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Transportation Research Procedia 14 (2016) 732 – 737

Transportation Research Procedia

www.elsevier.com/locate/procedia

6th Transport Research Arena April 18-21, 2016

Evaluation of asphalt mix with dolomite aggregates for wearing layer

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Abstract

Bearing capacity and durability of road pavement structure depends on design solution, transport loads, climate, materials and construction quality. But the main factors are selected materials for road pavement structure and their properties. Typically, there are selected high quality aggregates for asphalt wearing layer of heavy duty pavement. In Lithuania, granite aggregates are often used for asphalt wearing layer, but this magmatic rock is imported from other countries. Dolomite is one of the most available sedimentary rocks in Lithuania and quarries contain hundreds million tons of this material. Either, high quality dolomite is produced applying special extraction technology, and the mechanical properties of this material are similar to granite. The aim of this research is to evaluate high quality dolomite as aggregates for asphalt wearing layer and to design rut resistant asphalt mix with dolomite aggregates. Test results showed good bitumen-aggregate adhesion properties. There were designed asphalt concrete (AC) mixes using granite and high quality dolomite aggregates and stone mastic asphalt (SMA) mixes using high quality dolomite aggregates based on fundamental properties in accordance to standard EN 13108-1 and EN 13108-5. Resistance to permanent deformation of asphalt mixes is achieved by designing coarser gradation mixes with higher content of air voids (3–4%) comparing to traditional asphalt mixes for wearing layer (2–4%). Designed asphalt mixes were tested using empirical and performance based tests, which showed promising results for asphalt mixes with high quality dolomite aggregates.

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)

Keywords: Asphalt mix; high quality dolomite aggregates; resistance to permanent deformation; wheel tracking test

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Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)
doi:10.1016/j.trpro.2016.05.340

1. Introduction

Hot mix asphalt (HMA) is commonly used in roads and airport pavements as a surface layer. Permanent deformation is a major mode of failure in flexible pavements consisting of both rutting and shoving. This problem is more common in hot climates where the stiffness of the HMA is further decreased with the increase of the pavement temperature. Additionally, the different behavior of HMA pavement at intersection is related to the more complex stresses imposed at the pavement surface layer by the braking, accelerating and turning movements of heavy loaded trucks (Hajj et al. 2011).

Oscarsson (2011), Tarefder et al. (2003) grouped the factors affecting asphalt pavement durability into material properties (e.g. aggregate gradation, binder grade, binder content, air void content), loading specificity (e.g. magnitude of load, contact area, tire pressure) and climatic conditions (e.g. moisture, temperature). The proper incorporation of these factors into asphalt mixture design procedure ensures desirable asphalt pavement performance.

The volumetric characteristics (binder content, air voids content, absorbed binder content, effective binder content, voids in mineral aggregate, voids filled with binder as a volume percentage and etc.) of compacted asphalt mixture are the key in the proper asphalt mixture design procedure, because of their influence on the stability and durability of asphalt mixture (Christopher et al. 2011, Kassem et al. 2011, Kandhal et al. 1998).

Aggregate characteristics can be specified by shape, flakiness, resistance to fragmentation, resistance to polishing, percentage of crushed and broken surfaces in coarse aggregate particles and gradation.

According to resistance to permanent (plastic) deformation, there is recommended to use aggregates of shape index SI20 and FI20. Spherical aggregates and/or increasing the amount of this type particles reduce the interior friction and shear strength of the mixtures and increase susceptibility to plastic deformation. Crushed stone particles lead the strength of asphalt mixture. Furthermore, crushed coarse aggregates having longer or thinner shapes lead stiffer HMA (Arasan et al. 2011, Singh et al. 2012).

Depending on asphalt purpose various types of aggregates are used for its production e.g. aggregates with high resistance to fragmentation and polishing are used for asphalt wearing layer. In Lithuania, granite aggregates are often used for asphalt wearing layer, but this magmatic rock is imported from other countries.

Dolomite is one of the most available sedimentary rocks in Lithuania and quarries contain hundreds million tons of this material. These aggregates are often used for asphalt binder layer, base and base-wearing layers. According to Sybilski (2010), if the local materials does not meet with requirements for its intended application, there should be seeking ways to improve properties. Haritonovs et al. (2014) evaluated dolomite aggregates using for high modulus asphalt concrete mixes and obtained sufficient results.

However, in Lithuania high quality dolomite aggregates are produced applying special extraction technology, and the mechanical properties of this material are similar to granite. Considering these facts, there is question of using local high quality dolomite to rut resistant asphalt mix producing, which properties would be similar or better comparing to asphalt mixes with granite aggregates.

