DEFORMATION PARAMETERS AND FATIGUE OF THE RECYCLED ASPHALT MIXTURES

Juraj ŠRÁMEK^{1,*}

¹ Department of Construction Management, Faculty of Civil Engineering, University of Žilina, Univerzitná 1, 01026 Žilina, Slovakia.

* corresponding author: juraj.sramek@fstav.uniza.sk.

Abstract

The deformational properties of asphalt mixtures measured by dynamic methods and fatigue allow a design the road to suit the expected traffic load. Quality of mixtures is also expressed by the resistance to permanent deformation. Complex modulus of stiffness and fatigue can reliably characterize the proposed mixture of asphalt pavement. The complex modulus (E^*) measurement of asphalt mixtures are carried out in laboratory of Department of Construction Management at University of Žilina by two-point bending test method on trapezoid-shaped samples. Today, the fatigue is verified on trapezoid-shaped samples and is assessed by proportional strain at 1 million cycles (ϵ_6). The test equipment and software is used to evaluate fatigue and deformation characteristics.

Keywords:

Asphalt mixtures;
Recycling fatigue;
Deformation parameters;
Complex modulus.

1. Introduction

Deformation and resistance characteristics and fatigue of asphalt mixtures have the eminent influence on asphalt pavements operational performance. Until now, deformation properties assessment is realized on principle of dynamic (impact) test and fatigue life of asphalt pavement, on principle of resistance decrease or deformation increase in different binders and mixtures characteristics. Nowadays, it's used the standard for measurement of complex modulus and fatigue of the asphalt reinforced materials („mixtures“), which gives better description of the car axel during normal operation at the frequency from 6 to 25 Hz. The complex modulus (E^*) measurement of asphalt mixtures are carried out in laboratory of Department of Construction Management at University of Žilina by two-point bending test method on trapezoid-shaped samples. Today, the fatigue is verified on trapezoid-shaped samples and is assessed by proportional strain at 1 million cycles (ϵ_6). The test equipment and software called KATEMS is used to evaluate fatigue and deformation characteristics.

2. Test equipment

The tests of the complex modulus and fatigue were carried out in the laboratory of Department of Construction Management of University of Žilina. Bending tests are widely used for measuring the stiffness modulus and assessing the fatigue resistance of asphaltic paving materials. The two-point bending test on trapezoidal specimens is, arguably, the most repeatable and reproducible bending test method detailed in the relevant STN EN 12697 standards. In this test the specimen is mounted as a vertical cantilever. The base is fixed and the top is moved sinusoidally with a constant displacement amplitude. The trapezoidal shape ensures that the maximum values of bending stress and strain occur away from the ends of the specimen where there are likely to be stress concentrations.

With the Cooper Technology equipment, two trapezoidal specimens are tested simultaneously and stiffness modulus can be determined at a range of frequencies and temperatures. In the fatigue test the specimens are subjected to a constant strain amplitude at a selected frequency and temperature until the stiffness modulus decreases to a user-selected target level (normally 50 percent of its initial value).

The equipment (Fig. 1) works with constant deviation. Rigid test frame housed within temperature cabinet range - 20 to 30 °C. Frequency ranges from 0.1 to 30 Hz. Precise manual setting

of strain amplitude. Accurate pre-test displacement transducer adjustment was carried out by using software feedback. Two high-precision ± 2.5 kN fatigue rated piezoelectric force transducers.

Fig. 1: Two-point trapezoidal bending beam machine [7].

3. Measurements principle of deformational properties and fatigue of two-point bending test

The rheology characters materials are tested with the complex modulus method [2] [3].

The basic deformation characteristics include modulus of elasticity, deformation modulus, modulus of stiffness, creep modulus, Poisson's ratio.

Complex modulus is the ratio of tension and deformation at steady, harmonically variable oscillation in consideration of their mutual time shift.

$$E^* = \frac{\sigma_0}{\varepsilon_0} = \left(E_1^2 + E_2^2 \right)^{\frac{1}{2}} \quad (1)$$

Fatigue is decrease of material resistance by repetitive loading in comparison with resistance by single loading STN EN12697-24.

According to the Slovak dimensioning method the fatigue is given by:

$$S = a - b \cdot \log N_i \quad (2)$$

where: a, b - fatigue coefficients,
 N_i - number of load cycles.

Measurement of the complex stiffness modulus is performed at the short-term alternating harmonic load. It expresses the proportion of maximum amplitudes of excitation tension (σ_0) and deformation induced by it (ε_0) and their phase shift (φ). The stress (force), which varies sinusoidally in time, is applied on to the element of linear viscoelastic material, the strain (deformation) varies in time with the same frequency as the stress, but it lags behind by the phase. Graphical representation of measurement and complex modulus evaluation is represented in Fig. 2.

The measurements were performed on trapezoidal specimens according to Fig. 3 (STN EN 12697-26).

