

Performance Characterization of Bituminous Mixtures with Dolomite Sand Waste and BOF Steel Slag Aggregates

Viktors Haritonovs¹, Martins Zaumanis², Guntis Brencis³, Juris Smirnovs⁴, ¹⁻⁴Riga Technical University

Abstract: Dolomite and sandstone that can be found in Latvia, lack the mechanical strength, and for most of the large motorways the aggregates are imported from other countries causing increase of the costs and growth of emissions from transportation. On the other hand, large amounts of Basic Oxygen Furnace (BOF) steel slag aggregates with good qualities are being produced in Latvia and put to waste. During the recent decades, the dolomite sand waste has been accumulating and its quantity has reached a million of tons and is rapidly increasing. This paper presents the testing results of dense graded asphalt concrete AC 11 mixtures made of four types of aggregate: steel slag, dolomite sand waste, conventional imported dolomite aggregates and conventional local crushed quartz sand that were proportioned to develop a mixture that would satisfy the requirements of permanent deformation and stiffness. Analysis of the results showed that mixes with steel slag and dolomite waste sand or unconventional aggregate combination with dolomite in coarse portion, crushed quartz sand in sand portion and dolomite waste sand in sand and filler portions had high resistance to plastic deformations.

Key words: Steel slag, dolomite waste sand, asphalt mixture, Wheel Tracking test, permanent deformations.

INTRODUCTION

The industries of steel manufacturing and production of the crashed dolomites struggle to realize the co-products of the production. During the recent years, huge quantities of technological waste, such as steel slag and very fine crushed sand that need to be recycled with maximum efficiency, have accumulated in Latvia (Fig 1 and Fig 2). At the same time the road building industry in Latvia strives to utilize the local aggregates because the physical-mechanical characteristics of most of the materials do not meet the normative requirements.

In the EU and North America steel slag is used in bitumen bound materials; pipe bedding; hydraulically bound mixtures for subbase and base; unbound mixtures for subbase; capping; embankments and fill construction; clinker manufacture and fertilizer and soil improvement agents. However in Latvia for commercial road construction purposes it has been used only for unbound mixtures.

During the recent decades, the dolomite sand waste has been accumulating in Latvia and its quantity has reached more than a million of tons. The produced waste mostly remains unused on quarries occupying useful space and increasing the overall technological costs. However the research on the perspective use of dolomite waste sand in production of

asphalt has received relatively little attention. For example this material could be used to fully or partially replace the fine and filler portions. Such situation requires the integrated approach to recycling of the produced co-products [1-6].



Fig. 1. Unfracted BOF slag aggregate

The purpose of this research is to develop an asphalt mixture that would be resistant to heavy transport load by using raw materials as steel slag and dolomite waste sand. To achieve this aim the following asphalt compositions were proportioned and mixed:

- reference mixture from traditional dolomite aggregate and quartz sand;
- mixture consisting exclusively of by-products;
- combined mixture using different by-product and traditional mineral aggregate combinations.

Bitumen BND 60/90 and Polymer Modified Bitumen (PMB) 50/70-53 which was modified with Styren-Butadien-Styren (SBS) was used for mixing. All the combinations were tested for physical and mechanical (wheel tracking test and stiffness) characteristics.



Fig. 2. Unused dolomite waste sand

MATERIALS

The following materials were used in the study: Basic Oxygen Furnace (BOF) slag, dolomite waste sand, conventional aggregate (crushed dolomite and quartz sand) and bitumen.

Aggregate tests

Table 1 summarizes the chemical composition of by-product.

TABLE 1
Chemical composition of by-product

Oxide content, %			
BOF steel slag		Dolomite waste sand	
Oxide	Content, %	Oxide	Content, %
CaO	30.6	CaO	31.0
MgO	18.9	MgO	17.0
SiO ₂	19.9	SiO ₂	2.5
MnO	6.3	Na ₂ O	0.82
Al ₂ O ₃	5.0	Al ₂ O ₃	0.64
TiO ₂	0.52	K ₂ O	0.76
FeO	16.3	Fe ₂ O ₃	0.34

The physical and mechanical properties of steel slag, dolomite waste sand, crushed dolomite aggregate and quartz sand are summarized in table 2. Physical and mechanical properties were determined according to standard EN test methods. The properties of BOF steel slag correspond to the highest category of LVE EN 13043 standard. However, because of high abrasivity of this material, its proportion for wearing courses according to Latvian Road Specifications 2010 has been restricted to 20 present. The test results of steel slag main properties show very low flakiness index – 2, excellent mechanical strength with average LA value of 19, high frost resistance with average MS value of 3, low fines content – 0.5% and slag expansion tests showed that the expected swelling should be negligible.

