EXHIBIT A
SCOPE OF SERVICES

IMPACT OF LOWER ASPHALT BINDER FOR COARSE HOT MIX ASPHALT MIXES

BACKGROUND

Historically, asphalt mixes in Minnesota have been produced to be fine graded in nature. In recent years, there has been a large number of relatively coarse graded mixes being produced and used in highway construction. These coarse graded mixes typically have low total asphalt binder content as compared to the fine graded ones. The performance of the coarser low asphalt content mixes is not known. Some preliminary testing has shown that these mixes might be prone to premature cracking. Furthermore, the use of coarser mixes with lower asphalt content increases the permeability of the mix making them more prone to moisture induced damage. The increased permeability of mix is counter to pavement design assumption of dense graded surface layer that drains water over surface away from underlying granular layers. Thus pavements with permeable asphalt mix will be more susceptible to moisture damage as well as other distresses due to the reduction of unbound layer modulus values.

A study is needed to quantify the performance effects and pavement service life of these lower asphalt binder coarse mixes. It is very important to evaluate the asphalt mixes that are locally produced and placed in Minnesota and produced according to MnDOT's 2360 Specifications. The main objective of this study will be to quantitatively and qualitatively determine if the low asphalt binder coarse mixes are prone to performance issues and make recommendations regarding potential solutions to alleviate any identified problems. This project will evaluate 10-12 low asphalt binder content mixes from actual field projects. The field samples will be subjected to a battery of tests to determine the pavement performance using, fracture energy, dynamic modulus and permeability measurements. The lab results will be analyzed to predict the distress severity and life expectancies of the pavements. An in-depth statistical analysis will also be conducted to identify and quantify the effects of total asphalt binder content on pavement performance. Final outcomes will include quantitative measures of how asphalt binder content in coarse graded mixes affect pavement performance and recommendations on whether changes are necessary to the asphalt mix specifications (2360).

OBJECTIVE

The main objective of this study is determine if the coarse asphalt mixes with low binder content are prone to a reduced pavement service life and increased performance problems. The results from the study will not only provide answers to this question but also provide estimates of the pavement performances for low binder content mixes. The findings of this study will help modify MnDOT's 2360 Material Specifications for asphalt mixtures. The modifications will ensure that pavements provide the service for as designed time duration and have minimal performance problems that reduce the future rehabilitation and maintenance costs. The University will prepare a brief two page summary report for each of the pavement sections studied through this project. These reports will be helpful to the road owners in developing policy guidelines. The end users of this study will be MnDOT's Office of Materials and Road Research, MnDOT's District Offices and Local Agencies (Counties and Cities) across Minnesota that adopt MnDOT's material specifications for bituminous mixtures. The research team will make recommendations on the next steps to consider as part of the implementation efforts, this could range from recommendations for modifications to MnDOT's 2360 Specifications to conducting a comparative evaluation study of plant produced mixes at various asphalt binder contents and long term field pavement performance information.

SCOPE

This study will be conducted in four main steps and its scope will include evaluation of 10-12 asphalt mixes from pavement sections that were constructed within past 1-4 years. The first step will involve extensive interaction with the members of Technical Advisory Panel (TAP) to identify the locations of the projects. The Materials Data Records (MDR) will also be assessed to screen asphalt mix designs that meet the criteria of coarse graded mixes with low asphalt content. The second step will include development of a sampling plan that will be provided to MnDOT and any other participating agencies (Counties, Cities, etc.) to procure the field samples. The third and fourth steps will undertake majority of research contributions, they will include a battery of laboratory tests on the field core samples and a series of performance prediction and statistical analyses. The details on the laboratory testing and analysis are described next.

Laboratory Testing: The University will conduct a number of laboratory characterization tests on the field samples to obtain the necessary information on the performance of the asphalt mixes. The testing will include: 1) Volumetric; 2) Lab permeability; 3) Disk-shaped compact tension fracture; 4) Dynamic Modulus (E*); 5) Asphalt content and gradation testing; and 6) Dynamic Shear Rheometer (DSR) testing on extracted and recovered binder.

