

Four Variables That Affect the Performance of Lime in Asphalt-Aggregate Mixtures

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Four variables that affect the success of lime as an antistripping agent were evaluated: (a) four methods of adding two types of lime to asphalt-aggregates, (b) four lime products, (c) two different aggregate sources, and (d) air voids. Effects of the four variables on moisture sensitivity were evaluated by determining the resilient modulus and the tensile strength of samples before and after one cycle of the Lottman accelerated conditioning procedure (a freeze-thaw cycle subjecting water-saturated samples to freezing at -20°F and thawing in a 140°F water bath). The effects of the variables on temperature susceptibility were evaluated by determining the resilient modulus values at four different test temperatures. The following conclusions can be drawn from this research project: (a) quicklime added to the asphalt or to the dry aggregate can be detrimental to the mixture; (b) dolomitic lime can improve mixture properties to the same degree as hydrated lime; (c) mixture properties can be enhanced by the addition of hydrated lime, regardless of the moisture susceptibility of the untreated mixes; (d) an increase in the volume of lime used can further improve the mixture properties; and (e) air voids significantly affect mixture properties, regardless of lime variations.

A significant number of premature pavement failures in the Southeast, intermountain West, and Southwest have been associated with water sensitivity of asphalt-aggregate mixtures. Significant strength losses in mixtures can result without noticeable debonding or "stripping" of the asphalt cement from the aggregate. Partial or complete stripping will lead to strength loss on the order of from 70 to 95 percent.

Stripping is caused by several factors:

1. Asphalt-aggregate interactions,
2. Surface coatings on the aggregate,
3. Smooth aggregate surface texture, and
4. Improper pavement design and construction control.

There are several methods for either eliminating or correcting the causes of stripping:

1. Modifying the physical-chemical properties of the mix,
2. Washing the aggregate before mixing,
3. Crushing smooth-surfaced aggregates,
4. Providing adequate drainage to prevent the accumulation of water in pavement layers,
5. Sealing surfaces to reduce permeability,
6. Controlling compaction of the pavement to reduce permeability, and

7. Replacing a stripping aggregate with a nonstripping aggregate if such a practice is economical.

Although there are many methods of improving mixture properties, the treatment of asphalt concrete with an additive appears to be the most acceptable. Additives are easy to use and have a minimal cost. Although the reasons for the success of additives are not fully understood, three types of additives are generally recognized as treatments for stripping mixtures: hydrated lime, liquid antistripping agents, and portland cement.

The use of these additives has produced varying results in construction projects. Hydrated lime appears to be the most effective antistripping additive. Liquid antistripping agents, usually amines, have had variable success and portland cement has had some general success.

There are several theories about why hydrated lime is effective. First, lime improves the bonding of calcium with silicates in aggregate. Second, there is a possible interaction with the acidic portions of the asphalts (1). Third, if aggregates have clay coatings, there are ion exchange and pozzolanic reactions between the calcium in lime and the silica in clay.

The effect of lime on the moisture sensitivity of asphalt-aggregate mixtures is dependent on other variables:

1. Methods of introducing the lime into the mixture,
2. Types of lime products,
3. Changes in aggregate sources, and
4. Air voids present in the pavement.

This research program explores the effects of these variables.

RESEARCH PROGRAM

This research program was developed to individually evaluate the effect of four variables on the moisture sensitivity of asphalt-aggregate mixtures. The variables are methods of adding lime, various lime products, different aggregate sources, and effects of air voids.

Two types of lime were used in the investigation of methods of adding lime. Quicklime was introduced into the mixture by (a) adding it to the dry aggregate, (b) adding it to the asphalt, and (c) slurring the quicklime before adding it to the aggregate. Hydrated lime was introduced into the mixture by (a) adding it to dry aggregate and (b) adding it to wet aggregate.

Four types of lime added dry to one source of aggregate were used in the investigation of the effects of various lime products on asphalt-aggregate mixture properties. Two of these limes

were added dry to aggregate from a second source to establish the effects of different aggregate sources.

Two types of lime, added by various methods to aggregate from one source and compacted with air voids between 1 and 8 percent, were used to evaluate the effect of air voids on moisture sensitivity.

A control set of samples with no lime was used for comparison and to establish the effectiveness of the treatment methods.

MATERIALS AND SUPPLIES

Asphalt

Asphalt from only one source was used for this research program. This was an AR-4000. The physical properties of the asphalt are given in Table 1.

TABLE 1 PHYSICAL PROPERTIES OF AR-4000

Test	Original Asphalt	After Rolling Thin Film	After Extended Rolling Thin Film
Penetration			
39.2°F/100g/5sec	14	11	2
77°F/100g/5sec	54	34	—
Viscosity			
At 140°F (poise)	2184	3880	—
At 275°F (cSt)	268.4	344.8	8645.7
Ductility (cm)	100+	100+	0.5
Ring-and-ball softening point (°F)	123	127	185

NOTE: Dashes = data not available.

TABLE 2 PHYSICAL PROPERTIES OF AGGREGATES

	Bulk Specific Gravity	Bulk, SSD ^a , Specific Gravity	Apparent Specific Gravity	Absorption Capacity (%)
Aggregate 1				
Coarse	2.565	2.631	2.746	2.60
Fine	2.492	2.567	2.722	3.40
Aggregate 2				
Coarse	2.616	2.644	2.693	1.12
Fine	2.555	2.601	2.678	1.80

^aSSD = saturated surface dry.

