A Performance Comparison of Asphalt Mixtures Modified with Hydrated Lime, Polymer Modified Binder and Reclaimed Asphalt Shingles (RAS) On Route 50 Moniteau, Morgan and Pettis Counties

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Missouri Department of Transportation
Division of Construction and Materials
Joe Schroer, PE
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Hydrated lime was required in high traffic asphalt mixtures controlled by Section 403 of the Missouri Standard Specifications for Highway Construction from the late 1980's through much of the 1990's primarily as an anti-stripping agent but also for some initial stiffness and stability in mixtures during placement. With the advent of the Superpave mix design system and volumetric field control of HMA, contractors began to complain that the hydrated lime requirement added dust to their mixtures that made it more challenging to meet volumetric requirements in the field without adding harder, more durable, (in other words, more expensive) aggregate. Sources for these aggregates are not as wide spread and many times cost more and require hauling more than 100 miles. For roughly the same cost in the mixture, they could use liquid anti-stripping agents but save money by using more aggregate local to the project. It was agreed to allow contractors to choose liquid anti-stripping agents or hydrated lime. Rather quickly, hydrated lime use became limited amongst contractors.

The Missouri Department of Transportation (MoDOT) was approached by Mississippi Lime Company on the prospect of using hydrated lime to enhance performance of hot mix asphalt (HMA) mixtures. While hydrated lime has a history of being an effective anti-stripping agent in HMA, a study by the National Lime Association indicated that hydrated lime added to HMA with an unmodified binder could potentially increase the strength, dynamic modulus (E*), thereby allowing those mixtures to be placed in a thinner, less expensive, full-depth pavement at the same level of performance as mixtures with polymer-modified binders. The construction program for MoDOT at this time is projected to include very few full-depth asphalt pavements and focus on overlays for pavement preservation and maintenance due to a steep decline in available funds. Mississippi Lime contended that the concept of thinner pavements could also be applied to overlays so it was agreed to construct a project for comparison.

A project constructed in 2011 on US Route 50 in Moniteau, Morgan and Pettis Counties from the east side of Sedalia, Log Mile 82.59, to the east side of Tipton, Log Mile 106.45, awarded to APAC - Missouri appeared to be a good fit for the demonstration with polymer-modified PG 70-22 being the required binder for the mixtures on the project. The total length of the project was approximately 24 miles and included sections of concrete pavement and composite pavement, concrete previously overlain with asphalt. Through a change order agreement with APAC, mixtures with PG 64-22 with hydrated lime and PG 64-22 with reclaimed asphalt shingles (RAS) replaced the PG 70--22 mixtures on a portion of the project. The project was divided into 6 sections, 3 on the concrete pavement and 3 on the composite pavement. Each section was paved with 2 inches of SP190, 19.0 mm NMAS, and 1¾ inches of SP125, 12.5 mm NMAS, containing the same modifier. As a side note, Section 1015 of the specifications for asphalt binders was changed prior to construction of the project. Suppliers began supplying PG 64-22 Grade H or PG 64-22H in lieu of PG 70-22. Therefore, the PG 64-22H sections are considered as the control sections.

The performance testing plan set for the project included determining the dynamic modulus (E*) and flow number (FN) through the Asphalt Mixture Performance Tester (AMPT) and a cold weather cracking test. While stripping characteristics of the mixtures were a concern, testing by AASHTO T 283 and values determined were for specification compliance rather than as part of the evaluation. Stripping of the mixtures in the field and the associated distresses would require a longer observation period than intended for this trial. It should be noted, however, that the contractor found it necessary to include a liquid anti-strip agent in the mixtures with the hydrated lime mixtures to ensure meeting the minimum tensile strength retained (TSR) requirements when tested in accordance with T 283. Test areas approximately 500 feet long have been identified in each section as shown in Figure 1 to be observed over a period of up to 5 years for reflective cracking, rutting or any other visual distresses. A summary of the mixture properties is shown in Table 1.

