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Evaluation of High-Quality Dolomite Aggregate for Asphalt Wearing Course

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Abstract. In Lithuania dolomite is the third most excavated by the amount mineral resource, which is mostly used in subbase layer and hot asphalt mixtures for asphalt binder and base courses. Although, for asphalt wearing layer are often used granite aggregates, but this magmatic rock is imported from foreign countries. In one of the quarries of JSC “Dolomitas” higher quality dolomite is produced, which has similar mechanical properties to granite. To determine changes in mechanical properties of the different type of aggregates while using in the road, high-quality dolomite and two types of granite were chosen for laboratory testing. In this study, for evaluation of physical and mechanical properties of aggregates by laboratory tests for determining resistance to freezing-thawing, resistance to fragmentation, and polished stone value were carried out. Also, according to the results of laboratory testing, high-quality dolomite aggregate showed equal performance comparing to granite aggregates.

Keywords: aggregates, dolomite, granite, asphalt mixture, resistance to fragmentation, resistance to freezing and thawing, polishing stone value.

Conference topic: Roads and railways.

Introduction

Natural and artificial, organic and inorganic materials are used in road construction. Aggregates are one of major road building material and component of asphalt mixtures. Physical and mechanical properties of aggregates are main factors selecting the type of aggregates and satisfy the requirements (Šneideraitienė *et al.* 2016).

The largest amounts of resources excavated and consumed in the road construction are those of gravel, sand, and dolomite, for the production of building materials – limestone. Dolomite is the third most excavated by the amount mineral resource, which mostly is used in subbase layers and asphalt binder and base courses of asphalt pavement (Skrinskas *et al.* 2010). In Lithuania, granite aggregates are often used for asphalt wearing course, 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 ton of this aggregate. However, in Lithuania, high-quality dolomite aggregates are produced applying special extraction technology, and the mechanical properties of this material are similar to granite. Previous research have shown that high-quality dolomite aggregates could be used for asphalt wearing course ensuring adequate resistance to permanent deformation (Šernas *et al.* 2016). However, it is little known about resistance to freezing-thawing, resistance to the polishing of these materials while using the road.

Asphalt mixture is a different complex composite material of air, binder, and aggregates, used in modern pavement construction (Xu, Huang 2012). The asphalt wearing course is a top layer of the pavement, and it is subjected to the most severe traffic and climatic conditions. Due to these factors asphalt distresses as ruts, fatigue cracking, thermal cracking occurs. The best quality materials are highly recommended to prevent these failures because of high vertical stresses from truck tires; it is advisable to use crushed aggregates for both medium and high traffic volume, while a limited amount of gravel might be used in the asphalt mixtures for low-volume roads. For the same reason, a polymer modified asphalt should be used as the binder for high-volume roads (Newcomb 2006).

Aggregates used for hot asphalt mixtures should satisfy the highest requirements of shape index, flakiness index, Los Angeles index, resistance to polishing, the percentage of crushed and broken surfaces in aggregate particles ensuring proper bonding of aggregate particles and a strong skeleton of the asphalt mixture (Vaitkus *et al.* 2017). The shape of aggregates is very important because using more spherical aggregate and increasing the number of this kind particles, the internal friction and shear strength of the asphalt mixtures decreases resulting in more susceptibility to plastic deformation. Crushed stone particles in asphalt mixture ensure proper bonding, a strong skeleton of asphalt mixture and determine 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). Different aggregates due to the effect of traffic degrade in a various way. The mechanical degradation of aggregate can be characterised by category of resistance to fragmentation. It indicates the breakdown of the aggregate (Erichsen *et al.* 2011). Various aggregate types (limestone, granite, dolomite, etc.) produces different susceptibility to polishing. Aggregates of higher Polished Stone Value (PSV) may offer less loss of skid resistance (Kane *et al.* 2012). Aggregates must be frost-resistant to ensure long-term performance of asphalt pavements.

