RESEARCH

UDOT Keeping Utah Moving

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Report No. UT-24.04

HYDRATED LIME AND LIQUID ANTI-STRIP ADDITIVES: MOISTURE-INDUCED DAMAGE RESISTANCE STUDY

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16. Abstract

Stripping is a critical surface and or subsurface pavement distress affecting asphalt pavements and is caused by moisture infiltration and stressed by freeze-thaw cycles and traffic loading, leading to the loss of bond or adhesion between the aggregate and the asphalt binder. UDOT has used 1 percent hydrated lime by slurry pugmill mixing in all our asphalt mixtures since the early 90s. The use of hydrated lime has since eliminated almost all performance issues caused by stripping.

Industry representatives have asked if modern binder additives could replace the use of hydrated lime slurry in our mixtures. This study demonstrated the increased value of hydrated lime over the suggested liquid anti-strip additives. The study included testing four asphalt mixtures using the AASHTO T 283 Lottman Test, with 5 freeze-thaw cycles.

All four mixtures showed excellent stripping resistance when treated with hydrated lime, testing on average 25 percent better than no additive. Two asphalt mixtures showed lesser improvements in stripping resistance when treated with the liquid additives instead of hydrated lime. Two mixtures did not show improved stripping resistance when treated with the liquid-additives.

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UNIT CONVERSION FACTORS

In this report we have chosen to use the inch-pound or U.S. Customary system of units. In many cases the metric system units are also shown in parentheses.

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1000 L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. (Adapted from FHWA report template, Revised March 2003)

LIST OF ACRONYMS

AGC	Associated General Contractors
DOT	Department of Transportation
EPD	Environmental Product Declaration
FHWA	Federal Highway Administration
ICT	Immersion-Compression Test
MMOI	Materials Manual of Instruction
PI	Plastic Index
QMP	Quality Management Plan
RAP	Recycled Asphalt Pavement
SGC	Superpave Gyratory Compactor
SSD	Saturated Surface Dry aggregate condition
TSR	Tensile Strength Ratio or Retained or Recovered
UDOT	Utah Department of Transportation

EXECUTIVE SUMMARY

Stripping and moisture damage due to weathering was the leading distress on UDOT roads back in the early 90s. Utah, among other western states has an abundance of aggregates prone to stripping and a climate with a high number of freeze-thaw cycles. Previous to our use of hydrated lime, underlying asphalt layers were failing, which in turn required very expensive repairs as material in good condition above this layer also had to be removed in order to restore the pavement back to a good overall condition. UDOT followed the state of Nevada in implementing the use of hydrated lime added to virgin aggregates during asphalt mix production, as a solution to the stripping problem we were experiencing. The implementation required the use of pugmill mixing to incorporate the hydrated lime into the mix. During this initial stage of implementation, UDOT also paid for lime separately.

In general, most of our stripping problems on UDOT pavements were resolved when we started using hydrated lime. Moving forward to the present day, industry has questioned if we still need to require it, due to improvements that have been made in the liquid anti-strip additives. UDOT determined it would be a benefit to conduct laboratory testing to see if hydrated lime still is the best choice for stripping and durability protection for our asphalt mixtures, and then with the new liquid anti-strip products that are now available.

We proceeded to run 5-cycle Lottman testing on four UDOT mixtures with and without lime and two different types of liquid anti-strip products. The supplier of the anti-strip products provided direction regarding their use and dosages, which was followed.

Test results show an increased stripping durability resistance when compared to testing completed by UDOT in the early 90s. This may be due to the use of polymer-modified binders. However, all testing showed hydrated lime was superior to the liquid anti-strip additives by about 25 percent. Two of the aggregate sources that had been stored over 10 years in the lab showed increased tensile strength ratios (TSRs), with liquid anti-strip products. The other two freshly crushed materials showed little to no benefit from the liquid anti-strips. It is recommended that UDOT continue the use of hydrated lime. The test results of this study and the high cost resulting from stripping failures strongly support this direction.

INTRODUCTION

Problem Statement and Objective

For the state of Utah, pavements are its largest and most expensive assets. When the author joined UDOT in 1989, stripping and rutting, due to stripping of the underlying layers was the Achilles heel of our road network. See Figure 1 for an example of a typical core found in our pavements that was occurring back then. In response to this problem, UDOT researched the benefits of hydrated lime and did laboratory Lottman work (Figure 2). The result was a statewide policy to use 1 percent hydrated lime with slurry pugmill mixing to replace liquid anti-strip additives for all our asphalt mixtures.

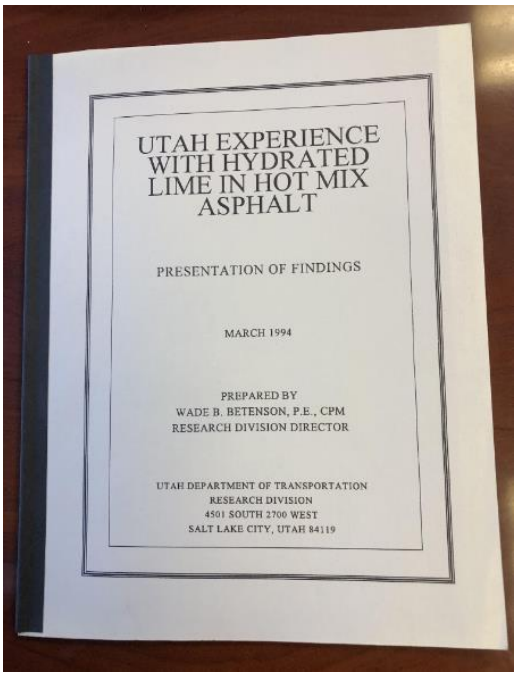
Core with Stripped Layer Below

Figure 1

With the use of hydrated lime along with the implementation of Superpave and dryer mixtures, (we no longer paid for asphalt binder separately), and with the implementation of the Hamburg Wheel Tracker test, rutting was largely eliminated from UDOT's road network.

Industry asked us to verify the need to continue the use of hydrated lime for stripping given they believe liquid anti-strip additives have improved enough to be able to provide the durability desired. The objective(s) of this research is to update the hydrated lime study that was

completed by UDOT's Central Materials Laboratory back in the early 90s, see Figure 2, that resulted in our required use of hydrated lime.



UDOT 1994 Hydrated Lime Research Report

Figure 2

Background

Asphalt binder forms the continuous phase in asphalt mix. Adhesion is the term used in an asphalt mix for the bond between the asphalt and the aggregate. Cohesion is the bond within the binder itself to pull apart.

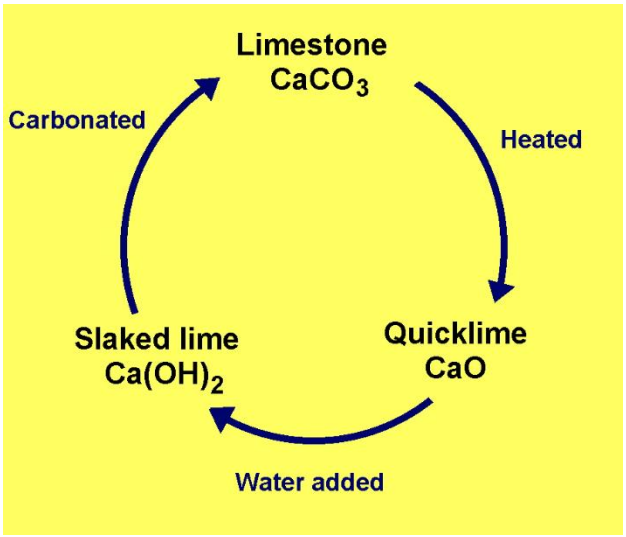
Adhesion failure, or stripping can result from any of the following: Natural weathering, including freeze-thaw cycles, exposure to air resulting in binder oxidation from both time and heat, and traffic loading which in turn forces water through the pavement. Historically, it is well known that some aggregate sources are prone to stripping. The reasons for this are not well understood. One theory is that recently crushed aggregates can pick up charges on their surfaces. We know that valence electrons on the outer shells or energy levels of the atoms move around

when handled or crushed resulting in a complex state of some negatively charged and some positively charged particles.

Adhesion failure or stripping was the number one pavement distress on UDOT roads when the author started with the department in 1989. Stripping can also show up as other forms of distress such as rutting and raveling as well. Before an asphalt surface course is used, it is imperative to know if the asphalt mix being used as a new surface course is susceptible to weathering and the action of water.

Stripping leads to the formation of tiny cracks and tearing, and, with time, will form potholes, reducing the strength and serviceability of pavements. The most challenging aspect of stripping is that it commonly initiates at the bottom or middle of asphalt mix layers and then propagates upward. The bond failure leads to the formation of an unbounded mixture and ultimately reduces the pavement's bearing capacity. It also is almost impossible to detect and verify it at early stages through visual observations. Once the problem manifests itself on the top surface of the pavement, it is generally too late for minor localized treatments. The lack of diagnostic testing tools for stripping makes developing proper pavement rehabilitation plans challenging. For instance, without knowing the stripping's extent, severity and depth, it becomes difficult to select an appropriate mill-depth for a new overlay or a proper rehabilitation strategy (i.e., mill and overlay, full-depth reconstruction, cold recycling etc.).

Figure 3 shows the lime cycle where limestone rock is mined and heated in a kiln to become calcium oxide, then water is added and it becomes hydrated lime. Over time, the hydrated lime can take on carbon dioxide from the atmosphere and revert back to limestone. Figure 4 shows an example of a lime kiln.



Limestone Lime Cycle

Figure 3

Kiln of a Lime Producing Plant

Figure 4

History

To determine the susceptibility of asphalt mix for stripping the Utah Department of Transportation from 1963 to 1989 used the Immersion-Compression Test (ICT). Liquid anti-strip additives available at the time were used to pass this test. However, UDOT was experiencing widespread stripping and rutting failures under this program, often due to stripping of underlying layers. Nevada DOT had recently adopted hydrated lime as an effective moisture treatment, and UDOT began to review that as an option. It was at this time, in the early 90s, that UDOT implemented AASHTO T 283 (1), the Lottman Procedure and eliminated using the Immersion Compression procedure, AASHTO T 165.

As shown in Figure 2, UDOT documented our experience with hydrated lime in 1994. Howard Anderson and Steve Niederhauser did the testing for this original study that was authored by Wade Betenson. The result of this study was the recommendation to use hydrated lime in all our asphalt mixes. At the time, we also required a horizontal twin shaft pugmill, to hydrate the lime and coat the aggregates prior to incorporating them into the asphalt mix. We also paid for the lime separately with the pugmill mixing in order to get it implemented. After a few years, industry was on board and had the required equipment and processes in place to incorporate hydrated lime into the asphalt mix, and so we did away with paying for the lime separately.

Below is our specification history related to moisture damage:

- The Dynamic Stripping test, MMOI 945
- Immersion Compression test, UDOT MMOI 943, AASHTO T-165
- Liquid Anti-Strip Additive used and lime allowed (rarely used) with ICT
- Lime Standard Specification 02746 (2), Lime QMP 510 early 1990s (3)
- Hydrated Lime if failed Lottman test 1989 to 1994, Modified AASHTO T 283
- Lottman test dropped, lime required in all asphalt mixtures, mid 1990s
- Contractor asphalt mix plant cert for lime, QMP 514 adopted in 2010 (4)

Hydrated Lime Implementation: early 90s.

- Horizontal Twin Shaft Pugmill required.
- Pay for lime separately for a few years.

The author presented to industry and the Association of General Contractors multiple times, talking about the need for good mixing in the pugmill through adequate retention time and the Department's desire to pay for lime separately as it was moved into full implementation.

Construction procedures:

- Moisten aggregates to 2% above the SSD condition needed for adequate reaction.
- Pugmill mixing – horizontal twin shaft.
- Continuous accurate weighing system.
- Three percent minimum total moisture by aggregate weight in specification.
- Quality control.

Benefits listed from our research with hydrated lime include:

- Water sensitivity resistance including freeze-thaw.
- Mineral filler to strengthen the binder.
- Reduces the P.I. or Plastic Index.
- Reduces Binder Oxidation.

Other state DOTs in the West were quick to follow Nevada and Utah with hydrated lime implementation.

RESEARCH PLAN

Materials Tested

We selected four different UDOT aggregate sources for this study. Each one of these were UDOT-approved half-inch nominal maximum aggregate size material with a PG 64-34 binder. We used mixtures with no recycled asphalt pavement (RAP), 15 percent RAP and 25 percent RAP as well as aggregates from various parts of the state. The mix designs used also covered all three of our primary asphalt binder suppliers. This attempts to cover the range of mixtures used by UDOT in the state. These mix designs meet the current UDOT specification 02741 – Asphalt Mix. The hydrated lime used for this study is from the Graymont Lime Pilot Peak plant just west of Wendover, Utah. Hydrated lime was added at 1.0 percent of the virgin aggregate weight. The liquid anti-stripping admixtures were added at 0.5 percent of the binder weight, as recommended by the supplier. The anti-stripping admixtures were dosed and blended into the virgin binder shortly before mixing. The following is a summary of each mix.

- Mix 1: Aggregate Source A, PG 64-34 Binder A, 5.3 percent with no RAP
- Mix 2: Aggregate Source B, PG 64-34 Binder B, 4.6 percent binder (3.84 virgin), 15 percent RAP
- Mix 3: Aggregate Source C, PG 64-34 Binder C, 4.6 percent binder (3.9 virgin) 25 percent RAP
- Mix 4: Aggregate Source D, PG 64-34 Binder A, 5.1 percent binder (3.83 virgin) 25 percent RAP

The test matrix is in Table 1 below. For each aggregate condition shown, there are results from three Lottman 6-inch (150 mm) gyratory samples, both dry and conditioned. For the conditioned samples in each case we used 5 freeze-thaw cycles with the AASHTO T 283 test procedure. Figure 5 shows the freezer where we prepared the samples for a minimum of 16 hours at -0.4ºF (-18ºC). Figure 6 shows the hot water bath where we conditioned the samples at 140ºF (60ºC) for 24 hours. Figure 7 and Figure 8 show the Test Quip equipment that was used to break the samples following the conditioning cycle. Figure 9 shows some of the Lottman samples after they were tested. The dry or unconditioned samples were tested on the same day as the

conditioned samples to make sure they were both of the same relative age and had gone through the same steric or physical hardening.

The Lottman test first ages the mix in the oven for 16 hours at 140º F (60ºC). The compacted conditioned samples are then saturated to between 70 and 80 percent. After freezing, they go into the hot water that also ages them. The actual test to break the samples is done with the samples conditioned to 77ºF (25ºC). The load rate for the test is 2 inches (50 mm) per minute. Each aggregate source was tested in four different conditions, with three samples each for both dry and conditioned specimens, for a total of 96 gyratory test samples. There were also some re-tests, so the actual number of test samples was well over 100 gyratory pucks.

Tables 2 through 5 below show the maximum load, in pound-force, of the 3 gyratory samples tested for each situation. There were also some retests done, and in each case all the data is shown, with no data being discarded. Of note is how the dry lime samples are stronger than the no-additive dry samples. Tables 2 through 5 also show the average and standard deviation for the tested samples in each case.

Table 1

Laboratory Testing Matrix

Mix	No Additive		Lime		Additive 1		Additive 2	
Mix 1	Dry	Cond.	Dry	Cond.	Dry	Cond.	Dry	Cond.
Mix 2	Dry	Cond.	Dry	Cond.	Dry	Cond.	Dry	Cond.
Mix 3	Dry	Cond.	Dry	Cond.	Dry	Cond.	Dry	Cond.
Mix 4	Dry	Cond.	Dry	Cond.	Dry	Cond.	Dry	Cond.

Lottman Conditioning Freezer at -0.4ºF (-18ºC)

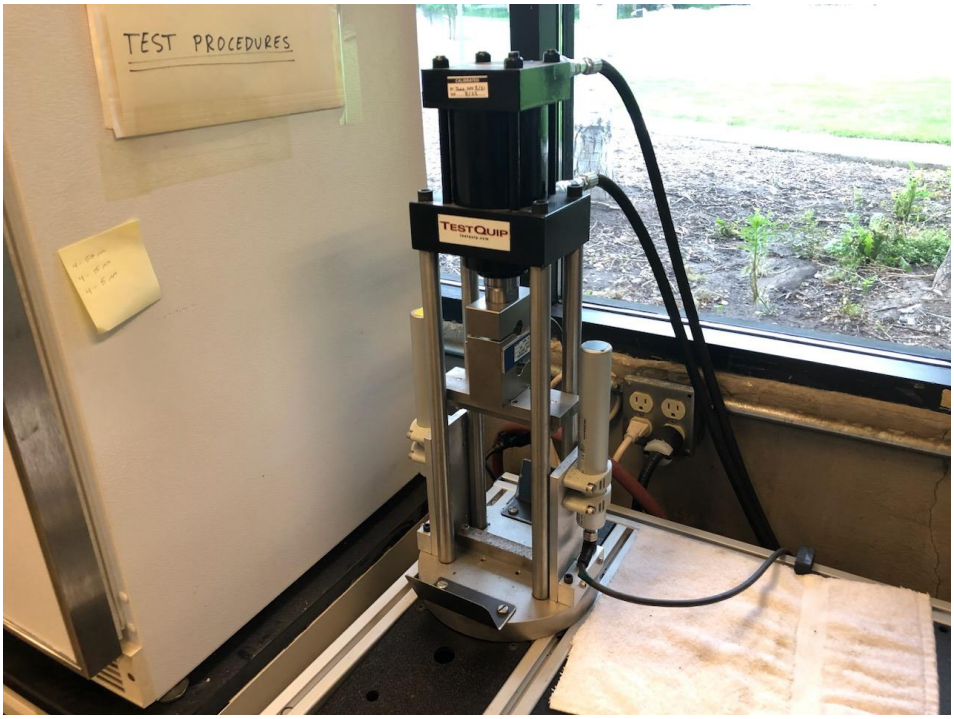
Figure 5

Lottman 140ºF (60ºC) Conditioning Water Bath

Figure 6

Lottman Test Apparatus

Figure 7



Lottman Test Apparatus Closeup

Figure 8

Lottman Samples After Testing

Figure 9

DATA COLLECTION AND RESULTS

Overview

Of the four UDOT asphalt mixtures that were selected, aggregates for Mix 1 and Mix 2 were already long-term stored in our central lab warehouse. Clark Allen and Jon Hardman carefully batched up those samples from buckets to obtain the individual sizes. We used previously approved mix designs for both of them as well. Aggregates for Mix 3 and Mix 4 were provided by our suppliers along with their current UDOT-approved mix designs. The blended samples were put together from the different aggregate supplier stockpiles and provided to us. Each aggregate source was mixed and compacted following standard procedures, including mixing and compaction temperatures and the Lottman procedure AASHTO T 283. The gyratory pucks were compacted to an air void content of 7 percent ± 0.5 percent. The conditioned samples were saturated to 70-80 percent. This typically took only 8 to 10 seconds of suction time in the AASHTO T 209 apparatus. Both the conditioned and unconditioned samples for each set were tested on the same day. In this way it was hoped to cancel out any impacts of steric or physical hardening that are known to occur over time.

Each conditioned set was put through a five-cycle conditioning of freezing and thawing in a 140ºF (60ºC) water bath for 24 hours and then back in the freezer at -0.4ºF (-18ºC) for a minimum of 16 hours. Tables 2 through 5 show the data according to the testing matrix of Table 1. In some cases, additional tests were run when there were questions regarding the results.

Appendix A includes the gyratory sample data for the percent air voids and saturation of the tested samples as well as the Lottman test results. Appendix B provides the actual printouts from the Lottman test apparatus. These have been modified graphically to indicate which mix or binder was used without identifying the suppliers. Appendix B also shows one Hamburg Wheel Tracker test that was run for information only.

The test results are shown in Tables 2 through 5. The tables also show the average results along with the standard deviation for each set. The Tensile Strength Ratio or Retained (TSR) is simply a ratio of the average strengths for each set. This is true because the gyratory samples were each

carefully compacted to 3.74 inches (95 mm) in height from the setting in the gyratory compactor. This was verified with each set produced and was very consistent.

With the Lottman test, the TSR is the ratio of the conditioned strength to the unconditioned strength. The idea of the test is to show how the material maintains its strength or stability after severe aging (hot water) and weathering (freeze-thaw) cycles. Utah experiences between 90 to 200 freeze thaw cycles a year. The Lottman test, done in a relatively short time (two to three weeks) is a best effort to model the long-term conditioning the pavement experiences in our climate along with heavy truck loads that can force water through any available voids.

Below the TSR row in each table is the ratio of the conditioned strength to the dry no-additive strength for each aggregate source. This is labeled as the TSR to the Dry No Additive. This data helps see how each material relates to what the pavement would be if nothing was done. It allows the comparison of each additive, whether it's Lime, Additive 1 or Additive 2, to a common base line. This gives slightly different numbers because the addition of lime normally increases the strength of the unconditioned samples. The anti-strip additive samples may also have a slightly different unconditioned strength, sometimes less, and at other times more than the baseline aggregate with no additive.

Results

Figure 10 shows a closeup of a typical broken face of the Lottman samples. Note that there is not much stripping and the color is dark. Also of note is that there are broken aggregates which is a good indication that the binder is still strong. Figure 11 shows a sample of Mix 4 with no lime. In this example you can see some of the stripped aggregate surfaces, fewer broken aggregates, and a lighter color representing less asphalt being present.

Figures 12 through 15 present the average maximum load each mix type held during the breaking in the indirect tension direction. In each case, the highest loads achieved are with the lime-treated mixtures. In each case for the additives, the Additive 2 mix was a little stronger than the Additive 1 material. Figures 16 through 19 show the tensile strength retained relative to the dry no additive of the aggregate mixture. Sometimes this shows a higher number and sometimes a lower number than the TSR of just the mix with the additive alone. Both ways of

looking at the data have been considered and each method is shown along with all the raw data in order to be completely transparent in this study.

The Source A and Source B aggregates from anonymous contractors were stored inside the central lab warehouse over 10 years ago. These were chosen because they were available and we had UDOT mix designs to go with them. The Source C and Source D aggregates are recently crushed and also provided by anonymous contractors for this study. In looking at Tables 2 through 5 and Figures 16 through 19 you can see the increased TSR in each case for the hydrated lime-treated mixes. Mix 3 and Mix 4 with Aggregate Source C and Source D, respectively, show very little if any value for Additive 1 and Additive 2 following the Lottman conditioning. Additive 1 and Additive 2 do show value but not as much improvement as lime following the Lottman testing for the stored Source A and Source B aggregates.

