LOUISIANA TRANSPORTATION RESEARCH CENTER

Technical Summary

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Implementation of Semi-circular Bend (SCB) Test for QC/QA of Asphalt Mixtures

Introduction

Conventional asphalt mixture design methodologies such as Superpave, Marshall, and Hveem are commonly used to determine optimal asphalt binder content. These methods rely on physical and volumetric laboratory measurements to ensure that the proportion and quantity of asphalt binder meets stability and durability requirements. However, as the use of recycled materials increases, there is a need to develop additional laboratory tests to assess the quality of asphalt binder and complement the Superpave volumetric mixture design procedure.

An important component to successful mixture design is the balance between volumetric composition and material compatibility. Balanced asphalt mixture design offers innovation in designing mixtures for performance and evaluation of the quality of a mixture design relative to the anticipated performance using a rational approach. The 2016 *Louisiana Department of Transportation and Development (DOTD) Specifications for Roads and Bridges* introduced the concept of balanced mixture design by incorporating the Hamburg wheel tracking (HWT) and semi-circular bend (SCB) tests to evaluate high temperature and intermediate temperature performance, respectively. However, the state's quality control/assurance (QC/QA) specifications and practices have not been updated accordingly, as they only consider volumetric properties to ensure that mixtures are produced as intended and perform as expected in the field. This research aims to address this gap by proposing a methodology to implement performance tests for rutting and cracking during the QC/QA phases in Louisiana, specifically focusing on the practical implementation of the SCB test.

In the asphalt mixture design process, the 2016 *Louisiana DOTD Specifications for Roads and Bridges* specifies a criterion for the critical strain energy release rate (J_c) obtained from the SCB test for different traffic levels. Typically, the SCB test is conducted on compacted samples that have been conditioned according to AASHTO R 30, which involves subjecting the samples to a temperature of 85°C for 5 days to simulate long-term aging (LTA) in the laboratory. However, QC/QA practices are time-sensitive, making it impractical to include LTA SCB samples in these tests. This research developed two approaches for the prediction of LTA SCB J_c: (1) a scaling factor than can be implemented to forecast SCB J_c at 5 days aging from SCB J_c at 0 days aging; and (2) a user-friendly interface for a proposed ANN model. For the artificial neural network (ANN) model, a stepwise regression analysis identified significant parameters correlated with SCB J_c, such as asphalt binder film thickness (FT), percent passing from sieve #4 (P4), aging level (day), asphalt binder polymer modification level (PM), and effective asphalt binder content (P_{be}). The proposed approaches eliminate the need for conditioning plant-

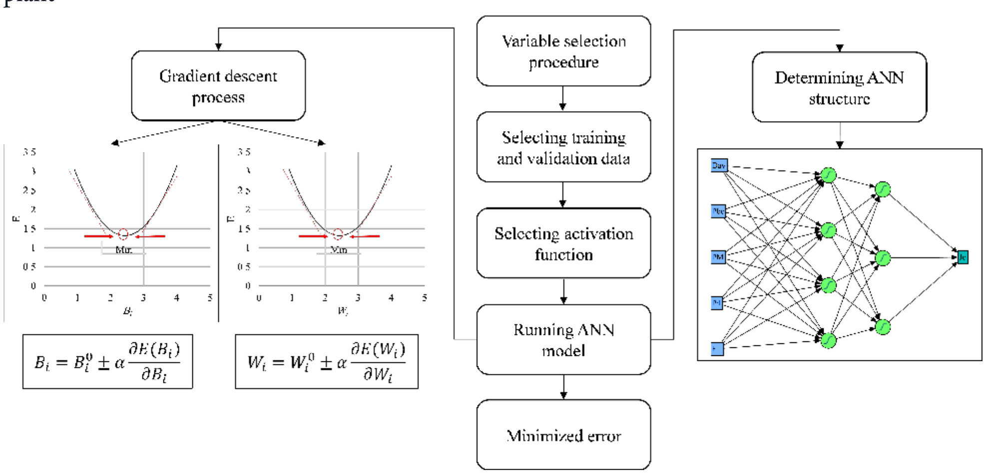

Figure 1. ANN Model Development Procedure

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produced asphalt mixture samples, making it practical for the implementation of the SCB test in QC/QA testing.

Objective

The objective of this study was to develop practical methods to predict SCB *Jc* of long term aged (LTA) asphalt mixtures for use in QC/QA programs.

