VARIABILITY OF THE MOISTURE SENSITIVITY OF FIELD HMA MIXES

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1.0 INTRODUCTION

In 2006, a research study was sponsored by the Regional Transportation Commission (RTC) of Washoe County to assess the impact of lime treatment and the method of adding the lime on the moisture damage of hot mix asphalt (HMA) mixes in the Truckee Meadows region (1). Hydrated lime is typically used to treat the aggregates prior to their use in the HMA mix. Normally the hydrated lime is added to the wet aggregates that are 2-3 percent above their saturated surface dry (SSD) condition. The lime-treated aggregates can either be introduced immediately into the HMA mix or they can be marinated for 48 hours prior to their introduction into the mixing process. This research evaluated the laboratory resistance of HMA mixes to raveling under the following three conditions: no lime treatment, lime treatment without marination, and lime treatment with 48 hours marination.

The study evaluated the resistance to moisture damage of 75 and 50 blows Marshall designed HMA mixes with a polymer-modified binder in terms of the resilient modulus (Mr) properties as a function of multiple freeze thaw (F-T) cycling and the extent of raveling through a visual inspection. It was found that the lime treatment of RTC's HMA mixes significantly improved their resistance to moisture damage and raveling with both the 75 and 50 blows Marshall designs. The data showed that the lime-treated mixes maintained Mr properties above 300,000 psi after 21 cycles of freeze-thaw while the Mr properties of the no lime mixes dropped to below 100,000 psi after the same number of freeze-thaw cycles. These differences in the Mr properties would translate into significant extensions in the pavement life under the environmental conditions of the Truckee Meadows region with severe freeze-thaw cycling. Based on the data generated in this research, it was recommended to continue on specifying the use of hydrated lime in RTC HMA mixes.

According to Nevada DOT's historical data throughout Nevada, the marination process has proven to improve the performance of mixes with high plasticity index (PI) fines and to reduce the variability of the moisture sensitivity of field produced mixes. Both of these issues were not evaluated in the RTC laboratory study. Since RTC's jurisdiction covers only a portion of the state, it was recommended that RTC monitors the performance of pavements constructed without marination and make recommendations on the use of marination based on their own experience.

As a continuation of the previous research study, the variability of the moisture sensitivity of field produced HMA mixes sampled from three different local projects were evaluated.

2.0 OBJECTIVE

The objective of this study is to evaluate the variability in moisture sensitivity of lime treated HMA mixes that were sampled during construction from three projects located in the Truckee Meadows region.

3.0 FIELD MIXES

Field produced HMA mixes were sampled from behind the paver on three local projects: Moana Lane Extension, Sparks Boulevard, and Robb Drive. The HMA mixes on Moana Lane and Sparks Boulevard were supplied by Granite Construction Company whereas Bardon Materials construction supplied the HMA mix on Robb Drive.

All mix designs were performed in accordance with the Standard Specifications for Public Works Construction (Orange Book) and the Marshall Mix Design method as specified in the Asphalt Institute's Manual Series 2 (MS-2). On each project, two distinct types of mixtures were used: a PG64-22/Type 2 for the bottom and middle lifts and a PG64-28NV/Type 2 for the top lifts. Both

the PG64-22 and PG64-28NV asphalt binders were supplied by Paramount Petroleum Company in Nevada and are also graded as AC-20 and AC-20P, respectively. All HMA mixes were designed for 75 blows and treated with 1.5% hydrated lime by dry weight of aggregates. Only the mixes from Bardon Materials were subjected to the marination process.

Tables 1 – 3 summarize the projects and sampling information. For each project and for each type of mix (i.e., PG64-22/Type 2 and PG64-28MV/Type 2), five samples were collected at different times of construction. A total of 30 samples were collected for laboratory evaluation.

Table 1 Moana Lane Extension Project Information.

