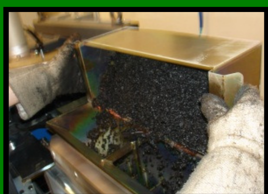
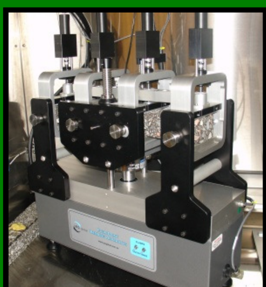
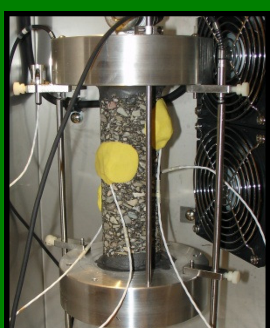
AHSRC Highway Sustainability Research Center

Innovative Research in Asphalt Pavements







Performance Characteristics of Asphalt Mixtures Incorporating Treated Ground Tire Rubber Added During the Mixing Process

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NEAUPG
North East Asphalt User/Producer Group

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Treated GTR

- Several researchers have treated GTR with additives that will allow the GTR when added during the mixing process at lower temperatures compared to the wet process to form the same viscous gel that is formed during the wet process.

Potential Benefits of Using Treated GTR

- If the dry process can provide the same benefits as the wet process, more GTR can be used as it will eliminate the need for the GTR to be added through special equipment or terminal blending.

- This might encourage more asphalt mixture producers to incorporate GTR in their mixtures.

Project Scope

The main objective of this study was to evaluate and compare the effects of <u>two treated GTR</u> that can be <u>added during the mixing process</u> (dry process) versus adding the GTR untreated to the asphalt binder (wet process) on the performance of a <u>dense graded and a gap graded mixtures</u>.

Project Scope

Untreated GTR

Treated GTR

Added to Binder
(Wet Process)

Two Types of Mixtures

Dense Graded Mixture

Gap Graded Mixture

Added to Mixture During Mixing
(Dry Process)

