A Comparison of Liquid Antistrip Additives and Hydrated Lime Using AASHTO T-283

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Background

Moisture damage or stripping is an asphalt pavement distress that is generally recognized as the loss of the bond between the asphalt binder and the aggregate. Several pavement distresses that can include stripping as the underlying cause are rutting, cracking, raveling, flushing, and bleeding. Stripping can progress from either the top or bottom of hot mix pavement layer. The common cause in all cases of stripping is the presence of water. The potential for a hot mix asphalt pavement to incur moisture damage can be controlled or reduced through material selection, mixture designs that include a high asphalt film thickness, additives, proper pavement design, construction, compaction, and drainage.

Many agencies include moisture sensitivity testing in the asphalt mixture design stage. The outcome of this testing can be used to eliminate certain asphalt and aggregate combinations or to require the use of an antistrip additive. The most commonly used antistrip additives are **hydrated lime** and **liquid chemical additives**. The moisture sensitivity test procedure recommended in the SHRP SuperPave mixture design protocol is AASHTO T-283, "Resistance of Compacted Bituminous Mixture to Moisture Induced Damage".

The purpose of this research is to determine if hydrated lime and **high performance** chemical additives perform similarly using AASHTO T-283 as the prediction model for the moisture sensitivity of a hot mix asphalt mixture. In this research, the optional freeze cycle was incorporated in the test method in order to increase the potential for moisture damage to occur to the specimens. This was done to distinguish high performing, no additive mixtures and also at the recommendation of McGennis and Aschenbrener that high traffic and severity one pavement mix designs should include it (1).

An additional purpose of this research was to determine the effective dosage concentrations for the liquid chemical additives.

Method of Investigation

Aggregates and asphalt binders were selected to represent a wide spectrum of paving materials in the United States. The mixture design was obtained for the specific aggregate and asphalt combination. All asphalt binders were obtained unmodified. The materials were blended according to the optimum asphalt content and mixed at temperatures selected from the temperature viscosity relationship for the specific asphalt binder. The liquid antistrip additive was dosed and blended into the asphalt binder and stored at the mixing temperature for two hours. The hydrated lime was added to the aggregate as slurry containing three percent water by weight of aggregate and then mechanically mixed until coated. A lime slurry is generally considered the optimum method for the addition of lime(2). The aggregate was then dried at the mixing temperature to a constant weight.

The asphalt and aggregate combination was mechanically mixed and allowed to cool at room temperature for two hours. The mixture was then cured in a 60C oven for 16 hours. After curing the mixture was placed in a 135C oven for two hours prior to compaction. The maximum theoretical specific gravity of each aggregate, additive, and asphalt combination was determined by following AASHTO T-209-94.

The compactive effort used was a SHRP gyratory compactor manufactured by Pine Instruments. The specimen mold size was 100 mm. The 100 mm mold size was selected due to it requiring less material than a 150 mm mold. The specimens were compacted to an air void level of 7.0 ? 0.5 percent. This is a slightly more restrictive than the range of 7.0 ? 1.0 percent that is specified in AASHTO T-283. A more restrictive air void range will give greater reproducibility of the test results among the individual specimens. A gyratory compactor can accomplish this range with a greater reproducibility than a Marshall hammer. The specimens were compacted using a ram pressure of 600 KPa and a compaction angle of 1.25 degrees. The number of gyrations varied to give an air void level of 7.0 ? 0.5 percent and a specimen height of approximately 63 mm. After extraction, the specimens were stored at room temperature for 72 hours.

The specimens were sorted into two subsets of three specimens each, so that the average air voids of the two subsets were approximately equal. One subset was conditioned by vacuum saturating with distilled water to 55 to 80 percent of the air void volume. These specimens were then placed in a freezer at –18C for a minimum of 16 hours. After removal from the freezer, they were placed in a 60C water bath for 24 hours. The specimens are then placed in a 25C bath for two hours. Also at this time the unconditioned specimens were placed in the 25C bath. After these two hours of temperature stabilization, the indirect tensile strength was determined on all the specimens. The indirect tensile strength is calculated by the following equation:

$$S_t = (2P) / ? \, t \, D$$

where: S_t = tensile strength, Pa

P = maximum load, Newton

t = specimen thickness, mm

D = specimen diameter, mm

The tensile strength ratio was calculated and a visual stripping rating given to the specimens. The tensile strength ratio is calculated by the following equation:

$$\text{Tensile Strength Ratio (TSR)} = S_2 / S_1$$

where: S_1 = average tensile strength of dry subset
S_2 = average tensile strength of conditioned subset

A range of zero to ten was used for the visual rating, with zero representing no stripping and ten being considered 100 percent stripped.

Additive Selection

The hydrated lime selected is a commercially available lime that was obtained locally. In all cases it was dosed at a rate of one percent by weight of aggregate. The liquid antistrip additives selected were a fatty amidoamine, and a blended polyamine. These are the most commonly used amine chemical additives. The liquid additives were dosed at rates of 0.25, 0.5, and 0.75 percent by weight of asphalt binder. One mixture from each aggregate and asphalt combination was tested “neat”, or without any additive.