Paving Contractor	HMA Mix				Sampling Date	Location	Lift	Mix ID
	Supplier	Design Date	Max Agg. Size	Binder Type				
Q & D Construction	Granite Construction Company	4/1/06	0.75 inch	PG64-22	8/25/06	N. bound, inside lane, stat. 27+50	Bottom	ML-B1
					9/7/06	N. bound, inside lane, stat. 75+80	Middle	ML-B2
					10/6/06	N. bound, outside lane, stat. 89+30	Bottom	ML-B3
					10/17/06	S. bound, outside lane, stat. 105+50	Bottom	ML-B4
					10/18/06	Inside lane, stat. 103+90	Middle	ML-B5
	Granite Construction Company	4/1/06	0.75 inch	PG64-28NV	8/30/06	Moana lane & Neil Road intersection	Top	ML-T1
					10/10/06	Nanette Circle	Top	ML-T2
					10/19/06	N. bound, outside lane, stat. 21+25	Top	ML-T3
					10/23/06	S. bound, stat. 11+25	Top	ML-T4
					10/24/06	S. bound, outside lane, stat. 82+70	Top	ML-T5

Table 2 Sparks Boulevard Project Information.

Paving Contractor	HMA Mix				Sampling Date	Location	Lift	Mix ID
	Supplier	Design Date	Max Agg. Size	Binder Type				
Frehner Construction	Granite Construction Company	4/1/06	0.75 inch	PG64-22	9/12/06	N. bound, right lane, stat. 56+00	Middle	SB-B1
					11/14/06	Lot #6.2, stat. 35+66	Bottom	SB-B2
					11/15/06	Lot #9.2, stat. 21+50	Bottom	SB-B3
					11/15/06	Lot #8.2, stat. 28+00	Bottom	SB-B4
					11/15/06	Lot #7.2, stat. 44+11	Bottom	SB-B5
	Granite Construction Company	4/1/06	0.75 inch	PG64-28NV	10/12/06	Lot #1.1, stat. 17+00	Top	SB-T1
					10/12/06	Lot #2.2, stat. 58+00	Top	SB-T2
					10/13/06	Lot #4.2, stat. 63+00	Top	SB-T3
					10/13/06	Sparks Blvd & Wells Fargo	Top	SB-T4
					10/16/06	Lot #10.2, stat. 47+50	Top	SB-T5

Table 3 Robb Drive Project Information.

Paving Contractor	HMA Mix				Sampling Date	Location	Lift	Mix ID
	Supplier	Design Date	Max Agg. Size	Binder Type				
Sierra Nevada Construction (SNC)	Bardon Materials	5/2/06	0.75 inch	PG64-22	9/14/06	Robb & Antero intersection	Bottom	RD-B1
					9/15/06	Right lane, stat. 109+00	Bottom	RD -B2
					9/15/06	Right lane, stat. 76+00	Bottom	RD -B3
					9/15/06	Round about, stat. 92+50	Middle	RD -B4
					9/15/06	Right lane, stat. 102+80	Middle	RD -B5
	Bardon Materials	5/2/06	0.75 inch	PG64-28NV	9/15/06	Right outside lane, stat. 103+50	Top	RD -T1
					9/16/06	Lot #7.2, stat. 77+00	Top	RD -T2
					9/16/06	Lot #8.1, stat. 96+50	Top	RD -T3
					9/16/06	Lot #9.1, stat. 82+25	Top	RD -T4
					9/16/06	Lot #10.1, stat. 97+50	Top	RD -T5

3.0 MOISTURE SENSITIVITY OF FILED HMA MIXES

Moisture sensitivity of HMA mixes is defined as the reduction in the internal strength of the mix due to moisture damage. The AASHTO T283 test method was used to evaluate the moisture sensitivity of the various mixes with the exception of using five samples at both the conditioned and unconditioned stages. The following represents a summary of the major steps of the AASHTO T283 test procedure used in this research.

- Compact a total of 10 samples to air-voids of 6.5 – 7.5%.
- Measure the tensile strength (TS) of 5 unconditioned samples at 77°F.
- Subject a set of 5 samples to 70-80% saturation.
- Subject the saturated samples to a freeze-thaw cycle; freezing at 0°F for 16 hours followed by 24 hours thawing at 140°F and 2 hours at 77°F.
- Measure the TS of the 5 samples after conditioning.
- Calculate the tensile strength ratio (TSR) as the ratio of the average TS of the conditioned samples over the average TS of the unconditioned samples.

For each project, the moisture sensitivity of the PG64-22/Type 2 and the PG64-28NV/Type 2 mixes was evaluated. As mentioned earlier, five samples of the field produced HMA mixtures were evaluated for each mix type. Tables 4 – 6 summarize the moisture sensitivity properties of the HMA field produced samples from the various projects along with the average properties for each mix type. The RTC specifies a minimum value for the unconditioned TS at 77°F of 65 psi and a minimum TSR of 70% for the Truckee Meadows (Reno) area.

