ISAET '21

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Impact of Emulsion Type on Cold-in-Place Recycled (CIR) Asphalt Mixtures

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Acknowledgment

- Nevada Department of Transportation
- Ergon Asphalt & Emulsions.

Background

- CIR: a process that has successfully been used for many years.
  - Existing asphalt material is reused in place.
  - Material mixed in-place without the application of heat.
- Regardless of its good performance & positive sustainability, the performance characteristics of CIR have not been developed.
- The Nevada Department of Transportation has long used CMS-2S emulsion for CIR projects.
- Observed difference in CIR performance with changing emulsion technology prompted assessment of CIR properties.

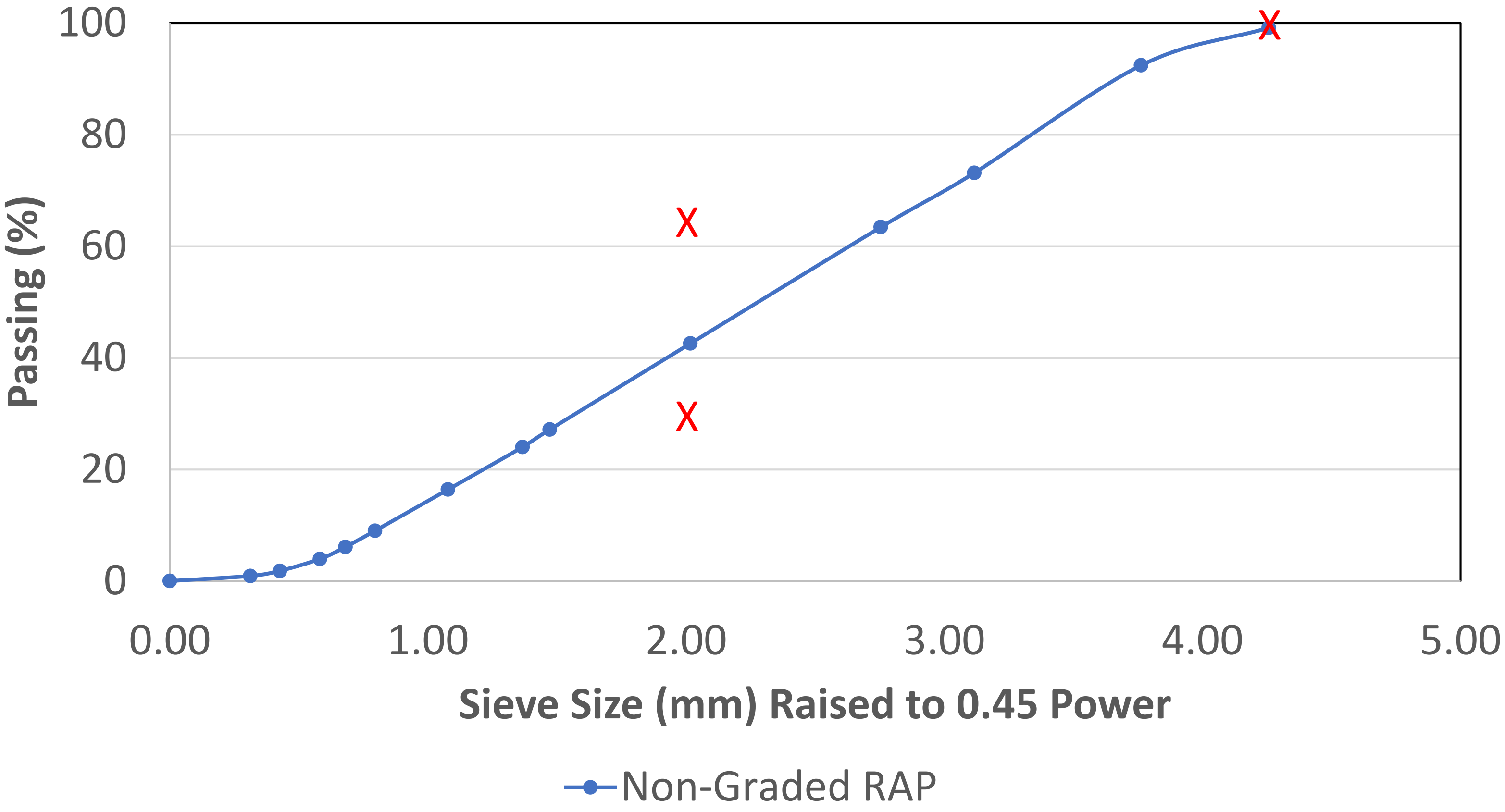
Objectives

- Evaluate the impact of asphalt emulsion type on the properties of CIR mixtures.
  - Superpave Design of CIR Mixtures.
  - Engineering Property: Dynamic Modulus.
  - Performance Characteristics.
    - Rutting.
    - Fatigue cracking.
    - Reflective cracking.

Asphalt Emulsions Used in Research

Asphalt Emulsion	Asphalt Residue (%)	True High Grade (°C)	True Intermediate Grade (°C)	True Low Grade (°C)		True Grade of Asphalt Residue	Superpave PG of Asphalt Residue
				S-controlled	m-controlled		
Type A: CMS-2S	65	55.2	13.2	-34.6	-35.9	55.2-34.6	52-34
Type B: Latex-Modified	72	68.1	20.1	-28.5	-28.7	68.1-28.5	64-28
Type C: Polymer-Modified	76	68.3	22.3	-30.2	-28.9	68.3-28.9	64-28
Type D: Rubber-Modified	63	59.4	16.6	-32.1	-31.1	59.4-31.1	58-28