The volumetric testing will provide information regarding various gravimetric parameters of the mix including, air void level, adjusted Asphalt Film Thickness (AFT), Voids in Mineral Aggregates (VMA), dust to effective binder ratio, etc. In the next step of the study, these parameters will be compared to the performance test results and predicted pavement life to evaluate their suitability as a specification criteria.

A study by Cooley et al. demonstrated that the coarse graded asphalt mixes are more prone to higher field permeability and further that a significantly greater increase in permeability results with a smaller increase to air void levels as compared to fine graded mixes. Increased permeability significantly increases the rate of mix deterioration due to higher potential for moisture induced stripping and freeze-thaw damage. Based upon the pavement design assumption of utilizing dense graded mixes and that rainfall would primarily drain across the surface of a pavement, highly permeable mixes would be counter to this assumption and thus be more susceptible to moisture damage as well as other distresses due to the reduction of unbound layer modulus values. Lab tests on cored samples will be conducted in the proposed study to measure the permeability of asphalt mixes. The measured permeability will be correlated to the lab measured performance test results (fracture and dynamic modulus) and to the predicted pavement performance.

The Disk-Shaped Compact Tension (DCT) fracture test has been successfully utilized in the past few years for prediction of the low temperature and reflective cracking performance of asphalt pavements and overlays. A recently completed low temperature cracking pooled fund study recommended the use of DCT fracture test as part of material selection criteria to screen the mixes prone to cracking. A recent MnDOT study recommended use of the DCT as a suitable test for purposes of performance based material specifications. The DCT tests will be conducted on the field cored samples from each pavement project. The DCT measurements will be compared against the recommended values from the low temperature cracking pooled fund study as well as used in conjunction with the IlliTC thermal cracking simulation model to predict the pavement cracking performance.

The E* test has been studied extensively in through series of National Cooperative Highway Research Program (NCHRP) studies. The test procedure has been proposed as Asphalt Material Performance Test (AMPT) and has been recommended as the test of choice for evaluation of rutting and fatigue cracking performance of asphalt mixes. The E* is also a primary input into the American Association of State and Highway Transportation Officials (AASHTO) Mechanistic-Empirical Pavement Design Guide (MEPDG), now referred to as Darwin M-E. The E* measurements will be made in this study at multiple test temperatures and loading frequencies. The E* test requires a 4" diameter and 6" high cylindrical specimen. The specimens will be obtained by reheating and compacting the asphalt mix from field core samples. The reheated samples will be compacted to achieve the same density and volumetric properties as the in-place conditions.

The specimens will be provided to MnDOT's Chemical Lab for extraction and recovery of asphalt binder and to conduct DSR testing on recovered binder. The DSR testing will provide the necessary input for conducting the Darwin M-E analysis.

At the conclusion of mechanical testing, the test specimens will be used to conduct the ignition oven tests. The ignition oven test provides the asphalt binder content information for the mixes. This information will provide further check against the MDR and also useful in analyzing the effect of total binder content on various properties as well as the gradation.

Data Analysis and Performance Prediction: The laboratory measured properties from previous step will undergo a series of analysis steps in this portion of the project. The main objectives of the analysis are twin fold: 1) Predict performance and service life of the pavement sections studied through the proposed project; and 2) Identify and quantify the effects of asphalt binder content in coarser mixes on the pavement performance measured evaluated in lab as well as predicted performance and service life.

The first objective will be realized through use of the IlliTC model and Darwin M-E. The IlliTC model was developed through the pooled fund study on low temperature cracking in asphalt pavements for which MnDOT was the lead agency. The University's Principal Investigator (PI) was key contributor to the development of the model. The IlliTC model utilizes the DCT fracture energy in conjunction with information regarding the pavement cross section and location to predict the thermal cracking performance of the roadway. This study will also utilize Darwin M-E with the objective to gain insight on the rutting and fatigue cracking performance of the pavement sections. The dynamic modulus measurements from the lab testing effort will be key input information as well as the pavement structure and loading conditions for prediction of performance and service life.

