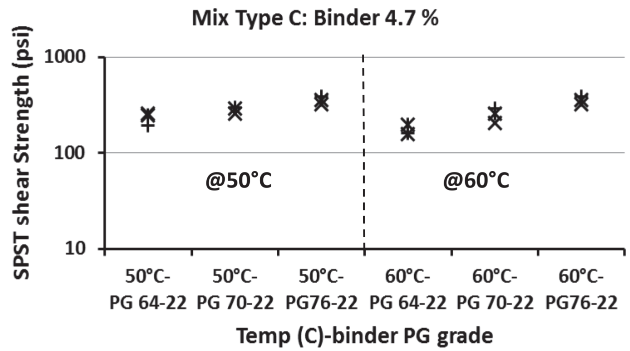
- ❑ HWTT vs. Asphalt Contents
  - AC 4.7%
  - AC 5.2%
  - AC 5.7%
- ❑ HWTT rutting increased with increased asphalt content as expected

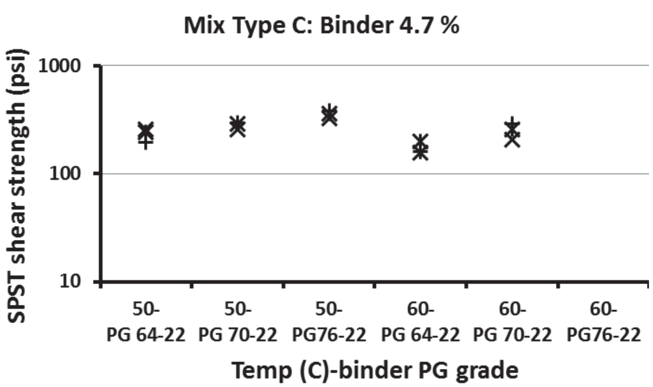


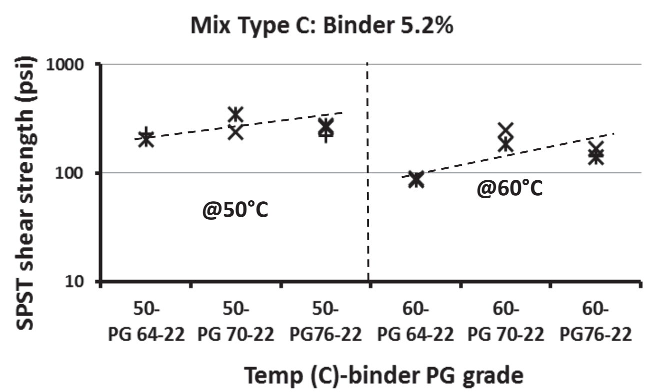
Task 4: Data Analysis

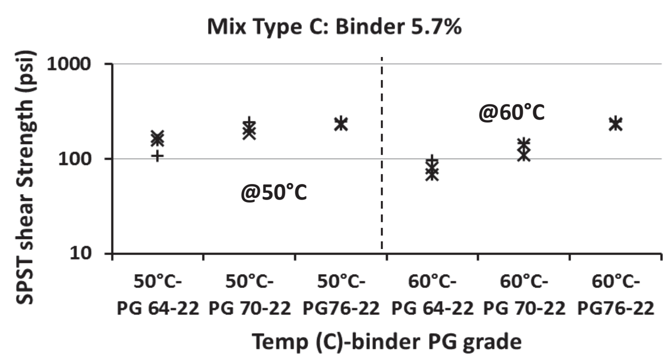
Sensitivity Analysis of the SPST-HWTT

- SPST vs. asphalt grade
  - PG 64-22
  - PG 70-
  - PG 76-
- HMA she
  with high





