RUT RESISTANCE OF ASPHALT CONCRETES OF DIFFERENT AGGREGATE GRADATION

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ABSTRACT

Comparative research of resistance of hot dense asphalt concretes of different gradations to rutting within wide temperature range has been carried out. The influence of different modifying additives on properties and rut resistance of asphalt concretes of various gradation has been studied. It has been established that increase of coarse aggregate (crushed stone retained on the 5.0 mm sieve) content in compositions of fine-graded asphalt concretes results in increase of their resistance to plastic deformations (rutting).

Keywords: Asphalt mix, rut resistance, aggregate, gradation.

INTRODUCTION

In Ukraine while constructing wearing courses on urban streets and roads of common use (i.e. state and local roads, except urban, technological roads and roads on private territories) hot fine-graded asphalt mix is the most widely used material. Stone mastic asphalt is used on heavily trafficked highways, while sand asphalt concrete is used for paving sidewalks, bicycle lanes and footpaths.

Results of an asphalt wearing course survey on the road network of Ukraine indicate that asphalt pavement layers are often characterized by permanent deformations such as ruts in summer period of service at high ambient temperature. One of the reasons of the deformation accumulation is insufficient shear resistance of asphalt concretes in wearing courses. However National Standard of Ukraine (DSTU B V.2.7-119 "Asphalt mixes, road and airfield asphalt concrete. Specifications") contains no requirements to parameter of rut resistance. This does not allow the prediction of asphalt pavement resistance to permanent deformation accumulation (rutting) on the stage of asphalt mix design.

It is known that the most popular simulation method of asphalt pavement resistance to permanent deformation accumulation (rutting) is testing of asphalt concrete samples by means of special equipment called Rut Testers (Ahmad et al., 2011; Gabet et al., 2011; Gabra, 2002; Kuger and Horak, 2005; Uzarowski et al., 2006; Verstraeten, 1995) or Asphalt Pavement Analyzers (Cooley et al., 2000; brown et al., 2004; Stricland et al., 2008). In Ukraine research of rut resistance of asphalt concretes with different aggregate gradation has not been carried out.

EXPERIMENTAL STUDY

The aim of the research is to perform comparative evaluation of rut resistance of hot dense asphalt concretes with different aggregate content within service temperature range as well as influence of bitumen modification by polymers on the magnitude of the parameter.

Fine-graded asphalt concrete mixes of type A, B and V, as well as sand asphalt concrete mixes of typ G were selected for the investigation. Asphalt concretes were prepared using petroleum road bitumen, characterized by penetration within 60 and 90 dmm, as well as polymer modified binder, characterized by penetration within 60 and 90dmm and softening point of 52 ^{o}C. The optimal binder content (Table 1) was selected at the maximum value of compressive strength at 50 ^{o}C provided that value of water saturation meets the specified requirements. Binder contents selected to study its influence on physical and mechanical properties of asphalt concretes were specified to meet the requirements of the Ukrainian norms. By aggregate gradation (Figure 1–5) and parameters of physical and mechanical properties (Table 1) the asphalt concretes meet the requirements of National Standard.

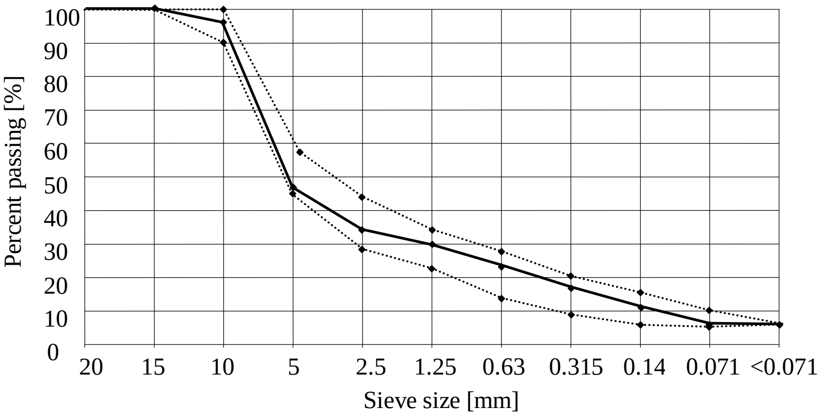

Figure 1 Aggregate gradation of type A dense fine-graded asphalt concrete characterized by continuous gradation with 10 mm maximum aggregate size