RAP Material: Gradation & Binder



Sieve Size	% Passing Criteria
1 inch (25 mm)	100
No. 4 (4.75 mm)	30–65

True Grade	PG
86.1-16.6	82-16

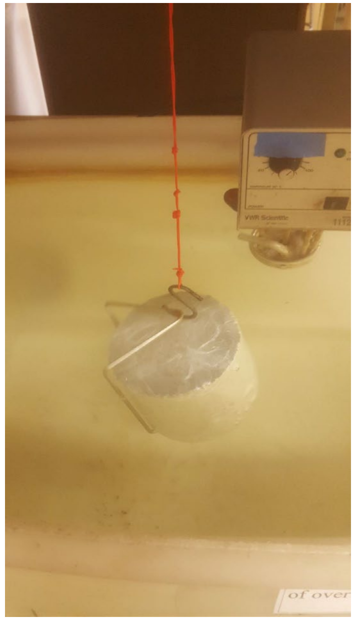
Superpave Mix Design: CIR

- Mix samples at: 2.5, 3.0, 3.5, and 4.0% emulsion by dry weight of RAP
- Lime slurry: 6.0% (by dry mass of milled materials)
- Measure G_{mm} at emulsion content of 3.0%
- Calculate G_{se}
- Calculate G_{mm} at others assuming constant G_{se}

Superpave Mix Design: CIR

- Compact 2 replicates to N_{design} & measure G_{mb}:
  - Perforated mold.
  - N_{design} = 75 (graded RAP).
  - Sample size: 150mm dia. x 115±5mm height.
  - Curing of extruded CIR mix sample:
    - 140ºF for 24 hrs for volumetric properties.
    - 140ºF for 48 hrs for E* & Performance properties.
  - Measure G_{mb} using ASTM D1188 parafilm.



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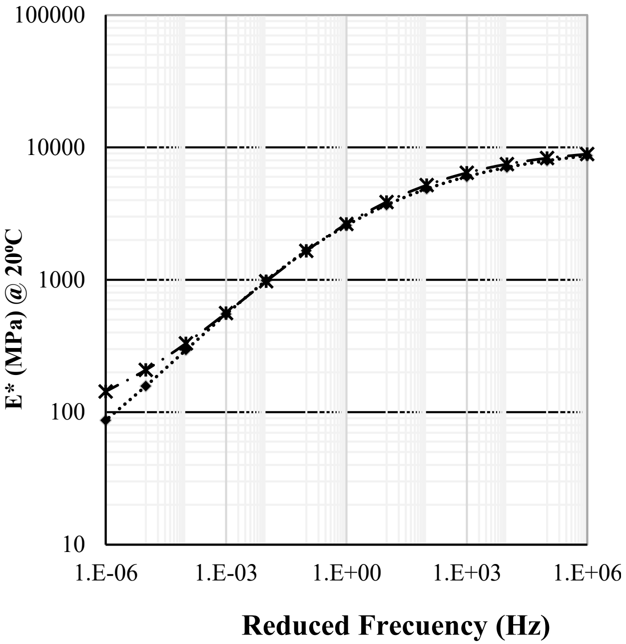
Optimum Emulsion Content (OEC)

- Air Voids at N_{design} = 13±1%.
- Sample Height: 115±5mm.
- Minimum dry TS at 77°F: 50 psi.
- Minimum TSR: 70% per AASHTO T 283 with 1 F-T cycle.

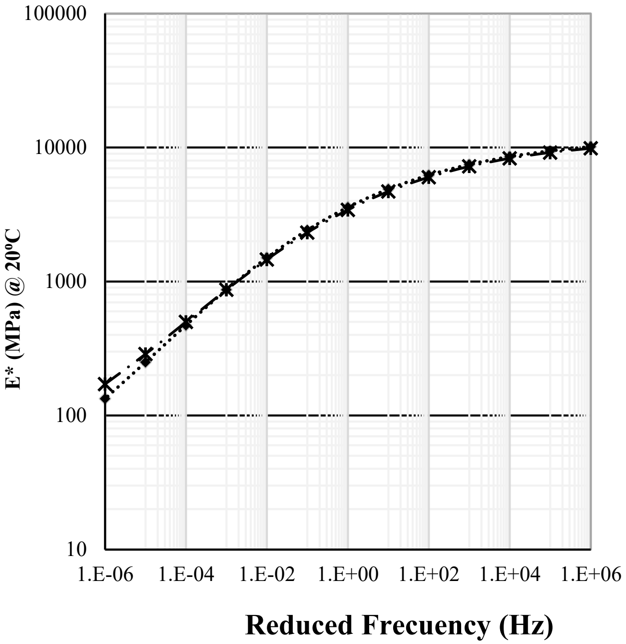
Optimum Emulsion Content (OEC) & Moisture Sensitivity

Asphalt Emulsion	Lime Slurry (%)	OEC (%)	Avg Dry TS @77°F (psi)	Avg Moisture-Conditioned TS @77°F (psi)	TSR @77°F (%)
A: Standard CMS-2S	6.0	4.0	52	40	77
B: Latex-Modified	6.0	3.0	57	45	79
C: Polymer-Modified	6.0	2.5	76	60	79
D: Rubber-Modified	6.0	4.0	56	43	77