Typical Lottman Broken Sample
Figure 10

Mix 4 Broken Sample No Lime
Figure 11

Table 2
Mix 1 with PG 64-34 Binder A at 5.3%, No RAP
Maximum Load in Pounds During the AASHTO T 283 Test

Description	Dry No Add	Cond No Add	Dry Lime	Cond Lime	Dry Add 1	Cond Add 1	Dry Add 2	Cond Add 2
Sample 1	2664.8	1987.7	3106.4	3429.8	2681.2	2684.9	2651.2	2978.6
Sample 2	2737.2	1998.2	3087.4	3777.9	2703.4	2631.7	2710.0	2813.4
Sample 3	2710.2	2012.7	2786.2	3796.2	2823.7	2641.5	2699.8	2999.2
Redo 1	3058.4	2171.4	2830.4	3729.0			2563.0	2955.0
Redo 2	2925.9	2296.9	2879.9	3657.3			2597.1	2724.9
Redo 3	2853.0	2268.6	2904.9	3748.7			2586.0	2842.4
Average	2824.9	2122.6	2932.5	3689.8	2736.1	2652.7	2634.5	2885.6
SDEV of all 6 or 3	149.7	141.3	133.9	136.2	76.7	28.3	61.8	108.9
TSR		**75.1**		**125.8**		**97.0**		**109.5**
TSR to Dry No Add		**75.1**		**130.6**		**93.9**		**102.1**

Table 3

Mix 2 with PG 64-34 Binder B at 4.6%, 15% RAP

Maximum Load in Pounds During the AASHTO T 283 Test

Description	Dry No Add	Cond No Add	Dry Lime	Cond Lime	Dry Add 1	Cond Add 1	Dry Add 2	Cond Add 2
Sample 1	2893.5	3394.2	4007.9	4592.6	N/A	3928.1	3913.9	4130.6
Sample 2	3389.2	3334.8	4270.7	4821.0	3540.7	3736.8	3833.4	4056.0
Sample 3	3380.5	3445.6	4108.8	4492.1	3516.5	4011.7	3738.3	4297.7
Redo 1	3663.0	3860.9						
Redo 2	3675.9	3814.1						
Redo 3	3603.7	4054.9						
Average	3434.3	3650.7	4129.1	4635.3	3528.6	3892.2	3828.6	4161.4
SDEV of all 6 or 3	295.5	297.3	132.6	168.5	12.1	140.9	87.9	123.7
TSR		**106.3**		**112.3**		**110.3**		**108.7**
TSR to Dry No Add		**106.3**		**135.0**		**113.3**		**121.2**

Table 4

Mix 3 with PG 64-34 Binder C at 4.6%, 25% RAP

Maximum Load in Pounds During the AASHTO T 283 Test

Description	Dry No Add	Cond No Add	Dry Lime	Cond Lime	Dry Add 1	Cond Add 1	Dry Add 2	Cond Add 2
Sample 1	3808.7	3650.0	3907.0	4139.9	3457.6	3456.2	3653.4	3580.5
Sample 2	3659.2	3485.9	3782.2	4545.6	3515.8	3550.9	3774.1	3579.0
Sample 3	3651.6	3801.5	3994.9	4513.5	3635.4	3499.2	3851.9	3682.4
Redo 1								
Redo 2								
Redo 3								
Average	3706.5	3645.8	3894.7	4399.7	3536.2	3502.1	3759.8	3614.0
SDEV	88.6	157.9	106.9	225.6	90.7	47.4	100.0	59.3
TSR		**98.4**		**113.0**		**99.0**		**96.1**
TSR to Dry No Add		**98.4**		**118.7**		**94.5**		**97.5**

Table 5
Mix 4 with PG 64-34 Binder A at 5.1%, 25% RAP
Maximum Load in Pounds During the AASHTO T 283 Test

Description	Dry No Add	Cond No Add	Dry Lime	Cond Lime	Dry Add 1	Cond Add 1	Dry Add 2	Cond Add 2
Sample 1	4042.0	3154.2	4483.0	4295.3	4215.6	2184.8	4557.2	3567.3
Sample 2	4345.1	3109.3	4343.7	4389.2	4208.1	2789.8	4530.6	3295.2
Sample 3	4607.3	3335.6	4740.1	4173.0	4176.5	2994.2	4532.1	3238.3
Redo 1								
Redo 2								
Redo 3								
Average	4331.5	3199.7	4522.3	4285.8	4200.1	2656.3	4540.0	3366.9
SDEV	282.9	119.8	201.1	108.4	20.8	420.9	14.9	175.8
TSR		**73.9**		**94.8**		**63.2**		**74.2**
TSR to Dry No Add		**73.9**		**98.9**		**61.3**		**77.7**

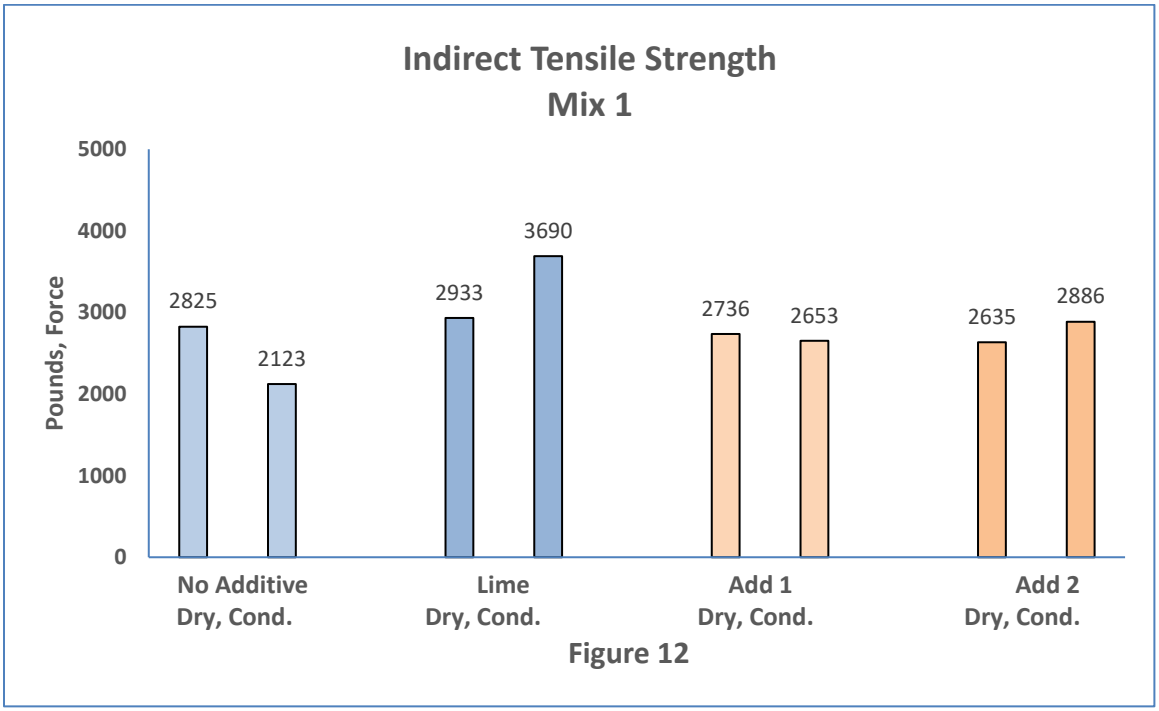


Figure 12

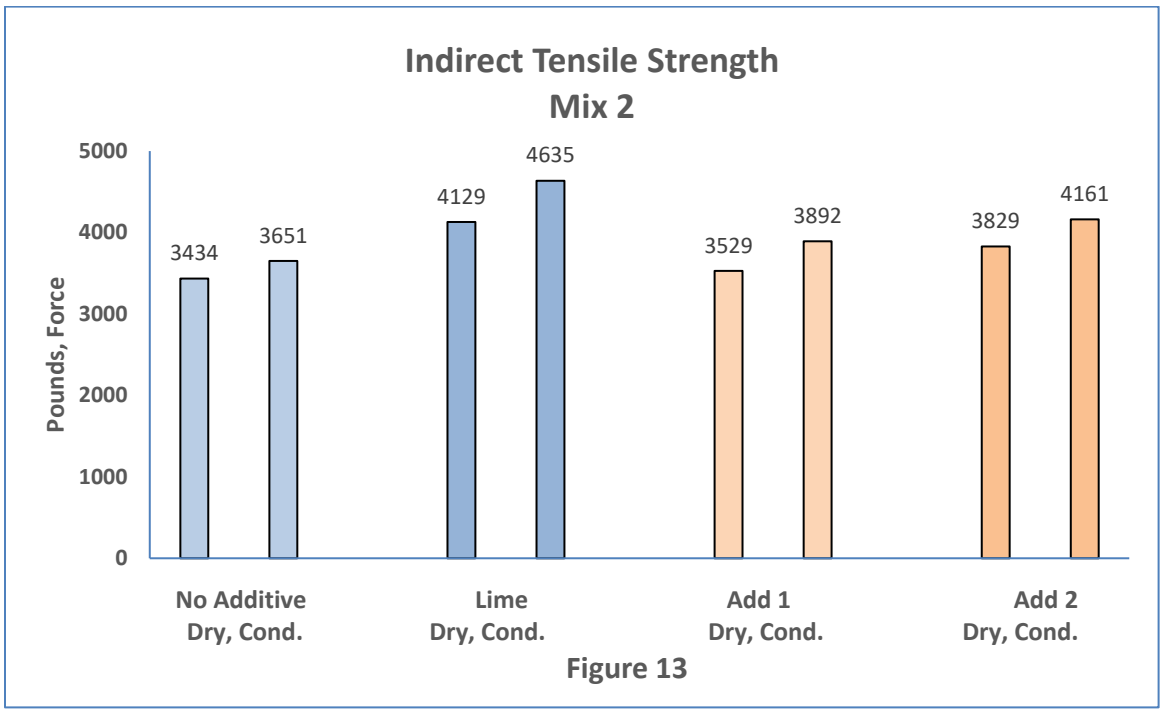


Figure 13

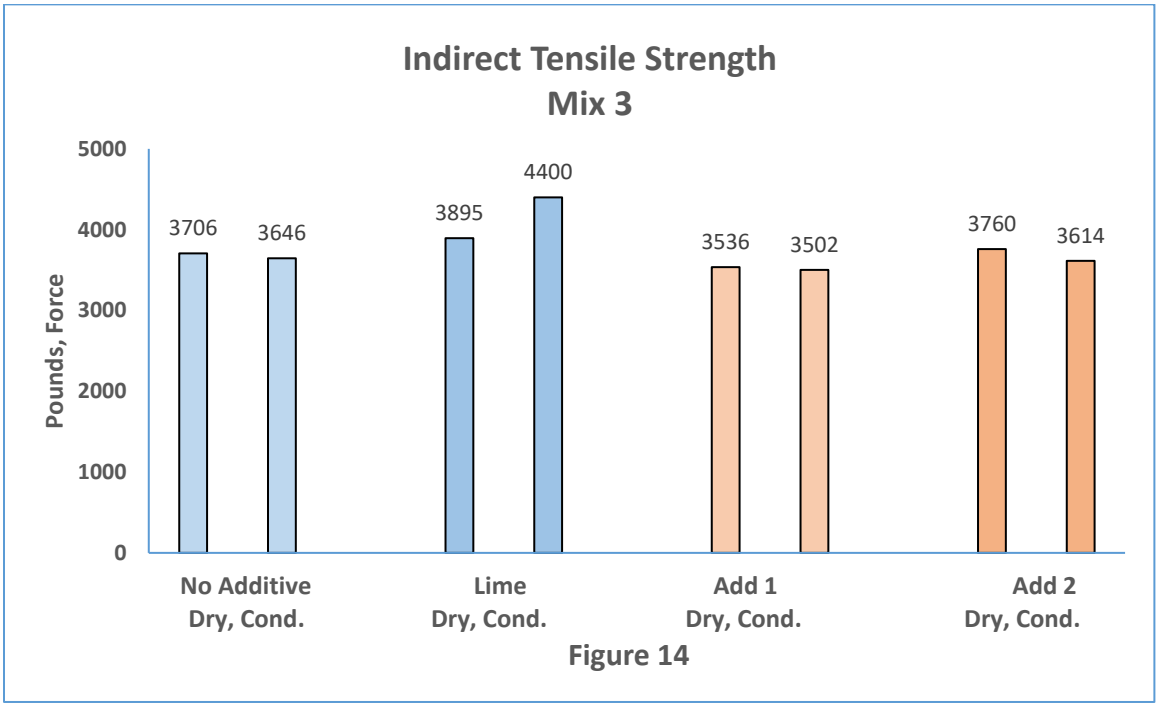


Figure 14

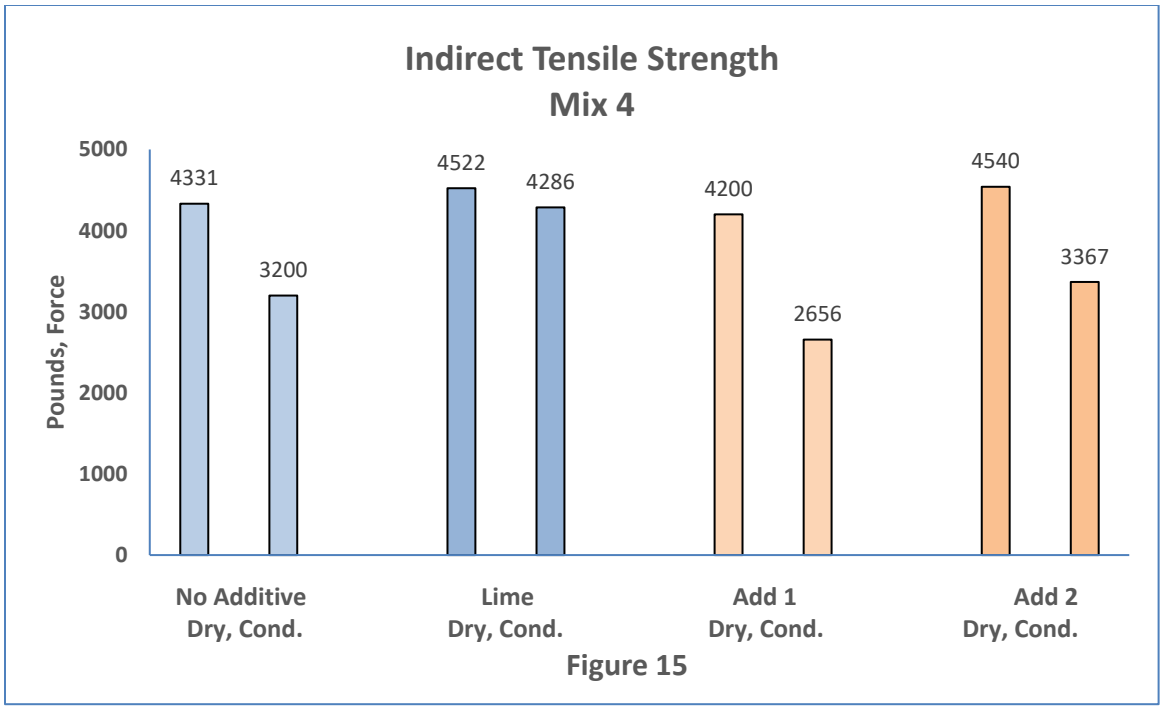


Figure 15

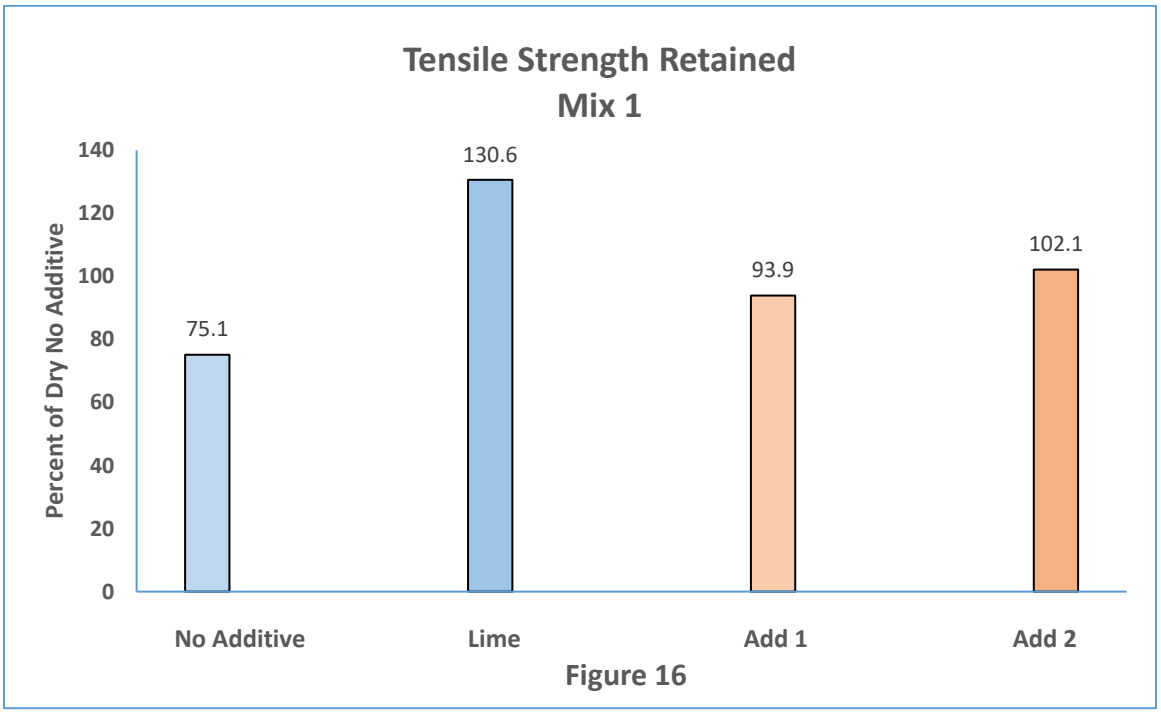


Figure 16

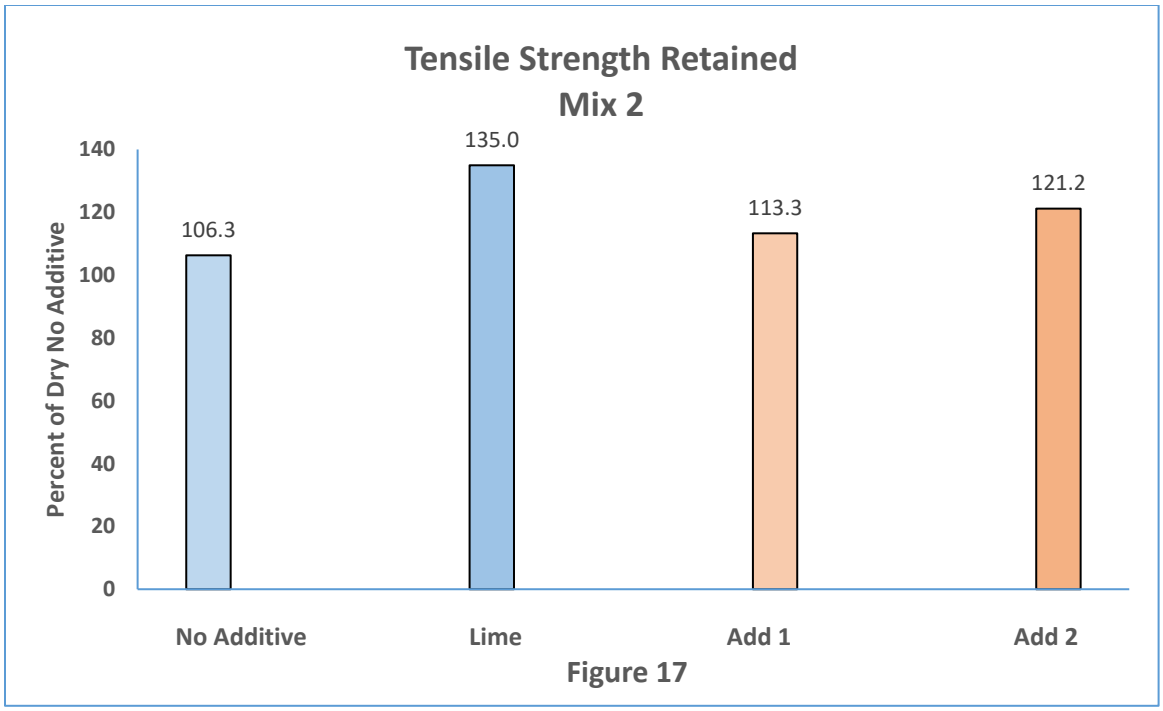


Figure 17

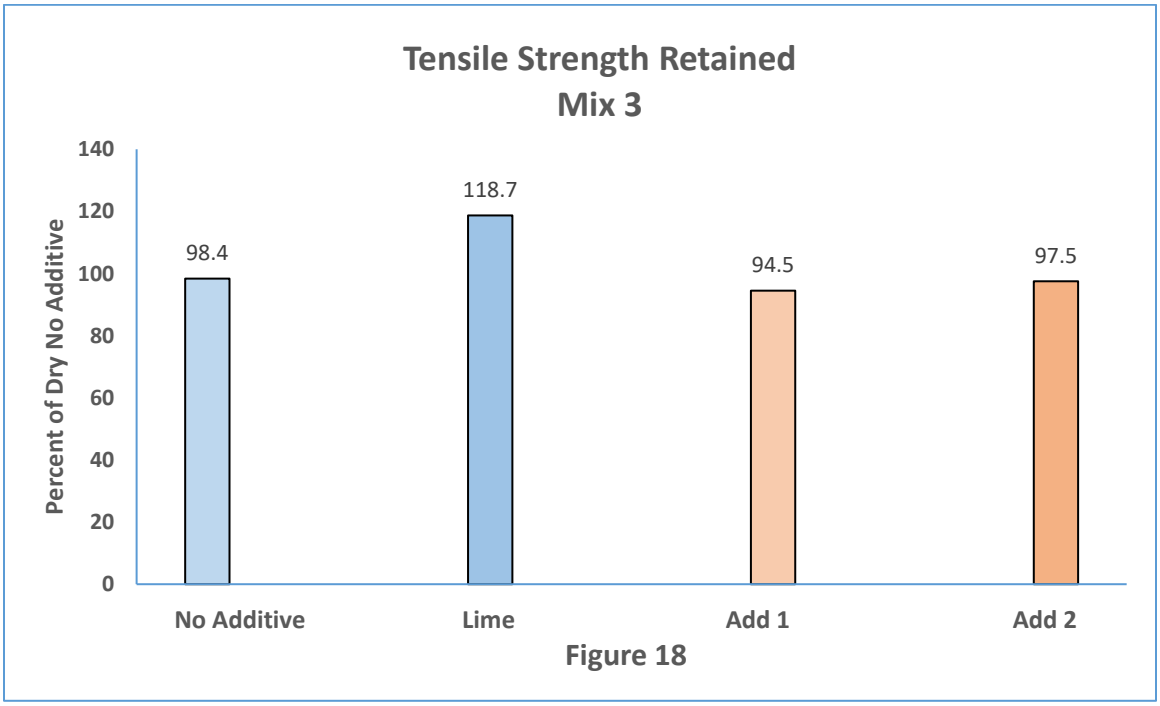


Figure 18

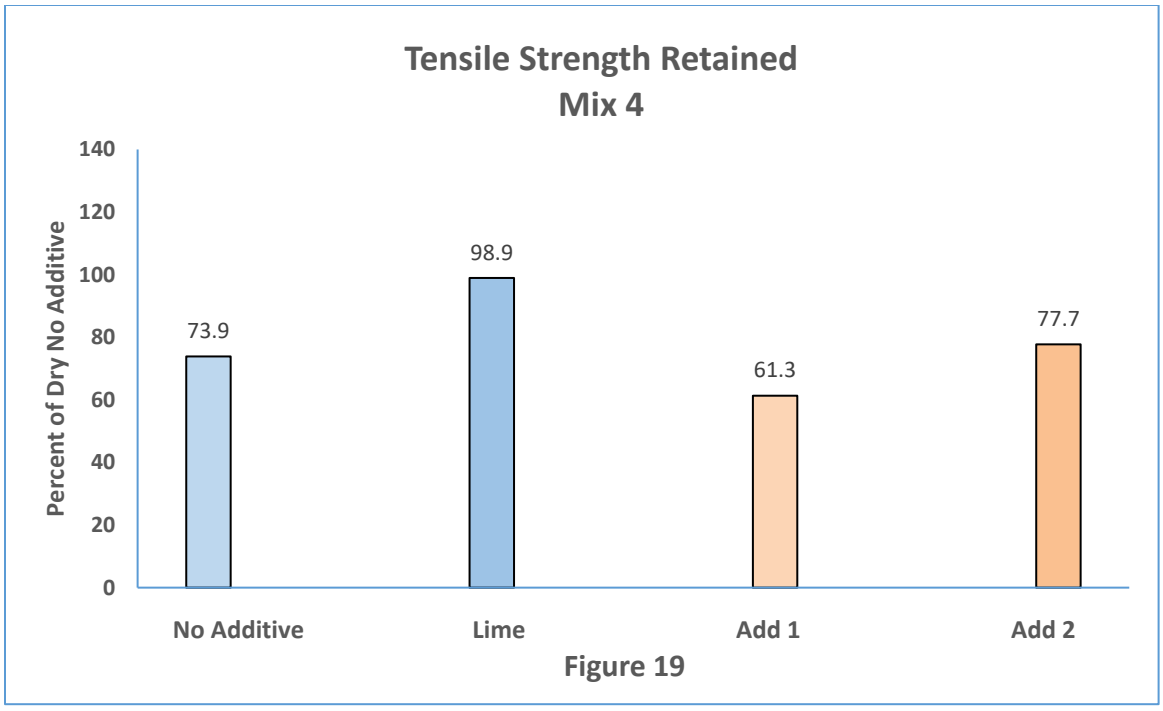

Tensile Strength Retained
Mix 4
Percent of Dry No Additive
140
120
100
80
60
40
20
0
73.9
98.9
61.3
77.7
No Additive
Lime
Add 1
Add 2

