Comparison of Dolomitic and Normally Hydrated Lime as Antistripping Additives

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Five paving mixtures typical to Utah and Nevada were prepared with and without 1.0 and 1.5 percent (by weight of aggregate) of dolomitic Type S or normally hydrated high-calcium (Type N) lime. The temperature and moisture susceptibility of each of the mixtures was determined. A slight increase in mixture stiffness resulted from the addition of either type of lime. Moisture sensitivity substantially decreased for all mixtures when lime, regardless of type, was used. The magnitude of the improvement appears to be unique for each asphalt-aggregate combination.

The stripping of asphalt from aggregate surfaces is a complex physical-chemical process that can result in early pavement distress. A popular method of combating the stripping problem is to introduce chemicals into the mixture that increase the attraction between polar sites in the asphalt and aggregate surfaces. Such chemicals are known as antistripping agents, the most popular of which is lime.

Lime is produced from high-calcium or dolomitic limestone. High-calcium limestone is almost pure calcium carbonate, whereas dolomitic limestone is a combination of calcium and magnesium carbonates (*1*). These differences in chemical composition require that each type of limestone be processed specially to obtain the final product of lime.

High-calcium limestone is calcined (i.e., burned) to produce calcium oxide (quicklime, CaO). The quicklime is then hydrated to produce hydrated lime. Lime produced in this manner is marketed as Type N lime.

Dolomitic limestone, once calcined, requires prolonged contact with water to completely hydrate the magnesium oxide and convert it into hydroxide. Because this prolonged contact is not economical, a continuous, high-pressure system is used to complete the hydration. The designation Type S indicates this type of manufacturing process.

Historically, only Type N lime has been used as an antistripping additive in asphalt concrete mixtures. However, in certain instances, Type N lime can be economically prohibitive. In these cases, substituting Type S lime for the traditional Type N would be economically preferable. This substitution can be widely accepted because of the benefits obtainable from Type S lime.

RESEARCH PROGRAM

This research program was designed to show the effectiveness of pressure-hydrated dolomitic lime in relationship to normally hydrated high-calcium lime in preventing moisture damage to asphalt concrete. Five aggregates commonly used by the Utah and Nevada Departments of Transportation were obtained. Asphalt cements commonly used for highway construction in these states were also obtained. Various combinations of these materials were used to produce typical paving mixtures, both with and without dolomitic or normally hydrated lime. Mixtures were evaluated for

1. Changes in temperature susceptibility, and
2. Resistance to moisture damage.

MATERIALS

Aggregates

Aggregates were obtained from five pits in Utah and Nevada that have evidenced a history of stripping problems:

1. Helm's Construction Company, Sparks, Nevada;
2. Interstate Highway 70 (IH-70), Utah;
3. Redmond pit, Utah;
4. Staker pit, Utah; and
5. Weaver Canyon, Utah.

The physical properties of these aggregates are presented in Table 1. Aggregate bulk specific gravities range from 2.427 to 2.803. Aggregate absorption capacities range from less than 1 percent to more than 4 percent.

All aggregate stockpiles were separated into 10 individual fractions: ½-in., ⅜-in., No. 4, No. 8, No. 16, No. 30, No. 50, No. 100, No. 200, and passing No. 200. Aggregates for each sample were then recombined into the gradations presented in Table 2, which are representative of typical highway construction projects for both states.

Asphalt Cement

Three asphalt cements were used during the course of this project:

1. Witco AR–4000,
2. Sahauro AC–10, and
3. Conoco AC–20R.

One type of asphalt cement was selected for each aggregate source.

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TABLE 1 PHYSICAL PROPERTIES OF AGGREGATES ON THE BASIS OF RECOMBINED GRADATION

Aggregate Source	Bulk Specific Gravity	Bulk Specific Gravity (SSD)	Apparent Specific Gravity	Absorption Capacity (%)
Helm's				
Fines	2.478	2.602	2.795	4.36
Coarse	2.542	2.596	2.705	2.31
Weaver				
Fines	2.572	2.597	2.637	0.95
Coarse	2.534	2.577	2.648	1.71
Staker				
Fines	2.785	2.811	2.859	0.93
Coarse	2.803	2.818	2.845	0.53
IH-70				
Fines	2.644	2.690	2.771	1.72
Coarse	2.543	2.594	2.680	2.00
Redmond				
Fines	2.427	2.520	2.627	2.58
Coarse	2.432	2.504	2.621	2.97

The AR-4000 was obtained from Witco's Golden Bear refinery in Oildale, California. Both the AC-10 (Sahauro Petroleum) and AC-20R (Conoco) were supplied by the Utah Department of Transportation. The physical properties of these asphalts are presented in Table 3.

Lime

The dolomitic lime was pressure-hydrated under 60 psi and was manufactured and supplied by Chemstar Lime Co., Inc., of Henderson, Nevada. The normally hydrated, high-calcium lime was also manufactured and supplied by the same source.

The chemical compositions of the limes were not available.

SAMPLE PREPARATION AND TESTING PROGRAM

The research was performed in two phases:

1. Determining optimum asphalt content, and
2. Evaluating temperature and moisture sensitivity of various mixtures.

These phases are described in detail in the following paragraphs.

The various combinations of asphalt cements and aggregates selected were

- AC-20R and IH-70 aggregate (Utah),
- AC-10 and Redmond pit aggregate (Utah),
- AC-10 and Staker pit aggregate (Utah),
- AC-10 and Weaver aggregate (Utah), and
- Witco AR-4000 and Helm's aggregate (Nev.).

