Prevention of Degradation of Basalt Aggregates Used in Highway Base Construction

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Highway base course failures due to degradation of basalt base aggregates by weathering is a serious problem in the areas of the United States where the vast deposits of basalt rock must be utilized for this purpose. The work reported in this paper consisted of laboratory weathering tests on asphalt-aggregate mixtures, field testing of an SS-1 asphalt emulsion stabilized base, and surface energy studies of asphalt and aggregate systems. Results show that the asphalt treatments do not completely stop degradation in laboratory weathering tests. However, the stability of the base is improved by treatment, as shown by both laboratory and field tests.

•HIGHWAY ENGINEERS have noted that one of the causes of base failure was the degradation of the base aggregate. This type of failure has occurred frequently in the Northwest where highway engineers must utilize the vast deposits of basalt rock. Some of this basalt is of high quality as a road building material; on the other hand, large deposits of basalt weathers, or degrades, easily thus causing failure of the highway base.

Degradation as used in this paper is the production of very fine particles by weathering action rather than by mechanical wear. The basalt aggregates that are of the poorer quality degrade rapidly producing fines that are smaller than a No. 200 mesh sieve. The fines produced by weathering become plastic when wet and cause loss of stability of the highway base.

The problem of base failures due to degrading basalt aggregates was brought to the attention of the Engineering Experiment Station at the University of Idaho by L. F. Erickson of the Idaho Department of Highways in 1956. Scott (1) reported base failures caused by degradation of secondary minerals. Turner (2) and Sibley (3) studied degradation of various Washington aggregates and gave specific attention to cement-treated aggregates. Idaho Department of Highways has developed a test (4) for measuring susceptibility of aggregates to degradation. Erickson (5) has made a study of the extent of this problem of degradation throughout the various State highway departments. The investigational work covered by this paper has been conducted through a series of graduate theses studies (6 through 11) sponsored by fellowship grants from Phillips Petroleum Company and supported by assistance from the Idaho Department of Highways.

EXPERIMENTAL WORK

The experimental work in this study has been approached in three ways: (a) laboratory weathering tests on asphalt-aggregate mixtures, (b) testing of samples removed from a field installation of an SS-1 asphalt emulsion-stabilized base, and (c) surface energy studies of asphalt-aggregate systems.

Weathering Tests

Several types of asphalts were used to coat the aggregates in an attempt to prevent the degradation of the basalt aggregates. Laboratory weathering tests were set up to evaluate the performance of the various asphalt-aggregate mixtures.