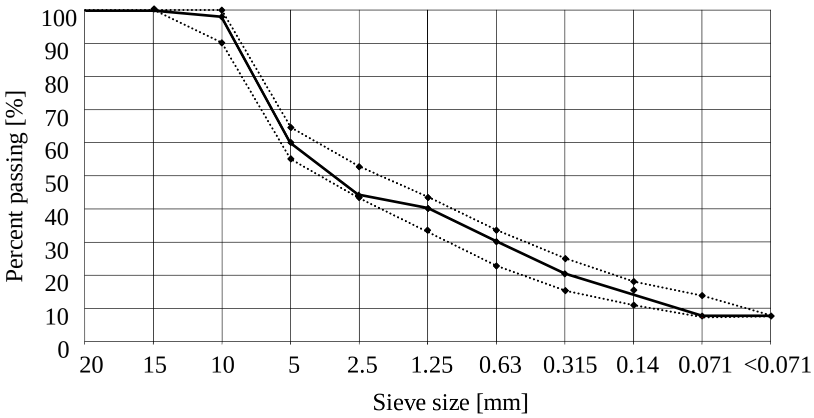

Figure 2 Aggregate gradation of type B dense fine-graded asphalt concrete characterized by continuous gradation with 10 mm maximum aggregate size

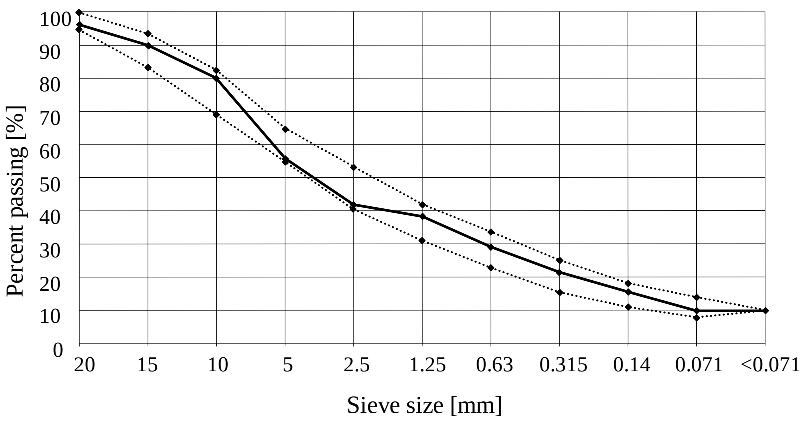

Figure 3 Aggregate gradation of type B dense fine-graded asphalt concrete characterized by continuous gradation with 20 mm maximum aggregate size

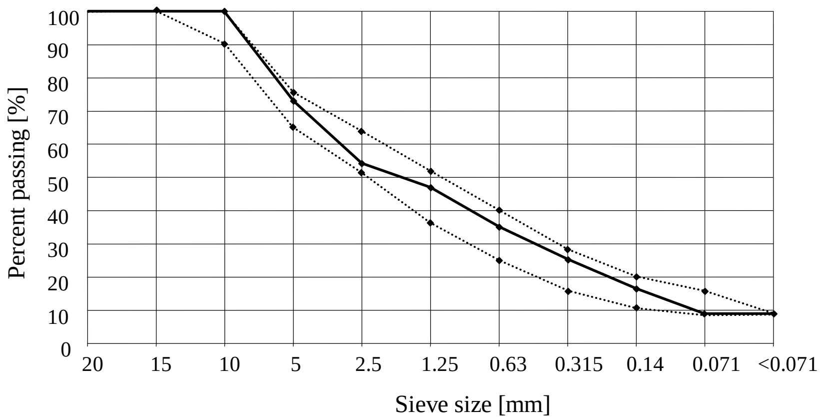

Figure 4 Aggregate gradation of type V dense fine-graded asphalt concrete characterized by continuous gradation with 10 mm maximum aggregate size