Aggregate Selection

The aggregates selected represented materials currently in production for hot mix asphalt. These aggregates came from the states of California, Florida, Georgia, Missouri, Mississippi, South Carolina, and Utah. The aggregates were sieved and put back together according to their respective mixture design. The predominate geology consisted of the following(3):

State	**Predominate Geology in Mixture**
California	Crushed Gravel, alluvial basin
Florida	Crushed Granite, Nova Scotia, Porcupine
Georgia	Crushed Granite
Missouri	Crushed Dolomite, some chert presence
Mississippi	Crushed Gravel, terrace deposit Crushed Limestone
South Carolina	Crushed Granite
Utah	Crushed Gravel, glaciofluvial deposit

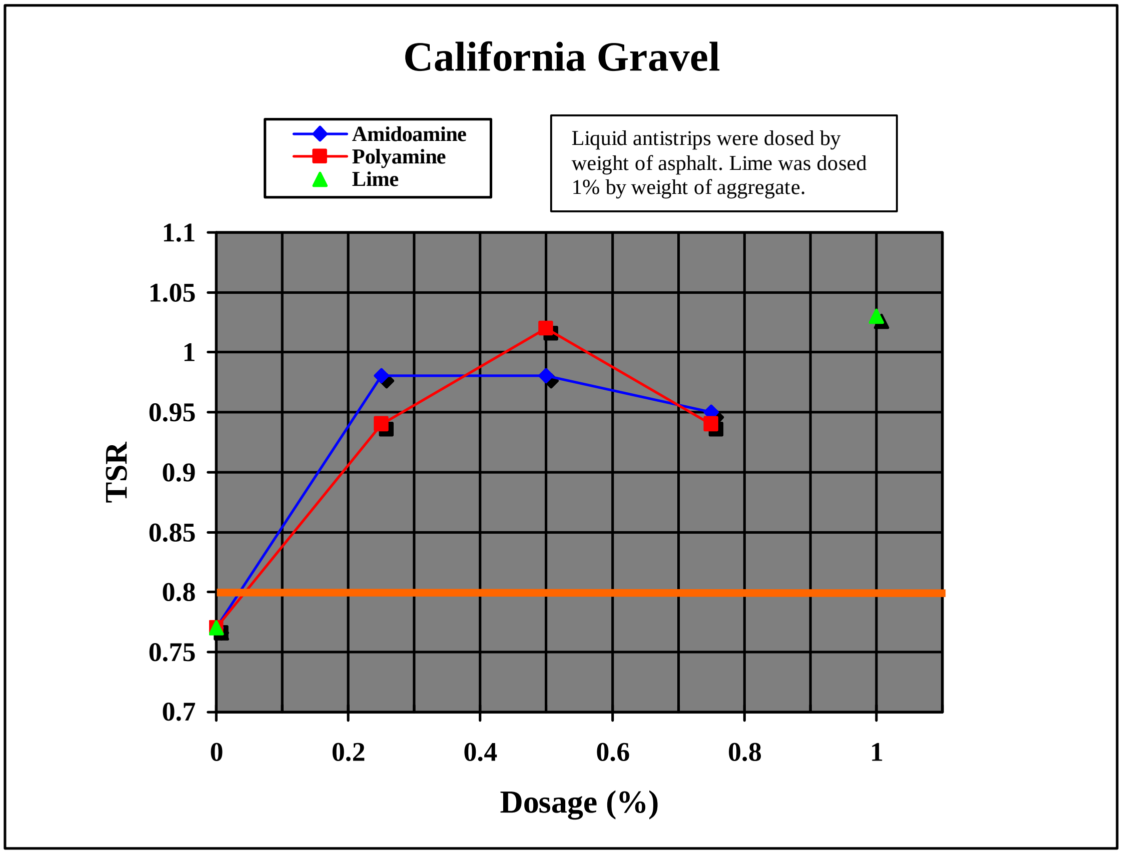
Asphalt Binder Selection

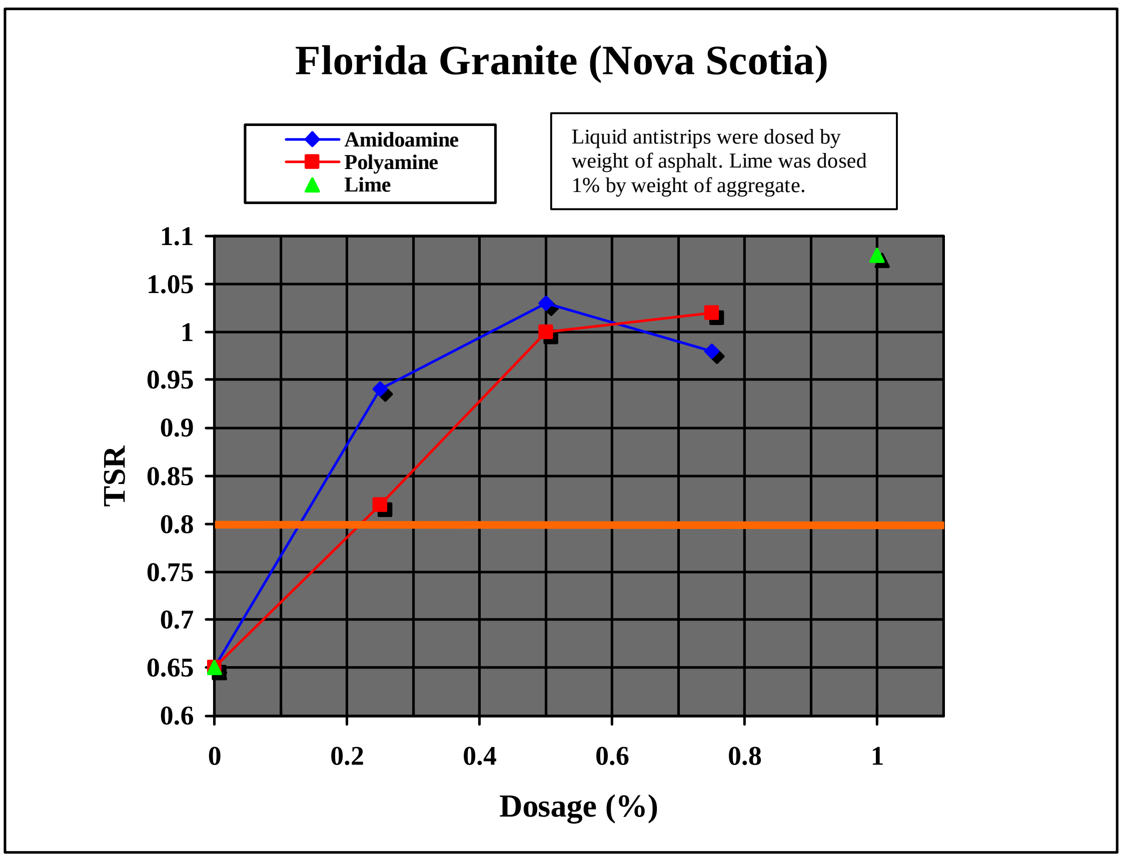
The asphalt binders were SHRP graded binders with the exception of four that were viscosity graded. All of the SHRP binders were unmodified to meet the PG grading. They varied from a PG67-22 to a PG64-22. On the crushed gravel from Mississippi, two mixtures were tested with two different asphalt binders. The geographical representations of the binders are:

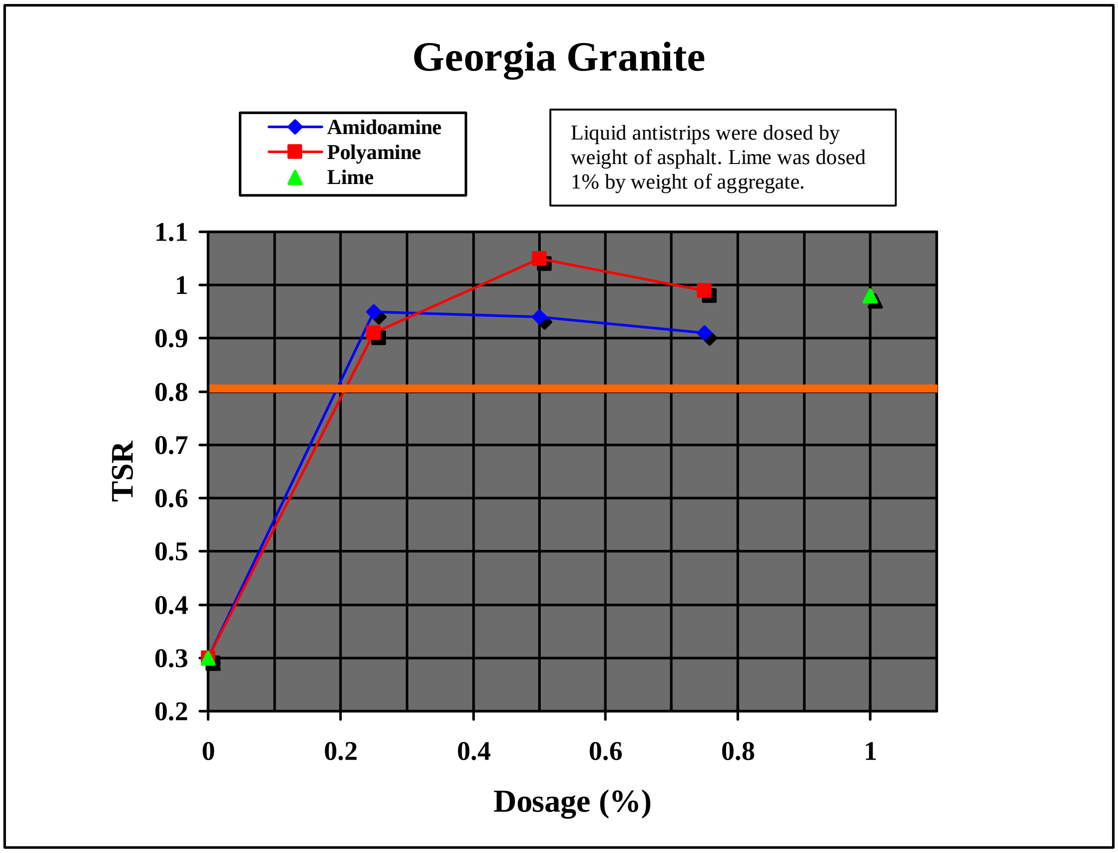
State	**Asphalt Binder**
California	AR4000
Florida	AC30
Georgia	PG64-22
Missouri	PG64-22
Mississippi	PG67-22 AC30
South Carolina	PG64-22
Utah	AC10