The second analysis step will be conducted through statistical investigation. Statistical analysis will be conducted to: 1) Identify if the low asphalt binder content in coarser mixes is significantly affecting lab measured performance properties and predicted pavement service lives; and 2) Quantify instances where asphalt binder content has a significant effect those effects.

***Mix Summary Sheets*:** For each of the asphalt mixes evaluated in this study, the University will prepare a 1-2 page long summary sheet. The summary sheet will show the information regarding the location of the pavement section, type of asphalt mix, project number as well as the lab measured properties (permeability, DCT fracture energy, dynamic modulus, volumetric properties) and predicted pavement performance and service life. These summary reports are expected to provide comprehensive information to the engineers at MnDOT's District and Materials Offices, as well as participating local agencies regarding the field sections. The summary reports will also help make plans for future pavement maintenance and rehabilitation for the roadways with low asphalt binder coarse graded mixes.

ASSISTANCE

MnDOT's Office of Materials and Road Research will take field cores and provide them to researchers. The MnDOT Chemical Lab will perform extraction and recovery of asphalt binder from samples provided to them by researchers and conduct DSR testing. MnDOT's Office of Materials and Road Research will assist researchers in conducting Darwin M-E analysis.

WORK PLAN

Task Descriptions

Task 1: MDR Data Collection and Selection of Field Section for Evaluation

In this task, the researchers will have a series of interactions with the TAP to identify the field sites for evaluation of asphalt mixes. The researchers will analyze the MDR to make proposals for potential study locations. A current MnDOT research study, being conducted by the University's PI, will help in obtaining some pavement performance data from the MnDOT's pavement management system. A total of 10-12 asphalt mixes will be selected for procuring samples and conducting laboratory tests and analysis.

Task 2: Field Sampling Plan and Sample Procurement

In this task, the researchers will develop a field sampling plan and provide it to the agencies. The sampling plan will provide details on the location of coring as well as the quantity and dimensions. The number of field cores from each pavement section is anticipated to be between 17-25, based on the thicknesses of asphalt lifts. The cores should be 6" in diameter. The agencies will procure the cored samples and have them delivered to MnDOT's Office of Material and Road Research laboratory. The researchers will travel to the laboratory to split the samples while ensuring that representative samples are distributed amongst the universities.

Task 3: Laboratory Testing

In this task, the researchers will conduct the laboratory tests on the field samples. This task overlaps with the previous task for duration of three months to facilitate testing to samples as they are made available to the researchers. The laboratory testing will include following:

1. ***Volumetric Testing*** (the University and Iowa State University [ISU]): Volumetric parameters of the mix will be determined through gravimetric testing and analysis. Properties such as air void content, adjusted AFT, VMA, etc. will be determined. The information from the MDR will be used in conjunction with the volumetric measurements for calculation of various properties.

2. ***Lab Permeability Testing*** (the University): The permeability of the cored samples will be determined using the falling head method.
3. ***DCT Fracture Tests*** (the University): The DCT testing according to the American Society for Testing and Materials (ASTM) D7313 specifications will be conducted. At least three test replicates will be tested at the test temperature representing 10° C warmer than the required low temperature performance grade by the Superpave PG system at a 98% level of reliability. The test results will provide fracture energy and estimated tensile strength of the mixture.
4. ***E* Tests*** (ISU): The dynamic modulus testing will be conducted on the specimens that will be prepared in the lab using the reheated and lab compacted mix from field cores. The lab compacted specimens will be manufactured to identically represent the air void content of the field and to a dimension of 4" diameter and 6" height. The E* tests will be conducted at nine frequencies (0.03, 0.1, 0.3, 0.5, 1.0, 3.0, 5.0, 10.0, 25.0 Hz) and three test temperatures (4, 21 and 38° C).
5. ***Asphalt Content and Gradation Tests*** (the University and ISU): Half of the asphalt mix specimens from the mechanical tests (DCT and E*) will be testing using the ignition oven to determine the asphalt content of the mixes and aggregate gradation.
6. ***Binder Extraction and Recovery and DSR Testing*** (MnDOT's Chemical Lab): The other half of specimens from mechanical testing will be provided to MnDOT's chemical lab for extraction and recovery of the binder. The recovered binder will be testing using the DSR to determine the complex shear modulus (G*) and phase angle of the binder. These are necessary inputs into the Darwin M-E.