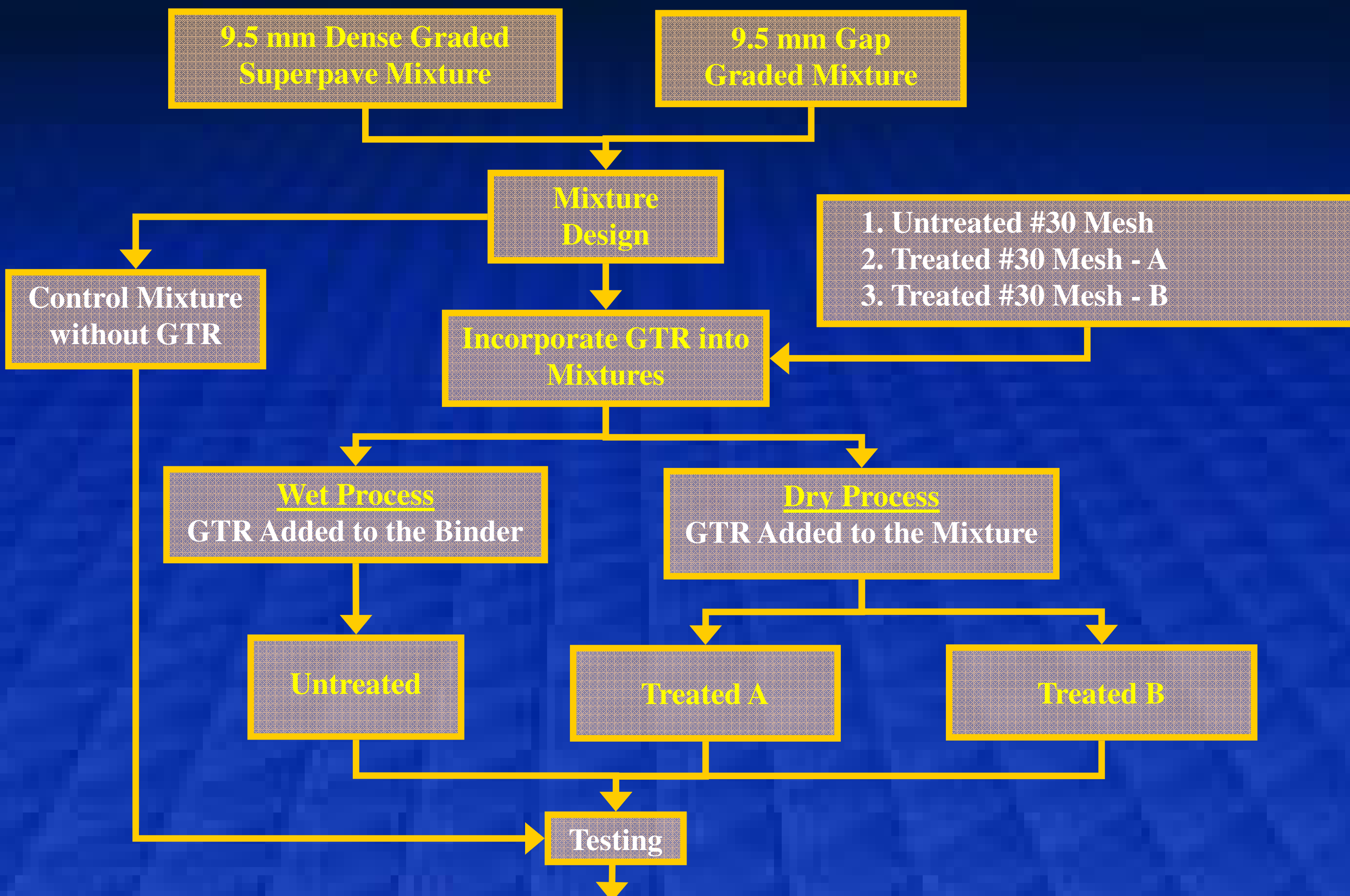
Project Objectives

1. Design a 9.5 mm Superpave and a 9.5 mm gap graded asphalt mixture using GTR modified asphalt binder.

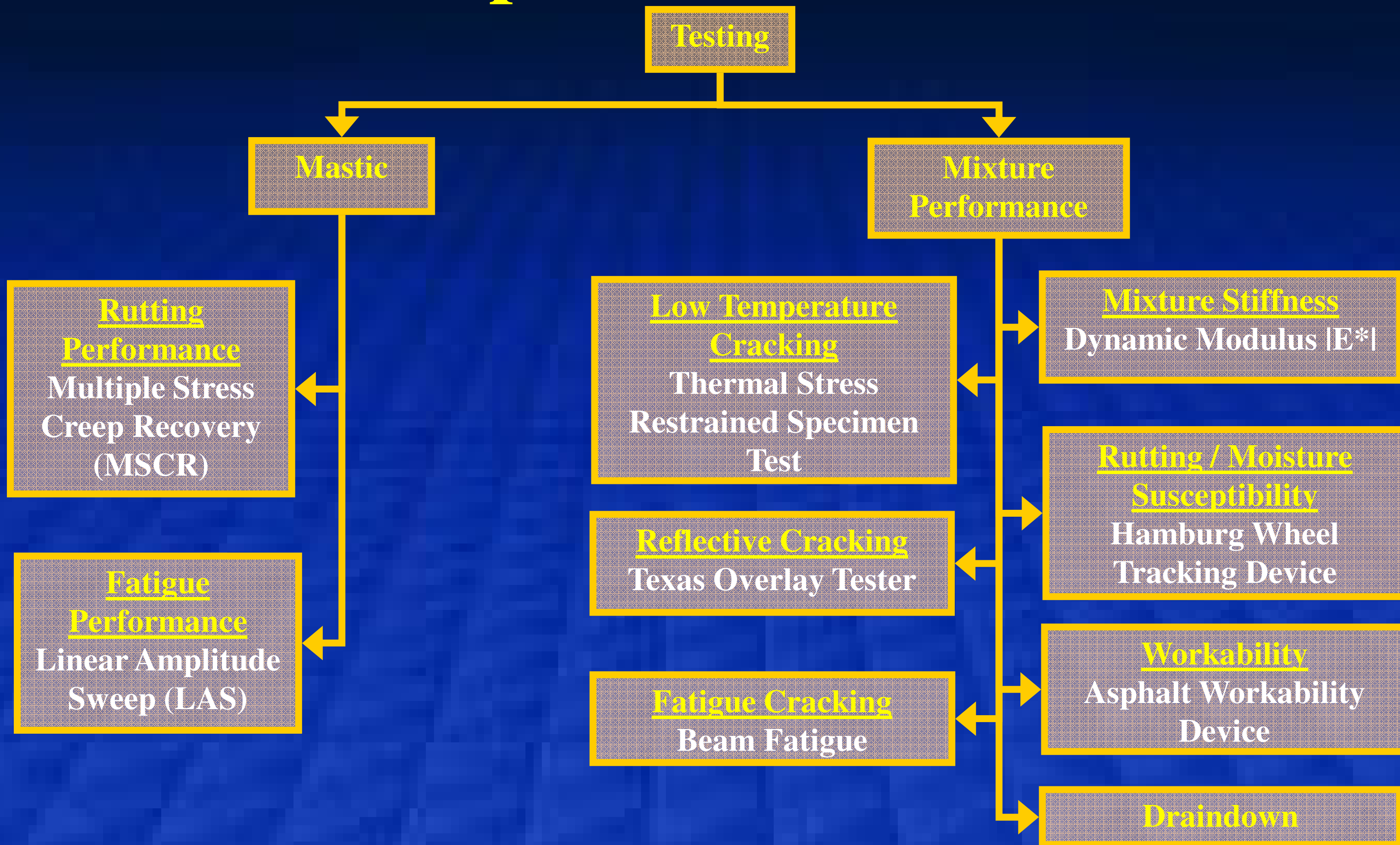
2. Redesign the same two mixtures using two types of treated GTR added during the mixing process.

3. Determine the effect of using the GTR in a wet process versus adding treated GTR in a dry process on the mixture stiffness, performance (rutting, moisture damage, low temperature cracking, reflective cracking, and fatigue cracking), mixture workability and draindown characteristics.

Experimental Plan



Experimental Plan



GTR Asphalt Binder (Wet Process)

- GTR asphalt binder was prepared in the laboratory using a wet process by blending a PG58-28 virgin binder with 10% untreated #30 mesh GTR.
- The virgin binder and GTR were blended using a Silverson L4RT-W bench top laboratory high shear mixer.
- The virgin binder was heated to 374ºF (190ºC). Once at temperature, mixing was commenced with the shear mixer at a speed of 5000 RPM.

GTR Asphalt Binder (Wet Process)

➔ The mixing of the virgin binder and GTR continued for 90 minutes at 374ºF (190ºC) after all the GTR was added.

➔ The mixing temperature and time utilized were sufficient to ensure that the G* of the binder reached an almost constant value. This was considered to be a sign of complete reaction between the rubber particles and the binder.

Treated GTR

- The untreated Liberty Tire Recycling #30 mesh GTR was sent to two different research groups (Sonneborn LLC and Polymer Consultants Inc.) who then treated the GTR.

- This yielded two distinct treated GTR to be incorporated into the mixture through a dry process.

  Sonneborn LLC = Treated GTR A
  Polymer Consultants Inc= Treated GTR B

Mixture Designs

- Two mixture designs completed.
- <u>9.5mm dense graded</u> mixture conformed to AASHTO M323 and R35.
- <u>9.5mm gap graded</u> mixture conformed to RIDOT Paver Placed Elastomeric Surface Treatment specification.
- Mixtures were designed first by utilizing the wet process GTR asphalt binder.

Mixture Designs

- ➔ Each mixture was then redesigned using each of the treated GTR incorporated using a dry process.
- ➔ Finally, for comparison purposes, mixtures without GTR (control) were prepared using the optimum binder content obtained during the GTR mixture designs.
- ➔ Design ESALs = 0.3 to < 3 million
- ➔ Ndesign = 75 gyration

Mixing and Compaction Temperatures

➔ **Rubberized Asphalt Mixtures (Wet Process)**

Mixing: 351ºF (177ºC), Compaction: 326ºF (163ºC). ***These temperatures were utilized for similar asphalt rubber mixtures placed in Massachusetts.***

➔ **Treated GTR Mixtures (Dry Process)**

Mixing: 326ºF (163ºC), compaction 302ºF (150ºC).
Temperatures based on polymer modified asphalt mixtures.

