Abridgment

Effects of Hydrated Lime on Asphalt and Aggregate Mixtures

Bob H. Welch, Transportation Research Board
Max L. Wiley, Utah Department of Transportation

This paper presents the essential results of a more extensive investigation into the effects of adding hydrated lime to asphalt and aggregate mixes.

High durability is a desirable asset of bituminous materials in highway pavement design and construction. Some characteristics of asphalt aggregates or the mixes that affect the service life of a highway pavement include adhesion between the asphalt-aggregate interface when dry and wet, hardening rate of the asphalt cement, and interaction between different bituminous cements and aggregates.

Additions of hydrated lime to bituminous mixtures have been observed to increase the mix immersion compression for some aggregate sources and to reduce the hardening rate of in-place asphalt cement. The degree to which hydrated lime influences these characteristics varies according to type of asphalt, aggregate, and lime and to amount of lime.

Laboratory samples, designed and prepared with mixes of hydrated lime, aggregate, and asphalt, were used to monitor interactions among the various bituminous mixtures over time. The sample combinations were made in compliance with a design comprising three asphalts (AC-10, AC-15, and AC-20), two aggregates (judged as good and poor performers by field experience), two sources of lime (Utah and South Dakota), and three concentrations of lime (0.0, 0.5, and 1.0 percent). For each combination, 21 samples were prepared that allowed three test replications of each category of bituminous mixture to span seven age-testing periods (24 h, 10 d, 3 months, 6 months, 12 months, 18 months, and 2 years). Test samples were aged by exposure to the weather in Salt Lake City.

Tests used to monitor the bituminous mixtures or their recovered asphalt fractions for each time period include penetration at 77°F (25°C); asphalt content, absolute viscosity at 140°F (60°C); kinematic viscosity at 275°F (135°C); flow, ductility at 39°F (4°C); cannon cone viscosity at 275°F (135°C); immersion compression (wet); specific gravity; asphaltene content; nitrogen base content; first acidaffin content; second acidaffin content; and paraffin content.

Throughout the 2-year period, the absolute and kinematic viscosities increased with age. The rate of increase was higher with the higher AC asphalts, although increases for the AC-10 and AC-15 asphalts are approximately equal after 6 months to a year. Correlation coefficients from an analysis of variance indicate which types of asphalt significantly affect kinematic and absolute viscosities with respect to time.

The effect of aggregate type on viscosity, with respect to time, differs after 3 to 9 months. The difference in degree of viscosity for the asphalt mixes with separate aggregates increases with age. Added hydrated lime has a greater retarding effect on increased viscosity for asphalts in mixes with relatively poor rather than good aggregates.

Use of separate lime sources causes negligible differences in absolute viscosity with respect to time. The degree of viscosity retardation varies directly with the amount of lime added (in the 0.0 to 1.0 percent range). Even though the addition of lime influences viscosity, the relative effect is not the same for all three asphalt sources evaluated. During the 2-year evaluation period, lime helped to reduce hardening rates most when it was mixed with the AC-15 asphalt and helped least when mixed with the AC-20 asphalt.

Ductility values decreased rapidly for 3 months and tapered off after 6 months in an exponential curve. However, original asphalt (as delivered) ductility values did not indicate what the ductility values would be over any specific period of time. Use of the more poorly performing aggregate initially yielded generally higher ductility values from extracted asphalts, but the differences deriving from the aggregate's source became indiscernible after 6 months.

Ductility values were approximately 44 percent higher for asphalts with lime added; amount or type of lime added did not affect this percentage. It is possible that the lime site is saturated and that higher concentrations of lime would extend the effect over a longer period. The greatest factor influencing ductility was the age of the specimen, which corresponds to an exponential decay rate curve.

Original cannon cone viscosity measurements for the three grades of asphalt cement were essentially the same. Residue values showed some difference between the AC-20 and both the AC-10 and AC-15 asphalts. All cannon cone viscosities increased over time, but AC-20 increased at the highest rate. Mixes prepared from the better versus the more poorly performing aggregates did not contribute to variance in cannon cone viscosity increases. Also, the type of lime at the concentrations used did not affect cannon cone viscosities.

The immersion compression (IC) values we obtained generally increased with time. Some variations corresponding to the seasonal weather variations during the year were noted: warmer seasons at the time of testing tended to raise IC. Each warm-cold seasonal cycle resulted in a net increased IC. All the bituminous mixture variables we evaluated influenced IC. The higher graded asphalts showed similar effect on IC, although the rates of IC change between test periods were not significantly different for the three asphalts used.