Aggregates

Aggregates were obtained from Sparks, Nevada (Aggregate 1), and Phoenix, Arizona (Aggregate 2). These aggregates were chosen because of their history of stripping problems and the similarity of their rounded shape and surface texture.

Aggregate stockpiles were separated into 10 sieve sizes. All aggregate larger than the No. 30 sieve was washed to provide tighter control on the amount of fines in the mix. The sample gradation is discussed further in the section on Testing Program and Procedures.

The physical properties of the aggregates are given in Table 2. The major difference among the aggregates is their absorption capacity. The Nevada aggregate has an absorption capacity between 2.6 and 3.4 percent, and that of the Arizona aggregate is between 1.1 and 1.8 percent.

Lime Products

Lime is manufactured from either high-calcium or dolomitic limestone. High-grade commercial deposits usually contain not more than 3 percent total impurities. Heat, water, and carbon dioxide are used to transform limestone into three distinct forms.

Limestone (calcium carbonate) is calcined (burned) to produce quicklime. Quicklime and water react to produce hydrated lime. Carbon dioxide in the air recombines with hydrated lime in the presence of water and converts it to the carbonated state (limestone).

Dolomitic limestone is a combination of calcium and magnesium carbonate. When dolomitic lime is hydrated, only a small portion of the magnesium oxide is hydrated. Complete hydration of the magnesium oxide is accomplished by a continuous high-pressure system.

A quicklime (QL), two hydrated limes (HD1 and HD2), and a dolomitic lime (DL) were used for this research project. The available physical, gradation, and chemical properties are given in Tables 3–5. The hydrated limes were obtained from Industry, California (HD1), and Nelson, Nevada (HD2). The Arizona lime was laboratory hydrated before it was shipped.

The major differences among the lime products are (a) yield in cubic feet of putty, (b) setting rate, and (c) density. The quicklime has a yield of 85 ft³ of putty compared with approximately 50 ft³ for both California lime (HD1) and dolomitic lime. The California lime (HD1), quicklime, and dolomitic

TABLE 3 PHYSICAL PROPERTIES OF LIMES

Physical Property	Hydrated Lime 1	Hydrated Lime 2	Quicklime	Dolomitic Lime
Yield of putty (ft ³) per				
Ton	51	—	85	56
Cubic foot	1.1	—	2.56	1.20
50-lb bag	1.3	—	—	1.25
Setting rate to 1/2 volume ^a (min)	150	—	350	420
Loose density (lb/ft ³)	28	86	60	25
Specific gravity	2.23	2.63	3.15	2.22

NOTE: Dashes = data not available.

^aASTM C 110.

TABLE 4 SIEVE ANALYSIS OF TWO LIMES

Sieve Size	Cumulative Percentage Passing	
	Hydrated Lime 1	Dolomitic Lime
20 mm	100	100
30 mm	100	99.6
35 mm	100	99.6
48 mm	100	99
65 mm	100	98
100 mm	Trace	96
150 mm	99	90
200 mm	97	86
325 mm	88	79

limes have setting times to half volume (ASTM C 110) of 150, 350, and 450 min, respectively. The Arizona lime (HD2) has the highest loose density followed by the quicklime and the two hydrated limes.

The most significant differences between the two hydrated limes are their densities and specific gravities. The loose densities for the California lime (HD1) and the Arizona lime (HD2) are 28 and 86 and their specific gravities are 2.23 and 2.63, respectively.

TEST PROGRAM AND PROCEDURES

The test program included selection of an appropriate aggregate gradation, two mix designs to determine optimum asphalt content, and methods for adding lime as well as determination of compactive efforts necessary to produce a wide range of air voids. When the test program had been defined, all samples were tested as outlined in the test sequence shown in Figure 1.

Aggregate Gradation

The aggregate gradation attempted to meet three standard specifications: Nevada DOT Type 2, Caltrans $3/4$ -in. maximum size (operating range), and ASTM D 3515 dense mixture ($1/2$ -in. maximum size) (2-4). It should be noted that the $1/2$ -in. sieve size is slightly out of range on the Nevada DOT Type 2 and the Caltrans $3/4$ -in. maximum size. This was unavoidable because

of the lack of overlap between the specifications at this sieve size.

The same gradation was used for aggregate from both sources. The sieve analysis of the aggregate gradations is given in Table 6. Because lime acts as a mineral filler as well as an admixture, a gradation was done for both aggregates with the HD1 lime added to dry aggregate (Table 6).

To control the fines, aggregate from both sources was sieved into individual sieve sizes. All aggregate above the No. 30 sieve was washed before sample preparation.

Mix Designs

Mix designs were completed for aggregate from both sources as outlined by the Asphalt Institute (5). Samples were compacted according to ASTM D 1559 using 50 blows per side. The optimum asphalt content for the Nevada aggregate (Aggregate 1) was 6.5 percent by total weight of mix. The optimum asphalt content for the Arizona aggregate (Aggregate 2) was 7.0 percent by total weight of mix.

