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RESEARCH PROJECT TITLE

The Use of Agriculturally Derived Lignin as an Antioxidant in Asphalt Binder

SPONSORS

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Using Lignin as an Asphalt Antioxidant

tech transfer summary

Lignin as an antioxidant in asphalt binder could help slow oxidative aging and delay pavement failures and aging problems.

Objective

The objective of this study was to evaluate the effects of lignin-containing ethanol co-products for use in asphalt binder. Work was performed to analyze how the lignin-containing co-products chemically and physically interacted with samples of asphalt binder.

Problem Statement

There is no performance enhancer in widespread use, acting as an antioxidant, that slows the oxidative aging of asphalt binder. As a pavement ages, oxidation stiffens a pavement, making it more susceptible to failure from load and thermal stresses. Slowing a pavement's oxidative aging would maintain its elastic properties and delay aging problems. Lignin, a known antioxidant derived from corn, could act as such a performance enhancer and help slow oxidative aging.

Research Description

This was a first-phase study that evaluated whether the co-products had an overall positive or negative effect on the binders.

For this study, four co-products were mixed with four asphalt binders to assess their oxidative effects. Three co-products contained lignin processed from corn. The fourth co-product had its lignin removed and acted as a control to measure the antioxidant activity of the three other lignin co-products.

The co-products were mixed with asphalt binders at varying levels, from 3% to 12% by weight, resulting in 52 treatment combinations that underwent asphalt binder performance testing. Each treatment combination was performance tested after being blended in a high-speed sheer mill. The performance testing consisted of dynamic shear rheometer and a bending beam rheometer testing coinciding with field simulative aging using a rolling thin film oven test and pressure aging vessel. Testing was performed to appropriate specifications.

Pavement failure examples (alligator cracks, left; pothole formation, right)

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Each binder and co-product combination was tested unaged immediately after mixing with the dynamic shear rheometer at three different temperatures. Next, each combination was short-term aged in a rolling thin film oven to mimic the aging a binder goes through when mixed and constructed in the field. The combinations were further aged with a pressure aging vessel to simulate 5–10 years of in-service aging.

Analysis of the binder and co-product treatments included analyzing each binder separately. Each binder was divided into four sections: unaged high critical temperature, RTFO-aged high critical temperature, PAV-aged intermediate critical temperature, and PAV-aged low critical temperature. For each section, the lignin-containing co-products were analyzed to determine which combination had the most/least beneficial effect on each binder. Each treatment combination was compared to the unmodified binder to determine if the resulting change in performance grade was significant.

The co-product without lignin was analyzed to determine if its effects were statistically different from the lignin-containing co-products.

Key Findings

The lignin-containing co-products stiffened the binder at all stages of aging. The result of stiffening was an improvement to the high temperature properties and a worsening to the low temperature properties. This widening of temperatures was a general trend among many of the treatment combinations.

This general widening of the continuous performance grade was beneficial to the binder and suggested some antioxidant activity of the lignin with the binder.

The testing of the co-product without lignin supported the idea that there was beneficial antioxidant activity because samples without ligning aged significantly more than the samples with lignin.

Fourier transform infrared spectroscopy testing also indicated some antioxidant effects by the reduction in some of the various chemical aging products, which were binder- and co-product-dependent.

Recommendations

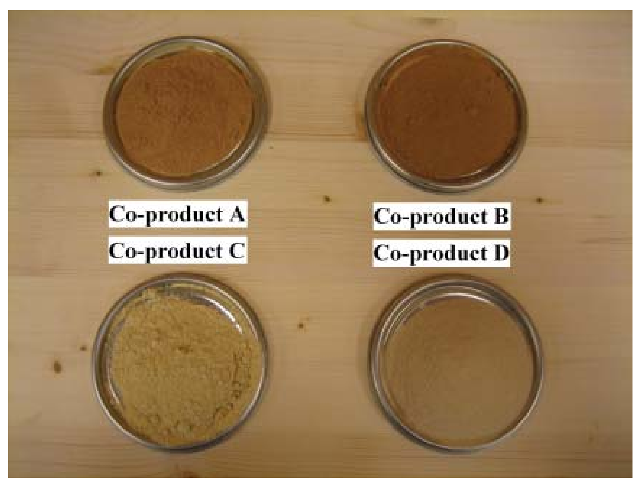
The research team recommends that, because separation effects were present when the binder and co-product blends were stored at high temperatures, a recirculation pump system be used to keep the binder and co-products in a continuously homogenous blend.

Other possible scenarios are to mix the co-products in with the binder just before it is mixed with aggregate during construction, or to mix the co-products simultaneously with the aggregate.

The research team also suggests that more separation testing can help evaluate what variables (physical size and chemical composition) make the co-products more susceptible to physical separation.

Even though the co-products stiffened the binders and increaseed the performance grades, they could provide a great benefit to the asphalt industry by simply acting as a renewable alternative for asphalt binder. In addition, lignin derived from corn used for ethanol production could also provide a benefit to the ethanol industry.

Futhermore, bio-oil and cellulosic ethanol production also produce large amounts of lignin and similar research could be conducted with these productions to evaluate their potential as successful asphalt binder modifers.



Physical appearance of the co-products. Co-products A, B, and C contained lignin; co-product D did not.