Evaluating Laboratory-Produced Asphalt Mixtures with RAP in Terms of Rutting, Fatigue, Predictive Capabilities, and High RAP Content Potential

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Objectives

- To evaluate the effect of the following factors on HMA properties:
  1) Incorporation of RAP
  2) Changes in binder grade
  3) The virgin asphalt content
- Nine laboratory-produced RAP mixtures were tested.
- This study seeks ways to incorporate higher percentages of RAP than are used currently by examining rutting resistance, fatigue resistance, and predictive qualities.

Materials

Mix Name	Binder PG	RAP (%)	Asphalt Content (%)
NH5820-opt	58-28	20	Optimum – 0.5%
NH5840-opt	58-28	40	Optimum – 0.5%
NH6400-opt	64-28	0	Optimum – 0.5%
NH6420-opt	64-28	20	Optimum – 0.5%
NH6440-opt	64-28	40	Optimum – 0.5%
NH6400opt	64-28	0	Optimum
NH6420opt	64-28	20	Optimum
NH6440opt	64-28	40	Optimum
NH6440+opt	64-28	40	Optimum + 0.5%

Test Methods

- Binder Testing
  - Extraction and recovery
  - Binder PG grade
  - Multiple stress creep and recovery (MSCR)
  - Low temperature cracking
- Mixture Testing
  - Dynamic Modulus
  - Cyclic Testing (S-VECD) + G^R Failure Criterion
  - Permanent Deformation (TSS)

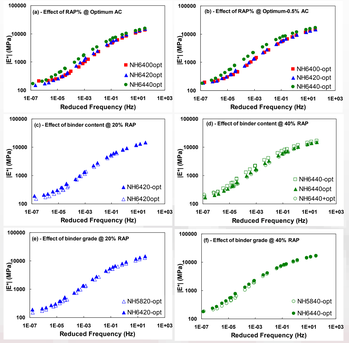
Binder Testing

Mix Name	Performance Grade (PG) - AASHTO M320				
	High Temp (°C)	Int. Temp (°C)	Low Temperature		
			AASHTO R29 (m-slope)	AASHTO R29 (Stiffness, S)	AASHTO R49 (T_{crit})
NH5820-opt	68.7	19.3	-26.9	-29.1	-27.1
NH5840-opt	73.7	22.3	-24.2	-28	-25
NH6400-opt	72.1	18.9	-30.2	-30.4	-27.9
NH6420-opt	75	20.1	-27.8	-29.3	-27
NH6440-opt	83.4	25.2	-19.9	-27	-23
NH6400opt	70.6	18.3	-28.8	-29.5	-27.2
NH6420opt	72.1	19.5	-26.5	-29.4	-26.6
NH6440opt	76.4	22.3	-16.3	-20.1	-24.5
NH6440+opt	76.1	21.7	-16.1	-19.3	-24.1

Mix Name	Multiple Stress Creep Recovery					
	58°C		64°C		70°C	
	J_{nr} (1/kPa)	% Rec	J_{nr} (1/kPa)	% Rec	J_{nr} (1/kPa)	% Rec
NH5820-opt	0.81	6.3	2.17	1.6	5.29	0.2
NH5840-opt	0.34	15.4	0.97	5.8	2.56	1.4
NH6400-opt	0.48	17.1	1.33	6.4	3.31	1.9
NH6420-opt	0.31	22.4	0.85	10.2	2.26	3.0
NH6440-opt	0.06	45.6	0.19	31.2	0.54	16.1
NH6400opt	0.61	15.2	1.56	5.94	3.97	1.4
NH6420opt	0.46	14.2	1.30	4.8	3.35	1.4
NH6440opt	0.22	22.3	0.65	10.5	1.79	3.2
NH6440+opt	0.23	22.5	0.67	10.7	1.82	3.4

