N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 421 (2017), 167 – 176

UDC 625.7/.8:691.16

B. B. Teltayev, Y. D. Amirbayev

Kazakhstan Highway Research Institute, Almaty, Kazakhstan.
E-mail: bagdatbt@yahoo.com, erik_neo@mail.ru

EXPERIMENTAL EVALUATION OF STRENGTH FOR ASPHALT AND POLYMER MODIFIED ASPHALT CONCRETES AT LOW TEMPERATURES

Abstract. Tensile strength of asphalt concretes and polymer asphalt concretes was determined experimentally at low temperatures through two methods in the paper. According to the first method the ends of the sample were fixed inflexibly. Temperature was reduced from +20°C with the rate of 10°C/h till sample damage. Critical stress and temperature were determined. According to the second method samples of asphalt and polymer asphalt concrete are deformed under the scheme of direct tension with constant rate (approximately 1 mm/min) at a constant temperature equal to -20°C till damage. The stress, when the damage of the sample occur (splitting into parts), has been admitted as the tensile strength of material. Prior to testing the samples were previously conditioned for 1, 10, 20, 30 and 40 hours. Test results showed that duration of preliminary conditioning impacts greatly on strength and deformability of asphalt and polymer asphalt concretes. During deformation with constant rate at -20°C tensile strength of all tested asphalt and asphalt concretes decreases with the increase of thermostatic conditioning duration up to 10 hours and further increase of duration does not impact practically on it. Meanwhile the strength decrease of asphalt concretes with bitumens grade BND 70/100 and BND 100/130, polymer asphalt concretes with polymers Elvaloy 4170, Calprene 501 and Butonal NS 198 is 49%, 32 %, 24 %, 25 % and 29 % respectively. During cooling with constant rate the duration of thermostatic conditioning does not impact practically on critical characteristics of asphalt concrete with bitumen grade BND 100/130 and polymer asphalt concrete with polymer Butonal NS 198. For other asphalt and polymer asphalt concretes the critical temperature is reduced with the duration increase of thermostatic conditioning, and critical stress increases. For all tested asphalt and polymer asphalt concretes the reduction of critical temperature at maximum thermostatic conditioning (40 h) is 2-2.5°C. Maximum increase of critical stress, which also complies with maximum duration of thermostatic conditioning (40 h), for asphalt concrete with bitumen grade BND 70/130, polymer asphalt concretes (BND 100/130 + Elvaloy 4170) and (BND 100/130 + Calprene 501) is equal to 28.0 %, 6.1 % and 15.0 % respectively.

Key words: asphalt concrete, polymer modified asphalt concrete, tensile strength, low temperature, thermostatic conditioning duration.

1. Introduction. Low temperature cracking is one of the most frequently occurred types of mechanical destruction for asphalt concrete pavement of a highway. This type of destruction occurs all over the territory of Kazakhstan. In northern regions they often appear during the first period of road operation, and their number is increased during the course of time. It was determined in the scientific discovery No. 495 [1] that at consequent coolings in asphalt concrete pavement there occurred transversal thermal cracks and blocks, which were the forms of adaptation of thermodynamic system to the external conditions, and the average amount of them were proportional to logarithm of air cooling amount till the first critical temperature of pavement, and the first critical temperature value depends on climatic characteristics, as well as on rheological properties of asphalt concrete, and on its tensile strength in particular.

In accordance with the requirements of standard [2], before testing the asphalt concrete samples were thermally conditioned at testing temperatures for an hour. But in real road situations the temperature conditions of asphalt concrete layers for pavement structure vary within a wide range and the duration for

the periods with specific temperature can be from several hours till several dozens of days. Taking into account the above, in this paper the samples of asphalt and polymer asphalt concretes were thermally conditioned before testing for 1, 10, 20, 30 and 40 hours at testing temperature equal to -20°C.

2. Materials and methods.

2.1. Bitumens and polymer bitumens. The following bitumen binders were used for preparing of asphalt and polymer asphalt concretes:

1) pure bitumen grade BND 70/100 and BND 100/130 of Pavlodar PetroChemical Plant (PPCP); 2) bitumen grade BND 100/130 PPCP with addition of polymer Elvaloy 4170 (1.4 % by weight of bitumen); 3) bitumen grade BND 100/130 of PPCP with addition of polymer Butonal NS 198 (3.0 %); 4) bitumen grade BND 100/130 of PPCP with addition of polymer Calprene 501(4.0 %).

