PERFORMANCE EVALUATION OF DIFFERENT ASPHALT MIXES IN LONG-TERM OPERATION

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ABSTRACT

Highway pavements have to withstand the traffic load under different seasonal and environmental conditions without excessive deformations (rutting and cracking). Either of these distress conditions can cause premature failure of the pavements. Hence, to reduce the possibility of forming such distresses in future, assessment of longevity of existing pavements is required.

In 2001 eight experimental sections of road pavements (approximately 300 m each) were constructed using various asphalt concrete wearing course recipes on Riga bypass A4. Monitoring of these sections was performed during the following years. The structural condition of the sections has been continuously determined using Falling Weight Deflectometer (FWD) testing method. Measurements of skid resistance were performed using the GripTester. Surface texture and unevenness were characterized with the International Roughness Index (IRI) profilometer. Asphalt samples were cored from the asphalt for determining the performance properties in laboratory. This paper offers the assessment of changes and dynamics of performance of these different asphalt mixes during operation period of twelve years

Keywords: Road pavement A, performance properties B, FWD C, skid resistance D, surface texture E

1. INTRODUCTION

A pavement's primary purpose is to provide a functional surface for a specific transportation need. The basic function is to withstand load, under different seasonal environmental conditions, without deforming or cracking. The function of the different layers in the pavement is to spread out the load on the surface and reduce its intensity with depth. Structural evaluation of pavement can be done in a number of different ways. In general, the deflection or the curvature of a pavement when subjected to a specific load is used for such measurement (Rajib B. Mallick and Tahar El-Korchi, 2009).

FWD is used by the road agencies for network level deflection survey for assessing the rate of pavement deterioration and to determine the timing for rehabilitation. Deflection basin parameters from FWD testing device are used extensively for assessing the structural integrity of a pavement and to back calculate the in situ layer moduli of a pavement. Pavement structural deformation is greatly dependent on the performance of the various pavement layers and the quality of the pavement subgrade (G. Chai, G. Lewer and G. Cancian, 2010).

Roughness of asphalt pavement affects the traffic safety, comfort of vehicle occupants and also generates dynamic load of heavy vehicles to give the pavement structure additional damage. The pavement damage increases due to increase of IRI, and its increasing degree becomes more remarkable as travel speed is high (T. Kanai, K. Tomisawa and T. Endoh, 2010). Good skid resistance predominantly dependent upon the aggregate in the surfacing (Franēois de Larrard et al, 2008, T. Sofilic et al, 2010).

In recent years, many transportation agencies have started investigation the applicability of long term maintenance contracts, e.g. performance – specified maintenance contracts (PSMC) or performance – based warranty contracts. These maintenance contracts transfer the long – term responsibility for planning and executing maintenance work from agencies to contractors. The agencies are able to obtain better budget estimate, hedge the performance related risk, and reduce the cost of maintenance. And the contractors are able to implement innovative construction methods and management techniques to make a profit (Jih-Chiang Lee et al, 2013).

To assess serviceability of wearing courses of different asphalt mixes in conditions of specific traffic load, in 2001, 8 different mixtures of wearing course were built into the road A4 Baltezers – Saulkalne section 16.131 – 19.380 km. From 2001 until 2002, constant monitoring was performed to as certain condition of these experimental mixes during operation:

- visual assessment of condition;
- measurements of skid resistance index of the surface with the Griptester equipment;
- measurements of permanent deformation – ruts – with a laser profilometer (IRI);
- measurements of surface evenness with a laser profilometer;
- measurements of bearing capacity of the pavement (surface resilient modulus), performed with FWD;
- borehole samples for laboratory testing to evaluate changes.

In the paper, the results of changes and dynamics of performance of different asphalt mixes during operation period of twelve years are presented, and suggestions to improve the current situation are also brought out.

