

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 the 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, 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 a high performance asphalt concrete for base and binder courses with using only locally available aggregates. In order to achieve resistance against deformations at a high ambient temperature a 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 with traditional asphalt. The design of the asphalt includes a combination of empirical and performance based tests, which in laboratory circumstances allow traffic and environmental loads to be simulated. High performance ACb 16 asphalt concrete has 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

Key words: dolomite aggregate, asphalt concrete, permanent deformations, fatigue resistance

INTRODUCTION

If the local material does not fulfill requirements, then one should seek a way for the improvement of its properties. If this is not possible, then one should seek a technological solution which will allow the application of the weaker material (Sybilski et al. 2010). One 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).

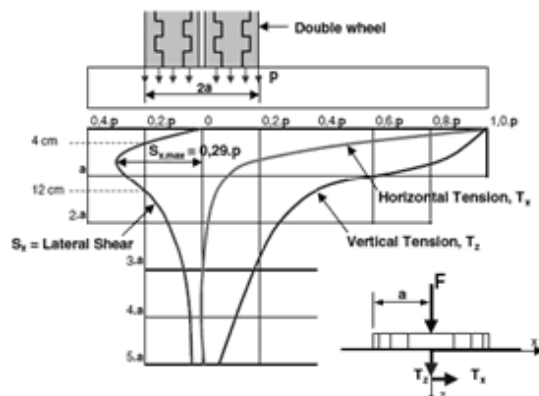


Figure 1. Lateral force diagram of heavy vehicle tire (Sivapatham et al. 2010)

HMAC is a mixture of asphalt concrete designed for use in the base and binder course of asphalt pavement. It has a closed structure with a comparatively large content of bitumen. Hard road bitumen grades are applied, mainly 10/20, 15/25, 20/30 and polymer modified bitumen. Hard bitumen assures the mixtures resistance to rutting. However a large content of bitumen assures workability, fatigue durability and water resistance (Sybilski et 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 general practice (AFNOR). In France, it is known under the acronym EME. In Poland, the acronym is AC WMS. The possible application of weaker mineral aggregate is one of the advantages of EMA (in English HMAC). Application of High Modulus Asphalt Concrete allows for saving on asphalt pavement's thickness thanks to a higher stiffness modulus which reduces tension strains in asphalt base layer.

The aim of the paper is to develop a 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 a high ambient temperature hard grade binder was used.

MATERIALS

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

Bitumen characteristics

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

Table 1

Bitumen properties		
Parameter	Result	Standard
Penetration at 25°C, dmm	25.3	LVS EN 1426
Softening point, °C	62.6	LVS EN 1427
Fraas temperature °C	- 13	LVS EN 12593
Kinematic viscosity, mm ² /s	1460	LVS EN 12595
Dynamic viscosity, Pa·s	3277	LVS EN 12596
Ageing characteristics of bitumen under the influence of heat and air (RTFOT method)		
Loss in mass, %	-0.02	LVS EN 12607-1
Retained penetration, %	75.9	LVS EN 1426
Increase of a softening point, °C	6.9	LVS EN 1427
Fraas breaking point after aging, °C	-11	LVS EN 12593

Properties of dolomite aggregate

The test results of dolomite's main properties show very low flakiness index – 5, high frost resistance with an 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 Concrete, where permitted LA value up to 40 (SPENS). The properties of dolomite aggregate are shown in Table 2

Table 2

Physical and mechanical characteristics of dolomite		
Physical and mechanical properties	Related standard	Result
Los Angeles (LA) coefficient, %	LVS EN 1097-2	33
Resistance to wear. Nordic test (AN), %	LVS EN 1097-9	21
Flakiness Index (FI), %	LVS EN 933-3	5
Water absorption, %	LVS EN 1097-6	2
Grain density, Mg/m ³	LVS EN 1097-6	2.80
Fine content, %	LVS EN 933-1	1
Freeze/thawing (MS), %	LVS EN 1367-2	7

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 a hard grade bitumen at a 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 the Marshall Test were prepared in the laboratory by impact compactor according to LVS EN 12697-30 with 2×50 blows of hammer at a 150°C temperature.

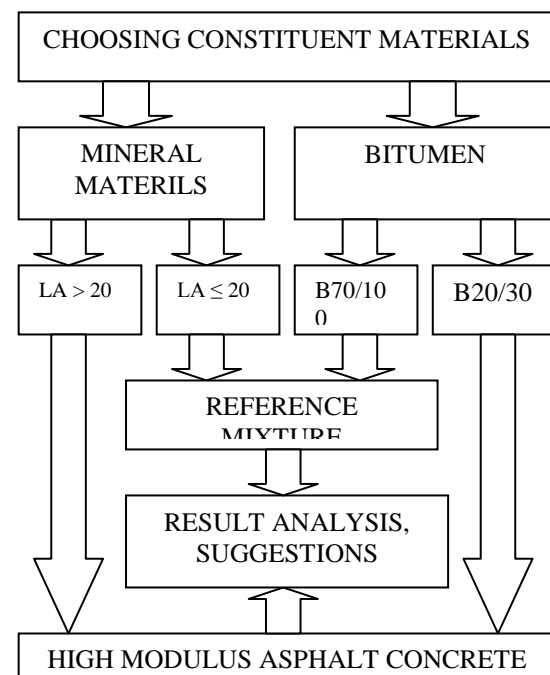


Figure 2. Experimental plan

RESULTS

Physical properties

Analysis of physical properties of the 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 the physical properties depending on the binder content.