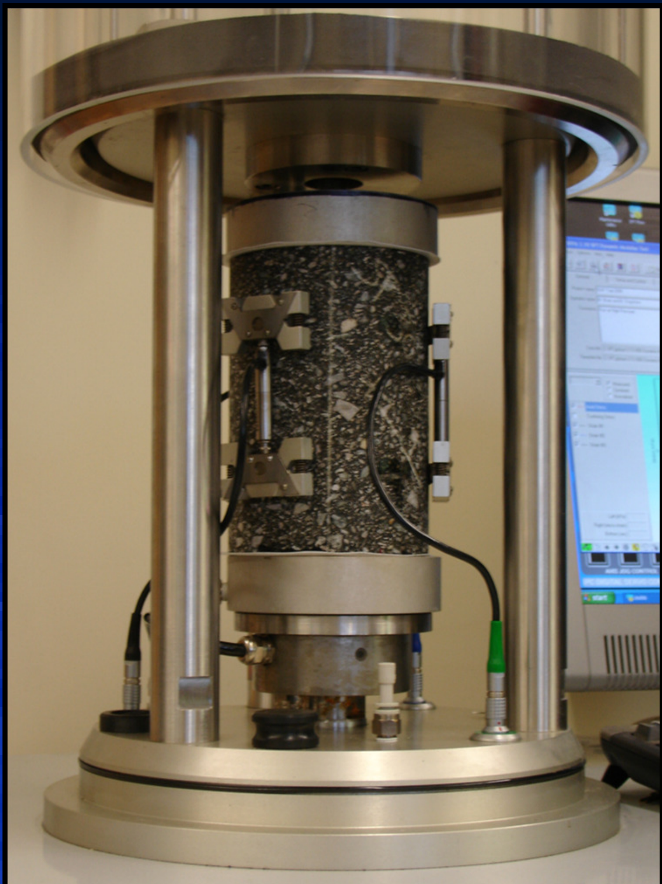
➔ **Control Mixtures**

PG58-28 binder only. Mixing: 150ºC (300ºF), Compaction: 138ºC (280ºF).
Temperatures were based on the viscosity of the binder.

Mixture Design

Sieve Size	9.5 mm Superpave Dense Graded	9.5 mm Superpave Specification	9.5 mm Gap Graded	9.5 mm Gap Graded Specification
12.5 mm	100.0	100 min	100	100
9.5 mm	97.1	90-100	92.4	91-95
4.75 mm (No. 4)	66.8	90 max	44.2	40-45
2.36 mm (No. 8)	47.8	32-67	25.9	22-26
1.18 mm (No. 16)	33.5	-	17.3	-
0.600 mm (No. 30)	23.0	-	12.0	9-12
0.300 mm (No. 50)	13.3	-	8.0	6-8
0.150 mm (No. 100)	7.1	-	6.1	-
0.075 mm (No. 200)	4.4	2-10	4.0	4.0
Binder Content, %	6.0%	-	7.5%	6.0% Min.

Mixture Stiffness - Dynamic Modulus



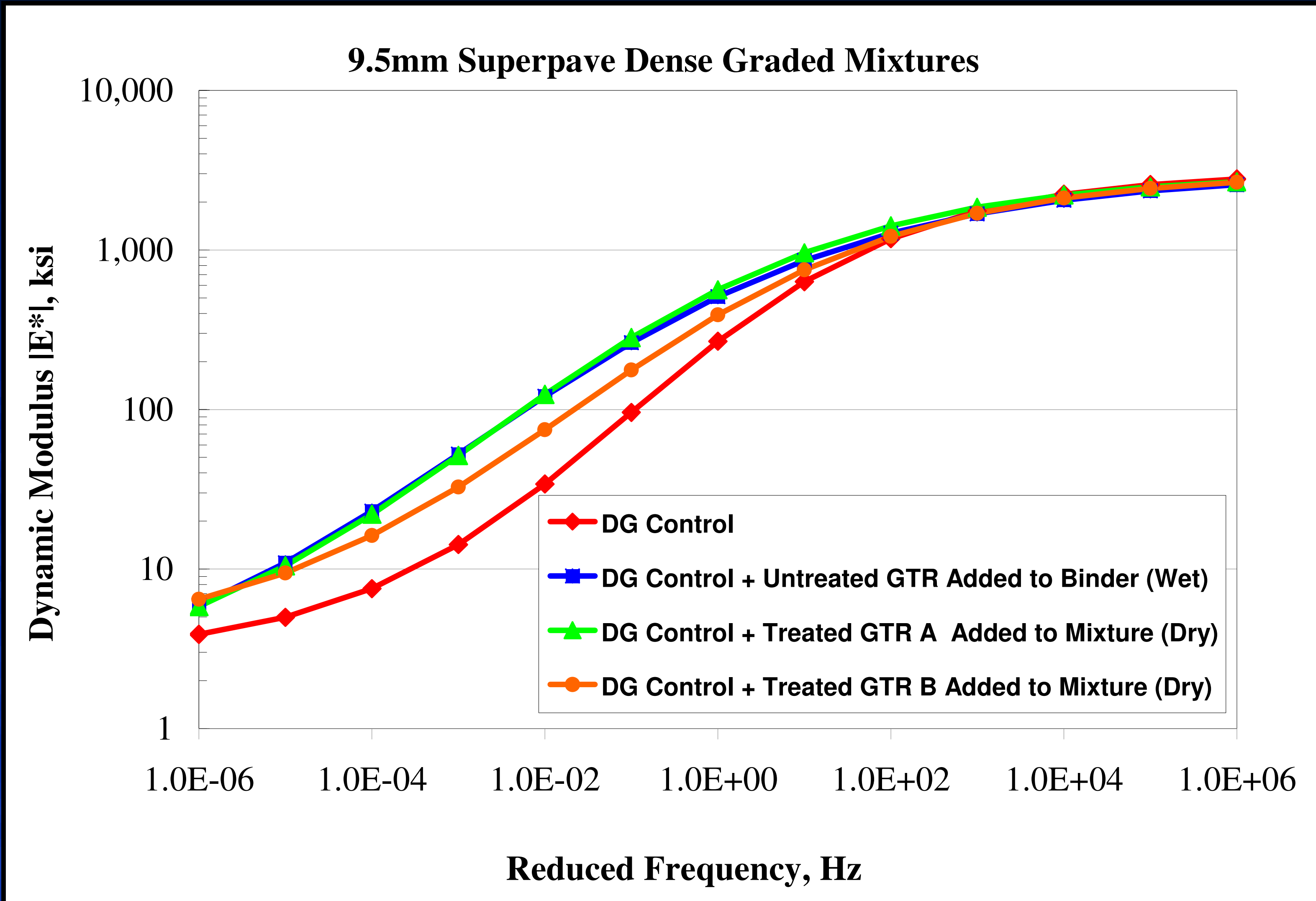
AASHTO TP62 in Asphalt Mixture Performance Tester (AMPT)