Figure 19

CONCLUSIONS

Summary

The data clearly demonstrates the value of using hydrated lime in asphalt mixtures. The average increased strength over the chemical admixtures is approximately 25 percent. Hydrated lime in a slurry is attracted to the aggregate because of its basic properties. The hydrated lime is then attracted to and bonds with the asphalt. As the asphalt pavement ages, the hydrated lime does not go away but slowly reverts back to calcium carbonate, limestone, maintaining the bond. Thirty years of experience with UDOT pavements has shown that hydrated lime works in controlling stripping.

There are many studies in the literature demonstrating longer pavement life resulting from the use of hydrated lime. One from the Federal Highway Administration demonstrated a 38 percent increase in pavement life with the use of hydrated lime. (5)

The data from this study also shows that there is a benefit for preventing stripping using the liquid anti-strip additives, but less benefit than hydrated lime. This was especially apparent with freshly crushed materials. Questions still remain such as: "When you modify an asphalt binder with a chemical admixture, how does that bond work over time?" and "Does the effect of the admixture age along with the binder?" We don't have long-term data to answer these questions.

Findings

The data from this study is summarized in Tables 2 through 5. Figures 12 through 19 show this in graphical form. Each of the mixes had similar trends as well as some noted differences. In every case, the dry strength of the hydrated lime samples and the strength of the 5-cycle conditioned lime samples were strongest, and TSR improved by about 25 percent.

It is clear that polymer-modified binders provide some protection against stripping on their own. Four of the asphalt mixtures retained 70 percent of their tensile strength through a five-cycle Lottman test with no additive at all. What is not clear is how much stripping durability

improvement the chemical admixtures or liquid anti-strips available for this study provide. Are the liquid anti-strip admixtures superior to the liquid anti-strip admixtures used in the 1994 study? The data we have from 5-cycle Lottman testing gives us no indication of this except for the long-term stored aggregates. This does not provide a benefit since our projects do not use aggregates that have been stored for 10 or more years, as those that showed the improvement in the study.

When hydrated lime is compared to Additive 1, hydrated lime provides a 30 percent durability improvement. When compared to Additive 2, we see 21 percent improved durability. On average for this study, Additive 2 was about 9 percent better than Additive 1. When comparing both anti-strip additives, the use of hydrated lime results in a durability that is 25 percent higher.

In comparing the two studies that UDOT has now completed, please note that the 1994 study specimens were 4 inches in diameter for Lottman testing, while this study used 6-inch specimens. The sample size difference is not believed to be significant. It is believed that the difference we see between the two studies is coming from improvements made in the binders now being used. Another indication of this is that the study is showing much higher TSR numbers, with the results also showing that the use of hydrated lime is still the best at providing long-term stripping protection in Utah's climate which is prone to have multiple daily freeze and thaw cycles.

Limitations and Challenges

UDOT has reportedly spent 25 percent more this year on patching potholes than on average for the last three years. This is potentially related to the high amount of moisture we received in 2023 coupled with the high number of freeze-thaw cycles seen in our state. (6)

Utah is not immune to the continued problems of water freeze-thaw cycles and durability. If we are seeing more problems this year and spending more than $1 million annually on durability repairs, then we can't say that we are using something we don't need, and that liquid anti-strips would be good enough. (7) The Salt Lake City area experiences about 90 freeze-thaw cycles per year. Other parts of Utah have as many as 200. For comparison, places like Seattle have 25, Fresno 14, and Tucson 9. This does not include the additional cycles produced by UDOT's aggressive anti-icing efforts and chemical applications. (8)

Utah has still experienced issues with freeze-thaw damage even with the use of hydrated lime. There are places that are prone to potholes, for example on and near bridge decks where compaction is difficult. Imperfect construction practices result in locations with poor compaction, resulting in more significant potholes and durability issues.

The AASHTO T 283 test procedure, commonly called the Lottman Test, has been the industry standard for many years in predicting the field performance of an asphalt mixture. We chose to use 5 freeze-thaw cycles in our testing to better match the harsh Utah climate. Very cold climates may freeze and not thaw for days, while other more mild climates do not freeze much at all.

Recommendations

Continue the current use of 1.0 percent hydrated lime by the dry weight of the virgin aggregates, in slurry form, in all UDOT asphalt mixtures. The state of Utah has over 30 years of good performance with the use of hydrated lime. It is estimated that the total cost to incorporate hydrated lime is about 3 percent of the mix cost. The cost of having a pavement failure or premature durability issues, far outweighs the cost of using hydrated lime.

As mentioned previously, we know that aggregates pick up electrical charges when they are crushed and handled. The outer valence electrons of the atoms jump around in a complex manner creating some negative and positively charged surfaces. With enough time, the charges tend to settle down and dissipate or go to neutral. This may explain the difference in the performance between these two sets of aggregates. It is recommended we test recently crushed materials from Aggregate Source A and or Source B to verify this hypothesis.

Cradle-to-Gate versus Cradle-to-Grave Carbon Footprint

The use of hydrated lime in our asphalt mixtures is sometimes criticized for increasing greenhouse gas emissions when using a cradle-to-gate only (being the construction process only) analysis. It is important to consider the entire life-cycle of the pavement infrastructure to know the true carbon footprint of any construction material. Though there may be a lower upfront carbon footprint without hydrated lime, the life-cycle carbon footprint would be much higher. Hydrated lime ensures a pavement durability (life) that is 25 percent higher overall, as shown in this study.

Carbon Footprint and Environmental Product Declarations (EPDs)

The ocean, soil, and forests are the world's largest carbon sinks. Lime has been referred to as a natural carbon sink. Hydrated lime in our mixtures takes on carbon dioxide, and it eventually reverts to limestone. This is, after all, the Lime Cycle, as was shown in Figure 3. How long it takes is not well known. This property has largely been ignored in the determination of an asphalt mix's overall EPD calculation.

"CO_2 capture via carbonation is permanent, as a large amount of heat energy is required to release it again. In other words, without remanufacturing into lime, the CO_2 remains permanently locked-up. Lime can therefore truly be considered as a permanent carbon sink." (9)

"Like cement, lime gives off carbon dioxide during manufacture. Yet, unlike cement, lime mortars and its related products re-absorb carbon dioxide during the production process and continue to carbonate CO_2 over its in-phase use, creating a complete life cycled, closed –loop process." (10)

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(4) 2023 UDOT Standard Specification 02746, Hydrated Lime

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APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 1: 5.3% PG 64-34 Binder A, No RAP		
Additive	No Lime Trial	Dosage	0
Compaction Method	SGC	Effort	
Date Tested	02-16-2022	By	Clark

Sample Identification		1	2	3	4	5	6
Diameter, mm	D	150.09	150.19	150.03	150.16	150.15	150.20
Thickness, mm	t	95.07	95.20	95.06	94.78	94.71	94.84
Dry mass in air, g	A	3711.4	3712.8	3709.8	3716.2	3714.4	3719.7
SSD mass, g	B	3741.7	3741.4	3741.7	3739.4	3743.2	3745.3
Mass in water, g	C	2139.2	2138.1	2138.4	2132.6	2134.8	2137.9
Volume (B-C), cm3	E	1602.5	1603.3	1603.3	1606.8	1608.4	1607.4
Bulk specific gravity (A/E)	Gmb	2.316	2.316	2.314	2.313	2.309	2.314
Maximum Specific gravity	Gmm	2.494	2.494	2.494	2.494	2.494	2.494
% air voids [100(Gmm-Gmb)/Gmm]	Pa	7.1%	7.1%	7.2%	7.3%	7.4%	7.2%
Volume of air voids (PaE/100), cm3	Va	114.4	114.6	115.8	116.7	119.1	115.9
Load, kN	P	11.854	12.176	12.056	*12.029	12.029	12.029
Saturated							
Thickness, mm	t1				94.78	94.71	94.84
SSD mass, g	B1				3824.0	3826.9	3826.7
Volume of absorbed water (B1-A), cm3	J1				107.80	112.50	107.00
% saturation (100J1/Va)	S1				92.34%	94.49%	92.29%
Load, kN	P1				8.842	8.889	8.953
Dry strength [2000P/πtD], kPa	S1				538.06	538.49	537.57
Wet strength [2000P1/πt1D], kPa	S2				395.51	397.94	400.12
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					73.51%	73.90%	74.43%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 1: 5.3% PG 64-34 Binder A, No RAP		
Additive	W/ Lime Trial	Dosage	1%
Compaction Method	SGC	Effort	
Date Tested	3/9/2022	By	Clark Allen

Sample Identification		1	2	3	4	5	6
Diameter, mm	D	150.04	150.09	150.05	150.00	150.00	150.00
Thickness, mm	t	94.90	95.19	95.30	95.00	95.00	95.00
Dry mass in air, g	A	3712.6	3722.9	37.3	3726.1	3724.8	3727.5
SSD mass, g	B	3740.1	3748.5	3751.3	3748.4	3748.9	3749.5
Mass in water, g	C	2140.9	2147.7	2146.6	2141.9	2139.7	2144.1
Volume (B-C), cm3	E	1599.2	1600.8	1604.7	1606.5	1609.2	1605.4
Bulk specific gravity (A/E)	Gmb	2.322	2.326	0.023	2.319	2.315	2.322
Maximum Specific gravity	Gmm	2.494	2.494	2.494	2.494	2.494	2.494
% air voids [100(Gmm-Gmb)/Gmm]	Pa	6.9%	6.8%	99.1%	7.0%	7.2%	6.9%
Volume of air voids (PaE/100), cm3	Va	110.6	108.1	1589.8	112.5	115.7	110.8
Load, kN	P	12.590	12.811	12.921	*12.774	12.774	12.774
Saturated							
Thickness, mm	t1				94.78	94.93	94.80
SSD mass, g	B1				3828.3	3831.8	3827.6
Volume of absorbed water (B1-A), cm3	J1				102.20	107.00	100.10
% saturation (100J1/Va)	S1				90.87%	92.48%	90.33%
Load, kN	P1				16.587	16.269	16.675
Dry strength [2000P/πtD], kPa	S1				570.68	570.68	570.68
Wet strength [2000P1/πt1D], kPa	S2				742.75	727.36	746.53
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					130.15%	127.45%	130.81%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:	

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 1: 5.3% PG 64-34 Binder A, No RAP		
Additive	No Lime	Dosage	
Compaction Method	SGC	Effort	
Date Tested	4/5/2022	By	Clark Allen

Sample Identification		2	4	5	1	3	6
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3727.6	3722.7	3718.7	3713.9	3721.6	3716.7
SSD mass, g	B	3754.1	3752.4	3749.8	3746.6	3756.3	3748.8
Mass in water, g	C	2144.9	2149.9	2152.2	2142.0	2148.6	2136.4
Volume (B-C), cm3	E	1609.2	1602.5	1597.6	1604.6	1607.7	1612.4
Bulk specific gravity (A/E)	Gmb	2.316	2.323	2.328	2.315	2.315	2.305
Maximum Specific gravity	Gmm	2.494	2.494	2.494	2.494	2.494	2.494
% air voids [100(Gmm-Gmb)/Gmm]	Pa	7.1%	6.9%	6.7%	7.2%	7.2%	7.6%
Volume of air voids (PaE/100), cm3	Va	114.6	109.8	106.5	115.5	115.5	122.1
Load, kN	P	13.604	13.015	12.691	*13.103	13.103	13.103
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3795.6	3803.7	3804.2
Volume of absorbed water (B1-A), cm3	J1				81.70	82.10	87.50
% saturation (100J1/Va)	S1				70.76%	71.10%	71.64%
Load, kN	P1				9.659	10.217	10.091
Dry strength [2000P/πtD], kPa	S1				585.39	585.39	585.39
Wet strength [2000P1/πt1D], kPa	S2				431.52	456.45	450.82
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					73.71%	77.97%	77.01%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 1: 5.3% PG 64-34 Binder A, No RAP		
Additive	W/ Lime	Dosage	1%
Compaction Method	SGC	Effort	
Date Tested	04/19/2022	By	Clark Allen

Sample Identification		2	4	6	1	3	5
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3733.6	3728.3	3718.0	3727.6	3729.0	3724.4
SSD mass, g	B	3760.3	3750.1	3749.3	3756.1	3753.3	3747.7
Mass in water, g	C	2157.5	2145.1	2147.1	2145.8	2146.0	2137.9
Volume (B-C), cm3	E	1602.8	1605.0	1602.2	1610.3	1607.3	1609.8
Bulk specific gravity (A/E)	Gmb	2.329	2.323	2.321	2.315	2.320	2.314
Maximum Specific gravity	Gmm	2.494	2.494	2.494	2.494	2.494	2.494
% air voids [100(Gmm-Gmb)/Gmm]	Pa	6.6%	6.9%	7.0%	7.2%	7.0%	7.2%
Volume of air voids (PaE/100), cm3	Va	105.8	110.1	111.4	115.7	112.1	116.5
Load, kN	P	13.818	13.733	12.394	*13.315	13.315	13.315
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3816.9	3815.8	3811.0
Volume of absorbed water (B1-A), cm3	J1				89.30	86.80	86.60
% saturation (100J1/Va)	S1				77.20%	77.42%	74.36%
Load, kN	P1				15.256	16.805	16.886
Dry strength [2000P/πtD], kPa	S1				594.85	594.85	594.85
Wet strength [2000P1/πt1D], kPa	S2				681.56	750.77	754.38
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					114.58%	126.21%	126.82%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 1: 5.3% PG 64-34 Binder A, No RAP		
Additive	Additive 1	Dosage	0.5% of Binder Wt.
Compaction Method	SGC	Effort	
Date Tested	6/22/2022	By	Clark Allen

Sample Identification		2	5	6	1	3	4
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3725.7	3726.4	3728.8	3724.0	3726.0	3727.5
SSD mass, g	B	3754.9	3752.4	3753.2	3752.2	3756.2	3751.5
Mass in water, g	C	2152.7	2148.0	2149.7	2147.3	2150.4	2146.3
Volume (B-C), cm3	E	1602.2	1604.4	1603.5	1604.9	1605.8	1605.2
Bulk specific gravity (A/E)	Gmb	2.325	2.323	2.325	2.320	2.320	2.322
Maximum Specific gravity	Gmm	2.494	2.494	2.494	2.494	2.494	2.494
% air voids [100(Gmm-Gmb)/Gmm]	Pa	6.8%	6.9%	6.8%	7.0%	7.0%	6.9%
Volume of air voids (PaE/100), cm3	Va	108.3	110.3	108.4	111.7	111.8	110.6
Load, kN	P	11.927	12.025	12.561	*12.171	12.171	12.171
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3811.8	3812.8	3812.1
Volume of absorbed water (B1-A), cm3	J1				87.80	86.80	84.60
% saturation (100J1/Va)	S1				78.59%	77.63%	76.48%
Load, kN	P1				11.943	11.707	11.750
Dry strength [2000P/πtD], kPa	S1				543.74	543.74	543.74
Wet strength [2000P1/πt1D], kPa	S2				533.55	523.01	524.93
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					98.13%	96.19%	96.54%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 1: 5.3% PG 64-34 Binder A, No RAP		
Additive	Additive 2 Re-Test	Dosage	0.5% of Binder Wt.
Compaction Method	SGC	Effort	
Date Tested	6/22/2022	By	Clark Allen

Sample Identification		1	4	6	2	3	5
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3724.2	3728.0	3722.4	3730.1	3725.3	3718.4
SSD mass, g	B	3759.2	3757.5	3757.1	3760.3	3760.8	3750.2
Mass in water, g	C	2162.0	2158.9	2156.9	2155.9	2158.4	2150.3
Volume (B-C), cm3	E	1597.2	1598.6	1600.2	1604.4	1602.4	1599.9
Bulk specific gravity (A/E)	Gmb	2.332	2.332	2.326	2.325	2.325	2.324
Maximum Specific gravity	Gmm	2.494	2.494	2.494	2.494	2.494	2.494
% air voids [100(Gmm-Gmb)/Gmm]	Pa	6.5%	6.5%	6.7%	6.8%	6.8%	6.8%
Volume of air voids (PaE/100), cm3	Va	103.9	103.8	107.7	108.8	108.7	109.0
Load, kN	P	11.401	11.552	11.503	*11.485	11.485	11.485
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3811.5	3810.6	3803.2
Volume of absorbed water (B1-A), cm3	J1				81.40	85.30	84.80
% saturation (100J1/Va)	S1				74.84%	78.48%	77.83%
Load, kN	P1				13.144	12.121	12.643
Dry strength [2000P/πtD], kPa	S1				513.11	513.11	513.11
Wet strength [2000P1/πt1D], kPa	S2				587.21	541.51	564.83
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					114.44%	105.53%	110.08%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:	

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 1: 5.3% PG 64-34 Binder A, No RAP		
Additive	Additive 2	Dosage	0.5% of Binder Wt.
Compaction Method	SGC	Effort	
Date Tested	5/7/2022	By	Clark Allen

Sample Identification		3	4	5	1	2	6
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3726.0	3725.6	3725.3	3725.2	3725.7	3731.2
SSD mass, g	B	3755.1	3750.9	3755.5	3752.4	3752.7	3759.8
Mass in water, g	C	2153.4	2148.4	2152.4	2150.2	2144.4	2153.4
Volume (B-C), cm3	E	1601.7	1602.5	1603.1	1602.2	1608.3	1606.4
Bulk specific gravity (A/E)	Gmb	2.326	2.325	2.324	2.325	2.317	2.323
Maximum Specific gravity	Gmm	2.494	2.494	2.494	2.494	2.494	2.494
% air voids [100(Gmm-Gmb)/Gmm]	Pa	6.7%	6.8%	6.8%	6.8%	7.1%	6.9%
Volume of air voids (PaE/100), cm3	Va	107.7	108.7	109.4	108.5	114.4	110.3
Load, kN	P	11.793	12.055	12.009	*11.952	11.952	11.952
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3806.9	3809.7	3815.3
Volume of absorbed water (B1-A), cm3	J1				81.70	84.00	84.10
% saturation (100J1/Va)	S1				75.28%	73.40%	76.23%
Load, kN	P1				13.250	12.514	13.341
Dry strength [2000P/πtD], kPa	S1				533.97	533.97	533.97
Wet strength [2000P1/πt1D], kPa	S2				591.95	559.06	596.01
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					110.86%	104.70%	111.62%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 2: 4.6% Target, 3.835% Virgin PG 64-34 Binder B, 15% RAP		
Additive	No Lime	Dosage	0.00%
Compaction Method	SGC	Effort	
Date Tested	7/19/2022	By	Clark Allen

Sample Identification		2	3	5	1	4	6
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3820.8	3824.1	3825.2	3814.8	3821.2	3823.4
SSD mass, g	B	3850.1	3850.2	3852.9	3846.2	3849.4	3853.8
Mass in water, g	C	2268.7	2265.1	2266.1	2262.9	2263.5	2264.2
Volume (B-C), cm3	E	1581.4	1585.1	1586.8	1583.3	1585.9	1589.6
Bulk specific gravity (A/E)	Gmb	2.416	2.413	2.411	2.409	2.409	2.405
Maximum Specific gravity	Gmm	2.603	2.603	2.603	2.603	2.603	2.603
% air voids [100(Gmm-Gmb)/Gmm]	Pa	7.2%	7.3%	7.4%	7.4%	7.4%	7.6%
Volume of air voids (PaE/100), cm3	Va	113.6	116.0	117.3	117.8	117.9	120.8
Load, kN	P	12.871	15.076	15.037	*14.328	14.328	14.328
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3905.3	3908.4	3916.7
Volume of absorbed water (B1-A), cm3	J1				90.50	87.20	93.30
% saturation (100J1/Va)	S1				76.85%	73.96%	77.26%
Load, kN	P1				15.098	14.834	15.327
Dry strength [2000P/πtD], kPa	S1				640.10	640.10	640.10
Wet strength [2000P1/πt1D], kPa	S2				674.50	662.71	684.74
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					105.37%	103.53%	106.97%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:	12.871 is this an outlier?

