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 has 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. Specimens are conditioned and tested at temperatures 10°C warmer than the 98% reliability low temperature in which they will be constructed, as determined by LTPPBind 3.1 software. Typically for Minnesota these test temperatures are between -18°C and -30°C. The DCT test is run by applying a tensile load with a constant rate of crack mouth opening displacement (CMOD) of 0.017 mm/s (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 construction season. In the "DCT Low Temperature Fracture Testing Pilot Project", contractors provided gyratory specimens at mix design 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. Samples were then taken at production and a final test was conducted to determine if the recommended mixture adjustments had an effect on fracture energy. Additional costs incurred with mix design changes were provided through Destination Innovation funds.

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 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
- Reducing amount of recycled materials (RAP or shingles)
- Using a smaller nominal aggregate size

Next Steps Toward Implementation

During the 2014 construction season, MnDOT efforts toward implementing the DCT into QC/QA provisions in Minnesota include an inter-laboratory study to determine the precision and repeatability of the DCT test between different labs. Additional work is being done to learn to what extent differences in fracture energy exist between mix design, laboratory hot compacted and re-heated samples from production, and post-construction cores. MnDOT also recently produced a video demonstrating DCT sample preparation.

A separate study is being conducted to review the use of DCT test results as performance requirements within agencies both regionally and nationally. This review will help gain insight to implementation approaches used by others as well as how they are utilizing the DCT results and improving mixes with this information.

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