DEVELOPMENT OF HIGH PERFORMANCE ASPHALT CONCRETE USING LOW QUALITY AGGREGATES

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Abstract. Dolomite is one of the most available sedimentary rocks in the territory of Latvia. Dolomite quarries contain about 1000 million tons of material. However, according to Latvian Road Specifications 2012, this dolomite cannot be used for average and high intensity roads because of its low quality (mainly, LA index). Therefore, mostly imported magmatic rocks (granite, disbase, gabbro, basalt) or imported dolomite are used which makes asphalt expensive. However, that practical experience shows that even with these high quality materials roads exhibit rutting, fatigue and thermal cracks. The aim of the paper is to develop high performance asphalt concrete for base and binder courses with using only locally available aggregates. In order to achieve resistance to deformations at high ambient temperature hard grade binder was used. Workability, fatigue and thermal cracking resistance, as well as sufficient water resistance is achieved by low porosity (3-5%) and higher binder content compared to traditional asphalt. Design of the asphalt includes a combination of empirical and performance based tests, which in the laboratory circumstances allow to simulate traffic and environmental loads. High performance ACb 16 asphalt concrete have been created using local dolomite aggregate B20/30 penetration grade bitumen. The mixtures will be specified based on fundamental properties in accordance with EN 13108-1 standard

Keywords: dolomite aggregate, asphalt concrete, permanent deformations, fatigue resistance

INTRODUCTION

If the local material does not fulfill requirements, then one should seek the way for the improvement of its properties. If this is not possible, then one should seek the technological solution which will allow application of the weaker material (Sybilski et al. 2010). One of a proper solution might be the use of dolomite as a component of High Modulus Asphalt Concrete (HMAC). Knowing that the binder courses, situated between 5 and 12 cm below the road surface (Fig. 1), are subject to the highest stresses high stiffness is probably the most important requirements for HMAC (De Backer et al. 2008).

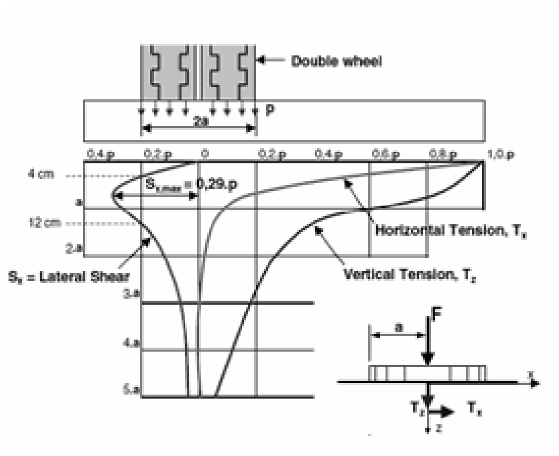

Fig. 1. Lateral force diagram of heavy vehicle tire (Sivapatham et al. 2010)

HMAC is a mixture of asphalt concrete designed for use in base and binder course of asphalt pavement. It has closed structure with comparatively large content of bitumen. Hard road bitumen grades are applied, mainly 10/20, 15/25, 20/30 and polymer modified bitumen. Hard bitumen assure the mixtures resistance to rutting. However large content of bitumen assure workability, fatigue durability and water resistance (Sybilski at al. 2008).

This type of an asphalt mixture is designed not only by empirical properties but also by performance based properties (rut test, stiffness modulus test, fatigue test) (SPENS).

France was also one of the first countries in which mechanistic asphalt pavement design was introduced into the general practice (AFNOR). In France, it is known under the acronym EME. In Poland, the acronym is AC WMS. Possible application of weaker mineral aggregate is one of the advantages of EMA (in English HMAC). Application of High Modulus Asphalt Concrete allowed for saving on asphalt pavement's thickness thanks to higher stiffness modulus which reduce tension strains in asphalt base layer.

The aim of the paper is to develop high performance asphalt concrete for base and binder courses with using only locally available aggregates – crushed dolomite. In order to achieve resistance to deformations at high ambient temperature hard grade binder was used.

