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**RESEARCH PROJECT TITLE**

Development of Bio-Based Polymers for Use in Asphalt

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# Development of Bio-Based Polymers for Use in Asphalt

tech transfer summary

The benefits of this research include the potential to utilize Iowa source materials (e.g., soybean oil) in producing biopolymers for use in Iowa asphalt binders.

## Background

Asphalt binder used for high-performing pavements needs sufficient properties to resist cracking at low temperatures and rutting caused by shear forces from sustained loads at high temperatures. To produce an asphalt binder with these performance characteristics, the binder is commonly modified with elastomeric polymers to improve its rheological properties and lower its temperature susceptibility over a range of in-service pavement temperatures.

The most common elastomeric polymers used for asphalt modification are styrenic block copolymers (SBCs). SBCs are composed of blocks of polybutadiene and polystyrene to produce styrene-butadiene (SB) diblock polymers and styrene-butadiene-styrene (SBS) triblock polymers.

Recent advances in polymerization techniques have led to the development of elastomeric block copolymers produced with polystyrene and polymerized soy-derived triglycerides. While the past two decades of plant-oil based polymer research has yielded only thermosets, the newly produced polymers are thermoplastic elastomers that are processable at high temperatures.

## Research Methodology

The thermoplastic elastomers were produced using a controlled radical polymerization technique to create the block copolymers.

Soybean oil triglycerides were first acrylated and epoxidized, creating acrylated epoxidized soybean oil (AESO). This process made them suitable to polymerize via controlled radical polymerization techniques, such as reversible addition-fragmentation chain-transfer polymerization (RAFT).

SBS-like triblock copolymers were then synthesized by polymerizing AESO and styrene monomer in the presence of a free radical initiator and a chain transfer agent to create polystyrene-*b*-polyAESO-*b*-polystyrene (PS-PAESO-PS). The polymerizing step was carried out under conditions effective to achieve a number-average degree of polymerization ( $N_n$ ) for the thermoplastic block copolymer of up to 100,000 repeat units per molecule without gelation. Following the same process, SB diblock copolymers were also produced.

## Laboratory Investigation

A laboratory investigation was conducted to characterize the PS-PAESO-PS and PS-PASEO biopolymers and to evaluate their effectiveness as a liquid asphalt modifier. Asphalt modified with the biopolymers was compared to asphalt modified with two commercially available Kraton polymers, D1101 (SBS) and SB D1118 (SB).

## Key Findings

Rheology test results showed the biopolymer has the ability to widen the grade range of asphalt and reduce its temperature susceptibility. The base asphalt tested as a continuous PG 51.1-37.7 for a grade range of 88.8°C. Adding two percent D1101 to the base asphalt increased its continuous high PG to 57.2 without changing its -34 grade qualification on the low temperature side. Adding two percent PS-PAESO-PS to the base asphalt changed its continuous PG to 70.4-33.0 for a 103.4°C grade range. With the addition of two percent PS-PAESO, the base asphalt changed to a continuous PG of 69.1-32.8 for a 101.9°C grade range.

Thus, biopolymers significantly enhanced the performance properties of the base asphalt. By adding two percent of either biopolymer to an asphalt binder, the rutting resistance and temperature performance range of an asphalt pavement will improve.

## Implementation Readiness and Benefits

Soybean oil is the world's most abundant vegetable oil and currently costs 40 percent less than butadiene. These lower costs will translate into lower costs of polymer-modified asphalt. Polymerized triglycerides are also intrinsically renewable, environmentally friendly, and safer to handle than butadiene.

With future implementation of the developed biopolymers, Iowa source materials (e.g., soybean oil) can be utilized to produce polymers for use in Iowa. This can create improved economic opportunities for soybeans resulting in economic value to Iowa and maintaining soil qualities through a balanced crop rotation with corn.

## Future Work

Currently, at a polymer content of two percent, a base asphalt's low temperature PG may increase one grade, which may warrant the use of a softer base asphalt to compensate for that effect. As additional data from asphalt-modification experiments become available, additional or improved polymer formulation designs may be developed. Future research can improve upon the biopolymers' molecular architecture, styrene content, and molecular weight distribution.

A larger reactor has been purchased that is capable of making two kilogram samples, substantially larger than the approximately 100 gram samples produced in this study. In addition, a pilot plant is currently being designed that can produce even larger quantities of the biopolymers for future research.

Further work evaluating asphalt mixtures for rutting, low temperature cracking, and moisture susceptibility should be done while the pilot plant is being constructed. Based upon the evaluation of the mixture, an additional phase of research should include a field demonstration project that tests the performance of asphalt pavement containing terminally blended asphalt binder modified with the soy-based block copolymers.