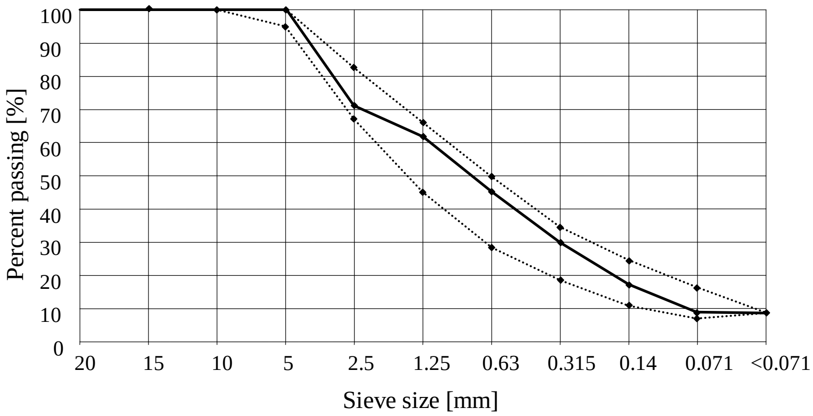

Figure 5 Gradation of type G dense sand asphalt concrete characterized by continuous gradation

Table 1 Physical and mechanical properties of asphalt concretes with 10 mm maximum aggregate size

Property	Types of asphalt concrete			
	A	B	V	G
Water saturation[1], % by volume	2.5	3.3	1.7	2.7
Air voids, %	3-4	3-4	3-4	3-4
Bulk specific gravity, kg/m^3	2,376	2,382	2,398	2,327
Swelling, % by volume	0	0.1	0	0
Uniaxial compressive strength[2], MPa, at:				
0 °C	8.0	7.9	9.5	9.0
20 °C	3.2	4.0	4.0	4.3
50 °C	0.70	1.25	1.26	1.28
Water resistance coefficient[3]	0.91	1.00	0.95	0.91
Bitumen content, %	5.5	5.6	6.2	7.4
Crushed stone content, %	53	40	27	0

[1] Water saturation is defined as the amount of water (percent by volume) absorbed by asphalt sample after conditioning the sample in water at (20±2) °C under pressure 2,000 Pa in vacuum for 1 hour and then under atmospheric pressure for 30 min.

[2] Rate of load application – 3.0 mm/min.

[3] Water resistance coefficient is defined as a ratio between compressive strength at 20 °C of asphalt samples saturated in vacuum and unsaturated samples.

Preparation of asphalt concrete samples for testing, indicated in Table 1 and Figures 8-10, included compaction of hot asphalt mixtures under static loading (30 Mpa for type A and B, 40 Mpa for type V) for 3 minutes. Compacted samples were 71.4 mm in diameter and (71.4±1.5) mm thick according to the requirements of the Ukrainian norms.

Samples (slabs) for rut testing were compacted by means of vibration followed by static loading similar to cylinder samples compacted with regard to the mix type. Dimensions of the compacted slabs were (300x150x70)mm. Testing was performed on not less than 5 samples providing 95% reliability of the results.

Asphalt concrete testing was performed by means of wheel tester equipped with rubberized wheel (Zhdanyuk et al., 2007) within the temperature range between 20 ^{o}C to 65 ^{o}C and 57.5 kN loading on the wheel.

Results of comparative experimental research of rut resistance of asphalt concretes of different aggregate gradation are shown in Figure 6.

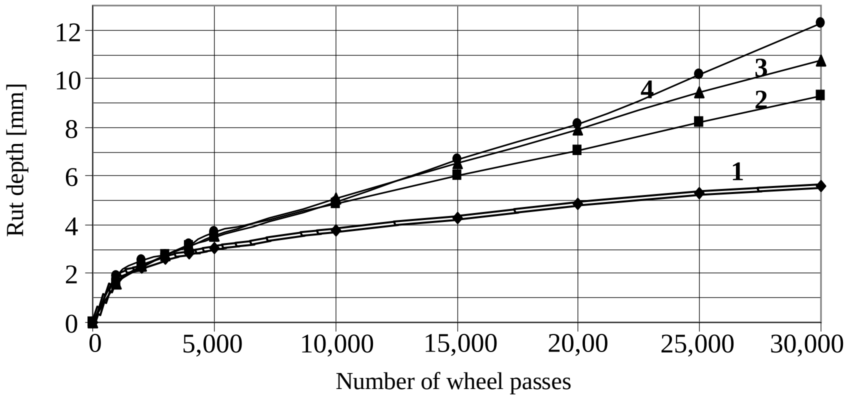

Figure 6 Rut depth versus number of wheel passes for asphalt concretes of different aggregate gradation at 50 ^{o}C (curve 1 – type A asphalt concrete, 2 – type B, 3 – type V, 4 – type G)