The level of variability in the measured data is indicated by the coefficient of variations (CV). The CV is defined as the ratio of the standard deviation over the average TS times 100. All samples tested in this study had a CV value below 10% indicating good repeatability of the measured data.

Table 4 shows that the samples of the PG64-22/Type 2 mix from Moana Lane Extension met the minimum unconditioned TS of 65 psi but failed to meet the minimum TSR value of 70%. On the other hand, the minimum RTC criterion for the unconditioned TS was met on all samples from the PG64-28NV/Type 2 mix and the minimum TSR criterion was only met on three samples out of five.

Table 4 Moana Lane Extension Project Moisture Sensitivity Properties.

Binder type	Mix ID	Lift	Unconditioned				Conditioned					Tensile strength ratio, TSR (%)
			Air voids (%)		Tensile strength TS at 77°F, psi		Air voids (%)		Average degree of saturation (%)	Tensile strength TS at 77°F, psi		
			Mean	CV*	Mean	CV*	Mean	CV*		Mean	CV*	
PG64-22	ML-B1	Bot.	6.8	5%	177.0	6%	6.9	3%	76.0	118.3	7%	66.8
	ML-B2	Mid.	6.9	3%	168.5	6%	6.9	4%	77.9	103.1	8%	61.2
	ML-B3	Bot.	7.1	5%	187.5	8%	7.1	3%	77.0	126.8	5%	67.6
	ML-B4	Bot.	7.1	4%	186.9	8%	7.1	3%	78.0	121.5	8%	65.0
	ML-B5	Mid.	7.2	4%	206.0	8%	7.2	2%	76.4	134.7	4%	65.4
Overall Average			7.0	--	185.2	--	7.0	--	77.1	120.9	--	65.2
Overall SD+			0.2	--	14.0	--	0.1	--	0.9	11.7	--	2.5
Overall CV*			2%	--	8%	--	2%	--	1%	10%	--	4%
PG64-28NV	ML-T1	Top	7.2	3%	199.4	7%	7.1	2%	77.2	120.7	7%	61.0
	ML-T2	Top	6.9	3%	72.3	5%	6.9	4%	73.8	62.8	8%	87.0
	ML-T3	Top	6.8	4%	162.5	3%	6.8	3%	76.6	116.1	7%	71.5
	ML-T4	Top	7.2	3%	179.6	3%	7.2	1%	76.4	118.0	4%	65.7
	ML-T5	Top	6.9	4%	146.4	5%	6.9	2%	78.5	105.1	6%	71.8
Overall Average			7.0	--	152.0	--	7.0	--	76.5	104.5	--	71.4
Overall SD+			0.2	--	48.7	--	0.2	--	1.7	24.1	--	9.8
Overall CV*			3%	--	32%	--	2%	--	2%	23%	--	14%

*CV denotes coefficient of variation
+ SD denotes standard deviation

Table 5 shows that the samples of the PG64-22/Type 2 mix from Sparks Boulevard met the minimum unconditioned TS of 65 psi but failed to meet the minimum TSR value of 70% on two samples out of five. On the other hand, the minimum RTC criteria for the unconditioned TS and TSR values were met on all five samples from the PG64-28NV/Type 2 mix.

Table 6 shows that samples of both the PG64-22/Type 2 and the PG64-28NV/Type 2 mixes from Robb Drive met the minimum RTC criteria for unconditioned TS and TSR values.

Table 5 Sparks Boulevard Project Moisture Sensitivity Properties.