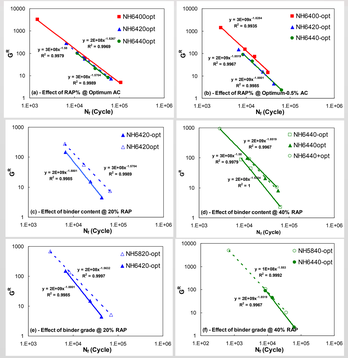
- Higher RAP percentages caused:
  1) Increase in the PG at both the high and low ends.
  2) Increase in high temperature performance (MSCR)
  3) Increase in low temperature critical cracking.
  4) Decrease in the non-recoverable creep compliance (J_{nr}) value, which suggests better rutting resistance.
- Increasing the binder content seemed to worsen the rutting resistance.
- At 20% RAP content, the use of a softer asphalt binder affected the asphalt binder properties similarly to adding 0.5% asphalt binder.
- At 40% RAP content the use of the softer asphalt binder was better able to lower the asphalt binder PG than the addition of 0.5% or 1.0% asphalt binder.

|E*| Testing



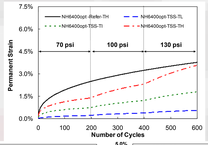
- incorporating RAP in the mixture increased the stiffness of the mixture.
- Increasing the binder content decreased the stiffness of the mixture.
- Using softer binder reduced the stiffness to some extent.

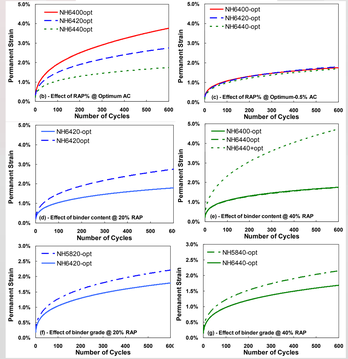
S-VECD Failure Criterion (G^R)



- The failure criterion lines move down with increases in RAP content, suggesting a decrease in fatigue resistance.
- Lowering the binder content decreased the fatigue resistance.
- The softer binder indicates better fatigue resistance.
- Adding RAP seems to shift only the failure criterion lines, whereas the binder content and binder grade appear to change the slopes as well.

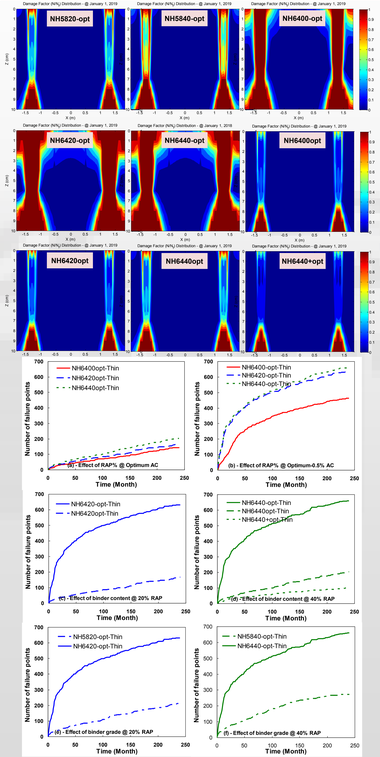
TSS Testing





- By incorporating more RAP into the mixture, the rutting resistance increased.
- As the binder content increased, the rutting resistance decreased. This decrease seems to be much more pronounced when the asphalt content exceeds the optimum binder content.
- The stiffer binder shows better rutting resistance.

LVECD Simulation



- By incorporating more RAP into the mixture, the fatigue resistance decreased.
- As the binder content increased, the rutting resistance increased.
- Using softer binder improved fatigue resistance.

Conclusions

- In general, all the factors that improved the fatigue resistance deteriorated the rutting resistance of the asphalt mixtures
- It is still possible to balance all the different factors to produce a material that performs well and is economical
- The use of soft binder emerged as a promising treatment among the different factors, as the LVECD software predictions showed a noticeable improvement in fatigue resistance, whereas the TSS data suggest that rutting resistance would not be compromised significantly.
- The LVECD program's predictions of fatigue cracking for both the thin and thick pavements clearly showed that high percentages of RAP can be tolerated easily once the layer thickness is increased
- The mixture with the optimum binder content was, not surprisingly, found to be the best in terms of performance
- Increasing the asphalt binder content above the optimum level resulted in significant rutting even at a high percentage of RAP, and decreasing the asphalt binder content below the optimum level caused a noticeable decrease in fatigue resistance
- The best strategies for incorporating high percentages of RAP into asphalt mixtures seem to include using a soft base binder and maintaining the optimum asphalt binder content and/or increasing the asphalt layer thickness.

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