Results of comparative experimental research of asphalt concrete resistance to accumulation of permanent deformations indicate that rut depth increases for all asphalt concretes used for research with the increase of wheel pass number. Rut depth of the asphalt concretes does not exceed 4 mm after up to 5,000 wheel passes. Among fine-graded asphalt concretes minimum rut depth is appropriate to asphalt concrete with the highest crushed stone content (type A), and asphalt concrete with the smallest crushed stone content (type V) is characterized by maximum rut depth. Sand asphalt concrete is characterized by the deepest rut in comparison with fine-graded asphalt concretes (Figure 7). After 25,000 wheel passes sand asphalt (type G) has twice as deep rut as fine-graded asphalt concrete of type A.

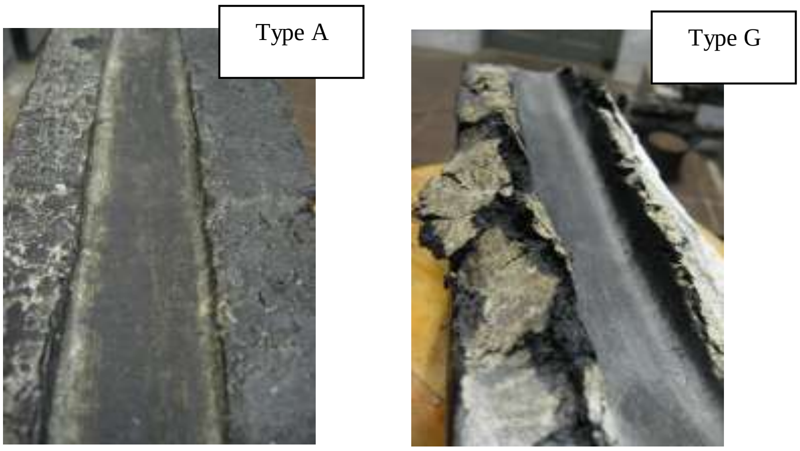

Figure 7 General view of asphalt concrete samples after 30,000 wheel passes (pure bitumen)

Experimental research results allow us to stumble at the objectivity of known statement that asphalt concretes with higher strength evaluated at uniaxial compression (at optimal bitumen content) are more shear resistant.

In order to evaluate the influence of bitumen content in asphalt concrete and temperature of the environment on rut formation process fine-graded asphalt concrete of type B with gradation, shown in Figure 3, was chosen as the material most used for wearing courses in Ukraine. The research performed indicates that bitumen content deviation from optimal value has significant influence on both physico-mechanical properties and rut resistance of asphalt concretes (Figure 8–11).

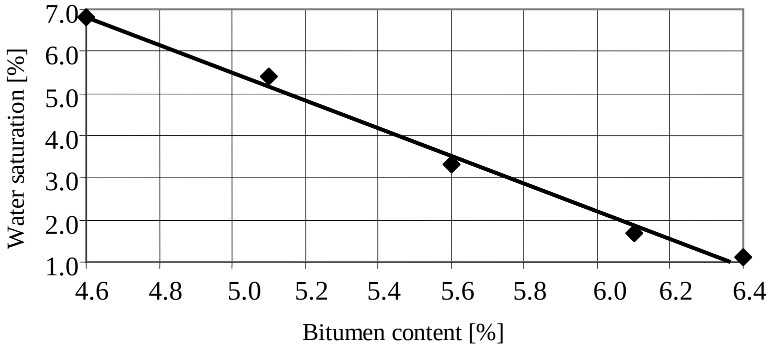

Figure 8 Dependence of water saturation of type B fine-graded asphalt concrete with 20 mm maximum aggregate size on bitumen content (pure bitumen)