2. CHARACTERIZATION OF TRAFFIC LOAD

Traffic intensity and axle load are one of the most important external factors influencing premature failure of the pavement. The traffic intensity and load data have been obtained from traffic statistic station, which is located at the Riga bypass A4 (Baltezers – Saulkalne). On figures 1 and 2 are shown traffic intensity and traffic content on Riga bypasss A4.

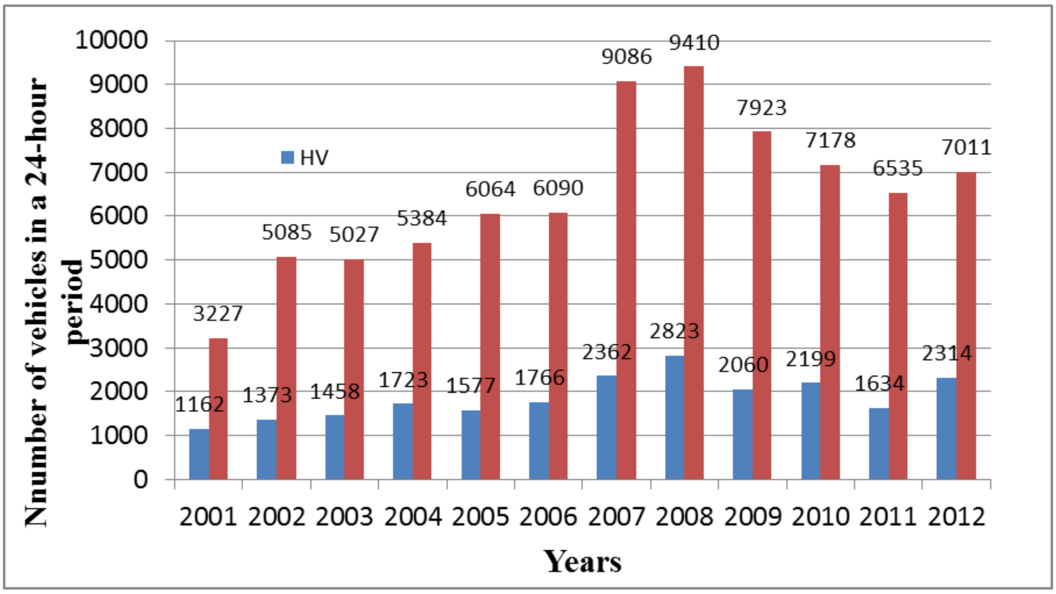

Figure 1: Traffic intensity on Riga A4 bypass

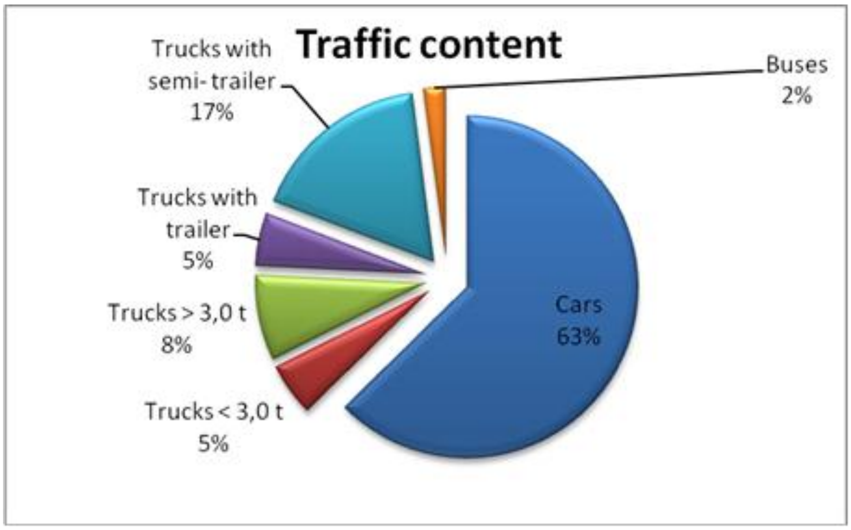

Figure 2: Traffic content on Riga A4 bypass

3. EXPERIMENTAL ROAD STRUCTURE

Experimental road constructions were prepared as follows. Reclaimed asphalt pavement (RAP) using cold recycling technology was constructed over an existing embankment soil. RAP, having layer thickness of 25cm, was treated with bitumen emulsion and Portland cement. Static deformation modulus of embankment and RAP sub-base layer were 170MPa and >170MPa respectively. Dense asphalt concrete AC 16 or stone mastic asphalt SMA 16 were used for asphalt pavement surface layer and ACb 32 was paved as base layer. Experimental road construction structure is shown in Figure 3.

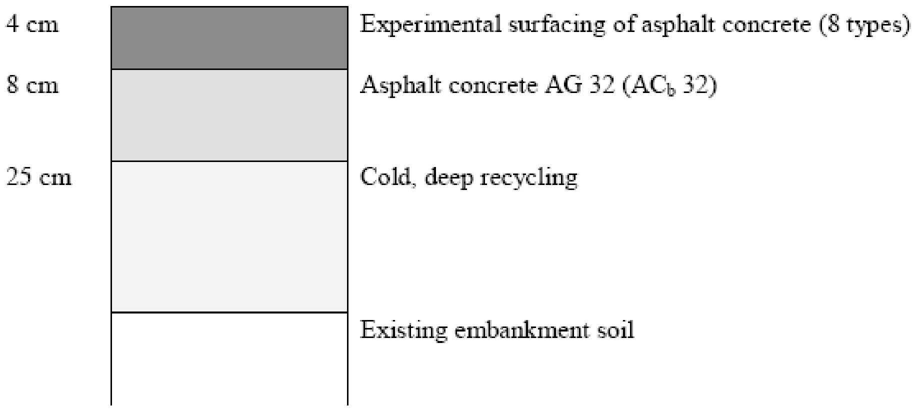

Figure 3: Experimental road structure

4. EXPERIMENTAL ASPHALT CONCRETE MIXES

