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Application News

No. SCA_300_066

Material Testing System Servopulser

Asphalt Testing Package Fatigue Test according to EN 12697-24:2004 Annex D, 4PB-PR

▪ Introduction

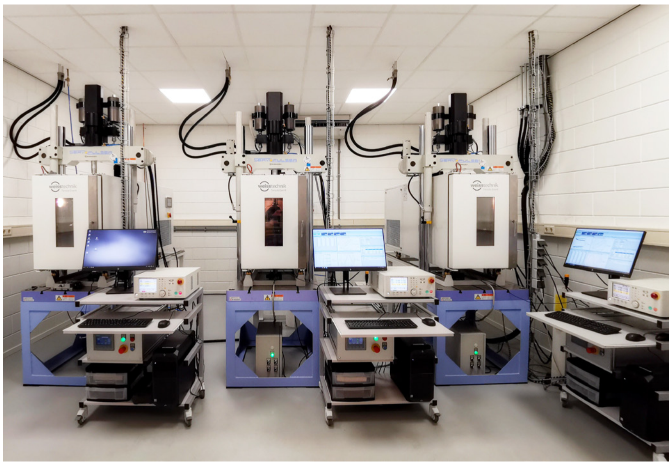

Figure 1: Shimadzu dedicated asphalt testing systems

EN 12697-24:2004 specifies the methods for characterizing the fatigue of bituminous mixtures using alternative tests, including bending tests and direct and indirect tensile tests. The tests are performed on compacted bituminous material under a sinusoidal loading or other controlled loading, using different types of specimens and supports. The procedure is used: a) to rank bituminous mixtures on the basis of resistance to fatigue; b) as a guide to relative performance in the pavement; c) to obtain data for estimating the structural behavior of the road; and d) to judge test data according to specifications for bituminous mixtures.
Because this European Standard does not impose a particular type of testing device, the precise choice of the test conditions depends on the possibilities and the working range of the device used. For the choice of specific test conditions, the requirements of the product standards for bituminous mixtures need to be respected.

Results obtained from different test methods or using different failure criteria are not assured to be comparable.

▪ 4PB Testing Setup

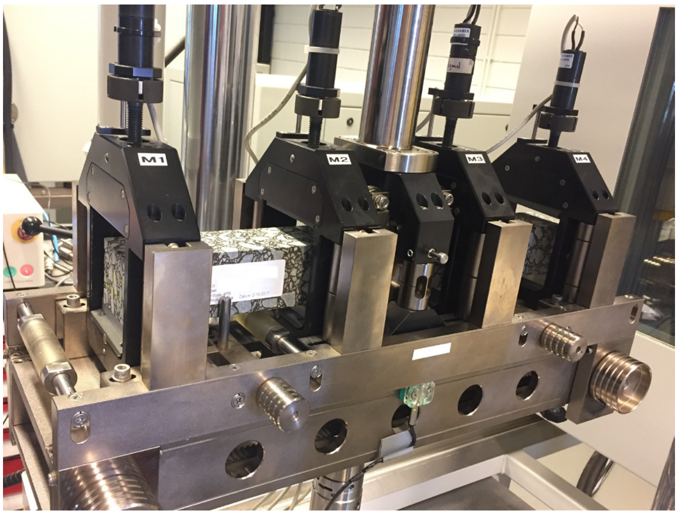

Figure 2: Assembly for 4PB Fatigue and Stiffness test

- 50 KN EHF-U Servopulser system
- 4PB testing tool (Figure 2)
- QF-40 Hydraulic power supply
- 4830 Controller
- Windows software for 4830 controller
- 4PB Fatigue calculation files

▪ Testing method

According to named standard this test is applied after the stiffness test (Stiffness test is a subject of No. SCA_300_065)

1. based on principle of 4-point bending test,
2. test sample: beams of 450 mm length, 50 mm x 50 mm or 70 mm x 70 mm,
3. LVDT controlled deflection sine wave, maximum bending strain should be chosen in three different levels, so that fatigue lives are between 1E4 and 2E6 cycles. Test frequency 30 Hz.
4. Definition of life time: when load peak values become half of values from first captured cycle in “constant deflection” loading mode.

Test conditions

1. EN standard distinguishes between two possible loading modes: “constant deflection” and “constant force”. This method is made for “constant deflection” loading mode.
2. Maximum amplitude for the bending strain of 105.19 µm, mean value 0 µm. Deflection is controlled by LVDT sensor built in 4PB tool.
3. Sinusoidal loading wave of 30 Hz is applied.
4. Tests are performed at 20 ºC.
5. Force, Stroke and 4PB deflection are sampled in 1000 cycles, from cycle 100 to 2.000.000.
6. Dynamic characteristic values are automatically calculated by 4830 software and automatically exported to CSV format.
7. Standard allows to stop the test when force drops to half of initial amplitude. Initial amplitude can be determined from the peak graph (Figure 3) and half initial amplitude set into the software, to stop the test at set value.

