METHOD OF TEST FOR THE DETERMINATION OF ASPHALT CEMENT'S RESISTANCE TO DUCTILE FAILURE USING DOUBLE EDGE NOTCHED TENSION TEST (DENT)

1. SCOPE

1.1 This test method covers the determination of an asphalt cement's resistance to ductile failure using a double-edge-notched tension test.

1.2 The test is conducted after thermal conditioning to determine the essential work of fracture, the plastic work of fracture, and an approximate critical crack tip opening displacement at a specified temperature and rate of loading.

1.3 LS-299 has been published as a provisional test method. The test is a working document, continuous refinement to the test method may be expected.

2. RELEVANT DOCUMENTS

2.1	AASHTO R28	Accelerated Aging of Asphalt Cement Using a Pressurized Aging Vessel (PAV)
	AASHTO T 240	Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-film Oven Test)
	AASHTO T 300	Force-Ductility Test of Bituminous Materials
	AASHTO T 301	Elastic Recovery Test of Asphalt Materials by Means of a Ductilometer
	AASHTO T 315	Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)
2.2	ASTM D8	Standard Definitions of Terms Relating to Materials for Roads and Pavements
	ASTM D113	Standard Test Method for Ductility of Bituminous Materials

3. DEFINITIONS AND ACRONYMS

MOLD: consists of two end pieces and a pair of matching DENT inserts all fitted together as shown in AASHTO T 301.

W_t - total work of fracture, area under the load versus load-line displacement curve, J

w_t - specific total work of fracture (W_t / Bℓ), kJ/m^2

w_e - specific essential work of fracture, the energy required to fracture or break the sample without plastic deformation away from the fracture zone, kJ/m^2

w_p - specific plastic work of fracture, the non-essential work dissipated during the deformation of a volume of asphalt around the fracture zone, MJ/m^3

β - geometric constant describing the shape of the plastic zone

δ_t - critical crack tip opening displacement also referred to as CTOD, mm

P - load, N

d - displacement in test, m

B - sample thickness, m

ℓ - ligament length, the space between the notches, m

σ_n - net section stress of sample, N/m^2

4. APPARATUS

BASE PLATES: The base plates shall be made of non-absorbent material of sufficient thickness to prevent deformation and of a sufficient size to hold from one to three molds, but still able to fit in the temperature controlled bath for conditioning. The plate shall be uniformly flat to ensure that the bottom surfaces of each mold will touch it throughout.

TESTING APPARATUS: A constant rate of displacement device capable of maintaining displacement at rates of 50 ± 2.5 mm/min. The maximum stroke for the instrument(s) shall be 1000 mm or greater. The apparatus should have a set of loading pins that ensure precise alignment of the sample during the test. The apparatus shall be able to determine displacement to an accuracy of ± 0.05 mm.

Note: DENT testing apparatus is commonly a force-ductility apparatus installed in a ductilometer.

LOAD SENSOR: The sensitivity of the load sensor and recording electronics shall allow the load, P, to be measured every 0.3 sec during the test with an accuracy of at least ± 1%. The load sensor shall be capable of measuring a nominal maximum force of up to 133 N.

TEMPERATURE CONTROLLED BATH FOR TESTING: Bath shall be large enough to contain the testing apparatus and samples in their molds prior to testing under a minimum of 25 mm of water. The equipment shall be capable of maintaining the water at the testing temperature to an accuracy of at least ± 0.5°C.

TEMPERATURE CONTROLLED BATH FOR CONDITIONING: Bath capable of maintaining 25 mm minimum of water over the sample at the conditioning temperature requirements to within ± 0.5°C. Typically, the temperature controlled bath for testing is utilized.

GLASS STIR: Stick capable of stirring the hot asphalt cement vigorously.

END PIECES: Six end pieces from the elastic recovery specimen mold according to AASHTO T 301.

