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DEFORMATION PROPERTIES OF ASPHALT MIXTURE WITH R-MATERIAL ADDITION

T. Olexa[1], J. Mandula[2]

[1,2] Technical University in Košice, Civil Engineering Faculty, Institute of Structural Engineering, Slovakia

ABSTRACT

Plenty of current road structural materials use additives reached from recycling process of various sources, for example used tires or milled asphalt mixture. Using of these additives is conditioned by improvement of asphalt mixture functional properties. Paper is focused on stiffness measurement of asphalt mixture with R-material addition. Stiffness is property of asphalt mixture which describes deformation resistance of mixture. In this study was used four point bending stiffness test according European standards and for comparison was made measurement of elasticity modulus according Australian standards. For comparison there was also made stiffness measurement of asphalt mixture without R-material addition in same laboratorial and time conditions. In conclusion is clearly described influence of R-material on deformation properties of asphalt mixture.

Keywords: Asphalt Mixture, R-Material, Stiffness

I. STIFFNESS OF BITUMEN BONDED MATERIALS

Asphalt mixture is one the most used construction material for roads in almost every part of the world. For correct design of road structure are material characteristics needed. Behavior of materials bonded by bitumen is mainly visco-elastic for specific temperature conditions. Properties of asphalt mixture which are mainly studied are e.g. fatigue resistance, resistance to permanent deformations, water resistance and also complex modulus of mixture.

Paper is focused on last of these properties, complex modulus or stiffness modulus describes material response on sinusoidal loading. Measurements and calculations of stiffness in the paper are according European standard [1]. According this standard, stiffness modulus is numerical value of complex modulus. Complex modulus *(E^*)* is calculated from two elements, real element of complex modulus *(E_1)* and virtual element of complex modulus *(E_2)*:

$$E_1 = \gamma \times \left(\frac{F}{z} \times cos(\varphi) + \frac{\mu}{10^3} \times \omega^2\right) \quad (1)$$

$$E_2 = \gamma \times \left(\frac{F}{z} \times sin(\varphi)\right) \quad (2)$$

$$|E^*| = \sqrt{E_1^2 + E_2^2} \quad (3)$$

where: γ - sample shape factor; μ - mass factor; F - force; z - displacement; φ - phase leg.

In this study was used equipment which is able to measure flexural stiffness and modulus of elasticity according Australian standard [2]. This measurement was chose only for comparison of complex modulus and elasticity modulus value. For elasticity modulus measurement was chosen only one frequency but it was done in every studied temperature condition. Equations of flexural stiffness *(S)* and modulus of elasticity *(E)* are below.

$$S = \frac{\sigma_t \times 10^3}{\varepsilon_t} \quad (4)$$

$$E = \left[\frac{F.z}{\varphi.w.h}\right] \times \left[\frac{3Sw^2 - 4Lw^2}{4h^2} + k \times (z + \upsilon)\right] \quad (5)$$

where: σ_t - tensile stress; ε_t - tensile strain; w - width of sample; h- height of sample; Sw - support span width; Lw - loading span width; k - actual shear stress divided by average shear stress; υ - Poisson´s ratio.

Both these standards uses four point bending method with prismatic beam specimen. Size of specimen was 380 x 50 x 50 mm and loading scheme of equipment could be seen in Fig. 1.

Beam is loaded in two inner points and it is fixed in two outer points in vertical direction. Load is applied with sinusoidal shape by inner clamps and frequency of loading could be set from 0.1 Hz to 50 Hz. Value of complex modulus is stiffness of beam in 100th loading cycle and control strain should be no more than 50 micro strains. Temperature conditions were set according Slovak design method TP 02/2009 [4] which are average temperatures during season of the year (winter 0 °C, spring and autumn 11 °C, summer 27 °C).

