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RESEARCH PROGRAMS

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Evaluation of the Engineering Characteristics of RAP/ Aggregate Blends

http://www.mdt.mt.gov/research/projects/mat/rap_aggregate.shtml

Introduction

Recycling milled asphalt has great potential not only for preserving valuable resources, but also for controlling escalating construction costs. However, the engineering characteristics of blends made from mixtures of reclaimed/recycled asphalt pavement (RAP) and aggregate have not been fully investigated; consequently, the long-term suitability and performance of RAP-aggregate blends in highway pavement sections is unknown. This study was designed to supplement previous tests by others while providing a focus on the most critical engineering properties for RAP blended materials, which include: durability, strength, stiffness, compressibility, and drainage.

What we did

An experimental laboratory testing program was undertaken to evaluate the suitability of using reclaimed and recycled asphalt pavement as an additive to aggregate base or granular soils (crushed and screened aggregates or natural soils). The laboratory testing program was oriented towards examining changes in engineering properties (compaction, gradation, strength, stiffness, permeability, and resistance to degradation) rather than the absolute engineering characteristics of RAP blends. Laboratory tests were conducted using four different aggregates blended with asphalt millings over a broad range of mix percentages. Three of the aggregates were mechanically processed crushed base course aggregates (designated CBC #1, CBC #2, and CBC #3). The fourth aggregate was a pit run sandy gravel.

The unblended aggregates were mechanically mixed with reclaimed asphalt millings (20, 50, and 75%). Laboratory tests including grain size analyses, specific gravity, modified Proctor compaction, relative density, Los Angeles abrasion, large-sample direct shear, R-value, permeability, and X-ray computed tomography scans were conducted on the blends. The unblended materials were well-graded and exhibited relatively smooth gradation curves that covered a wide distribution of particle sizes. Of the four unblended materials, the pit run was the coarsest, while CBC #1 contained the finest distribution of particle sizes. CBC #2 and CBC #3 had similar particle size distributions.

What we found

Gradation. The addition of RAP to the virgin materials resulted in an increase in the amount of particles passing the upper sieves, and a decrease in the percentage of particles passing the lower sieves. Changes in the finer region of the gradation curves are primarily attributed to the adhesiveness and viscidity of the asphalt particles.

In comparison to natural alluvial gravel or manufactured crusher-run aggregate, the milling process produces proportionally fewer particles finer than the #4 sieve. Changes observed in the upper region of the gradation curves were attributed to the particle size characteristics of the RAP millings, which in comparison to the virgin materials contain a greater proportion of material above the #4 sieve size.

Compaction. Results from modified Proctor compaction tests indicate that the addition of RAP to virgin aggregate decreases the maximum dry density and alters the amount of water needed to reach optimum compaction. Results from this study indicate that the addition of RAP to an aggregate will cause the compaction curve to drop and shift to the left. In other words, the maximum dry density is inversely proportional to the percentage of asphalt millings contained in a RAP/aggregate blend. Overall, the changes in optimum water content are relatively minor and are within the normal range of accuracy for the Proctor test.

Degradation/abrasion. Los Angeles abrasion tests (AASHTO T-96) were conducted to obtain a relative measure of the degradation resistance of the virgin aggregates and the blended RAP mixes. There appears to be no causal relationship between RAP percentage and degradation loss.

Strength. The strength, stiffness, compressibility, and drainage characteristics of the material underlying an asphalt surface can significantly influence pavement performance and long-term maintenance. Subgrade and base layers must be strong enough to resist shear failure and have adequate stiffness to limit plastic vertical deflections. Stronger and stiffer materials provide a more effective foundation for the riding surface and are more resistant to stresses from repeated loadings and environmental conditions.

Measurements taken using a large (12 in x 12 in) direct shear test apparatus indicate that as the RAP content increases, the measured stress versus displacement response becomes softer. At a given displacement, both shear strength and secant modulus decreased as the quantity of RAP in the blends increased. As shown in Figure 1, a shear strength decrease of 2 psi (at a confining pressure of 3.6 psi) was observed for CBC #3 after mixing with 75% RAP. This drop in shear strength does not seem to be substantial enough to merit the exclusion of RAP as a base course material, especially after considering previous studies that indicate minor strength gains likely occur during the first few weeks after placement. The shear strength of the virgin pit run was initially lower than that of CBC #3. The addition of RAP did not substantially alter the shear strength of the pit run material. This is somewhat dichotomous to the results for CBC #3 blends, in which the addition of RAP reduced both the shear strength and the friction angle. The modest shear strength increase observed in the pit run blends was most likely caused by the lack of angular material in the virgin sample. It is postulated that the crushed angular aggregate in the asphalt millings increased particle interlock and possibly (to a lesser extent) interparticle sliding friction. This effect was most noticeable at low confining pressures.

