CE 400 Highway Materials Engineering

Homework #3: Asphalt Binder Properties
Due Thursday, March 6, 2008

1. (10 points) The log flexural creep stiffness versus log time data collected in the BBR test at -12C is automatically fit by the BBR software with a 2nd order polynomial as follows:

$$\log(S(t,T)) = A + B(\log(t)) + C(\log(t))^2$$

a) Derive an equation to solve for the creep rate, m, the slope of the log stiffness-log time curve. To derive the equation for m, solve the following derivative:

$$m = \left| \frac{d(\log S(t,T))}{d(\log(t))} \right|_{t=60\,sec}$$

b) Use your equation to solve for m for a binder at -12C with A=5.559, B=-0.038334, C=-0.10731. Don't forget to take the absolute value, as shown above. (Note: units, time is in seconds, S(t, T) is in kPa).

c) Plot logs(t, T) versus logt, and show your computed m-value as a tangent line to the curve at t=60sec. Plot the original data on log axis. In other words, do not take the log of the data and plot the "logged" data on arithmetic scales, because it's hard to interpret when plotted this way.

2. (10 points) A DSR testing data file has been sent to you by email. Those were run at standard conditions and 64°C degree temperature. Conduct a data analysis and answer the following questions:
   (1) Calculate Complex Shear Modulus
   (2) Calculate Loss Modulus
   (3) Calculate Storage modulus
   (4) Use the Superpave rutting criteria and ~~fatigue~~ criteria to check if this binder will pass. Consider both aged and un-aged conditions.

Homework 3 Asphalt Binder Properties Solutions

Question 1:

(3) a) $\log S(t,T) = A + B\log(t) + C\log(t)^2$

$$m = \left|\frac{d\log S(t,T)}{d\log(t)}\right|_{t=t_c} = \left|2\times C\log(t) + B\right|_{t=t_c}$$

(3) b) $A = 5.557$ $B = -0.08334$ $C = -0.10731$

$$m = \left|2\times(-0.10731)\times\log t_c - 0.08334\right| = 0.420$$

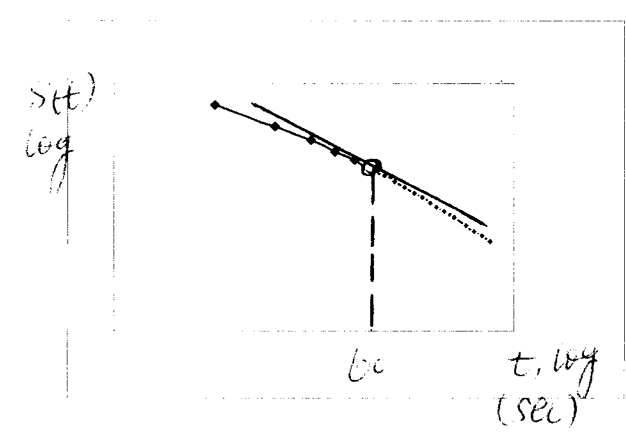
c) tangent line slope = −0.42 ∴ $\log S(t) = -0.42\log(t) + b$

$t = t_c$, $\log S(t) = 5.557 + (-0.08334)\log t_c + (-0.10731)\times\log^2 t_c = 5.1515\,\%$