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 2: 4.6% Target, 3.835% Virgin PG 64-34 Binder B, 15% RAP		
Additive	No Lime Re-Run	Dosage	0.00%
Compaction Method	SGC	Effort	
Date Tested	9/13/2022	By	Clark Allen

Sample Identification		1	3	4	2	5	6
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3855.6	3860.2	3859.6	3855.7	3858.4	3863.1
SSD mass, g	B	3876.3	3883.4	3883.5	3882.1	3881.1	3888.8
Mass in water, g	C	2286.6	2292.2	2290.5	2286.0	2286.2	2287.8
Volume (B-C), cm3	E	1589.7	1591.2	1593.0	1596.1	1594.9	1601.0
Bulk specific gravity (A/E)	Gmb	2.425	2.426	2.423	2.416	2.419	2.413
Maximum Specific gravity	Gmm	2.603	2.603	2.603	2.603	2.603	2.603
% air voids [100(Gmm-Gmb)/Gmm]	Pa	6.8%	6.8%	6.9%	7.2%	7.1%	7.3%
Volume of air voids (PaE/100), cm3	Va	108.5	108.2	110.2	114.8	112.6	116.9
Load, kN	P	16.294	16.351	16.030	*16.225	16.225	16.225
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3943.7	3945.6	3950.7
Volume of absorbed water (B1-A), cm3	J1				88.00	87.20	87.60
% saturation (100J1/Va)	S1				76.62%	77.44%	74.93%
Load, kN	P1				17.174	16.966	18.037
Dry strength [2000P/πtD], kPa	S1				724.85	724.85	724.85
Wet strength [2000P1/πt1D], kPa	S2				767.25	757.96	805.80
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					105.85%	104.57%	111.17%

*Load, kN (P) AVERAGE Sample 1-3 Originals

Notes:	

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 2: 4.6% Target, 3.835% Virgin PG 64-34 Binder B, 15% RAP		
Additive	With Lime	Dosage	1 %
Compaction Method	SGC	Effort	
Date Tested	8/23/2022	By	Clark Allen

Sample Identification		3	4	5	1	2	6
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3877.6	3878.8	3876.5	3870.0	3876.0	3881.7
SSD mass, g	B	3899.4	3903.0	3900.2	3889.6	3903.6	3905.4
Mass in water, g	C	2306.9	2310.0	2309.2	2296.3	2308.3	2305.3
Volume (B-C), cm3	E	1592.5	1593.0	1591.0	1593.3	1595.3	1600.1
Bulk specific gravity (A/E)	Gmb	2.435	2.435	2.437	2.429	2.430	2.426
Maximum Specific gravity	Gmm	2.603	2.603	2.603	2.603	2.603	2.603
% air voids [100(Gmm-Gmb)/Gmm]	Pa	6.5%	6.5%	6.4%	6.7%	6.7%	6.8%
Volume of air voids (PaE/100), cm3	Va	102.8	102.9	101.8	106.6	106.2	108.9
Load, kN	P	17.828	18.997	18.277	*18.367	18.367	18.367
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3952.3	3953.8	3961.6
Volume of absorbed water (B1-A), cm3	J1				82.30	77.80	79.90
% saturation (100J1/Va)	S1				77.24%	73.22%	73.40%
Load, kN	P1				20.429	21.445	19.982
Dry strength [2000P/πtD], kPa	S1				820.56	820.56	820.56
Wet strength [2000P1/πt1D], kPa	S2				912.67	958.06	892.70
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					111.22%	116.76%	108.79%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 2: 4.6% Target, 3.835% Virgin PG 64-34 Binder B, 15% RAP		
Additive	Additive 1	Dosage	0.5% of Binder Wt.
Compaction Method	SGC	Effort	
Date Tested	9/29/2022	By	Clark Allen

Sample Identification		**6	2	5	1	3	4
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3859.5	3861.6	3857.4	3855.4	3853.5	3857.7
SSD mass, g	B	3881.1	3882.3	3879.8	3879.4	3873.4	3878.2
Mass in water, g	C	2283.9	2285.6	2282.1	2287.5	2281.6	2284.1
Volume (B-C), cm3	E	1597.2	1596.7	1597.7	1591.9	1591.8	1594.1
Bulk specific gravity (A/E)	Gmb	2.416	2.418	2.414	2.422	2.421	2.420
Maximum Specific gravity	Gmm	2.603	2.603	2.603	2.603	2.603	2.603
% air voids [100(Gmm-Gmb)/Gmm]	Pa	7.2%	7.1%	7.2%	7.0%	7.0%	7.0%
Volume of air voids (PaE/100), cm3	Va	114.5	113.2	115.8	110.8	111.4	112.1
Load, kN	P	N/A	15.750	15.642	*15.696	15.696	15.696
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3938.8	3939.2	3941.7
Volume of absorbed water (B1-A), cm3	J1				83.40	85.70	84.00
% saturation (100J1/Va)	S1				75.30%	76.93%	74.95%
Load, kN	P1				17.473	16.622	17.845
Dry strength [2000P/πtD], kPa	S1				701.22	701.22	701.22
Wet strength [2000P1/πt1D], kPa	S2				780.61	742.59	797.23
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					111.32%	105.90%	113.69%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:	**Puck 6 was not tested

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 2: 4.6% Target, 3.835% Virgin PG 64-34 Binder B, 15% RAP		
Additive	Additive 2	Dosage	0.5% of Binder Wt.
Compaction Method	SGC	Effort	
Date Tested	10/25/2022	By	Clark Allen

Sample Identification		2	4	6	1	3	5
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3860.8	3856.3	3860.0	3849.7	3855.5	3858.8
SSD mass, g	B	3882.8	3884.3	3884.6	3875.3	3879.2	3885.4
Mass in water, g	C	2288.8	2289.2	2287.3	2280.9	2282.6	2285.6
Volume (B-C), cm3	E	1594.0	1595.1	1597.3	1594.4	1596.6	1599.8
Bulk specific gravity (A/E)	Gmb	2.422	2.418	2.417	2.415	2.415	2.412
Maximum Specific gravity	Gmm	2.603	2.603	2.603	2.603	2.603	2.603
% air voids [100(Gmm-Gmb)/Gmm]	Pa	7.0%	7.1%	7.2%	7.2%	7.2%	7.3%
Volume of air voids (PaE/100), cm3	Va	110.8	113.6	114.4	115.5	115.4	117.4
Load, kN	P	17.410	17.052	16.629	*17.030	17.030	17.030
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3937.2	3941.0	3950.5
Volume of absorbed water (B1-A), cm3	J1				87.50	85.50	91.70
% saturation (100J1/Va)	S1				75.79%	74.07%	78.14%
Load, kN	P1				18.374	18.042	19.117
Dry strength [2000P/πtD], kPa	S1				760.83	760.83	760.83
Wet strength [2000P1/πt1D], kPa	S2				820.86	806.03	854.05
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					107.89%	105.94%	112.25%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:	

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 3: 4.6% Target, 3.9% Virgin PG 64-34 Binder C, 25% RAP		
Additive	No Lime	Dosage	0%
Compaction Method	SGC	Effort	
Date Tested	2/2/2023	By	Clark Allen

Sample Identification		1	2	3	4	5	6
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3707.2	3712.4	3709.9	3708.6	3707.8	3712.1
SSD mass, g	B	3737.4	3746.4	3740.9	3743.2	3744.1	3748.2
Mass in water, g	C	2131.4	2130.0	2127.0	2128.7	2126.1	2131.6
Volume (B-C), cm3	E	1606.0	1616.4	1613.9	1614.5	1618.0	1616.6
Bulk specific gravity (A/E)	Gmb	2.308	2.297	2.299	2.297	2.292	2.296
Maximum Specific gravity	Gmm	2.469	2.469	2.469	2.469	2.469	2.469
% air voids [100(Gmm-Gmb)/Gmm]	Pa	6.5%	7.0%	6.9%	7.0%	7.2%	7.0%
Volume of air voids (PaE/100), cm3	Va	104.5	112.8	111.3	112.4	116.3	113.1
Load, kN	P	16.942	16.277	16.243	*16.487	16.487	16.487
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3794.7	3798.4	3797.0
Volume of absorbed water (B1-A), cm3	J1				86.10	90.60	84.90
% saturation (100J1/Va)	S1				76.58%	77.93%	75.06%
Load, kN	P1				16.236	15.506	16.910
Dry strength [2000P/πtD], kPa	S1				736.57	736.57	736.57
Wet strength [2000P1/πt1D], kPa	S2				725.35	692.73	755.46
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					98.48%	94.05%	102.56%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 3: 4.6% Target, 3.9% Virgin PG 64-34 Binder C, 25% RAP		
Additive	With Lime	Dosage	1 %
Compaction Method	SGC	Effort	
Date Tested	2/22/2023	By	Clark Allen

Sample Identification		1	2	3	4	5	6
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3700.5	3701.4	3713.0	3704.0	3702.0	3706.2
SSD mass, g	B	3734.5	3738.1	3749.0	3741.2	3738.9	3739.4
Mass in water, g	C	2125.1	2125.4	2132.4	2123.4	2123.9	2125.8
Volume (B-C), cm3	E	1609.4	1612.7	1616.6	1617.8	1615.0	1613.6
Bulk specific gravity (A/E)	Gmb	2.299	2.295	2.297	2.290	2.292	2.297
Maximum Specific gravity	Gmm	2.469	2.469	2.469	2.469	2.469	2.469
% air voids [100(Gmm-Gmb)/Gmm]	Pa	6.9%	7.0%	7.0%	7.3%	7.2%	7.0%
Volume of air voids (PaE/100), cm3	Va	110.6	113.6	112.8	117.6	115.6	112.5
Load, kN	P	17.379	16.824	17.770	*17.324	17.324	17.324
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3794.3	3791.1	3789.0
Volume of absorbed water (B1-A), cm3	J1				90.30	89.10	82.80
% saturation (100J1/Va)	S1				76.79%	77.07%	73.60%
Load, kN	P1				18.415	20.220	20.077
Dry strength [2000P/πtD], kPa	S1				773.97	773.97	773.97
Wet strength [2000P1/πt1D], kPa	S2				822.69	903.33	896.94
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					106.30%	116.71%	115.89%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 3: 4.6% Target, 3.9% Virgin PG 64-34 Binder C, 25% RAP		
Additive	Additive 1	Dosage	0.5% by wt. of binder
Compaction Method	SGC	Effort	
Date Tested	3/30/2023	By	Clark Allen

Sample Identification		1	2	3	4	5	6
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3708.2	3712.8	3709.3	3709.9	3709.8	3708.8
SSD mass, g	B	3740.9	3743.6	3738.4	3741.8	3744.9	3746.8
Mass in water, g	C	2126.9	2133.1	2126.1	2125.6	2122.6	2124.3
Volume (B-C), cm3	E	1614.0	1610.5	1612.3	1616.2	1622.3	1622.5
Bulk specific gravity (A/E)	Gmb	2.298	2.305	2.301	2.295	2.287	2.286
Maximum Specific gravity	Gmm	2.469	2.469	2.469	2.469	2.469	2.469
% air voids [100(Gmm-Gmb)/Gmm]	Pa	6.9%	6.6%	6.8%	7.0%	7.4%	7.4%
Volume of air voids (PaE/100), cm3	Va	112.1	106.7	110.0	113.6	119.7	120.4
Load, kN	P	15.380	15.639	16.171	*15.730	15.730	15.730
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3796.6	3798.4	3802.2
Volume of absorbed water (B1-A), cm3	J1				86.70	88.60	93.40
% saturation (100J1/Va)	S1				76.32%	73.99%	77.60%
Load, kN	P1				15.374	15.795	15.565
Dry strength [2000P/πtD], kPa	S1				702.74	702.74	702.74
Wet strength [2000P1/πt1D], kPa	S2				686.84	705.64	695.37
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					97.74%	100.41%	98.95%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 3: 4.6% Target, 3.9% Virgin PG 64-34 Binder C, 25% RAP		
Additive	Additive 2	Dosage	0.5% by wt. of binder
Compaction Method	SGC	Effort	
Date Tested	3/16/2023	By	Clark Allen

Sample Identification		1	2	4	3	5	6
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3707.0	3711.0	3709.9	3702.7	3708.8	3709.2
SSD mass, g	B	3738.0	3747.5	3739.1	3737.6	3744.9	3748.2
Mass in water, g	C	2125.7	2132.3	2127.8	2122.2	2125.5	2129.3
Volume (B-C), cm3	E	1612.3	1615.2	1611.3	1615.4	1619.4	1618.9
Bulk specific gravity (A/E)	Gmb	2.299	2.298	2.302	2.292	2.290	2.291
Maximum Specific gravity	Gmm	2.469	2.469	2.469	2.469	2.469	2.469
% air voids [100(Gmm-Gmb)/Gmm]	Pa	6.9%	6.9%	6.7%	7.2%	7.2%	7.2%
Volume of air voids (PaE/100), cm3	Va	110.9	112.2	108.7	115.7	117.3	116.6
Load, kN	P	16.251	16.788	17.134	*16.724	16.724	16.724
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3789.6	3796.2	3797.3
Volume of absorbed water (B1-A), cm3	J1				86.90	87.40	88.10
% saturation (100J1/Va)	S1				75.09%	74.54%	75.56%
Load, kN	P1				15.927	15.920	16.380
Dry strength [2000P/πtD], kPa	S1				747.16	747.16	747.16
Wet strength [2000P1/πt1D], kPa	S2				711.54	711.23	731.78
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					95.23%	95.19%	97.94%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 4: 5.1% Target, 3.825% Virgin PG 64-34 Binder A, 25% RAP		
Additive	No Lime	Dosage	0
Compaction Method	SGC	Effort	
Date Tested	7/13/2023	By	Clark Allen

Sample Identification		1	4	6	2	3	5
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3722.7	3726.5	3726.6	3722.0	3722.1	3722.8
SSD mass, g	B	3758.6	3761.2	3758.7	3757.7	3755.2	3758.0
Mass in water, g	C	2139.2	2143.3	2139.9	2137.1	2134.7	2138.2
Volume (B-C), cm3	E	1612.2	1617.9	1618.8	1620.6	1620.5	1619.8
Bulk specific gravity (A/E)	Gmb	2.309	2.303	2.302	2.297	2.297	2.298
Maximum Specific gravity	Gmm	2.482	2.482	2.482	2.482	2.482	2.482
% air voids [100(Gmm-Gmb)/Gmm]	Pa	7.0%	7.2%	7.2%	7.5%	7.5%	7.4%
Volume of air voids (PaE/100), cm3	Va	112.3	116.5	117.3	121.0	120.9	119.9
Load, kN	P	17.980	19.328	20.494	*19.267	19.267	19.267
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3815.5	3812.7	3814.4
Volume of absorbed water (B1-A), cm3	J1				93.50	90.60	91.60
% saturation (100J1/Va)	S1				77.27%	74.96%	76.41%
Load, kN	P1				14.030	13.831	14.838
Dry strength [2000P/πtD], kPa	S1				860.77	860.77	860.77
Wet strength [2000P1/πt1D], kPa	S2				626.79	617.90	662.89
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					72.82%	71.78%	77.01%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 4: 5.1% Target, 3.825% Virgin PG 64-34 Binder A, 25% RAP		
Additive	With Lime	Dosage	1 %
Compaction Method	SGC	Effort	
Date Tested	7/11/2023	By	Clark Allen

Sample Identification		1	4	5	2	3	6
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3725.1	3731.3	3730.7	3723.8	3731.5	3728.7
SSD mass, g	B	3766.6	3765.6	3771.7	3764.3	3770.0	3766.7
Mass in water, g	C	2154.4	2149.1	2154.2	2145.1	2150.3	2143.4
Volume (B-C), cm3	E	1612.2	1616.5	1617.5	1619.2	1619.7	1623.3
Bulk specific gravity (A/E)	Gmb	2.311	2.308	2.306	2.300	2.304	2.297
Maximum Specific gravity	Gmm	2.482	2.482	2.482	2.482	2.482	2.482
% air voids [100(Gmm-Gmb)/Gmm]	Pa	6.9%	7.0%	7.1%	7.3%	7.2%	7.5%
Volume of air voids (PaE/100), cm3	Va	111.4	113.2	114.4	118.9	116.3	121.0
Load, kN	P	19.941	19.322	21.085	*20.116	20.116	20.116
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3814.1	3819.2	3820.7
Volume of absorbed water (B1-A), cm3	J1				90.30	87.70	92.00
% saturation (100J1/Va)	S1				75.96%	75.42%	76.03%
Load, kN	P1				19.107	19.524	18.562
Dry strength [2000P/πtD], kPa	S1				898.68	898.68	898.68
Wet strength [2000P1/πt1D], kPa	S2				853.61	872.24	829.26
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					94.98%	97.06%	92.27%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:	

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 4: 5.1% Target, 3.825% Virgin PG 64-34 Binder A, 25% RAP		
Additive	Additive 1	Dosage	0.50%
Compaction Method	SGC	Effort	
Date Tested	8/10/2023	By	Jon Hardman

Sample Identification		2	3	4	1	5	6
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3727.0	3722.1	3727.9	3624.3	3725.5	3725.7
SSD mass, g	B	3764.3	3755.4	3757.3	3693.2	3762.4	3763.2
Mass in water, g	C	2142.7	2141.6	2136.5	2094.2	2141.8	2138.2
Volume (B-C), cm3	E	1612.2	1613.8	1620.8	1599.0	1620.6	1625.0
Bulk specific gravity (A/E)	Gmb	2.312	2.306	2.300	2.267	2.299	2.293
Maximum Specific gravity	Gmm	2.482	2.482	2.482	2.482	2.482	2.482
% air voids [100(Gmm-Gmb)/Gmm]	Pa	6.9%	7.1%	7.3%	8.7%	7.4%	7.6%
Volume of air voids (PaE/100), cm3	Va	110.6	114.2	118.8	138.8	119.6	123.9
Load, kN	P	18.752	18.719	18.578	*18.683	18.683	18.683
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3729.0	3812.3	3817.5
Volume of absorbed water (B1-A), cm3	J1				104.70	86.80	91.80
% saturation (100J1/Va)	S1				75.45%	72.58%	74.08%
Load, kN	P1				9.718	12.410	13.319
Dry strength [2000P/πtD], kPa	S1				834.67	834.67	834.67
Wet strength [2000P1/πt1D], kPa	S2				434.15	554.42	595.03
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					52.02%	66.42%	71.29%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:

APPENDIX A: Gyratory Puck Lottman Data Sheets

Asphalt Mix	Mix 4: 5.1% Target, 3.825% Virgin PG 64-34 Binder A, 25% RAP		
Additive	Additive 2	Dosage	0.50%
Compaction Method	SGC	Effort	
Date Tested		By	Clark Allen

Sample Identification		1	2	3	4	5	6
Diameter, mm	D	150.00	150.00	150.00	150.00	150.00	150.00
Thickness, mm	t	95.00	95.00	95.00	95.00	95.00	95.00
Dry mass in air, g	A	3719.8	3725.4	3725.1	3723.3	3725.2	3722.3
SSD mass, g	B	3748.7	3760.8	3764.6	3762.9	3763.0	3762.7
Mass in water, g	C	2142.5	2141.2	2148.5	2142.6	2142.6	2143.5
Volume (B-C), cm3	E	1612.2	1619.6	1616.1	1620.3	1620.4	1619.2
Bulk specific gravity (A/E)	Gmb	2.307	2.300	2.305	2.298	2.299	2.299
Maximum Specific gravity	Gmm	2.482	2.482	2.482	2.482	2.482	2.482
% air voids [100(Gmm-Gmb)/Gmm]	Pa	7.0%	7.3%	7.1%	7.4%	7.4%	7.4%
Volume of air voids (PaE/100), cm3	Va	113.5	118.6	115.3	120.2	119.5	119.5
Load, kN	P	20.271	20.153	20.160	*20.195	20.195	20.195
Saturated							
Thickness, mm	t1				95.00	95.00	95.00
SSD mass, g	B1				3816.2	3817.3	3815.3
Volume of absorbed water (B1-A), cm3	J1				92.90	92.10	93.00
% saturation (100J1/Va)	S1				77.30%	77.06%	77.84%
Load, kN	P1				15.868	14.658	14.405
Dry strength [2000P/πtD], kPa	S1				902.20	902.20	902.20
Wet strength [2000P1/πt1D], kPa	S2				708.90	654.85	643.54
Visual moisture damage (0 to 5 rating)							
Cracked/Broken aggregate?							
TSR (S2/S1)					78.58%	72.58%	71.33%

*Load, kN (P) AVERAGE Sample 1-3 Originals

NOTES:

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 1

Date	2/16/2022
Time	1:00:30 PM
Operator	Clark Allen
Specimen ID	Puck # 1
Comments	Dry No Lime
Diameter	95.07 , mm
Thickness	95.07 , mm
Air Void Content	7.1 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.316
Percent Saturation	0.0 , %
Actual Test Rate	50.108 , mm/min
Actual Seat Load	0.170 , kN
Max Load	11.854 , kN
Max Load	2664.8 lbs
Time at Max Load	4.500 , seconds
Disp at Max Load	3.689 , mm
Max Load Index	226
Servo Offset	0.001
Starting LLD_L	27.202 , mm
Starting LLD_R	26.757 , mm
Test Duration	17.9800 , seconds
Tensile Strength	834.929 , kPa
Tensile Strength	121.10 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	3/8/2022
Time	12:22:21 PM
Operator	Clark Allen
Specimen ID	Puck 4
Comments	Conditioned No Lime
Diameter	150.16 , mm
Thickness	95.06 , mm
Air Void Content	7.3 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.313
Percent Saturation	72.47 , %
Actual Test Rate	49.932 , mm/min
Actual Seat Load	0.184 , kN
Max Load	8.842 , kN
Max Load	1987.7 lbs
Time at Max Load	6.080 , seconds
Disp at Max Load	5.018 , mm
Max Load Index	305
Servo Offset	0.013
Starting LLD_L	26.335 , mm
Starting LLD_R	25.888 , mm
Test Duration	29.4000 , seconds
Tensile Strength	394.332 , kPa
Tensile Strength	57.19 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	2/16/2022
Time	1:03:52 PM
Operator	Clark Allen
Specimen ID	Puck # 2
Comments	Dry No Lime
Diameter	150.19 , mm
Thickness	95.2 , mm
Air Void Content	7.1 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.316
Percent Saturation	0.0 , %
Actual Test Rate	50.100 , mm/min
Actual Seat Load	0.150 , kN
Max Load	12.176 , kN
Max Load	2737.2 lbs
Time at Max Load	4.640 , seconds
Disp at Max Load	3.812 , mm
Max Load Index	233
Servo Offset	-0.003
Starting LLD_L	26.865 , mm
Starting LLD_R	26.334 , mm
Test Duration	18.9600 , seconds
Tensile Strength	542.114 , kPa
Tensile Strength	78.63 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	3/8/2022
Time	12:29:18 PM
Operator	Clark Allen
Specimen ID	Puck 5
Comments	Conditioned No Lime
Diameter	150.15 , mm
Thickness	95.21 , mm
Air Void Content	7.4 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.309
Percent Saturation	70.3 , %
Actual Test Rate	50.050 , mm/min
Actual Seat Load	0.135 , kN
Max Load	8.889 , kN
Max Load	1998.2 lbs
Time at Max Load	6.160 , seconds
Disp at Max Load	5.084 , mm
Max Load Index	309
Servo Offset	0.005
Starting LLD_L	26.186 , mm
Starting LLD_R	25.799 , mm
Test Duration	24.0800 , seconds
Tensile Strength	395.828 , kPa
Tensile Strength	57.41 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	2/16/2022
Time	1:07:09 PM
Operator	Clark Allen
Specimen ID	Puck # 3
Comments	Dry No Lime
Diameter	150.16 , mm
Thickness	95.06 , mm
Air Void Content	7.2 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.314
Percent Saturation	0.0 , %
Actual Test Rate	50.019 , mm/min
Actual Seat Load	0.017 , kN
Max Load	12.056 , kN
Max Load	2710.2 lbs
Time at Max Load	9.460 , seconds
Disp at Max Load	7.822 , mm
Max Load Index	474
Servo Offset	-0.008
Starting LLD_L	23.109 , mm
Starting LLD_R	22.648 , mm
Test Duration	27.6600 , seconds
Tensile Strength	537.669 , kPa
Tensile Strength	77.98 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	3/8/2022
Time	12:35:10 PM
Operator	Clark Allen
Specimen ID	Puck 6
Comments	Conditioned No Lime
Diameter	150.2 , mm
Thickness	95.22 , mm
Air Void Content	7.2 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.314
Percent Saturation	70.21 , %
Actual Test Rate	50.066 , mm/min
Actual Seat Load	0.172 , kN
Max Load	8.953 , kN
Max Load	2012.7 lbs
Time at Max Load	5.460 , seconds
Disp at Max Load	4.501 , mm
Max Load Index	274
Servo Offset	-0.003
Starting LLD_L	26.216 , mm
Starting LLD_R	25.836 , mm
Test Duration	17.7400 , seconds
Tensile Strength	398.511 , kPa
Tensile Strength	57.80 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 1