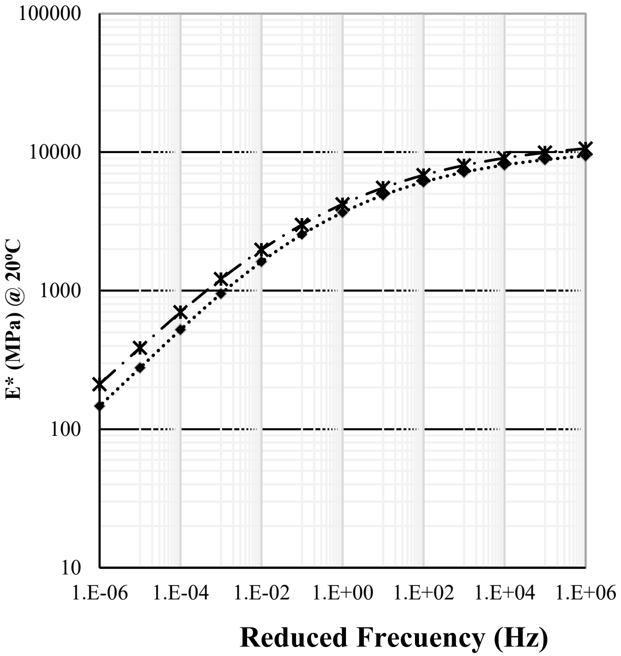
Comparison of Dynamic Modulus E*



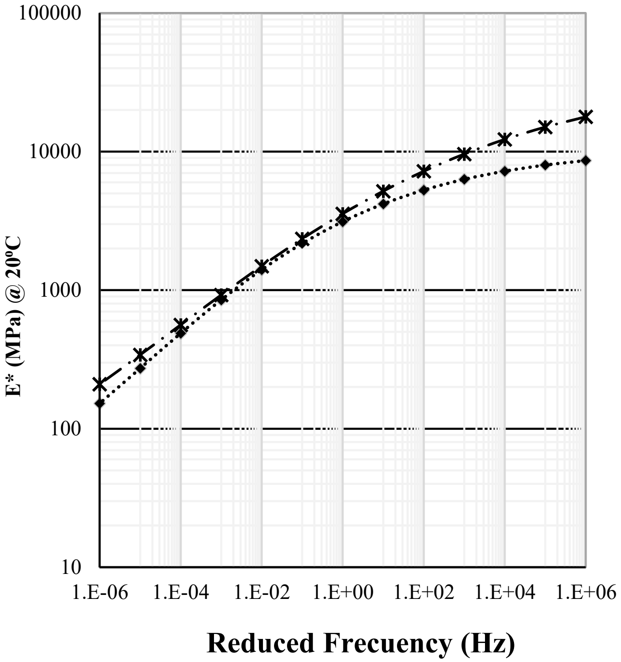
Emulsion A: CMS-2S
OEC = 4.0%
PG 52-34



Emulsion B: LM
OEC = 3.0%
PG 64-28

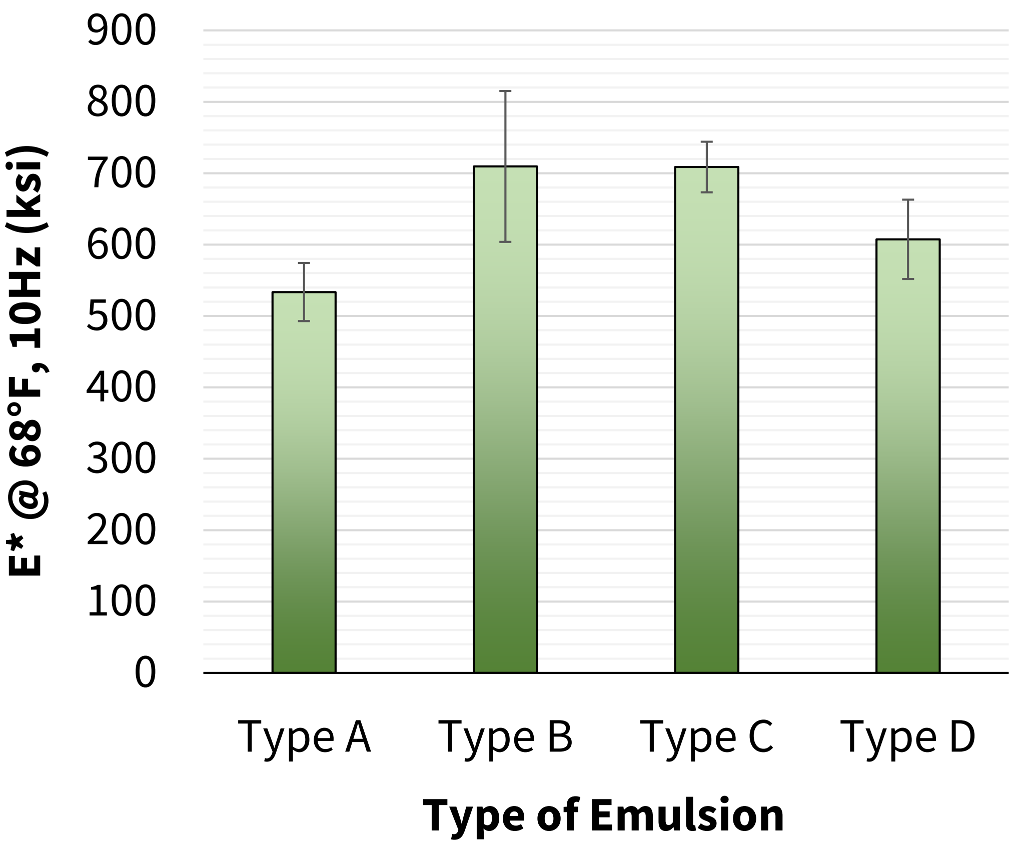


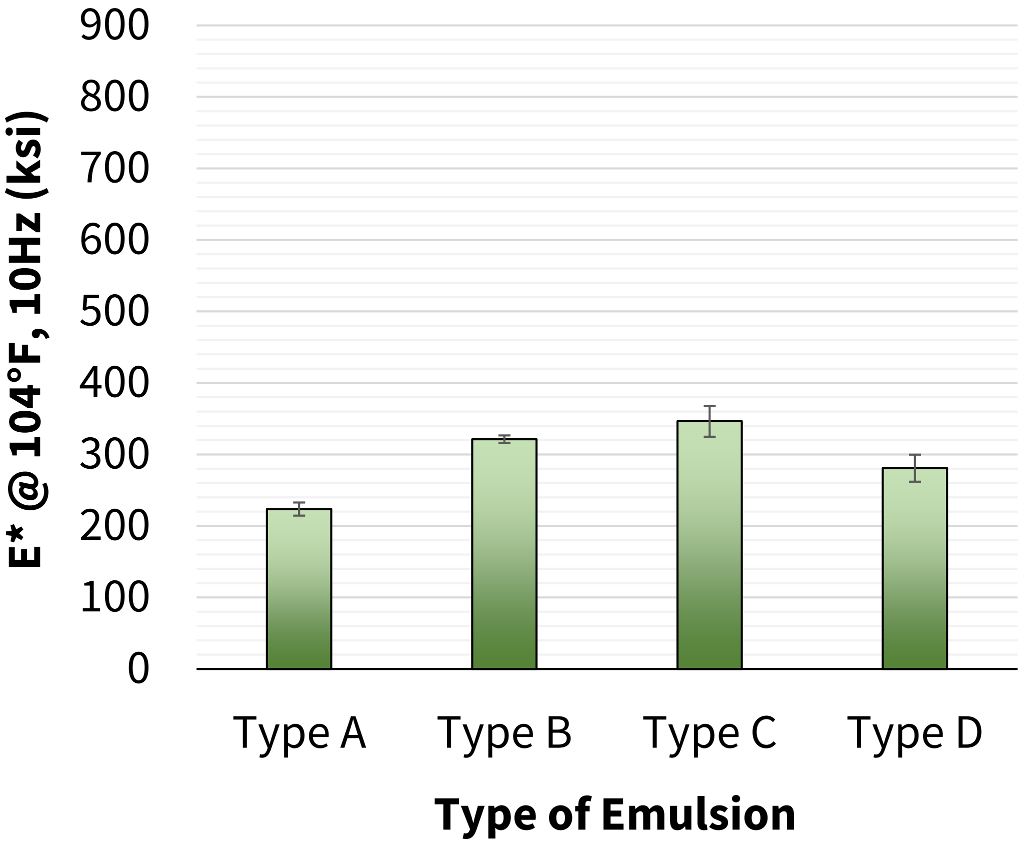
Emulsion C: PM
OEC = 2.5%
PG 64-28