Large differences (1469 kPa or 213 lbf/in^2) were noted in IC for the two aggregates after 10 d of aging. This value does not hold constant but varies between zero and 1296 kPa (188 lbf/in^2) over the 2-year test period. Higher IC values were noted with mixes prepared from the better performing aggregate. For all six test periods evaluated for IC, the force is greater for higher concentrations of lime. From the 3-month period onward, the magnitude of 0.5 or 1.0 percent lime test results are only 15 percent higher than those for the 0.0 percent lime. For samples evaluated after 2 years, however, the no-lime IC values reached 262 percent above the 1207 kPa (175 lbf/in^2) minimum required for acceptance of bituminous surface courses in Utah.

IC values obtained from the wet, 120°F (48.8°C) test procedure were least variable. Higher curing temperatures resulted in lower test accuracy for specific bituminous mixtures. Test samples cured in dry rather than wet conditions also showed more variability in the test results, possibly because of variations in the samples' water absorption rate.

The influence of aggregate type and concentrations of lime on IC has a much greater effect than the type of asphalt or type of lime used.

In order to further evaluate the effect of aggregate type on IC, 972 bituminous mixtures were prepared from seven aggregate sources, three types of asphalt, and 0.0 and 1.0 percent lime. Results from the IC test indicated that the silicon dioxide (SiO_2) content, calcium oxide (CaO) content, aluminum oxide (Al_2O_3) content, and calcium carbonate ($CaCO_3$) content of the aggregates did not yield a distinguishable pattern in terms of their influence on IC. The ferrous oxide content (Fe_2O_3) in the aggregate with the addition of 1.0 percent lime had a stabilizing influence on the erratic IC values compared with the no-lime mixtures. There was a tendency for higher ferrous oxide concentrations to raise IC values with the addition of 1.0 percent lime, but there were no correlations with no lime.

We checked to see if the natural calcium oxide content of the aggregate would significantly change IC values when combined with ferrous oxide, and their sum ($Fe_2O_3 + CaO$) and ratio (Fe_2O_3/CaO) were compared with IC values. We observed, from an analysis of variance, that the IC values correlated much better with the percentage of asphalt in the bituminous mixtures than with anything else. Without exception, as the optimum percentage of asphalt for a given asphalt-aggregate combination increased, the corresponding IC value decreased. From the data available, it would appear that the optimum asphalt content at an aggregate source had much more influence on mix stability than did the chemical characteristics of either the asphalt or the aggregate.

The addition of hydrated lime to asphalt concrete mixes affected different combinations of asphalt and aggregate differently. For the six possible combinations of relatively well versus poorly performing aggregates and viscosity graded asphalts (AC-10, AC-15, and AC-20), no significantly adverse consequences were seen, and in some instances hydrated lime produced beneficial effects.

Two potential benefits occurred with hydrated lime supplements: an increase of mix stability and a decrease in flow evaluated by the IC test, and decreased hardening rates of the asphalt binder as determined by the absolute, the kinematic, and the cannon cone viscosities. Potential benefits as an antistripping agent were not determined.

Bituminous mixtures made from separate aggregate or asphalt sources were enhanced in varying degrees by the use of hydrated lime. For the materials tested in this investigation, the AC-10 and AC-15 asphalt sources were best suited for bituminous mixtures with hydrated lime, because the effect retarded the hardening rate and increased mix stability. Bituminous mixtures prepared with the AC-20 asphalt indicated that the use of hydrated lime did not reduce the binder hardening over time or result in significant increases of IC.

Originally, it was thought that asphalt cements softened more with a siliceous aggregate, but the results of this study indicated that the more calcareous aggregate yielded slower hardening rates after the bituminous mixtures had aged 6 months. Lime supplements in either of these two aggregate types tended to increase IC values and to decrease hardening of the asphalt binder. The degree of influence on binder hardness appeared more dependent on asphalt type than on aggregate type.

From the types of lime evaluated, the only conclusion we drew was that lime source contributes little if at all to corresponding changes in asphalt binder or mix properties.

Data based on pavement performance that could support or reliably suggest new minimum standards for IC values differing from the 1034 kPa (150 lbf/in^2) present (average of three tests) for bituminous base courses or 1207 kPa (175 lbf/in^2) for bituminous surface courses are not available. Assuming that our present criteria are adequate, a minimum IC value of 2103 kPa (305 lbf/in^2) on surface courses and 1931 kPa (280 lbf/in^2) on base courses would be required for an average of three tests ($\alpha = 0.10$) to compensate for the variability of the testing procedure.

In most cases, the addition of 0.5 percent lime will yield results comparable to those for 1.0 percent lime.

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