DENT INSERTS (Inserts): Six inserts made from a 360 brass, built to dimensions shown in Figure 1. These inserts come in pairs and each pair is manufactured to have a space between the matching pair of notches equal to the three different ligament lengths of 15, 10, and 5 mm when fitted with the end pieces.

5. PREPARATION OF SAMPLES

5.1 Prepare the DENT samples according to the procedure for Preparation of Apparatus and Molding of Test Specimens in AASHTO T 300 with the following exceptions and additional requirements.

5.2 Six samples shall be prepared using degassed PAV aged asphalt cement, 2 for each ligament length of 15, 10, and 5 mm by fitting each of the three matching pairs of inserts with three pairs of end pieces so the space between the matching pair of notches is equal to the three different ligament lengths of 15, 10, and 5 mm to a tolerance of 0.25 mm. Asphalt cement shall be short term aged according to AASHTO T 240 (RTFO) and long term aged according to AASHTO R28 (PAV). The aged asphalt cement shall then be heated for 1 h at 160 ± 5°C to ensure that the asphalt cement readily flows when dispensed from the container into the prepared molds.

Note: The heating temperature may be raised to a maximum of 180°C to provide a low enough viscosity but the sample material shall not be overheated.

5.3 Prior to pouring the asphalt cement into the mold, measure and record the actual ligament length, ℓ, to within 0.1 mm.

5.4 After any trimming, measure and record the sample thickness, B, in metres to 4 decimal places (to 0.1 mm). If trimmed flush with the mold, this will be the thickness of the mold.

6. TEST PROCEDURES

6.1 Condition the samples on the base plates at 15 ± 0.5°C for 3 hours ± 5 min in their molds in a temperature controlled bath under a minimum of 25 mm of water.

6.2 Once conditioned, prepare the sample for testing, without causing excessive deformation or stress concentrations to the sample, by removing the sample from the base plate. Keep the sample always under the surface of the water, detach the DENT inserts, and load it through the holes in the end pieces onto the testing apparatus' loading pins. The sample shall be loaded so there is a minimum of 25 mm of water below and above the sample. Allow the sample to sit and equilibrate for a minimum of 5 min before starting the test.

6.3 Run the test according to AASHTO T 300 at a displacement rate of 50 ± 2.5 mm/min in a bath maintained at 15 ± 0.5°C, until ductile failure is reached or a stroke length of 1000 mm is reached.

6.4 If ductile failure is not achieved before the stroke length of 1000 mm is reached, the test shall be stopped and retested as follows at a lower temperature: reheat the sample material in a manner that minimizes damage to the material (see section 5), prepare the sample as per section 5, and condition and retest according to steps 6.1, 6.2, and 6.3 at a temperature of 4 ± 0.5°C instead of 15°C as in the initial stopped run.

6.5 Record actual sample ligament length, ℓ, displacement rate, water bath temperature, and load every 0.3 sec for the entire test time.

6.6 Repeat steps 6.1 to 6.5 on the duplicate and then on all the other ligament length samples.

7. CALCULATIONS

7.1 Calculate the average W_t for each ligament length where W_t for each sample is:

$$W_t = \int_0^{t_f} P \times d \text{ , kJ}$$

t_f = time when ductile failure or the maximum stroke length is reached, which ever comes first.

Note: Any negative load readings or negative W(t) values are not to be included in calculating W_t. Any W(t) obtained after t_f are not to be included in calculating W_t. Although it is not always noticeable, additional data is often recorded for the run after failure. For example when the load is very small and then increases slightly or the load is very small and remains constant this data is a residual load on the device.. Please check each of the run sheets to ensure that these residual and any initial pre-start values are zeroed so they are not included in the total W_t.