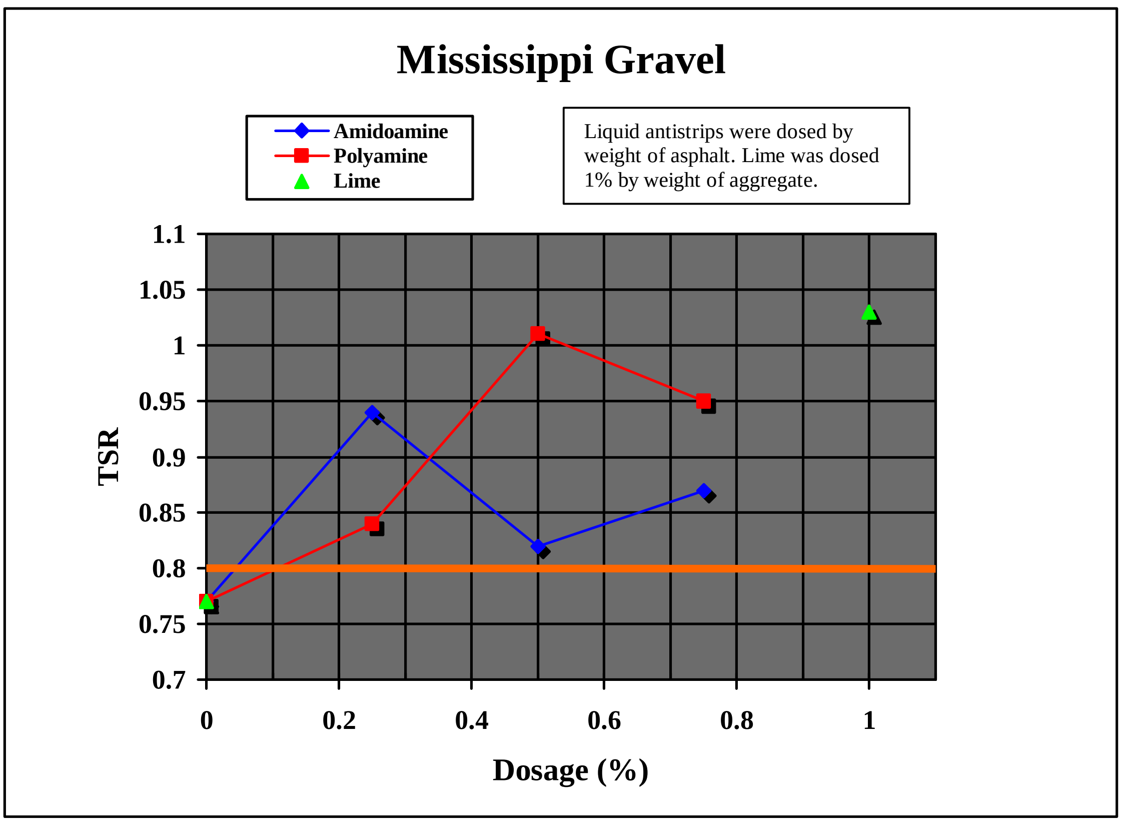
Test Results

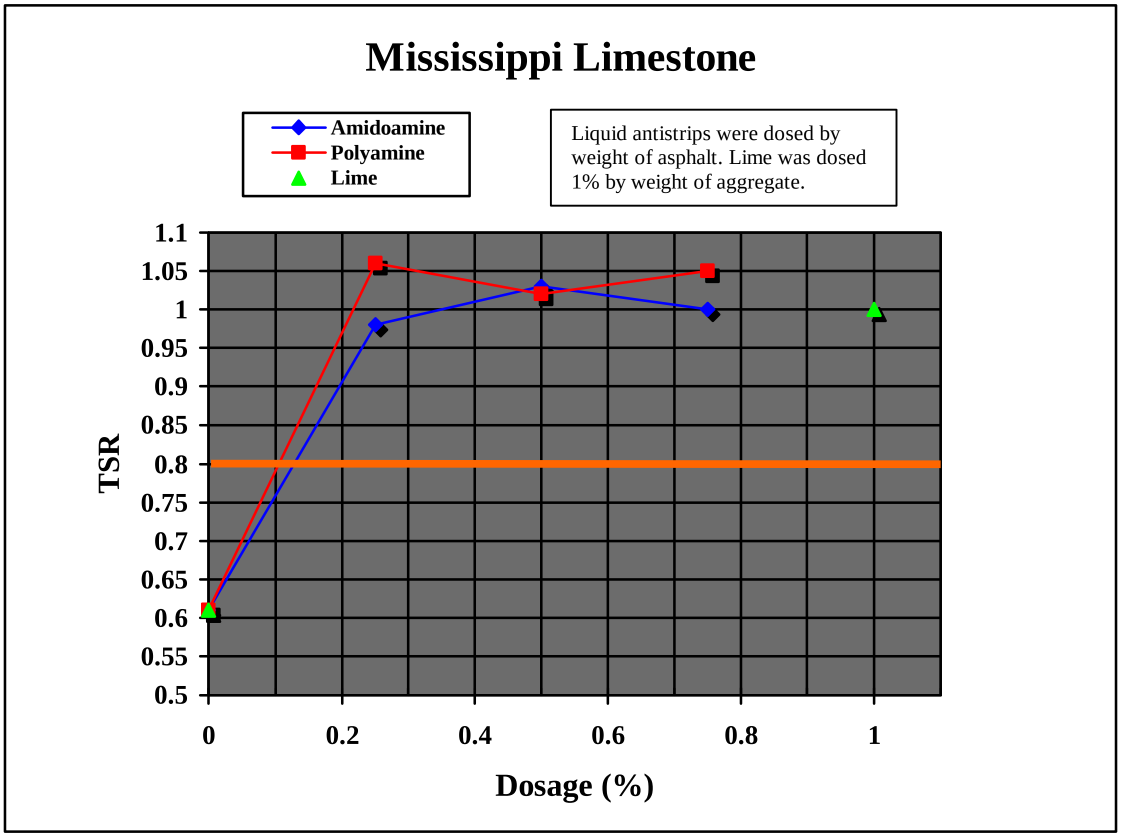
A summary of the test results appears in Table A1 in Appendix A. These test results include percent air voids, percent final saturation level, percent swell, unconditioned strength, conditioned strength, tensile strength ratio, and the visual rating of the conditioned specimens. The final saturation level is reported since it gives more accurate representation of the condition of the specimen at the time of