Emulsion D: RM
OEC = 4.0%
PG 58-28

Comparison of Dynamic Modulus E*





Emulsion A: CMS-2S
OEC = 4.0%
PG 52-34

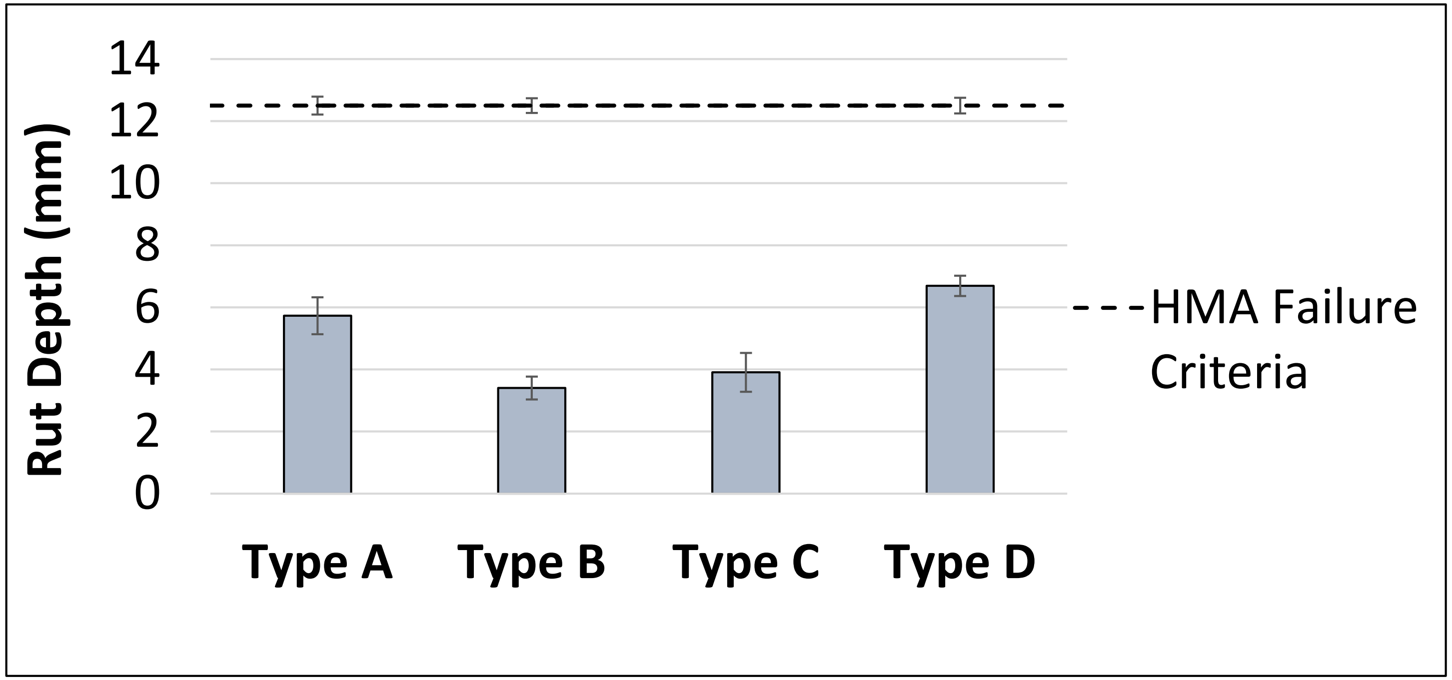
Emulsion B: LM
OEC = 3.0%
PG 64-28

Emulsion C: PM
OEC = 2.5%
PG 64-28

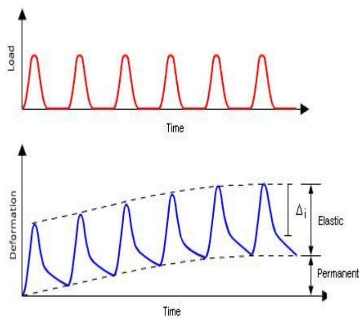
Emulsion D: RM
OEC = 4.0%
PG 58-28

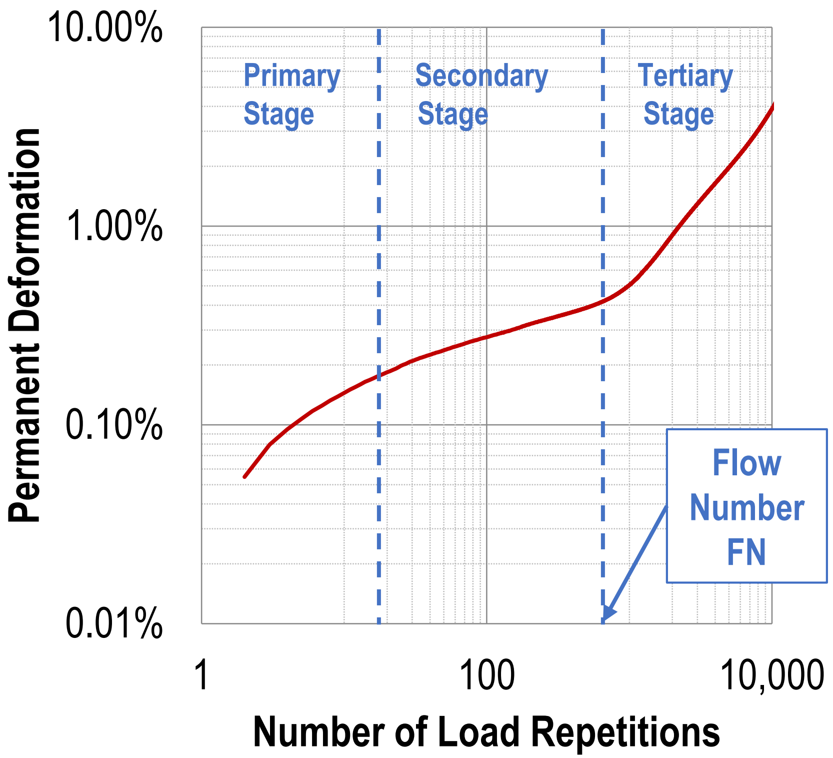