The aim of this research is to evaluate high quality dolomite as aggregates for asphalt wearing layer and to design rut resistant asphalt mix with dolomite aggregates. Asphalt mixtures were designed considering not only air void content, but also performance based wheel tracking test results.

2. Materials

In Lithuania, there is requirement to use polymer modified bitumen for heavy loaded pavement wearing layer asphalt mixes. In order to design rut resistant asphalt mixes, there were selected polymer modified bitumen PMB 45/80-55. Additionally, there was decided to design similar gradation asphalt concrete mix AC 11 VS gr with granite aggregates on purpose to compare influence of aggregate type to rutting resistance. Characteristics of the binder (needle penetration, softening point, elastic recovery and bond of bitumen with mineral aggregates) and characteristics of both aggregates (flakiness index, shape index and resistance to freeze-thaw) were evaluated. The tests results are shown in Table 1 and Table 2.

2.1. Bitumen characteristics

As it can be seen from Table 1, penetration, softening point and elastic recovery properties of the selected bitumen indicated that it is suitable for the rut resistant asphalt mix designing. Moreover, polymer modified bitumen PMB 45/80-55 showed good bitumen-aggregate adhesion properties with both aggregates.

Table 1. Characteristics of the polymer modified bitumen PMB 45/80-55.

Parameter	Results	Standard
Penetration at 25 °C, 0.1 mm	60.0	EN 1426
Softening point, °C	59.2	EN 1427
Elastic recovery, %	80.5	EN 13398
Adhesion with dolomite, %	85.0	LST 1362.23
Adhesion with granite, %	80.0	LST 1362.23

2.2. Properties of mineral aggregates

The test results of mineral aggregates indicated that both of dolomite and granite flakiness index (FI) and shape index (SI) are less than 15%. Determined mechanical characteristics of both aggregates showed excellent results: impact value (SZ) is less than 18%, Los Angeles coefficient is less than 15 % and polished stone value (PSV) is over 50%. Freeze-thaw test showed that high quality dolomite mass lost is less than 1% by mass. These results indicated that both aggregates are suitable for the rut resistant asphalt mix design. The properties of high quality dolomite and granite aggregates are shown in Table 2.

Table 2. Properties of mineral aggregates.

Properties	Dolomite	Granite	Standard
Flakiness index (FI), %	< 15	< 15	EN 933-3
Shape index (SI), %	< 15	< 15	EN 933-4
Freeze-thaw (F), %	< 1	< 1	EN 1367-1
Polished stone value (PSV),	> 50	> 50	EN 1097-8
Los Angeles coefficient (LA), %	< 15	< 15	EN 1097-2
Impact value (SZ), %	< 18	< 18	EN 1097-2

3. Mix design

The basic idea of this research was to evaluate high quality dolomite as aggregate for asphalt wearing layer mixes manufacturing and to design asphalt mixes with high quality dolomite. For designing were selected in Lithuania common used asphalt wearing layer mixes AC 11 VS and SMA 11 S. Asphalt concrete (AC) mixes have been designed using granite and high quality dolomite aggregates based on fundamental properties in accordance to standard EN 13108-1. Granite aggregates were selected on purpose to compare influence of aggregate type to rutting resistance Stone mastic asphalt (SMA) mixes have been designed using high quality dolomite aggregates in accordance to standard EN 13108-5. The optimal air void content was used for the determination of the optimal bitumen content and optimal particles size distribution in the mix. Test specimens were prepared in the laboratory using impact compactor according to standard EN 12697-30 with 2×50 blows hammer at 150 °C temperature.

4. Results

4.1. Particle size distribution

Gradation of asphalt concrete AC 11 VS gr with granite aggregates was selected to according to Lithuanian technical regulations *TRA ASFALTAS 08*. Gradation of asphalt concrete AC 11 VS dol1 with high quality dolomite aggregates (Fig. 1) was selected to obtain similar or better rut resistance comparing with AC 11 VS gr. Because of too small binder content (Table. 3) comparing to requirements ($B_{min\ 5.6}$) and too big rut depth of AC 11 VS dol1 comparing with AC 11 VS gr (Fig. 3), there was decided to design coarser asphalt mix with higher binder content. Considering coarser structure, AC 11 VS dol2 was designed with smaller mineral aggregate surface area than common used AC 11 VS mixes (Fig. 1).

