MnROAD [Safer, Smarter, Sustainable Pavements through Innovative Research]

Implementation of the Disk-Shaped Compact Tension Test

Introduction

The most prevalent asphalt pavement distress found in cold climate regions is low-temperature cracking (LTC). Once formed, cracks allow moisture ingress and deterioration from traffic loads, deicing chemicals and freeze-thaw cycles. The goal of recent MnDOT efforts in this area have been to evaluate different laboratory procedures, material properties and pavement features in order to develop an optimal system for selecting low temperature crack resistant asphalt mixtures.

Current MnDOT specifications combat thermal cracking by specifying low temperature binder grades. This is not enough though, and asphalt mixtures as a whole must be tested to account for differing aggregate type, gradation, and presence of recycled materials. The LTC phase II pooled-fund study TPF-5(132) recommended using the Disk-Shaped Compact Tension Test (DCT) to address thermal cracking. The study, a combined effort of several state DOTs (Connecticut, Iowa, New York, Wisconsin, and North Dakota), the Federal Highway Administration, MnDOT Office of Research Services, Local Road Research Board, MnDOT Office of Materials and Road Research, and MnROAD, was performed by University of Illinois, University of Minnesota (Twin Cities and Duluth), Iowa State University, and University of Wisconsin-Madison.

What is the DCT Test?

The DCT test is used to determine the fracture energy of brittle materials under tensile stresses, similar to what develops in an asphalt pavement as it shrinks during cooling. Fracture energy of a mixture, calculated as Joules per square meter (J/m^2), has been found to be a good indicator of resistance to low-temperature cracking in asphalt pavements. The DCT test is performed on a 150-mm diameter, 50-mm thick cylindrical specimen with two holes cut for loading the sample, a flat face to mount gage points, and a notch cut to initiate the crack. Seen to the right, the specimen is mounted in the testing chamber. The crack displacement gage can be seen, which measures crack propagation in response to loading of the sample. Samples are conditioned and tested at a temperature 10°C warmer than the low temperature performance grade of the asphalt binder. For example, if the performance grade for a mix is 64-34, the sample will be conditioned and tested at -24°C. Typical test temperatures in Minnesota are -18°C, -24°C, or -30°C. The DCT test is run by applying a tensile load with a constant rate of crack mouth opening displacement (CMOD) of 1 mm/min. The load applied to the sample as well as the CMOD are used in calculating the fracture energy of the mix.

DCT specimen mounted in fixture with CMOD gage located at right.

Recent Implementation Work

Using recommendations made in the LTP phase II pooled-fund study DCT requirements were specified on five asphalt paving projects in Minnesota during the 2013 season. In the "DCT Low Temperature Fracture Testing Pilot Project" contractors provided gyratory specimens at mix design stage to the University of Minnesota Duluth for testing. Mixture adjustment recommendations were made if the fracture energy did not meet the minimum value of 400 J/m^2.

Additional costs incurred with mix design changes were provided through Destination Innovation funds. The current recommendations for minimum fracture energy based on traffic level are seen in the table below:

	TRAFFIC LEVEL		
	Low <10M ESALS	**Moderate 10-30M ESALS**	**High >30M ESALS**
Minimum Fracture Energy (J/m^2)	400	460	690

Utilizing DCT Test Results

In practice, DCT results provide data that can be used to improve asphalt mixes by increasing fracture resistance. Some of these recommendations include:

- Reducing amount of recycled materials (RAP or shingles)
- Reducing the low end temperature performance grade
- Increasing the high end temperature performance grade
- Using modified asphalt binder instead of unmodified
- Using a harder, crushed quarry rock opposed to limestone or gravel aggregates
- Increasing binder content of the mixture
- Using a smaller nominal aggregate size

Next Steps Toward Implementation

In 2014 MnDOT is actively working towards implementation with refinement of test procedures and specifications. Work is being done to learn to what extent differences in fracture energy exist between mix design stage, laboratory hot compacted and re-heated samples from production, and post-construction cores. A recently produced video demonstrates DCT sample preparation to ensure consistent practices between testing laboratories. Two separate projects involve an inter-laboratory study to determine the precision and repeatability of the DCT test between different labs and another to review the use of DCT test results as performance requirements within agencies both regionally and nationally. This review will provide insight to implementation approaches, test procedures, specifications, and experiences acquired by others. During the next two upcoming construction seasons MnDOT will push towards final implementation of the DCT test and fracture energy requirements in bituminous specifications for MnDOT and conduct training.

For further information about MnDOT research on low-temperature cracking and DCT test implementation, contact:

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A recently produced video demonstrates sample preparation for the DCT test:
http://youtu.be/7gLU83b6eSs