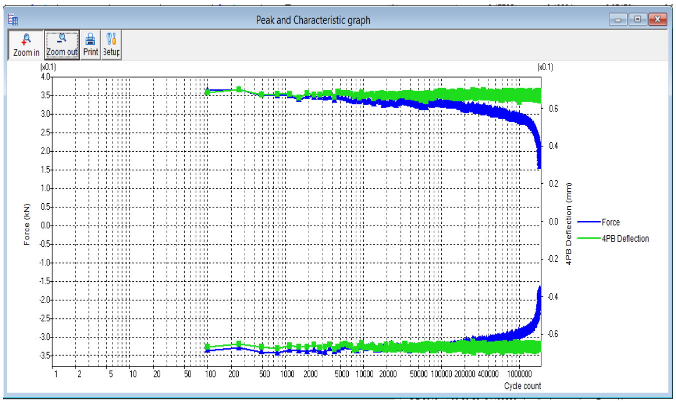

Figure 3: Force and deflection peak values

Results and postprocessing

Figure 5 shows Result window for one sample. Calculated stiffness and phase angle are shown in regard to the cycle number. A separate sheet is created for each sample and a Result sheet with final results (Figure 4).

The Results worksheet contains a table which summarizes the individual results and additional table for calculating the linear regression over the logarithms of the result for the fatigue line, together with the correlation coefficient of the regression and the residual standard deviation. With the regression results, the strain level for a fatigue life at defined number of cycles (10^6) is calculated.

Fatigue line for the 4PB calculation is shown in Fatigue Line worksheet, Figure 6. It contains graph with the fatigue line and the individual measured data points and the strain level for the fatigue life of 10^6 cycles.

Fatigue line ln(N) = A0 + A1*ln(ε)

$q = A_0$:	190.075
$p = A_1$:	-35.504
R^2:	1.000
$s_{x/y}$:	0.000

Fatigue line $N = k_1 \cdot \varepsilon^{k2}$

$\log_{10} k_1$:	82.548
k_2:	-35.504

Final Results

ID	Temp.	Strain	E_{ini}	E_{fat}	N_{fat}	ln(
S20190121_0711	20	140.0	6866	3433	2239409	
S20190122_0639	20	150.0	6734	3367	196900	
----		138.9				
----		152.8				

Figure 4: Results window

Capture list / Results / Measurement values

	N [-]	e [mm/m]	E* [MPa]	Phase angle [°]	p-p mm	InPhase kN/mm	OutPhase kN/mm
1	100	131.2	6703	24.8	0.1971	2.426	1.119
2	250	139.8	6549	25.5	0.2101	2.357	1.123
3	490	139.6	6511	25.9	0.2098	2.334	1.135
4	783	139.8	6423	26.0	0.2101	2.301	1.122
5	1116	139.8	6382	26.1	0.2101	2.285	1.119
6	1483	140.2	6361	26.3	0.2106	2.272	1.125
7	1878	140.8	6293	26.3	0.2116	2.249	1.112
8	2300	140.0	6289	26.7	0.2103	2.240	1.126
9	2745	140.3	6236	26.8	0.2109	2.220	1.120
10	3211	140.6	6227	26.8	0.2113	2.215	1.121
11	3698	139.8	6214	26.8	0.2101	2.211	1.116
12	4204	139.5	6195	27.1	0.2097	2.199	1.124
13	4728	140.5	6161	27.1	0.2111	2.186	1.119
14	5268	140.0	6130	26.9	0.2103	2.179	1.107
15	5825	140.1	6149	27.0	0.2106	2.184	1.114
16	6396	140.0	6110	27.0	0.2103	2.171	1.104
17	6983	139.7	6077	27.1	0.2099	2.157	1.104
18	7584	140.7	6041	27.1	0.2114	2.145	1.096
19	8198	140.4	6049	27.2	0.2110	2.145	1.103
20	8825	139.1	6060	27.3	0.2090	2.147	1.109
21	9465	139.5	6015	27.3	0.2096	2.130	1.102
22	10117	139.9	5991	27.4	0.2102	2.121	1.099
23	10782	139.8	5985	27.5	0.2101	2.116	1.103
24	11457	140.1	5958	27.5	0.2105	2.107	1.097
25	12144	139.3	5984	27.7	0.2093	2.112	1.111
26	12842	139.9	5943	27.7	0.2102	2.098	1.101

Final results

ID	Temp.	Strain	E_{ini}	E_{fat}	N_{fat}
S20190121_0711	20	140.0	6703	3352	2201014