Preparation of Aggregate-Lime Treatments

Four methods of introducing the lime into the mixture were used although not all methods were used for every lime product. Each method of treatment used 1.5 percent lime by dry weight of aggregate. All aggregate was dried at 230°F for a minimum of 15 hr before treatment. Six samples were prepared for use in testing each variable.

The procedures for introducing the lime into the mixture, the lime products, and the aggregates used for each method were as follows.

1. Dry lime was added to cold aggregate, mixed well to coat the aggregate, then reheated before mixing. Quicklime, dolomitic lime, and both hydrated limes were added to both aggregates.
2. Lime was added to the asphalt before mixing with aggregate. The quicklime was the only lime added by this method, and only Aggregate 1 was used.
3. Lime was combined with water in a four-to-one ratio,

TABLE 5 CHEMICAL PROPERTIES OF LIME PRODUCTS

Property	Hydrated Lime 1 (%)	Hydrated Lime 2 (%)	Quicklime (%)	Dolomitic Lime (%)
Acid insoluble	1.5	1.0	2.0	0.5
Iron oxide	0.1	0.05	0.20	0.20
Aluminum oxide	0.5	0.2	0.7	1.0
Magnesium carbonate	—	0.5	—	—
Calcium carbonate	1.5	—	1.5	2.0
Calcium oxide	Nil	—	92.0	—
Magnesium oxide	1.0	—	2.0	1.0
Magnesium hydroxide	—	—	—	40.0
Calcium hydroxide	93.0	94.0	1.0	56.0
Moisture	0.5	—	Nil	0.5
ASTM available lime	91.5	92.0	91.0	—

NOTE: Dashes = data not available.

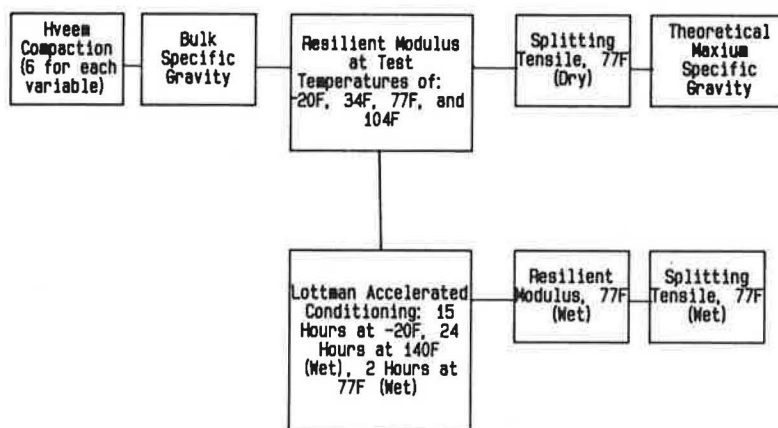


FIGURE 1 Test sequence flow chart.

then mixed with cold aggregate. The lime-aggregate mixture was then dried again at 230°F for a minimum of 15 hr before mixing. The quicklime was the only lime added by this method, and only Aggregate 1 was used.

4. Water (6 percent by dry weight of aggregate) was added to cooled oven dry aggregate before the lime was added. The lime-aggregate mixture was then dried again at 230°F for a minimum of 15 hr before mixing. The California hydrated lime (HD1) was the only lime added by this method, and only Aggregate 1 was used.

Several details were noted during preparation of lime treatments. During the mixing of dry lime with dry aggregate, it was noted that the California hydrated lime (HD1) coated the dry aggregate thoroughly whereas the quicklime failed to completely coat the coarse aggregate. Some foaming was noted during mixing the quicklime with asphalt; thickening of the asphalt and settlement of the lime to the bottom of the asphalt were also observed. An extensive exothermic reaction was noted when the quicklime and water were combined; to keep the reaction to a minimum, the quicklime was added in small quantities. A hard crust was noticed on the surface of the quicklime slurry-aggregate mixture after it was removed from

the oven. This crust had to be broken before asphalt could be added.

Compactive Effort

Two Hveem compactive efforts were used to produce a wide range of air voids. The 100 percent compactive effort as described in ASTM D 1561 (150 strokes at 500 psi and a leveling load of 12,600 lb) produced between 1 and 3 percent air voids. The 95 percent compactive effort (ASTM D 1561 modified by using 30 strokes and 250 psi and a leveling load of 11,600 lb) produced between 4 and 8 percent air voids.

All samples used in the evaluation of the effects of methods of adding lime, lime products, and aggregate sources were prepared with the 95 percent compactive effort. Six samples were prepared with California hydrated lime (HD1) added dry, quicklime added dry, slurried quicklime, the control mix, and Aggregate 1 with the greater (100 percent) compactive effort.

Test Sequence

Six samples for evaluating each variable were prepared and tested according to the sequence shown in Figure 1. The testing procedures are outlined next.

After mixing, samples were heated at 140°F for 15 hr and then compacted according to ASTM D 1561 and modified ASTM D 1561. Bulk specific gravities were determined and the samples were then stored overnight at 77°F. Resilient modulus values were determined for sample temperatures of -20°F, 34°F, 77°F, and 104°F. Testing was performed according to ASTM D 4123; the load cycle was 0.1 sec applied load with a 3-sec pause between loads. The samples were then divided into two groups of three samples each.