TABLE 2 AGGREGATE GRADATIONS USED FOR PREPARING LABORATORY SAMPLES

Sieve Size	Cumulative Percent Passing
3/4-inch	100
1/2-inch	92
3/8-inch	80
No. 4	57
No. 8	40
No. 16	28
No. 30	20
No. 50	12
No. 100	8
No. 200	4

Optimum Asphalt Content

Previous research has indicated that the presence of lime does not significantly affect the optimum asphalt content (*2*). Therefore, only one mix design for each aggregate source was performed. The mix design test results for each aggregate source are presented in Table 4.

The optimum asphalt content was determined by the Marshall mix design procedure (*3*). Briefly, aggregates and asphalt were heated to at least 300°F before mixing; temperature was dependent on the type of binder used. Samples were immediately compacted with 50 blows per side. Optimum asphalt content was based on Marshall stability and flow, air voids, and unit weight. All mixtures had voids in mineral aggregate (VMA) greater than the minimum of 14 percent.

Sample Preparation for Temperature and Moisture Susceptibility Specimens

A Hveem kneading compactor was used to compress all the samples prepared for this testing with sufficient energy to

TABLE 3 PHYSICAL PROPERTIES OF ASPHALT CEMENT

Test	Witco AR4000	AC 10	AC 20R
Viscosity:			
140F, Poise	2184		1071
275F, cSt	268		---
Penetrations:		Not Available	
77F, 100g/5sec.	54		---
Ductility, cm			
Toughness and	---		85.7
Tenacity	---		75.2
(20-in./min in. lb.)			
After Aging:			
Viscosity:			
140F, Poise	3880		
275F, cSt	345		3427

Penetrations:		Not Available	
77F, 100g/5sec.	34		---
Ductility, cm	100+		31

TABLE 4 RESULTS OF MARSHALL MIX DESIGNS

Aggregate/ Asphalt	Marshall		Air Voids	Unit Weight	Asphalt Content+
	Stability (lbs.)	Flow (0.01 in.)	(%)	(pcf)	(%)
Helm's Agg.					
AR 4000	1350	8	7.4	137.2	5.5
	1410	8	6.2	138.0	6.0
	1678	11	4.7	139.2	6.5
	2354	11	3.4	140.3	7.0 *
	1569	11	0.32	138.9	7.5
IH-70 Agg.					
AC 20R**	2325	14	11.2	138.8	4.5
	2464	15	8.2	144.8	5.0
	2471	17	7.8	141.5	5.5 *
	2007	14	6.7	141.1	6.0
	1912	13	5.9	135.4	6.5
Redmond Agg.					
AC 10	1275	14	5.5	139.0	4.5
	1498	16	4.4	139.7	5.0 *
	1378	14	2.6	141.6	5.5
	1360	13	1.6	142.0	6.0
	1299	16	0.5	142.8	6.5
Staker Agg.					
AC 10	1757	12	4.4	150.7	4.5 *
	1654	11	3.1	151.5	5.0
	1514	14	2.4	151.6	5.5
	1338	20	1.3	152.1	6.0
	1242	18	0.6	152.3	6.5
Weaver Agg.					
AC 10	1335	10	7.7	138.9	4.5
	1586	12	5.3	141.5	5.0
	1385	10	4.4	141.9	5.5 *
	1335	10	3.7	142.0	6.0
	1242	11	3.1	142.1	6.5

* Asphalt cement content chosen as optimum

** Difficulties were encountered in achieving air voids; opt. asphalt content was based on maximum stability.

\+ By dry weight of aggregate.

produce samples with air voids between 6 and 8 percent (30 blows, 250 psi, and leveling load of 11,600 lb). A change from Marshall to Hveem compaction achieved an aggregate-asphalt matrix that would better simulate field conditions (*4*). A set of six samples was prepared for each mixture.

Samples were stored at 140°F for 15 hr, and then moved to a 230°F oven 2 hr before compaction (*5*). They were then tested according to the flow chart shown in Figure 1. Resilient moduli values were determined at a load duration and interval of 0.1 and 2.9 sec, respectively. Values were determined for 0°F, 34°F, 77°F, and 104°F according to ASTM D4123.

Indirect tensile strengths were determined using a constant 2-in./min deformation rate at 77°F (ASTM D4123).

ANALYSIS OF TEST RESULTS

Temperature Susceptibility

Table 5 indicates that some stiffening of the mixture generally existed, in agreement with previous research (*6,7*).

Figures 2 and 3 show examples of typical resilient modulus versus temperature for two of the mixtures. The changes in temperature susceptibility vary between mixtures. Figure 2 shows that the mixtures with Helm's aggregate and AR-4000 varied at temperatures less than 77°F, and exhibited little change at 104°F. Figure 3 shows trends exhibited by the remaining materials—addition of lime slightly stiffens the mixtures, regardless of type or percentage of lime.

Moisture Susceptibility

The addition of lime has various effects both on the absolute values of the resilient modulus and on tensile strengths, with either initial or Lottman conditioning (see Table 6). In two cases (see Figures 4 and 5) there is a slight softening (i.e., decrease in resilient modulus) of approximately 50 ksi from the initial material stiffness. However, this decrease may not be significant. Figures 6–8 show a slight-to-moderate increase of 75 to 250 ksi in initial material stiffness when either lime is added. The absolute value for resilient modulus after conditioning shows improvement in all cases (see Figures 4–8).