Stiffness. The addition of asphalt millings to a granular soil results in a more ductile or softer response to loading than exhibited by virgin aggregate, and the ductility increases as the percentage of RAP in the sample increases. The relative effect of RAP was more pronounced with the crushed material than the pit run; however, the overall or absolute moduli values of the crushed aggregate were greater than the pit run. Initially, the unblended crushed aggregate provided a much stiffer response than the unblended pit run because of the difference in particle shape and surface roughness characteristics of the two materials. But as the RAP content was increased to 75%, the stiffness of the two materials became more similar. At higher levels of RAP, the characteristics of the asphalt millings begin to control the behavior of the blend. This results in a less stiff response and lower shear strength.

R-value. The R-value test provides results that can be directly related to a soil's resilient modulus, which is used for designing asphalt concrete pavement sections. In concept, the thickness of a pavement section is directly related to the R-value of the subgrade and each layer comprising the section. As shown in Figure 2, the addition of asphalt millings had little effect, if any, on the R-value of the crushed aggregate (CBC #3). However, the R-value for the pit run increased when mixed with RAP.

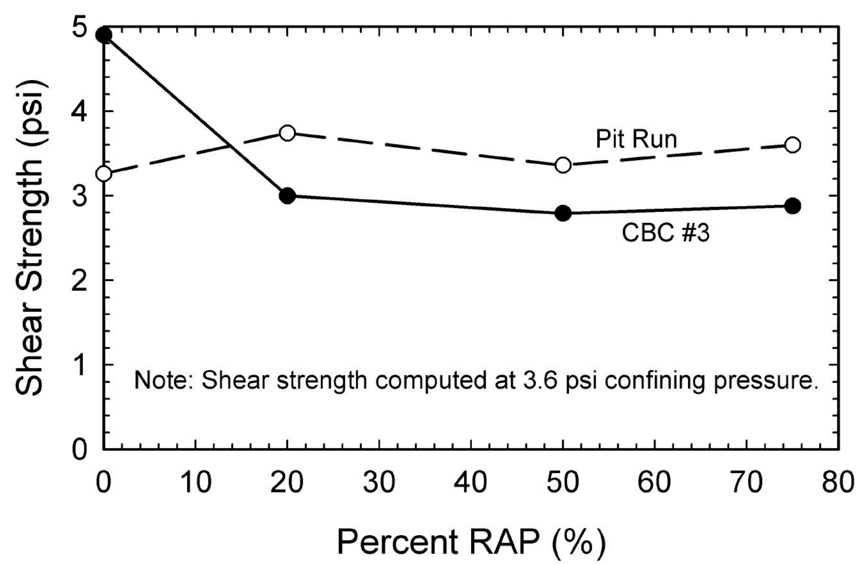

FIGURE 1. Relationship between shear strength and RAP content

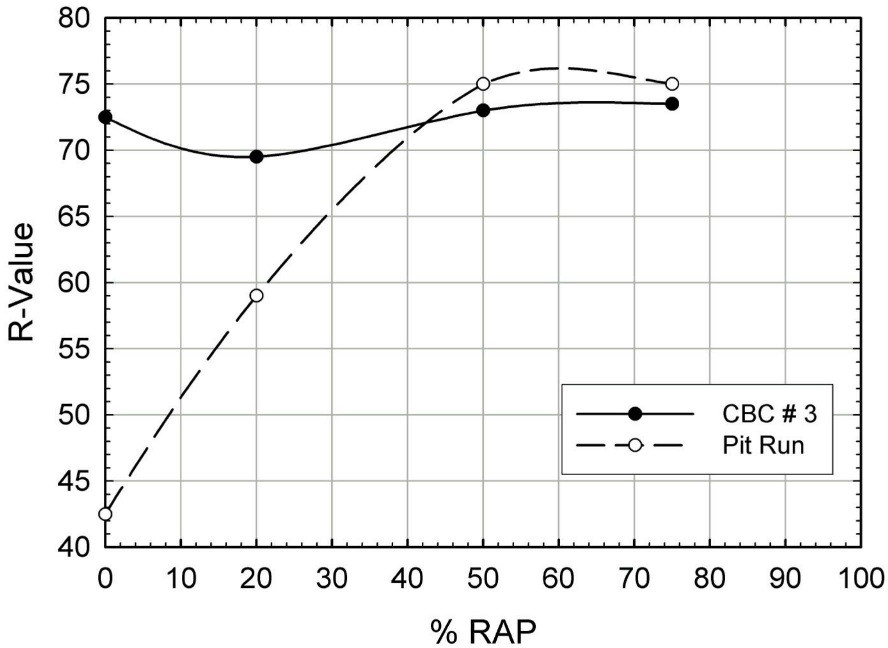

FIGURE 2. Average R-value as a function of percent RAP

These are both positive outcomes. The test results suggest that the addition of asphalt millings to crushed angular aggregate will have only minor effects on the R-value, while the addition of RAP to natural pit run soil may result in an R-value increase. The relationship between percent RAP and R-value is primarily dependent upon the properties of the virgin material. For the materials tested in this study, it appears that adding RAP to cohesionless, predominately coarse-grained material will not adversely affect the R-value of the blended mix.