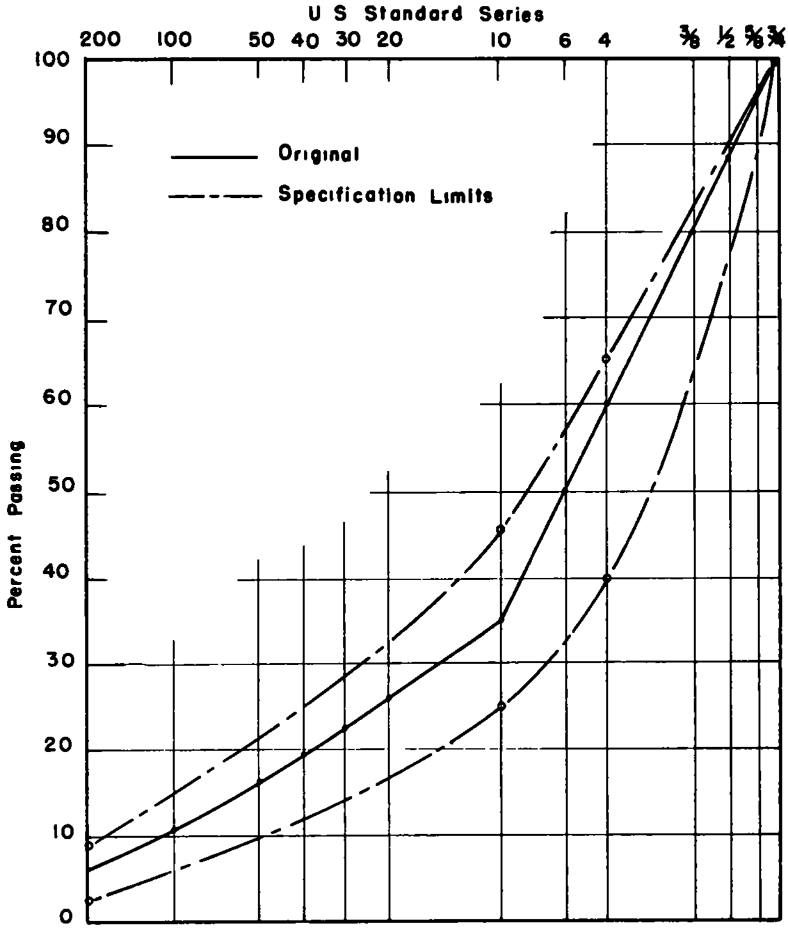

Figure 1. Comparison of particle size distribution of original reconstituted sample and Idaho Department of Highways specifications limits for base aggregate.

The basalt aggregates used in the weathering tests were quarried from Idaho County Pit 93. Representative samples were taken from various parts of the pit and crushed to a 3/4-in. maximum size in the laboratory.

The asphalts used were 85-100 penetration asphalt cement, MC-2, MC-3, and SC-2 cutbacks, a special road oil, SS-1, SS-2, and DM-K asphalt emulsions, and a foamed asphalt. The most extensive and also most recent tests have been with slow-setting asphalt emulsions made from residuals of varying penetrations.

The samples were prepared by first building each sample to the same gradation. The gradation is shown in Figure 1 Individually weighted and prepared samples were used to insure that the percentage of fines in each sample was the same at the beginning of the testing. Tests were run with treated samples in both uncompacted and compacted states. The compacted samples were prepared and left in 4-in. moulds so that they could be subjected to a loading using a kneading compactor during the weathering cycles.

The weathering cycle consisted of periods of moistening, freezing, thawing, loading, and heating or drying. During the moistening period the samples had water available at both the top and bottom of the moulded specimen. They were subjected to the moisture period for 12 hr. The freezing period was for 3 hr at 10 F. The thawing period was at room temperature for 4 hr. During the thawing period the simulated wheel loading was applied with a kneading compactor once every 10 weathering cycles.

The loading consisted of 100 blows of the compactor at a foot-pressure of 250 psi. A small foam rubber disk was placed between the foot and the sample to reduce effect of impact. The heating period was for 4 hr in an oven set at 140 F.

The number of weathering cycles was limited to 45 after noting that the greatest amount of degradation took place during the first 45 cycles.

Immediately after weathering tests were completed, the stability of each compacted specimen was determined with the Hveem stabilometer. The asphalt was then extracted from the samples in reflux-type extractors and the remaining aggregates were resieved to determine the change in particle size due to weathering.

Field Sampling

During 1958 the section of US 95A between Potlatch and Emida, Idaho, was reconstructed, using an asphalt emulsion-stabilized base. The base of the road had been built two years before and surfaced with a single-surface treatment. In two years the base aggregate had degraded to the extent that rutting and potholing had made the road nearly impassable. A 0.25-ft depth of the base material was treated with 5 percent SS-1 asphalt emulsion. Mixing was done in a Woods pugmill-type mixer. Samples were taken at the time of mixing and extractions and gradations run on the aggregate. In 1959, additional samples were taken from the base to determine if degradation was continuing in the treated base. Asphalt in the samples of base material was extracted, and a sieve analysis run to determine the change in particle size that had occurred in one year.

Surface Energy Studies

Surface energy studies have been conducted to characterize the aggregate and determine the type of asphalt best suited for the treatment of degrading basalt aggregates. The surface energy studies have been made by measuring the contact angles of droplets of various asphalts on aggregate surfaces. A technique suggested by Thelen (12) was used. This technique consisted of placing a small drop of asphalt on the surface of an aggregate in a special temperature controlled cell. A lamp and lens system projected the image of the asphalt drop on a screen where the contact angle could be measured or a photographic reproduction made of the image.

The apparatus for the contact angle measurements consisted of a mercury arc lamp, a teflon cell to hold the aggregate sample, and a set of lenses to project the image on a screen. Angle measurements were made on the projected image with a straightedge and protractor.