Both the initial and conditioned tensile strengths generally exhibit trends similar to those for resilient modulus. A slight initial decrease in resilient modulus with the addition of lime results in a corresponding trend for the tensile strength (see Figure 4). The addition of lime increases the after-conditioned tensile strengths (see Figures 4–8) for all mixtures, regardless of type of binder or aggregate source. These increases varied from as little as 15 psi to as much as 50 psi over the original values.

Overall moisture sensitivity, as determined by the ratios, decreased for all mixtures regardless of binder type or aggregate source. Figure 4 shows an improvement of 30 to 40 per-

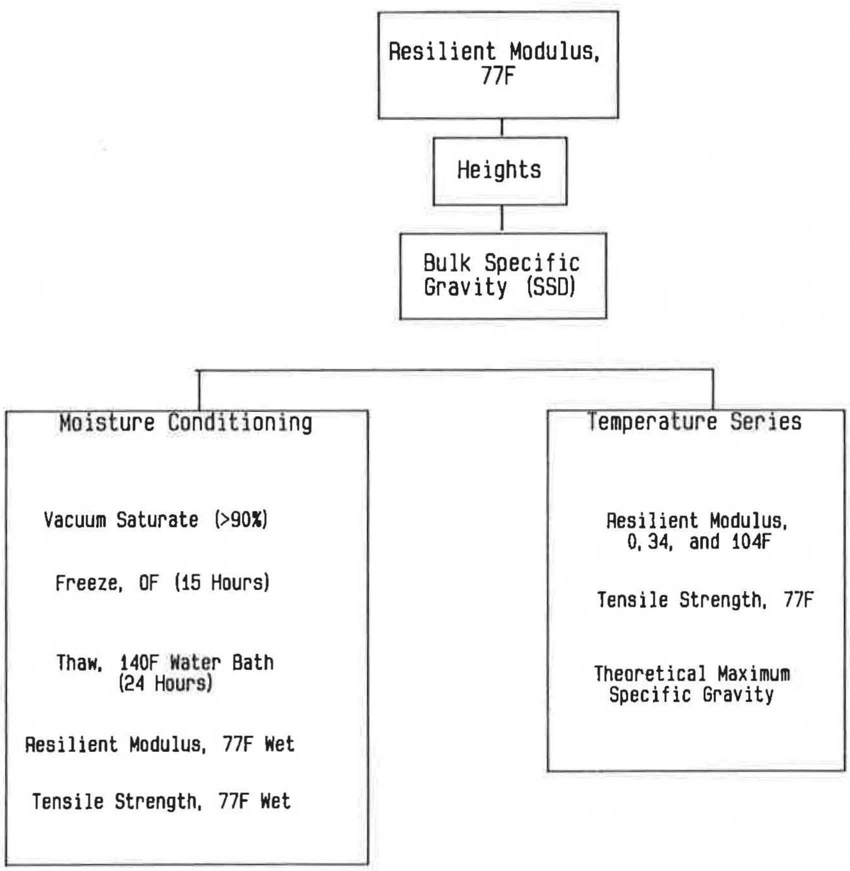

FIGURE 1 Flow chart of testing sequence.

TABLE 5 TEST RESULTS FOR LOTTMAN-ACCELERATED CONDITIONING

Aggregate Source	Resilient Modulus, 1000 psi			Tensile Strength, psi		
	77°F Dry	77°F Wet	Ratio	77°F Dry	77°F Wet	Ratio
Helm's-AR 4000						
No Lime	474	262	54	168	89	53
Dolomitic						
1.0 Percent	NA	NA	NA	159	123	78
1.5 Percent	400	341	85	155	131	84
Normally Hydrated						
1.0 Percent	NA	NA	NA	134	104	78
1.5 Percent	430	414	96	157	140	89
IH-70-AC 20R						
No Lime	167	52	31	59	32	54
Dolomitic						
1.0 Percent	148	91	62	56	46	82
1.5 Percent	122	104	88	67	65	97
Normally Hydrated						
1.0 Percent	178	116	66	63	63	101
1.5 Percent	235	153	65	64	72	112
Redmond-AC 10						
No Lime	228	121	53	78	46	59
Dolomitic						
1.0 Percent	346	232	67	78	85	101
1.5 Percent	309	244	79	72	62	89
Normally Hydrated						
1.0 Percent	273	220	80	65	59	92
1.5 Percent	304	279	92	64	68	105
Staker-AC 10						
No Lime	214	64	30	80	23	30
Dolomitic						
1.0 Percent	288	158	65	87	59	68
1.5 Percent	317	182	58	83	59	71
Normally Hydrated						
1.0 Percent	273	132	49	78	53	69
1.5 Percent	434	159	37	189	67	36
Weaver-AC 10						
No Lime	110	24	23	66	34	52
Dolomitic						
1.0 Percent	137	94	69	82	72	88
1.5 Percent	179	131	74	78	76	98
Normally Hydrated						
1.0 Percent	162	126	78	91	92	101
1.5 Percent	168	143	85	102	87	85

cent for either resilient modulus or tensile strength ratios for mixtures with the Nevada aggregate and AR–4000 binder. Figure 5 shows an improvement of over 50 percent for either ratio for mixtures with a Utah aggregate (IH-70) and a latex-modified AC–20R binder. Figures 6–8 show improvements of 20 to 60 percent for either ratio for mixtures with various Utah aggregates and an AC–10 binder.