The aim of this research was to evaluate mechanical and physical properties of high-quality dolomite and compare to granite aggregates. Furthermore, to assess changes in different aggregates mechanical and physical properties while using in the road, standard tests at more severe conditions were conducted. PSV, resistance to freezing-thawing and fragmentation tests were carried out.

Experimental research

Object and methods of research

High-quality dolomite (hereafter dolomite "Petrašiūnai 2") and two types of granite (hereafter granite "Mikaševičiai" and granite "Norvegija") were chosen for laboratory testing to determine differences in mechanical properties of different aggregates.

Laboratory testing of dolomite and two types of granite aggregates was carried out at Road Research Laboratory of Road Research Institute of Environmental Engineering Faculty of Vilnius Gediminas Technical University and laboratory of JSC "Dolomites":

- determination of resistance to freezing and thawing by *LST EN 1367-1:2007 Tests for Thermal and Weathering Properties of Aggregates − Part 1: Determination of Resistance to Freezing and Thawing*;
- determination of resistance to fragmentation by the Los Angeles test method by *LST EN 1097-2:2010 Tests for Mechanical and Physical Properties of Aggregates − Part 2: Methods for the Determination of Resistance to Fragmentation*, chapter No. 5;
- determination of resistance to fragmentation by the Los Angeles test method by *LST EN 1097-2:2010*, chapter No. 5, after 10, 20 and 30 freezing-thawing cycles;
- determination of polished stone value by *LST EN 1097-8:2009 Tests for Mechanical and Physical Properties of Aggregates − Part 8: Determination of the Polished Stone Value*.

Figure 1 presents the scheme of the experiment.

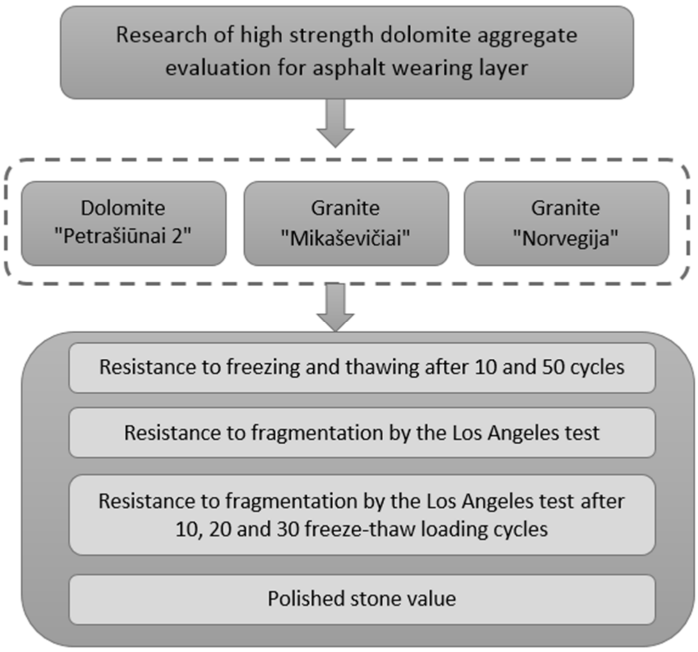

Fig. 1. The scheme of the experiment

Results of the aggregate testing

Determination of frost-resistance showed that dolomite and both types of granite satisfy the requirements of Lithuanian technical regulations *TRA MIN 07 Technical Specification of Aggregates of Motor Roads* for aggregates used in asphalt wearing course (Table 1) for frost-resistance category F_1. Tests have shown that granite "Mikaševičiai" is the aggregate, which is the most frost-resistant aggregate, e.i. the percentage loss in mass after freezing-thawing cycles is 0.18%. Thus, dolomite "Petrašiūnai 2" and granite "Norvegija" the percentage loss in mass is 0.22%. Considering results of these tests, it could be said, that the differences among results are insignificant.