A spreading coefficient was derived from surface energy relationships which give a measure of relative wetting tendencies of liquids on solids. The spreading coefficient is given by

$$S = (\cos \theta - 1) \gamma_{LG}$$

in which θ is the contact angle and γ_{LG} is the surface tension of the liquid in contact with a gas.

Also related to the contact angle studies was the use of an ion exchange unit to characterize the aggregates according to their surface active ions. Crushed aggregates of sizes between the No. 16 and No. 30 sieve were placed in a vertical lucite percolation column. A sodium chloride solution of known pH was run through the aggregate at a constant rate. The change in the pH of the effluent was determined by making periodic measurements with a pH meter. Three basalt aggregates of known quality based on field experience were used. The degrading-type aggregate from Idaho County Pit 93 was used along with two higher quality basalts from other pits.

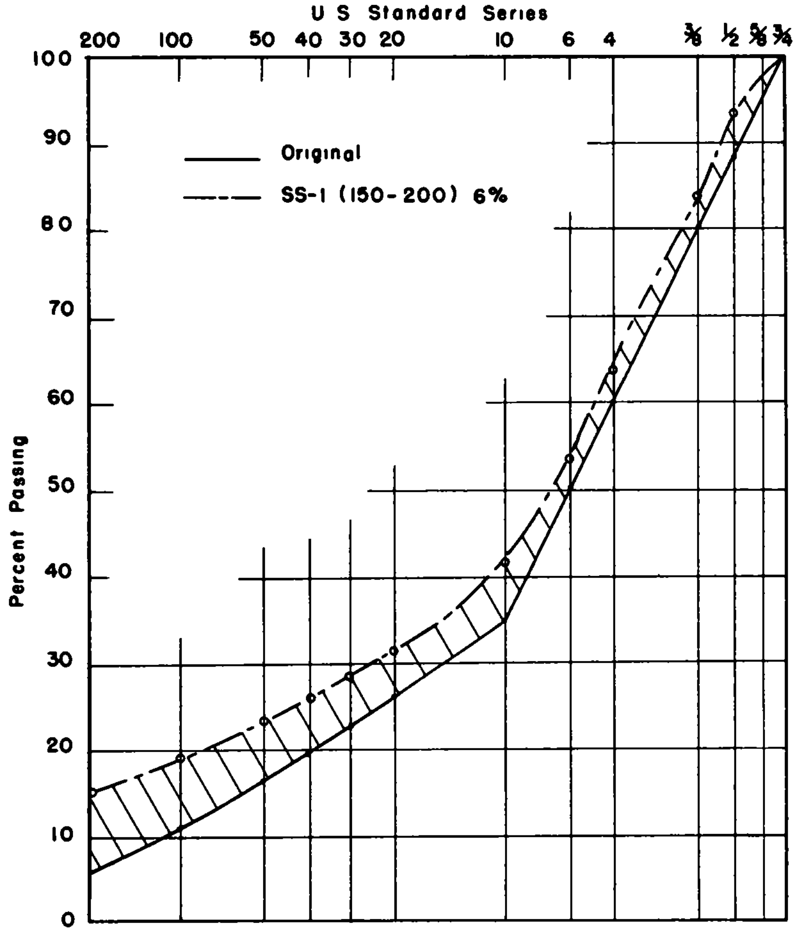

Figure 2. Comparison of particle size distribution of original sample and asphalt emulsion (150-200 pen SS-1 of 6 percent) treated sample subjected to 45 weathering cycles.

TABLE 1
RESULTS OF SAMPLES SUBJECTED TO 45 WEATHERING CYCLES

Identification of Treatment	Empirical Area (No.)	Percent Passing No. 200 Sieve	Hveem Stability
Control samples	31.9	14.2	--
SS-1 (150-200):			
6 percent	26.4	15.2	47
10 percent	28.2	14.5	19
SS-1 (200-300), 5 percent	29.6	16.5	49
SS-1 (50-60), 5 percent	32.5	17.0	45
SS-1 (0-10), 5 percent	27.6	16.4	51
DM-K (50-60), 5 percent	30.7	16.5	36
Foamed asphalt	34.2	15.2	43
SS-1 (150-200):			
6 percent	--	--	50[a]
10 percent	--	--	34[a]

[a]Tested before weathering tests.