In summary, all mixtures show a substantial decrease in moisture susceptibility with either dolomitic or normally hydrated lime. The magnitude of improvement appears to depend on both the quantity of a particular lime and the specific aggregate-asphalt mixture.

CONCLUSIONS

The following conclusions can be drawn from this research:

1. The addition of either dolomitic or normally hydrated lime, in the quantities covered by this research program, appears to cause a slight increase in mixture stiffness.
2. All mixtures studied had a significant decrease in moisture sensitivity when either dolomitic or normally hydrated lime was added, regardless of the various aggregates sources (Nevada and Utah) and binder types (AR–4000, AC–20R, AC–10) used in this study.

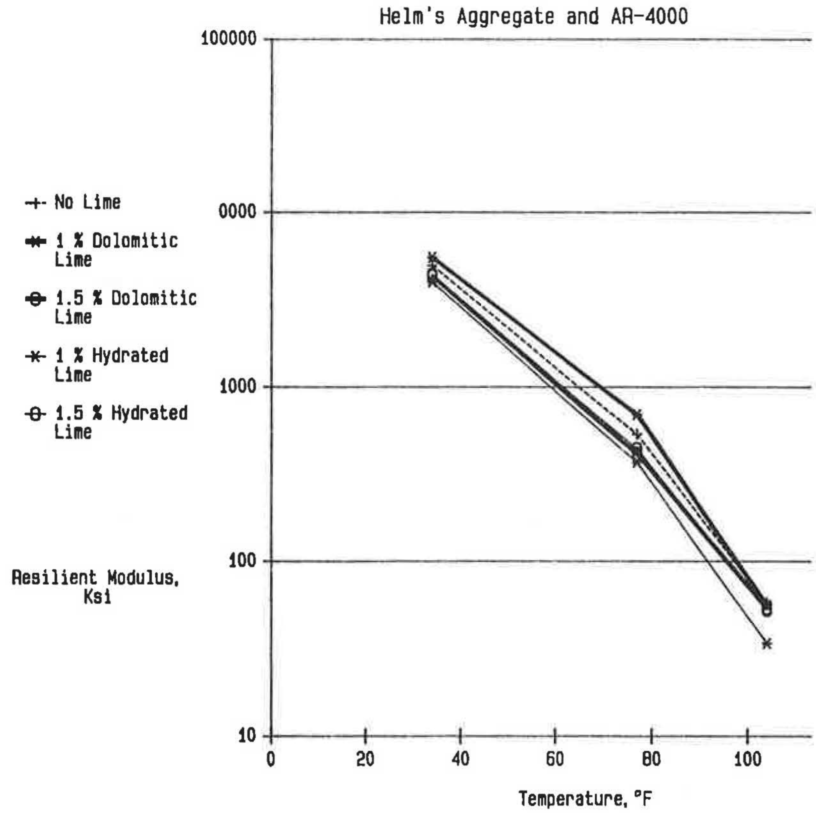

FIGURE 2 Resilient modulus at various test temperatures for mixtures prepared with Helm's aggregate and various types of lime.

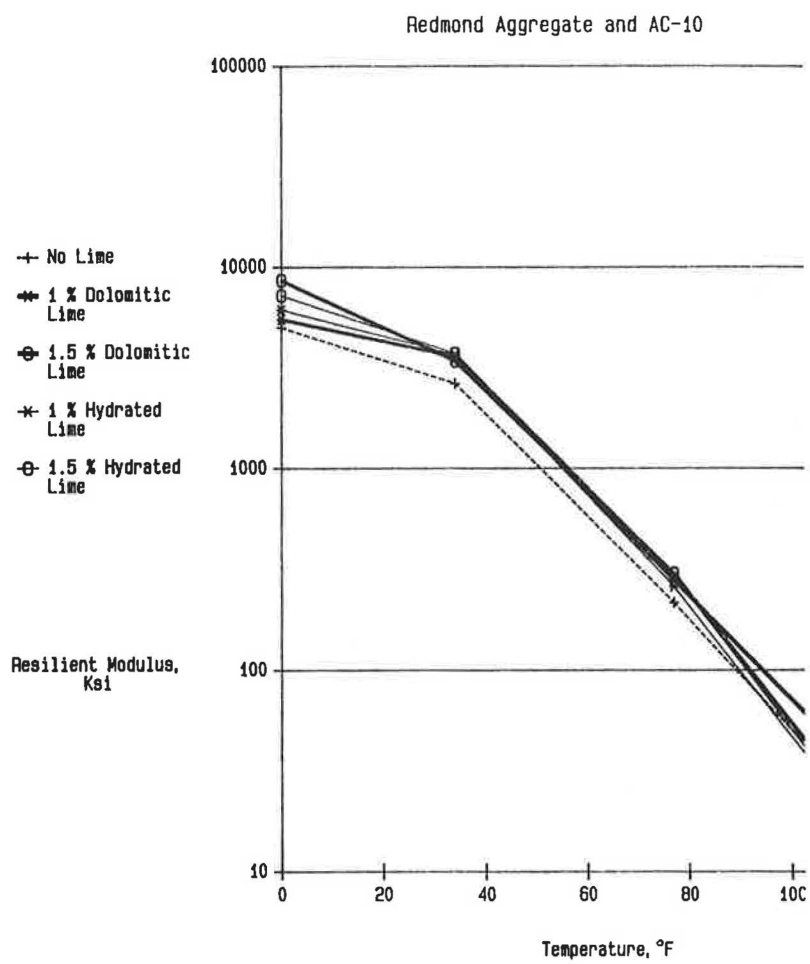

FIGURE 3 Resilient modulus at various test temperatures for mixtures prepared with Redmond aggregate and various types of lime.