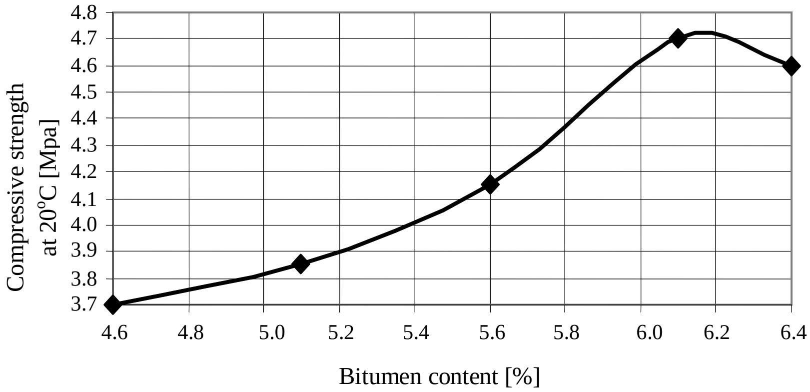

Figure 9 Dependence of compressive strength of type B fine-graded asphalt concrete with 20 mm maximum aggregate size on bitumen content (pure bitumen)

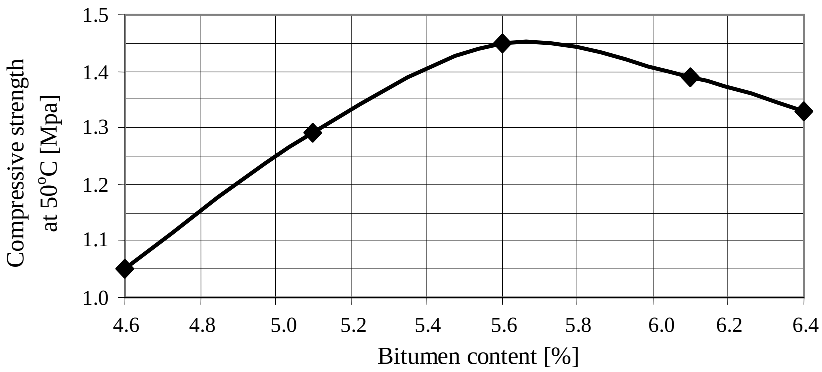

Figure 10 Dependence of compressive strength of type B fine-graded asphalt concrete with 20 mm maximum aggregate size on bitumen content (pure bitumen)

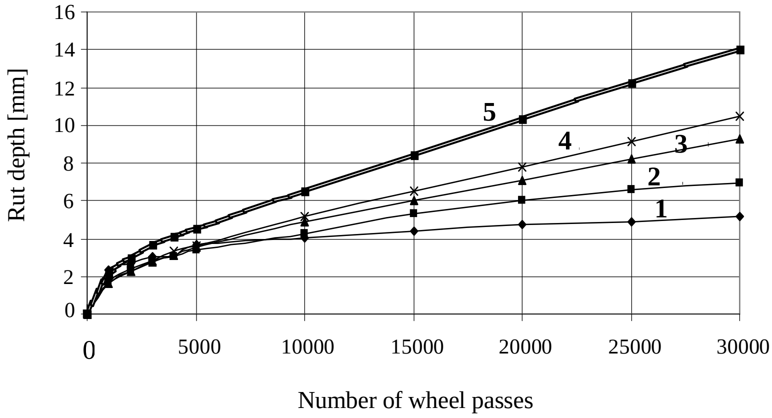

Figure 11 Rut depth versus number of wheel passes for type B asphalt concrete with 20 mm maximum aggregate size at 50 °C (pure bitumen) (curve 1 – bitumen content in asphalt concrete 4.6 %; 2 – 5.1 %; 3 – 5.6 %; 4 – 6.1 %; 5 – 6.4 %)

Dependence of rut depth on bitumen content in asphalt concrete is characterized by absence of extremum as compared to uniaxial compressive strength. The same character has rut depth dependence on asphalt concrete test temperature (Figure 12).