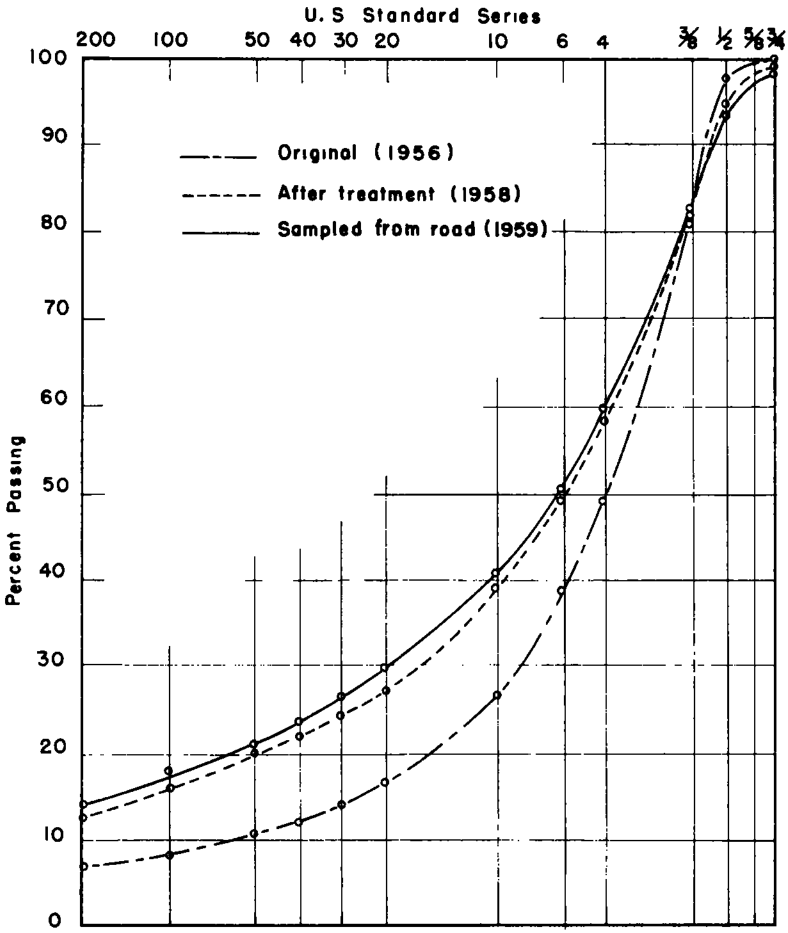

Figure 3. Comparison of average particle size distribution of three different field samplings of aggregate used in asphalt-treated base material for US 95-A.

RESULTS

Weathering Tests

Early experimentation by Keller (6) and Lu (7) with both unconfined and confined samples indicated that treatments with SS-1 and SS-2 asphalt emulsion showed the most promise for preventing degradation. The results of the last tests by Collett (10) showed rather minor improvements in prevention of degradation but a definite retention of stability of the mix.

Results of the weathering tests were expressed in two ways: (a) as the increase in the percentage of material passing the No. 200 sieve, and (b) as an empirical area number which is similar to a fineness modulus for the aggregate. The original gradation of all samples had 6 percent passing the No. 200 sieve. Table 1 gives the percentages passing the No. 200 sieve after 45 weathering cycles for the control samples and a number of asphalt treatments.

The empirical area method uses the area between the original and final gradation curves expressed as tenths of square inches. This area is cross-hatched in Figure 2, which is typical for the many evaluations used in the study. This is a relative number that can be used only for samples with the same original gradation that are all plotted at the same scale. The results of the empirical area determination are given in Table 1. The lower the number, the less change in particle size; therefore, the less total degradation.

The results of the weathering test show that the average change in minus No. 200 material was from an initial value of 6 percent to a final value of 15 percent. Comparing the untreated to the treated samples, the increases in fines were nearly the same regardless of the type of treatment. Using the empirical area method, the treated samples show less total change in particle size than the untreated samples. The 6 percent treatment using SS-1 asphalt emulsion with a 150-200 penetration residual gave the best apparent results.