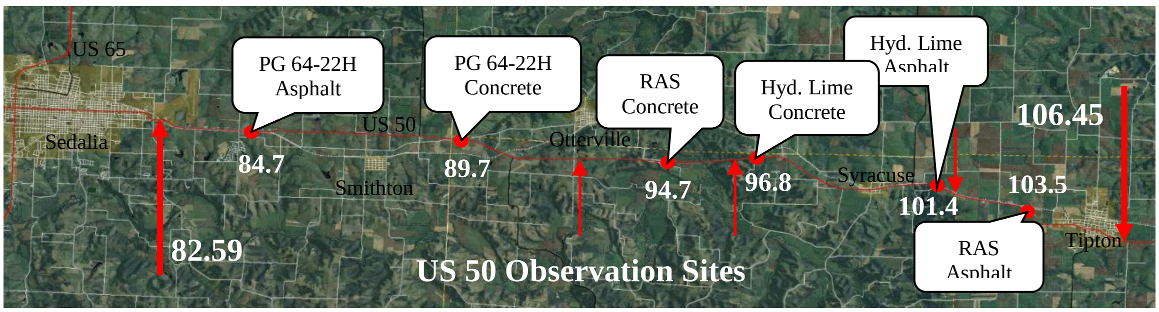


Figure 1

The mixtures were designed to be as similar as possible with roughly the same volumetrics including the binder content. The most significant difference is that the control mixtures were produced from a different quarry and rock formation than the RAS and hydrated lime mixtures. Gradations are shown in Table 2.

Table 1

Mixture Properties from Job Mix Formula						
Mixture	SP125 A	SP125 B	SP125 C	SP190 A	SP190 B	SP190 C
G_{mm}	2.440	2.462	2.474	2.470	2.472	2.476
Total Binder, %, P_b	5.0	5.2	5.0	4.5	4.6	4.5
Virgin Binder, %, P_{bv}	3.7	3.7	3.8	3.3	3.2	3.4
P_{bev} Ratio, %	72	68	74	74	67	75
VMA, %	14.5	14.5	14.2	13.4	13.7	13.5
VFA, %	72	72	72	70	71	70
Eff. Binder, P_{be}	10.5	10.5	10.2	9.4	9.7	9.5
Dust Ratio, P_{-200}/P_{be}	1.1	1.2	1.4	1.1	1.3	1.4
RAP, %	28	20	28	25	18	25
RAS, %	--	3	--	--	3	--
Hydrated Lime, %	--	--	1.0	--	--	1.0
Anti-strip Liquid, %	1.4	1.0	1.0	1.4	1.0	1.0
TSR, %	85	86	92	90	81	87

Table 2

Mixture Gradation, Percent Passing by Weight						
Mixture	SP125 A	SP125 B	SP125 C	SP190 A	SP190 B	SP190 C
1”	100.0	100.0	100.0	100.0	100.0	100.0
3/4”	99.9	100.0	100.0	100.0	98.1	98.1
1/2”	95.8	95.5	95.3	82.8	89.5	89.4
3/8”	86.7	89.8	89.3	67.4	81.3	81.0
#4	46.8	60.0	60.4	38.4	53.4	47.6
#8	28.3	31.3	31.9	23.1	28.2	23.8
#16	18.4	18.4	19.2	15.3	16.8	15.3
#30	13.6	12.2	13.2	11.5	11.2	11.0
#50	9.9	8.9	9.8	8.6	8.3	8.5
#100	7.1	6.2	6.7	6.1	5.8	6.0
#200	5.0	4.5	5.1	4.3	4.3	4.5

The results of performance testing are shown in Table 3. Performance testing in MoDOT’s Central Laboratory on the AMPT was completed for all mixtures except the SP190 containing PG 64-22H which was placed before samples were obtained. The E* obtained for the mixtures is an indicator of rutting resistance at lower reduced frequencies (higher temperatures) and fatigue resistance at higher reduced frequencies (cooler temperatures.) A comparison of mixtures would find the ideal mixture has more stiffness at high temperature and less stiffness at cool temperatures. As shown in Table 3, the hydrated lime mixtures performed at least as well as the Control or PG 64-22H. The graphical representation in Figure 2 shows some differentiation of the mixtures in regard to rutting but that they converge at fatigue or cracking temperatures. The Control mixture was the least stiff at the cooler temperatures. This is noted for the discussion of cold temperature testing. A comparison of the Flow Number (FN) shows that all mixtures would be considered highly rut resistant. The differences in FN may be attributed to them approaching the testing limit of 10,000 cycles. Acceptable FN for asphalt mixtures would be well under 1000 cycles at the stress levels used of 10 psi confining stress and 100 psi axial applied deviator stress.

The TSR values for each mixture were determined by averaging MoDOT and the contractor’s QC test results. While stripping will not be a measure for this project, the hydrated lime mixtures did show slight improvement over the other mixtures. The largest improvement due to the addition of hydrated lime was seen in the SP190 mixtures.