7.2 Calculate w_t for each ligament length for each average W_t where:

w_t = (average W_t)/(Bℓ), J/m^2

7.3 Plot w_t for the three ligament lengths, ℓ, and draw a best fit straight line (see Figure 2 for an example). From the graph or using the method of least squares fitting, obtain values for w_e, and the term βw_p, where:

w_e is the specific essential work of fracture, i.e. w_t for ℓ = 0.0

βw_p is the slope of the best fit straight line, for $w_t = w_e + \beta w_p \ell$

7.4 Determine $\delta_t = w_e / \sigma_n$, where:

$\sigma_n = P_{peak} / (B\ell)$,

P_{peak} = average peak load obtained for the sample tested with the smallest ligament length, i.e. the average maximum load for the 5 mm ligament samples.

8. REPORTING OF RESULTS

8.0 Report the following on a form similar to Figure 4: w_e, βw_p, δ_t, P_{peak}, best fit line for the w_t versus ligament lengths plot and the plot (see Figure 2 for example), and for each ligament length the average actual sample ligament length, the average actual sample thickness, average W_t, w_t, and load versus displacement curves (see Figure 3 for example).

Figure 1 – DENT Inserts

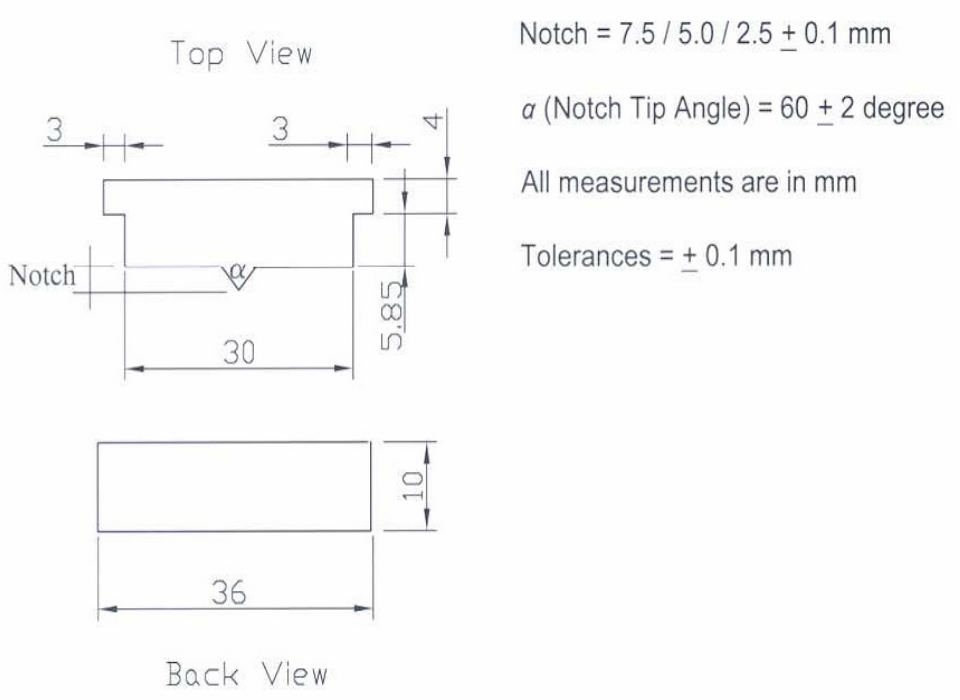

Figure 2 – Example w_t versus Ligament Length Plot for Determining Essential Work of Fracture