AC 16 and SMA 16 mixtures have been designed in accordance with Marshall method by using unmodified bitumen B70/100 and aggregates (crushed granite, diabase and dolomite) of different origins. Aggregates were selected to contain the main natural stone materials which are conventionally used in asphalt concrete in Latvia. Properties of aggregates and bitumen have been investigated and their conformity to the technical specifications has been evaluated (Table 1 and Table 2).

Table 1: Main properties of aggregates

No.	Aggregate	Properties				Mix No.
		Micro-Deval value (M_{DE})	Nordic abrasion test (A_N)	Flakiness index (FI)	Los angeles abrasion loss value (LA)	
1.	Crushed granite “Lohja Rudus” (Finland)	4.4	8.4	1.2	15	1, 7
2.	Crushed granite “Mikaševiči” (Belarus)	10.8	11.5	1.2	16	8, 10, 12
3.	Crushed diabase “Karlshamn” (Sweden)	9.6	9.9	1.3	15	11
4.	Crushed dolomite “Dolomitas” (Lithuania)	12.3	16.5	1.3	21	2, 9
Target value in accordance with technical requirements		-	14	15	20	

Table 2: Main properties of bitumen

No.	Bitumen	Properties							Mix No.	
		Initial in 2001								
					Aging 163^{0}C					
		Penetration 25^{0}C [0.1mm]	Fraass breaking point [^{0}C]	Softening point [^{0}C]	Change of mass [%]	Penetration 25^{0}C [0.1mm]	Softening point [^{0}C]	Kinematic viscosity, mm^2/s	1,2,7,8,9,,11,12	10
1.	B70/100 “Nynas”	88	-16.1	45.1	0.14	60.2	51.0	287	x	
2.	B70/100 “Ķiriši”	77	-22.5	47.3	0.06	48.0	52.3	231		x
Recovered in 2012										
1.	B70/100 “Nynas”	51 (-42%)	-9 (+44%)	52.5 (+11%)	-	-	-	-	x	
2.	B70/100 “Ķiriši”	50 (-35%)	-15 (+33%)	52.7 (+11%)	-	-	-	-		x