TABLE 6 RESILIENT MODULUS VALUES AT VARIOUS TEST TEMPERATURES—HELM'S AGGREGATE WITH AR-4000

Aggregate Asphalt	Resilient Modulus, 1000 psi			
	0°F	34°F	77°F	104°F
Helm's-AR 4000				
No Lime	10956	5854	567	38
Dolomitic				
1.0 Percent	100018	5551	695	56
1.5 Percent	5996	5976	502	55
Normally Hydrated				
1.0 Percent	7612	3996	369	34
1.5 Percent	12014	6883	528	45
IH-70-AC 20R				
No Lime	4169	1128	152	19
Dolomitic				
1.0 Percent	2985	1880	159	23
1.5 Percent	4928	2223	239	30
Normally Hydrated				
1.0 Percent	4521	1806	211	27
1.5 Percent	5399	1553	201	27
Redmond-AC 10				
No Lime	4995	2644	216	39
Dolomitic				
1.0 Percent	5502	3583	279	56
1.5 Percent	5245	2674	305	47
Normally Hydrated				
1.0 Percent	5416	2428	251	41
1.5 Percent	5220	3165	306	50
Staker-AC 10				
No Lime	12042	2800	201	34
Dolomitic				
1.0 Percent	*	3504	383	56
1.5 Percent	*	3533	402	62
Normally Hydrated				
1.0 Percent	*	2867	261	44
1.5 Percent	7089	3955	427	74
Weaver-AC 10				
No Lime	5285	2115	101	15
Dolomitic				
1.0 Percent	6675	3157	166	23
1.5 Percent	7048	1859	179	23
Normally Hydrated				
1.0 Percent	*	4812	143	21
1.5 Percent	*	5775	190	27

* Values in excess of equipment range

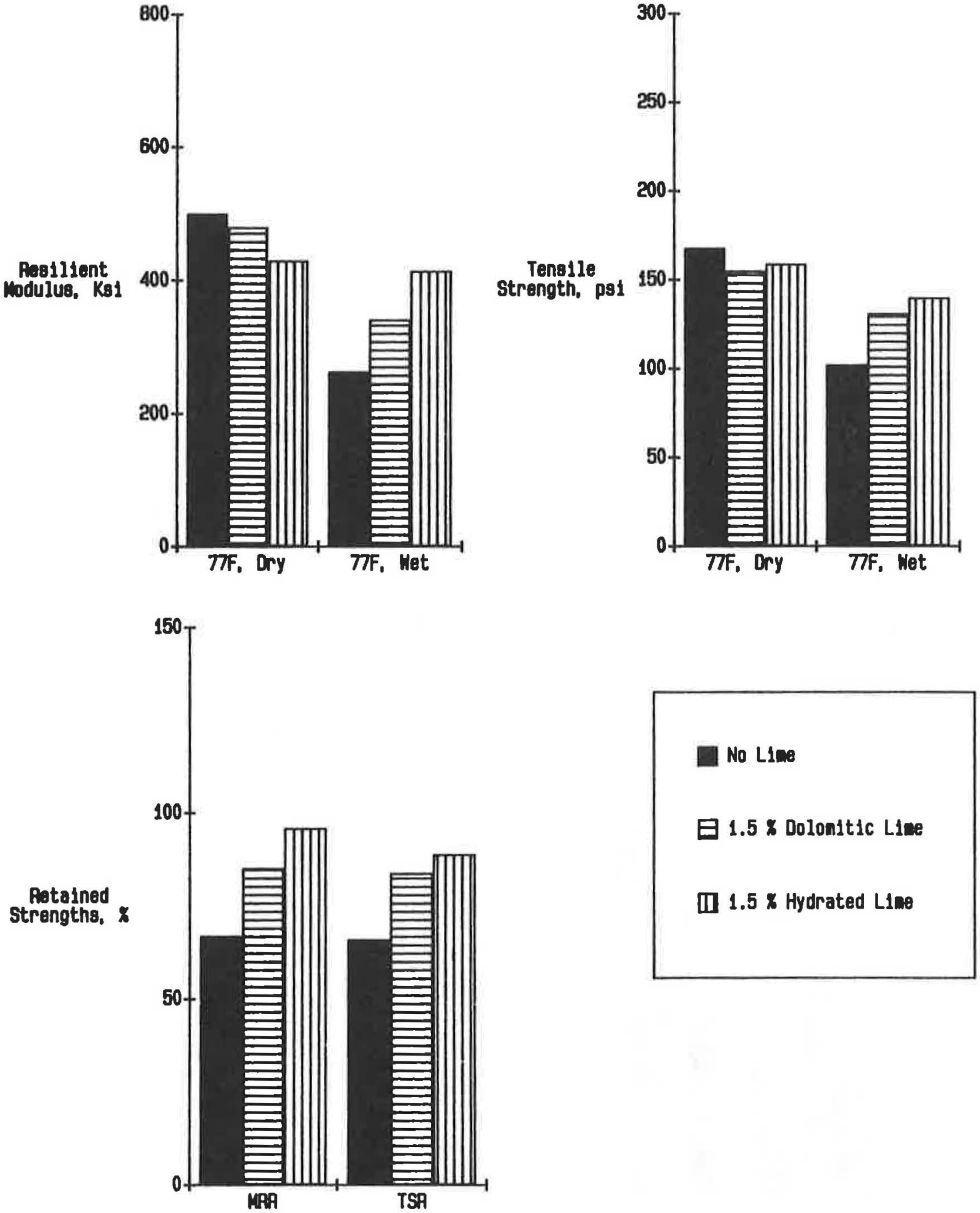

FIGURE 4 Test results after Lottman conditioning for Helm's aggregate.