Dolomite waste sand test results present excellent angularity with average flow coefficient of 33. The fines content in dolomite waste sand is more than 10% therefore the Latvian Road Specifications 2010 require this material to satisfy also the requirements attributed to mineral filler. Test results show that the fines quality is high – the material has low methylene blue (MB) value – 0.5, high carbonate content – more than 90%, excellent Rigden air voids and Delta ring and ball tests – 28 and 11 respectively (Table 2).

TABLE 2

Physical and mechanical characteristics of the aggregate

Physical and mechanical properties	Standard	BOF steel slag	Dolomite waste sand	Crushed dolomite aggregate	Crushed quartz sand
Los Angeles coefficient (LA), %	LVS EN 1097-2	19	-	22	-
Resistance to wear. Nordic test (A _N), %	LVS EN 1097-9	14,4	-	15,7	-
Sand equivalent test, %	LVS EN 933-8	80*	60	-	91
Flakiness Index (FI), %	LVS EN 933-3	2	-	12	-
Flow coefficient (E _{Cs})	LVS EN 933-6	43*	33	-	35
Water absorption, %	LVS EN 1097-6	2,4	-	2,7	5,4
Grain density, Mg/m ³	LVS EN 1097-6	3,25	2,80	2,80	2,70
Fine content, %	LVS EN 933-1	0,5	18,6	0,9	0,9
Freeze/thawing (MS), %	LVS EN 1367-2	3	-	9	-
Expansion, %	LVS EN 1744-1 p.19.3	2	-	-	-
Methylene blue test (MB), g/kg	LVS EN 933-9	-	0,5	-	-
Carbonate content, %	LVS EN 196-21	-	> 90	-	-
Rigden air voids, %	LVS EN 1097-4	-	28-30	-	-
Delta ring and ball test, °C	LVS EN 13179-1	-	11	-	-

* BOF steel slag 0-5mm

Aggregate gradation

In total nine aggregate gradations were used for producing the AC 11 mixtures – five unconventional co-product aggregate and four conventional crushed dolomite and quartz sand aggregates (Tables 3 and 4). Dolomite waste sand can be categorized as G_F85, steel slag 0/5 as G_A90 and steel slag 4/8 as G_C90/20 according to LVS EN 13043. Steel slag which is categorised as 8/11 does not comply to any of the standard categories, because only 81.8 present particles are passing D sieve (11,2mm) while standards require at least 85 present. The 2/5 steel slag also does not correspond to the standard category, because of high percentage of particles passing 1.0 mm (d/2) sieve (the standard requires <5).

TABLE 3
By-product aggregate gradation

Sieve, mm	Passing, %				
	BOF Steel slag				Dolomite waste sand
	0/5	2/5	4/8	8/11	
11,2	100	100	100	81,8	100
8,0	99,9	100	94,6	17,9	100
5,6	99,2	99,2	47,6	4,7	100
4,0	95,6	62,4	16,3	2,0	99,5
2,0	66,4	22,4	4,4	1,3	90,1
1,0	39,3	14,1	3,6	1,2	67,1
0,5	21,6	10,1	3,4	1,2	52,9
0,250	11,4	7,5	2,8	1,0	44,4
0,125	6,0	5,1	2,0	0,8	34,6
0,063	3,5	3,6	1,4	0,8	18,6
Category	GA90	N/A	GC90/20	N/A	GF85

TABLE 4
Conventional aggregate gradation

Sieve, mm	Passing, %			
	Crushed dolomite			Crushed quartz sand
	2/5	5/8	8/11	
11,2	100	100	90,7	100
8,0	100	88,4	16,1	100
5,6	93,0	11,7	4,1	98,4
4,0	57,6	3,1	1,7	89,6
2,0	9,1	1,8	1,3	71,9
1,0	2,7	1,5	1,3	55,0
0,5	2,0	1,3	1,1	34,9
0,250	1,8	1,2	1,0	10,5
0,125	1,7	1,0	0,9	1,4
0,063	1,4	0,9	0,7	0,7
Category	GC90/15	GC85/15	GC90/20	GA90