The basic purpose of mix design is to select and combine the different components in such a way as to result in mix that has the most optimum levels of all relevant properties. Analysis of physical properties of asphalt concrete (the compaction degree), which is characterized by three volume parameters – voids (V), voids in mineral aggregate (VMA) and voids filled with bitumen (VFB) and two mechanical properties – compressive strength of specimens under the static load at temperature of

60^0C (Marshall stability) and displacement at the moment of specimen deterioration (Marshall flow), has been made for determination of optimum asphalt content.
In total eight (two SMA 16 and six AC 16) asphalt mixture have been designed in accordance with Marshal method (Table 3).

Table 3: Asphalt concrete mixes

Recipe No.	Asphalt concrete mix type	No.	Mix content	Volume, %
1	AC 16	1.	Crushed granite "Lohja Rudus" fr. 8/16	14.3
		2.	Crushed granite "Lohja Rudus" fr. 6/12	31.5
		3.	Washed sand from quarry "Salenieki"	42.5
		4.	Filler "Brocēni"	7.1
		5.	Bitumen 70/100 "Nynas"	4.6
2	AC 16	1.	Crushed dolomite "Dolomitas" fr. 11/16	24.1
		2.	Crushed dolomite "Dolomitas" fr. 5/11	27.0
		3.	Washed sand from quarry "Salenieki"	38.5
		4.	Filler "Brocēni"	5.6
		5.	Bitumen 70/100 "Nynas"	4.8
7	AC 16	1.	Crushed granite "Lohja Rudus" fr. 8/16	14.3
		2.	Crushed granite "Lohja Rudus" fr. 6/12	13.3
		3.	Granite fines "Lohja Rudus" fr. 0/5	43.1
		4.	Filler "Brocēni"	4.5
		5.	Bitumen 70/100 "Nynas"	4.8
8	SMA 16	1.	Crushed granite "Mikaševiči" fr. 11/16	45.6
		2.	Crushed granite "Mikaševiči" fr. 5/11	27.5
		3.	Washed sand from quarry "Salenieki"	12.9
		4.	Filler "Brocēni"	8.3
		5.	Bitumen 70/100 "Nynas"	5.3
		6.	Celulose fibres	0.4
9	SMA 16	1.	Crushed dolomite "Dolomitas" fr. 11/16	45.2
		2.	Crushed dolomite "Dolomitas" fr. 5/11	29.0
		3.	Washed sand from quarry "Salenieki"	11.1
		4.	Filler "Brocēni"	8.3
		5.	Bitumen 70/100 "Nynas"	5.9
		6.	Celulose fibres	0.5
10	AC 16	1.	Crushed granite "Mikaševiči" fr. 11/16	24.8
		2.	Crushed granite "Mikaševiči" fr. 5/11	25.8
		3.	Washed sand from quarry "Salenieki"	37.5
		4.	Filler "Brocēni"	7.3
		5.	Bitumen 70/100 "Ķiriši"	4.6
11	AC 16	1.	Crushed diabase "Karlshamn" fr. 11/16	17.8
		2.	Crushed diabase "Karlshamn" fr. 8/11	21.4
		3.	Crushed diabase "Karlshamn" fr. 5/8	19.6
		4.	Washed sand from quarry "Salenieki"	30.2
		5.	Filler "Brocēni"	6.7
		6.	Bitumen 70/100 "Nynas"	4.3
12	AC 16	1.	Crushed granite "Mikaševiči" fr. 11/16	25.3
		2.	Crushed granite "Mikaševiči" fr. 5/11	18.8
		3.	Crushed granite "Mikaševiči" fr. 0/5	46.9
		4.	Filler "Brocēni"	4.7
		5.	Bitumen 70/100 "Nynas"	4.3