Date	4/7/2022
Time	9:26:28 AM
Operator	Clark Allen
Specimen ID	Puck # 2
Comments	Dry No Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.1 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.316
Percent Saturation	0.0 , %
Actual Test Rate	50.132 , mm/min
Actual Seat Load	0.147 , kN
Max Load	13.604 , kN
Max Load	3058.4 lbs
Time at Max Load	4.180 , seconds
Disp at Max Load	3.423 , mm
Max Load Index	210
Servo Offset	-0.011
Starting LLD_L	27.055 , mm
Starting LLD_R	26.650 , mm
Test Duration	16.9600 , seconds
Tensile Strength	607.774 , kPa
Tensile Strength	88.15 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	4/7/2022
Time	9:15:40 AM
Operator	Clark Allen
Specimen ID	Puck # 1
Comments	Conditioned No Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.2 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.314
Percent Saturation	70.76 , %
Actual Test Rate	50.058 , mm/min
Actual Seat Load	0.150 , kN
Max Load	9.659 , kN
Max Load	2171.4 lbs
Time at Max Load	6.020 , seconds
Disp at Max Load	4.965 , mm
Max Load Index	302
Servo Offset	0.004
Starting LLD_L	26.476 , mm
Starting LLD_R	26.057 , mm
Test Duration	22.6600 , seconds
Tensile Strength	431.512 , kPa
Tensile Strength	62.59 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	4/7/2022
Time	9:30:03 AM
Operator	Clark Allen
Specimen ID	Puck # 4
Comments	Dry No Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.9 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.323
Percent Saturation	0.0 , %
Actual Test Rate	50.071 , mm/min
Actual Seat Load	0.115 , kN
Max Load	13.015 , kN
Max Load	2925.9 lbs
Time at Max Load	5.880 , seconds
Disp at Max Load	4.833 , mm
Max Load Index	295
Servo Offset	-0.016
Starting LLD_L	26.154 , mm
Starting LLD_R	25.797 , mm
Test Duration	19.0800 , seconds
Tensile Strength	581.453 , kPa
Tensile Strength	84.33 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	4/7/2022
Time	9:19:42 AM
Operator	Clark Allen
Specimen ID	Puck # 3
Comments	Conditioned No Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.2 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.315
Percent Saturation	71.1 , %
Actual Test Rate	50.065 , mm/min
Actual Seat Load	0.165 , kN
Max Load	10.217 , kN
Max Load	2296.9 lbs
Time at Max Load	6.680 , seconds
Disp at Max Load	5.513 , mm
Max Load Index	335
Servo Offset	-0.002
Starting LLD_L	26.200 , mm
Starting LLD_R	25.787 , mm
Test Duration	21.3800 , seconds
Tensile Strength	456.452 , kPa
Tensile Strength	66.20 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	4/7/2022
Time	9:33:28 AM
Operator	Clark Allen
Specimen ID	Puck # 5
Comments	Dry No Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.7 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.328
Percent Saturation	0.0 , %
Actual Test Rate	50.100 , mm/min
Actual Seat Load	0.127 , kN
Max Load	12.691 , kN
Max Load	2853.0 lbs
Time at Max Load	4.580 , seconds
Disp at Max Load	3.763 , mm
Max Load Index	230
Servo Offset	-0.023
Starting LLD_L	27.206 , mm
Starting LLD_R	26.789 , mm
Test Duration	20.9000 , seconds
Tensile Strength	566.958 , kPa
Tensile Strength	82.23 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	4/7/2022
Time	9:22:27 AM
Operator	Clark Allen
Specimen ID	Puck # 6
Comments	Conditioned No Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.5 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.305
Percent Saturation	71.64 , %
Actual Test Rate	50.072 , mm/min
Actual Seat Load	0.163 , kN
Max Load	10.091 , kN
Max Load	2268.6 lbs
Time at Max Load	6.240 , seconds
Disp at Max Load	5.150 , mm
Max Load Index	313
Servo Offset	-0.006
Starting LLD_L	26.140 , mm
Starting LLD_R	25.759 , mm
Test Duration	19.4000 , seconds
Tensile Strength	450.824 , kPa
Tensile Strength	65.39 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 1

Date	3/9/2022
Time	12:26:45 PM
Operator	Clark Allen
Specimen ID	Puck # 1
Comments	Dry W/ Lime
Diameter	150.04 , mm Trial
Thickness	94.9 , mm
Air Void Content	7.0 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.319
Percent Saturation	71.04 , %
Actual Test Rate	50.105 , mm/min
Actual Seat Load	0.141 , kN
Max Load	12.590 , kN
Max Load	2830.4 lbs
Time at Max Load	4.720 , seconds
Disp at Max Load	3.874 , mm
Max Load Index	237
Servo Offset	-0.013
Starting LLD_L	27.189 , mm
Starting LLD_R	26.776 , mm
Test Duration	19.8400 , seconds
Tensile Strength	562.915 , kPa
Tensile Strength	81.64 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	3/22/2022
Time	10:21:04 AM
Operator	Clark Allen
Specimen ID	Puck # 4
Comments	W/ Lime Conditioned
Diameter	150.0 , mm Trial
Thickness	94.78 , mm
Air Void Content	7.0 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.319
Percent Saturation	90.87 , %
Actual Test Rate	50.125 , mm/min
Actual Seat Load	0.123 , kN
Max Load	16.587 , kN
Max Load	3729.0 lbs
Time at Max Load	5.220 , seconds
Disp at Max Load	4.276 , mm
Max Load Index	262
Servo Offset	-0.007
Starting LLD_L	26.925 , mm
Starting LLD_R	26.522 , mm
Test Duration	21.2200 , seconds
Tensile Strength	742.765 , kPa
Tensile Strength	107.73 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	3/9/2022
Time	12:31:39 PM
Operator	Clark Allen
Specimen ID	Puck # 2
Comments	Dry W/ Lime
Diameter	150.09 , mm Trial
Thickness	95.19 , mm
Air Void Content	7.2 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.315
Percent Saturation	71.65 , %
Actual Test Rate	50.116 , mm/min
Actual Seat Load	0.131 , kN
Max Load	12.811 , kN
Max Load	2879.9 lbs
Time at Max Load	4.280 , seconds
Disp at Max Load	3.506 , mm
Max Load Index	215
Servo Offset	-0.017
Starting LLD_L	27.134 , mm
Starting LLD_R	26.726 , mm
Test Duration	18.9800 , seconds
Tensile Strength	570.826 , kPa
Tensile Strength	82.79 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	3/22/2022
Time	10:24:17 AM
Operator	Clark Allen
Specimen ID	Puck # 5
Comments	W/ Lime Conditioned
Diameter	150.0 , mm Trial
Thickness	94.93 , mm
Air Void Content	7.2 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.315
Percent Saturation	92.48 , %
Actual Test Rate	50.126 , mm/min
Actual Seat Load	0.161 , kN
Max Load	16.269 , kN
Max Load	3657.3 lbs
Time at Max Load	5.620 , seconds
Disp at Max Load	4.613 , mm
Max Load Index	282
Servo Offset	-0.009
Starting LLD_L	26.797 , mm
Starting LLD_R	26.363 , mm
Test Duration	20.5600 , seconds
Tensile Strength	727.336 , kPa
Tensile Strength	105.49 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	3/9/2022
Time	12:34:22 PM
Operator	Clark Allen
Specimen ID	Puck # 3
Comments	Dry W/ Lime
Diameter	150.05 , mm Trial
Thickness	95.3 , mm
Air Void Content	6.9 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.322
Percent Saturation	70.48 , %
Actual Test Rate	50.105 , mm/min
Actual Seat Load	0.169 , kN
Max Load	12.921 , kN
Max Load	2904.9 lbs
Time at Max Load	5.040 , seconds
Disp at Max Load	4.139 , mm
Max Load Index	253
Servo Offset	-0.021
Starting LLD_L	27.181 , mm
Starting LLD_R	26.782 , mm
Test Duration	20.4400 , seconds
Tensile Strength	575.258 , kPa
Tensile Strength	83.43 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	3/22/2022
Time	10:28:13 AM
Operator	Clark Allen
Specimen ID	Puck # 6
Comments	W/ Lime Conditioned
Diameter	150.0 , mm Trial
Thickness	94.8 , mm
Air Void Content	6.9 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.322
Percent Saturation	90.33 , %
Actual Test Rate	50.137 , mm/min
Actual Seat Load	0.181 , kN
Max Load	16.675 , kN
Max Load	3748.7 lbs
Time at Max Load	5.280 , seconds
Disp at Max Load	4.330 , mm
Max Load Index	265
Servo Offset	-0.015
Starting LLD_L	26.866 , mm
Starting LLD_R	26.430 , mm
Test Duration	21.3000 , seconds
Tensile Strength	746.527 , kPa
Tensile Strength	108.27 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 1

Date	4/19/2022
Time	9:07:29 AM
Operator	Clark Allen
Specimen ID	Puck # 2
Comments	Dry W/ Lime
Diameter	150.0 , mm
Thickness	62.0 , mm
Air Void Content	6.6 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.329
Percent Saturation	0.0 , %
Actual Test Rate	50.112 , mm/min
Actual Seat Load	0.151 , kN
Max Load	13.818 , kN
Max Load	3106.4 lbs
Time at Max Load	4.540 , seconds
Disp at Max Load	3.717 , mm
Max Load Index	228
Servo Offset	-0.059
Starting LLD_L	27.098 , mm
Starting LLD_R	26.676 , mm
Test Duration	21.3600 , seconds
Tensile Strength	945.893 , kPa
Tensile Strength	137.19 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	4/19/2022
Time	9:19:52 AM
Operator	Clark Allen
Specimen ID	Puck # 1
Comments	Conditioned W - Lime
Diameter	150.0 , mm
Thickness	62.0 , mm
Air Void Content	77.2 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.315
Percent Saturation	7.2 , %
Actual Test Rate	50.102 , mm/min
Actual Seat Load	0.191 , kN
Max Load	15.256 , kN
Max Load	3429.8 lbs
Time at Max Load	6.100 , seconds
Disp at Max Load	5.011 , mm
Max Load Index	306
Servo Offset	-0.061
Starting LLD_L	26.369 , mm
Starting LLD_R	25.885 , mm
Test Duration	20.5800 , seconds
Tensile Strength	1044.358 , kPa
Tensile Strength	151.47 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	4/19/2022
Time	9:10:45 AM
Operator	Clark Allen
Specimen ID	Puck # 4
Comments	Dry W/ Lime
Diameter	150.0 , mm
Thickness	62.0 , mm
Air Void Content	6.9 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.323
Percent Saturation	0.0 , %
Actual Test Rate	50.131 , mm/min
Actual Seat Load	0.161 , kN
Max Load	13.733 , kN
Max Load	3087.4 lbs
Time at Max Load	4.440 , seconds
Disp at Max Load	3.639 , mm
Max Load Index	223
Servo Offset	-0.056
Starting LLD_L	27.157 , mm
Starting LLD_R	26.748 , mm
Test Duration	17.6000 , seconds
Tensile Strength	940.093 , kPa
Tensile Strength	136.35 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	4/19/2022
Time	9:22:37 AM
Operator	Clark Allen
Specimen ID	Puck # 3
Comments	Conditioned W - Lime
Diameter	150.0 , mm
Thickness	62.0 , mm
Air Void Content	7.0 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.32
Percent Saturation	77.42 , %
Actual Test Rate	50.155 , mm/min
Actual Seat Load	0.158 , kN
Max Load	16.805 , kN
Max Load	3777.9 lbs
Time at Max Load	5.100 , seconds
Disp at Max Load	4.179 , mm
Max Load Index	256
Servo Offset	-0.064
Starting LLD_L	26.902 , mm
Starting LLD_R	26.524 , mm
Test Duration	18.4600 , seconds
Tensile Strength	1150.351 , kPa
Tensile Strength	166.84 psi

TSR v1.0.3 (2018.2.16 Mix 1

Date	4/19/2022
Time	9:13:22 AM
Operator	Clark Allen
Specimen ID	Puck # 6
Comments	Dry W/ Lime
Diameter	150.0 , mm
Thickness	62.0 , mm
Air Void Content	0.0 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.321
Percent Saturation	6.9 , %
Actual Test Rate	50.100 , mm/min
Actual Seat Load	0.166 , kN
Max Load	12.394 , kN
Max Load	2786.2 lbs
Time at Max Load	5.260 , seconds
Disp at Max Load	4.322 , mm
Max Load Index	264
Servo Offset	-0.059
Starting LLD_L	27.038 , mm
Starting LLD_R	26.642 , mm
Test Duration	18.7400 , seconds
Tensile Strength	848.395 , kPa
Tensile Strength	123.05 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	4/19/2022
Time	9:25:10 AM
Operator	Clark Allen
Specimen ID	Puck # 5
Comments	Conditioned W - Lime
Diameter	150.0 , mm
Thickness	62.0 , mm
Air Void Content	7.2 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.314
Percent Saturation	74.36 , %
Actual Test Rate	50.122 , mm/min
Actual Seat Load	0.163 , kN
Max Load	16.886 , kN
Max Load	3796.2 lbs
Time at Max Load	5.460 , seconds
Disp at Max Load	4.473 , mm
Max Load Index	274
Servo Offset	-0.065
Starting LLD_L	26.863 , mm
Starting LLD_R	26.487 , mm
Test Duration	21.7000 , seconds
Tensile Strength	1155.937 , kPa
Tensile Strength	167.65 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 1

Date	6/1/2022
Time	11:59:07 AM
Operator	Clark Allen
Specimen ID	Puck # 2
Comments	Dry Additive 1
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.8 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.325
Percent Saturation	0.0 , %
Actual Test Rate	50.085 , mm/min
Actual Seat Load	0.154 , kN
Max Load	11.927 , kN
Max Load	2681.2 lbs
Time at Max Load	5.360 , seconds
Disp at Max Load	4.406 , mm
Max Load Index	269
Servo Offset	-0.034
Starting LLD_L	26.929 , mm
Starting LLD_R	26.544 , mm
Test Duration	22.6200 , seconds
Tensile Strength	532.827 , kPa
Tensile Strength	77.28 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	6/1/2022
Time	11:38:36 AM
Operator	Clark Allen
Specimen ID	Puck # 1
Comments	Additive 1 Cond.
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.0 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.32
Percent Saturation	78.59 , %
Actual Test Rate	50.070 , mm/min
Actual Seat Load	0.134 , kN
Max Load	11.943 , kN
Max Load	2684.9 lbs
Time at Max Load	6.320 , seconds
Disp at Max Load	5.205 , mm
Max Load Index	317
Servo Offset	0.030
Starting LLD_L	26.567 , mm
Starting LLD_R	26.187 , mm
Test Duration	23.5400 , seconds
Tensile Strength	533.562 , kPa
Tensile Strength	77.39 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	6/1/2022
Time	12:03:19 PM
Operator	Clark Allen
Specimen ID	Puck # 5
Comments	Dry Additive 1
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.9 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.323
Percent Saturation	0.0 , %
Actual Test Rate	50.068 , mm/min
Actual Seat Load	0.144 , kN
Max Load	12.025 , kN
Max Load	2703.4 lbs
Time at Max Load	5.580 , seconds
Disp at Max Load	4.588 , mm
Max Load Index	280
Servo Offset	-0.041
Starting LLD_L	26.436 , mm
Starting LLD_R	26.065 , mm
Test Duration	23.1400 , seconds
Tensile Strength	537.234 , kPa
Tensile Strength	77.92 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	6/1/2022
Time	11:44:28 AM
Operator	Clark Allen
Specimen ID	Puck # 3
Comments	Additive 1 Cond.
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.0 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.32
Percent Saturation	77.63 , %
Actual Test Rate	50.071 , mm/min
Actual Seat Load	0.172 , kN
Max Load	11.707 , kN
Max Load	2631.7 lbs
Time at Max Load	5.720 , seconds
Disp at Max Load	4.717 , mm
Max Load Index	287
Servo Offset	0.007
Starting LLD_L	26.830 , mm
Starting LLD_R	26.265 , mm
Test Duration	25.2400 , seconds
Tensile Strength	522.993 , kPa
Tensile Strength	75.85 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	6/1/2022
Time	12:06:10 PM
Operator	Clark Allen
Specimen ID	Puck # 6
Comments	Additive 1
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.8 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.325
Percent Saturation	0.0 , %
Actual Test Rate	50.084 , mm/min
Actual Seat Load	0.167 , kN
Max Load	12.561 , kN
Max Load	2823.7 lbs
Time at Max Load	4.660 , seconds
Disp at Max Load	3.822 , mm
Max Load Index	234
Servo Offset	-0.043
Starting LLD_L	26.904 , mm
Starting LLD_R	26.510 , mm
Test Duration	22.8800 , seconds
Tensile Strength	561.145 , kPa
Tensile Strength	81.39 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	6/1/2022
Time	11:50:27 AM
Operator	Clark Allen
Specimen ID	Puck # 4
Comments	Additive 1 Cond.
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.9 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.322
Percent Saturation	76.48 , %
Actual Test Rate	50.081 , mm/min
Actual Seat Load	0.121 , kN
Max Load	11.750 , kN
Max Load	2641.5 lbs
Time at Max Load	5.720 , seconds
Disp at Max Load	4.712 , mm
Max Load Index	287
Servo Offset	-0.011
Starting LLD_L	26.532 , mm
Starting LLD_R	26.138 , mm
Test Duration	22.4400 , seconds
Tensile Strength	524.923 , kPa
Tensile Strength	76.13 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 1

Date	5/7/2022
Time	9:13:49 AM
Operator	Clark Allen
Specimen ID	Puck # 4
Comments	Dry, Lime Vs Antistrip W/ Additive 2
Diameter	150.0 , mm
Thickness	62.0 , mm 95mm
Air Void Content	6.7 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.326
Percent Saturation	0.0 , %
Actual Test Rate	50.085 , mm/min
Actual Seat Load	0.173 , kN
Max Load	11.793 , kN
Max Load	2651.2 lbs
Time at Max Load	4.620 , seconds
Disp at Max Load	3.795 , mm
Max Load Index	232
Servo Offset	-0.011
Starting LLD_L	27.140 , mm
Starting LLD_R	26.694 , mm
Test Duration	22.0400 , seconds
Tensile Strength	807.281 , kPa
Tensile Strength	117.09 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	5/7/2022
Time	9:43:01 AM
Operator	Clark Allen
Specimen ID	Puck # 1
Comments	Cond., Lime Vs Antistrip W/ Additive 2
Diameter	150.0 , mm
Thickness	62.0 , mm 95mm
Air Void Content	6.8 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.325
Percent Saturation	75.28 , %
Actual Test Rate	50.095 , mm/min
Actual Seat Load	0.188 , kN
Max Load	13.250 , kN
Max Load	2978.6 lbs
Time at Max Load	5.040 , seconds
Disp at Max Load	4.139 , mm
Max Load Index	253
Servo Offset	-0.053
Starting LLD_L	26.920 , mm
Starting LLD_R	26.454 , mm
Test Duration	23.8400 , seconds
Tensile Strength	906.985 , kPa
Tensile Strength	131.55 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	5/7/2022
Time	9:18:34 AM
Operator	Clark Allen
Specimen ID	Puck # 4
Comments	Dry, Lime Vs Antistrip W/ Additive 2
Diameter	150.0 , mm
Thickness	62.0 , mm 95mm
Air Void Content	6.8 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.325
Percent Saturation	0.0 , %
Actual Test Rate	50.091 , mm/min
Actual Seat Load	0.189 , kN
Max Load	12.055 , kN
Max Load	2710.0 lbs
Time at Max Load	4.540 , seconds
Disp at Max Load	3.729 , mm
Max Load Index	228
Servo Offset	-0.017
Starting LLD_L	27.245 , mm
Starting LLD_R	26.806 , mm
Test Duration	21.3200 , seconds
Tensile Strength	825.193 , kPa
Tensile Strength	119.68 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	5/7/2022
Time	9:46:05 AM
Operator	Clark Allen
Specimen ID	Puck # 2
Comments	Cond., Lime Vs Antistrip W/ Additive 2
Diameter	150.0 , mm
Thickness	62.0 , mm 95mm
Air Void Content	7.1 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.317
Percent Saturation	73.4 , %
Actual Test Rate	50.079 , mm/min
Actual Seat Load	0.137 , kN
Max Load	12.514 , kN
Max Load	2813.4 lbs
Time at Max Load	6.480 , seconds
Disp at Max Load	5.347 , mm
Max Load Index	325
Servo Offset	-0.054
Starting LLD_L	26.637 , mm
Starting LLD_R	26.125 , mm
Test Duration	21.1400 , seconds
Tensile Strength	856.660 , kPa
Tensile Strength	124.25 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	5/7/2022
Time	9:22:24 AM
Operator	Clark Allen
Specimen ID	Puck # 5
Comments	Dry, Lime Vs Antistrip W/ Additive 2
Diameter	150.0 , mm
Thickness	62.0 , mm 95mm
Air Void Content	6.8 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.324
Percent Saturation	0.0 , %
Actual Test Rate	50.091 , mm/min
Actual Seat Load	0.209 , kN
Max Load	12.009 , kN
Max Load	2699.8 lbs
Time at Max Load	4.720 , seconds
Disp at Max Load	3.878 , mm
Max Load Index	237
Servo Offset	-0.022
Starting LLD_L	27.069 , mm
Starting LLD_R	26.609 , mm
Test Duration	22.1600 , seconds
Tensile Strength	822.078 , kPa
Tensile Strength	119.23 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	5/7/2022
Time	9:48:50 AM
Operator	Clark Allen
Specimen ID	Puck # 6
Comments	Cond., Lime Vs Antistrip W/ Additive 2
Diameter	150.0 , mm
Thickness	62.0 , mm 95mm
Air Void Content	6.9 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.323
Percent Saturation	76.23 , %
Actual Test Rate	50.087 , mm/min
Actual Seat Load	0.113 , kN
Max Load	13.341 , kN
Max Load	2999.2 lbs
Time at Max Load	6.120 , seconds
Disp at Max Load	5.037 , mm
Max Load Index	307
Servo Offset	-0.055
Starting LLD_L	26.720 , mm
Starting LLD_R	26.265 , mm
Test Duration	23.7800 , seconds
Tensile Strength	913.253 , kPa
Tensile Strength	132.46 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 1