Splitting tensile strength was determined for the first group of three samples. Theoretical maximum specific gravities were determined by ASTM D 2041; a correction was made for absorptive aggregates (4).

The second group of three samples was subjected to one cycle of the Lottman accelerated conditioning procedure (6). Resilient modulus values and splitting tensile strengths were determined for wet samples at a test temperature of 77°F.

TABLE 6 GRADATION OF AGGREGATES WITH AND WITHOUT HYDRATED LIME

Sieve Size	Percentage Passing			
	Aggregate 1		Aggregate 2	
	Without Lime	With Lime	Without Lime	With Lime
3/4 in.	100	100	100	100
1/2 in.	94.7	94.7	94.9	95.2
3/8 in.	72.4	72.0	72.7	72.9
No. 4	52.2	52.6	52.1	53.1
No. 8	36.2	37.4	36.5	37.6
No. 16	30.2	31.4	30.2	31.0
No. 30	19.8	22.1	16.4	16.7
No. 50	13.1	14.7	10.1	10.4
No. 100	9.0	10.1	6.7	7.0
No. 200	5.8	6.4	4.1	4.3

NOTE: Washed aggregate was batched with and without lime, and a sieve analysis was then performed.

TABLE 7 TEST RESULTS FOR METHODS OF ADDING QUICKLIME (Aggregate 1)

Test	Method of Adding Lime					Control
	QL to Dry Aggregate	QL to Asphalt	Slurried QL	HD1 to Dry Aggregate	HD1 to Wet Aggregate	
Resilient modulus (ksi) at						
-20°F	5,960	6,621	7,585	—	5,591	8,208
34°F	4,725	4,372	4,419	—	3,005	4,354
77°F	521	570	449	292	404	467
104°F	69	78	56	—	46	43
Resilient modulus (ksi) after one cycle of Lottman accelerated conditioning						
77°F, dry	521	570	449	292	404	467
77°F, wet	184	82	739	260	316	150
Ratio	35	14	165	89	78	32
Tensile Strength (psi) at						
77°F, dry	213	222	162	90	106	176
77°F, wet	70	43	192	70	117	131
Ratio	33	20	118	78	110	74
Air voids (%)	3	4	1	6	4	2

NOTE: Dashes = data not available.

TEST RESULTS

Test results are discussed in terms of the variables investigated.

Methods of Adding Lime

There was little difference in the temperature susceptibility of the five mixtures as evidenced by the negligible variations in stiffness at any given temperatures (Table 7).

The best retained resilient modulus values after one cycle of conditioning were achieved by the slurried quicklime with a resilient modulus ratio greater than 100 percent. The hydrated lime added to dry and to wet aggregate produced the next best results with resilient modulus ratios of 89 and 78 percent, respectively. Adding the quicklime to dry aggregate did not improve the mix and adding it to the asphalt actually decreased

the resilient modulus ratio compared with the control. Test results are given in Table 7 and shown in Figure 2; the ratios are shown in Figure 3.

The best tensile strength ratio after one cycle of conditioning was achieved by the slurried quicklime, the hydrated lime added to wet aggregate, and hydrated lime added to dry aggregate. The quicklime added to dry aggregate and to the asphalt actually decreased the tensile strength ratios. The test results are given in Table 7 and shown in Figure 4; the ratios are shown in Figure 3.

Types of Lime

There was little difference in the temperature susceptibility of the five mixtures (Table 8).

The best retained resilient modulus values were obtained

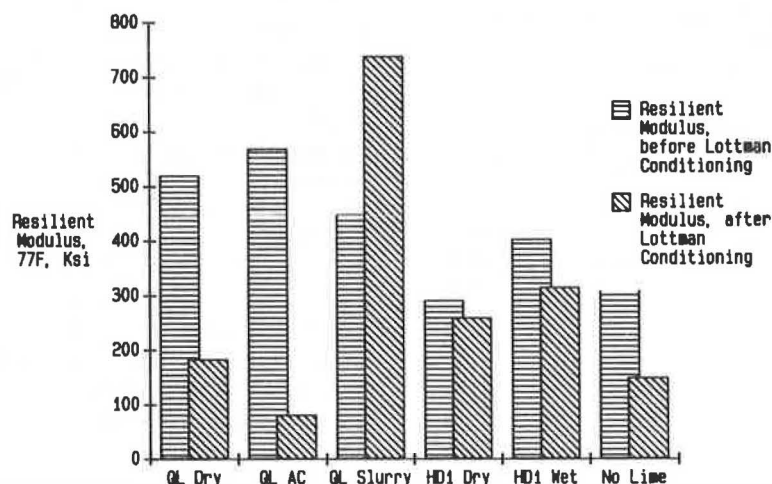


FIGURE 2 Resilient modulus for various methods of adding lime (Aggregate 1).