Permeability. Three to five constant head permeability tests were conducted on aggregate blends of 0, 20, and 50 percent RAP using large 10-inch-diameter permeameters. Test results indicate that permeability increases as the percentage of RAP in the mix is increased, as shown in Figure 3. This is considered a desirable trait for material used to support asphaltic pavement surfaces.

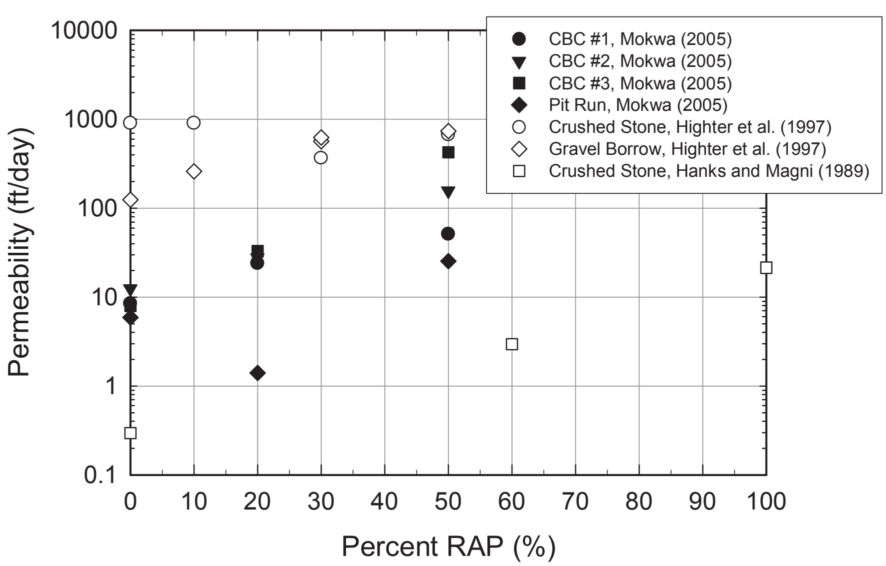

FIGURE 3. Permeability versus percent RAP

What the researchers recommend

The outlook for the continued implementation of RAP as an additive to granular base and subbase materials for use in highway construction looks promising. Laboratory testing conducted during this study indicates that blending asphalt millings with granular cohesionless material like crushed aggregate or pit run gravel results in only minor changes to the engineering properties of the virgin material.

Small changes to strength and compressibility were observed; however, the changes did not appear to increase or decrease in a regular manner. Measured R-values for two different virgin aggregates were acceptable even when as much as 75% millings were used to create the RAP blends. Because shear strength and stiffness are highly particle dependent, it is recommended that these parameters be evaluated on a project-by-project basis as necessary, until enough data becomes available to statistically evaluate any trends that may exist.

This laboratory study should be regarded as a step towards full-scale adaptation of RAP/aggregate blends in highway pavement sections. Supplemental field testing and controlled highway test sections should be considered to evaluate the affect of regional soil, weather, and traffic loading conditions. The long-term performance of RAP blends is likely to be highly dependent on the methods used during construction and the quality control/quality assurance testing that occurs during material placement. It is recommended that future studies include an investigation and evaluation of these practices.

For More Details . . .

The research is documented in Report FHWA/MT-05-008/8117-24, *Evaluation of the Engineering Characteristics of Rap/Aggregate Blends*.

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MDT Implementation Status
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These findings are based solely on laboratory tests. MDT's Pavement Analysis Section has compiled a list of projects dating back to 1988 where a RAP/Aggregate blend was used for construction of the surfacing section. A review of how the projects over 5 years old are performing will provide a true measure of the performance of these mixtures. Personnel from the Materials Bureau will work with District personnel familiar with the projects to evaluate the performance of these projects. This evaluation will be used to determine whether the reduced strength characteristics shown in the study are translating into problems on the roadway. Problems with overall performance of these roadways have not been documented to this point. Based on this fact it has been determined the use of the RAP/aggregate blends will continue, as before, until the evaluation can be completed. Once the evaluation has been completed, a determination will be made whether further modifications to MDT practices are necessary.

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