Scope

Fourteen field asphalt mixtures from throughout Louisiana were selected for this study. Loose asphalt mixtures were compacted, laboratory aged at 85°C for 0, 2, 5, 7, and 10 days, followed by SCB testing. Asphalt binders were extracted and recovered from the aged SCB samples for chemical and rheological characterization. Chemical characterization included Saturate, Aromatic, Resin, and Asphaltene (SARA) analysis, Fourier transform infrared spectroscopy (FTIR), and gel permeation chromatography (GPC) tests. Rheological tests performed were Superpave performance grading, frequency sweep, linear amplitude sweep (LAS), and multiple stress creep recovery (MSCR) tests.

Results obtained from the chemical and rheological characterizations were analyzed in relation to the material composition. GPC analysis revealed changes in asphalt binder components with increased aging level, while rheological characterization indicated a decrease in cracking resistance. SCB test results demonstrated a reduction in fracture resistance with increased aging. Stepwise regression analysis identified significant parameters correlated with SCB *Jc*, such as asphalt binder film thickness (FT), percent passing from sieve #4 (P4), aging level (day), asphalt binder polymer modification level (PM), and effective asphalt binder content (P_{be}). An ANN model utilizing gradient descent backpropagation was developed, validated, and determined to be able to accurately predict the LTA fracture parameter SCB *Jc* of asphalt mixtures. Two approaches were developed for the prediction of LTA SCB *Jc*: (1) a scaling factor than can be implemented to forecast SCB *Jc* at 5 days aging from SCB *Jc* at 0 days aging; and (2) a user-friendly interface for the proposed ANN model. Both approaches are recommended for implementation in the Louisiana DOTD asphalt mixtures QC/QA programs. The ANN model leverages the capability of artificial neural networks to capture complex relationships between input variables and output parameters. A user-friendly interface for the proposed ANN model is shown in Figure 1.

Conclusions

- Chemical tests were effective in capturing incremental aging.
- GPC analysis revealed that maltenes and high-molecular weight components of the asphalt binders reduced with an increase in aging level, while medium-molecular weight and asphaltene components increased due to oxidative aging.
- SARA analysis showed that asphaltene content increased with increasing aging durations.
- FTIR analysis indicated that carbonyl index (*CI*) increased as a result of oxidative aging.
- Rheological tests were able to capture the effect of oxidative aging.
- ΔTc parameter obtained from the BBR test showed larger negative values when aging level increased, which indicates that the stress relaxation capability decreased.
- G-R parameter obtained from frequency sweep increased with increasing aging levels.
- A_{LAS} parameter obtained from LAS test decreased with increasing aging duration.
- SCB test was effective in capturing the effect of progressive aging. Cracking resistance of asphalt mixtures in terms of the SCB *Jc* fracture parameter decreased with an increase in aging level.
- SCB *Jc*, A_{LAS}, and FTIR *CI* parameters were consistently able to capture the effect of asphalt binder type (unmodified and polymer modified) on the aging susceptibility of asphalt mixture and asphalt binder.
- Correlation analysis indicated that A_{LAS} had a strong correlation with *CI* and *%As*. SCB *Jc* also showed a strong correlation with ΔTc and moderate correlation with A_{LAS}. These observations suggest a correspondence between the molecular structure of asphalt binder due to aging and rheological characteristics of asphalt binder as well as the fracture properties of asphalt mixture.
- A scaling factor was developed to forecast SCB *Jc* at 5 days 85°C aging from SCB *Jc* at 0 days aging (i.e., plant produced mixtures).
- Statistical analysis of the test results using stepwise regression method showed that the aging level, P_{be}, P4, FT, and PM parameters were significant in determining the SCB *Jc* of asphalt mixtures.
- The ANN approach using gradient descent backpropagation process has shown to be effective in predicting SCB *Jc* of asphalt mixtures. The predictive ANN model was able to accurately predict fracture performance of asphalt mixtures.
- A user-friendly interface was developed for implementation in Louisiana DOTD asphalt mixtures' QC/QA programs.

Implementation

It is anticipated that the results from this study will provide guidance to state agencies in QC/QA processes to shorten the required time for asphalt mixture aging prior to the SCB test. Two approaches were developed for the prediction of LTA SCB *Jc*: (1) a scaling factor to forecast SCB *Jc* at 5 days aging from SCB *Jc* at 0 days aging; and (2) a model using artificial neural network (ANN) methodology to predict the LTA SCB *Jc* of asphalt mixtures, incorporating variables such as aging duration, mixture volumetric properties, and the chemical and rheological characteristics of asphalt binders as inputs. Both approaches eliminate the need for long term conditioning plant-produced asphalt mixture samples, making it practical for the implementation of the SCB test in QC/QA testing.