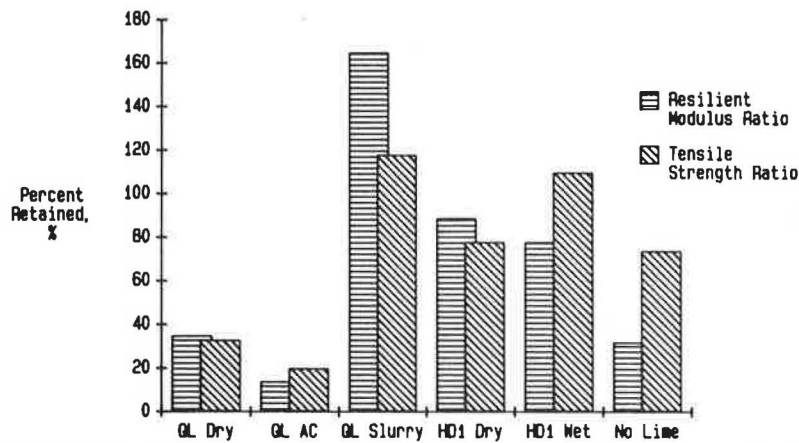


FIGURE 3 Percentage retained after Lottman cycling for various methods of adding lime (Aggregate 1).

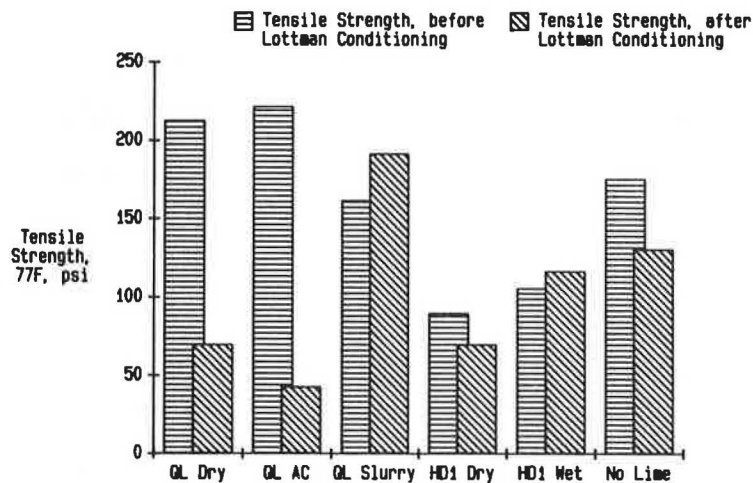


FIGURE 4 Tensile strengths for various methods of adding lime (Aggregate 1).

TABLE 8 TEST RESULTS FOR VARIOUS TYPES OF LIME (added to dry Aggregate 1)

Test	Types of Lime				
	Hydrated Lime 1	Hydrated Lime 2	Quicklime	Dolomitic Lime	Control
Resilient modulus (ksi) at					
-20°F	—	4,749	—	3,861	—
34°F	—	4,097	—	3,861	—
77°F	292	337	237	401	231
104°F	—	40	—	42	—
Resilient modulus (ksi) after one cycle of Lottman accelerated conditioning					
77°F, dry	292	337	237	401	231
77°F, wet	260	237	—	221	93
Ratio	89	71	—	55	41
Tensile strength (psi) at					
77°F, dry	90	115	65	99	73
77°F, wet	70	64	25	67	34
Ratio	78	56	39	67	47
Air voids (%)	6	7	8	5	8

NOTE: Dashes = data not available.

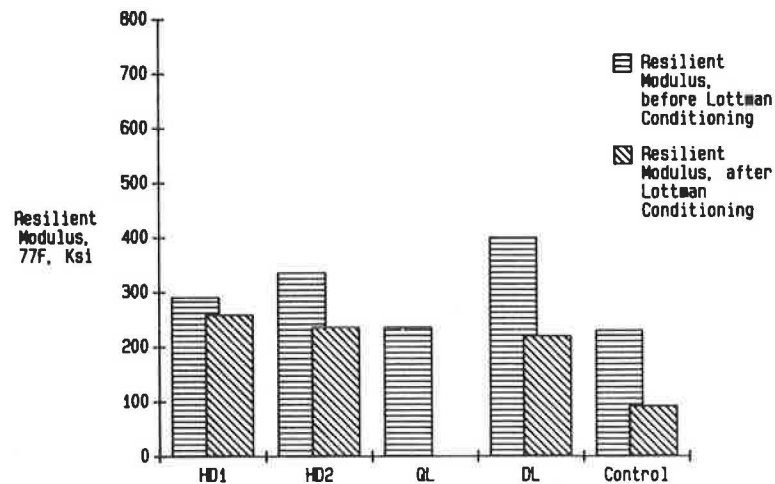


FIGURE 5 Resilient modulus for various types of lime (Aggregate 1).

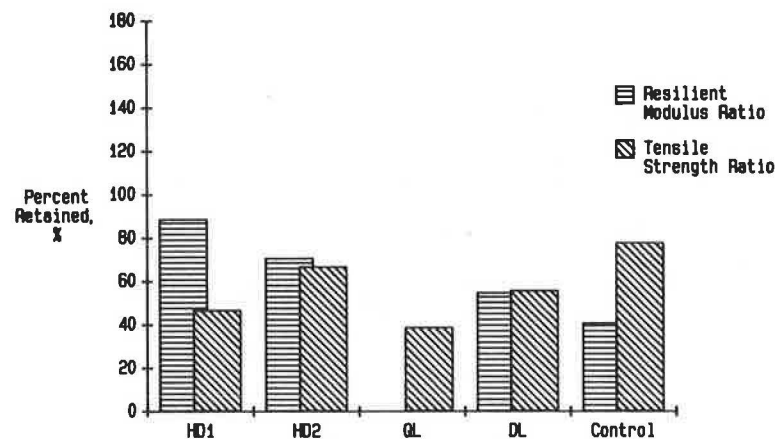


FIGURE 6 Percentage retained after Lottman cycling for various types of lime added dry to Aggregate 1.

with the hydrated limes. Although the dolomitic lime produced a resilient modulus value, before soaking, that was approximately equal to that of the hydrated limes, the original strength was higher and the resilient modulus ratio was therefore reduced. Test results are given in Table 8 and shown in Figure 5; the ratios are shown in Figure 6.