Pure bitumens and modified bitumens comply with the requirements of standards [3, 4]. Basic standard indicators of pure bitumen and polymer bitumens are shown in Tables 1 and 2.

Table 1 – Basic standard indicators of the bitumen

Indicator	Measurement unit	Requirements of ST RK 1373-2013		Value	
		BND 70/100	BND 100/130	BND 70/100	BND 100/130
Penetration: - 25°C - 0°C	0.1 mm	71-100 22	101-130 30	75 32	110 37
Penetration Index PI	–	-1.0… +1.0	-1.0... +1.0	-0.87	-0.82
Tensility at temperature: - 25^0C - 0^0C	cm	≥ 75 ≥ 3.8	≥ 90 ≥ 4.0	118 5.2	135 6.6
Softening point	^{0}C	≥ 45	≥ 43	47.5	44.0
Fraas point	^{0}C	≤ -20	≤ -22	-28.5	-30.2
Dynamic viscosity, 60^0C	Pa·s	≥ 145	≥ 120	229.0	121.0
Kinematic viscosity	mm^2/s	≥ 250	≥ 180	428.0	329.0

Table 2– Basic standard indicators of the polymer bitumen

Indicator	Measurement unit	Requirements of ST RK 2534-2014		Value		
		PMB 50/70	PMB 100/130	BND 100/130 + Elvaloy 4170 – 1.4%	BND 100/130 + Calprene 501 – 4.0%	BND 100/130 + Butonal NS 198 – 3.0 %
Penetration: 25 °C	0.1 мм	≥ 51-70	≥ 70-100	86	58	83
Tensility at emperature: 25 ^{0}C	см	≥20	≥ 25	70	42.5	51.0
Softening point	°C	≥62	≥ 60	63.5	73.0	61.0
Fraas point	°C	≤ -16	≤ -18	-29.1	-32.3	-27.4
Ductility at temperature 25°C	%	≥60	≥60	72	84	71

2.2. Asphalt concretes and polymer asphalt concretes. Hot dense asphalt concretes and polymer asphalt concretes of type B that met the requirements of the Kazakhstan standard CT PK 1225-2013 [5] were prepared with the use of aggregate fractions of 5–10 mm (20%); 10–15 mm (13%); and 15–20 mm (10%) from the Novo-Alekseevsk rock pit (Almaty region); sand of fraction 0–5 mm (50%) from the plant "Asphaltconcrete-1" (Almaty city); and activated mineral powder (7%) from the Kordai rock pit (Zhambyl region).

The bitumen content of grades PMB 50/70 and PMB 70/130 in the asphalt concretes and in the polymer asphalt concretes was 5.4% and 4.8% by weight of dry mineral material respectively. Basic standard indicators of the asphalt concretes and polymer asphalt concretes are shown in Tables 3 and 4, respectively. A granulometric composition curve for the mineral part of asphalt concretes and polymer asphalt concretes is shown in Figure 1.

Table 3 – Basic standard indicators of the asphalt concrete

Indicator	Measurement unit	Requirements of ST RK 1225-2013	Value	
			BND 70/100	BND 100/130
Average density	g/cm^3	-	2.39	2.38
Water saturation	%	1.5-4.0	2.9	3.4
Voids in mineral aggregate	%	≤ 19	15.1	16.3
Air void content in asphalt concrete	%	2.5-5.0	3.5	3.8
Compression strength at temperature:	MPa			
0°C		≤ 13.0	7.4	7.1
20°C		≥ 2.5	3.5	3.8
50°C		≥ 1.3	1.43	1.38
Water resistance	–	≥ 0.83	0.90	0.92
Shear resistance	MPa	≥ 0.38	0.40	0.39
Crack resistance	MPa	4.0-6.5	4.0	4.3