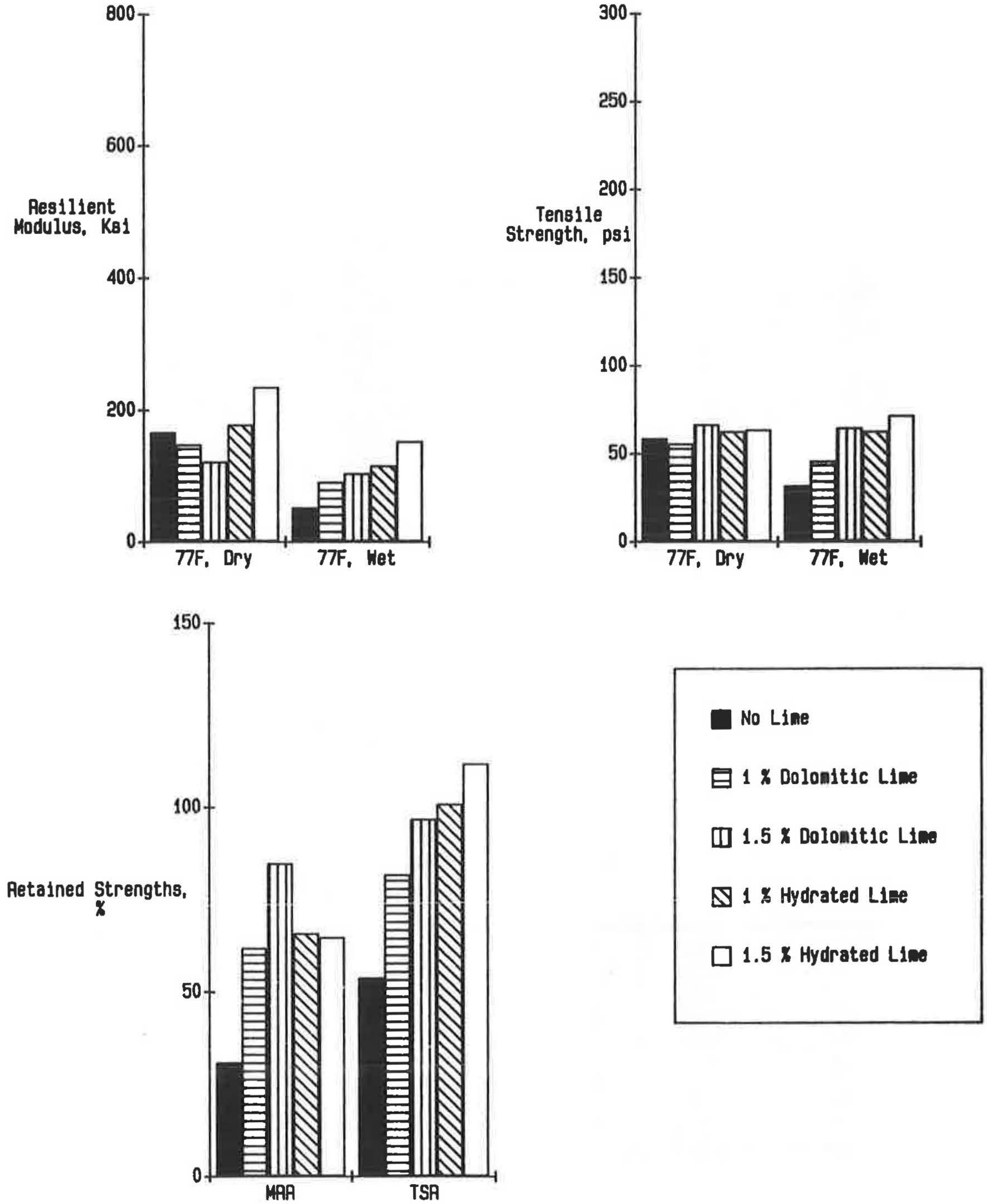

FIGURE 5 Test results after Lottman conditioning for IH-70 aggregate.