Task 4: Data Analysis and Performance Prediction

In this task, the researcher's will analyze the laboratory test results from the previous task to evaluate the pavement performance and to develop brief reports on each project. The data analysis will include the following:

1. ***IlliTC Cracking Analysis*** (the University): The IlliTC simulations will be conducted for all the pavement sections studied in the proposed project. The analysis will provide the predicting transverse cracking performance for each section and allow researchers to correlate the pavement performance with the impacts of asphalt binder content in coarse mixes.
2. ***Darwin M-E Analysis*** (the University and MnDOT): The Darwin M-E (formerly known as, AASHTO MEPDG) analysis will also be conducted for the pavement sections to predict the rutting and fatigue cracking performances. Similar to IlliTC analysis, the predicted distresses from Darwin M-E will be correlated to the effect of asphalt binder content in the mix.
3. ***Statistical Analysis*** (ISU): A statistical analysis of the measured material properties will be conducted to identify and quantify the significance of total asphalt binder content in mixes on the various lab measured performance related properties (permeability, fracture energy, dynamic modulus). The statistical analysis will also provide insight on the effects of various asphalt mix volumetric properties on pavement performance.

This task will also include producing a 1-2 page summary sheets on each of the roadway section that provides information about the project location (Stat Project Number, MDR information), mix volumetrics, lab measured permeability and performance related mechanical properties (fracture energy, E*), and predicted field performance from IlliTC and Darwin M-E. The analysis will also result in recommendations regarding whether performance issues can arise from the low asphalt binder content mixes or not, and if so, then the type of issues.

Task 5: Compile Report, TAP Review and Revisions

In this task, the University will prepare a draft report, following MnDOT's publication guidelines, to document project activities, findings and recommendations. This report will need to be reviewed by the TAP, updated by the University's Principal Investigator and then approved by the Technical Liaison before this task is considered complete. Holding a TAP meeting to discuss the draft report and review comments is strongly encouraged. TAP members may be consulted for clarification or discussion of comments.

Task 6: Final Published Report Completion

During this task, the Approved Report will be processed by MnDOT's Contract Editors. The editors will review the document to ensure the document meets the publication standard. The University will then prepare a Final Report and submit it for publication through MnDOT's publishing process.

Task Deliverables

Task:	Deliverable(s):
1:	Summary Report on Task 1; A List of Field Sections for Evaluation
2:	Field Sampling Plan; Summary Report on Task 2
3:	Summary Report on Task 3
4:	Summary Report on Task 4; 1-2 Page Summary Reports for each Field Site
5:	Approved Report
6:	Final Published Report

PROJECT SCHEDULE

Task Durations

Months:	2013					2014												2015						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Task 1	X	X	X	X																				
Task 2					X	X	X	X	X	X	X	X												
Task 3									X	X	X	X	X	X	X									
Task 4																X	X	X	X					
Task 5																				X	X	X		
Task 6																							X	X

Task Completion Dates

Task:	Completion Date:
1:	November 30, 2013
2:	July 31, 2014
3:	October 31, 2014
4:	February 28, 2015
5:	May 31, 2015
6:	July 31, 2015

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