Table 1. Requirements for aggregates used in asphalt wearing course by *TRA MIN 07*

Asphalt mixtures	Resistance to freezing-thawing cycles	Resistance to fragmentation by the Los Angeles test method	Polished stone value
AC PD	F_1, $(F_2)^*$	LA_{30}	$PSV_{declared}$
AC VN, AC VL, MA N	F_1	LA_{25}, LA_{30}	PSV_{44}
SMA S, SMA N, MA S, AC VS		LA_{20}	$PSV_{declared}$ (48), PSV_{50}
PA		LA_{25}, LA_{30}	PSV_{50}
**Note*: when the constructor has long-term experience in using or partly using aggregate, which resistance to freezing satisfies the requirements of category F_2.			

After 50 freezing-thawing cycles, the most frost-resistant aggregate is granite "Mikaševičiai" and the percentage loss in mass after the test is 0.22%. This result shows that 50 freezing-thawing cycles does not affect this type of granite. Taking into account difference between frost-resistance after 10 and 50 freezing-thawing cycles results showed that the difference among determined percentage loss in mass of granite "Mikaševičiai" is 0.08%. After 50 freezing-thawing cycles, the least frost-resistant aggregate is dolomite "Petrašiūnai 2" and the percentage loss in mass after the test is 1.39%. Figure 2 presents results of determination of resistance to freezing-thawing cycles tests.