Conducted to determine changes in mixture stiffness due to wet and dry process GTR utilized.

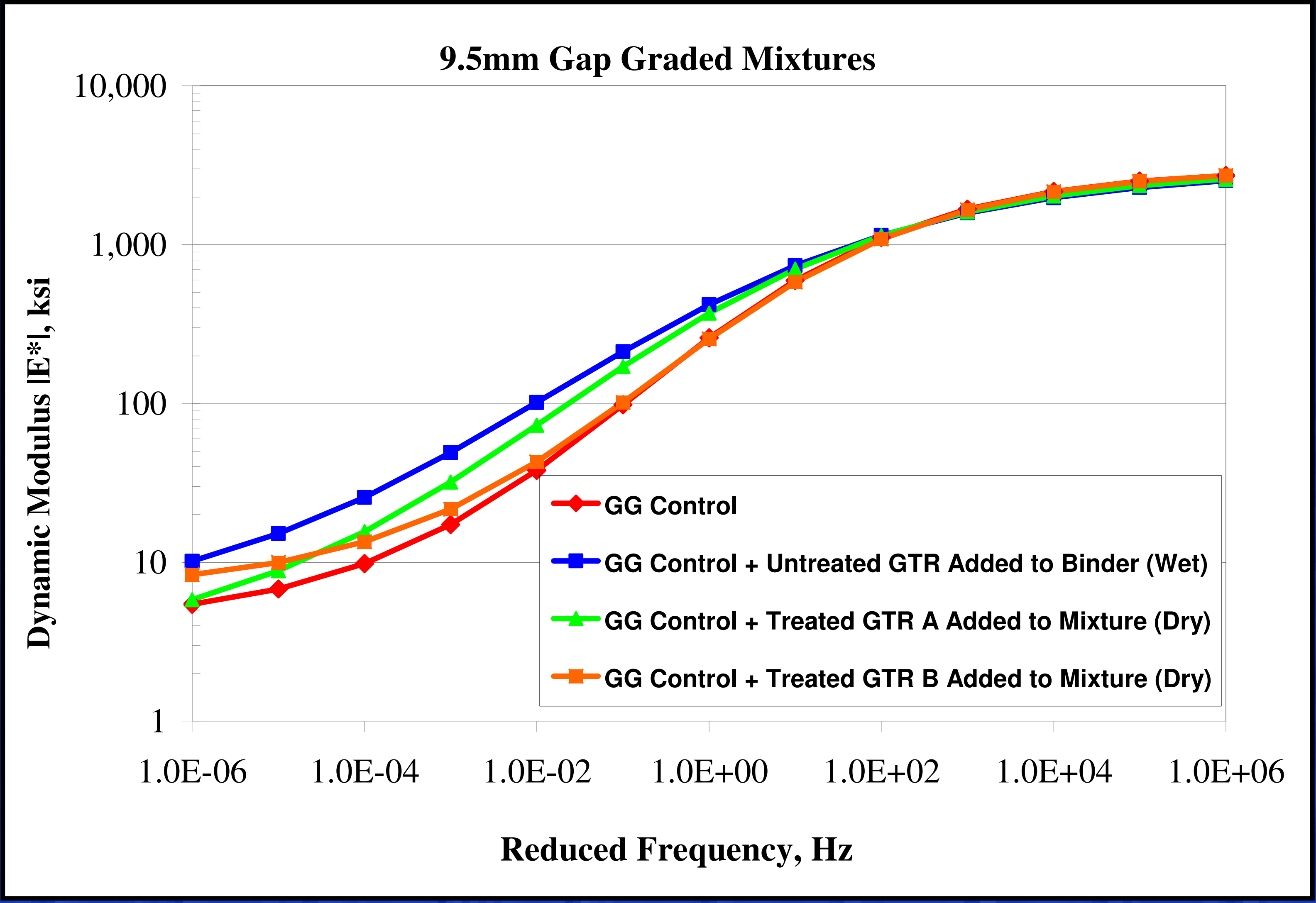
Temperature	Frequency
4°C	10 Hz, 1Hz, 0.1Hz
20°C	10 Hz, 1Hz, 0.1Hz
40°C	10 Hz, 1Hz, 0.1Hz, 0.01Hz

Specimens were fabricated at a target air void level of 7.0 ± 1.0%.