5. RESULTS

5.1 Skid resistance

Skid resistance comes from a complex mechanism among the road surface, the tires, and the environment. Out of all the factors that affect the skid resistance of a surface, the texture is the only thing that can be controlled through engineering ways. Many studies which focused on the relationship between texture design and skid resistance showed that when the texture on the test surface is arranged orderly, its skid resistance will be affected by the shape, size and depth of the texture (Chai-Pei Chou and Ning Lee , 2013; T. F. Fwa et al, 2003). There are many types of skid resistance tester. Each of them obtains frictional values in completely different systems, and so far there are no reliable correlation equations to transform one system to another (A. E. Gendy and E. Shalaby, 2007).

Skid resistance values obtained from eight experimental sections are illustrated in Figure 5. Sections 1, 2, 9 and 10 showed the lowest skid resistance values – skid resistance index below 0.5. The results confirm strong relationship between pavement functional properties and aggregate properties: asphalt concrete mixes containing dolomite aggregate showed the lowest skid resistance, 0.2 (Sections 2 and 9), while sections containing crushed granite and diabase aggregates (7, 11 and 12) showed highest skid resistance value, 0.6. It is important to note that replacing fine crushed granite and diabase aggregates with washed natural sand caused significant drop in skid resistance: the index decreased from 0.6 (Section 7) to 0.4 (Section 1) and from 0.7 (Section 12) to 0.5 (Section 8).

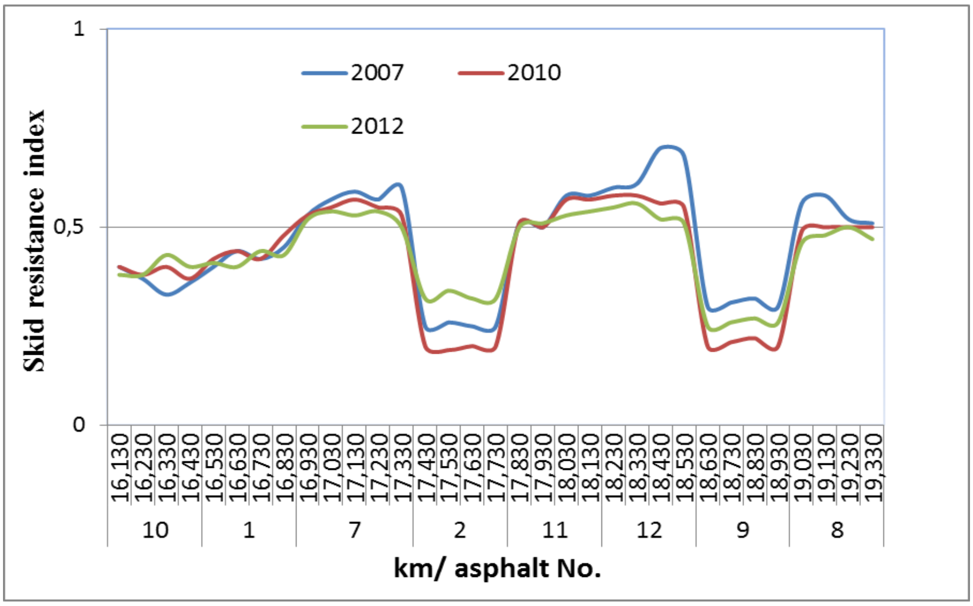

Figure 4: Diagram of skid resistance index

5.2 Load bearing capacity of pavement

A Falling Weight Deflectometer (FWD) equipment was used to assess the current structural pavement condition. The FWD applies a dynamic load on the pavement surface by dropping a weight that is transmitted through a circular loading plate. Such dynamic load simulates the effect of a wheel load on the pavement surface by generating temporally pavement deformations, which are recorded by sensors located radially at 2.5 m from the point of application of the load (S. M. Sargand et al, 2013). The magnitude of the impulse load transmitted by the FWD device to the pavement can vary from 30 kN to 250 kN by varying the weight and drop height (S. Sargand, 2002). The FWD testing method is widely used because is easy to implement, reliable, and cost-effective with respect to other methods (W. Edwards et al, 1989).