testing. The following eight graphs represents the dosage level of the additives plotted verse tensile strength ratio. The hydrated lime results are also included as a single data point at a dosage level of one percent by weight of aggregate.

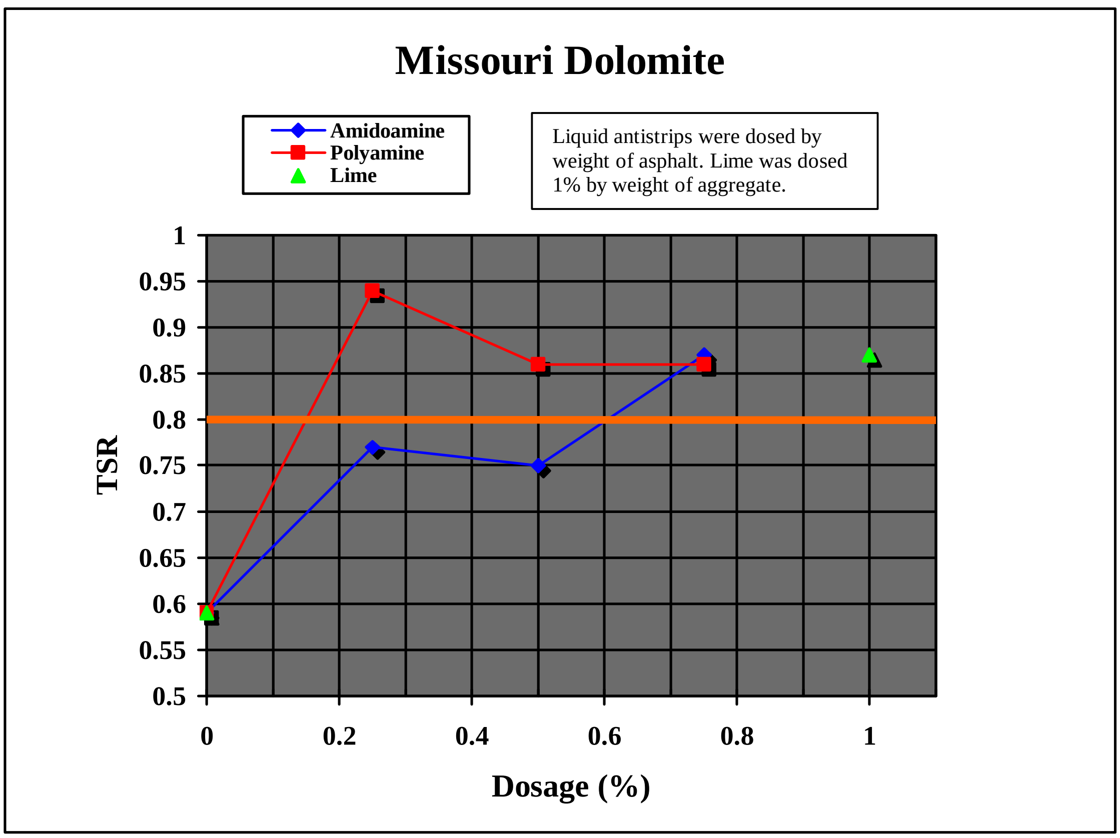

California Gravel
Amidoamine
Polyamine
Lime
Liquid antistrips were dosed by weight of asphalt. Lime was dosed 1% by weight of aggregate.
TSR
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0
0.2
0.4
0.6
0.8
1
Dosage (%)

