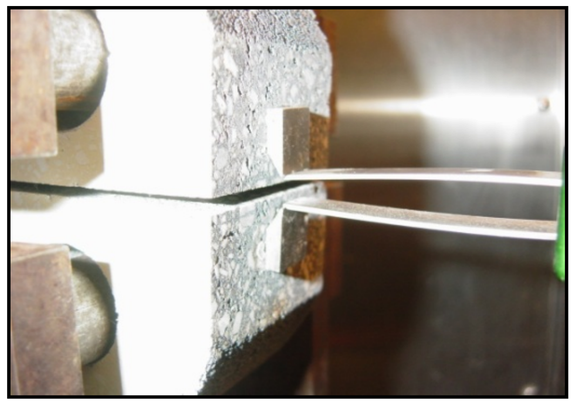
Disk-Shaped Compact Tension Test

Dr. Bill Buttlar – University of Illinois

Background

The Disk-Shaped Compact Tension Test (DC(T)) as shown in Figure 1 is specified in ASTM D7313(07), which is provided in Appendix A. The test is generally used to obtain the fracture energy of asphalt mixture lab or field specimens, which can be used in performance-type specifications to control various forms of cracking, such as thermal, reflective, and block cracking of pavements surfaced with asphalt concrete. Standard testing is conducted at 10C warmer than the PG low temperature grade.

(1a)



(1b)

Figure 1 – The DC(T) test (Figure 1a) and CMOD gage attached to gage points (Figure 1b)

The DC(T) test is run in crack mouth opening displacement (CMOD) control mode at a rate of 1 mm/min. Typically, specimens are completely failed in the range of 1 to 6 mm of CMOD travel. Although the actual test takes only 1 to 6 minutes to perform, the actual amount of testing time per specimen is probably more akin to 15 minutes, accounting for stabilization of test temperature, loading samples into the test apparatus, etc.

Sample preparation involves sawing and coring operations. First, a water-cooled masonry saw (14 or 20 inch blade) is used to create the flat, circular faces, similar to the production of an indirect tension test specimen or simple performance test specimen. A single or dual saw system may be used. A dual saw system, while more costly, will produce more parallel faces and uniform thickness specimens, which may improve test repeatability. A marking template is then used to indicate the location of the 1.0 inch loading holes to be drilled, as shown in Figure 2. A water-cooled drilling device is then used to fabricate the loading holes.   Next, a smaller masonry table saw is used to produce the final two cuts: a flattened face to facilitate the placement of the CMOD gage (see Figure 1b) and a notch, which is a necessary feature of a true fracture mechanics based test. Figure 3 illustrates a dual-masonry saw system, which simultaneously produces the flat face and notch on two separate specimens (the saw on the left produces the flat face, while the saw on the right produces a notch on a second specimen). After one operation of the dual saw, the specimen on the left is rotates 90 degrees and moved to the saw table on the right, the specimen on the right is complete, and removed from the sawing device, and a new specimen is placed on the saw table on the left and the dual sawing process is repeated in assembly line fashion.