Mixture Master Curves – Dense Graded



Mixture Master Curves – Gap Graded



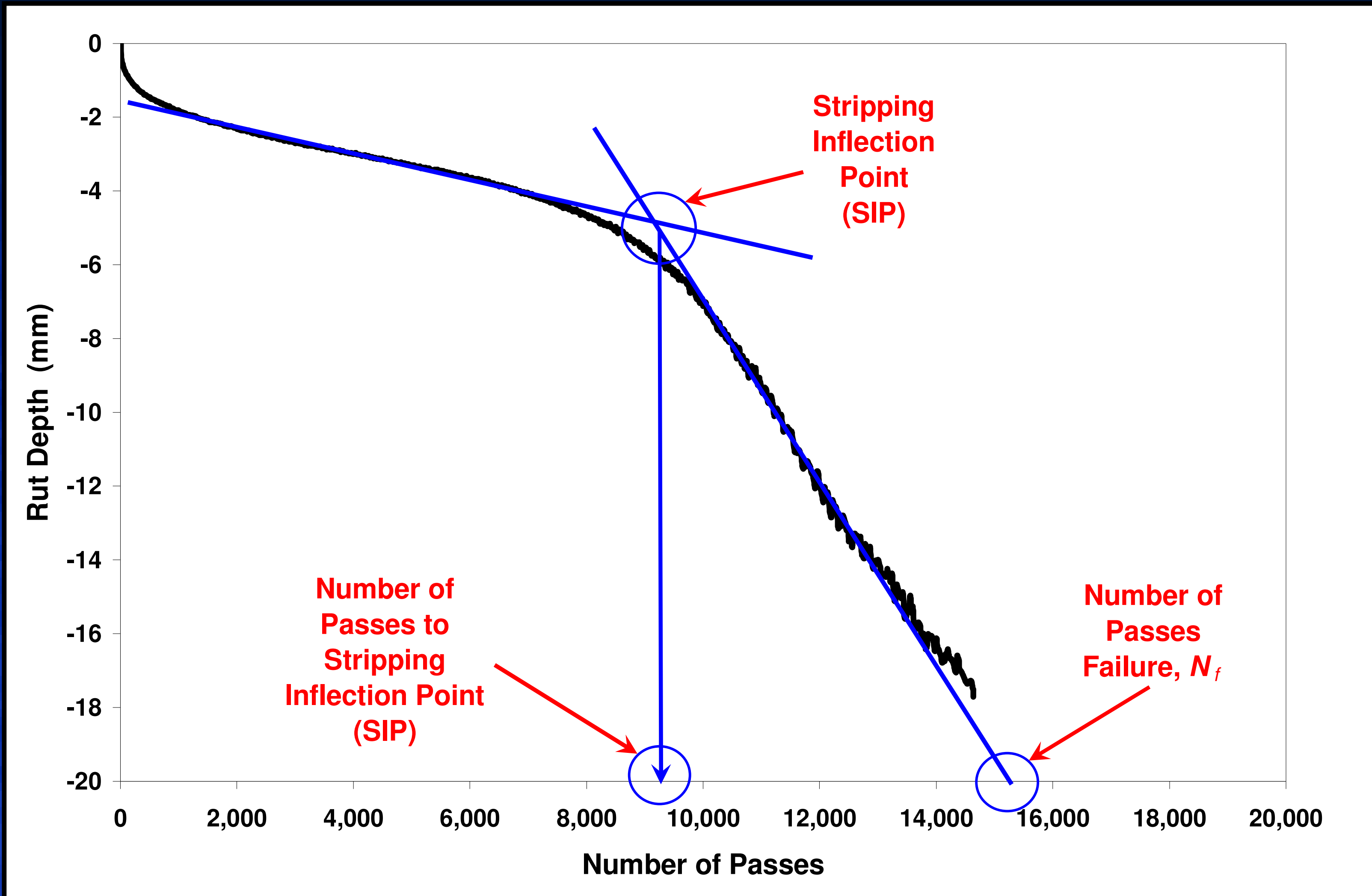
Mixture Stiffness - Discussion

- The control mixture had the lowest stiffness.
- Generally, wet process mixtures yielded the highest increase in stiffness at all testing temperatures relative to the control mixtures with no GTR.

Rutting/Moisture Susceptibility - Hamburg Wheel Tracking Device (HWTD)

- HWTD testing conducted in accordance with AASHTO T324
- Water temperature of 50ºC (122ºF)
- Test duration of 20,000 cycles

Stripping Inflection Point (SIP)



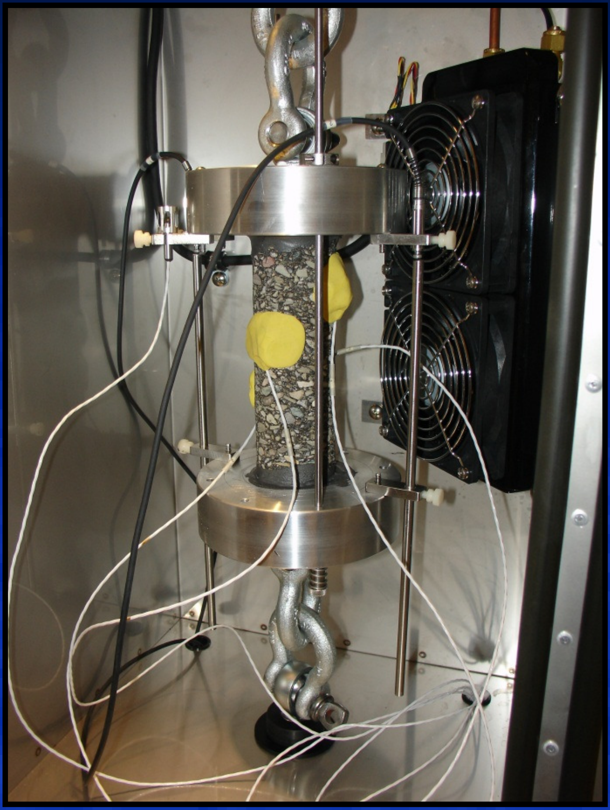
Rutting/Moisture Susceptibility –Results

Dense Graded Mixtures	GTR Introduction Method	Stripping Inflection Point	Rut Depth at 10,000 Passes (mm)	Rut Depth at 20,000 Passes (mm)
DG Control	n/a	5,300	>20	>20
DG Control + Untreated GTR (Wet)	Added to Binder	NONE	0.70	0.85
DG Control + Treated GTR A (Dry)	Added to Mixture	NONE	1.22	2.00
DG Control + Treated GTR B (Dry)	Added to Mixture	NONE	1.60	2.76
Gap Graded Mixtures	**GTR Introduction Method**	**Stripping Inflection Point**	**Rut Depth at 10,000 Passes (mm)**	**Rut Depth at 20,000 Passes (mm)**
GG Control	n/a	3,100	>20	>20
GG Control + Untreated GTR (Wet)	Added to Binder	NONE	1.76	2.31
GG Control + Treated GTR A (Dry)	Added to Mixture	14,750	2.93	>20
GG Control + Treated GTR B (Dry)	Added to Mixture	16,400	3.35	9.01