Binder type	Mix ID	Lift	Unconditioned				Conditioned					Tensile strength ratio, TSR (%)
			Air voids (%)		Tensile strength TS at 77°F, psi		Air voids (%)		Average degree of saturation (%)	Tensile strength TS at 77°F, psi		
			Mean	CV*	Mean	CV*	Mean	CV*		Mean	CV*	
PG64-22	SB-B1	Mid.	6.6	6%	153.2	8%	6.6	2%	76.0	112.3	2%	73.3
	SB-B2	Bot.	7.1	3%	142.5	5%	7.1	4%	76.1	101.6	7%	71.2
	SB-B3	Bot.	7.4	1%	136.5	9%	7.4	1%	76.5	85.6	5%	62.7
	SB-B4	Bot.	7.1	3%	159.2	5%	7.1	3%	76.8	113.4	7%	71.2
	SB-B5	Bot.	6.9	5%	139.8	6%	6.9	4%	76.7	91.4	5%	65.4
Overall Average			7.0	--	146.2	--	7.0	--	76.4	100.9	--	68.8
Overall SD+			0.3	--	9.6	--	0.3	--	0.4	12.4	--	4.5
Overall CV*			4%	--	7%	--	4%	--	0%	12%	--	7%
PG64-28NV	SB-T1	Top	6.8	6%	117.2	6%	6.8	4%	76.2	107.9	8%	92.1
	SB-T2	Top	6.8	4%	121.8	5%	6.8	2%	77.1	107.0	4%	87.8
	SB-T3	Top	6.9	5%	114.6	7%	6.9	2%	79.8	100.4	8%	87.6
	SB-T4	Top	6.7	3%	123.2	3%	6.7	2%	74.8	108.4	7%	88.0
	SB-T5	Top	6.8	4%	128.1	4%	6.8	2%	77.2	109.2	1%	85.2
Overall Average			6.8	--	121.0	--	6.8	--	77.0	106.6	--	88.1
Overall SD+			0.1	--	5.3	--	0.1	--	1.8	3.5	--	2.5
Overall CV*			1%	--	4%	--	1%	--	2%	3%	--	3%

*CV denotes coefficient of variation
+ SD denotes standard deviation

Table 6 Robb Drive Project Moisture Sensitivity Properties.

Binder type	Mix ID	Lift	Unconditioned				Conditioned					Tensile strength ratio, TSR (%)
			Air voids (%)		Tensile strength TS at 77°F, psi		Air voids (%)		Average degree of saturation (%)	Tensile strength TS at 77°F, psi		
			Mean	CV*	Mean	CV*	Mean	CV*		Mean	CV*	
PG64-22	RD-B1	Bot.	6.5	2%	169.1	7%	6.5	1%	74.6	126.2	10%	75.6
	RD-B2	Bot.	6.8	3%	151.3	9%	6.8	1%	75.0	148.6	5%	98.2
	RD-B3	Bot.	6.9	3%	149.4	3%	6.9	2%	76.1	113.3	4%	75.9
	RD-B4	Bot.	6.7	5%	154.1	6%	6.7	1%	76.7	134.8	6%	87.5
	RD-B5	Mid.	7.4	1%	143.6	5%	7.4	2%	74.9	126.8	5%	88.3
Overall Average			6.9	--	153.5	--	6.9	--	75.5	129.9	--	85.1
Overall SD+			0.3	--	9.5	--	0.3	--	0.9	13.0	--	9.5
Overall CV*			5%	--	6%	--	5%	--	1%	10%	--	11%
PG64-28NV	RD-T1	Top	6.8	3%	132.0	7%	6.8	3%	75.0	107.4	6%	81.3
	RD-T2	Top	6.8	4%	128.4	4%	6.8	2%	74.2	103.3	5%	80.4
	RD-T3	Top	6.7	3%	138.8	4%	6.7	1%	76.5	112.5	7%	81.0
	RD-T4	Top	6.9	4%	135.8	7%	6.9	4%	76.9	110.5	4%	81.4
	RD-T5	Top	7.4	2%	135.5	5%	7.4	1%	78.1	107.3	6%	79.2
Overall Average			6.9	--	134.1	--	6.9	--	76.1	108.2	--	80.7
Overall SD+			0.3	--	4.0	--	0.3	--	1.6	3.5	--	0.9
Overall CV*			4%	--	3%	--	4%	--	2%	3%	--	1%

*CV denotes coefficient of variation
+ SD denotes standard deviation

Table 7 summarizes the number of samples that failed to meet the 70% TSR criterion out of the five field samples evaluated from each project. It should be noted that none of the mixes evaluated in this study failed to meet the unconditioned TS criterion of 65 psi at 77°F.

The data in Table 7 show that the marination process reduces the probability of field produced HMA mixes to fail the TSR criterion. In addition, the use of polymer-modified asphalt binder (i.e., PG64-28NV) masked the variability introduced by not marinating the aggregate during production by showing a lower number of failing samples when compared to mixes produced with neat asphalt binders (i.e., PG64-22).

Table 7 Summary of the Moisture Sensitivity Properties of the Various Evaluated Projects.