The results of the field sampling from US 95A are shown in Figure 3. Results confirm the cause of failure of the original construction to have been a large change in particle size from 1956 to 1958. The degradation was not completely stopped by the treatment between 1958 and 1959 but the total change in particle size during the year of exposed field use was small. The stability of the road has been increased to the point that no sign of failure has occurred at this time (1961).

The results of the Hveem stability tests on the confined moulded specimens are also shown in Table 1. There are no stability results for the untreated samples, but stabilities were run on treated samples before weathering. Although degradation did take place during weathering, there was no appreciable loss of stability. This indicates that the degrading aggregates can be stabilized with asphalt treatments. The 6 percent SS-1 asphalt emulsion-treated sample had the least change in the stability number during the weathering tests and showed the least change in particle gradation and thus appeared to be the best of the various asphalt treatments studied.

Surface Energy Studies

The contact-angle studies indicate that it is difficult to distinguish between basalt aggregates that will or will not degrade. The results of spreading coefficients for various asphaltic materials on aggregate surfaces are shown in Table 2. For complete wetting, the spreading coefficient is zero and for non-wetting the spreading coefficient approached a minus two times the surface tension of the liquid. The cationic emulsion has greater attraction for the degrading type aggregates than the anionic emulsion. The MC-3 liquid asphalt has better spreading coefficients than the asphalt emulsion for all the aggregates investigated.

TABLE 2
EQUILIBRIUM SPREADING COEFFICIENTS OF ASPHALT MATERIALS ON AGGREGATES AT SATURATED SURFACE DRY CONDITIONS

Aggregate	Asphaltic Material		
	SS-1 Asphalt Emulsion (Anionic)	RS-K Asphalt Emulsion (Cationic)	MC-3 Liquid Asphalt
ID-93 degrading	-18.30	-13.01	-6.37
Np-109 nondegrading	- 5.02	- 7.15	-6.82
Np-x nondegrading	- 7.56	- 8.96	-4.72

The results of the ion exchange tests (11) show that the highway aggregates might be characterized according to their basicity and acidity. The Id-93 basalt aggregate caused a sudden large increase in hydrogen ion concentration of the effluent, indicating that the hydrogen ions on the surface of the rock predominate and were replaced by the sodium ions in the solution. Consequently, the pH value was lowered. Quartzite, although not tested, exhibits similar characteristics and is known to be an acidic aggregate. Almost no change resulted in the pH of the effluent in passing through the sample of Np-109 aggregate (a good basalt). This indicated that the aggregate is neutral or slightly basic. An acidic aggregate will lower the pH value. The Np-X basalt aggregate caused a definite rise in pH value of the effluent indicating it was basic.

CONCLUSIONS

The results of the laboratory weathering tests indicate that asphalt treatments do not completely prevent the degradation of basalt aggregates. Using the area number method of evaluating degradation, there is reduction in the total breakdown and thus benefit due to treatment.

The highway base aggregates are definitely stabilized by asphalt treatment and would in all probability remain stable although slight degradation of the aggregate takes place. Results from the field testing show that some degradation continued after treatment but the highway has remained in good condition under heavy logging-truck traffic. Future field testing now planned may confirm the extent to which degradation continues and the value of asphalt treatment in maintaining stability of the road.

Ion-exchange tests might be used as a means of characterizing the basalt aggregates. It appears from this limited study of three basalt aggregates that basalt of an acidic nature will degrade when used in highway construction, whereas basalts of a basic nature will retain their strength and not degrade in the highway base.

The cationic asphalt emulsions spread easier on the degrading basalt aggregates, whereas the anionic asphalt emulsions have better spreading coefficients on the non-degrading basalts. The MC-3 cutback asphalt spread easily on all aggregates. The contact angle measurements cannot be used as a means of characterizing the aggregates according to their susceptibility to degradation. However, surface energy studies of this nature may have value in relating what type of asphalt will give the best treatment and bonding of asphalt to aggregates. Further study is recommended in this respect.

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