Comparison of Rutting Resistance: HWTT

- Performed at OEC at 13±1% air voids.
- Performed at 50°C (122°F).
- Failure criteria: 12.5 mm max rut depth & 20,000 cycles to failure.

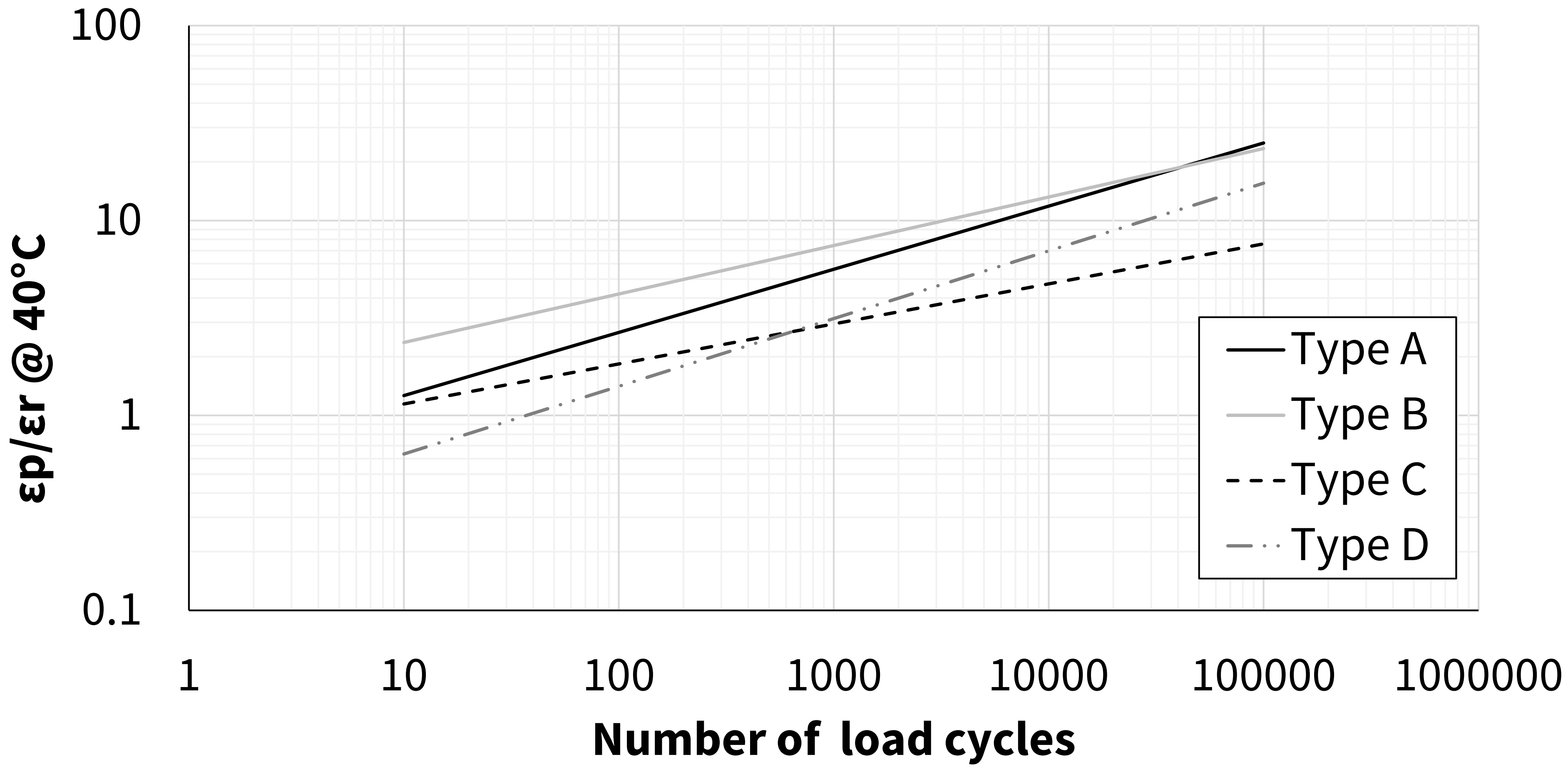


Comparison of Rutting Resistance: Repeated Load Triaxial Test @ High Temp.