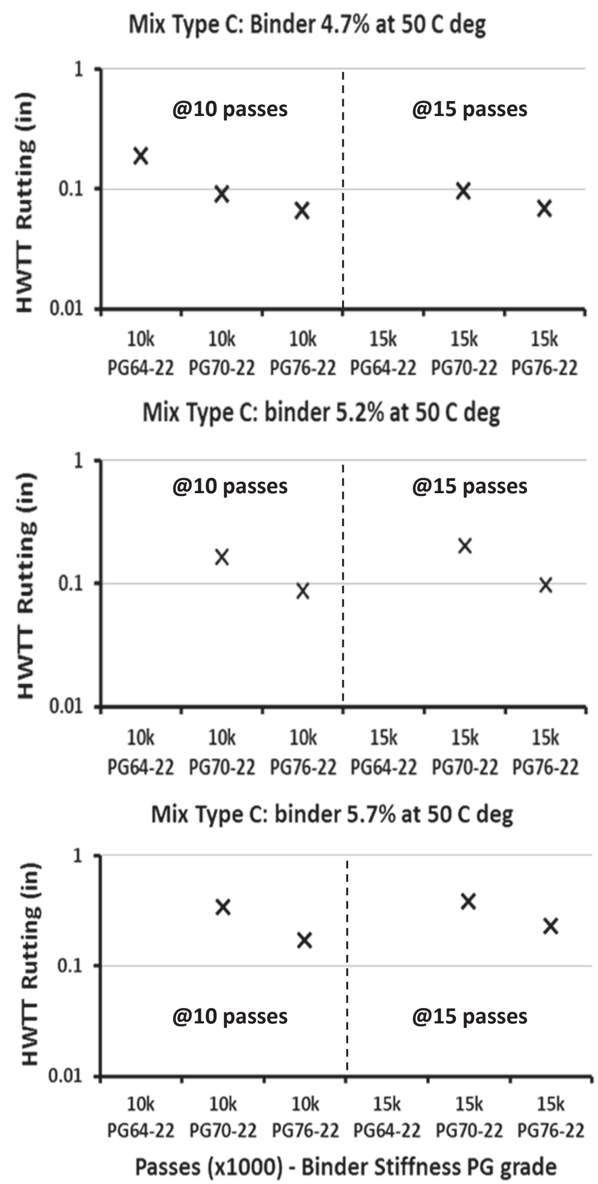




Task 4: Data Analysis

Sensitivity Analysis of the SPST-HWTT

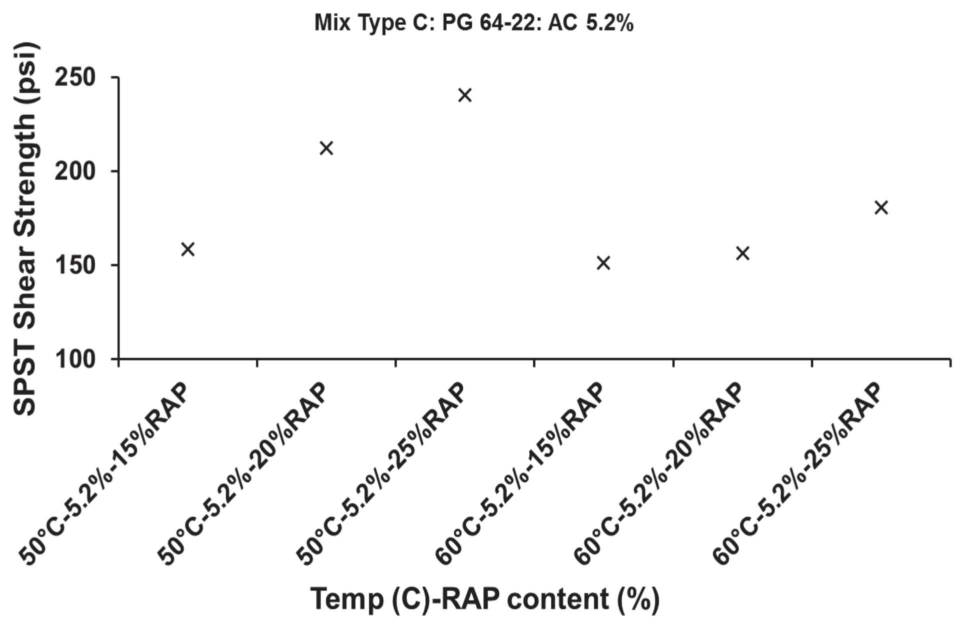
- ❑ HWTT vs. asphalt grade
  - PG 64-22
  - PG 70-22
  - PG 76-22
- ❑ HWTT rutting decreased with higher asphalt grade



