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Development of Non-Petroleum Based Binders for Use in Flexible Pavements

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Abstract
Bio-oils can be implemented as binders to help reduce the pavement industry's reliance on fossil fuels.

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RESEARCH PROJECT TITLE
Development of Non-Petroleum Based Binders for Use in Flexible Pavements

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Development of Non-Petroleum Based Binders for Use in Flexible Pavements

tech transfer summary

Bio-oils can be implemented as binders to help reduce the pavement industry's reliance on fossil fuels.

Objectives

Test the properties of non–fossil fuel bio-oils to determine the applicability of using bio-oils as binders in the pavement industry.

Problem Statement

Most bituminous adhesives or binders used for pavement materials are derived primarily from fossil fuels. However, as petroleum oil reserves become depleted and a public effort to reduce fossil fuel usage is urged, there is a drive to develop and produce binders from alternative sources, particularly from non-food source biorenewable resources.

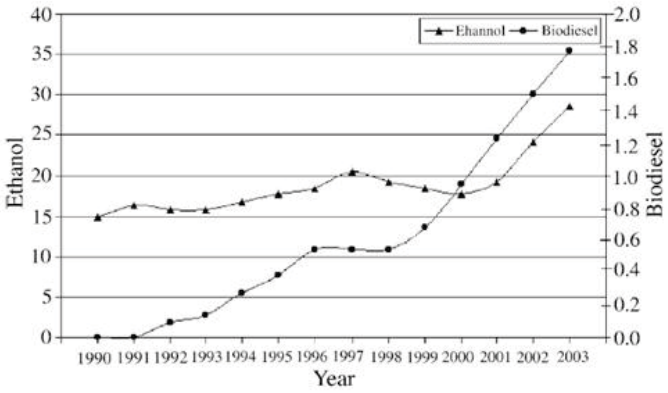
Biorenewable resources including sugars, triglyceride oils, and proteins have been tested as alternative sources for producing binders. Due to the availability of large quantities of biorenewable materials from different agricultural and forest co-product sources, there is technical and economic potential for using them to produce bio-binders.

Experimental Plan

Different types of bio-oils derived from three bio-mass sources, oakwood, switchgrass, and cornstover, were examined. All three sources of oils were subjected to physical, chemical, and rheological testing.

Cornstover used to make bio-oils

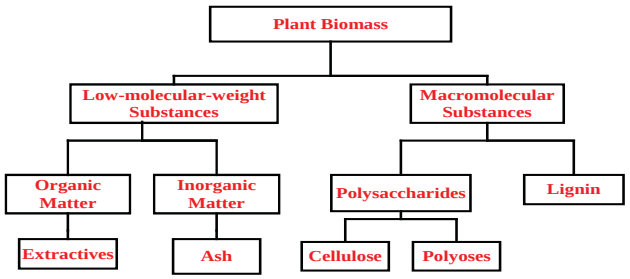
Physical testing involved measuring the oils' separation potential and the specific gravity. Chemical testing was used to determine the chemical properties of the unmodified bio-binders (pre-treated/pre-upgraded bio-oils) through gas chromatography-mass spectrometry (GC/MS) and Fourier transform infrared spectroscopy (FTIR). Rheological testing measured the viscosity over time of the untreated bio-oils (original/virgin bio-oils), the temperature and duration for developing bio-binders, the simulated effect of short-term aging, the low, high, and intermediate temperature performance grade of the pre-treated bio-oils/bio-binders.



World production of ethanol and bio-diesel (billion liters), 1990-2003

Key Findings

- Due to the bio-oils' large amounts of water and volatile contents, bio-oils cannot be used as bio-binders/pavement materials without first applying a heat treatment or upgrading procedure.
- The heat treatment/upgrading procedure for deriving bio-binders from bio-oils should be determined for each type of bio-oil separately, due to the significant difference between different types of bio-oils.
- The current testing standards and specifications, especially Superpave, should be modified to account for the different properties of the bio-binders derived from bio-oils, largely due to the chemical differences between bio-oils and crude-petroleum binders.
- The mixing and compaction temperature range of the bio-oils' viscous behavior should be determined precisely, as the range varies depending on the type of bio-oil and polymer modifier. In general, the temperature range for bio-oils may be lower than that of bitumen binders by about 30–40°C.
- The rheological properties (temperature and shear susceptibilities) of the unmodified bio-binders vary from those of bitumen binders, but adding polymer modifiers changes the bio-binders' rheological properties significantly.



Chemical structure of bio-oils

- The high-temperature performance grade for the developed bio-binders may not vary significantly from that of the bitumen binders; however, the low-temperature performance grade may vary significantly due to the high oxygen content in the bio-binders.

Recommendations

- The suitability of bio-oils as bio-binders should be investigated further by examining bio-oils derived from different bio-mass sources.
- Polymer modifiers should be chosen with care because of the differences in temperature ranges between the developed bio-binders and the polymer modifiers commonly used in the bitumen industry.
- The effect of different polymer modifiers on different bio-oils should be studied extensively.
- More research should be conducted to study the applicability of using bio-oils as alternative binders in the pavement industry (100% replacement). Research areas may include mix design development and performance testing of mixes containing bio-binders.
- More investigation is needed to validate the heat treatment or upgrading procedure.
- More research is needed to develop and validate proposed modifications to the Superpave procedures and criteria.
- The resistance of the developed bio-binders against water and moisture intrusion should be studied before bio-binders are used as pavement materials.
- New means and methods to quantify the aging occurring in bio-binders should be studied extensively to establish a standard procedure or a specification to chemically quantify the aging taking place.

Implementation Benefits

As petroleum and oil reserves diminish, it will become beneficial to develop an alternative to fossil fuel–based binders. Bio-oils offer an alternative that is renewable and sustainable and that can be produced from many natural resources. As this research has shown, bio-binders can be become a viable replacement for bituminous binders.