Measured surface deflections were used in back-calculating “effective” modulus of pavement layer witch are assumed to represent the in-situ strength or conditions of the layers after long term performance.

The Dynatest ELMOD 5 computer program, developed by Dynatest, was used as the back-calculation procedure in this study. ELMOD analyzes the pavement response from the by determining the modulus, stress and strain of each significant layer.

The load level used for the FWD drops was 50kN, which corresponds to a load pressure of approximately 750 kPa. Seismic geophones which monitor the deflections were placed at 0 mm, 200 mm, 300 mm, 450 mm, 600 mm, 900 mm, 1500 mm, 1800 mm and 2100 mm offsets to measure the full pavement deflection basin. The testing was performed at ambient temperatures of 10^0C to 11^0C. Figure 5 show modulus of elasticity for surface layers of experimental sections. The mean value of elasticity modulus for experimental sections is approximately 1000MPa. However, it is important to note that modulus of elasticity for the same experimental section changed significantly. This may be caused by inhomogeneity of bituminous and unbound layers.

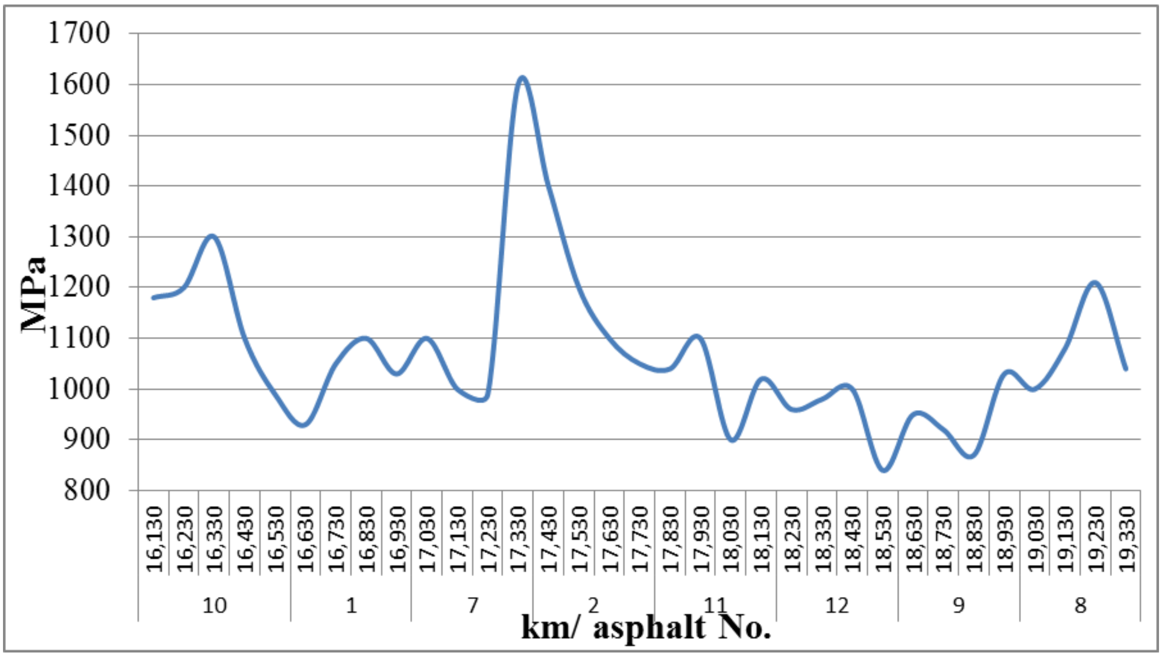

Figure 5: Surface layer modulus of elasticity

5.3 Pavement surface evenness

Pavement surface roughness is a major concern associated with driving quality. Furthermore, pavement roughness indicates pavement surface deformation, which may affect pavement drainage, drive safety, etcetera (Jyh-Dong Lin et al, 2003). Since pavement roughness causes an increase in vertical stress received by pavement and the aggravation of pavement fatigue, pavement roughness certainly accelerates pavement distress deterioration. Any pavement distresses will also result in a deterioration of the pavement roughness index value. Thus, the above shows that pavement distress and pavement roughness have a mutually causal relationship, affecting one another in both directions (M. S. Janoff et al, 1985). The