(4) $\log S(t) = -0.42\log(t) + b$

$\Rightarrow b = 5.5984$ Tangent line $\log S(t) = -0.42\log(t) + 5.8984$

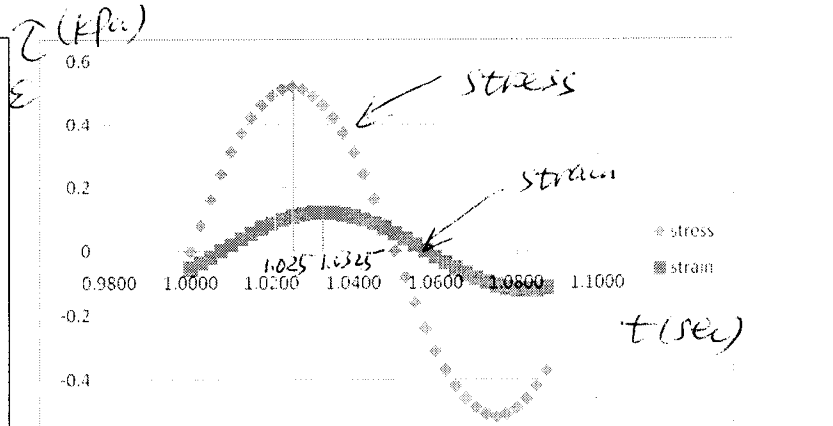
t	log(t)	log(s)	s	t	log(t)	log(s)	s
10	1	5.413356	259033.5	110	2.041393	5.033554	108032.4
20	1.30103	5.327485	212561.7	120	2.079181	5.015396	103608.7
30	1.477121	5.268238	185454.6	130	2.113943	4.998422	99637.27
40	1.60206	5.222165	166788.2	140	2.146128	4.982475	96045.03
50	1.69897	5.184121	152799.3	150	2.176091	4.967429	92774.54
60	1.778151	5.151541	141755.9	160	2.20412	4.95318	89780.03
70	1.845098	5.122945	132722.7	180	2.255273	4.92674	84477.38
80	1.90309	5.097397	125140.2	200	2.30103	4.902614	79912.34
90	1.954243	5.074262	118648.5	220	2.342423	4.880402	75927.94
100	2	5.053092	113003.5	240	2.380211	4.859802	72410.63



Question 2:

time (sec)	stress (kPa)	strain (mm/mm)
1.0000	0	-0.054
1.0025	0.08	-0.037
1.0050	0.16	-0.019
1.0075	0.24	0
1.0100	0.31	0.019
1.0125	0.37	0.037
1.0150	0.42	0.054
1.0175	0.46	0.071
1.0200	0.49	0.085
1.0225	0.51	0.097
→1.0250	0.52	0.107
1.0275	0.51	0.114
1.0300	0.49	0.119
→1.0325	0.46	0.12
1.0350	0.42	0.119
1.0375	0.37	0.114
1.0400	0.31	0.107
1.0425	0.24	0.097
1.0450	0.16	0.085
1.0475	0.08	0.071
1.0500	0	0.054
1.0525	-0.08	0.037
1.0550	-0.16	0.019
1.0575	-0.24	0
1.0600	-0.31	-0.019
1.0625	-0.37	-0.037
1.0650	-0.42	-0.054
1.0675	-0.46	-0.071
1.0700	-0.49	-0.085
1.0725	-0.51	-0.097
1.0750	-0.52	-0.107
1.0775	-0.51	-0.114
1.0800	-0.49	-0.119
1.0825	-0.46	-0.12
1.0850	-0.42	-0.119
1.0875	-0.37	-0.114

a)



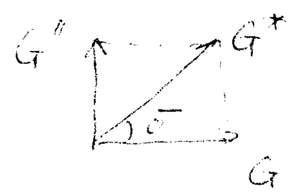
Solution

1) $\tau_{max} = 0.52$ $\gamma_{max} = 0.12$

$$|G^*| = \frac{\tau_{max}}{\gamma_{max}} = \frac{0.52}{0.12} = 4.33 (kPa)$$

$$\delta = \frac{(1.0325 - 1.025)}{(1.05 - 1)} \times 180 = 27^\circ$$

(2) Loss modulus



$G'' = G^* \cdot \sin\delta$

$= 4.33 \times \sin 27^\circ = 1.966 (kPa)$

(3) Storage modulus

$G' = G^* \cdot \cos\delta$

$= 4.33 \times \cos 27^\circ = 3.858 (kPa)$

(4) rutting parameter

$G^*/\sin\delta = 4.33/\sin 27^\circ = 9.538$ kPa

it's > 1.0 kPa for tank binder

> 2.2 kPa for RTFO binder

~~$G^* \cdot \sin\delta$~~ No fatigue parameter can be calculated as the test is done @ 64°C