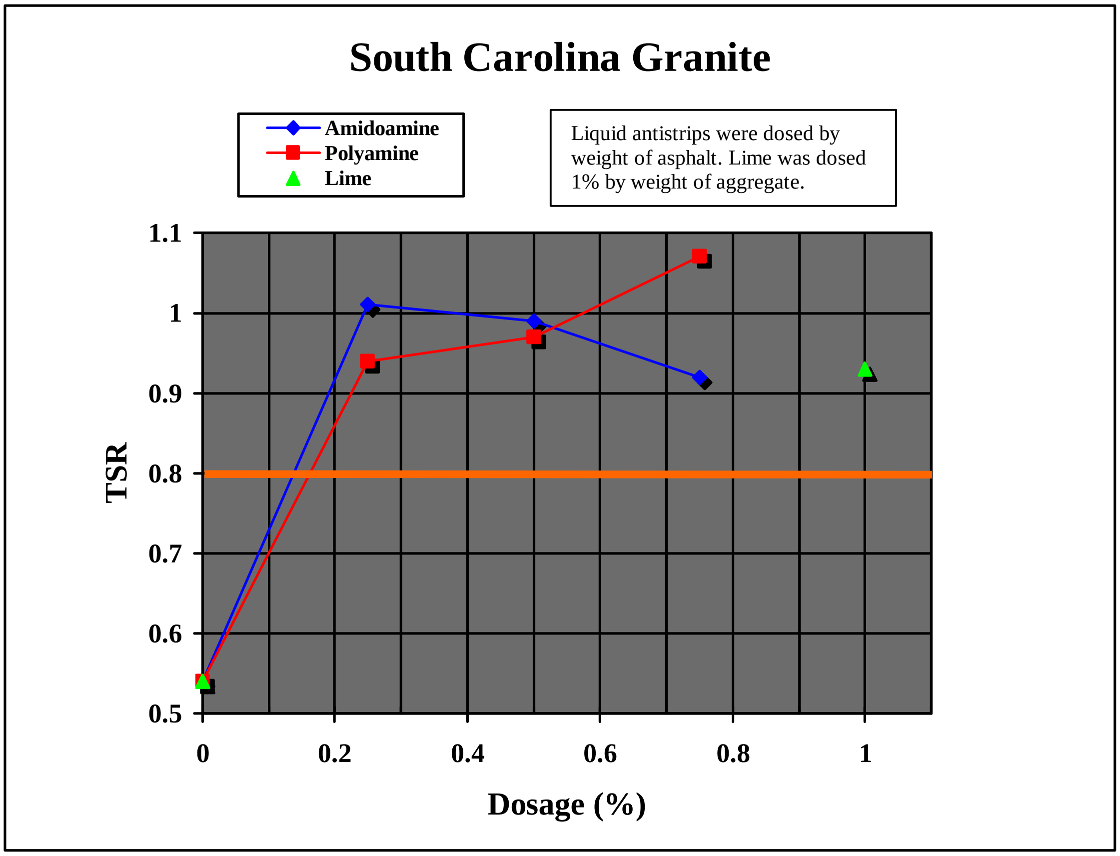

Florida Granite (Nova Scotia)
Amidoamine
Polyamine
Lime
Liquid antistrips were dosed by weight of asphalt. Lime was dosed 1% by weight of aggregate.
TSR
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0
0.2
0.4
0.6
0.8
1
Dosage (%)