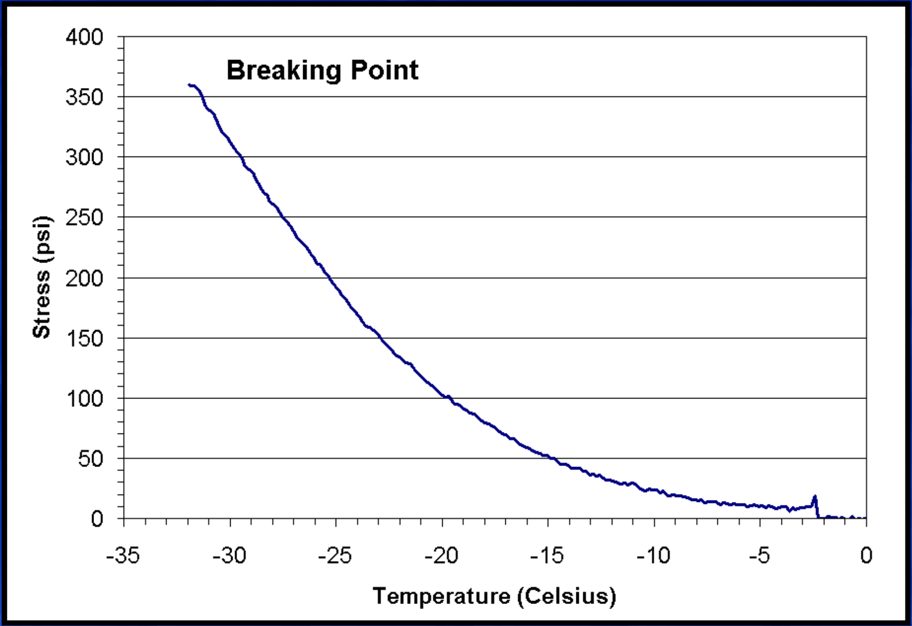
Rutting/Moisture Susceptibility - Discussion

- For dense graded mixtures, the wet and dry process GTR mixtures passed the test.
- For gap graded mixtures, the wet process mixture was more effective in improving the moisture and rutting resistance and as compared to the dry process treated GTR mixtures.

Mixture Low Temperature Cracking - TSRST



- Cooling Rate of -10ºC/hour
- Testing in accordance with AASHTO TP10-93



TSRST Low Temperature Results

Dense Graded Mixtures	GTR Introduction Method	TSRST Specimen Temperature at Failure, ºC
DG Control	n/a	-24.3
DG Control + Untreated GTR (Wet)	Added to Binder	-28.7
DG Control + Treated GTR A (Dry)	Added to Mixture	-26.8
DG Control + Treated GTR B (Dry)	Added to Mixture	-29.3
Gap Graded Mixtures	**GTR Introduction Method**	**TSRST Specimen Temperature at Failure, ºC**
GG Control	n/a	-24.3
GG Control + Untreated GTR (Wet)	Added to Binder	-28.0
GG Control + Treated GTR A (Dry)	Added to Mixture	-25.2
GG Control + Treated GTR B (Dry)	Added to Mixture	-28.5

TSRST Low Temperature Discussion

- The wet process mixtures low cracking temperatures were significantly colder than those for the control and Treated GTR A mixtures.
- The wet process and Treated GTR B mixtures were not significantly different. This indicates that the wet and dry process could be comparable.

Reflective Cracking - Overlay Tester

- Test Temperature = 15ºC (59ºF)
- Test Termination at 2,000 cycles or 93% Load reduction
- Testing in accordance with Tex-248-F