Project	Mix	Number of samples failing in TSR
Moana Lane Extension	PG64-22/Type 2	5 out of 5
	PG64-28NV/Type 2	2 out of 5
Sparks Boulevard	PG64-22/Type 2	2 out of 5
	PG64-28NV/Type 2	0 out of 5
Robb Drive	PG64-22/Type 2	0 out of 5
	PG64-28NV/Type 2	0 out of 5

3.0.1 Data Analysis Based on Average Properties

Figures 1 and 2 compare the average tensile strength (TS) values and the average tensile strength ratio (TSR) of the PG64-22/Type 2 and PG64-28NV/Type 2 mixes on each project. The top of each figure presents the average data with a +/- one standard deviation and the bottom portion of the figure presents the average data with the minimum and maximum values. Figure 1 shows that all mixes meet the minimum unconditioned TS of 65 psi and all mixes maintained an average conditioned TS value above 65 psi. Figure 2 shows that the average TSR values met RTC's criterion for the PG64-28NV/Type 2 mixes on all three projects while the PG64-22/Type 2 mixes met the RTC's criterion on the Robb Drive project only.

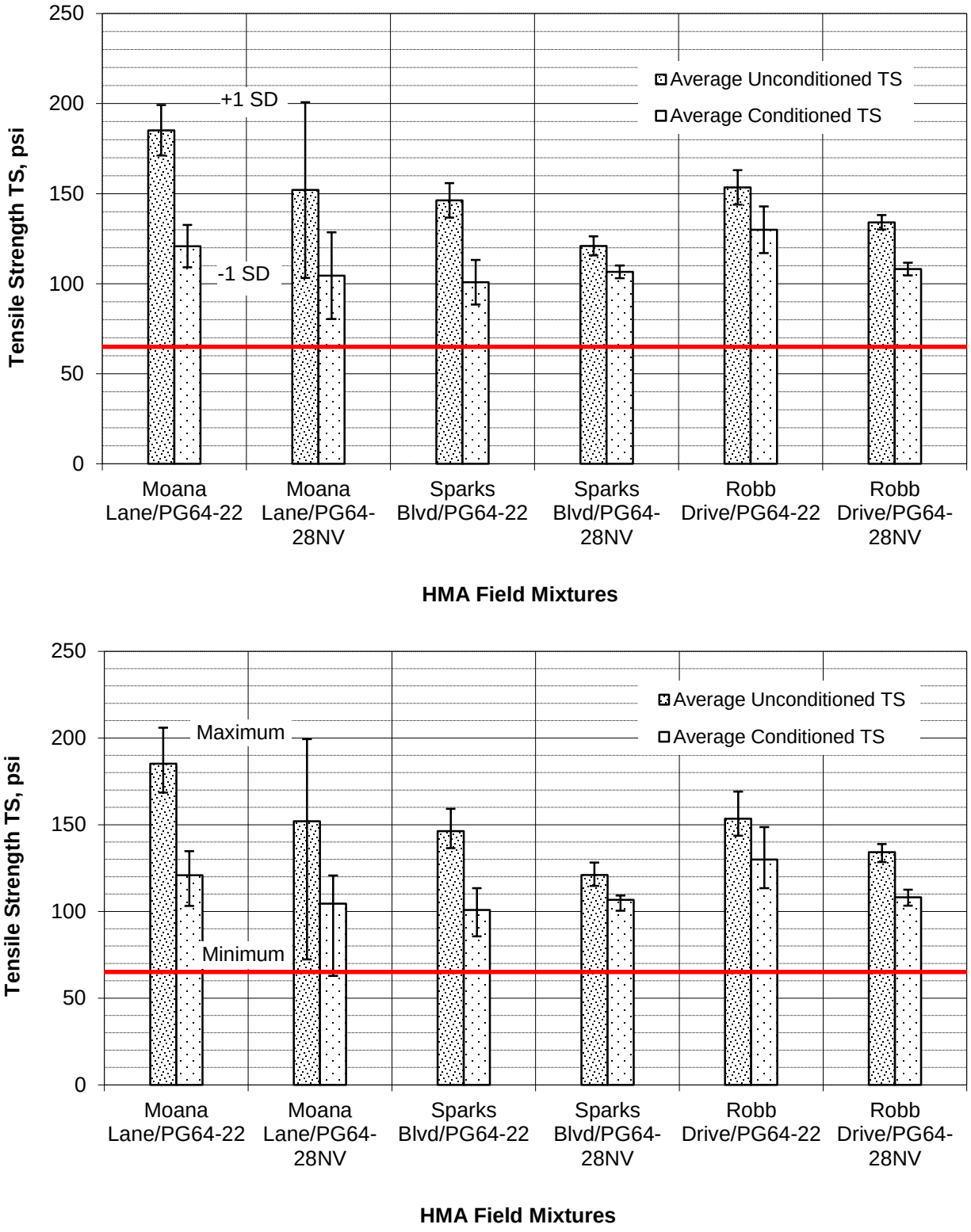

Figure 1 Average tensile strength of various mixtures at 77°F

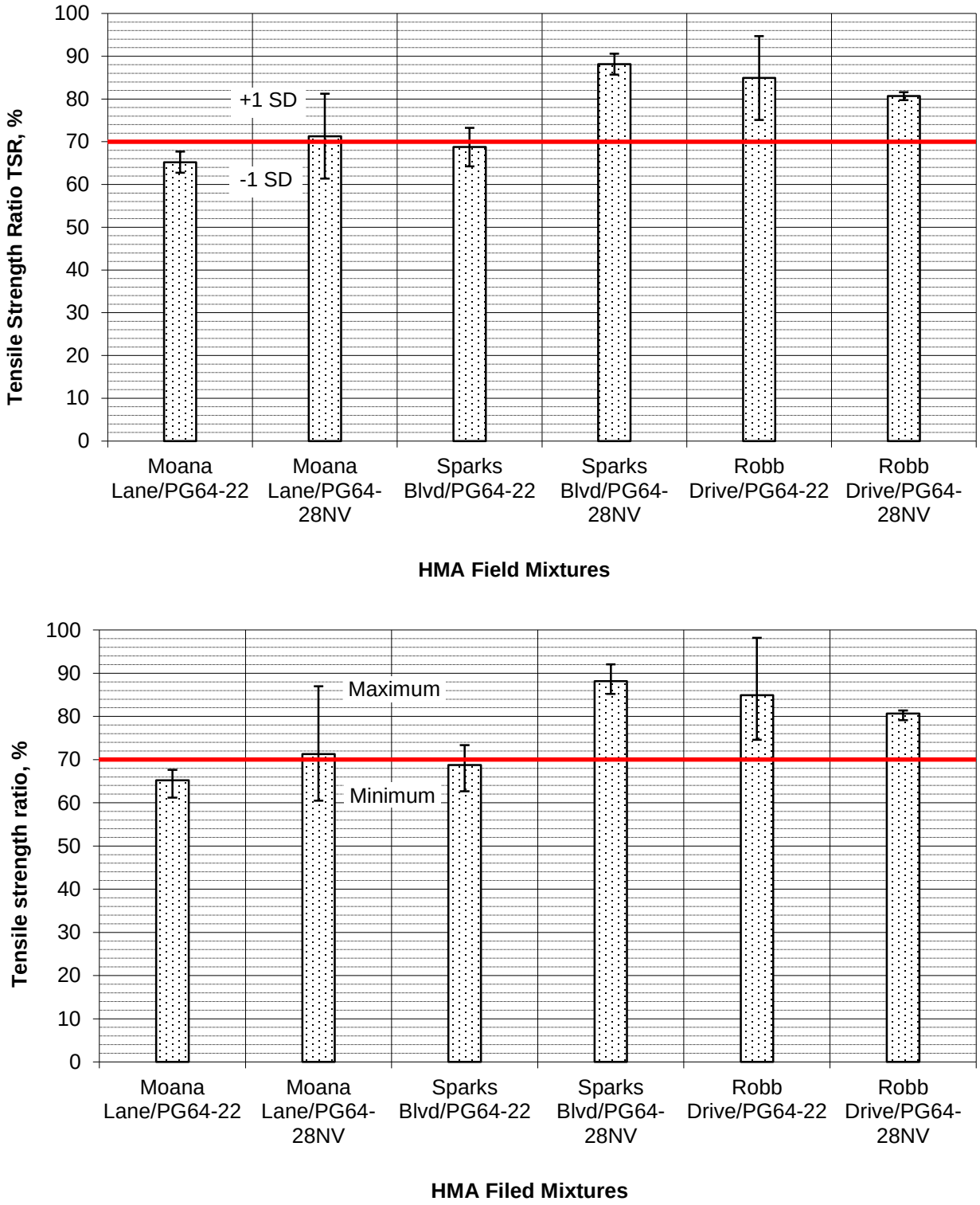

Figure 2 Average tensile strength ratio of various mixtures at 77°F

3.0.2 Data Analysis Based on NDOT Quality Assurance Process

The Nevada Department of Transportation (NDOT) conducts the AASHTO T283 moisture sensitivity test on field produced HMA mixes as part of their quality control system. NDOT assesses demerits after the first failure of the specifications and shut down the project after two consecutive failures until the problem is solved.