International Roughness Index (IRI) is the roughness index most commonly obtained from measured longitudinal road profiles. The roughness measurement is performed by the Roughness Subsystem, which consists of a roughness computer, laser SDP software, the accelerometer, and the roughness lasers.

The IRI results are shown on figure 6. The two experimental sections (10 and 9) in which asphalt concrete mixes contain dolomite and granite aggregates with washed natural sand showed the highest surface evenness mean value: 1.9m/km for Section 10 and 2.3m/km for Section 9. However, IRI values within the same experimental sections changed significantly.

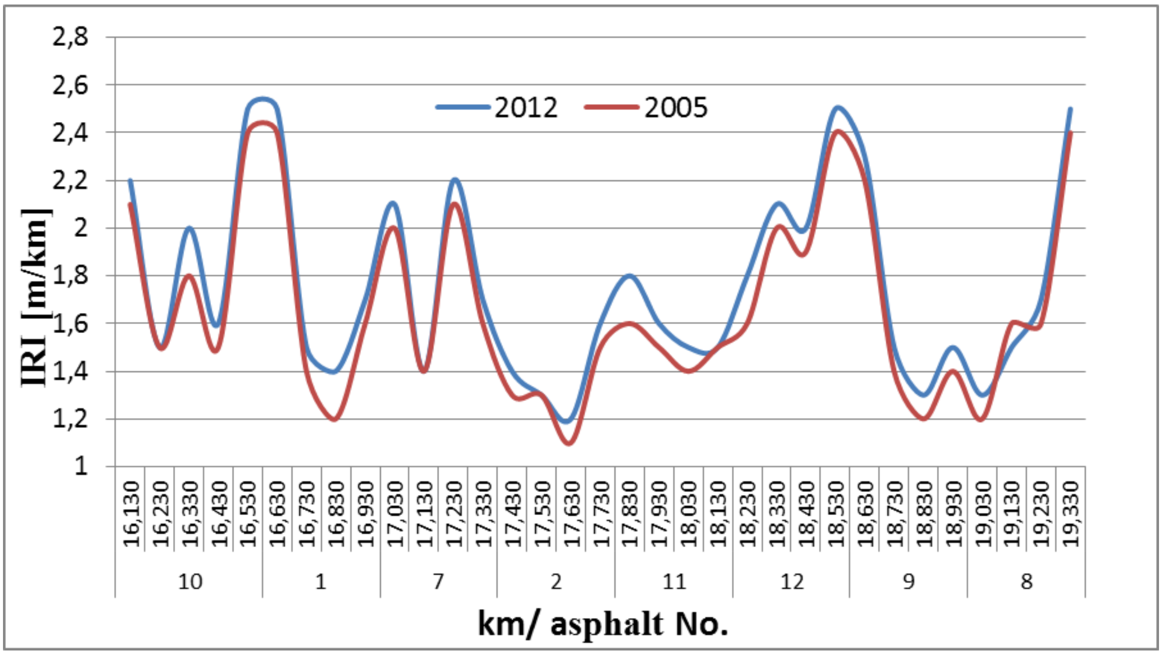

Figure 6: Road surface evenness

5.4 Laboratory testing

A wheel tracking apparatus was used to simulate the effect of traffic and to measure the plastic deformations of the borehole asphalt concrete samples. Tests were performed according to standard EN 12697-22 method B (wheel tracking test with small size device in air). This test method is designed to repeat the stress conditions observed in the field and therefore can be categorized as simulative. The resistance of asphalt mixture to permanent deformation is assessed by measuring the rut depth and its increments caused by repetitive cycles (26.5 cycles per minute) under constant temperature at 60°C. The rut depths are monitored by means of two linear variable displacement transducers (LVDTs), which measure the vertical displacements of each of the two wheel axles independently as rutting progresses (V. Haritonovs et al, 2013).