1 MATERIALS

The basic materials used in this study are fractionated crushed dolomite aggregate and unmodified hard grade bitumen B20/30. Crushed dolomite aggregate were obtained from Pļaviņu DM ltd. (Latvia), and hard grade bitumen B20/30 from Grupa LOTOS S.A (Poland).

1.1 Bitumen characteristics

The binder properties have been tested by means of conventional binder tests: needle penetration, softening point, aging and Fraas breaking point. The test results are listed in Table 1.

Table 1. Bitumen properties

Parameter	Bitumen		Standard
	B 20/30	B70/100	
Penetration at 25°C, dmm	29	80	LVS EN 1426
Softening point, °C	62.7	46	LVS EN 1427
Fraas temperature °C	- 13	-20	LVS EN 12593
Ageing characteristics of bitumen under the influence of heat and air (RTFOT method)			
Loss in mass, %	0	0	LVS EN 12607-1
Retained penetration, %	72	76	LVS EN 1426
Increase of a softening point, °C	6.9	5,4	LVS EN 1427
Fraas breaking point after aging, °C	-11	-17	LVS EN 12593

1.2 Properties of dolomite aggregate

The test results of dolomite main properties show very low flakiness index – 5, high frost resistance with average MS value of 7 and low fines content – 0,6%. However LA value is only 33. These aggregates are suitable for use as a component of High Modulus Asphalt Concere, where permitted LA value up to 40 (SPENS). The properties of dolomite aggregate are shown in Table 2

Table2 . Physical and mechanical characteristics of dolomite

Physical and mechanical properties	Unit	Related standard	Value	Requirement	
				S-I	S-II
Los Angeles (LA) coefficient	%	LVS EN 1097-2	33	LA_{25}	LA_{20}
Resistance to wear. Nordic test (A_N)	%	LVS EN 1097-9	21	-	
Flakiness Index (FI)	%	LVS EN 933-3	5	< 30	
Water absorption	%	LVS EN 1097-6	2	< 1	
Grain density	Mg/m^3	LVS EN 1097-6	2,80	-	
Fine content	%	LVS EN 933-1	0,5	< 10	
Freeze/thawing (MS)	%	LVS EN 1367-2	7	< 25	< 18

2 MIX DESIGN

HMAC-16 asphalt concrete mixtures have been designed by using conventional and unconventional (bitumen - B20/30, dolomite aggregate LA > 30) raw materials (Fig. 2). The basic idea of HMAC is to design a mix with hard grade bitumen at high binder content. (Rohde et al. 2008). The Marshall mix design procedure was used for the determination of the optimal bitumen content for the reference mixture, considering the mixture test results for Marshall stability and flow, as well as the volumetric values: air voids (V), voids in mineral aggregate (VMA) and voids filled with bitumen (VFB) Test specimens for Marshall Test were prepared in the laboratory by impact compactor according to LVS EN 12697-30 with 2×50 blows of hammer 150°C temperature

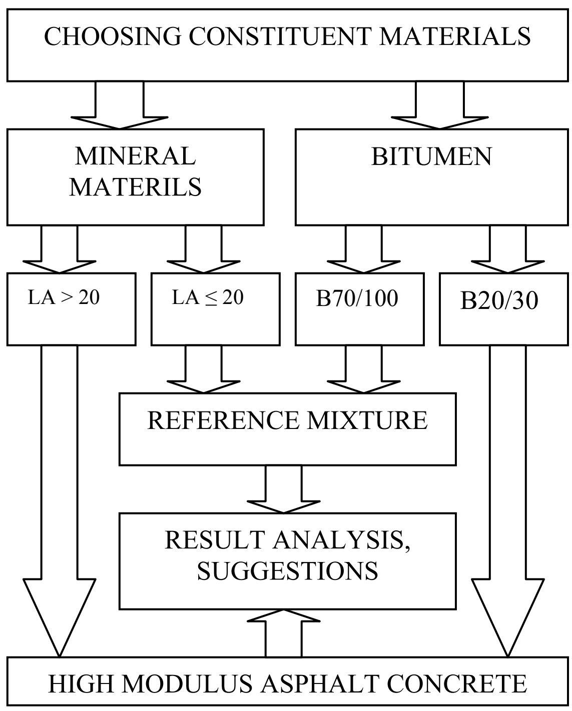

Fig.2. Experimental plan

3 RESULTS

3.1 Physical properties

Analysis of physical properties of asphalt mixtures (the compaction degree), which is characterized by three volume parameter has been made. The binder content has been optimized and conformity to HMAC requirements (SPENS) has been evaluated. Table 3 contains test results of physical properties depending on the binder content.