Gradation of stone mastic asphalt SMA 11 S (Fig. 2) was designed only with high quality dolomite according to Lithuanian technical regulations *TRA ASFALTAS 08* requirements, but with different binder quantity (6.4% and 5.5%). In order to achieve higher air void content, bitumen content of SMA 11 S (2 var.) was selected 0.9% lower than requirements ($B_{min\ 6.4}$). Gradations of all designed mixtures are shown in Figure 1 and Figure 2.

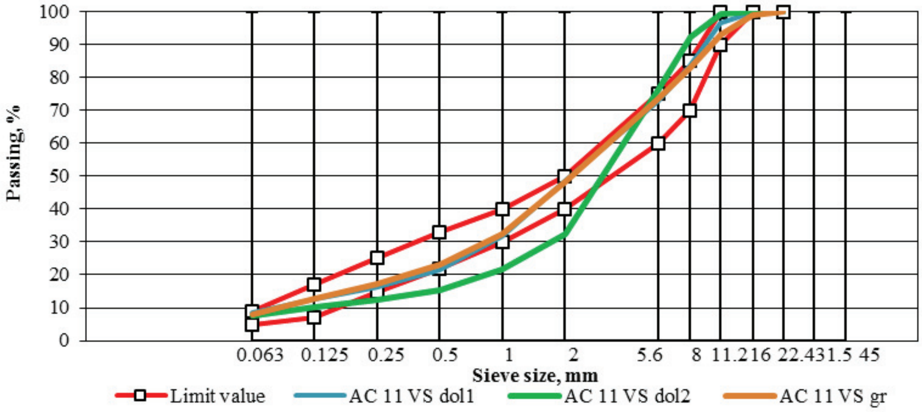

Fig. 1. Gradations of asphalt concrete mixes.

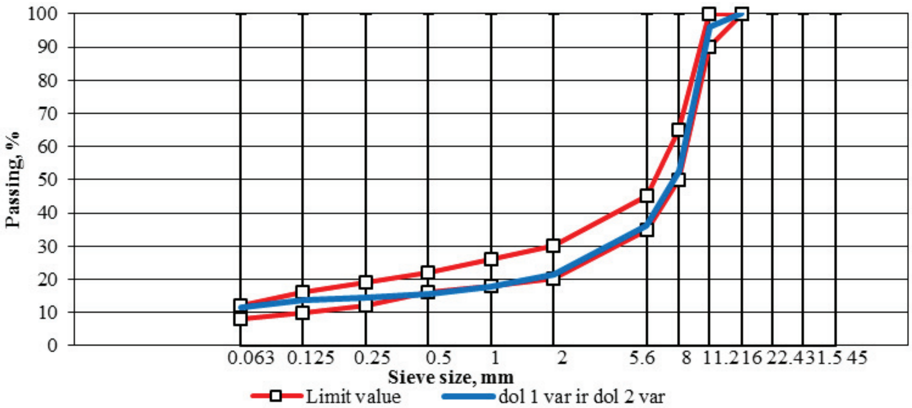

Fig. 2. Gradation of stone mastic asphalt mixtures.

4.2. Volumetric properties

Analysis of volumetric parameters of the different asphalt mixtures was performed. The results are presented in Table 3. The binder content and particles size distribution was optimized according to experimental test results.

Table 3. Volumetric properties of designed asphalt mixtures.

	Asphalt mixtures				
Parameter	AC 11 VS dol1	AC 11 VS dol2	AC 11 VS gr	SMA 11 S dol1	SMA 11 S dol2
Voids content, %	3.8	3.5	2.4	2.4	2.7
Binder content, %	4.7	5.6	5.6	6.4	5.5

4.3. Wheel tracking test

A wheel tracking apparatus was used to simulate the effect of traffic and to measure the plastic deformations of the asphalt concrete samples. Tests were performed according to standard EN 12697-22 method B (wheel tracking test with small 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. The obtained results after 10 000 cycles demonstrated that the highest rut depth of 7.1% was determined for the AC 11 VS dol1 (Fig. 3). Asphalt concrete AC 11 VS dol2 demonstrated result having 6.4% rut depth. Asphalt concrete AC 11 VS gr mixture showed the highest rutting resistance with 5.9%. SMA 11 S dol1 mixture demonstrates result having 8.3% rut depth. SMA 11 S dol2 mixture showed the rutting resistance with 6.2%. Proportional rut depth and wheel tracking slope results are presented in Figure 3 and Figure 4.