The HD1 produced slightly lower before-conditioning

values than did the HD2 but produced higher strengths after conditioning. The difference in strengths might not be due to differences in lime products but to the volume of lime present in the mixtures. HD2 has a significantly higher specific gravity than does HD1; this difference in specific gravities results in a lower volume of HD2 when limes are added on a weight basis.

The best tensile strength ratios as shown in Figure 6 were

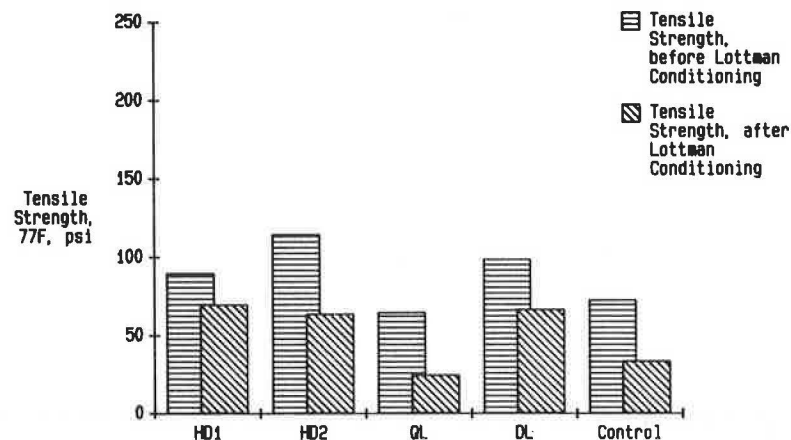


FIGURE 7 Tensile strengths for various types of lime added dry to Aggregate 1.

TABLE 9 TEST RESULTS FOR AGGREGATES FROM VARIOUS SOURCES (hydrated lime was added to dry aggregate)

Test	Aggregate 1			Aggregate 2		
	HD1	HD2	Control	HD1	HD2	Control
Resilient modulus (ksi) at						
-20°F	—	4,749	—	6,271	5,600	5,600
34°F	—	4,097	—	3,853	4,271	3,173
77°F	92	337	231	269	224	198
104°F	—	40	—	33	27	32
Resilient modulus (ksi) after one cycle of Lottman accelerated conditioning						
77°F, dry	292	337	231	269	224	198
77°F, wet	260	237	93	310	219	139
Ratio	89	71	41	118	99	70
Tensile strength (psi) at						
77°F, dry	90	115	15	100	86	90
77°F, wet	70	64	34	159	109	84
Ratio	78	56	47	160	126	93
Air voids (%)	6	7	8	5	4	7

NOTE: Dashes = data not available.

produced by HD1 and dolomitic lime. Although the ratios range from 78 to 56 percent for both of the hydrated limes and the dolomitic limes, the final tensile strengths for these three groups are approximately the same (Table 8 and Figure 7).

Aggregate from Different Sources

Changing aggregate sources or types of hydrated limes had little effect on the temperature susceptibility of the mixtures (Table 9).

The resilient modulus values for Aggregate 1 before conditioning were slightly higher than those for Aggregate 2 (Table 9 and Figure 8). The resilient modulus values for Aggregate 1 after conditioning were slightly lower than those for Aggregate 2. The HD1 produced slightly better resilient modulus values, both before and after conditioning, than did the HD2. This is, again, probably due to the difference in volumes of lime present in the mixtures. Both limes showed significant improvement over both sets of control samples.

Although Aggregate 2 was not as susceptible to water as Aggregate 1, as shown by the difference in the resilient modulus and tensile strength ratios (Figure 9), the presence of lime in either asphalt-aggregate mixture greatly improves the mix properties.

The tensile strength before conditioning was approximately the same for both aggregates with both hydrated limes (Table 9 and Figure 10). Aggregate 2 showed a significant gain in tensile strength after conditioning. The tensile strength ratios of both aggregates were improved by the addition of lime, although HD1 produced better results.