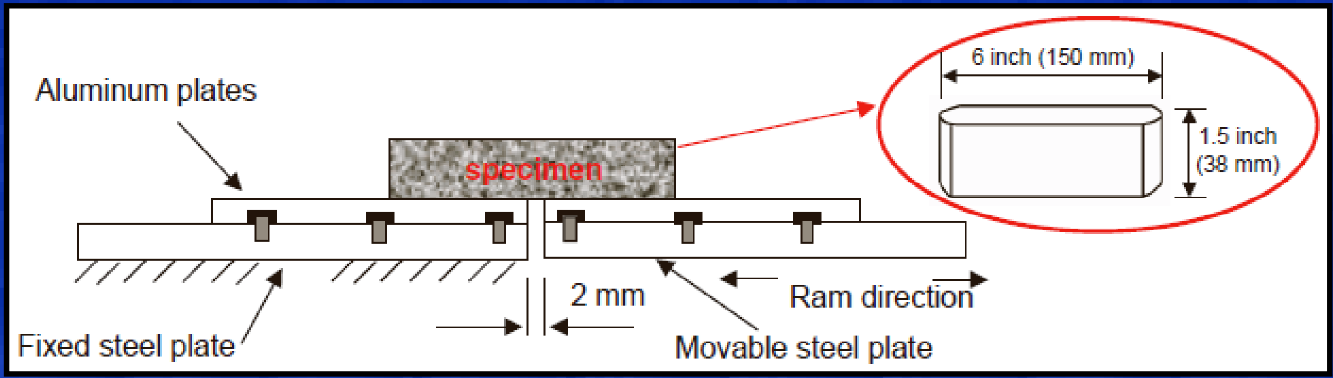
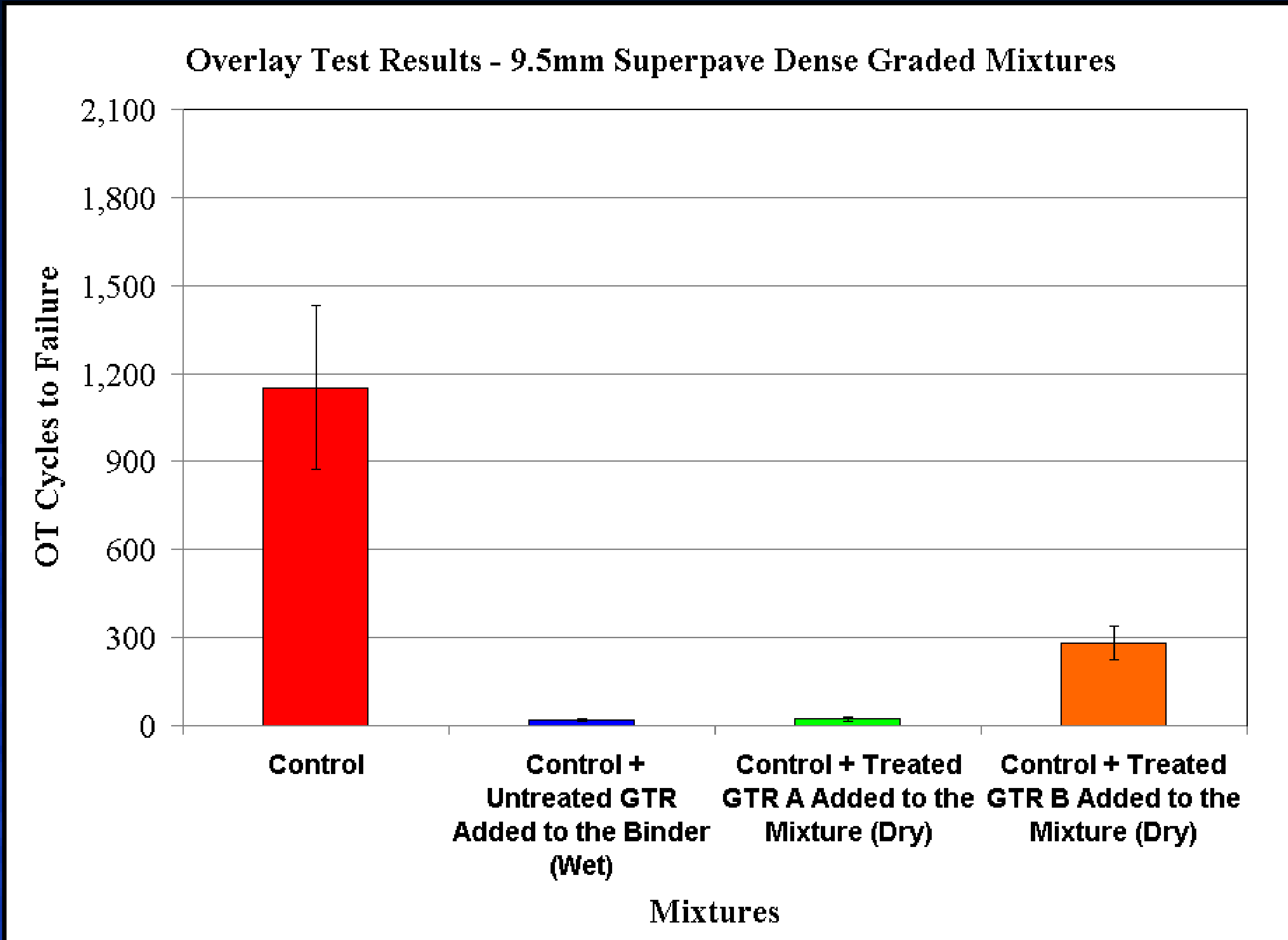
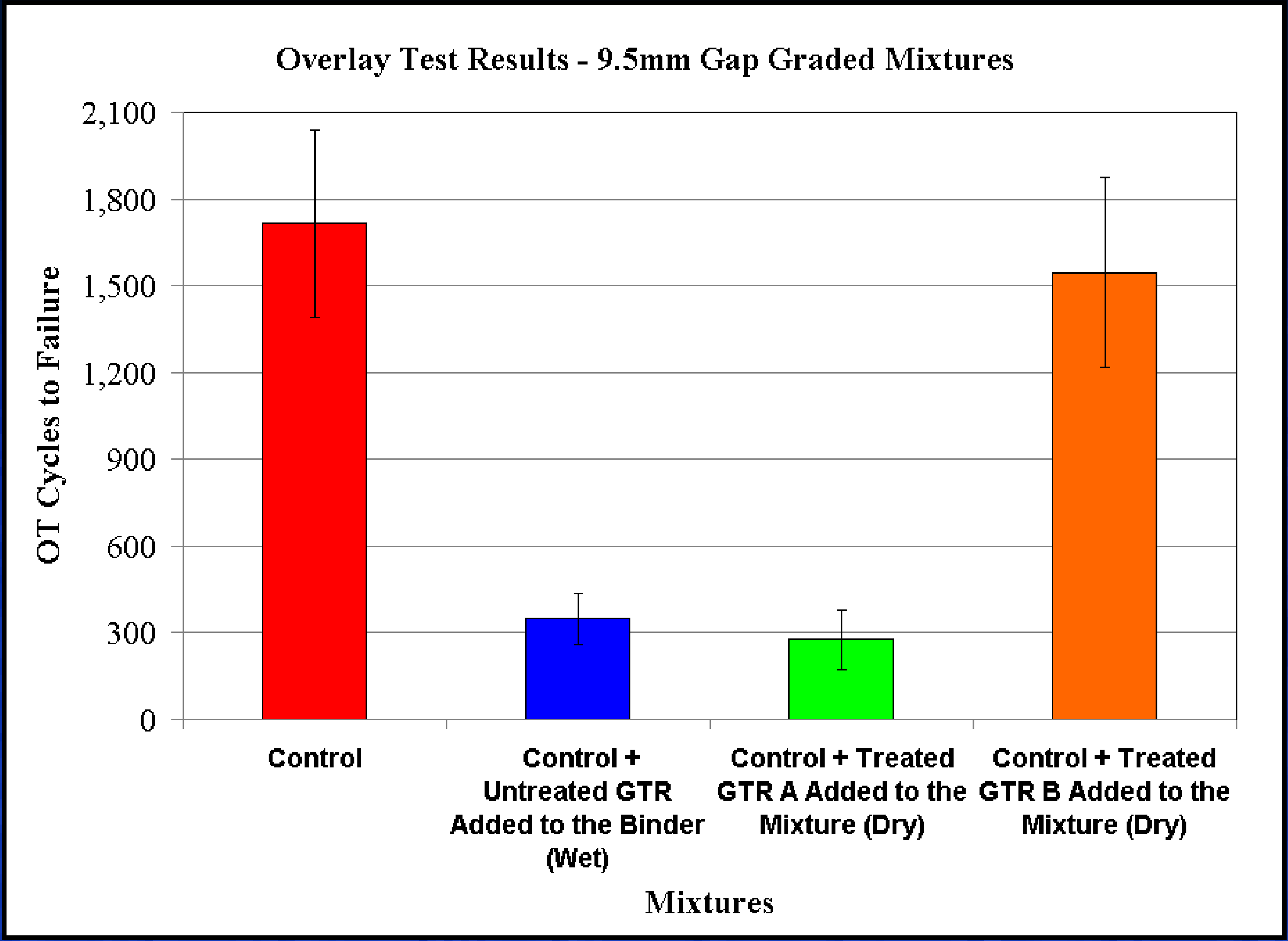