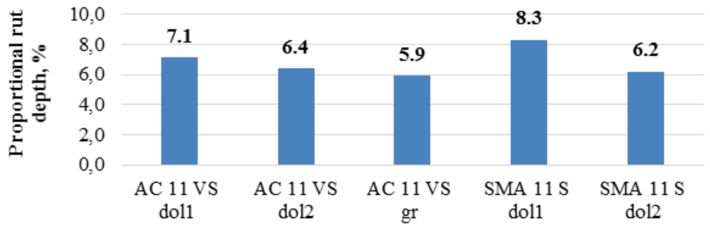

Fig. 3. Results of the proportional rut depth (PRDAIR).

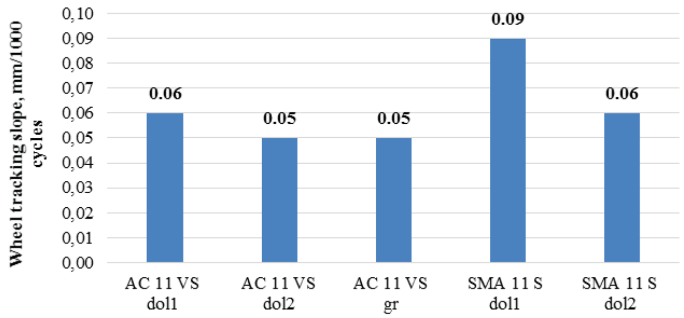

Fig. 4. Results of wheel tracking slope (WTS_{AIR}).

5. Conclusions

Test results showed sufficient bitumen-aggregate adhesion properties. Resistance to permanent deformation of asphalt mixes is achieved by designing coarser gradation mixes with higher content of air voids (3–4%) comparing to traditional asphalt mixes for wearing layer (2–4%). Designed asphalt mixes were tested using empirical and performance based tests, which showed promising results for asphalt mixtures with high quality dolomite aggregates:

- The research shows that positive influence to resistance to permanent deformation could be achieved by optimizing quantity of binder and granular composition of aggregates.
- Asphalt concrete mix AC 11 VS with high quality dolomite aggregates could be used for the asphalt pavement wearing layer with ESALs $\leq$ 3.0 mln. during design period.
- The use of stone mastic asphalt mix SMA 11 S with high quality dolomite aggregates for asphalt wearing layer should be evaluated additionally, taking into account the change of physical and mechanical properties of high quality dolomite aggregates during road maintenance.

References

Arasan, S., Yenera, E., Hattatoglu, F., Hinislioglua, S., 2011. Correlation between Shape of Aggregate and Mechanical Properties of Asphalt Concrete Correlation between Shape of Aggregate and Mechanical Properties of Asphalt Concrete. Road Materials and Pavement Design 12(2), 239–262.

Christopher, W.J., Crawford, F.J., Edward, T.H., Adock, M., Delaney, E.P., Freer, H., 2011. A Manual for Design of Hot Mix Asphalt with Commentary. NCHRP Report No. 673.

Hajj, E.Y., Tannoury, G., Sebaaly, P.E., 2011. Evaluation of Rut Resistant Asphalt Mixtures for Intersection. Road Materials and Pavement Design 12(2), 263–292.

Haritonovs, V., Tihonovs, J., Zaumanis, M., Krasnikovs, A., 2014. High Modulus Asphalt Concrete with Dolomite Aggregates. In Proceedings of Transport Research Arena 2014 (TRA 2014). Paris, France.

Kandhal, P.S., Foo, K.Y., Mallick, R.B., 1998. A Critical Review Of VMA Requirements In Superpave. NCAT Report No. 98-1.

Kassem, E., Masad, E., Lytton, R., Chowdhury, A., 2011. Influence of Air Voids on Mechanical Properties of Asphalt Mixtures Influence of Air Voids on Mechanical Properties of Asphalt Mixtures. Road Materials and Pavement Design 12(3), 37–41.

Oscarsson, E., 2011. Modelling Flow Rutting in In-Service Asphalt Pavements using the Mechanistic-Empirical Pavement Design Guide. Road Materials and Pavement Design 12(1), 37–56.

Singh, D., Zaman, M., Commuri, S., 2012. Inclusion of Aggregate Angularity, Texture, and Form in Estimating Dynamic Modulus of Asphalt Mixes. Road Materials and Pavement Design, 13(2), 327–344.

Sybilski, D., Bankowski, W., Krajewski, M., 2010. High Modulus asphalt concrete with limestone aggregate. International Journal of Pavement Research and Technology 3(2), 96–101.

Tarefder, R.A., Zaman, M., Hobson, K., 2003. A Laboratory and Statistical Evaluation of Factors Affecting Rutting. International Journal of Pavement Engineering 4(1), 59–68.