Comparison of Rutting Resistance: CIR



Emulsion A: CMS-2S
OEC = 4.0%
PG 52-34

Emulsion B: LM
OEC = 3.0%
PG 64-28

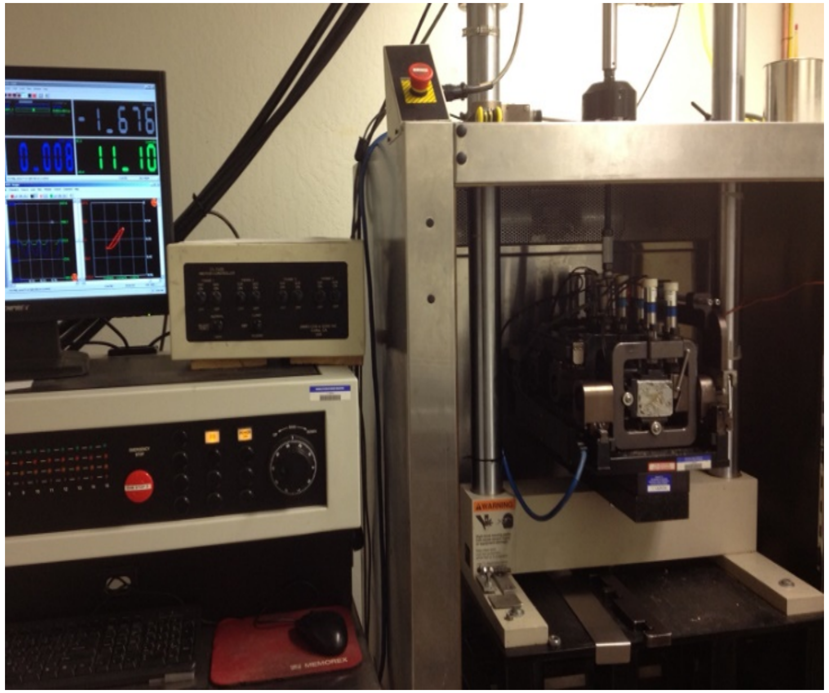
Emulsion C: PM
OEC = 2.5%
PG 64-28

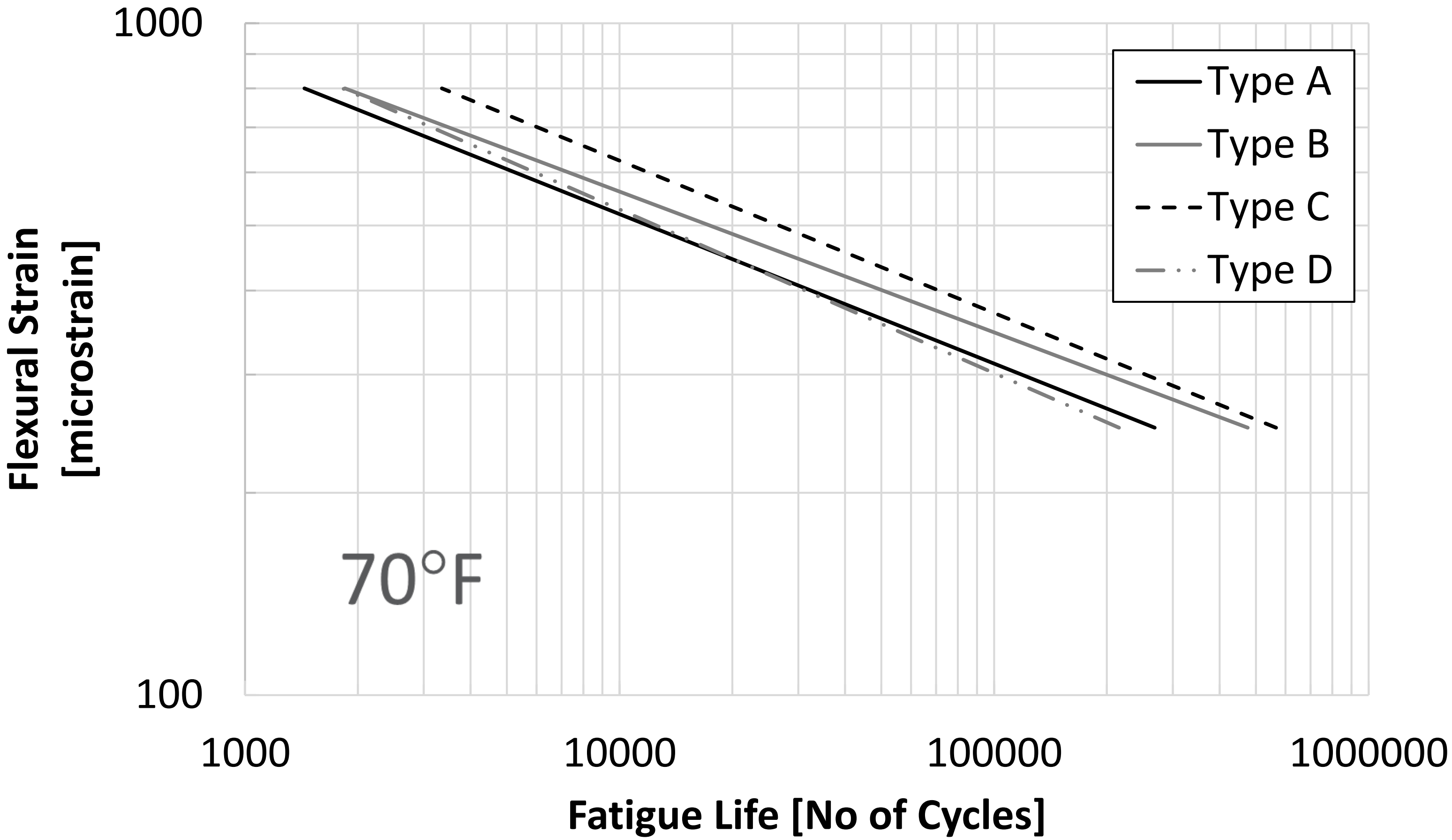
Emulsion D: RM
OEC = 4.0%
PG 58-28

Rutting Resistance Models: CIR

Asphalt Emulsion	Rutting Model
A: Standard CMS-2s	$\frac{\varepsilon_P}{\varepsilon_r} = 10^{-10.93031}\,(N)^{0.32408}\,(T)^{5.30878}$
B: Latex-Modified	$\frac{\varepsilon_P}{\varepsilon_r} = 10^{-8.10753}\,(N)^{0.24871}\,(T)^{4.08190}$
C: Polymer-Modified	$\frac{\varepsilon_P}{\varepsilon_r} = 10^{-1.75152}\,(N)^{0.20540}\,(T)^{0.79574}$
D: Rubber-Modified	$\frac{\varepsilon_P}{\varepsilon_r} = 10^{-10.16571}\,(N)^{0.34739}\,(T)^{4.76969}$