Date	6/22/2022
Time	10:17:18 AM
Operator	Clark Allen
Specimen ID	Puck # 1
Comments	Additive 2 Re-Test DRY
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.5 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.332
Percent Saturation	0.0 , %
Actual Test Rate	50.093 , mm/min
Actual Seat Load	0.166 , kN
Max Load	11.401 , kN
Max Load	2563.0 lbs
Time at Max Load	4.280 , seconds
Disp at Max Load	3.510 , mm
Max Load Index	215
Servo Offset	-0.009
Starting LLD_L	27.177 , mm
Starting LLD_R	26.751 , mm
Test Duration	20.1000 , seconds
Tensile Strength	509.339 , kPa
Tensile Strength	73.87 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	6/22/2022
Time	10:30:23 AM
Operator	Clark Allen
Specimen ID	Puck # 2
Comments	Additive 2 Re-Test Cond
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.8 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.325
Percent Saturation	74.84 , %
Actual Test Rate	50.081 , mm/min
Actual Seat Load	0.166 , kN
Max Load	13.144 , kN
Max Load	2955.0 lbs
Time at Max Load	6.360 , seconds
Disp at Max Load	5.242 , mm
Max Load Index	319
Servo Offset	-0.038
Starting LLD_L	26.865 , mm
Starting LLD_R	26.379 , mm
Test Duration	24.8400 , seconds
Tensile Strength	587.226 , kPa
Tensile Strength	85.17 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	6/22/2022
Time	10:20:33 AM
Operator	Clark Allen
Specimen ID	Puck # 4
Comments	EAdditive 2 Re-Test DRY
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.5 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.332
Percent Saturation	0.0 , %
Actual Test Rate	50.092 , mm/min
Actual Seat Load	0.183 , kN
Max Load	11.552 , kN
Max Load	2597.1 lbs
Time at Max Load	5.180 , seconds
Disp at Max Load	4.262 , mm
Max Load Index	260
Servo Offset	-0.016
Starting LLD_L	27.064 , mm
Starting LLD_R	26.656 , mm
Test Duration	19.7000 , seconds
Tensile Strength	516.108 , kPa
Tensile Strength	74.86 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	6/22/2022
Time	10:33:27 AM
Operator	Clark Allen
Specimen ID	Puck # 3
Comments	Additive 2 Re-Test Cond
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.8 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.325
Percent Saturation	78.48 , %
Actual Test Rate	50.066 , mm/min
Actual Seat Load	0.134 , kN
Max Load	12.121 , kN
Max Load	2724.9 lbs
Time at Max Load	6.860 , seconds
Disp at Max Load	5.654 , mm
Max Load Index	344
Servo Offset	-0.046
Starting LLD_L	26.425 , mm
Starting LLD_R	26.017 , mm
Test Duration	24.0000 , seconds
Tensile Strength	541.511 , kPa
Tensile Strength	78.54 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	6/22/2022
Time	10:24:02 AM
Operator	Clark Allen
Specimen ID	Puck # 6
Comments	Additive 2 Re-Test DRY
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.7 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.326
Percent Saturation	0.0 , %
Actual Test Rate	50.082 , mm/min
Actual Seat Load	0.181 , kN
Max Load	11.503 , kN
Max Load	2586.0 lbs
Time at Max Load	5.180 , seconds
Disp at Max Load	4.263 , mm
Max Load Index	260
Servo Offset	-0.024
Starting LLD_L	27.059 , mm
Starting LLD_R	26.625 , mm
Test Duration	21.9200 , seconds
Tensile Strength	513.911 , kPa
Tensile Strength	74.54 psi

TSR v1.0.3 (2018.2.16) Mix 1

Date	6/22/2022
Time	10:37:09 AM
Operator	Clark Allen
Specimen ID	Puck # 5
Comments	Additive 2 Re-Test Cond
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.8 , %
Specific Gravity	2.494
Bulk Specific Gravity	2.324
Percent Saturation	77.83 , %
Actual Test Rate	50.080 , mm/min
Actual Seat Load	0.158 , kN
Max Load	12.643 , kN
Max Load	2842.4 lbs
Time at Max Load	6.300 , seconds
Disp at Max Load	5.186 , mm
Max Load Index	316
Servo Offset	-0.050
Starting LLD_L	26.627 , mm
Starting LLD_R	26.133 , mm
Test Duration	21.8200 , seconds
Tensile Strength	564.848 , kPa
Tensile Strength	81.92 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 2

Date	8/4/2022
Time	8:55:53 AM
Operator	Clark Allen
Specimen ID	Puck # 2
Comments	Mix 2 No Lime Dry
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.2 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.408
Percent Saturation	0.0 , %
Actual Test Rate	50.080 , mm/min
Actual Seat Load	0.176 , kN
Max Load	12.871 , kN
Max Load	2893.5 lbs
Time at Max Load	6.100 , seconds
Disp at Max Load	5.007 , mm
Max Load Index	306
Servo Offset	-0.006
Starting LLD_L	26.087 , mm
Starting LLD_R	25.690 , mm
Test Duration	22.4000 , seconds
Tensile Strength	575.010 , kPa
Tensile Strength	83.40 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	8/4/2022
Time	9:13:23 AM
Operator	Clark Allen
Specimen ID	Puck # 1
Comments	Mix 2 No Lime Cond
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.5 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.409
Percent Saturation	76.85 , %
Actual Test Rate	50.160 , mm/min
Actual Seat Load	0.174 , kN
Max Load	15.098 , kN
Max Load	3394.1 lbs
Time at Max Load	3.480 , seconds
Disp at Max Load	2.808 , mm
Max Load Index	175
Servo Offset	-0.036
Starting LLD_L	26.984 , mm
Starting LLD_R	26.568 , mm
Test Duration	16.9200 , seconds
Tensile Strength	674.482 , kPa
Tensile Strength	97.83 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	8/4/2022
Time	8:59:14 AM
Operator	Clark Allen
Specimen ID	Puck # 3
Comments	Mix 2 No Lime Dry
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.3 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.413
Percent Saturation	0.0 , %
Actual Test Rate	50.103 , mm/min
Actual Seat Load	0.168 , kN
Max Load	15.076 , kN
Max Load	3389.3 lbs
Time at Max Load	5.640 , seconds
Disp at Max Load	4.618 , mm
Max Load Index	283
Servo Offset	-0.011
Starting LLD_L	26.700 , mm
Starting LLD_R	26.317 , mm
Test Duration	21.5800 , seconds
Tensile Strength	673.539 , kPa
Tensile Strength	97.69 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	8/4/2022
Time	9:17:25 AM
Operator	Clark Allen
Specimen ID	Puck # 4
Comments	Mix 2 No Lime Cond
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.5 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.409
Percent Saturation	73.96 , %
Actual Test Rate	50.155 , mm/min
Actual Seat Load	0.202 , kN
Max Load	14.834 , kN
Max Load	3334.8 lbs
Time at Max Load	3.440 , seconds
Disp at Max Load	2.783 , mm
Max Load Index	173
Servo Offset	-0.040
Starting LLD_L	26.939 , mm
Starting LLD_R	26.530 , mm
Test Duration	17.6800 , seconds
Tensile Strength	662.709 , kPa
Tensile Strength	96.12 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	8/4/2022
Time	9:02:47 AM
Operator	Clark Allen
Specimen ID	Puck # 5
Comments	Mix 2 No Lime Dry
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.4 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.41
Percent Saturation	0.0 , %
Actual Test Rate	50.113 , mm/min
Actual Seat Load	0.201 , kN
Max Load	15.037 , kN
Max Load	3380.5 lbs
Time at Max Load	5.000 , seconds
Disp at Max Load	4.084 , mm
Max Load Index	251
Servo Offset	-0.017
Starting LLD_L	26.730 , mm
Starting LLD_R	26.326 , mm
Test Duration	22.3200 , seconds
Tensile Strength	671.783 , kPa
Tensile Strength	97.43 psi

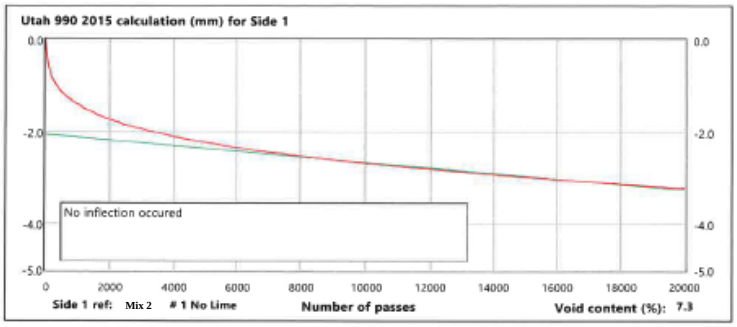
TSR v1.0.3 (2018.2.16) Mix 2

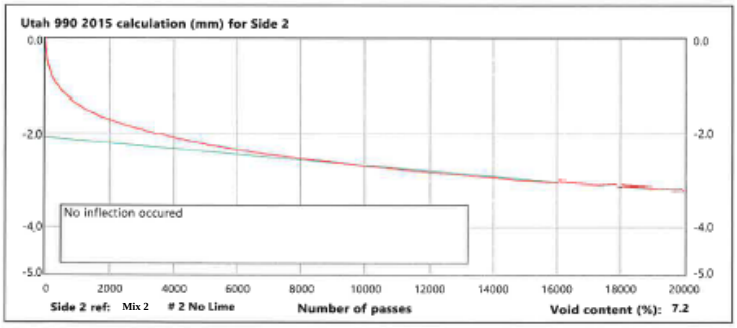
Date	8/4/2022
Time	9:22:59 AM
Operator	Clark Allen
Specimen ID	Puck # 5
Comments	Mix 2 No Lime Cond
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.4 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.41
Percent Saturation	77.26 , %
Actual Test Rate	50.140 , mm/min
Actual Seat Load	0.135 , kN
Max Load	15.327 , kN
Max Load	3445.7 lbs
Time at Max Load	3.760 , seconds
Disp at Max Load	3.048 , mm
Max Load Index	189
Servo Offset	-0.046
Starting LLD_L	27.038 , mm
Starting LLD_R	26.643 , mm
Test Duration	19.9800 , seconds
Tensile Strength	684.738 , kPa
Tensile Strength	99.31 psi

APPENDIX B: Lottman Puck Break Test Data

Hamburg Wheel-Tracker Test Results

AASHTO T324 2019		Date sampled:	8/16/2022
Date/time of test:	8/16/2022 6:07 AM	Job number:	clark
Laboratory number:	Central Materials	Project number:	No Lime
Project name:	Lime Vs Antistrip	Project Engineer:	Howard Anderson
Submitted by:	Research	Threshold:	50%





Rut depths (mm)

Pass No.	Side 1	Side 2
5000	-2.22	-2.21
10000	-2.67	-2.68
15000	-2.97	-2.98
20000	-3.21	-3.21

Mix type:	HMA
Asphalt grade:	64-34
HMA production:	Laboratory
Compaction method:	Slab
Mix source:	Mix 2
Test temperature (°C):	50.0
Mix Depth (mm):	43.00

AASHTO T209 (Rice) Project: Lime vs Antistrip % A.C 4.6 Target

Mix 2

Hamburg

wt. Of Pyc. Filled w/ H_2O	wt. Of mix in air	wt. Of Pyc. And mix + H_2O	Vol. of voidless mix	m.m. Density
A	B	C	D	E
			(A+B)-C	B/D

AASHTO T166 Bulk Density

Gmm = 2.603

Spec. No.	Weight in Grams: In Air Dry F	In Air SSD G	In Water H	Volume cc I	Bulk Density J	AASHTO T269 Total Voids in Mix % K
				G-H	F/I	((E-J)/E) x100
Slab 1	8580.8	8335.5	4905.5	3430.0	2.414	7.3
2	8587.4	8342.1	4910.3	3431.8	2.415	7.2

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 2

Date	9/13/2022
Time	10:20:27 AM
Operator	Clark Allen
Specimen ID	Puck # 1
Comments	Mix 2 Dry Binder B
Diameter	150.0 , mm NO
Thickness	95.0 , mm Lime
Air Void Content	6.8 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.425
Percent Saturation	0.0 , %
Actual Test Rate	50.136 , mm/min
Actual Seat Load	0.164 , kN
Max Load	16.294 , kN
Max Load	3662.9 lbs
Time at Max Load	3.860 , seconds
Disp at Max Load	3.126 , mm
Max Load Index	194
Servo Offset	0.025
Starting LLD_L	26.704 , mm
Starting LLD_R	26.322 , mm
Test Duration	19.2000 , seconds
Tensile Strength	727.916 , kPa
Tensile Strength	105.58 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	9/13/2022
Time	10:32:11 AM
Operator	Clark Allen
Specimen ID	Puck # 2
Comments	Cond , Mix 2 Dry Binder B
Diameter	150.0 , mm NO
Thickness	95.0 , mm Lime
Air Void Content	7.2 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.416
Percent Saturation	76.62 , %
Actual Test Rate	50.132 , mm/min
Actual Seat Load	0.169 , kN
Max Load	17.174 , kN
Max Load	3860.9 lbs
Time at Max Load	4.980 , seconds
Disp at Max Load	4.057 , mm
Max Load Index	250
Servo Offset	-0.006
Starting LLD_L	26.544 , mm
Starting LLD_R	26.176 , mm
Test Duration	20.6000 , second
Tensile Strength	767.263 , kPa
Tensile Strength	111.28 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	9/13/2022
Time	10:23:26 AM
Operator	Clark Allen
Specimen ID	Puck # 3
Comments	Mix 2 Dry Binder B
Diameter	150.0 , mm NO
Thickness	95.0 , mm Lime
Air Void Content	6.8 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.426
Percent Saturation	0.0 , %
Actual Test Rate	50.170 , mm/min
Actual Seat Load	0.134 , kN
Max Load	16.351 , kN
Max Load	3675.8 lbs
Time at Max Load	3.460 , seconds
Disp at Max Load	2.792 , mm
Max Load Index	174
Servo Offset	0.018
Starting LLD_L	26.973 , mm
Starting LLD_R	26.583 , mm
Test Duration	17.3000 , seconds
Tensile Strength	730.478 , kPa
Tensile Strength	105.95 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	9/13/2022
Time	10:35:39 AM
Operator	Clark Allen
Specimen ID	Puck # 5
Comments	Cond , Mix 2 Dry Binder B
Diameter	150.0 , mm NO
Thickness	95.0 , mm Lime
Air Void Content	7.1 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.419
Percent Saturation	77.44 , %
Actual Test Rate	50.153 , mm/min
Actual Seat Load	0.164 , kN
Max Load	16.966 , kN
Max Load	3814.2 lbs
Time at Max Load	4.340 , seconds
Disp at Max Load	3.533 , mm
Max Load Index	218
Servo Offset	-0.015
Starting LLD_L	26.872 , mm
Starting LLD_R	26.452 , mm
Test Duration	19.2600 , seconds
Tensile Strength	757.968 , kPa
Tensile Strength	109.93 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	9/13/2022
Time	10:27:39 AM
Operator	Clark Allen
Specimen ID	Puck # 4
Comments	Mix 2 Dry Binder B
Diameter	150.0 , mm NO
Thickness	95.0 , mm Lime
Air Void Content	6.9 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.423
Percent Saturation	0.0 , %
Actual Test Rate	50.142 , mm/min
Actual Seat Load	0.110 , kN
Max Load	16.030 , kN
Max Load	3603.7 lbs
Time at Max Load	3.540 , seconds
Disp at Max Load	2.865 , mm
Max Load Index	178
Servo Offset	0.008
Starting LLD_L	26.956 , mm
Starting LLD_R	26.570 , mm
Test Duration	20.6200 , seconds
Tensile Strength	716.153 , kPa
Tensile Strength	103.87 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	9/13/2022
Time	10:39:36 AM
Operator	Clark Allen
Specimen ID	Puck # 6
Comments	Cond , Mix 2 Dry Binder B
Diameter	150.0 , mm NO
Thickness	95.0 , mm Lime
Air Void Content	7.3 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.413
Percent Saturation	74.93 , %
Actual Test Rate	50.144 , mm/min
Actual Seat Load	0.119 , kN
Max Load	18.037 , kN
Max Load	4054.8 lbs
Time at Max Load	4.440 , seconds
Disp at Max Load	3.608 , mm
Max Load Index	223
Servo Offset	-0.024
Starting LLD_L	26.960 , mm
Starting LLD_R	26.571 , mm
Test Duration	21.9800 , seconds
Tensile Strength	805.797 , kPa
Tensile Strength	116.87 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 2

Date	8/23/2022
Time	9:09:44 AM
Operator	Clark Allen
Specimen ID	Puck # 3
Comments	Dry , Mix 2 W/Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.5 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.435
Percent Saturation	0.0 , %
Actual Test Rate	50.193 , mm/min
Actual Seat Load	0.181 , kN
Max Load	17.828 , kN
Max Load	4007.9 lbs
Time at Max Load	3.220 , seconds
Disp at Max Load	2.588 , mm
Max Load Index	162
Servo Offset	-0.018
Starting LLD_L	27.182 , mm
Starting LLD_R	26.763 , mm
Test Duration	17.6000 , seconds
Tensile Strength	796.467 , kPa
Tensile Strength	115.52 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	8/23/2022
Time	9:21:48 AM
Operator	Clark Allen
Specimen ID	Puck # 1
Comments	Mix 2 Cond W/Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.7 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.429
Percent Saturation	77.24 , %
Actual Test Rate	50.211 , mm/min
Actual Seat Load	0.141 , kN
Max Load	20.429 , kN
Max Load	4592.6 lbs
Time at Max Load	3.700 , seconds
Disp at Max Load	2.972 , mm
Max Load Index	186
Servo Offset	-0.039
Starting LLD_L	26.831 , mm
Starting LLD_R	26.406 , mm
Test Duration	18.2400 , seconds
Tensile Strength	912.653 , kPa
Tensile Strength	132.37 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	8/23/2022
Time	9:13:53 AM
Operator	Clark Allen
Specimen ID	Puck # 4
Comments	Mix 2 Dry W/Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.5 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.435
Percent Saturation	0.0 , %
Actual Test Rate	50.197 , mm/min
Actual Seat Load	0.171 , kN
Max Load	18.997 , kN
Max Load	4270.7 lbs
Time at Max Load	3.220 , seconds
Disp at Max Load	2.589 , mm
Max Load Index	162
Servo Offset	-0.025
Starting LLD_L	27.152 , mm
Starting LLD_R	26.625 , mm
Test Duration	18.5400 , seconds
Tensile Strength	848.686 , kPa
Tensile Strength	123.09 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	8/23/2022
Time	9:25:11 AM
Operator	Clark Allen
Specimen ID	Puck # 2
Comments	Mix 2 Cond W/Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.6 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.43
Percent Saturation	73.22 , %
Actual Test Rate	50.243 , mm/min
Actual Seat Load	0.162 , kN
Max Load	21.445 , kN
Max Load	4821.1 lbs
Time at Max Load	3.640 , seconds
Disp at Max Load	2.918 , mm
Max Load Index	183
Servo Offset	-0.045
Starting LLD_L	26.851 , mm
Starting LLD_R	26.459 , mm
Test Duration	15.5200 , seconds
Tensile Strength	958.075 , kPa
Tensile Strength	138.96 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	8/23/2022
Time	9:17:26 AM
Operator	Clark Allen
Specimen ID	Puck # 5
Comments	Mix 2 Dry W/Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.4 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.437
Percent Saturation	0.0 , %
Actual Test Rate	50.188 , mm/min
Actual Seat Load	0.187 , kN
Max Load	18.277 , kN
Max Load	4108.7 lbs
Time at Max Load	3.180 , seconds
Disp at Max Load	2.544 , mm
Max Load Index	160
Servo Offset	-0.033
Starting LLD_L	27.108 , mm
Starting LLD_R	26.638 , mm
Test Duration	17.9000 , seconds
Tensile Strength	816.507 , kPa
Tensile Strength	118.42 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	8/23/2022
Time	9:28:02 AM
Operator	Clark Allen
Specimen ID	Puck # 6
Comments	Mix 2 Cond W/Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.8 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.426
Percent Saturation	73.4 , %
Actual Test Rate	50.219 , mm/min
Actual Seat Load	0.153 , kN
Max Load	19.982 , kN
Max Load	4492.2 lbs
Time at Max Load	3.780 , seconds
Disp at Max Load	3.044 , mm
Max Load Index	190
Servo Offset	-0.051
Starting LLD_L	26.805 , mm
Starting LLD_R	26.378 , mm
Test Duration	16.7000 , seconds
Tensile Strength	892.716 , kPa
Tensile Strength	129.48 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 2