Parameter	Mixtures					
	(HMAC-2/1)	(HMAC-2/2)	(HMAC-2/3)	(HMAC-2/4)	(HMAC-2/5)	Reference
Bulk density, kg/m3	2383	2411	2430	2455	2457	2550
Maksimum density, kg/m3	2602	2586	2586	2555	2551	2680
Voids content, %	8,4	6,8	6	3,9	3,7	4,85
VMA	19,3	18,8	18,3	17,8	18	17,6
VFB	56,3	64	67,2	78,2	79,6	72,4
Bitumen content, %	4,56	4,99	5,06	5,67	5,83	5,0

3.2 Marshall test

Table 4 contains Marshall test results depending on the binder content. The results show that HMAC mixtures has higher Marshall stability compared to reference mixture.

Parameter	Mixtures					
	(HMAC-2/1)	(HMAC-2/2)	(HMAC-2/3)	(HMAC-2/4)	(HMAC-2/5)	Reference
Stability at 60°C (kN)	Not tested (voids content > 5%)			16,6	15,4	12,0
Flow at 60°C (mm)				3,8	5,9	4,2

3.3 Wheel Tracking test

To perform rut resistance test, a wheel tracking apparatus is used to simulate the effect of traffic and to measure the deformation susceptibility of asphalt concrete samples. Tests were performed according to standard LVS EN 12697-22 method B (wheel tracking test with small size device in air) (Fig. 3.). This test method is designed to repeat the stress conditions observed in the field therefore can be categorized as simulative. The asphalt mixture resistance to permanent deformation is assessed by the depth of the track and its increments caused by repetitive cycles (26,5 cycles per minute) under constant temperature (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.

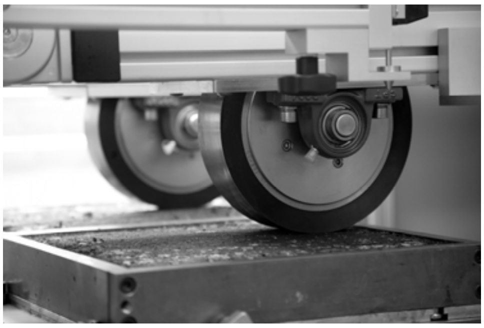

Fig.3. Wheel tracking test device

The obtained results demonstrate that the largest rut depth (5,7mm) appear for the HMAC mixture with 5,83% bitumen content. Second best results show reference mixture – 5,3mm. HMAC mixture wit 5,67 bitumen content show the best result – 3,8mm. Figure 4 summarize wheel tracking test results.