Comparison of Fatigue Resistance





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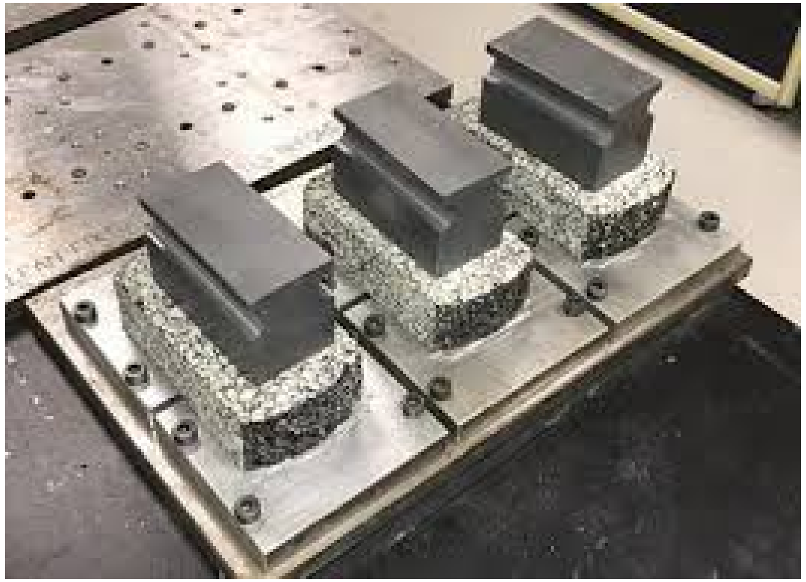
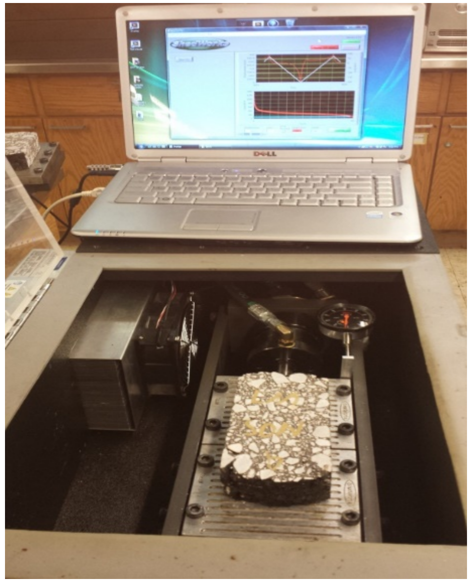
Fatigue Cracking Models: CIR

Asphalt Emulsion	Fatigue Model
A: Standard CMS-2s	$N_f = 4.40 * 10^{10} \left(\frac{1}{\varepsilon_t}\right)^{4.494} \left(\frac{1}{E}\right)^{3.749}$
B: Latex-Modified	$N_f = 7.42 * 10^{10} \left(\frac{1}{\varepsilon_t}\right)^{4.771} \left(\frac{1}{E}\right)^{3.845}$
C: Polymer-Modified	$N_f = 1.80 * 10^{13} \left(\frac{1}{\varepsilon_t}\right)^{4.409} \left(\frac{1}{E}\right)^{4.006}$
D: Rubber-Modified	$N_f = 1.16 * 10^{5} \left(\frac{1}{\varepsilon_t}\right)^{4.104} \left(\frac{1}{E}\right)^{2.516}$