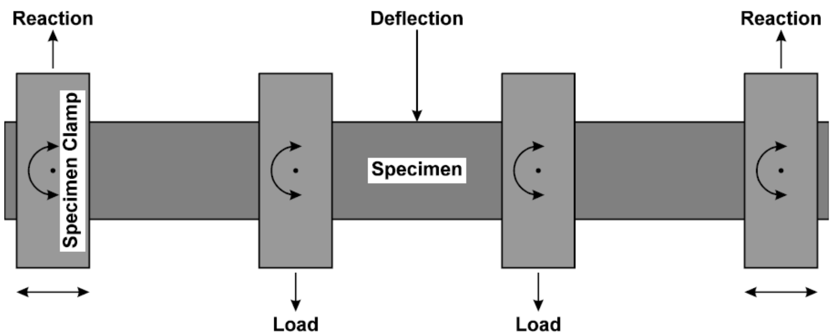

Figure 1: Side View on loading scheme of 4-PB apparatus [3]

II. STUDIED MATERIALS

In this study was measured asphalt mixture which is one of the most used road construction material for surface and binder course of roads in Slovakia. Asphalt concrete with continual gradation curve has maximal size of grain 11mm and used binder was road bitumen with penetration 50 / 70 with adhesive additives. There were made two variants of mixture, first variant was ordinary asphalt concrete (AC 11) and second variant was asphalt concrete with 10 % of R-material (AC 11 - R10). Depend on results there is option for using of asphalt concrete with R-material on heavy loaded roads, the most important criteria are deformation characteristics of mixture.

R-material was reached by milling of surface course of second class road. This surface layer also consists of asphalt concrete 11. Binder content in this R-material was 5.3 % of total mass. R-material was added to mixture in amount of 10 % of total mixture mass and R-material replaced part of aggregate with size 0 - 2 mm.

These mixtures were also tested on basic properties of asphalt mixtures according standards for type testing. Results of measurements could be seen in Table 1.

Table 1: Results of Basic Asphalt Mixture Measurements

mixture	AC_{11}	$AC_{11} + R_{10}$
binder content [%]	5.4	5.4
air void content [%]	3.0	3.9
void content filled by bitumen [%]	81.1	76.4
indirect tensile strength ratio [%]	85	86
wheel tracking slope [mm/10^3cycles]	0.06	0.06
proportional rut depth [%]	4.45	4.68

The results of measurement show that both variants of mixture are good enough for using in pavement construction also in heavy loaded road sections. Differences between variants of mixture are minimal and after these tests could be claimed that addition of R-material in asphalt mixture has good influence on characteristics of mixture. According these results there was assumption that also stiffness of these variants reaches similar values.

III. EVALUATION OF MEASUREMENTS

The temperature conditions were same for both mixtures and both test of stiffness and test of elasticity modulus. Frequency conditions for stiffness measurement were chosen in recommended range (0.5 Hz; 1 Hz; 5 Hz; 10 Hz; 20 Hz; 50 Hz), frequency of elasticity modulus measurement was set up to 10 Hz because this frequency is close to standard recommended frequency 8 Hz. The tests were done on same specimen and by same testing equipment. At first was done stiffness measurement for every frequency with one temperature and after that was measured modulus of elasticity with same temperature. Strain amplitude 50 $\mu\varepsilon$ was used for stiffness and elasticity modulus measurements. The measured phase angle was higher during stiffness measurement (about 3 degrees) and also strain amplitude was little bit higher (about 0.1 MPa) than during elasticity measurement. For the both mixtures were tested four samples. The results were in statistical range ± 10 % of average value. In the Fig. 2 and Fig. 3 could be seen complex modulus for both mixtures in whole temperature and frequency range.