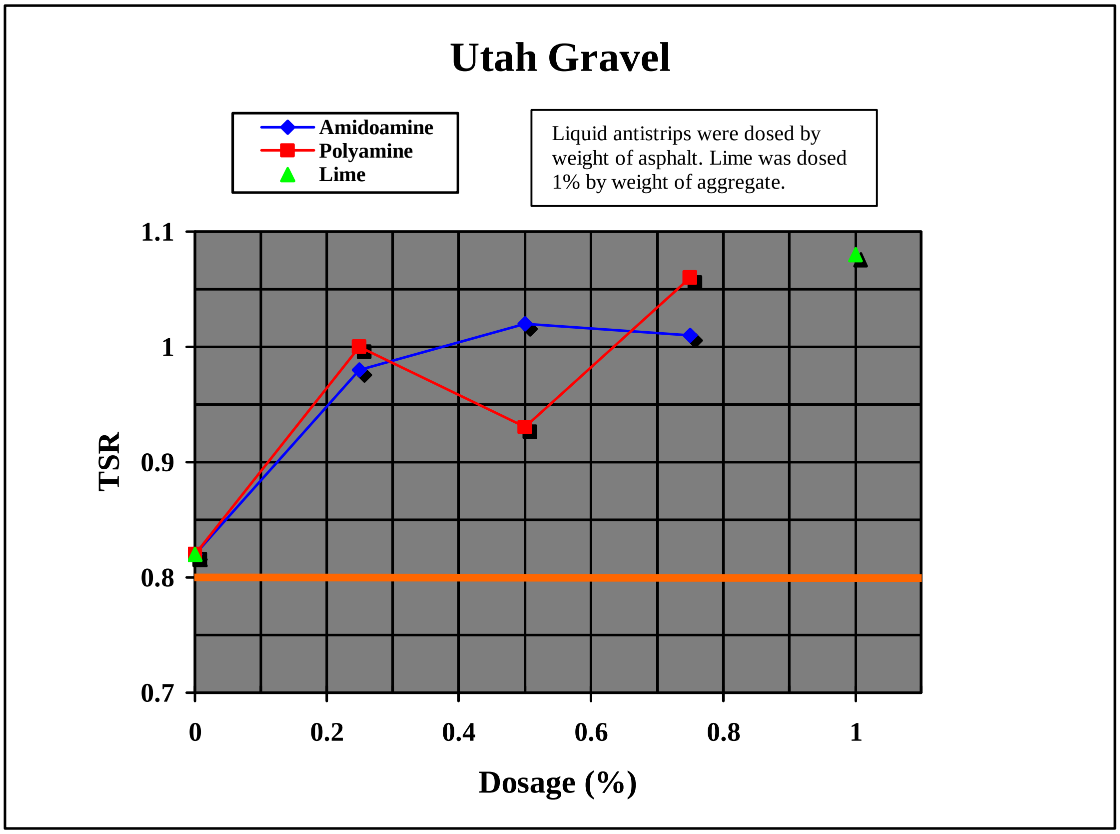

Georgia Granite
Amidoamine
Polyamine
Lime
Liquid antistrips were dosed by weight of asphalt. Lime was dosed 1% by weight of aggregate.
TSR
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
0.2
0.4
0.6
0.8
1
Dosage (%)


Mississippi Gravel
Amidoamine
Polyamine
Lime
Liquid antistrips were dosed by weight of asphalt. Lime was dosed 1% by weight of aggregate.
TSR
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0
0.2
0.4
0.6
0.8
1
Dosage (%)


Mississippi Limestone
Amidoamine
Polyamine
Lime
Liquid antistrips were dosed by weight of asphalt. Lime was dosed 1% by weight of aggregate.
TSR
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0
0.2
0.4
0.6
0.8
1
Dosage (%)


Missouri Dolomite
Amidoamine
Polyamine
Lime
Liquid antistrips were dosed by weight of asphalt. Lime was dosed 1% by weight of aggregate.
TSR
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0
0.2
0.4
0.6
0.8
1
Dosage (%)


South Carolina Granite
Amidoamine
Polyamine
Lime
Liquid antistrips were dosed by weight of asphalt. Lime was dosed 1% by weight of aggregate.
TSR
1.1
1
0.9
0.8
0.7
0.6
0.5
0
0.2
0.4
0.6
0.8
1
Dosage (%)


Utah Gravel
Amidoamine
Polyamine
Lime
Liquid antistrips were dosed by weight of asphalt. Lime was dosed 1% by weight of aggregate.
TSR
1.1
1
0.9
0.8
0.7
0
0.2
0.4
0.6
0.8
1
Dosage (%)

Conclusions

AASHTO T-283 is the most widely recognized laboratory test method for the prediction of moisture sensitivity. It is also recommended for use in the SuperPave mixture design method. The SuperPave criterion for the tensile strength ratio is a minimum of 0.80. In this research project, all the mixtures tested containing no type of additive failed the SuperPave criteria with the exception of the Utah gravel mixture. The untreated Utah mixture had a tensile strength ratio of 0.82. All the liquid antistrip additive and the hydrated lime mixtures met or exceeded the SuperPave tensile strength ratio criteria with the exception of the amidoamine used on the Missouri dolomite mixture at the 0.25 and 0.5 percent dosage level. Based on this research and using tensile strength criteria alone, it appears the optimum use level of these liquid antistrip additives is 0.25 percent by weight of asphalt cement.