Date	9/29/2022
Time	10:11:21 AM
Operator	Jon Hardman
Specimen ID	Puck 2
Comments	Dry , Mix 2, Additive 1
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.1 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.418
Percent Saturation	0.0 , %
Actual Test Rate	50.171 , mm/min
Actual Seat Load	0.136 , kN
Max Load	15.750 , kN
Max Load	3540.8 lbs
Time at Max Load	3.580 , seconds
Disp at Max Load	2.891 , mm
Max Load Index	180
Servo Offset	0.003
Starting LLD_L	26.979 , mm
Starting LLD_R	26.493 , mm
Test Duration	16.9600 , seconds
Tensile Strength	703.634 , kPa
Tensile Strength	102.05 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	9/29/2022
Time	10:21:03 AM
Operator	Jon Hardman
Specimen ID	Puck 1
Comments	Additive 1 , Mix 2 Condition
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.0 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.422
Percent Saturation	75.3 , %
Actual Test Rate	50.118 , mm/min
Actual Seat Load	0.170 , kN
Max Load	17.473 , kN
Max Load	3928.0 lbs
Time at Max Load	4.840 , seconds
Disp at Max Load	3.940 , mm
Max Load Index	243
Servo Offset	-0.021
Starting LLD_L	26.226 , mm
Starting LLD_R	25.860 , mm
Test Duration	20.8400 , seconds
Tensile Strength	780.592 , kPa
Tensile Strength	113.22 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	9/29/2022
Time	10:15:13 AM
Operator	Jon Hardman
Specimen ID	Puck 5
Comments	Dry , Mix 2, Additive 1
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.3 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.414
Percent Saturation	0.0 , %
Actual Test Rate	50.144 , mm/min
Actual Seat Load	0.179 , kN
Max Load	15.642 , kN
Max Load	3516.4 lbs
Time at Max Load	3.700 , seconds
Disp at Max Load	2.994 , mm
Max Load Index	186
Servo Offset	-0.009
Starting LLD_L	26.897 , mm
Starting LLD_R	26.460 , mm
Test Duration	19.4800 , seconds
Tensile Strength	698.802 , kPa
Tensile Strength	101.35 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	9/29/2022
Time	10:24:15 AM
Operator	Jon Hardman
Specimen ID	Puck 3
Comments	Additive 1 , Mix 2 Conditioned
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.0 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.421
Percent Saturation	76.93 , %
Actual Test Rate	50.157 , mm/min
Actual Seat Load	0.196 , kN
Max Load	16.622 , kN
Max Load	3736.8 lbs
Time at Max Load	4.540 , seconds
Disp at Max Load	3.695 , mm
Max Load Index	228
Servo Offset	-0.027
Starting LLD_L	26.901 , mm
Starting LLD_R	26.491 , mm
Test Duration	17.6400 , seconds
Tensile Strength	742.593 , kPa
Tensile Strength	107.70 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	9/29/2022
Time	10:27:21 AM
Operator	Jon Hardman
Specimen ID	Puck 4
Comments	Additive 1 , Mix 2 Condition
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.0 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.42
Percent Saturation	74.95 , %
Actual Test Rate	50.146 , mm/min
Actual Seat Load	0.172 , kN
Max Load	17.845 , kN
Max Load	4011.8 lbs
Time at Max Load	4.880 , seconds
Disp at Max Load	3.963 , mm
Max Load Index	245
Servo Offset	-0.036
Starting LLD_L	26.614 , mm
Starting LLD_R	26.227 , mm
Test Duration	21.4200 , seconds
Tensile Strength	797.235 , kPa
Tensile Strength	115.63 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 2

Date	10/25/2022
Time	9:11:40 AM
Operator	Clark Allen
Specimen ID	Puck # 2
Comments	Mix 2 Dry W/ Additive 2
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.0 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.422
Percent Saturation	0.0 , %
Actual Test Rate	50.177 , mm/min
Actual Seat Load	0.165 , kN
Max Load	17.410 , kN
Max Load	3913.9 lbs
Time at Max Load	3.360 , seconds
Disp at Max Load	2.706 , mm
Max Load Index	169
Servo Offset	0.035
Starting LLD_L	26.793 , mm
Starting LLD_R	26.367 , mm
Test Duration	17.4800 , seconds
Tensile Strength	777.790 , kPa
Tensile Strength	112.81 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	10/25/2022
Time	9:24:23 AM
Operator	Clark Allen
Specimen ID	Puck # 1
Comments	Additive 2 , Mix 2 Conditioned
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.2 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.415
Percent Saturation	75.79 , %
Actual Test Rate	50.117 , mm/min
Actual Seat Load	0.161 , kN
Max Load	18.374 , kN
Max Load	4130.7 lbs
Time at Max Load	4.420 , seconds
Disp at Max Load	3.583 , mm
Max Load Index	222
Servo Offset	0.007
Starting LLD_L	26.629 , mm
Starting LLD_R	25.997 , mm
Test Duration	26.1800 , seconds
Tensile Strength	820.873 , kPa
Tensile Strength	119.06 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	10/25/2022
Time	9:15:49 AM
Operator	Clark Allen
Specimen ID	Puck # 4
Comments	Mix 2 Dry W/ Additive 2
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.1 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.418
Percent Saturation	0.0 , %
Actual Test Rate	50.138 , mm/min
Actual Seat Load	0.138 , kN
Max Load	17.052 , kN
Max Load	3833.5 lbs
Time at Max Load	4.200 , seconds
Disp at Max Load	3.407 , mm
Max Load Index	211
Servo Offset	0.027
Starting LLD_L	27.149 , mm
Starting LLD_R	26.711 , mm
Test Duration	22.3200 , seconds
Tensile Strength	761.803 , kPa
Tensile Strength	110.49 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	10/25/2022
Time	9:28:06 AM
Operator	Clark Allen
Specimen ID	Puck # 3
Comments	Additive 2 , Mix 2 Conditioned
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.2 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.415
Percent Saturation	74.07 , %
Actual Test Rate	50.155 , mm/min
Actual Seat Load	0.143 , kN
Max Load	18.042 , kN
Max Load	4056.0 lbs
Time at Max Load	4.640 , seconds
Disp at Max Load	3.762 , mm
Max Load Index	233
Servo Offset	-0.004
Starting LLD_L	26.450 , mm
Starting LLD_R	25.857 , mm
Test Duration	19.5400 , seconds
Tensile Strength	806.020 , kPa
Tensile Strength	116.90 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	10/25/2022
Time	9:18:24 AM
Operator	Clark Allen
Specimen ID	Puck # 6
Comments	Mix 2 Dry W/ Additive 2
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.1 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.417
Percent Saturation	0.0 , %
Actual Test Rate	50.173 , mm/min
Actual Seat Load	0.184 , kN
Max Load	16.629 , kN
Max Load	3738.3 lbs
Time at Max Load	3.500 , seconds
Disp at Max Load	2.827 , mm
Max Load Index	176
Servo Offset	0.019
Starting LLD_L	26.951 , mm
Starting LLD_R	26.551 , mm
Test Duration	16.3200 , seconds
Tensile Strength	742.898 , kPa
Tensile Strength	107.75 psi

TSR v1.0.3 (2018.2.16) Mix 2

Date	10/25/2022
Time	9:31:15 AM
Operator	Clark Allen
Specimen ID	Puck # 5
Comments	Additive 2 , Mix 2 Conditioned
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.3 , %
Specific Gravity	2.603
Bulk Specific Gravity	2.412
Percent Saturation	78.14 , %
Actual Test Rate	50.147 , mm/min
Actual Seat Load	0.198 , kN
Max Load	19.117 , kN
Max Load	4297.6 lbs
Time at Max Load	5.100 , seconds
Disp at Max Load	4.158 , mm
Max Load Index	256
Servo Offset	-0.008
Starting LLD_L	26.512 , mm
Starting LLD_R	26.061 , mm
Test Duration	23.0800 , seconds
Tensile Strength	854.038 , kPa
Tensile Strength	123.87 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 3

Date	3/2/2023
Time	9:54:43 AM
Operator	Clark Allen
Specimen ID	Puck # 1
Comments	Mix 3 No Lime Dry
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.5 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.308
Percent Saturation	0.0 , %
Actual Test Rate	50.142 , mm/min
Actual Seat Load	0.194 , kN
Max Load	16.942 , kN
Max Load	3808.6 lbs
Time at Max Load	4.860 , seconds
Disp at Max Load	3.983 , mm
Max Load Index	244
Servo Offset	0.016
Starting LLD_L	27.140 , mm
Starting LLD_R	26.666 , mm
Test Duration	19.2000 , seconds
Tensile Strength	756.872 , kPa
Tensile Strength	109.77 psi

TSR v1.0.3 (2018.2.16) Mix 3

Date	3/2/2023
Time	10:20:21 AM
Operator	Clark Allen
Specimen ID	Puck # 4
Comments	Mix 3 No Lime Cond
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.0 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.297
Percent Saturation	76.58 , %
Actual Test Rate	50.098 , mm/min
Actual Seat Load	0.174 , kN
Max Load	16.236 , kN
Max Load	3650.0 lbs
Time at Max Load	6.820 , seconds
Disp at Max Load	5.615 , mm
Max Load Index	342
Servo Offset	-0.016
Starting LLD_L	26.040 , mm
Starting LLD_R	25.616 , mm
Test Duration	25.1600 , seconds
Tensile Strength	725.354 , kPa
Tensile Strength	105.20 psi

TSR v1.0.3 (2018.2.16) Mix 3

Date	3/2/2023
Time	10:11:09 AM
Operator	Clark Allen
Specimen ID	Puck # 2
Comments	Mix 3 No Lime Dry
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.0 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.297
Percent Saturation	0.0 , %
Actual Test Rate	50.133 , mm/min
Actual Seat Load	0.164 , kN
Max Load	16.277 , kN
Max Load	3659.3 lbs
Time at Max Load	5.260 , seconds
Disp at Max Load	4.317 , mm
Max Load Index	264
Servo Offset	-0.005
Starting LLD_L	26.864 , mm
Starting LLD_R	26.458 , mm
Test Duration	19.4600 , seconds
Tensile Strength	727.196 , kPa
Tensile Strength	105.47 psi

TSR v1.0.3 (2018.2.16) Mix 3

Date	3/2/2023
Time	10:24:14 AM
Operator	Clark Allen
Specimen ID	Puck # 5
Comments	Mix 3 No Lime Cond
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.2 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.292
Percent Saturation	77.93 , %
Actual Test Rate	50.107 , mm/min
Actual Seat Load	0.174 , kN
Max Load	15.506 , kN
Max Load	3485.8 lbs
Time at Max Load	6.540 , seconds
Disp at Max Load	5.383 , mm
Max Load Index	328
Servo Offset	-0.021
Starting LLD_L	26.521 , mm
Starting LLD_R	25.921 , mm
Test Duration	20.8200 , seconds
Tensile Strength	692.721 , kPa
Tensile Strength	100.47 psi

TSR v1.0.3 (2018.2.16) Mix 3

Date	3/2/2023
Time	10:14:35 AM
Operator	Clark Allen
Specimen ID	Puck # 3
Comments	Mix 3 No Lime Dry
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.9 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.299
Percent Saturation	0.0 , %
Actual Test Rate	50.164 , mm/min
Actual Seat Load	0.089 , kN
Max Load	16.243 , kN
Max Load	3651.6 lbs
Time at Max Load	4.780 , seconds
Disp at Max Load	3.916 , mm
Max Load Index	240
Servo Offset	-0.011
Starting LLD_L	26.974 , mm
Starting LLD_R	26.537 , mm
Test Duration	17.4200 , seconds
Tensile Strength	725.670 , kPa
Tensile Strength	105.25 psi

TSR v1.0.3 (2018.2.16) Mix 3

Date	3/2/2023
Time	10:27:13 AM
Operator	Clark Allen
Specimen ID	Puck # 6
Comments	Mix 3 No Lime Cond
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.0 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.296
Percent Saturation	75.06 , %
Actual Test Rate	50.111 , mm/min
Actual Seat Load	0.179 , kN
Max Load	16.910 , kN
Max Load	3801.5 lbs
Time at Max Load	6.880 , seconds
Disp at Max Load	5.660 , mm
Max Load Index	345
Servo Offset	-0.026
Starting LLD_L	26.363 , mm
Starting LLD_R	25.760 , mm
Test Duration	23.1400 , seconds
Tensile Strength	755.462 , kPa
Tensile Strength	109.57 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 3

Date	2/22/2023
Time	9:33:18 AM
Operator	Jon Hardman
Specimen ID	Puck 1
Comments	Mix 3 W-Lime Dry
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.9 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.299
Percent Saturation	0.0 , %
Actual Test Rate	50.121 , mm/min
Actual Seat Load	0.191 , kN
Max Load	17.379 , kN
Max Load	3906.9 lbs
Time at Max Load	4.460 , seconds
Disp at Max Load	3.647 , mm
Max Load Index	224
Servo Offset	-0.001
Starting LLD_L	26.997 , mm
Starting LLD_R	26.561 , mm
Test Duration	25.2600 , seconds
Tensile Strength	776.392 , kPa
Tensile Strength	112.61 psi

TSR v1.0.3 (2018.2.16) Mix 3

Date	2/22/2023
Time	9:49:46 AM
Operator	Jon Hardman
Specimen ID	Puck 4
Comments	Mix 3 W-Lime Cond
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.2 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.29
Percent Saturation	76.79 , %
Actual Test Rate	50.127 , mm/min
Actual Seat Load	0.169 , kN
Max Load	18.415 , kN
Max Load	4139.8 lbs
Time at Max Load	6.320 , seconds
Disp at Max Load	5.194 , mm
Max Load Index	317
Servo Offset	-0.024
Starting LLD_L	26.230 , mm
Starting LLD_R	25.808 , mm
Test Duration	23.2800 , seconds
Tensile Strength	822.676 , kPa
Tensile Strength	119.32 psi

TSR v1.0.3 (2018.2.16) Mix 3

Date	2/22/2023
Time	9:37:24 AM
Operator	Jon Hardman
Specimen ID	Puck 2
Comments	Mix 3 W-Lime Dry
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.0 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.295
Percent Saturation	0.0 , %
Actual Test Rate	50.204 , mm/min
Actual Seat Load	0.157 , kN
Max Load	16.824 , kN
Max Load	3782.2 lbs
Time at Max Load	4.480 , seconds
Disp at Max Load	3.670 , mm
Max Load Index	225
Servo Offset	-0.006
Starting LLD_L	27.006 , mm
Starting LLD_R	26.512 , mm
Test Duration	15.0000 , seconds
Tensile Strength	751.612 , kPa
Tensile Strength	109.01 psi

TSR v1.0.3 (2018.2.16) Mix 3

Date	2/22/2023
Time	9:53:26 AM
Operator	Jon Hardman
Specimen ID	Puck 5
Comments	Mix 3 W-Lime Cond
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.2 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.292
Percent Saturation	77.07 , %
Actual Test Rate	50.171 , mm/min
Actual Seat Load	0.188 , kN
Max Load	20.220 , kN
Max Load	4545.7 lbs
Time at Max Load	6.040 , seconds
Disp at Max Load	4.951 , mm
Max Load Index	303
Servo Offset	-0.028
Starting LLD_L	26.295 , mm
Starting LLD_R	25.889 , mm
Test Duration	19.5000 , seconds
Tensile Strength	903.341 , kPa
Tensile Strength	131.02 psi

TSR v1.0.3 (2018.2.16) Mix 3

Date	2/22/2023
Time	9:40:21 AM
Operator	Jon Hardman
Specimen ID	Puck 3
Comments	Mix 3 W-Lime Dry
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.0 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.297
Percent Saturation	0.0 , %
Actual Test Rate	50.174 , mm/min
Actual Seat Load	0.176 , kN
Max Load	17.770 , kN
Max Load	3994.8 lbs
Time at Max Load	4.400 , seconds
Disp at Max Load	3.595 , mm
Max Load Index	221
Servo Offset	-0.009
Starting LLD_L	27.017 , mm
Starting LLD_R	26.606 , mm
Test Duration	18.6000 , seconds
Tensile Strength	793.865 , kPa
Tensile Strength	115.14 psi

TSR v1.0.3 (2018.2.16) Mix 3

Date	2/22/2023
Time	9:57:17 AM
Operator	Jon Hardman
Specimen ID	Puck 6
Comments	Mix 3 W-Lime Cond
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.0 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.297
Percent Saturation	73.6 , %
Actual Test Rate	50.190 , mm/min
Actual Seat Load	0.160 , kN
Max Load	20.077 , kN
Max Load	4513.5 lbs
Time at Max Load	5.620 , seconds
Disp at Max Load	4.603 , mm
Max Load Index	282
Servo Offset	-0.034
Starting LLD_L	26.619 , mm
Starting LLD_R	26.239 , mm
Test Duration	17.8400 , seconds
Tensile Strength	896.947 , kPa
Tensile Strength	130.09 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 3

Date	, 3/30/2023	
Time	, 10:18:02 AM	
Operator	, Jon Hardman	
Specimen ID	, Puck #1	
Comments	, Dry, Mix 3, Additive 1	
Diameter	, 150.0 , mm	
Thickness	, 95.0 MM	
Air Void Content	, 6.9 , %	
Specific Gravity	, 2.469	
Bulk Specific Gravity	, 2.298	
Percent Saturation	, 76.32 , %	
Actual Test Rate	, 50.136 , mm/min	
Actual Seat Load	, 0.190 , kN	
Max Load	, 15.380 , kN	
Max Load	, 3457.6 lbs	
Time at Max Load	, 4.620 , seconds	
Disp at Max Load	, 3.780 , mm	
Max Load Index	, 232	
Servo Offset	, 0.018	
Starting LLD_L	, 26.945 , mm	
Starting LLD_R	, 26.411 , mm	
Test Duration	, 19.5400 , seconds	
Tensile Strength	, ~~1052.845~~ , kPa	
Tensile Strength	, ~~152.70~~ psi	

TSR v1.0.3 (2018.2.16)

Date	, 3/30/2023	
Time	, 10:30:44 AM	
Operator	, Jon Hardman	
Specimen ID	, Puck #4	
Comments	, Cond, Mix 3, Additive 1	
Diameter	, 150.0 , mm	
Thickness	, 95.0 MM	
Air Void Content	, 7.0 , %	
Specific Gravity	, 2.469	
Bulk Specific Gravity	, 2.295	
Percent Saturation	, 76.32 , %	
Actual Test Rate	, 50.089 , mm/min	
Actual Seat Load	, 0.159 , kN	
Max Load	, 15.374 , kN	
Max Load	, 3456.1 lbs	
Time at Max Load	, 7.040 , seconds	
Disp at Max Load	, 5.798 , mm	
Max Load Index	, 353	
Servo Offset	, -0.008	
Starting LLD_L	, 25.551 , mm	
Starting LLD_R	, 25.147 , mm	
Test Duration	, 26.6600 , seconds	
Tensile Strength	, ~~1052.386~~ , kPa	
Tensile Strength	, ~~152.64~~ psi	

TSR v1.0.3 (2018.2.16) Mix 3

Date	, 3/30/2023	
Time	, 10:21:13 AM	
Operator	, Jon Hardman	
Specimen ID	, Puck #2	
Comments	, Dry, Mix 3, Additive 1	
Diameter	, 150.0 , mm	
Thickness	, 95.0 MM	
Air Void Content	, 6.6 , %	
Specific Gravity	, 2.469	
Bulk Specific Gravity	, 2.305	
Percent Saturation	, 73.99 , %	
Actual Test Rate	, 50.154 , mm/min	
Actual Seat Load	, 0.158 , kN	
Max Load	, 15.639 , kN	
Max Load	, 3515.9 lbs	
Time at Max Load	, 4.440 , seconds	
Disp at Max Load	, 3.637 , mm	
Max Load Index	, 223	
Servo Offset	, 0.012	
Starting LLD_L	, 27.038 , mm	
Starting LLD_R	, 26.612 , mm	
Test Duration	, 17.3400 , seconds	
Tensile Strength	, ~~1070.569~~ , kPa	
Tensile Strength	, ~~155.27~~ psi	

TSR v1.0.3 (2018.2.16)

Date	, 3/30/2023	
Time	, 10:34:23 AM	
Operator	, Jon Hardman	
Specimen ID	, Puck #5	
Comments	, Cond, Mix 3, Additive 1	
Diameter	, 150.0 , mm	
Thickness	, 95.0 MM	
Air Void Content	, 7.4 , %	
Specific Gravity	, 2.469	
Bulk Specific Gravity	, 2.287	
Percent Saturation	, 73.99 , %	
Actual Test Rate	, 50.113 , mm/min	
Actual Seat Load	, 0.152 , kN	
Max Load	, 15.795 , kN	
Max Load	, 3550.8 lbs	
Time at Max Load	, 7.120 , seconds	
Disp at Max Load	, 5.863 , mm	
Max Load Index	, 357	
Servo Offset	, -0.011	
Starting LLD_L	, 25.808 , mm	
Starting LLD_R	, 25.391 , mm	
Test Duration	, 21.4000 , seconds	
Tensile Strength	, ~~1081.199~~ , kPa	
Tensile Strength	, ~~156.81~~ psi	

TSR v1.0.3 (2018.2.16) Mix 3

Date	, 3/30/2023	
Time	, 10:24:52 AM	
Operator	, Jon Hardman	
Specimen ID	, Puck #3	
Comments	, Dry, Mix 3, Additive 1	
Diameter	, 150.0 , mm	
Thickness	, 95.0 MM	
Air Void Content	, 6.8 , %	
Specific Gravity	, 2.469	
Bulk Specific Gravity	, 2.301	
Percent Saturation	, 77.6 , %	
Actual Test Rate	, 50.150 , mm/min	
Actual Seat Load	, 0.179 , kN	
Max Load	, 16.171 , kN	
Max Load	, 3635.3 lbs	
Time at Max Load	, 4.220 , seconds	
Disp at Max Load	, 3.452 , mm	
Max Load Index	, 212	
Servo Offset	, 0.008	
Starting LLD_L	, 27.077 , mm	
Starting LLD_R	, 26.649 , mm	
Test Duration	, 19.7400 , seconds	
Tensile Strength	, ~~1106.934~~ , kPa	
Tensile Strength	, ~~160.55 psi~~	

TSR v1.0.3 (2018.2.16) Mix 3

Date	, 3/30/2023	
Time	, 10:37:47 AM	
Operator	, Jon Hardman	
Specimen ID	, Puck #6	
Comments	, Cond, Mix 3, Additive 1	
Diameter	, 150.0 , mm	
Thickness	, 95.0 MM	
Air Void Content	, 7.4 , %	
Specific Gravity	, 2.469	
Bulk Specific Gravity	, 2.286	
Percent Saturation	, 77.6 , %	
Actual Test Rate	, 50.107 , mm/min	
Actual Seat Load	, 0.188 , kN	
Max Load	, 15.565 , kN	
Max Load	, 3499.1 lbs	
Time at Max Load	, 6.360 , seconds	
Disp at Max Load	, 5.239 , mm	
Max Load Index	, 319	
Servo Offset	, -0.020	
Starting LLD_L	, 26.167 , mm	
Starting LLD_R	, 25.763 , mm	
Test Duration	, 21.5800 , seconds	
Tensile Strength	, ~~1065.469~~ , kPa	
Tensile Strength	, ~~154.53~~ psi	