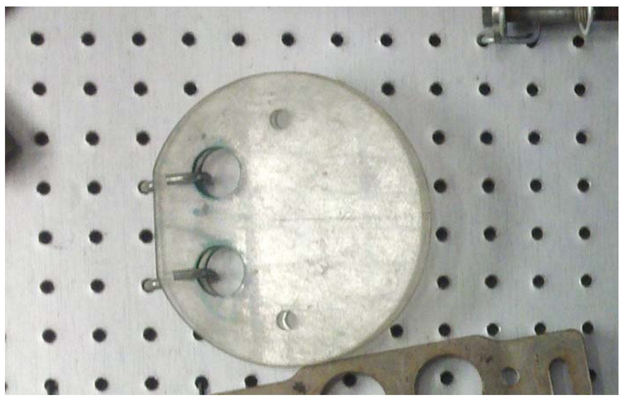


Figure 2. Marking template

Time, cost, and repeatability of DC(T) testing

Researchers at the University of Illinois have determined the average fabrication time per specimen to be in the 10 to 15 minute range for DC(T) testing, which includes the four saw cuts and two cored holes. This is based upon mass production of at least a dozen test specimens. The fabrication of fewer test specimens will obviously lead to a longer per-specimen preparation time. Thus, combined with testing time, each DC(T) test will take approximately 30 minutes of technician time for specimen preparation and testing when larger batches of specimens are tested. Material testing labs are currently charging in the neighborhood of $200 per test specimen (replicate) for DC(T) testing, and somewhat less for larger quantities of specimens ($150 per test). This is similar to the cost to perform other mixture and binder performance tests. The typical COV associated with DC(T) testing is around 10%; less for carefully controlled lab experiments with precisely fabricated specimens and uniform materials, and more for less carefully prepared and/or less homogeneous lab specimens and field cores. A COV level of 10% is excellent when compared to other fracture tests performed on infrastructure materials, which can have COV levels of 20 or even 30% or more.

Estimated Cost of DC(T) Apparatus

The individual cost of the components required to build a DC(T) apparatus on an existing servo-hydraulic loading machine are estimated as:

Item	Estimated Cost
Loading Fixtures	$3,000.00
X-Y Tables to facilitate coring and sawing	$1,500.00
CMOD Extensometer (Epsilon)	$1,400.00
Temperature-Chamber*	$20,000.00
Temperature modules and thermocouples	$400.00
PC for Data Acquisition	$1,000.00
Labview Based Interface Board	$700.00
Coring barrels (qty = 5)	$500.00
Labview Software for Data Acquisition	$1,500.00
Labview Programming**	$3000.00
Dual water cooled masonry saws***	$10,000.00
Dual saw system for flat face and notching***	$7000.00

*A temperature chamber can be a major expense in low temperature performance testing of asphalt mixtures. The $20,000 estimate is for a high-power, condenser-type cooling chamber, capable of testing down to -30C. A lower cooling chamber cost can result if a less stringent cooling capacity is specified, or if a liquid-nitrogen based system is used.
** A simple Labview based data acquisition program (a labview "VI") can be provided to the participating states by the research team free of charge.
*** These items are optional, but recommended for labs conducting a high volume of testing

Equipment Cost Scenarios

Estimate #1
Lab with existing loading frame, existing cooling chamber, existing saws and coring rig, without optional dual saws: **$10,000.00** ($13,000 if Labview programming costs are to be included).

Estimate #2
Same as estimate #1, except cooling chamber purchase required: **$30,000.00**
(a lower estimate should be used if a simpler cooling chamber configuration is to be specified)

Estimate #3
Purchase of all components, including cooling chamber and both dual-saw systems: **$47,000.00**

Future Equipment Scenarios for DC(T) Testing – Commercially available apparatus

At least two equipment manufacturers have recently developed or are in the process of developing DC(T) test apparatus, the most notable being James Cox and Sons, Inc. Although exact cost estimates should be pursued by contacting the equipment manufacturers directly, it is estimated that a future, simplified DC(T) test based upon a screw-type actuator system, would cost in the range of $50k, not including dual-saw devices for sample prep. A more elaborate DC(T) test device, with a universal servo-hydraulic load frame capable of performing other tests, such as the simple performance test, IDT test, etc., would be expected to be in the $140k range. Dual-saw sample preparation apparatus is currently being manufactured by Precision Machine Works (PMW) out of Salinas, KS. PMW also manufactures a version of the Hamburg Wheel track test.

Semi Circular Bend Test

Dr. Mihai Marasteanu – University of Minnesota

Background

The Semi Circular Bend Test (SCB) is shown in Figure 3; a draft AASHTO specification is being developed at University of Minnesota and a copy of the draft in progress is provided in Appendix B. Similar to DCT, SCB test is used to obtain the fracture energy of asphalt mixture lab or field specimens, which can be used in performance-type specifications to control various forms of cracking, such as thermal, reflective, and block cracking of pavements surfaced with asphalt concrete. Standard testing is conducted at 10C warmer than the PG low temperature grade.