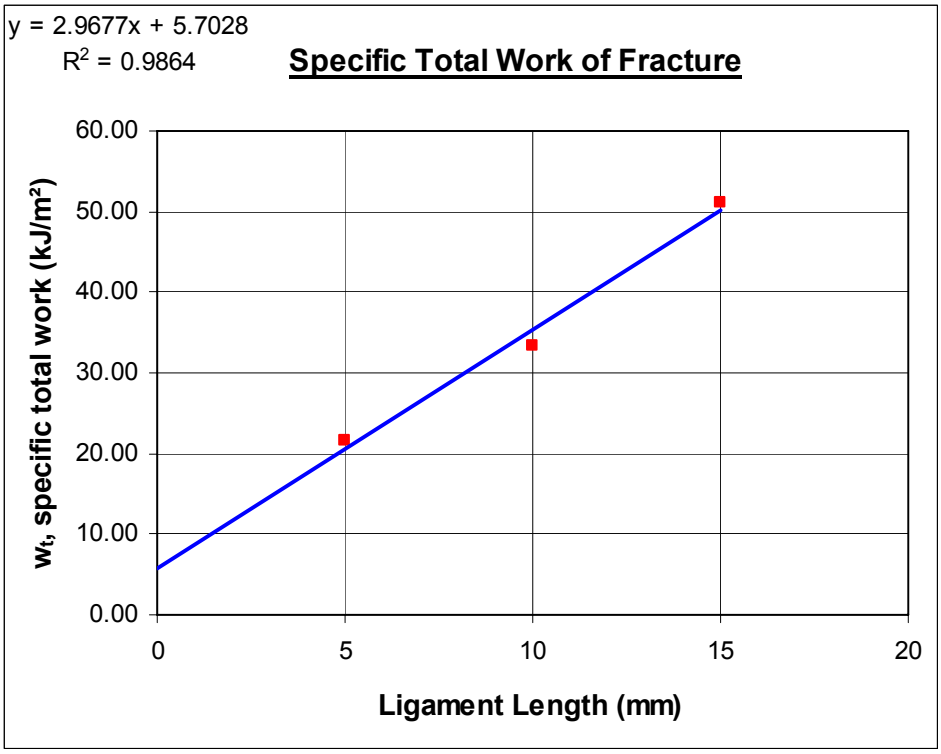

Figure 3 – Typical Load-Displacement Curves for Essential Work of Fracture Test

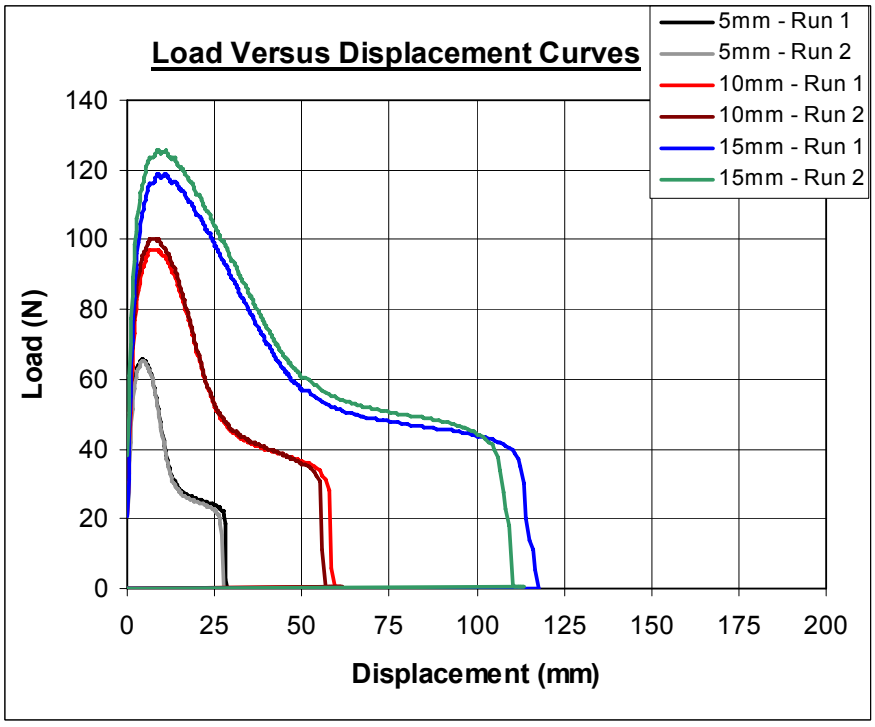

Figure 4 – Example Reporting Sheet