Task 4: Data Analysis

Sensitivity Analysis of the SPST-HWTT

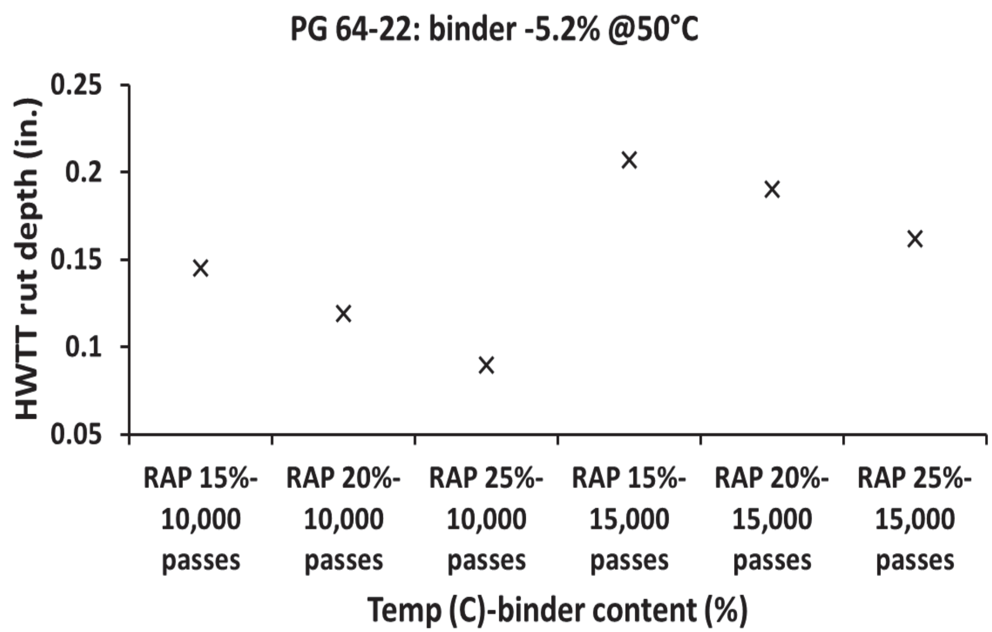
- SPST vs. RAP Contents
  - RAP 15%
  - RAP 20%
  - RAP 25%
- Increased RAP content improved shear strength of HMA mixtures @50°C & 60°C
- HMA shear strength increased with increased RAP%



Task 4: Data Analysis

Sensitivity Analysis of the SPST-HWTT

- HWTT vs. RAP Contents
  - RAP 15%
  - RAP 20%
  - RAP 25%
- Increased RAP content improved rut resistance of the HMA mixtures
- HWTT rut decreased with increased RAP%



Task 4: Data Analysis

Comparison of SPST-HWTT Tests

- ❑ SPST is relatively
  - ❑ Simple to operate—but requires UTM or MTS setup
    - No cutting test specimens
    - No carrying of heavy wheel arm (158 lb)!
  - ❑ Fast to run
    - Can provide quick results with little interruption to work
  - ❑ Cost effective and time efficient
    - 20 min. for PSPT vs. 7 hr. for HWTT