Table 3

Performance Tests AASHTO TP 79 and T 283				
Mixture	Component	E* (ksi), 0.01 Hz @ 104F	FN (cycles) @ 136F	TSR (%), average
SP125 A	PG 64-22H	56	8428	87
SP125 B	PG 64-22 w/ RAS	107	7521	86
SP125 C	PG 64-22 w/ Hyd. Lime	87	8907	88
SP190 A	PG 64-22H	--	--	84
SP190 B	PG 64-22 w/ RAS	74	8423	83
SP190 C	PG 64-22 w/ Hyd. Lime	51	9755	89

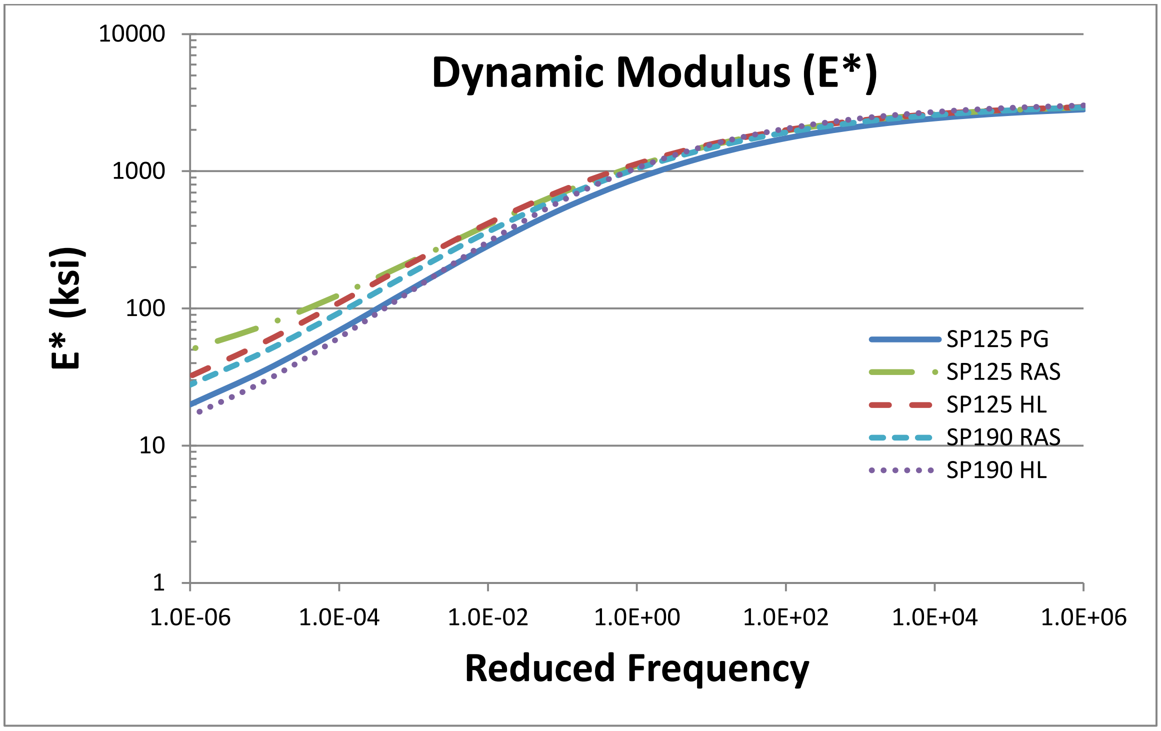


Figure 2

Cold temperature performance of the mixtures is not typically an evaluation made by MoDOT due to the complexity and cost for test equipment, preparation of test specimens and evaluation of the test results. Several methods were considered but one was found that could be completed using equipment currently in MoDOT's Central Laboratory. The University of Minnesota developed a method to test mixture beams in the bending beam rheometer (BBR) through NCHRP IDEA Project 133. Using beams with the same dimensions and temperatures, 10C above the lower grade temperature, as when testing binders, beams are tested with a load of 4000 mN or roughly four times the binder beam loading. Through additional study by the Utah Department of Transportation, preliminary target values were set for m-value and creep stiffness. M-value is the rate of change in creep stiffness over time. As demonstrated through these efforts, the test can be used to discriminate between anticipated performances of mixtures.

