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ELASTICITY OF BITUMEN BINDERS AND THE FACTORS CAUSING IT

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Abstract. *The article deals with the influence of the initial bitumen penetration grade and different concentrations of the mineral filler on the elasticity of the polymer-modified bitumen (PMB) with 3 and 6 % of SBS type polymer. The dependences of elasticity of the PMB on the test conditions – such as the temperature and the stress state level are shown additionally.*

Key words: *elasticity, polymer-modified bitumen, ductility, mineral filler, penetration grade.*

ЕЛАСТИЧНІСТЬ БІТУМНИХ В'ЯЖУЧИХ, ТА ФАКТОРИ ЩО ЇЇ ОБУМОВЛЮЮТЬ

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Анотація. *Розглянуто вплив температури та рівня напруженого стана при визначенні еластичності бітумів, модифікованих полімером (БМП). Досліджено залежності еластичності від марки бітуму для БМП з 3 та 6 % полімеру типу СБС, та показано зниження еластичності БМП при наповненні різною концентрацією мінерального порошку.*

Ключові слова*: еластичність, модифікований полімером бітум, дуктильність, мінеральний порошок, марка бітуму.*

ЭЛАСТИЧНОСТЬ БИТУМНЫХ ВЯЖУЩИХ, И ФАКТОРЫ ЕЁ ОБУСЛАВЛИВАЮЩИЕ

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Аннотация. *Рассмотрено влияние температуры и уровня напряжённого состояния при определении эластичности битумов модифицированных полимером (БМП). Исследованы зависимости эластичности от марки битума для БМП с 3 и 6 % полимера типа СБС, и показано снижение эластичности БМП при наполнении разной концентрацией минерального порошка.*

Ключевые слова*: эластичность, модифицированный полимером битум, дуктильность, минеральный порошок, марка битума.*

Introduction

The elasticity of bitumen binders is interpreted as the ability of the binder to accept large flowing in time reversible deformation. Thus, for bitumen without modification there were used different methods for determining the elasticity [1], and there were established the dependences of the elasticity on the structural and rheological bitumen type [2].

Analysis of publications

As such, the elasticity of bitumen did not present much interest for researchers, until the bitumen modified by polymers (PMB) became widely used. A number of publications made it possible to establish the influence of elasticity, imparted to bitumen by polymer, on the number of cycles to failure of samples of polymerasphalt concrete [3], [4].

Aim and problem formulation

For polymers (and in particular thermoplastic elastomers, as the most widespread bitumen modifiers) the ability to high reversible deformation with a relatively small load is one of the characteristic features, and it is determined by several tests - rebound, elastic recovery, plastelastic properties in the rheometer, the modulus of elasticity in tension.

Methods for determining the elasticity of bitumen, which are standardized in various countries, involve establishing a level of reversible deformation after stretching the sample “eight-shape”. However, in the EU the test temperature may vary from 25 °C. In the EU, recovery is determined after a 20 centimeter stretch, in Ukraine and Russia after the stretching of the sample to failure.

It is important to establish the effect of all factors on elasticity. These may include: the level of stress state, the penetration grade of the initial bitumen, the level of structuring PMB by fine mineral filler, which is an essential part of the road asphalt concrete.

Influence of initial bitumen penetration grade on elasticity of PMB

For confirmation of elasticity dependence on the initial bitumen penetration grade at its modification by different content of linear styrene-butadiene-styrene (SBS) there were used four binders - three types of bitumen PG 40/60, 60/90 and 130/200, and petroleum tar with penetration 435×0.1mm. The results obtained are shown in Table 1.

Table 1 Changes of the properties of the binders with different penetration, modified by different content of SBS

Initial binder	SBS content, %	Penetration at 25 °C, 0,1мм	Softening point temperature, °C	Ductility at 25 °C, cm	Elasticity at 25 °C, %
Petroleum tar	0	435	34,7	36	-
	3	252	47,4	50	92,5
	6	164	89,4	62	100
Bitumen PG 130/200	0	174	41,3	>100	-
	3	114	46,4	>100	77
	6	72	79,2	69	100
Bitumen PG 90/130	0	89	46,6	>100	-
	3	67	54,3	46	70
	6	48	76,6	61	100
Bitumen PG 40/60	0	50	54,9	55	-
	3	41	62,8	18	67,5
	6	34	84,6	41	88

For bitumen, modified by 3 % linear SBS, elasticity is in the range from 67 % to 77 %, depending on the penetration of initial bitumen. For bitumen modified by 6 % of SBS elasticity is 88 % only for the most viscous bitumen, for the remaining binders it reaches a level close to 100 %.

Elasticity of PMB at various test conditions

To determine the influence of the stress state level on the elasticity there were used the samples of PMB with initial bitumen PG 130/200, 90/130, 40/60, modified by 3 % linear styrene-butadiene-styrene. Ductility values corresponding to the strands failure at the temperature of 25 °C for produced PMB were 85 cm, 69 cm and 21 cm respectively. Elasticity corresponding to the failure of samples was taken as elasticity at the 100 % level of deformation. The samples were then elongated by 20 %, 40 %, 60 % and 80 % of the maximum elongation and cut, after this elasticity was determined by the length of contraction of the “eights” halves.