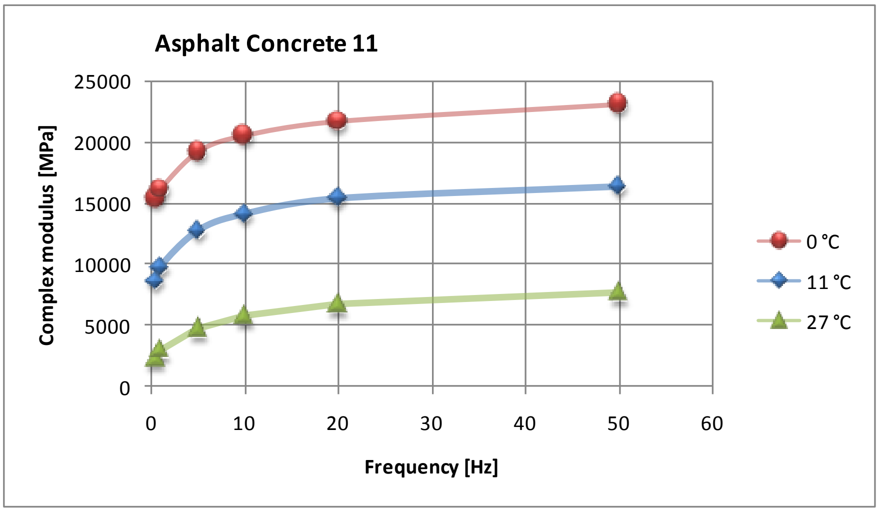

Figure 2: Complex modulus of mixture Asphalt Concrete 11 in different frequencies and temperatures

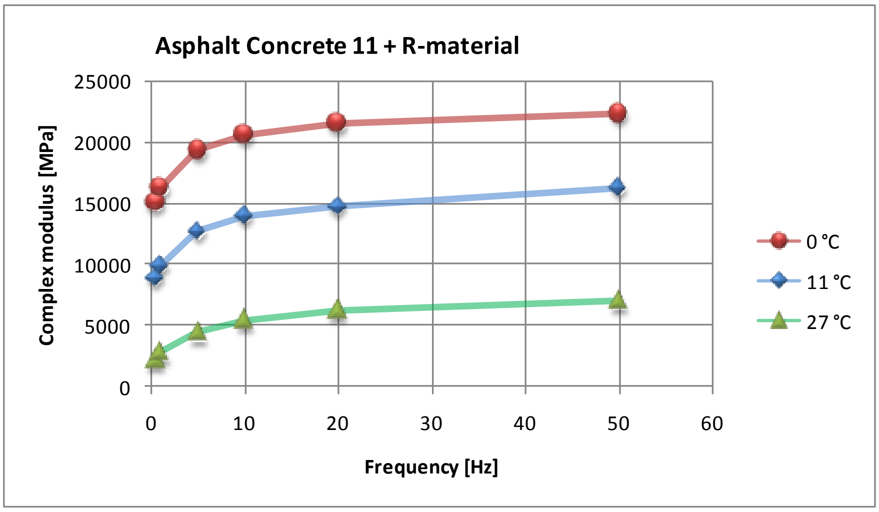

Figure 3: Complex modulus of mixture Asphalt Concrete 11+R_{10} in different frequencies and temperatures

According to these results, stiffness of mixture with R-material addition is little bit lower than stiffness of traditional reference mixture but it´s still comparable. In every studied temperature, mixture with R-material had similar values of stiffness like the traditional mixture. From stiffness point of view, R-material has no negative influence on traditional asphalt mixture.

Comparison of complex modulus, flexural stiffness and modulus of elasticity is illustrated in Fig. 4 and Fig. 5. As could be seen modulus of elasticity is slightly higher than complex modulus but variance is only about 5 % of value. On the other hand flexural stiffness is lower than complex modulus and also with variance about 5 %.

Same comparison was made also on mixture with R-material addition and again there are no big differences. Values are little bit lower in comparison with tradition mixture but variance is no more than 10 %. Based on these results it seems that flexural stiffness is similar like real element of complex modulus and complex modulus is modulus of elasticity. Differences between results could be caused by standard measured error or error in calculation because equations are slightly different.