According to research of number of scientists, ruts with the depth of ≥ 13mm become dangerous, when the vehicle speed exceeds 80km/h (S. Erkens, 2002). Rutting measurement results illustrated in figure 7 show that only in Sections 1 and 10 ruts deeper than 13mm developed. Crushed granite and diabase aggregates were replaced with washed natural sand in these sections.

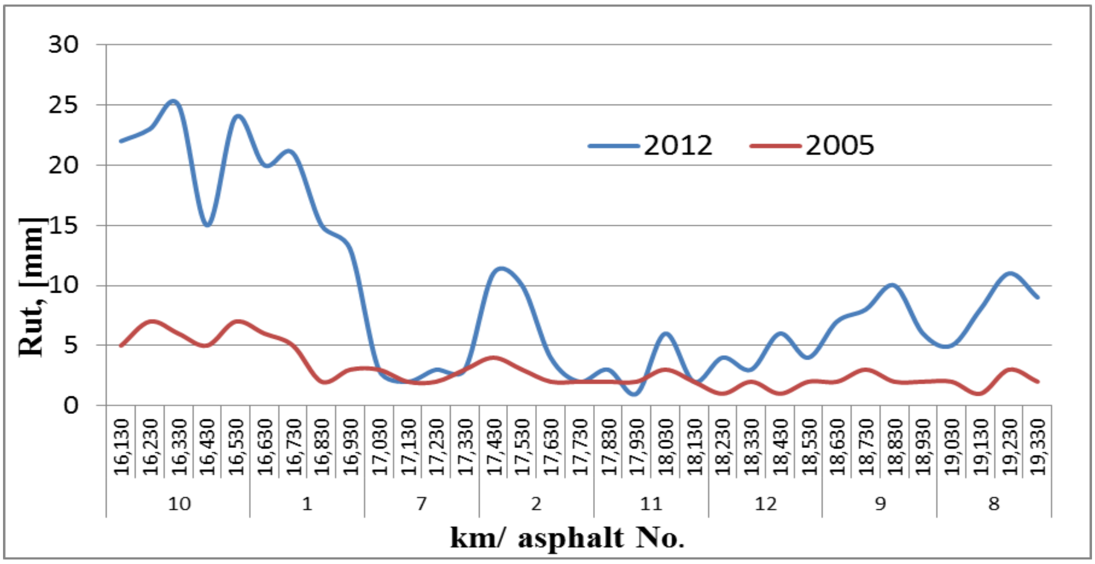

Figure 7: Rut depth

6. CONCLUSIONS

Indexes of performance properties of these experimental mixes, as well as, other results were used for development of "Road Specifications 2012" and "Road Specifications 2013".
Results of performance of the experimental pavement sections of a wearing course were taking into consideration when defining the following qualitative parameters and requirements:

- evenness of a wearing course (IRI) when defining different values in projects of periodic maintenance and new construction sites;
- skid resistance values in different levels of traffic intensity;
- resistance to permanent deformations (WTSAIR) in different levels of traffic intensity;
- resistance to wear from studded tyres of aggregates used in a base course (also in surface dressing).

The results demonstrated a strong relationship between functional properties of pavement and aggregates. Asphalt concrete mixes containing dolomite aggregate showed the lowest skid resistance while mixtures containing crushed granite and diabase aggregates had the highest skid resistance. It was found that replacing fine crushed granite and diabase aggregates with washed natural sand caused skid and rut resistance to drop significantly. However, the performance characteristics within the same experimental sections changed significantly. This is likely to be caused by the inhomogeneity of bituminous and unbound layers.

7. ACKNOWLEDGEMENT

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