Applying NDOT's quality assurance process on the three evaluated projects would result in the recommendations shown in Table 8. The projects were analyzed in the chronological order of the time of sampling. Table 8 shows that the Moana Lane would have been subjected to a total shut down during the construction of the bottom/middle lifts (i.e., PG64-22/Type 2 mix) and to the assessments of demerits during the construction of the top lift (i.e., PG64-28NV/Type 2 mix).

In the case of the Sparks Boulevard project, demerits would have been assessed for the PG64-22/Type 2 mix of the bottom and middle lifts whereas no demerits would have been assessed for the PG64-28NV/Type 2 mix.

No actions would have been taken on the Robb Drive project since all samples passed the specifications for the moisture sensitivity test.

Table 8 Summary of the Moisture Sensitivity Properties of the Various Evaluated Projects.

Project	Mix	Sampling Date	TSR (%)	Action
Moana Lane Extension	PG64-22/Type 2	8/25/06	66.8	Demerits
		9/7/06	61.2	Shut Down
		10/6/06	67.6	Shut Down
		10/17/06	65.0	Shut Down
		10/18/06	65.4	Shut Down
	PG64-28NV/Type 2	8/30/06	61.0	Demerits
		10/10/06	87.0	No action
		10/19/06	71.5	No action
		10/23/06	65.7	Demerits
		10/24/06	71.8	No action
Sparks Boulevard	PG64-22/Type 2	9/12/06	73.3	No action
		11/14/06	71.2	No action
		11/15/06	62.7	Demerits
		11/15/06	71.2	No action
		11/15/06	65.4	Demerits
	PG64-28NV/Type 2	10/12/06	92.1	No action
		10/12/06	87.8	No action
		10/13/06	87.6	No action
		10/13/06	88.0	No action
		10/16/06	85.2	No action
Robb Drive	PG64-22/Type 2	9/14/06	75.6	No action
		9/15/06	98.2	No action
		9/15/06	75.9	No action
		9/15/06	87.5	No action
		9/15/06	88.3	No action
	PG64-28NV/Type 2	9/15/06	81.3	No action
		9/16/06	80.4	No action
		9/16/06	81.0	No action