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 3

Date	3/16/2023
Time	10:39:34 AM
Operator	Clark Allen
Specimen ID	Puck # 1
Comments	Dry Add. 2 , Mix 3, Binder C PG-34
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.9 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.299
Percent Saturation	0.0 , %
Actual Test Rate	50.173 , mm/min
Actual Seat Load	0.180 , kN
Max Load	16.251 , kN
Max Load	3653.3 lbs
Time at Max Load	4.420 , seconds
Disp at Max Load	3.613 , mm
Max Load Index	222
Servo Offset	0.033
Starting LLD_L	27.144 , mm
Starting LLD_R	26.672 , mm
Test Duration	17.0000 , seconds
Tensile Strength	726.009 , kPa
Tensile Strength	105.30 psi

TSR v1.0.3 (2018.2.16) Mix 3

Date	3/16/2023
Time	10:53:01 AM
Operator	Clark Allen
Specimen ID	Puck # 3
Comments	Cond. Add. 2 , Mix 3, Binder C PG-34
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.2 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.292
Percent Saturation	75.09 , %
Actual Test Rate	50.105 , mm/min
Actual Seat Load	0.115 , kN
Max Load	15.927 , kN
Max Load	3580.5 lbs
Time at Max Load	6.780 , seconds
Disp at Max Load	5.585 , mm
Max Load Index	340
Servo Offset	-0.002
Starting LLD_L	26.035 , mm
Starting LLD_R	25.643 , mm
Test Duration	25.1800 , seconds
Tensile Strength	711.527 , kPa
Tensile Strength	103.20 psi

TSR v1.0.3 (2018.2.16) Mix 3

Date	3/16/2023
Time	10:42:57 AM
Operator	Clark Allen
Specimen ID	Puck # 2
Comments	Dry Add. 2 , Mix 3, Binder C PG-34
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.9 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.298
Percent Saturation	0.0 , %
Actual Test Rate	50.168 , mm/min
Actual Seat Load	0.143 , kN
Max Load	16.788 , kN
Max Load	3774.2 lbs
Time at Max Load	4.580 , seconds
Disp at Max Load	3.749 , mm
Max Load Index	230
Servo Offset	0.025
Starting LLD_L	26.949 , mm
Starting LLD_R	26.430 , mm
Test Duration	17.7400 , seconds
Tensile Strength	750.026 , kPa
Tensile Strength	108.78 psi

TSR v1.0.3 (2018.2.16) Mix 3

Date	3/16/2023
Time	10:55:35 AM
Operator	Clark Allen
Specimen ID	Puck # 5
Comments	Cond. Add. 2 , Mix 3, Binder C PG-34
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.3 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.29
Percent Saturation	74.54 , %
Actual Test Rate	50.086 , mm/min
Actual Seat Load	0.115 , kN
Max Load	15.920 , kN
Max Load	3579.0 lbs
Time at Max Load	8.060 , seconds
Disp at Max Load	6.654 , mm
Max Load Index	404
Servo Offset	-0.011
Starting LLD_L	25.865 , mm
Starting LLD_R	25.393 , mm
Test Duration	20.2800 , seconds
Tensile Strength	711.237 , kPa
Tensile Strength	103.16 psi

TSR v1.0.3 (2018.2.16) Mix 3

Date	3/16/2023
Time	10:47:18 AM
Operator	Clark Allen
Specimen ID	Puck # 4
Comments	Dry Add. 2 , Mix 3, Binder C PG-34
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.8 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.302
Percent Saturation	0.0 , %
Actual Test Rate	50.177 , mm/min
Actual Seat Load	0.175 , kN
Max Load	17.134 , kN
Max Load	3851.8 lbs
Time at Max Load	4.360 , seconds
Disp at Max Load	3.562 , mm
Max Load Index	219
Servo Offset	0.008
Starting LLD_L	26.995 , mm
Starting LLD_R	26.553 , mm
Test Duration	17.5800 , seconds
Tensile Strength	765.453 , kPa
Tensile Strength	111.02 psi

TSR v1.0.3 (2018.2.16) Mix 3

Date	3/16/2023
Time	10:58:31 AM
Operator	Clark Allen
Specimen ID	Puck # 6
Comments	Cond. Add. 2 , Mix 3, Binder C PG-34
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.2 , %
Specific Gravity	2.469
Bulk Specific Gravity	2.291
Percent Saturation	75.56 , %
Actual Test Rate	50.116 , mm/min
Actual Seat Load	0.164 , kN
Max Load	16.380 , kN
Max Load	3682.3 lbs
Time at Max Load	6.880 , seconds
Disp at Max Load	5.659 , mm
Max Load Index	345
Servo Offset	-0.019
Starting LLD_L	26.073 , mm
Starting LLD_R	25.448 , mm
Test Duration	21.1600 , seconds
Tensile Strength	731.766 , kPa
Tensile Strength	106.13 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 4

Date	7/13/2023
Time	12:51:01 PM
Operator	Clark Allen
Specimen ID	Puck # 1
Comments	No Add. Mix 4 Dry
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.3 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.299
Percent Saturation	0.0 , %
Actual Test Rate	50.236 , mm/min
Actual Seat Load	0.193 , kN
Max Load	17.980 , kN
Max Load	4042.0 lbs
Time at Max Load	3.480 , seconds
Disp at Max Load	2.803 , mm
Max Load Index	175
Servo Offset	0.018
Starting LLD_L	27.005 , mm
Starting LLD_R	26.540 , mm
Test Duration	14.0800 , seconds
Tensile Strength	803.245 , kPa
Tensile Strength	116.50 psi

TSR v1.0.3 (2018.2.16) Mix 4

Date	7/13/2023
Time	1:05:18 PM
Operator	Clark Allen
Specimen ID	Puck # 2
Comments	No Add. Mix 4 Conditioned
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.4 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.297
Percent Saturation	77.27 , %
Actual Test Rate	50.138 , mm/min
Actual Seat Load	0.141 , kN
Max Load	14.030 , kN
Max Load	3154.2 lbs
Time at Max Load	5.260 , seconds
Disp at Max Load	4.297 , mm
Max Load Index	264
Servo Offset	-0.038
Starting LLD_L	25.885 , mm
Starting LLD_R	25.346 , mm
Test Duration	16.2400 , seconds
Tensile Strength	626.808 , kPa
Tensile Strength	90.91 psi

TSR v1.0.3 (2018.2.16) Mix 4

Date	7/13/2023
Time	12:54:14 PM
Operator	Clark Allen
Specimen ID	Puck # 4
Comments	No Add. Mix 4 Dry
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.2 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.303
Percent Saturation	0.0 , %
Actual Test Rate	50.238 , mm/min
Actual Seat Load	0.202 , kN
Max Load	19.328 , kN
Max Load	4345.1 lbs
Time at Max Load	3.740 , seconds
Disp at Max Load	3.024 , mm
Max Load Index	188
Servo Offset	0.002
Starting LLD_L	27.018 , mm
Starting LLD_R	26.421 , mm
Test Duration	14.0000 , seconds
Tensile Strength	863.487 , kPa
Tensile Strength	125.24 psi

TSR v1.0.3 (2018.2.16) Mix 4

Date	7/13/2023
Time	1:09:16 PM
Operator	Clark Allen
Specimen ID	Puck # 3
Comments	No Add. Mix 4 Conditioned
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.4 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.294
Percent Saturation	74.96 , %
Actual Test Rate	50.117 , mm/min
Actual Seat Load	0.155 , kN
Max Load	13.831 , kN
Max Load	3109.3 lbs
Time at Max Load	4.820 , seconds
Disp at Max Load	3.938 , mm
Max Load Index	242
Servo Offset	-0.047
Starting LLD_L	26.146 , mm
Starting LLD_R	25.713 , mm
Test Duration	18.6000 , seconds
Tensile Strength	617.896 , kPa
Tensile Strength	89.62 psi

TSR v1.0.3 (2018.2.16) Mix 4

Date	7/13/2023
Time	12:57:53 PM
Operator	Clark Allen
Specimen ID	Puck # 6
Comments	No Add. Mix 4 Dry
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.2 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.302
Percent Saturation	0.0 , %
Actual Test Rate	50.230 , mm/min
Actual Seat Load	0.170 , kN
Max Load	20.494 , kN
Max Load	4607.3 lbs
Time at Max Load	3.760 , seconds
Disp at Max Load	3.024 , mm
Max Load Index	189
Servo Offset	-0.012
Starting LLD_L	26.954 , mm
Starting LLD_R	26.533 , mm
Test Duration	16.5400 , seconds
Tensile Strength	915.586 , kPa
Tensile Strength	132.79 psi

TSR v1.0.3 (2018.2.16) Mix 4

Date	7/13/2023
Time	1:12:40 PM
Operator	Clark Allen
Specimen ID	Puck # 5
Comments	No Add. Mix 4 Conditioned
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.4 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.298
Percent Saturation	76.41 , %
Actual Test Rate	50.138 , mm/min
Actual Seat Load	0.163 , kN
Max Load	14.838 , kN
Max Load	3335.6 lbs
Time at Max Load	5.080 , seconds
Disp at Max Load	4.144 , mm
Max Load Index	255
Servo Offset	-0.054
Starting LLD_L	26.252 , mm
Starting LLD_R	25.821 , mm
Test Duration	17.6000 , seconds
Tensile Strength	662.873 , kPa
Tensile Strength	96.14 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 4

Date	7/11/2023
Time	9:25:39 AM
Operator	Jon Hardman
Specimen ID	Dry Puck #1
Comments	Mix 4 64-34 W/Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.9 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.311
Percent Saturation	0.0 , %
Actual Test Rate	50.231 , mm/min
Actual Seat Load	0.176 , kN
Max Load	19.941 , kN
Max Load	4483.0 lbs
Time at Max Load	3.700 , seconds
Disp at Max Load	3.003 , mm
Max Load Index	186
Servo Offset	-0.052
Starting LLD_L	27.199 , mm
Starting LLD_R	26.749 , mm
Test Duration	15.7200 , seconds
Tensile Strength	890.879 , kPa
Tensile Strength	129.21 psi

TSR v1.0.3 (2018.2.16) Mix 4

Date	7/11/2023
Time	9:37:34 AM
Operator	Jon Hardman
Specimen ID	Conditioned Puck #2
Comments	Mix 4 64-34 W/Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.3 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.3
Percent Saturation	75.96 , %
Actual Test Rate	50.187 , mm/min
Actual Seat Load	0.160 , kN
Max Load	19.107 , kN
Max Load	4295.3 lbs
Time at Max Load	4.620 , seconds
Disp at Max Load	3.770 , mm
Max Load Index	232
Servo Offset	-0.076
Starting LLD_L	26.501 , mm
Starting LLD_R	25.995 , mm
Test Duration	17.8800 , seconds
Tensile Strength	853.588 , kPa
Tensile Strength	123.80 psi

TSR v1.0.3 (2018.2.16) Mix 4

Date	7/11/2023
Time	9:28:54 AM
Operator	Jon Hardman
Specimen ID	Dry Puck #4
Comments	Mix 4 64-34 W/Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.0 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.308
Percent Saturation	0.0 , %
Actual Test Rate	50.225 , mm/min
Actual Seat Load	0.183 , kN
Max Load	19.322 , kN
Max Load	4343.7 lbs
Time at Max Load	3.960 , seconds
Disp at Max Load	3.228 , mm
Max Load Index	199
Servo Offset	-0.058
Starting LLD_L	27.155 , mm
Starting LLD_R	26.736 , mm
Test Duration	17.0600 , seconds
Tensile Strength	863.196 , kPa
Tensile Strength	125.20 psi

TSR v1.0.3 (2018.2.16) Mix 4

Date	7/11/2023
Time	9:40:41 AM
Operator	Jon Hardman
Specimen ID	Conditioned Puck #3
Comments	Mix 4 64-34 W/Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.2 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.304
Percent Saturation	75.42 , %
Actual Test Rate	50.198 , mm/min
Actual Seat Load	0.187 , kN
Max Load	19.524 , kN
Max Load	4389.2 lbs
Time at Max Load	4.800 , seconds
Disp at Max Load	3.920 , mm
Max Load Index	241
Servo Offset	-0.080
Starting LLD_L	26.711 , mm
Starting LLD_R	26.295 , mm
Test Duration	15.4600 , seconds
Tensile Strength	872.248 , kPa
Tensile Strength	126.51 psi

TSR v1.0.3 (2018.2.16) Mix 4

Date	7/11/2023
Time	9:32:44 AM
Operator	Jon Hardman
Specimen ID	Dry Puck #5
Comments	Mix 4 64-34 W/Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.1 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.306
Percent Saturation	0.0 , %
Actual Test Rate	50.311 , mm/min
Actual Seat Load	0.184 , kN
Max Load	21.085 , kN
Max Load	4740.1 lbs
Time at Max Load	3.940 , seconds
Disp at Max Load	3.196 , mm
Max Load Index	198
Servo Offset	-0.062
Starting LLD_L	27.059 , mm
Starting LLD_R	26.646 , mm
Test Duration	12.6400 , seconds
Tensile Strength	941.984 , kPa
Tensile Strength	136.62 psi

TSR v1.0.3 (2018.2.16) Mix 4

Date	7/11/2023
Time	9:43:43 AM
Operator	Jon Hardman
Specimen ID	Conditioned Puck #6
Comments	Mix 4 64-34 W/Lime
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.5 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.297
Percent Saturation	76.03 , %
Actual Test Rate	50.200 , mm/min
Actual Seat Load	0.175 , kN
Max Load	18.562 , kN
Max Load	4173.0 lbs
Time at Max Load	4.680 , seconds
Disp at Max Load	3.820 , mm
Max Load Index	235
Servo Offset	-0.087
Starting LLD_L	26.554 , mm
Starting LLD_R	26.103 , mm
Test Duration	17.1600 , seconds
Tensile Strength	829.275 , kPa
Tensile Strength	120.28 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 4

Date	8/10/2023
Time	10:05:06 AM
Operator	Jon Hardman
Specimen ID	Puck #2
Comments	Mix 4, with Additive 1 Dry
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.4 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.298
Percent Saturation	0.0 , %
Actual Test Rate	50.185 , mm/min
Actual Seat Load	0.164 , kN
Max Load	18.752 , kN
Max Load	4215.6 lbs
Time at Max Load	4.120 , seconds
Disp at Max Load	3.334 , mm
Max Load Index	207
Servo Offset	0.003
Starting LLD_L	26.827 , mm
Starting LLD_R	26.393 , mm
Test Duration	17.7000 , seconds
Tensile Strength	837.748 , kPa
Tensile Strength	121.50 psi

TSR v1.0.3 (2018.2.16) Mix 4

Date	8/10/2023
Time	10:15:07 AM
Operator	Jon Hardman
Specimen ID	Puck #1
Comments	Mix 4, with Additive 1 Cond
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	8.7 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.267
Percent Saturation	75.45 , %
Actual Test Rate	50.061 , mm/min
Actual Seat Load	0.152 , kN
Max Load	9.718 , kN
Max Load	2184.8 lbs
Time at Max Load	5.600 , seconds
Disp at Max Load	4.586 , mm
Max Load Index	281
Servo Offset	-0.021
Starting LLD_L	26.041 , mm
Starting LLD_R	25.635 , mm
Test Duration	22.0200 , seconds
Tensile Strength	434.164 , kPa
Tensile Strength	62.97 psi

TSR v1.0.3 (2018.2.16) Mix 4

Date	8/10/2023
Time	10:07:59 AM
Operator	Jon Hardman
Specimen ID	Puck #3
Comments	Mix 4, with Additive 1 Dry
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.1 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.306
Percent Saturation	0.0 , %
Actual Test Rate	50.201 , mm/min
Actual Seat Load	0.188 , kN
Max Load	18.719 , kN
Max Load	4208.1 lbs
Time at Max Load	3.760 , seconds
Disp at Max Load	3.039 , mm
Max Load Index	189
Servo Offset	-0.004
Starting LLD_L	26.803 , mm
Starting LLD_R	26.363 , mm
Test Duration	16.9600 , seconds
Tensile Strength	836.255 , kPa
Tensile Strength	121.29 psi

TSR v1.0.3 (2018.2.16) Mix 4

Date	8/10/2023
Time	10:18:30 AM
Operator	Jon Hardman
Specimen ID	Puck #5
Comments	Mix 4, with Additive 1 Cond
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.4 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.299
Percent Saturation	72.58 , %
Actual Test Rate	50.086 , mm/min
Actual Seat Load	0.178 , kN
Max Load	12.410 , kN
Max Load	2789.8 lbs
Time at Max Load	5.260 , seconds
Disp at Max Load	4.295 , mm
Max Load Index	264
Servo Offset	-0.029
Starting LLD_L	26.059 , mm
Starting LLD_R	25.586 , mm
Test Duration	21.4000 , seconds
Tensile Strength	554.400 , kPa
Tensile Strength	80.41 psi

TSR v1.0.3 (2018.2.16) Mix 4

Date	8/10/2023
Time	10:11:28 AM
Operator	Jon Hardman
Specimen ID	Puck #4
Comments	Mix 4, with Additive 1 Dry
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.3 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.3
Percent Saturation	0.0 , %
Actual Test Rate	50.199 , mm/min
Actual Seat Load	0.195 , kN
Max Load	18.578 , kN
Max Load	4176.5 lbs
Time at Max Load	3.680 , seconds
Disp at Max Load	2.970 , mm
Max Load Index	185
Servo Offset	-0.011
Starting LLD_L	26.936 , mm
Starting LLD_R	26.438 , mm
Test Duration	16.1400 , seconds
Tensile Strength	829.968 , kPa
Tensile Strength	120.38 ps

TSR v1.0.3 (2018.2.16) Mix 4

Date	8/10/2023
Time	10:21:49 AM
Operator	Jon Hardman
Specimen ID	Puck #6
Comments	Mix 4, with Additive 1 Cond
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.6 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.293
Percent Saturation	74.08 , %
Actual Test Rate	50.109 , mm/min
Actual Seat Load	0.177 , kN
Max Load	13.319 , kN
Max Load	2994.2 lbs
Time at Max Load	5.280 , seconds
Disp at Max Load	4.321 , mm
Max Load Index	265
Servo Offset	-0.034
Starting LLD_L	26.164 , mm
Starting LLD_R	25.734 , mm
Test Duration	18.3000 , seconds
Tensile Strength	595.030 , kPa
Tensile Strength	86.30 psi

APPENDIX B: Lottman Puck Break Test Data

TSR v1.0.3 (2018.2.16) Mix 4

Date	8/8/2023
Time	10:07:19 AM
Operator	Jon Hardman
Specimen ID	Puck #1
Comments	Mix 4, with Additive 2
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	6.7 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.316
Percent Saturation	0.0 , %
Actual Test Rate	50.195 , mm/min
Actual Seat Load	0.138 , kN
Max Load	20.271 , kN
Max Load	4557.2 lbs
Time at Max Load	3.740 , seconds
Disp at Max Load	3.017 , mm
Max Load Index	188
Servo Offset	0.007
Starting LLD_L	26.979 , mm
Starting LLD_R	26.555 , mm
Test Duration	18.5600 , seconds
Tensile Strength	905.627 , kPa
Tensile Strength	131.35 psi

Dry

TSR v1.0.3 (2018.2.16) Mix 4

Date	8/8/2023
Time	10:23:08 AM
Operator	Jon Hardman
Specimen ID	Puck #4
Comments	Mix 4, with Additive 2
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.4 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.298
Percent Saturation	77.3 , %
Actual Test Rate	50.138 , mm/min
Actual Seat Load	0.126 , kN
Max Load	15.868 , kN
Max Load	3567.3 lbs
Time at Max Load	5.560 , seconds
Disp at Max Load	4.546 , mm
Max Load Index	279
Servo Offset	-0.034
Starting LLD_L	26.341 , mm
Starting LLD_R	25.954 , mm
Test Duration	15.4400 , seconds
Tensile Strength	708.903 , kPa
Tensile Strength	102.82 psi

Cond

TSR v1.0.3 (2018.2.16) Mix 4

Date	8/8/2023
Time	10:10:50 AM
Operator	Jon Hardman
Specimen ID	Puck #2
Comments	Mix 4, with Additive 2
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.3 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.3
Percent Saturation	0.0 , %
Actual Test Rate	50.171 , mm/min
Actual Seat Load	0.199 , kN
Max Load	20.153 , kN
Max Load	4530.6 lbs
Time at Max Load	5.320 , seconds
Disp at Max Load	4.336 , mm
Max Load Index	267
Servo Offset	-0.002
Starting LLD_L	26.273 , mm
Starting LLD_R	25.856 , mm
Test Duration	17.2600 , seconds
Tensile Strength	900.346 , kPa
Tensile Strength	130.58 psi

Dry

TSR v1.0.3 (2018.2.16) Mix 4

Date	8/8/2023
Time	10:27:12 AM
Operator	Jon Hardman
Specimen ID	Puck #5
Comments	Mix 4, with Additive 2
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.4 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.299
Percent Saturation	77.06 , %
Actual Test Rate	50.120 , mm/min
Actual Seat Load	0.165 , kN
Max Load	14.658 , kN
Max Load	3295.2 lbs
Time at Max Load	5.380 , seconds
Disp at Max Load	4.400 , mm
Max Load Index	270
Servo Offset	-0.046
Starting LLD_L	25.917 , mm
Starting LLD_R	25.505 , mm
Test Duration	18.9400 , seconds
Tensile Strength	654.837 , kPa
Tensile Strength	94.98 psi

Cond

TSR v1.0.3 (2018.2.16) Mix 4

Date	8/8/2023
Time	10:13:28 AM
Operator	Jon Hardman
Specimen ID	Puck #3
Comments	Mix 4, with Additive 2
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.1 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.305
Percent Saturation	0.0 , %
Actual Test Rate	50.189 , mm/min
Actual Seat Load	0.180 , kN
Max Load	20.160 , kN
Max Load	4532.1 lbs
Time at Max Load	4.180 , seconds
Disp at Max Load	3.390 , mm
Max Load Index	210
Servo Offset	-0.009
Starting LLD_L	26.803 , mm
Starting LLD_R	26.390 , mm
Test Duration	18.4000 , seconds
Tensile Strength	900.632 , kPa
Tensile Strength	130.63 psi

Dry

TSR v1.0.3 (2018.2.16) Mix 4

Date	8/8/2023
Time	10:30:48 AM
Operator	Jon Hardman
Specimen ID	Puck #6
Comments	Mix 4, with Additive 2
Diameter	150.0 , mm
Thickness	95.0 , mm
Air Void Content	7.4 , %
Specific Gravity	2.482
Bulk Specific Gravity	2.299
Percent Saturation	77.84 , %
Actual Test Rate	50.109 , mm/min
Actual Seat Load	0.201 , kN
Max Load	14.405 , kN
Max Load	3238.3 lbs
Time at Max Load	5.800 , seconds
Disp at Max Load	4.738 , mm
Max Load Index	291
Servo Offset	-0.050
Starting LLD_L	25.925 , mm
Starting LLD_R	25.530 , mm
Test Duration	15.7600 , seconds
Tensile Strength	643.530 , kPa
Tensile Strength	93.34 psi

Cond