The suggested target values for m-value and stiffness are a minimum of 0.12 and maximum of 15,000 MPa, respectively. None of the mixtures exceeded the minimum for m-value and all were well under the maximum limit for stiffness as shown in Table 4. It would appear from the results that the Control sections would perform slightly better than the hydrated lime and RAS sections in regard to cold temperature cracking. This confirms the results indicated by the E* master curve showing a lower modulus at the higher reduced frequencies for the SP125 with PG 64-22H as mentioned previously. A check of typical test results for the binder supplier shows that the m-value for PG 64-22H and PG 64-22 is consistently just above the minimum value of 0.300. However, the MEPDG input for cold temperature cracking is creep compliance. Creep compliance may be obtained by the inverse of stiffness obtained by the BBR. Higher values indicate more compliance or resistance to cold temperature cracking. The RAS mixtures would appear to be more crack resistant (as shown in Figure 3) when comparing this characteristic but the values are too close to distinguish any of the mixtures as superior to the others.

Table 4

Cold Temperature Performance Experimental BBR Method				
		@ -12C, 60 sec.		@ -12C, 100 sec.
Mixture	Component	m-value	Stiffness (MPa)	Creep Compliance (1/GPa)
SP125 A	PG 70-22	0.107	9526	0.1122
SP125 B	PG 64-22 w/ RAS	0.082	7528	0.1219
SP125 C	PG 64-22 w/ Hyd. Lime	0.080	8424	0.1077
SP190 A	PG 70-22	--	--	---
SP190 B	PG 64-22 w/ RAS	0.090	7822	0.1176
SP190 C	PG 64-22 w/ Hyd. Lime	0.072	7930	0.1042

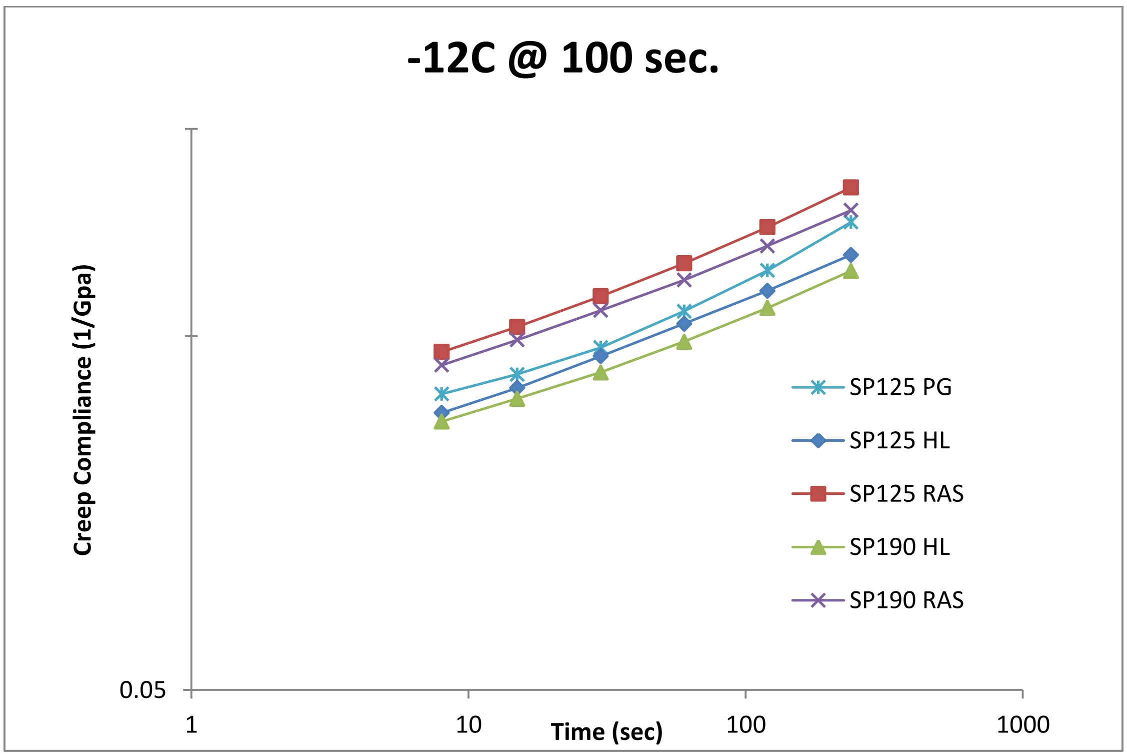


Figure 3

As demonstrated through laboratory testing, the sections with PG 64-22 Grade H, PG 64-22 and 1% hydrated lime and PG 64-22 and 5% RAS mixtures should perform relatively the same. Overall, the mixtures are expected to perform equivalently on the roadway. This would confirm the findings of the National Lime Association's study without consideration of freeze-thaw conditioning.