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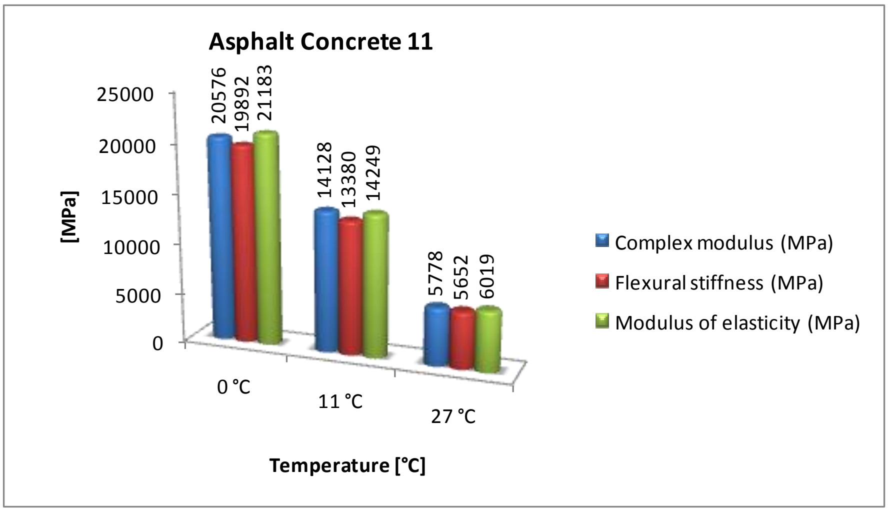

Figure 4: Comparison of complex modulus, flexural stiffness and modulus of elasticity (AC 11)

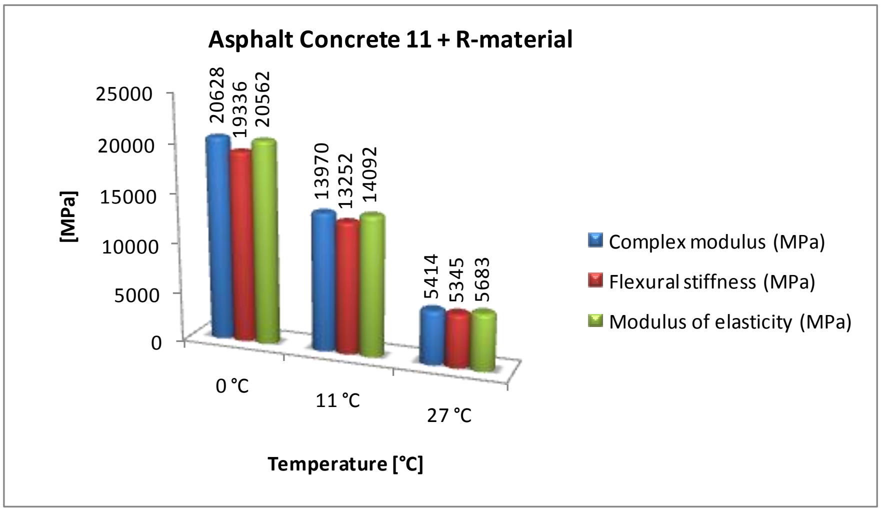

Figure 5: Comparison of complex modulus, flexural stiffness and modulus of elasticity (AC 11+R_{10})

IV. CONCLUSION

In this study was observed deformation properties of asphalt mixture with addition of R-material. Amount of R-material was chosen according actual standard as 10 % replacement of aggregate, which is maximal allowed amount. Studied traditional asphalt concrete 11, had quality properties as wheel tracking resistance and also water resistance. By addition of R-material this properties were no negatively affected.

Attention in this paper was mainly focused on stiffness of these mixtures. Stiffness of traditional mixture was much higher than are Table values in Slovak pavement design manual [4], but it is consequence of fact that Table values are calculated and results in this paper are laboratory measured. Mixture with R-material has still good enough values of stiffness. Stiffness was slightly lower than stiffness of traditional mixture difference was about 3 % in average. The results definitely showed that addition of R-material reached from old pavement structures is appropriate material for new road layers bonded by bitumen. In case of comparison European standard and Australian standard (complex modulus vs. modulus of elasticity) there was no big difference between measured values.

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