Diagram from: Zhou et al. "Overlay Tester: Simple Performance Test for Fatigue Cracking" Transportation Research Record: Journal of the Transportation Research Board, No. 2001, Transportation Research Board of the National Academies, Washington, D.C., 2007, pp. 1–8.

Overlay Tester Results – Dense Graded



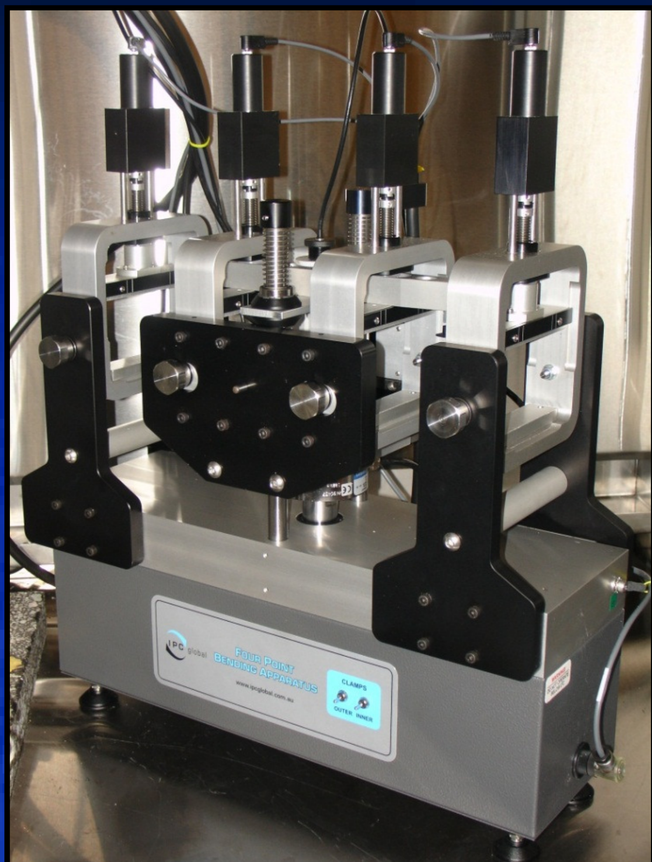
Overlay Tester Results – Gap Graded



Reflective Cracking Discussion

- For both mixture types, the control and Treated GTR B mixtures exhibited the most cycles to failure which correlated well with the mixture stiffness testing. Mixture stiffness testing indicated that these were the least stiff mixtures.

Fatigue – Four Point Bending Beam



Testing in Accordance with AASHTO T321

- Specimens were fabricated at a target air void level of 7.0 ± 1.0%
- Testing conducted in strain control mode
- Loading Frequency = 10Hz
- Sinusoidal Wave Form
- Failure Criteria = 50% reduction in initial stiffness per AASHTO T321 method

Temperature	Strain Level
15°C (59°F)	900με

Beam Fatigue Results

Dense Graded Mixtures	GTR Introduction Method	Average Number of Cycles to 50% Initial Stiffness, N_f
		900με
DG Control	n/a	31,616
DG Control + Untreated GTR (Wet)	Added to Binder	56,756
DG Control + Treated GTR A (Dry)	Added to Mixture	25,042
DG Control + Treated GTR B (Dry)	Added to Mixture	79,836
Gap Graded Mixtures	**GTR Introduction Method**	**Average Number of Cycles to 50% Initial Stiffness, N_f**
		900με
GG Control	n/a	NT
GG Control + Untreated GTR (Wet)	Added to Binder	60,972
GG Control + Treated GTR A (Dry)	Added to Mixture	30,791
GG Control + Treated GTR B (Dry)	Added to Mixture	88,176

Beam Fatigue Discussion

- The wet process and Treated GTR B dry process mixtures had similar fatigue cracking performance. This suggests that a wet or dry process can provide comparable fatigue characteristics of the mixtures.

Draindown

- Because the interaction of treated GTR and virgin binder in the dry process was unknown, draindown of the mixtures was a concern for the gap graded mixtures in this study.

- Draindown tests were conducted in accordance with AASHTO T305 "Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures."

Draindown Results

Gap Graded Mixtures	GTR Introduction Method	Draindown at Mixing Temperature	Draindown at Mixing Temperature +15ºC
GG Control	n/a	1.1%	1.3%
GG Control + Untreated GTR (Wet)	Added to Binder	0.1%	0.1%
GG Control + Treated GTR A (Dry)	Added to Mixture	0.1%	0.2%
GG Control + Treated GTR B (Dry)	Added to Mixture	0.1%	0.1%

Draindown Discussion

- The draindown using the wet process was 0.1% which was much lower than the control mixture. This might be due to the viscous gel that the GTR forms when added to the asphalt binder.

- The draindown for the dry process was 0.2% or less which was also much lower than the control mixture.

- This might indicate that the dry process using the two treated GTR led to the same formation of a viscous gel in the mixture.

Conclusions

- Overall, the data analysis indicated that treated GTR added in a dry process can yield mixtures that have similar performance characteristics to the same mixtures designed using the wet process.

Acknowledgements

The following people have been instrumental in completing the research presented here:

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Thank You!