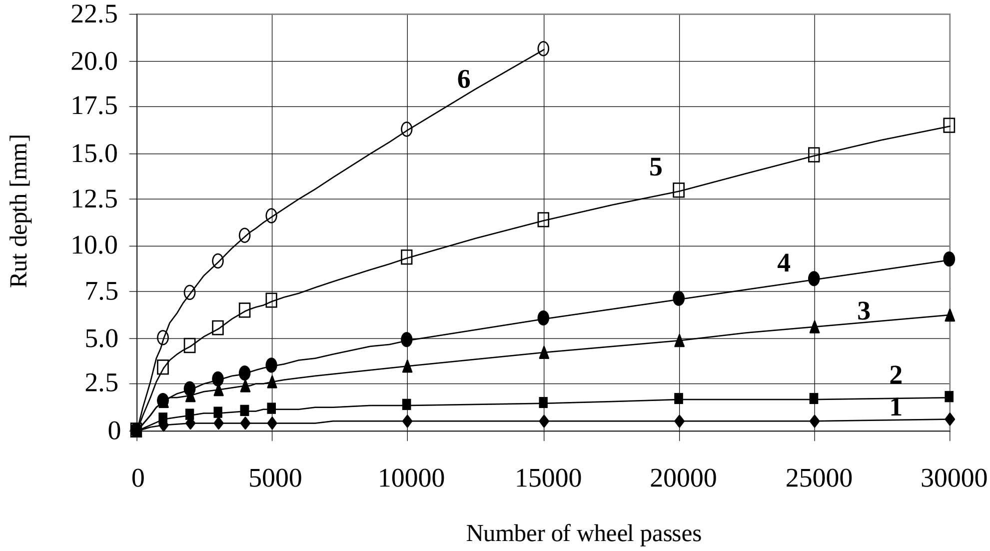

Figure 12 Rut depth versus number of wheel passes for type B fine-graded asphalt concrete at different temperatures (pure bitumen) (curve 1 – test temperature 20 ºC; 2 – 35 ºC; 3 – 45 ºC; 4 – 50 ºC; 5 – 57 ºC; 6 – 65 ºC)

Dependences shown indicate that temperature increase results in significant increase of rut depth. Thus, when increasing the temperature from 20 °C to 50 °C, rut depth increases up to 6 mm after 15,000 wheel passes. When further raising the temperature up to 65 °C rut depth increases more intensively and reaches more that 20 mm.

Research results of influence of crushed stone size in fine-graded asphalt concrete of type B on rut formation process are shown in Figure 13. It is evident that the smaller the maximum size of crushed stone in fine-graded asphalt concrete of type B the less is rut depth.

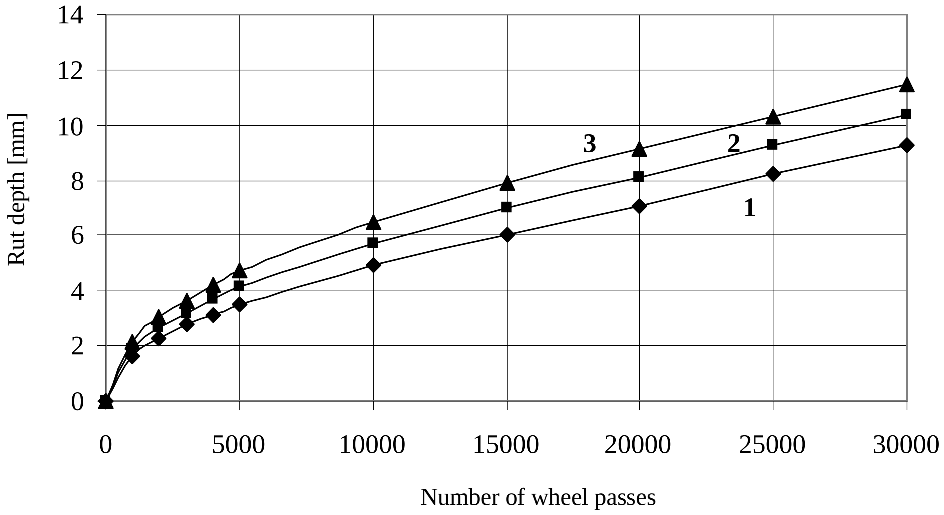

Figure 13 Rut depth versus number of wheel passes for type B fine-graded asphalt concrete at 50 ºC (pure bitumen) (curve: 1 – asphalt concrete with maximal aggregate size 10 mm; 2 – 15 mm; 3 – 20 mm)

Results of comparative research of polymer modified binder influence on rut formation process in fine-grained asphalt concrete of type B with 10 mm maximum crushed stone size are given in Figure 14.