Air Voids

With one exception, there was a significant drop in resilient modulus values, both wet and dry, as the percentage of air voids increased (Table 10 and Figure 11). The exception was the mixture with hydrated lime 1; the wet resilient modulus was approximately the same regardless of the percentage of air

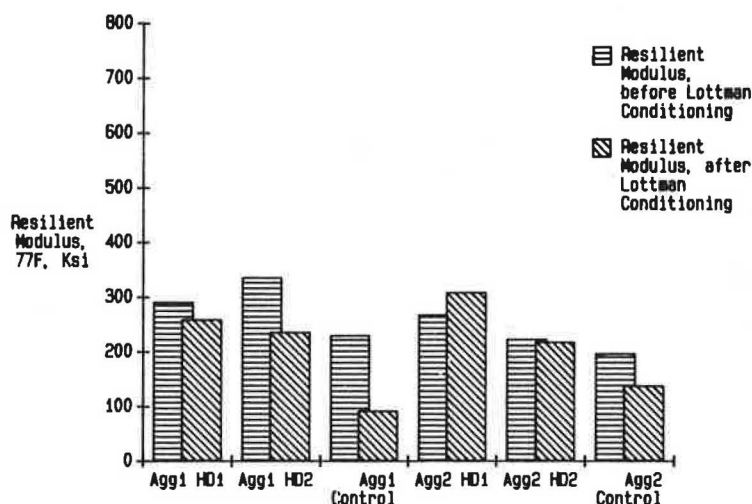


FIGURE 8 Resilient modulus for mixes with aggregate from different sources (lime added to dry aggregate).

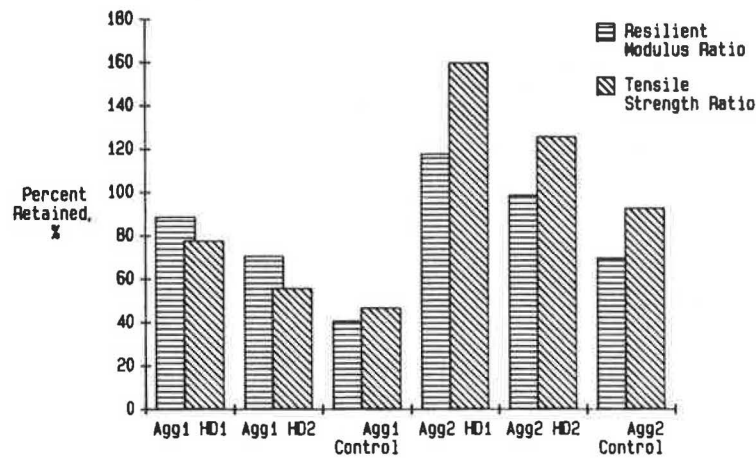


FIGURE 9 Percentage retained after Lottman conditioning for mixes with aggregate from different sources (lime added to dry aggregate).

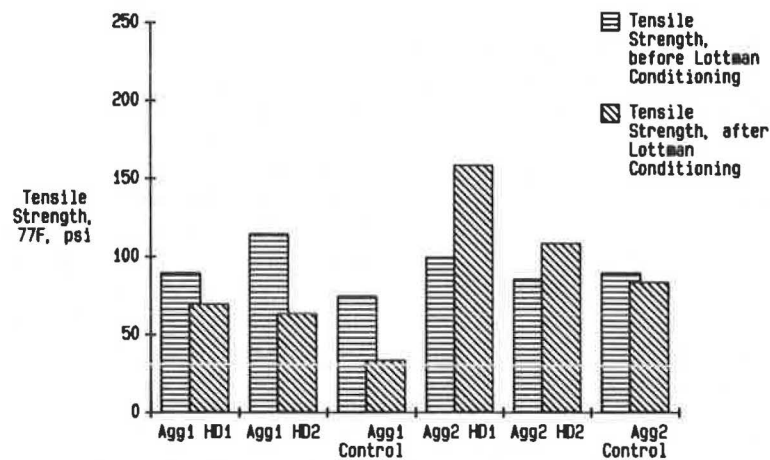


FIGURE 10 Tensile strengths for mixes with aggregates from different sources (lime added to dry aggregate).

TABLE 10 TEST RESULTS FOR VARIATIONS IN AIR VOIDS (Aggregate 1)

Test	95% Compactive Effort/100% Compactive Effort			
	Hydrated Lime 1 with Dry Aggregate	Quicklime with Dry Aggregate	Slurried Quicklime	Control
Resilient modulus (ksi)				
after one cycle of Lottman accelerated conditioning				
77°F, dry	292/473	238/521	321/449	231/467
77°F, wet	260/240	—/184	452/738	93/150
Ratio	89/51	—/35	142/165	41/32
Tensile strength (psi) at				
77°F, dry	90/180	65/213	127/162	73/176
77°F, wet	70/162	25/70	142/192	34/131
Ratio	78/92	39/33	118/118	47/74
Air voids (%)	6/1	8/4	3/1	8/2

NOTE: Dashes = data not available.