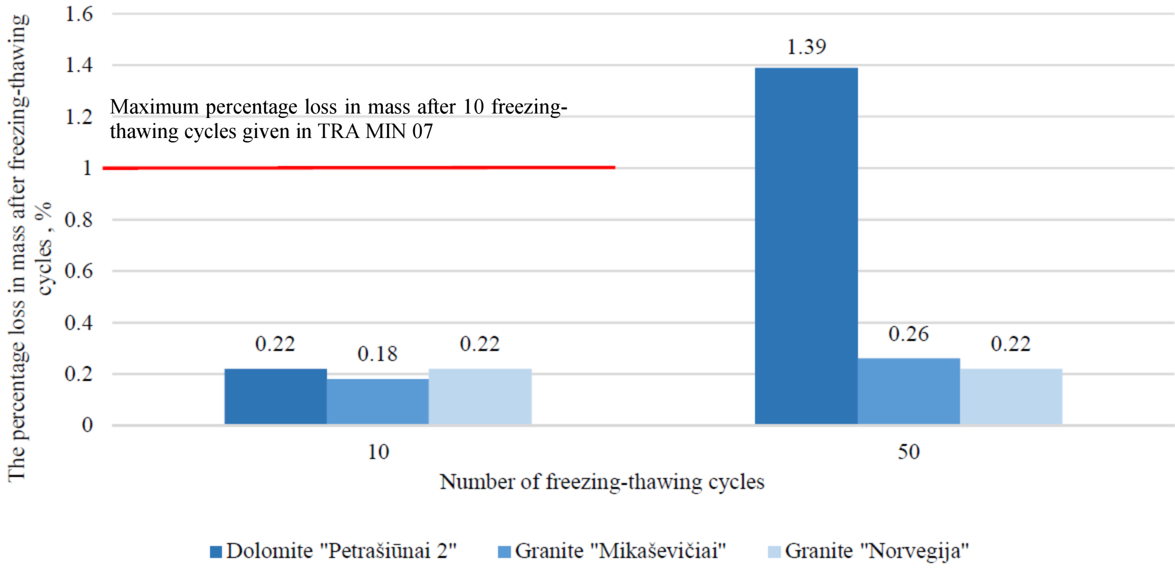

Fig. 2. Results of determination of resistance to freezing-thawing cycles

Determination of resistance to fragmentation by the Los Angeles test method under standard conditions, and after 10, 20 and 30 freezing-thawing cycles shown that dolomite and both types of granite satisfy the requirements of *TRA MIN 07* for aggregates used in asphalt wearing course (Table 1) for resistance to fragmentation (category LA_{20}). Tests have shown that granite "Norvegija" is the most resistant to fragmentation aggregate: in standard conditions, Los Angeles coefficient is 10.86; after ten freezing-thawing cycles is 10.87; after 20 freezing-thawing cycles is 11.46; after 30 freezing-thawing cycles is 10.94. Los Angeles coefficient of dolomite "Petrašiūnai 2" in standard conditions is 16.92; after freezing-thawing cycles is 14.35; after 20 freezing-thawing cycles is 15.97; after 30 freezing-thawing cycles is 15.55. Least resistant to fragmentation aggregate is granite "Mikaševičiai": in standard conditions, Los Angeles coefficient is 19.11; after ten freezing-thawing cycles is 15.95; after 20 freezing-thawing cycles is 17.29; after 30 freezing-thawing cycles is 16.19. Figure 3 presents results of determination of resistance to fragmentation tests.

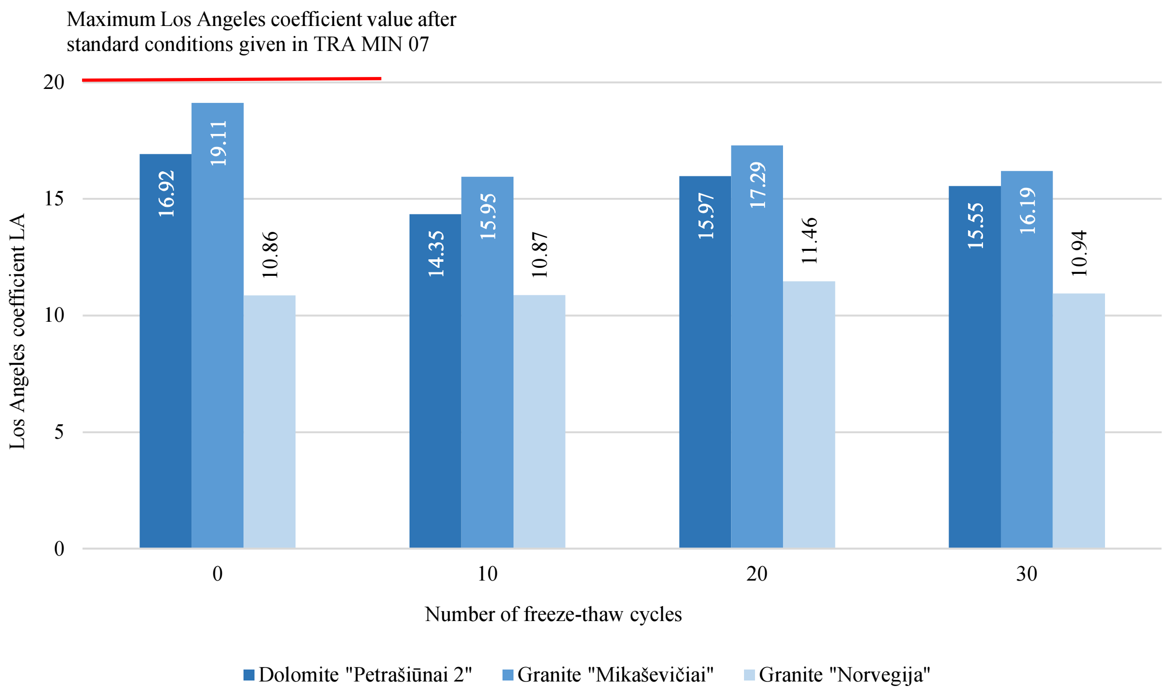

Fig. 3. Results of determination of resistance to fragmentation by the Los Angeles test method

Taking into account difference among resistances to fragmentation by the Los Angeles test method after different freezing-thawing cycle numbers, it was determined, that after ten freezing-thawing resistance to fragmentation cycles of dolomite "Petrašiūnai 2" and granite "Mikaševičiai" increased respectively by 15.19% and 16.54%. Resistance to fragmentation of granite "Norvegija" decreased by 0.09%. After 20 freezing-thawing cycles dolomite "Petrašiūnai 2" and granite "Mikaševičiai" resistance to fragmentation had increased respectively by 5.61% and 9.52%; granite "Norvegija" resistance to fragmentation decreased by 5.52%. After 30 freezing-thawing cycles dolomite "Petrašiūnai 2" and granite "Mikaševičiai" resistance to fragmentation had increased respectively by 8.10% and 15.28%; granite "Norvegija" resistance to fragmentation decreased by 0.74%. Figure 4 presents examples of aggregate before determination of resistance to fragmentation test, after determination of the resistance to fragmentation test and washed material after determination of resistance to fragmentation test.