		9/16/06	81.4	No action
		9/16/06	79.2	No action

4.0 CONCLUSION

The moisture sensitivity of field mixtures sampled from behind the paver on three local projects were evaluated in the laboratory in accordance with the AASHTO T283 test method with the exception of using five samples instead of three at both the conditioned and unconditioned stages. All mixes were treated with 1.5% hydrated lime with only the mixes from Robb Drive being subjected to the 48-hrs marination process. All mixes were designed according to the RTC Marshall mix design method which requires a minimum unconditioned

tensile strength of 65 psi and a minimum tensile strength ratio of 70%. Based on the data analyzed in this study the following conclusions were made:

- All field produced mixtures met the minimum tensile strength value of 65 psi regardless whether the aggregates were marinated or not.
- All field produced mixtures from the project that used 48-hrs marination met the RTC's TSR criterion of 70% whereas some samples from the two projects that used non-marinated aggregate failed to meet the RTC's TSR criterion.
- The marination process reduced the possibility of failing the TSR criterion on the field produced mixtures.
- The use of polymer-modified asphalt binder (i.e., PG64-28NV) masked the variability introduced by not marinating the aggregate during production by showing a lower number of failing samples when compared to mixes produced with neat asphalt binders (i.e., PG64-22).

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1. Sebaaly, P.E. and Manoharan S. (2006). "Task E: Impact of Lime on Raveling of HMA Mixtures," Washoe Regional Transportation Commission, RTC, Reno, Nevada.