The discernible difference in the mixtures as shown in Table 5 is the price. Producing mixture for the entire project with the hydrated lime would yield a savings just under $10,000. Using the RAS mixtures, the savings would total over $135,000.

Table 5

Cost Comparison				
Mixture	Component	Mix Price	Mix Cost	Savings
SP125 A	PG 64-22 Gr. H	$47.99	$1,556,695	---
SP190 A	PG 64-22 Gr. H	$44.81	$1,650,939	
SP125 B	PG 64-22 w/ RAS	$45.88	$1,488,251	$135,867
SP190 B	PG 64-22 w/ RAS	$42.98	$1,583,516	
SP125 C	PG 64-22 w/ Hyd. Lime	$47.79	$1,550,207	$9,067
SP190 C	PG 64-22 w/ Hyd. Lime	$44.74	$1,648,360	

These projects will be evaluated for a period up to 5 years to determine performance differences due to environmental factors such oxidation and stripping. No cracking was reported for any of the sections during the last evaluation.

References

Sebaaly, P.E., Hajj, E., Little, D., Shivakolunthar, S., Sathanathan, T. and Vasconcelos, K. *Performance of Lime in Hot Mix Asphalt Pavements*. National Lime Association, June, 2010. http://www.lime.org/documents/publications/free_downloads/report-6-9-10.pdf

Marasteanu, M., Velasquez, R., Falchetto, A.C., and Zofka, A. *Development of a Simple Test to Determine the Low Temperature Creep Compliance of Asphalt Mixtures.* NCHRP IDEA 133, 2009.

Romero, P., Ho, C., VanFrank, K. *Development of Methods to Control Cold Temperature and Fatigue Cracking for Asphalt Mixtures.* Utah Department of Transportation, May, 2011.

APPENDIX
OBSERVATION LOCATIONS OF TEST SECTIONS

Contract ID 101022-503
Project No. J5P0916 & J5P0961
Route 50,
Moniteau, Morgan & Pettis Counties

	Mix ID	J5P0916	J5P0961
PG 64-22H	SP125 11-11	14,242.5	
	SP190 11-5	15,683.3	
PG 64-22 RAS	SP125 11-34	2,096.4	6,206.9
	SP190 11-33	4,680.9	7,005.5
PG 64-22 Hyd. Lime	SP125 11-37	4,389.9	5,502.2
	SP190 11-32	3,011.5	6,461.9
		44,104.5	25,176.5

PG/RAP 64-22H on asphalt Log Mile 82.59 to 85.14

PG/RAP 64-22H on concrete Log Mile 85.14 to 92.80

RAS/RAP 64-22 on concrete Log Mile 92.80 to 96.24

RAP/Lime 64-22 on concrete Log Mile 96.24 to 97.80

RAP/Lime 64-22 on asphalt Log Mile 97.80 to 101.97
Morgan Moniteau Co. Line

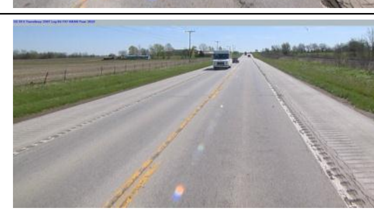
RAP/RAS 64-22 on asphalt Log Mile 101.97 to 107.45
East City Limits of Tipton

SP125 11-11
SP190 11-5

EBL Log Mi. 84.7 to 84.8 – PG 64-22H over asphalt





EBL Log Mi. 89.7 to 89.8 – PG 64-22H over concrete SP125 11-11 SP190 11-5

EBL Log Mi. 94.7 to 94.8 – PG 64-22 RAS over concrete SP125 11-34 SP190 11-33

EBL Log Mi. 96.8 to 96.9 – PG 64-22 Hydrated Lime over concrete SP125 11-37 SP190 11-32

SP125 11-37
EBL Log Mi. 101.4 to 101.5 – PG 64-22 Hydrated Lime over asphalt SP190 11-32

SP125 11-34
EBL Log Mi. 103.5 to 103.6 – PG 64-22 RAS over asphalt SP190 11-33