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Project Title

Relation between Dynamic Modulus of Asphalt Material and Its Cracking Tolerance

University

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Principal Investigators

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Research Needs

The pavement structural design process and the asphalt materials that are used to build these pavements are currently disconnected. Asphalt mixture properties obtained from adopted quality-control or quality-assurance (QC/QA) tests such as the IDEAL CT are not used as input to the pavement structural design process. While AASHTOWare Pavement ME® has been adopted in the structural design, the actual material inputs required in the process are not always available, resulting in the use of average or default values that do not necessarily represent what is placed in the field (i.e., Level 3 inputs). This practice results in the AASHTOWare Pavement ME® process over/under estimating rutting, fatigue, and thermal cracking in pavement sections. Cost optimization opportunities are therefore being missed.

Previous work done as part of an MPC project resulted in the development of a theoretical relation between the cracking tolerance index (CT index) obtained from the IDEAL CT and the dynamic modulus obtained from the AMPT testing. This theoretical relation was developed based on the work done during dynamic modulus testing and the transfer of energy to create a new surface (i.e., a crack). It was hypothesized that that energy is related to the fracture energy obtained from the IDEAL CT test, and part of the CT index. Such theoretical relation was verified using a limited number for asphalt mixtures obtained from the field. However, an actual predictive relation is needed to incorporate the results from the single value tests (i.e., CT index) and the dynamic modulus master curves that is used as input to the pavement structural design software. Such relation could potentially reduce the testing requirements to design pavements and allow for predictions based on actual material used in the field.

Research Objectives

The overall objective of this research is to develop a relation between material tests that are currently being used for quality control and the dynamic modulus, E*, master curve values used as input to the pavement design software (Level 1 in AASHTOWare Pavement ME®). It is expected that such relation will allow for a selection of an E* master curve that is directly related to the asphalt mixture used in the pavement. To accomplish this objective a multi-phase approach was adopted, the first phase developed a theoretical model and confirmed the relation between variables. This phase of the overall project proposes to confirm the applicability of the theoretical model based on new asphalt mixtures and to develop a relation between the cracking tolerance index of asphalt mixtures and their dynamic modulus master curve.

The specific objectives of this work are:

1. Validate the theoretical and experimental results previously obtained using asphalt mixtures with different properties (i.e., different binder grade, different RAP content).
2. Develop a relation to predict the asphalt mixture dynamic modulus master curve using the IDEAL CT data.
3. Simulate dynamic modulus master curves obtained from the different mixtures using IDEAL CT data. Then validate this simulation by comparing the predicted values with actual dynamic modulus data.
4. Propose a framework to incorporate other tests currently used for mixture testing (i.e., Hamburg WTD and BBR).

Research Methods

This research will coordinate with asphalt mixture producers to obtain asphalt materials that are approved by highway agencies and represent actual materials placed on the roads. The team will test them using the IDEAL CT test to obtain their cracking tolerance index. The same asphalt mixtures will be tested using the Asphalt Mixture Pavement Tester, AMPT, to obtain the dynamic modulus of the material. Using the dynamic modulus data at different temperature and frequencies, a master curve of dynamic modulus versus reduced frequency will be developed. The values will be organized in a manner consistent for input into AASHTOWare Pavement ME® design software. The characteristic of each master curve will be determined using different statistical methods and machine learning algorithms so that the relation between the materials cracking tolerance and the dynamic modulus characteristics will be determined. An already existing dataset has been analyzed and correlations were developed so the new data will be used to validate previous results and create a relation that incorporates different mixtures. Once this relation is established, it could be used to select typical master curves that relate to the cracking tolerance index, thus allowing practitioners to develop the required input for pavement design based on the characteristics of the actual material being placed on the roads.

Expected Outcomes

The expected outcome of this work will include a relation that can be used to predict the dynamic modulus master curves of asphalt mixtures based on the cracking tolerance index. This relation will likely relate cracking tolerance values to a characteristic dynamic modulus master curve that matches the prediction. In other words, a ‘family’ that can then be used as input to the AASHTOWare Pavement ME® design software currently being adopted across the country.

Having the ability to produce a dynamic modulus master curve that is closer to the properties of the materials being placed on the field (as opposed to the Level 3 inputs based on national averages) will allow for more locally targeted designs and potentially longer lasting pavements.

Relevance to Strategic Goals

This work is directly related to the USDOT strategic goal of State of Good Repair; by having the ability to relate material properties to pavement design, highway agencies and industry partners could optimize the design of asphalt mixtures to improve its longevity and thus minimize the life-cycle cost of the system.

At a regional level, this is part of the stated activities to improve pavement mixes to minimize weather-related cracking and to the development of quality-control acceptance standards for high performance pavements.

Educational Benefits

Given the limited funding, one graduate student will assist on this project. Student will be involved in all aspects of the project including data collection, analyses, and development of limits. Beyond the obvious acquisition of knowledge, by being involved in the research the student will have to present results and write journal articles on the discoveries, thus greatly improving his/her communication skills.

At the end of their studies, the student will join the workforce as knowledgeable practitioners.

Technology Transfer

The main objective of this work is to relate material testing, currently done by most highway agencies and structural pavement design. Technology transfer will be an integral component of this project since this work is part of a larger project with partners both from state highway agencies and asphalt material producers. There is a UDOT advisory committee in place who would guide the process and ensure the technology will be applicable to the state department of transportation as well as the region. Furthermore, the work will include publication in the leading journals and presentation in conferences such as the Transportation Research Board Meeting that occurs every January. The PI will work with MCP staff to advertise the results so that other interested parties can benefit from the technology being developed.

A report will be provided so that agency leaders, materials engineers, and interested staff can evaluate for themselves the relation between the quality of materials as obtain from existing tests and the structural design of pavements. Using AASHTOWare Pavement ME®, the performance of the pavement can be predicted allowing for optimization purposes.

Work Plan

To accomplish the objectives of this project, he following major tasks are anticipated:

1. Testing of selected mixtures
    a. A set of plant-produced mixtures will be collected and then tested using the IDEAL CT test at 25 ºC following standard protocols. The mixtures will be different than the ones previously tested to ensure the models being proposed are applicable to most mixtures.
    b. Samples from the mixtures obtained in 1a will be fabricated and tested using the AMPT at 3 temperatures and 3 or 4 frequencies to generate their dynamic modulus master curves.

2. Dynamic Modulus Master Curve Relation
    a. Based on the results from Task 1, dynamic modulus master curve parameters will be related to the CT index. This relation will cover the full master curve based on the parameters that defined the curve
    b. Using the relation developed as part of 2a, dynamic modulus master curves will be simulated and compared to the measured values previously obtained. The error between the simulated values and the measured values will be quantified.
    c. If available, the simulated dynamic master curve results will be used as input to the AASHTOWare Pavemewnt ME® software and the predicted performance will be documented.
3. Final Report
    a. A final report will be written following MPC standards that describes the work done and provides guidelines for selecting asphalt concrete dynamic modulus master curves as input in the AASHTOWare Pavement ME® software.

Project Cost

Total Project Costs:	$90,000
MPC Funds Requested:	$40,000
Matching Funds:	$50,000
Source of Matching Funds:	Utah Department of Transportation