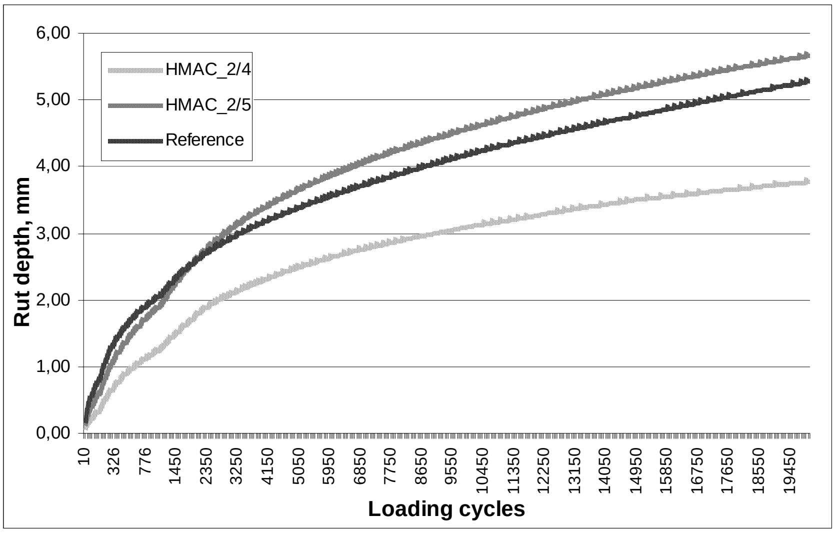

Fig.4. Wheel tracking test results

3.4 Fatigue

To determine the fatigue life of the prepared asphalt concrete mixes, a four point bending fatigue test was conducted (Fig. 5.). The test was run at 10°C, 10Hz at 130 µm/m strain level. The beams were compacted in the laboratory by using roller compactor. They were saw cut to the required dimensions of 50mm wide, 50mm high and 400mm long. The failure criterion used in the study is the traditional 50% reduction in initial stiffness.

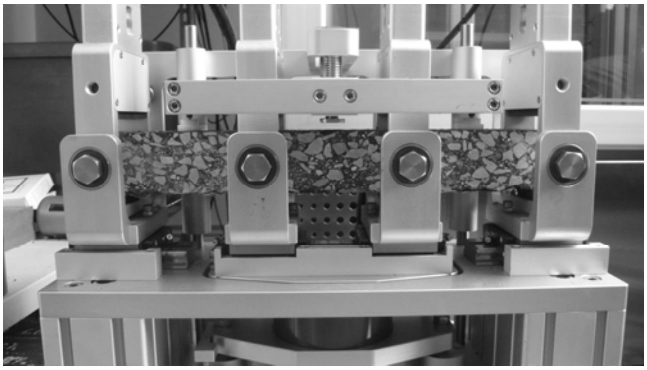

Fig.5. Fatigue test device (4PB)

The obtained results indicate that HMAC mixture with showed high resistance to fatigue, compared to results for reference mixture made with conventional aggregates and bitumen. The stiffness reduction curves are shown in Figure 6.

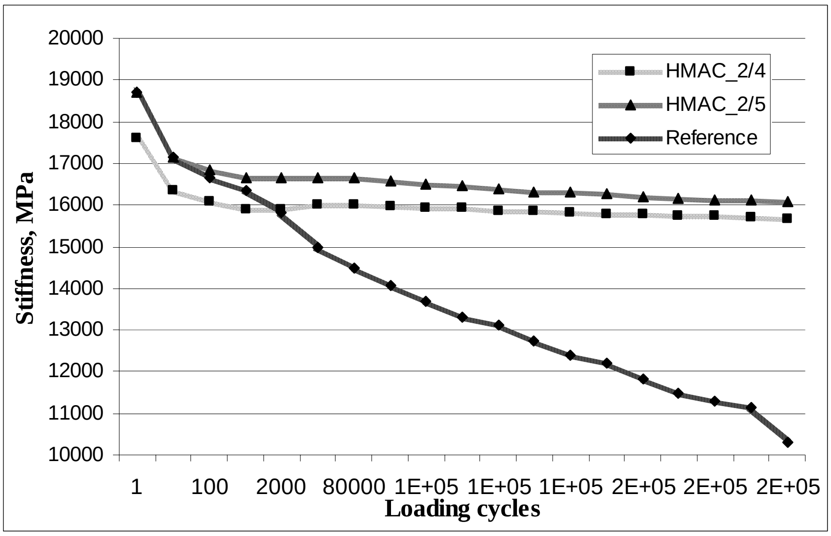

Fig.6. Fatigue test results

CONCLUSIONS

Use of dolomite aggregate in High Modulus Asphalt Concrete was evaluated. Comparative testing was performed on $AC16_{bin}$ (reference) with conventional bitumen B70/100 and granite aggregate. Reference mixture proved that low binder content resulted in lower fatigue life despite high rut resistance. However both HMAC mixture showed high rut und fatigue resistance.

Results of tests show that Latvian dolomite may be applied without any fear in High Modulus Asphalt Concrete for base and binder courses.

HMAC mixtures fulfil the HMAC asphalt concrete requirements in accordance with SPENS project recommendations (SPENS).

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