Fig. 2: Measurement of complex modulus; L_p - length of period; φ - phase-shift; A_s - amplitude forces; A_d - amplitude deformation.

Fig. 3: Scheme of measuring and Dimensions of test samples; $B = 56$ mm; $b = 25$ mm; $e = 25$ mm; $h = 250$ mm for the mixture with $D \leq 14$ mm; P_o – acting force; y_o – deformation [2].

4. Tested mixtures and measurements results

The measurements were carried out on the test specimen trapezoidal shape for recycled asphalt mixture AC 16 L; II. (there was used 100 % recycled mixture).

The measuring of complex modulus was performed in temperatures ranging from + 5 °C to + 25 °C. The results of complex modulus of recycled asphalt mixture for different temperatures are listed in Table 1 and Fig. 4. Relevant for classification into categories is measuring by temperature + 15 °C and frequency 10 Hz.

Table 1: Complex modulus of the recycled asphalt mixture.

Frequency (Hz)	Complex modulus (MPa)		
5	9520.4	5246.8	4172.2
10	9989.7	6192.6	4462.0
15	10455.8	6611.9	4990.6
20	10583.9	6596.6	5362.3
25	10768.4	7011.0	5821.5
Temperature (°C)	5	15	25

Fig. 4: Complex modulus of the recycled asphalt mixture.

Classification of the asphalt mixtures according to values of deformation characteristics is shown in Table 2 (STN EN 13 108-1). Measured recycled mixtures as classified in Category $S_{\min}$ 5500.

Table 2: Minimal stiffness, $S_{\min}$ [1].

Minimal stiffness	Category	Minimal stiffness	Category
(MPa)	$S_{\min}$	(MPa)	$S_{\min}$
21000	$S_{\min 21\ 000}$	4500	$S_{\min 4\ 500}$
17000	$S_{\min 17\ 000}$	3600	$S_{\min 3\ 600}$
14000	$S_{\min 14\ 000}$	2800	$S_{\min 2\ 800}$
11000	$S_{\min 11\ 000}$	2200	$S_{\min 2\ 200}$
9000	$S_{\min 9\ 000}$	1800	$S_{\min 1\ 800}$
7000	$S_{\min 7\ 000}$	1500	$S_{\min 1\ 500}$
5500	$S_{\min 5\ 500}$	No requests	$S_{\min NR}$

The results of the measurements of the fatigue are from samples, which were loaded by temperature + 10 °C with loading in unit of measure by frequency 25 Hz. The fatigue line is estimated in a bi-logarithmic system as a linear regression of fatigue life versus amplitude levels. Using these results, the strain is corresponding to an average of 10^6 cycles (ϵ_6) and the slope of the fatigue line $1/b$ (STN EN 12697-24).

The parameters for evaluation of fatigue are:

- ϵ_6 ,
- $\Delta\epsilon_6$,
- slope $1/b$,
- estimated residual standard deviation s_N ,
- correlation coefficient r^2 .

The results of the fatigue are on Table 3 and the example of the mixtures fatigue in form of Wöhler's diagram is on Fig.5.

Table 3: Fatigue of the recycled asphalt mixture.

Mixture	T	F	$\varepsilon_6 \cdot 10^{-6}$	b	r^2	s/N	$\Delta \varepsilon_6$	Category
	(°C)	(Hz)	(mikrostrain)	(-)	(-)			
AC 16 L; II	10	25	96.98	0.9836	0.8985	0.13138	2.91E-09	Fat _{e min85}

Fig. 5: Fatigue - Wöhler's diagram.

Classification of the asphalt mixtures according to values of fatigue is shown in Table 4 (STN EN 13 108-1). Measured recycled mixtures as classified in Category Fat_{e min85}.

Table 4: Values of fatigue [1].

Category	Fat _{e min}	Category	Fat _{e min}
	(strain x10 ⁶)		(strain x10 ⁶)
Fat _{e min310}	310	Fat _{e min100}	100
Fat _{e min260}	260	Fat_{e min85}	85
Fat _{e min220}	220	Fat _{e min70}	70
Fat _{e min190}	190	Fat _{e min60}	60
Fat _{e min160}	160	Fat _{e min50}	50
Fat _{e min135}	135	Fat _{e minNR}	-
Fat _{e min115}	115		

5. Conclusions

According to results of measurements is recycled asphalt mixture AC 16 L; II suitable for work activities relating to the maintenance of roads, repair local disturbances and repair asphalt cover. The use of recycled materials protects the environment, reduces the usage of traditional quality materials and allows more roads to be built or repaired. Recycled mixtures can be used for pavement sub-layers and if the required criteria are met, in some cases even for pavement wearing courses.

It is recommended that the functional test of fatigue for asphalt mixtures design is used during the design of asphalt mixtures; such test will determine the mixture life expectancy of pavement regarding its operational performance. It is important to know not only the proportional strain at 1 million cycles ε_6 , but also the trend of fatigue line from Wöhler diagram for the assessment of mixtures following fatigue resist.

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