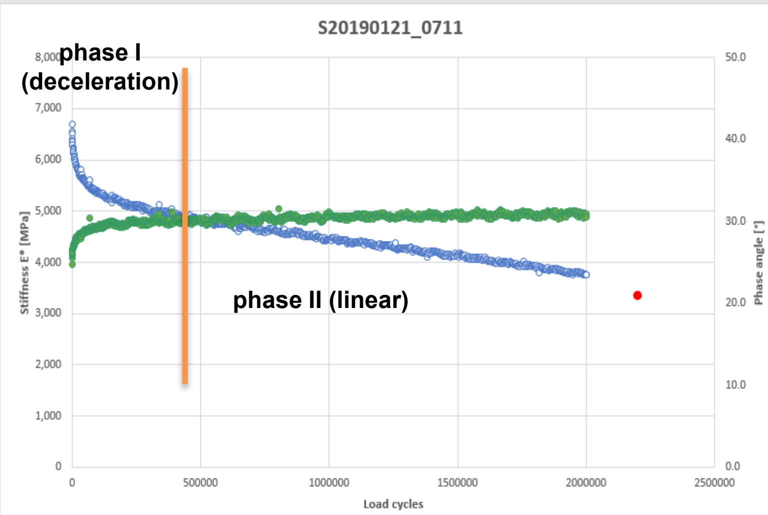

Figure 5: Result window for a sample

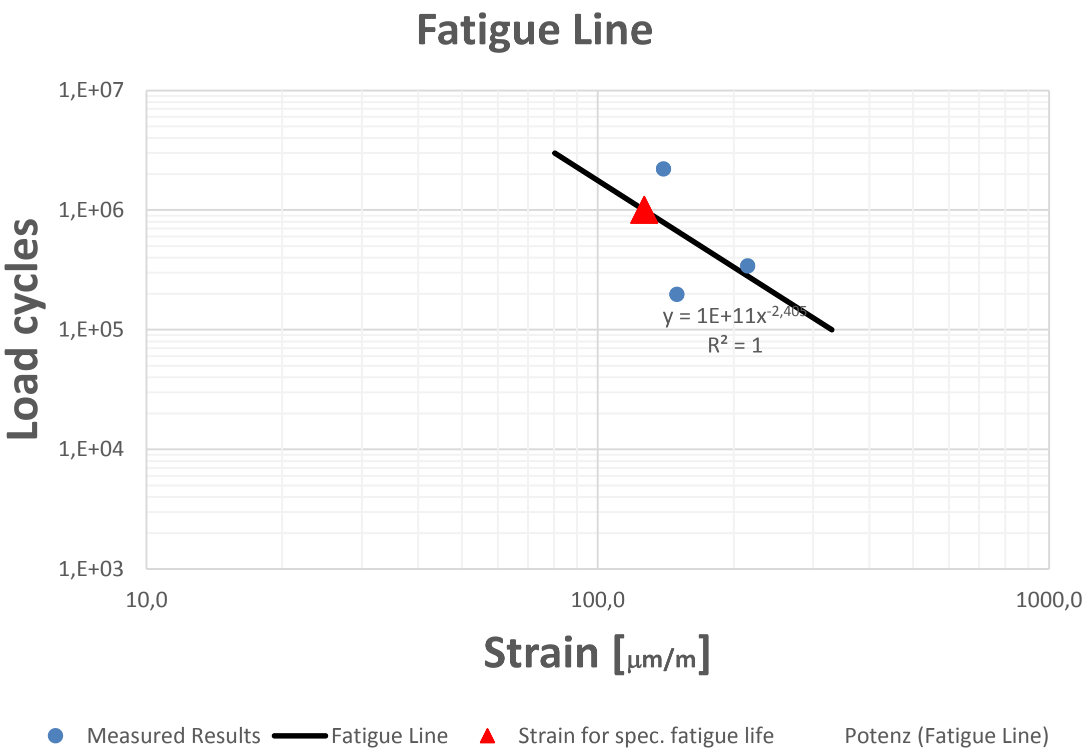

Figure 6: Results window

Summary

During the fatigue tests, the complex modulus continuously reduces and the phase angle continuously increases as shown in the Figure 5. The test can be terminated when the complex modulus reaches 50% of it original value. Generally three phases can be determined on the graph (Figure 5 and 7). With 2 million cycles done at 105.19 µm deflection, the third phase is not expressed. It can be observed that the specimens initial complex modulus defined at 100 cycles was 6.703 MPa and 3.820 MPa at the last cycle.

Curve on Figure 6 shows relation between fatigue failure criteria and strain amplitude. This fatigue data is expressed using the Whöler type fatigue line which was drawn by making a linear regression between the decimal logarithm of N and ε:

$$Log(N_i) = A_0 + A_1 Log(\varepsilon)^2$$

Material coefficient A_0 and slope A_1 can be determined in this way. From the material coefficient A_0 and A_1, the resistance to fatigue at 1 million cycles defined as ε_6 can be calculated.

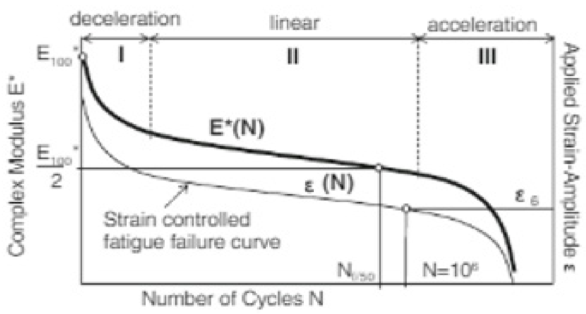

Figure 7: Three regions of fatigue failure criteria

Reference

1. EN 12697-24:2004, Bituminous mixtures – test methods for hot mix asphalt part 24: resistance to fatigue.
2. Asphalt testing package v 1.1, Shimadzu Europa GmbH, 2019

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