Evaluation of Dynamic Modulus Predictive Models for Typical Australian Asphalt Mixes

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Introduction

Project Background

Experimental Plan

Review of Nominated Dynamic Modulus Models

Evaluation of Nominated Dynamic Modulus Models

Perpetual Pavement NCAT Criteria

Asphalt Pavement Alliance (APA):
- Last longer than 50 years
- No major structural deterioration
- Only periodic surface renewal

Transportation Research Laboratory (TRL):
- Designed for 40 years and 80 MSA
- The rate of deflection remains constant over time or indeed reduces despite heavy traffic loading

National Centre for Asphalt Technology (NCAT):
- Field data suggested the existence of a limiting cumulative distribution of strain to avoid asphalt fatigue cracking.

Asphalt Pavement Solutions – For Life (APS-FL)
- AAPA introduced the APS – FL project in 2011 to investigate the current pavement design system which is believed to be overly conservative.
- The objective of the APS-FL project is to improve the effective deployment of Long Life Asphalt Pavement structures within Australian highway construction practice.
- National Asphalt Materials Characterization Study was introduced to provide hard data on the performance characteristics of typical Australian asphalt materials.
- 28 dense graded asphalt mixes produced by Australia’s major asphalt producers were taken from plant production and subjected to performance tests (Dynamic Modulus).
Experimental Plan

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Material Selection

Sample Preparation Procedure

Advanced Performance Tests

Material Collection

Coring & Trimming

Drying Cores in Silica Beads

Attaching Lugs

Triplicate Samples (Sent to NCAT)

Applying Membrane and Clamps

Dynamic Modulus Test

Duplicate Samples

28 Mixtures

A Total Combination of 72

AASHTO TP79-11

Asphalt Mixture Performance Tester (AMPT)

Dynamic Shear Rheometer (DSR):

To characterize the viscous and elastic behavior of binders at medium to high temperatures.

Test outputs:

Complex Shear Modulus, $|G^*|$

Phase Angle, $\delta$

Dynamic Modulus Graph

Log $\text{Dynamic Modulus (MPa)}$ vs. Reduced Frequency (Hz)

$\log\text{ Dynamic Modulus (MPa)} = \delta + \frac{\beta}{1 + e^{(\alpha - r)/A}}$

Sigmoidal function:

AASHTO PP 62-10

Goodness-of-fit:

$R^2 > 0.99$

$Se/Sy < 0.05$
Sample Master Curve

Review of Nominated Dynamic Modulus Models

Evaluation of Nominated Dynamic Modulus Models

Costly
The accuracy of four most commonly used dynamic modulus predictive models was evaluated.

Dynamic moduli of 28 different typical dense graded Australian asphalt mixes were tested over a spectrum of temperatures, loading frequencies and confinement pressures. The databases based on which the studied models were developed and calibrated.

It is believed that part of the inaccuracy and errors observed in the models' predictions are highly dependent on the inputs related to binder characteristics ($G^*$ and $\eta$) and project background data.

Sensitivity analyses on the nominated models showed that the models perform fairly poorly at low temperatures (5 and 20°C).

Generally, it was found that the models' predictions are highly dependent on the inputs related to databases based on which the studied models were developed and calibrated.

Evaluation of Nominated Dynamic Modulus Models

Conclusions

- Dynamic moduli of 28 different typical dense graded Australian asphalt mixes were tested over a spectrum of temperatures, loading frequencies and confinement pressures.
- Dynamic modulus master curves for the studied mixes were developed and a database of mechanical behaviors and performance properties of the mixtures was established.
- The accuracy of four most commonly used dynamic modulus predictive models was established (1344 data points).
The level of bias and error developed in the models suggested that the application of the nominated models to predict $E^*$ for Australian mixes is impractical.

Obtaining reliable dynamic modulus predictions requires modification and calibration of the models against Australian asphalt materials.

Future work: Extension of the developed local database (Various binder types, asphalt technologies e.g. Warm mix asphalt,...)