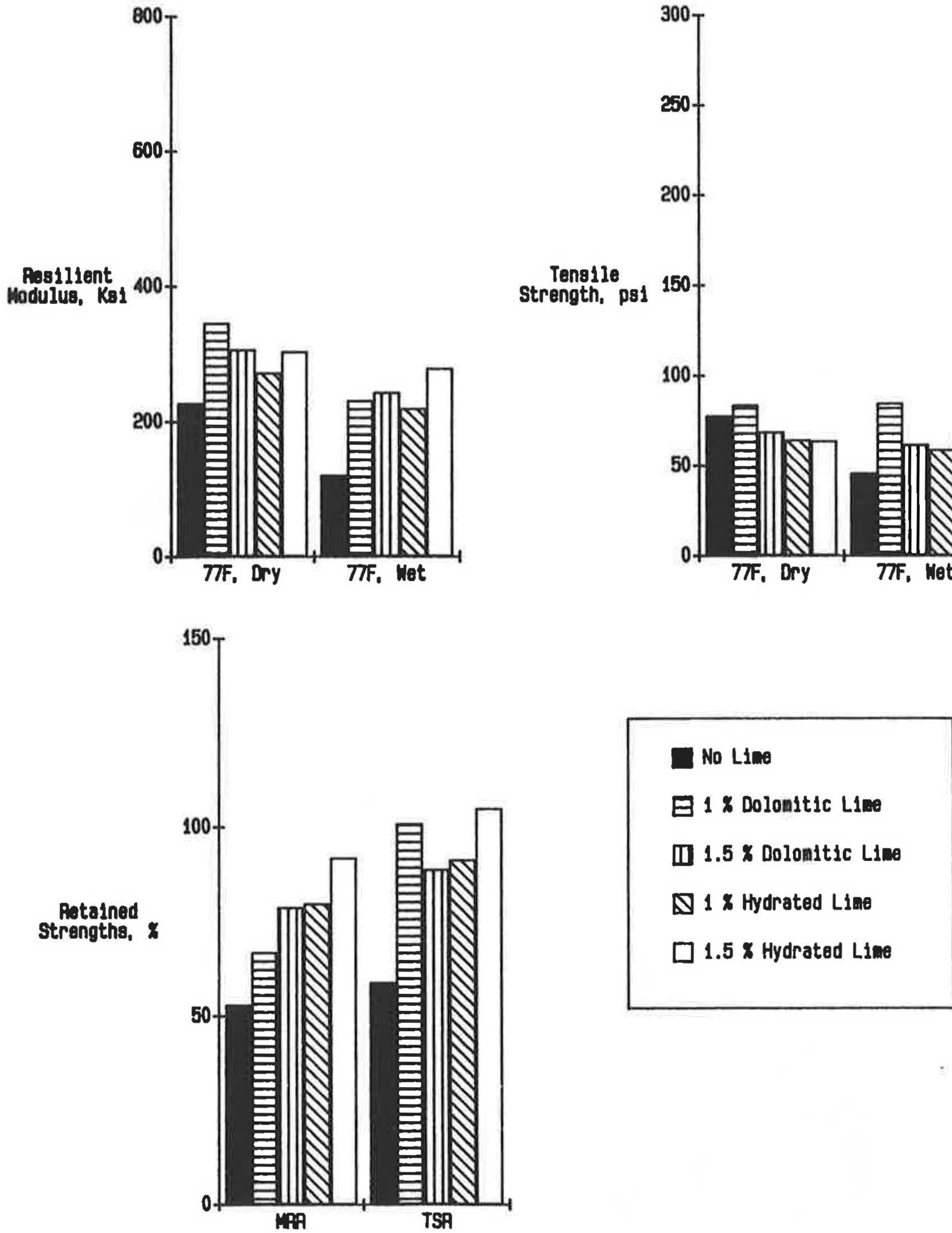

FIGURE 6 Test results after Lottman conditioning for Redmond aggregate.