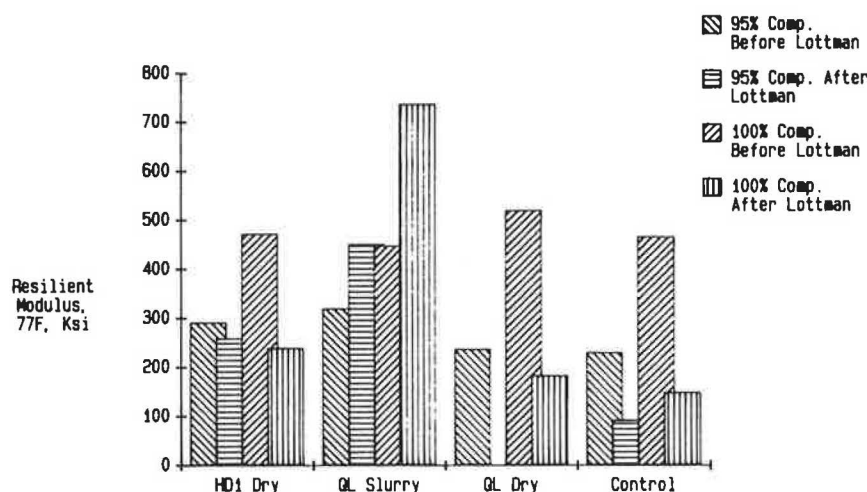


FIGURE 11 Comparison of resilient modulus values for samples prepared with different compactive efforts.

voids. All tensile strengths decreased with increasing air voids (Table 10 and Figure 12).

Although the change in air voids greatly affected the resilient modulus and tensile strength values, there were limited changes in percentage retained values (Figure 13).

CONCLUSION

Four variables that affect the success of lime as an antistripping agent were evaluated: (a) four methods of adding two types of lime to asphalt-aggregates, (b) four lime products, (c) aggregate from two different sources, and (d) air voids.

Effects of the variables on moisture sensitivity were evaluated by testing samples before and after one cycle of the Lottman accelerated conditioning procedure (6). The effects of

the variables on temperature susceptibility were evaluated by determining the resilient modulus values at four different test temperatures.

The following conclusions can be drawn from this research:

1. Neither methods of adding lime, types of lime, nor aggregate sources appear to have a significant effect on the temperature susceptibility of the mixtures.
2. Slurried quicklime improves resistance to water damage.
3. Both hydrated lime added to dry aggregate and hydrated lime added to wet aggregate improve resistance to water damage.
4. Adding quicklime to asphalt or adding it dry to aggregate is detrimental to the mixture.
5. Both of the hydrated limes and the dolomitic lime improve resistance to water damage.

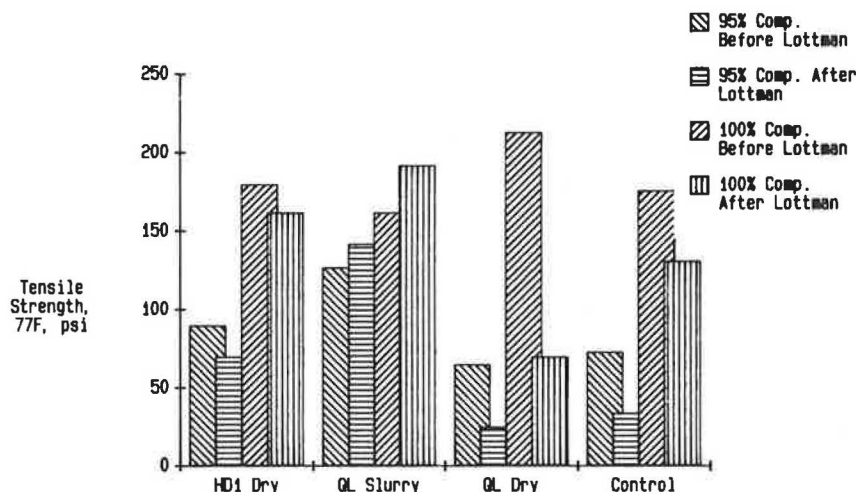


FIGURE 12 Comparison of tensile strengths of samples prepared with different compactive efforts.

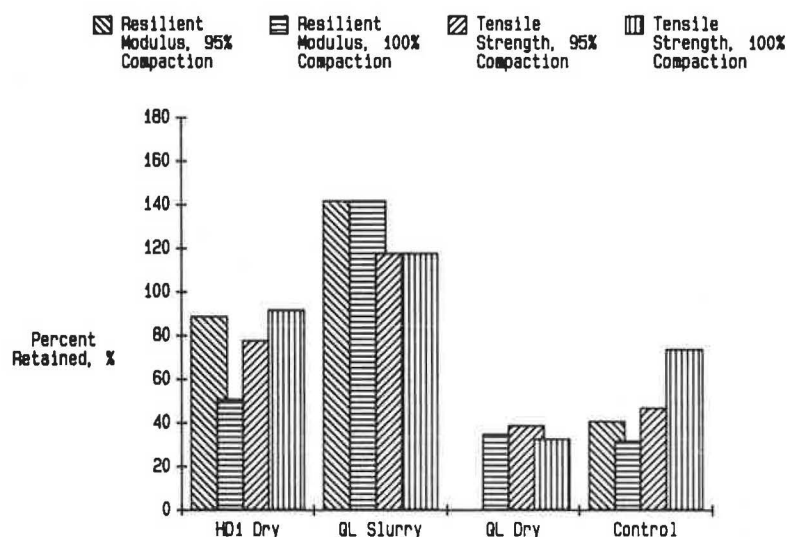


FIGURE 13 Percentage retained after Lottman conditioning for mixes with different air voids.

6. Either hydrated lime added to an asphalt-aggregate mixture, regardless of original moisture susceptibility, improves resistance to water damage.

7. Air voids greatly affect the strength of a mixture but have limited effects on percentage retained strengths.

ACKNOWLEDGMENT

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