Scientific Innovations in Microsurfacing and Slurry Seal Mixture Design

tech transfer summary

Incorporating more science into the art of pavement preservation will ultimately enhance performance. This study investigates using zeta potential measurements to provide an indicator of emulsion stability and to understand emulsion/fine aggregate interactions and cohesive strength gain in slurry seal mixtures.

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RESEARCH PROJECT TITLE
Scientific Innovations in Microsurfacing and Slurry Seal Mixture Design

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Problem Statement

Engineering a microsurfacing or slurry seal emulsion to achieve adequate mixing followed by a quick set once placed on the pavement surface is complex, and the formulation must be tailored to the context in which it will be used. Many civil engineering practitioners do not have extensive experience working with asphalt emulsions or an in-depth understanding of how slurry-mixture parameters influence setting time and time-to-traffic.

Project Focus and Goal

This study focuses on important variables in asphalt emulsion manufacturing and on measuring how changes in parameters influence the stability and setting characteristics of a slurry mixture. The aim of this research project was to use scientific measurements and a controlled experimental design to show how parameters influence setting time for slurry seal and microsurfacing mixtures.

Objectives

The objectives of this study were to determine the feasibility of using zeta potential to better understand asphalt emulsion stability, asphalt emulsion/fine aggregate interactions, and development of cohesion in slurry seal mixtures over time. Using measurements during the microsurfacing or mixtures over slurry seal mixture design may help practitioners make more informed decisions about mixture adjustments when adapting to varying field conditions.

Background

Pavement preservation treatments that utilize asphalt emulsions are growing in popularity due to the overwhelming need to preserve infrastructure and ensure treatment cost effectiveness, as well as due to the versatility of asphalt emulsion applications. However, emulsions are not well understood by many practitioners in the civil engineering community.

Both microsurfacing and slurry seal treatments use quick-setting emulsions. These emulsion formulations and mixture designs are engineered to work together to maintain adequate consistency during mixing and then rapidly set and break once placed on the roadway surface. This rapid break allows for rapid curing of the new pavement surface, allowing the road to be opened to traffic in as little time as an hour after treatment application.

Microsurfacing and slurry seal asphalt emulsions, just like other colloidal systems, have a diffused double layer formed by the potential difference between charges on the asphalt droplets and that of the liquid medium. This potential is known as the zeta potential.

Research Description

This study consisted of two phases:

- Phase 1 to determine the effects of emulsion formulation parameters on the zeta potential of asphalt emulsions
- Phase 2 to determine the effect of emulsion formulation/zeta potential, emulsion content, and water content on the cohesion development of slurry seal mixtures

Phase 1: Effect of Emulsion Formulation Parameters on Emulsion Zeta Potential

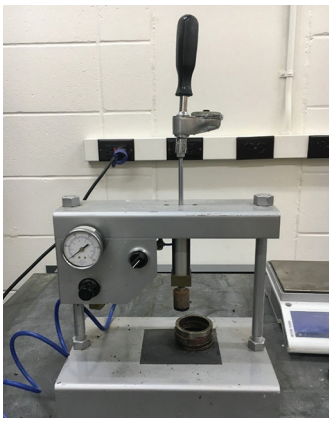
Slurry seal emulsions were prepared with PG 64-22 binder and a quick-setting emulsifying agent. The dosage of the emulsifier was varied as well as the pH of the emulsifier solution, and ultimately, the asphalt emulsion. Nine emulsions were produced, each with three different levels of emulsifier loading and pH.

The emulsions were diluted and tested for zeta potential in a Zetasizer Nano NS at three different temperatures. A Box-Behnken response surface design was employed to record the zeta potential at three levels of emulsifier loading, pH, and temperature. Each level of emulsifier loading, pH, and temperature was measured three times by the instrument, which led to a total of 81 readings.

Equipment used to manufacture asphalt emulsions and maintain desired temperatures during milling in the laboratory

Phase 2: Effect of Emulsion Stability on Performance of Slurry Seal Mixes

Slurry seal mixes were prepared with different amounts of emulsion and water content based on the dry weight of aggregates along with the emulsion formulation variables that had had a significant effect on zeta potential in Phase 1.



Equipment used to test and measure the cohesion of mix design samples after laboratory curing

The mixes were tested for cohesive strength developed after 60 and 90 minutes. A surface response experimental design was used to determine the factors that affect cohesive strength.

Key Findings

Phase 1: Effect of Emulsion Formulation Parameters on Emulsion Zeta Potential

- The ranges of pH and temperature studied had a significant effect on the measured zeta potential of emulsions
- A decrease in pH reduced zeta potential for high emulsifier dosages, especially at 25°C
- Emulsifier dosage had a significant effect on emulsion zeta potential according to the statistical model, but not as significant as the effects of pH and temperature
- A reduction in zeta potential was observed at a pH level of 1.5 for all emulsifier dosages in the study

Phase 2: Effect of Emulsion Stability on Performance of Slurry Seal Mixes

- pH had a significant effect on the cohesive strength of slurry seal mixes after 60 minutes of curing, with less stable emulsions gaining strength faster and having higher cohesion values than more stable emulsions
- The effect of pH ceased to be significant at 90 minutes, indicating that the more stable emulsions continued to gain strength until they were level with the less stable emulsions
- Emulsion content had a significant effect on cohesive strength at both 60 and 90 minutes, as higher emulsion content meant more emulsion residue was available to form bonds between aggregates
- The moisture content of aggregates did not have a significant effect on cohesive strength; however, higher water content did improve workability and mix timing, especially with higher emulsion content

Examples of modes of emulsified asphalt rupture: "solid spin" (left) and "normal" (right)

Implementation Readiness and Benefits

When implemented successfully, microsurfacing and slurry seals can be cost-effective treatments for increasing pavement life. In addition, their rapid curing allows a road to be opened to traffic in as little as one hour after treatment application.

This study introduces zeta potential as a scientific measurement able to enhance understanding of emulsions, so mix designs can be fine-tuned based on this number to get peak performance out of new surface treatments.

Recommendations for Future Research

This was one of six Innovative Projects funded by the Iowa Highway Research Board in 2018. Future studies should verify if the differences in zeta potential demonstrated in this laboratory study reflect field observations.

For example, laboratory and field differences in temperature and humidity could contribute to differences in strength gain. In addition, exposing samples to a wide range of environments could prove useful in determining important additional environmental factors that impact the development of cohesive strength.

Finally, more research could be done with additional types of emulsions having different chemistries, such as tack coats and cold-in-place mixtures, to determine whether zeta potential can help predict setting times for these emulsions as well.