Table 3
Physical characteristics of HMAC mixtures

Parameter	Mixtures					Reference
	(HMAC-2/1)	(HMAC-2/2)	(HMAC-2/3)	(HMAC-2/4)	(HMAC-2/5)	
Bulk density, kg/m ³	2383	2411	2430	2455	2457	2550
Maximum density, kg/m ³	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

Marshall test

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

Marshall test results

Table 4

Parameter	Mixtures					Reference
	(HMAC-2/1)	(HMAC-2/2)	(HMAC-2/3)	(HMAC-2/4)	(HMAC-2/5)	
Stability at 60°C (kN)	Not tested (voids content > 5%)			16.6	15.4	12.0
Flow at 60°C (mm)	Not tested (voids content > 5%)			3.8	5.9	4.2

Wheel tracking test

To perform a 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 the 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 and 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. The obtained results demonstrate that the largest rut depth (5.7mm) appear for the HMAC mixture with 5.83% bitumen content. The second best results are shown for reference mixture – 5.3mm. HMAC mixture with a 5.67 bitumen content, show the best result – 3.8mm. Figure 6 summarizes the wheel tracking test results.



Figure 3. Test equipment for wheel tracking test



Figure 4. Test equipment for fatigue test

Fatigue

To determine the fatigue life of the prepared asphalt concrete mixes, a four point bending fatigue test was conducted (Fig. 4.). The test was run at 10°C,

10Hz at 130 $\mu\text{m/m}$ strain level. The beams were compacted in the laboratory by using a roller compactor (Fig. 5.). 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. The obtained results indicate that the HMAC mixture showed high resistance to fatigue, compared with the results for the reference mixture made with conventional aggregates and bitumen. The stiffness reduction curves are shown in Figure 7.



Figure 5. Roller compactor

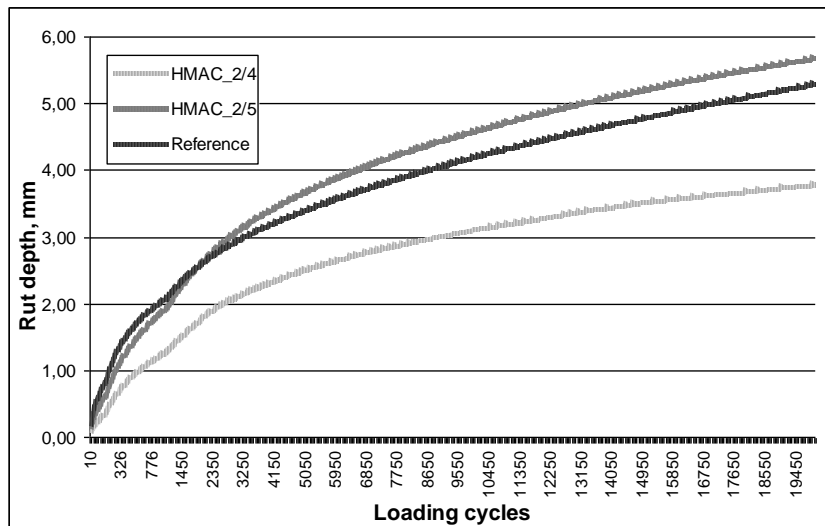


Figure 6. Wheel Tracking Test Results

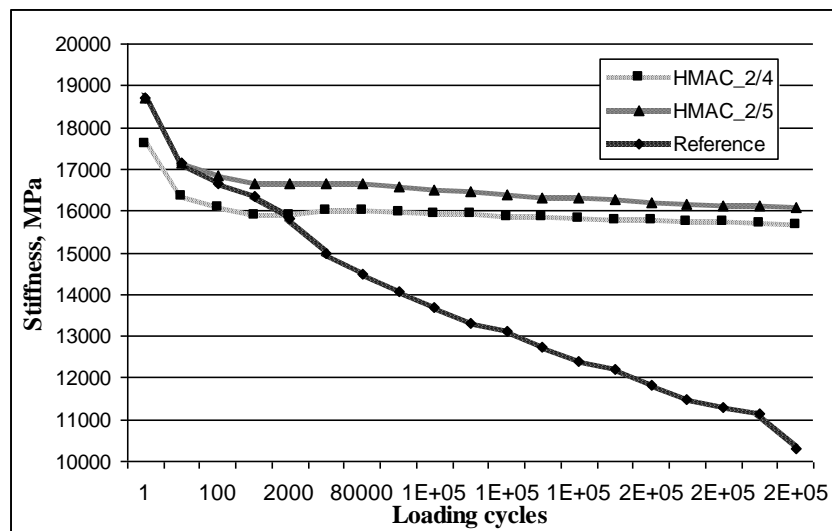


Figure 7. Wheel Tracking Test Results

CONCLUSIONS

Use of dolomite aggregate in High Modulus Asphalt Concrete was evaluated. Comparative testing was performed on the AC16_{bin} (reference) with conventional bitumen B70/100 and granite aggregate. Reference mixture proved that a low binder content resulted in lower fatigue life despite high rut resistance. However both HMAC mixtures showed high rut and 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 meet the HMAC asphalt concrete requirements in accordance with SPENS project recommendations (SPENS).

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