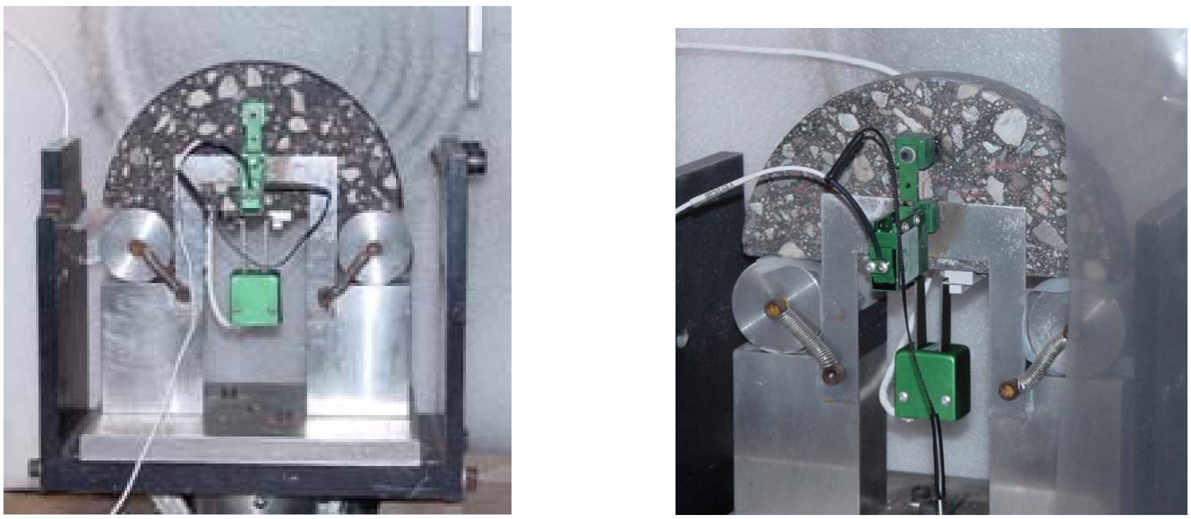


Figure 3 – The SCB test

Similar to DC(T) test, the SCT test is run in crack mouth opening displacement (CMOD) control mode. *However, the rate is 0.03 mm/min, 33 times slower than the DCT loading rate, which increases the duration of the test to as much as 30 minutes. Another significant difference is in the thickness of the specimen: DC(T) is 2" thick, while SCB is 1" thick.*

Sample preparation is similar to DCT except that no coring is required. The only additional operation is gluing one IDT-type button on each face of the specimen, which are used to measure load line displacement (the displacement in the direction of the applied force) required to calculate fracture energy.

Time, cost, and repeatability of DC(T) testing

Researchers at the University of Minnesota have determined the average fabrication time per specimen to be in the 10 to 15 minute range, similar to the time for DC(T) specimens preparation at University of Illinois. The typical coefficient of variation (COV) associated with SCB testing is around 20%; less for carefully controlled lab experiments with precisely fabricated specimens and uniform materials, and more for less carefully prepared and/or less homogeneous lab specimens and field cores. This is higher than the COV level of 10% reported for DCT.

Estimated Cost of SCB Apparatus

To facilitate the comparison of the costs associated with DC(T) and SCB, a table with the individual cost of the components required to build a DC(T) and a SCB apparatus on an existing servo-hydraulic loading machine are given below:

Item	**DCT**	**SCB**
Loading fixtures	$3,000	$1,000
X-Y Tables to facilitate coring and sawing	$1,500	0
CMOD Extensometer (Epsilon)	$1,400	$1,400
LLD extensometers (SCB only)	0	$4,000
Temperature-Chamber*	$20,000	$20,000
Temperature modules and thermocouples	$400	$400
PC for Data Acquisition	$1,000	$1,000
Labview Based Interface Board	$700	$700
Coring barrels (qty = 5)	$500	0
Labview Software for Data Acquisition	$1,500	$1,500
Labview Programming**	$3,000	$3,000
*Dual water cooled masonry saws****	*$10,000*	*$10,000*
*Dual saw system for flat face and notching****	*$7,000*	*$7,000*

*A temperature chamber can be a major expense in low temperature performance testing of asphalt mixtures. The $20,000 estimate is for a high-power, condenser-type cooling chamber, capable of testing down to -30C. A lower cooling chamber cost can result if a less stringent cooling capacity is specified, or if a liquid-nitrogen based system is used.
** A simple Labview based data acquisition program (a labview "VI") can be provided to the participating states by the research team free of charge.
*** These items are optional, but recommended for labs conducting a high volume of testing

For laboratories that have testing frames capable of performing other types of mechanical tests, it is usually possible to make simple changes to the testing instructions and perform either DCT or SCB tests using the existing software and existing signal conditioning boxes at no additional costs. In this case, the Labview interface board, software and programming are not required.