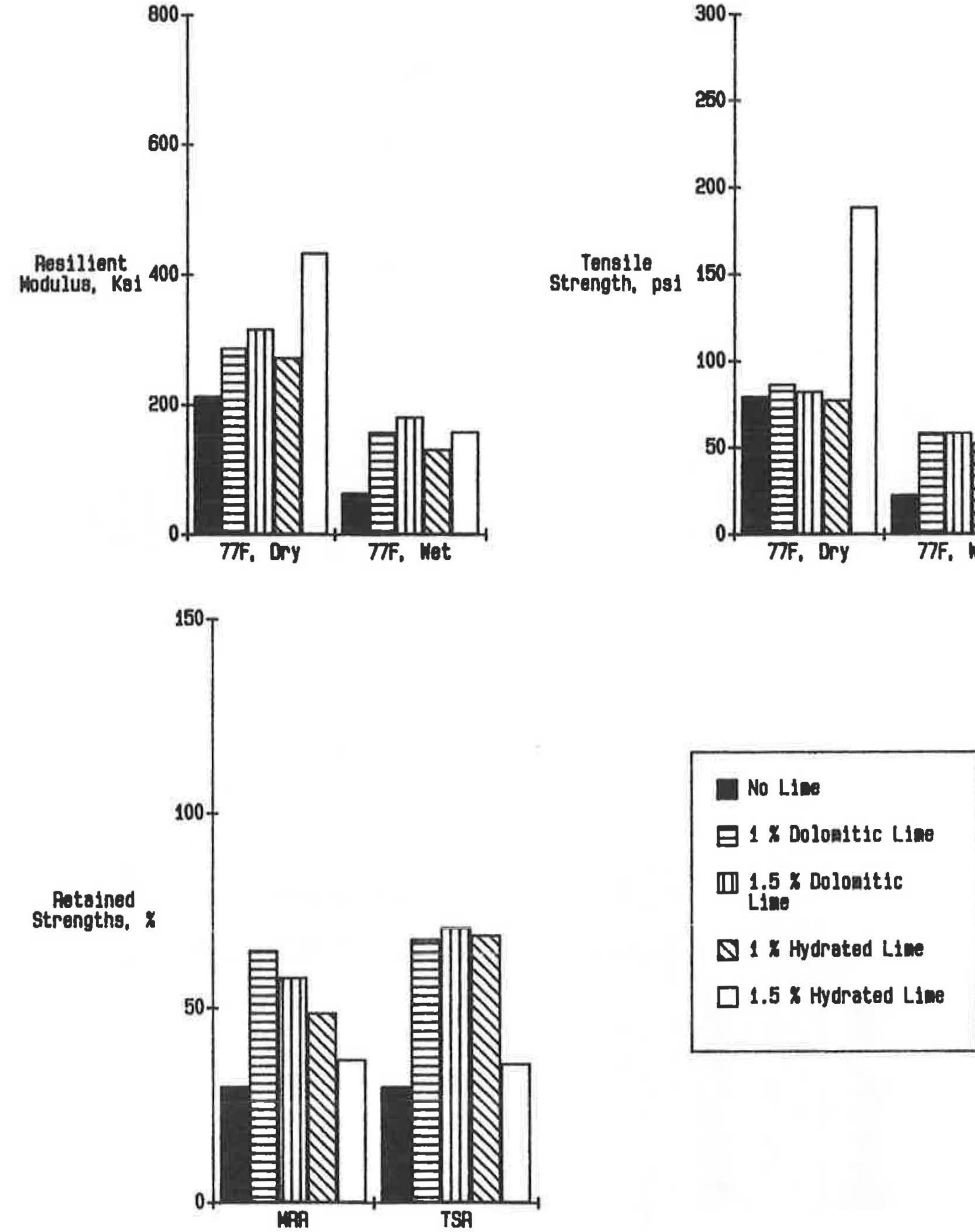

FIGURE 7 Test results after Lottman conditioning for Staker aggregate.

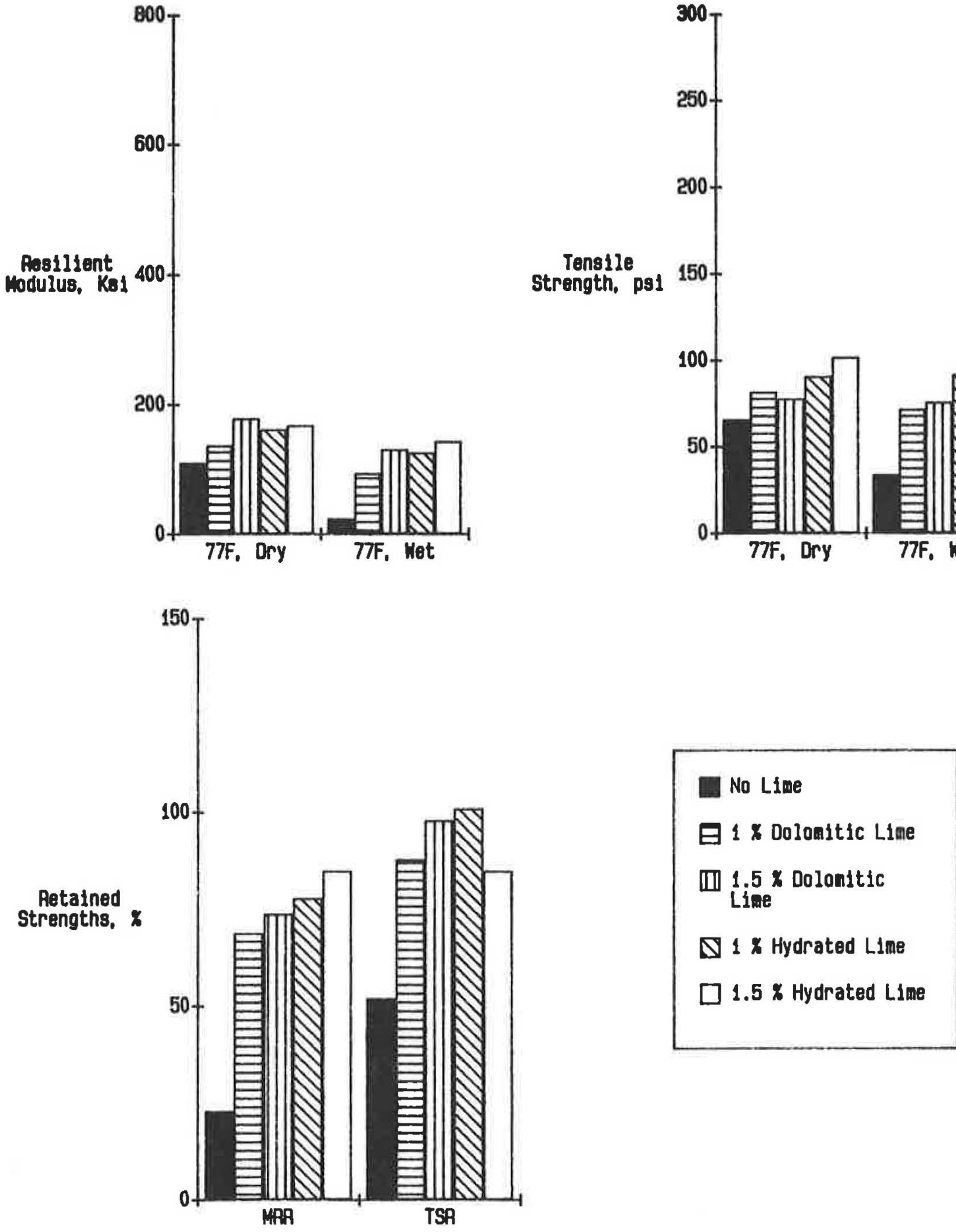

FIGURE 8 Test results after Lottman conditioning for Weaver aggregate.

3. The magnitude of the improvement appears to be unique to each aggregate-asphalt-lime system.

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