Raised by push of a button

Manually raised

Lubinda

Task 4: Data Analysis

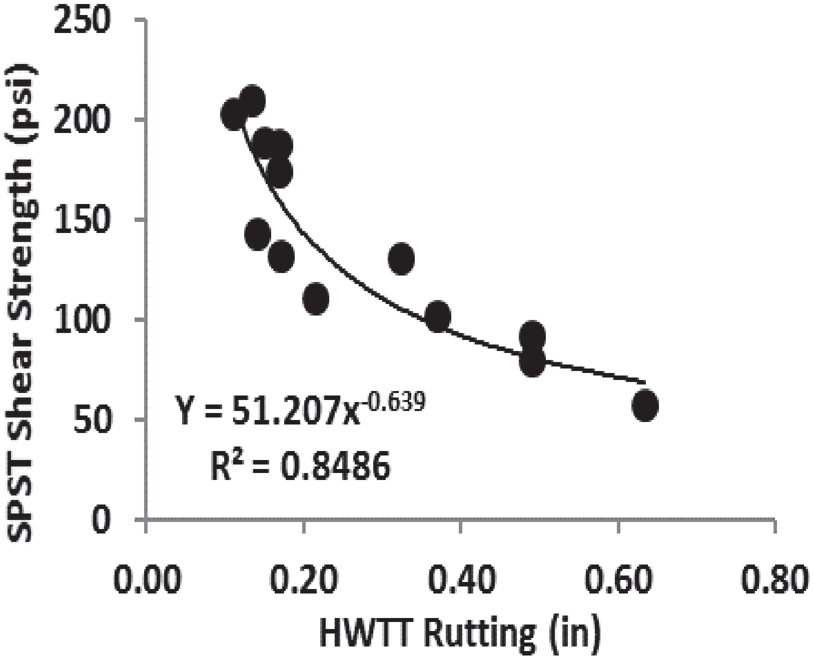
SPST Variability: COV < 30%

Mix	SPST shear strength									
	50°C					60°C				
	1	2	3	AVG	CV	1	2	3	AVG	CV
Type C (FM 1887)	296	349	351	332	**8%**	213	224	244	227	**6%**
Type D (FM 2100)	222	223	188	211	**8%**	217	217	187	207	**7%**
Type B (APT)	304	296		300	**1%**	223	229	235	229	**2%**
Type C (SH304)	261	244	278	261	**5%**	207	224	214	215	**3%**
Type C/ PG64-22/4.7%	255	244	193	231	**12%**	158	198	161	172	**11%**
Type C/ PG64-22/5.2%		204	231	217	**6%**	89	86		87	**2%**
Type C/ PG64-22/5.7%	173	157	107	146	**19%**	80	68	96	81	**14%**
Type C/ PG70-22/4.7%	259	289	294	281	**5%**	207	256	289	251	**13%**
Type C/ PG70-22/5.2%	236	345		291	**19%**	245	185		215	**14%**
Type C/ PG70-22/5.7%	185	212	241	213	**11%**	141	110	147	133	**12%**
Type C/ PG76-22/4.7%	324	356	383	355	**7%**	207	202	186	198	**4%**
Type C/ PG76-22/5.2%	313	308	292	304	**3%**	228	239	142	203	**21%**
Type C/ PG76-22/5.7%	234	229	248	237	**3%**	97	104	98	100	**3%**
Type D/PG64-22/4.5% / Chico	189	266	268	241	**15%**	270	234	238	247	**6%**
Type D/PG64-22/5% / Chico	185	213	212	203	**6%**	200	197	170	189	**7%**
Type D/PG64-22/5.5% / Chico	162	150	158	157	**3%**	-	-	-	-	**-**
Type D/PG70-22/4.5% / Chico	265	240	271	259	**5%**	200	228	247	225	**9%**
Type D/PG70-22/5% / Chico	203	228	239	223	**7%**	184	208	223	205	**8%**
Type D/PG70-22/5.5% / Chico	196	200	203	200	**1%**	151	176	184	170	**8%**
Rap/ PG 64-22/ 15% / Laredo	152	166		159	**5%**	149	152	153	151	**1%**
Rap/ PG 64-22/ 20% / Laredo	295	226	199	240	**17%**	157	138		147	**6%**
Rap/ PG 64-22/ 25% / Laredo	239	243		241	**1%**	160	183	199	181	**9%**
Type D/PG76-22/4.5%/Chico	303	280	318	300	**5%**	272	300	272	281	**5%**
Type D/PG76-22/5%/Chico	296	302	306	301	**1%**	180	268	239	229	**16%**
Type D/PG76-22/5.5% /Chico	198	253	220	224	**10%**	219	200	163	194	**12%**

Task 4: Data Analysis

SPST-HWTT Correlations

- Comparison of SPST shear strength and HWTT rutting



Summary and Conclusions

- Sensitivity analysis
- Implementation and field validation
- Key findings and conclusions

Sensitivity Analysis

- Parallel SPST-HWTT testing was conducted to evaluate the SPST sensitivity to HMA mixture-design variables.
- HMA shear strength at 50°C is higher than one at 60°C for the same asphalt-binder content.
- HMA rut depth from the HWTT tests increased with increasing asphalt-binder content as expected.
- The SPST is fairly repeatable (CV< 30%).
- The SPST shear strength produced better correlation with HWTT and field data than other SPST output.

Implementation and Field Validation

- The validation was performed using 9 highway test sections determined by pavement type, surface HMA mixture, climate, and traffic volume.
- The TxME software was used to estimate the surface layer rutting from the measured total field rut depth.
- The SPST shear strength versus the field rut depths produced a fairly good correlation.
- SPST implementation—assisted various districts (ATL, BRY, LRD, PHR, etc.) for their routine mix-design.

Key Findings and Conclusions

1) HWTT: consider running at multiple temperatures for surface HMA mixes to be used in high-temperature high shear-stress environments

2) SPST: ideal for evaluating HMA shear properties of surface HMA mixes as a surrogate and/or supplement to HWTT for high-temperature high shear-stress environments

3) Recommended SPST pass-fail screening criteria:

$$HMA\ Shear\ Strength\ (\tau) \geq \begin{cases} 300\ psi\ at\ 50℃ \\ 200\ psi\ at\ 60℃ \end{cases}$$

End

- Discussions
- Contributions
- Comments