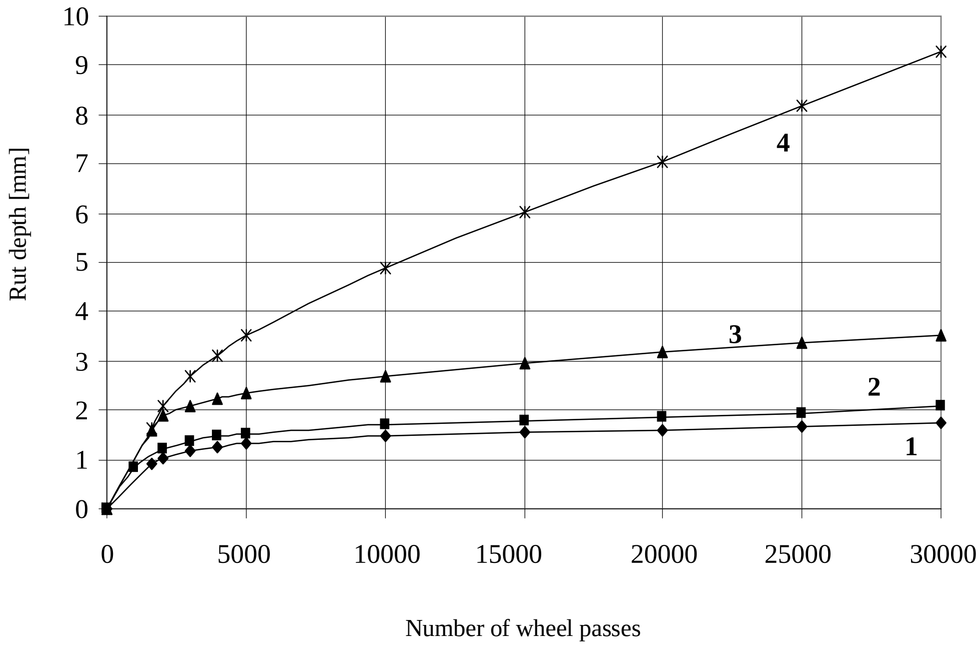

Figure 14 Rut depth versus number of wheel passes for type B fine-graded asphalt concrete with maximum aggregate size at 50 ºC (curve 1 – asphalt concrete on bitumen modified with 3 % Kraton D 1101; 2 – 1.5 % Kraton D 1101 and 1.5 % low-molecular modifier Licomont BS 100; 3 – 3 % Licomont BS 100; 4 – pure bitumen)

The dependence indicate that addition of 3 % low-molecular modifier Licomont BS 100 to petroleum road bitumen, characterized by penetration within 90 to 130 dmm, decreases intensity of rut depth increase in fine-graded asphalt concrete, prepared on it, almost by three times. Application of bitumen modified simultaneously with 1.5 % low-molecular modifier Licomont BS 100 and 1.5 % polymer Kraton D 1101 for asphalt concrete preparation, promotes further decrease of rut depth. Asphalt concrete prepared on bitumen modified with 3 % thermoplastic elastomer Kraton D 1101 is characterized by the smallest rut depth in comparison with other asphalt concrete chosen for the research.

CONCLUSIONS

Analysis of experimental research results shows that the increase of crushed stone content in asphalt concrete and decrease of its size results in increase of their resistance to permanent deformations. Out of all asphalt concretes taken for the research, prepared on pure petroleum road bitumen, fine-graded asphalt concrete of type A is the most rut resistant and sand asphalt concrete turned out to be the least resistant material.

Shear resistance of asphalt concrete significantly decreases with the increase of bitumen content in asphalt concrete composition, number of wheel passes or temperature. Significant increase of rut resistance of asphalt concrete can be gained through utilization of bitumen modified with high-molecular polymer Kraton D 1101 of SBS type, low molecular modifier Licomont BS 100 as well as simultaneous application of the additives mentioned above.

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