Table 4 – Basic standard indicators of the polymer asphalt concretes

Indicator	Measure-ment unit	Requirements of ST RK 1223-2013	Value		
			BND 100/130 + Elvaloy 4170 – 1,4 %	BND 100/130 + Calprene 501 – 4,0 %	BND 100/130 + Butonal NS 198 – 3,0 %
Average density	g/cm^3		2.41	2.41	2.405
Water saturation	%	1.5-3,0	2.5	2.2	2.6
Voids in mineral aggregate	%	≤ 19	16.0	14.3	16.6
Air void content in asphalt concrete	%	2.5-5.0	3.4	3.2	3.7
Compression strength at temperature:					
0 °C	MPa	≤ 9.0	7.3	6.8	7.7
50 °C		≥ 1.8	2.4	2.6	2.2
Water resistance	–	≥ 0.80	0.96	0.94	0.96
Shear resistance	MPa	≥ 0.45	0.53	0.49	0.47
Crack resistance	MPa	4-6	4.5	4.8	4.3

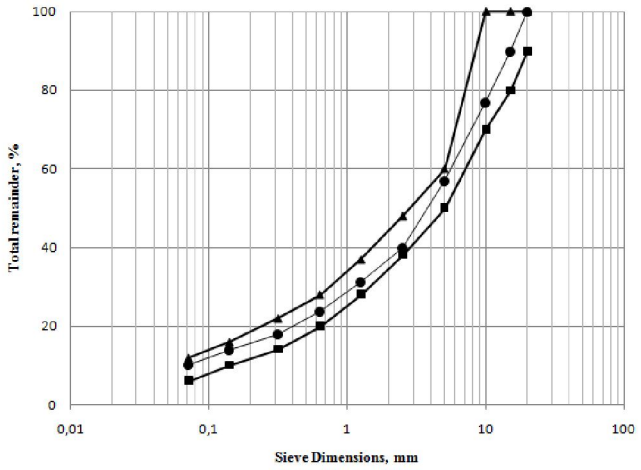

Figure 1 – A granulometric composition curve for the mineral part of asphalt concretes and polymer asphalt concretes

2.3. Samples preparing. Samples of the asphalt concretes and polymer asphalt concretes in the form of a rectangular prism with dimensions 5x5x16 cm (Figure 2) were manufactured as follows. First, the asphalt concrete and polymer concrete samples were prepared in the form of a square slab with dimensions 5x30.5x30.5 cm (Figure 3) using a Cooper compactor (UK, model CRT-RC2S) (Figure 4) according to the standard EN 12697-33 [6]. The samples were then cut from the asphalt concrete slabs in the form of a prism in a specially assembled installation. Deviations in sizes of the beams did not exceed 2 mm. Metal plates, designed to connect the samples to loaded installation and to measuring sensors, were glued to the ends of the samples and the samples were in the specially assembled installation for twenty-four hours to provide strength between the plates and the sample (Figure 5).

Figure 2 – Samples of the asphalt concretes and polymer asphalt concretes with dimension 5x5x16 cm to be tested

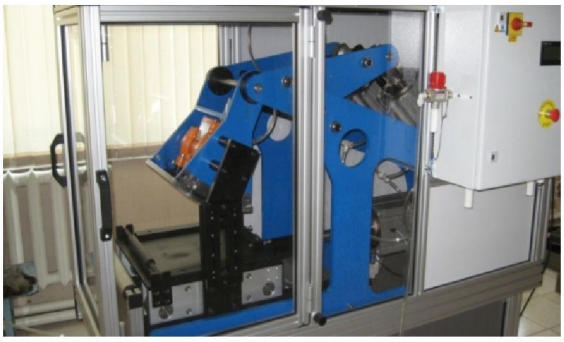

Figure 3 – The Cooper compactor CRT-RC2S

Figure 4 – A square slab of asphalt concrete with dimension 5x30.5x30.5 cm

Figure 5 – The asphalt concrete sample with glued metal plates in a specially assembled installation

Before testing the samples of asphalt concretes and polymer asphalt concretes were installed into freezing chamber (Figure 6) with the temperature of -20°C, and they were thermally conditioned for 1, 10, 20, 30 and 40 hours.

Figure 6 – The asphalt concrete samples in a freezing chamber

Figure 7 – The asphalt concrete sample under test in a thermal chamber of TRAVIS