Resistance to Reflective Cracking: OT

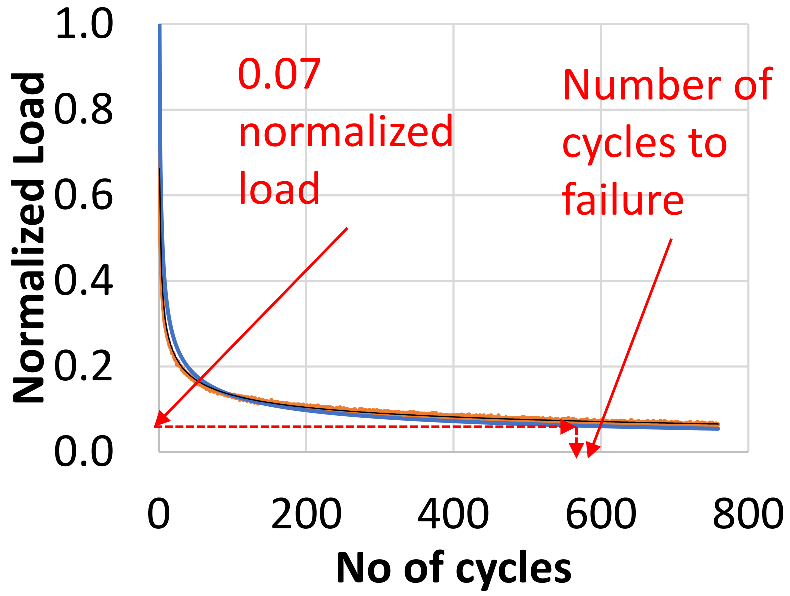


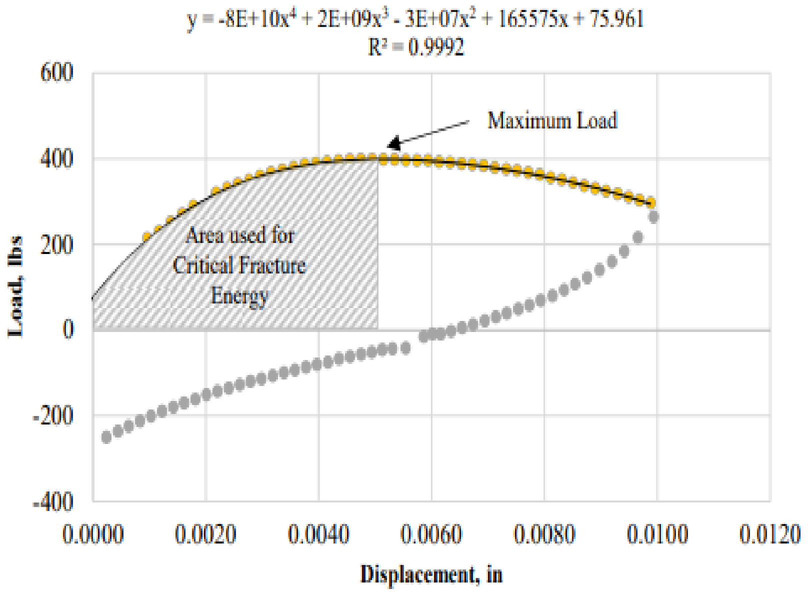


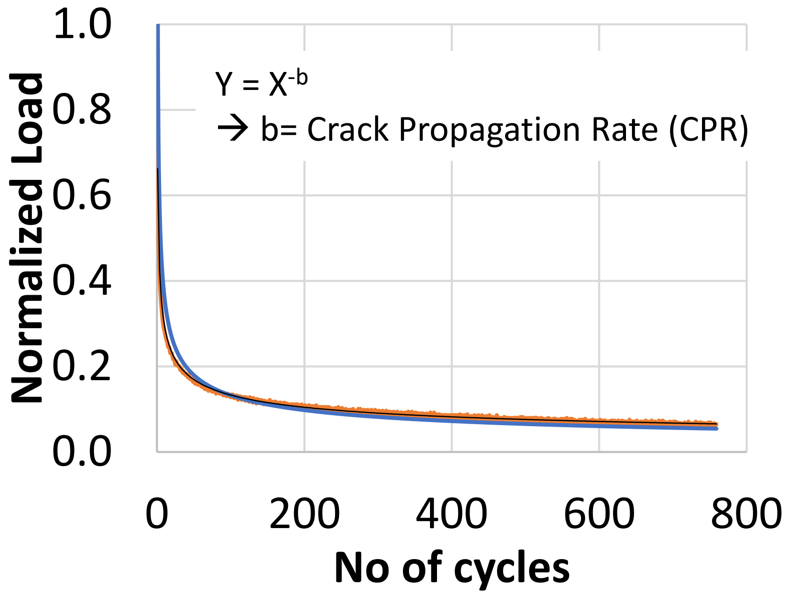
- Texas Overlay Test:
  - Controlled displacement mode as per Tex-248-F.
  - Opening displacement of 0.01 inches (0.25 mm).
  - Sample size 150 mm long, 76 mm wide and 38 mm thick.
  - Performed at OEC with a Target air voids of 13 ± 1%.
  - Test temperature 25°C.

Resistance to Reflective Cracking: OT Analysis Criteria

- Number of cycles to failure ~ Drop of 93% of the maximum load.
- Resistance to Crack Initiation ~ Dissipated energy required to initiate a crack.
- Crack Propagation rate ~ Fitting a power equation to the load reduction curve.







Comparison of Reflective Cracking Resistance: CIR

Asphalt Emulsion	Air Voids (%)	No of Cycles to Failure	Critical Fracture Energy (CFE)	Crack Propagation Rate (CPR)
A: Standard CMS-2s	13.6	496	0.33	0.44
B: Latex-Modified	13.8	132	0.36	0.51
C: Polymer-Modified	13.1	280	0.20	0.41
D: Rubber-Modified	13.6	1,254	0.24	0.35

Desired Properties:
- High Cycles to Failure
- High Critical Fracture Energy
- Low Crack Propagation Rate

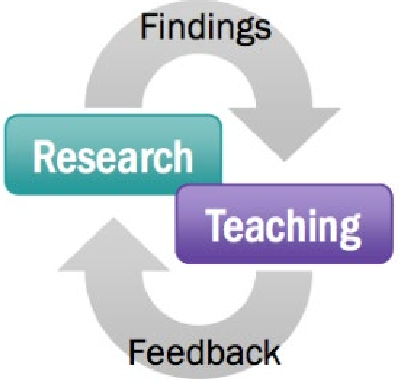
Conclusions

- OEC varied by emulsion type and asphalt binder residue.
- PM increased TS properties & improved resistance to moisture damage.
- PM increased the rutting resistance of CIR mixtures at the high critical rutting temperature of 60°C.
- The fatigue models of four CIR mixtures were comparable at the two critical fatigue temperatures of 13 and 21°C.
  - Follow-up mechanistic pavement analysis is needed to properly assess the mixtures resistance to fatigue cracking

Conclusions

- The rubber modifications increased reflective cracking resistance of CIR mixtures.

- Criteria for the OT parameters need to be established for CIR mixtures based on performance needs.



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