After tests visual inspection has been performed and it was determined, that dolomite "Petrašiūnai 2" has been crushed the most of all aggregates comparing to samples observed before the test. Granite "Mikaševičiai" had the most fines after the test.

Determination of PSV demonstrated that dolomite and both types of granite satisfy the requirements of *TRA MIN 07* for aggregates used in asphalt wearing layer (Table 2) for PSV (category PSV_{50}). Tests have shown that granite "Norvegija" is the most resistant to polishing action aggregate and determined PSV is 57, while PSV is 50 of dolomite "Petrašiūnai 2", and PSV is 56 of granite "Mikaševičiai". Table 2 presents results of determination of PSV tests.

Table 2. Results of determination of polished stone value tests

Property	PSV		
	Dolomite "Petrašiūnai 2"	Granite "Mikaševičiai"	Granite "Norvegija"
Determination of the polished stone value *by LST EN 1097-8:2009 Tests for Mechanical and Physical Properties of Aggregates - Part 8: Determination of the Polished Stone Value*	50	56	57

Before determination of resistance to fragmentation test

Dolomite “Petrašiūnai 2” Granite “Mikaševičiai” Granite “Norvegija”

After determination of resistance to fragmentation test

Dolomite “Petrašiūnai 2” Granite “Mikaševičiai” Granite “Norvegija”

Washed aggregate after determination of resistance to fragmentation test

Dolomite “Petrašiūnai 2” Granite “Mikaševičiai” Granite “Norvegija”

Fig. 4. Examples of aggregates before and after tests of determination of resistance to fragmentation

Conclusions

Test results of dolomite “Petrašiūnai 2”, granite “Mikaševičiai” and granite “Norvegija” showed promising results and let to conclude:

1. Dolomite and both types of granite satisfy the requirements given in Lithuanian technical regulations *TRA MIN 07 Technical Specification of Aggregates of Motor Roads* for aggregates used in asphalt wearing course construction for resistance to freezing-thawing category F_1, for fragmentation category LA_{20} and polished stone value category PSV_{50}.
2. Resistance to freezing-thawing cycles of dolomite “Petrašiūnai 2” is 18.18% less than granite’s “Mikaševičiai” and is the same as granite’s “Norvegija”. However, resistance to freezing-thawing of dolomite “Petrašiūnai 2“ after 50 freezing-thawing cycles is 81.29% more than granite “Mikaševičiai” and 84.17% more than granite “Norvegija”.
3. Resistance to fragmentation by Los Angeles coefficient of dolomite’s “Petrašiūnai 2” in standard conditions is 12.94% more than granite’s “Mikaševičiai” and 35.82% less than granite’s “Norvegija”. However after ten freezing-thawing cycles, Los Angeles coefficient is 11.15% more than granite’s “Mikaševičiai” and 24.25% lower than granite’s “Norvegija”. Los Angeles coefficient after 20 freezing-thawing cycles of dolomite’s “Petrašiūnai 2” is 8.20% less than granite’s “Mikaševičiai” and 28.24% more than granite’s “Norvegija”. However Los Angeles coefficient after 30 freezing-thawing cycles is 4.12% more than granite’s “Mikaševičiai” and 29.65% less than granite’s “Norvegija”.
4. Resistance to the polishing of dolomite “Petrašiūnai 2” is 12.0% less than granite “Mikaševičiai” and 14.0% less than granite “Norvegija”.

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