To determine the temperature influence on the reversibility of the BMP, the deformation test was replicated at 13 °C and 2 °C. The results are shown in Table 2.

Reducing of elasticity of BMP with mineral filler

To assess the changes in elasticity of BMP with filler, bitumen with a penetration of 90×0.1 mm, modified by 3 % SBS, was mixed with 30 %, 40 %, 50 %, 60 % and 70 % (by weight) carbonate filler consists of a particle size less than 0.071 mm.

Table 2 Stress state level and temperature influence on the elasticity (E) of the PMB

PMB	Stress state level, %	Test temperature, °C					
		25		13		2	
		Elongation, cm	E, %	Elongation, cm	E, %	Elonga-tion, cm	E, %
Bitumen PG 130/200 + 3 % SBS	100	84,8	92,3	70,3	88,8	23,3	69,5
	80	67,8	92,1	56,2	88,8	18,6	69,4
	60	50,9	93,5	42,2	89,7	14,0	70,7
	40	33,9	94,2	28,1	88,8	9,3	69,4
	20	17,0	92,6	14,1	88,3	4,7	66,0
	average value		92,9		88,9		69,0
Bitumen PG 90/130 + 3 % SBS	100	69,1	84,7	19,7	74,3	13,5	74,7
	80	55,3	86,9	15,8	75,0	10,8	72,2
	60	41,7	84,4	11,8	78,8	8,2	79,3
	40	27,6	83,3	7,9	75,3	5,4	74,1
	20	13,8	83,0	3,9	76,9	2,7	77,8
	average value		84,5		76,1		75,6
Bitumen PG 40/60 + 3 % SBS	100	21,0	79,2	18,2	69,8	8,4	58,1
	80	16,8	80,1	14,6	67,8	6,7	61,2
	60	12,6	80,6	10,9	70,6	5,0	63,0
	40	8,4	79,2	7,3	70,5	3,3	71,2
	20	4,2	82,1	3,6	73,6	1,7	79,4
	average value		80,2		70,5		66,6

Reducing of elasticity at introducing small quantities of filler observed by the test results (Figure 1) is almost linear up to concentration of 50 %.

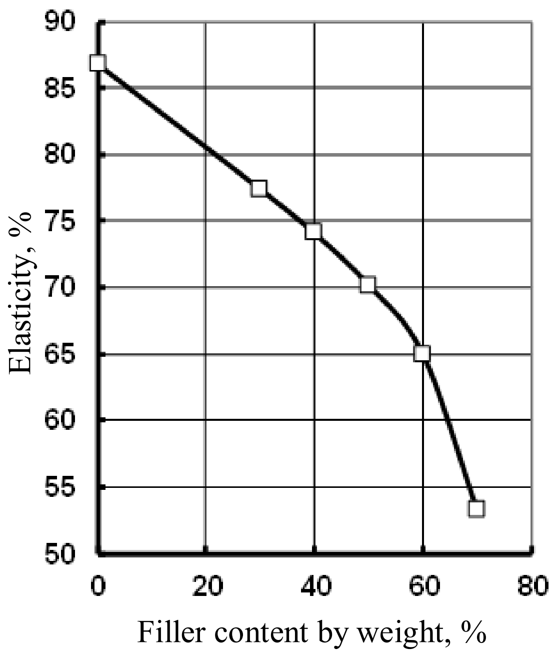

Fig. 1. Elasticity reduction at PMB structuring by thin mineral filler

When approaching a concentration of 70 % elasticity decreases sharply, which can be explained by the grains contacting through the adsorption-solvation layers.

Conclusions

The result of the test at 25 °C confirms the elasticity dependence of the initial bitumen penetration - at lowering the penetration the elasticity naturally decreases: for PMB on bitumen PG 40/60 it is from 14 % to 16 % lower than for PMB on bitumen PG 130/200.

The stress state level has little effect on the value of elastic deformation. At 25 °C the deviation from the average value of elasticity is not more than 2%, and it is within the measurement error, which implies no correlation between elasticity and the stress state level. Therefore, the elastic recovery capacity for PMB remains at the same level, even if there is a failure, which justifies the comparability of elasticity obtained at different elongation of the sample as well as at its failure under otherwise equal conditions.

By reducing the test temperature down to 13 °C and 2 °C, the effect of the stress state level in the elasticity of the sample PMB cannot be traced either, but the average elasticity of the sample BMP decreases with temperature drop.

The filler content in the binary system, which is close to 60-70% corresponds to the ratio of thin mineral filler to bitumen = 1.5 - 2.33, inherent in asphalt concrete. The elasticity of the system, close to 55 % can be considered as a basis for increasing the durability of asphaltpolymer concrete compared to asphalt concrete on unmodified bitumen.

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