Appendix A

Table A1

Additive	Dosage, %	Voids, %	Final Saturation, %	Swell, %	Unconditioned Strength, KPa	Conditioned Strength, KPa	TSR	Visual, 0 - 10
California Gravel								
Neat	0	6.7	78.6	0.45	884.6	677.1	0.77	4
Amidoamine	0.25	7.2	68.9	0.04	806.7	792.9	0.98	2
Amidoamine	0.5	7.4	71.7	0.11	850.8	833.8	0.98	0
Amidoamine	0.75	6.3	72.6	-0.13	785.3	746.1	0.95	0
Polyamine	0.25	6.6	71.9	0.16	781.9	735.0	0.94	1
Polyamine	0.5	6.8	71.1	0.04	740.5	752.2	1.02	0
Polyamine	0.75	7.4	72.3	0.03	853.6	801.2	0.94	0
Lime	1.0*	7.4	77.6	0.27	784.0	807.4	1.03	1
Florida Granite (Nova Scotia)								
Neat	0	6.1	87.0	0.21	680.7	1054.2	0.65	4
Amidoamine	0.25	6.1	79.3	0.33	1154.8	1088.6	0.94	0.5
Amidoamine	0.5	7.5	81.0	0.09	709.7	729.0	1.03	0
Amidoamine	0.75	7.1	82.9	0.27	749.6	737.2	0.98	0
Polyamine	0.25	6.9	82.5	0.08	889.5	732.4	0.82	1.5
Polyamine	0.5	6.8	79.0	0.07	884.0	887.4	1.00	0
Polyamine	0.75	6.7	81.2	0.09	844.0	857.8	1.02	0
Lime	1.0*	6.7	79.0	-0.12	795.8	858.5	1.08	0.5
Georgia Granite								
Neat	0	6.8	113.3	2.2	839.1	255.8	0.30	8
Amidoamine	0.25	6.8	74.6	0.06	927.4	882.6	0.95	1
Amidoamine	0.5	7.2	73.5	-0.14	870.8	817.1	0.94	1
Amidoamine	0.75	7.1	73.8	-0.16	912.9	872.9	0.91	0
Polyamine	0.25	7.2	73.9	-0.24	869.5	790.9	0.91	1
Polyamine	0.5	7.0	70.8	-0.23	896.4	943.2	1.05	0
Polyamine	0.75	7.2	72.4	-0.35	814.3	809.5	0.99	0
Lime	1.0*	7.0	70.3	-0.23	880.5	866.7	0.98	0
Mississippi Gravel								
Neat	0	7.0	88.6	1.54	564.7	446.1	0.79	8
Amidoamine	0.25	6.9	100.4	2.36	664.0	623.3	0.94	2.5
Amidoamine	0.5	7.1	89.6	2.25	748.8	612.3	0.82	1
Amidoamine	0.75	7.3	87.4	1.75	695.0	606.8	0.87	0.5
Polyamine	0.25	7.4	92.5	2.04	736.4	618.6	0.84	1.5
Polyamine	0.5	7.3	89.9	1.64	619.2	625.4	1.01	0.5
Polyamine	0.75	7.2	87.3	1.64	728.8	691.6	0.95	0
Lime	1.0*	7.4	77.9	1.39	622.6	639.9	1.03	2
Mississippi Limestone								
Neat	0	7.5	88.0	0.13	918.4	606.8	0.61	8
Amidoamine	0.25	7.8	81.3	-0.16	836.4	815.7	0.98	0.5
Amidoamine	0.5	6.9	78.2	-0.28	1057.0	1088.7	1.03	0
Amidoamine	0.75	6.7	79.4	-0.14	1093.5	1094.9	1.00	0
Polyamine	0.25	7.0	79.3	-0.22	977.2	1032.2	1.06	0
Polyamine	0.5	6.8	78.5	-0.22	1047.4	1068.7	1.02	0
Polyamine	0.75	7.6	81.4	-0.24	938.4	981.2	1.05	0
Lime	1.0*	6.8	81.0	-0.29	1077.0	1081.1	1.00	2

Additive	Dosage, %	Voids, %	Final Saturation, %	Swell, %	Unconditioned Strength, KPa	Conditioned Strength, KPa	TSR	Visual, 0 - 10
Missouri Dolomite								
Neat	0	6.7	111.3	1.92	604.0	355.8	0.59	6
Amidoamine	0.25	6.5	95.9	0.90	666.7	510.2	0.77	5
Amidoamine	0.5	7.4	93.9	1.53	681.9	514.4	0.75	4
Amidoamine	0.75	6.6	90.0	0.86	575.0	502.0	0.87	2
Polyamine	0.25	7.2	90.0	0.90	637.8	601.2	0.94	2
Polyamine	0.5	7.1	90.7	0.61	644.0	553.0	0.86	2
Polyamine	0.75	7.1	88.8	0.63	683.3	584.7	0.86	1
Lime	1.0*	6.3	73.3	-0.26	733.6	637.1	0.87	1
South Carolina Granite								
Neat	0	6.6	85.1	0.47	707.4	380.6	0.54	8
Amidoamine	0.25	6.4	77.2	0.03	756.4	766.7	1.01	1
Amidoamine	0.5	7.0	76.7	-0.14	662.6	657.8	0.99	0
Amidoamine	0.75	6.6	77.6	-0.02	690.2	637.1	0.92	1
Polyamine	0.25	7.0	75.6	-0.18	700.5	661.2	0.94	1
Polyamine	0.5	6.8	73.9	-0.17	710.2	691.6	0.97	0
Polyamine	0.75	6.9	74.8	-0.13	689.5	737.1	1.07	0
Lime	1.0*	6.8	77.3	-0.08	715.7	663.3	0.93	0
Utah Gravel								
Neat	0	6.9	77.6	-0.06	561.9	462.7	0.82	6
Amidoamine	0.25	6.4	72.1	0.47	639.2	626.8	0.98	0.5
Amidoamine	0.5	7.2	73.6	-0.07	655.7	666.7	1.02	0
Amidoamine	0.75	7.1	75.5	0.31	670.9	678.5	1.01	0
Polyamine	0.25	7.5	70.8	0.71	619.9	621.9	1.00	0.5
Polyamine	0.5	7.1	73.5	-0.12	677.8	628.1	0.93	0
Polyamine	0.75	7.4	75.0	-0.11	494.4	525.4	1.06	0
Lime	1.0*	7.7	72.9	-0.18	481.3	519.9	1.08	1

* = Percent by weight of aggregate

References

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2. Button, J., "Maximizing the Beneficial Effects of Lime in Asphalt Paving Mixtures", *Evaluation and Prevention of Water Damage of Asphalt Paving Materials, ASTM STP 899,* B. Ruth, Eds., 1985.

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