Bitumen tests

Unmodified bitumen BND 60/90 (category defined in accordance to Russian specifications) and SBS polymer modified bitumen PMB 45/80-55 was used for the testing. Unmodified bitumen is characterized by a pen of 65 dmm at 25°C, softening point is reached at 50,4 °C and Fraas temperature is -25°C. The SBS modified bitumen has a pen of 59 dmm, softening point of 67,7°C and Fraas temperature -16°C. All the test results of bitumen BND 60/90 and PMB 45/80-55 are shown in Table 5.

TABLE 5
Typical characteristics of bitumen BND 60/90 and PMB 45/80-55

Parameter	Bitumen		Standard
	BND60/90	PMB 45/80-55	
Penetration at 25°C, dmm	65,0	59,0	LVS EN 1426
Softening point, °C	50,4	67,7	LVS EN 1427
Fraas temperature, °C	- 25,0	- 16,0	LVS EN 12593
Kinematic viscosity, mm ² /s	607	-	LVS EN 12595
Dynamic viscosity, Pa·s	340	-	LVS EN 12596
Elastic recovery, %	-	88	LVS EN 13398
Ageing characteristics of bitumen under the influence of heat and air (RTFOT method)			
Loss in mass, %	-0,1	0	LVS EN 12607-1
Retained penetration, %	70,8	40,0	LVS EN 1426
Increase of a softening point, °C	6,4	1,9	LVS EN 1427
Fraas breaking point after aging, °C	-20,0	-	LVS EN 12593
Retained elastic recovery,%	-	84	LVS EN 13398

MIX DESIGN

Dense graded AC mixtures have been designed by using conventional and unconventional raw materials. Aggregate gradation fulfilled the basic requirements defined in LVS EN 13108-1 and the complementary Latvian criteria specified in [7]. 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 had the shape of cylinder with diameter of 101mm and height range from 62.5 to 64.5mm. All of them were prepared in the laboratory by impact compactor according to LVS EN 12697-30 with 2x50 blows of hammer 140°C temperature.

In total three different groups of mixtures were analysed:

- Two reference mixtures without co-products (with conventional and SBS bitumen), which were used as a control;
- Mixtures containing only BOF slag and dolomite waste sand;
- Combination of conventional and unconventional materials.

In order to determine the potential of using unconventional aggregates in the mixtures, the second and third group of mixtures were prepared by using only conventional bitumen. Each group of mixtures are characterized by different bitumen contents in the range 5.4 – 7.0% on the weight of the aggregate. The optimal bitumen content was determined by optimisation of the volumetric characteristics and considering resistance to deformation with wheel tracking test. This variation of bitumen content even with having similar grading curves is connected with high

hygroscopicity of dolomite waste material and differences in aggregate bulk density and surface texture for steel slag.

PERFORMANCE EVALUATION

Resistance against permanent deformations

Resistance against permanent deformation was determined according to standard LVS EN 12697-22 method B (wheel tracking test with small size device in air). This test method is designed to replicate the stress conditions observed in the field therefore can be categorised 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) (Fig. 3.). 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. Test equipment for wheel tracking test

Rectangular shape specimens with the base area of 305×305mm have been prepared for the test by using roller compactor according to LVS EN 12697-33 (Fig. 4). Thickness of the tested specimens conforms to that of the traditional pavement surface layer – 40mm. The test assesses three parameters:

- Wheel Tracking slope (WTS_{AIR}), which is defined as increase of depth of wheel track per 1000 test cycles;
- Rut depth (RD_{AIR}) which is the accumulated permanent deformation after 10000 cycles;
- Proportional rut depth (PRD_{AIR}) which is the relative depth of wheel track after 10000 test cycles in proportion to the test specimen thickness.



Fig 4. Roller compactor

Figure 5 reports the evolution of the loading cycles – rut depth curves during the test conducted. The wheel tracking slope has been calculated by using the equation Eq 1.

$$WTS_{AIR} = \frac{(d_{10000} - d_{5000})}{5} \quad (1)$$

where WTS_{AIR} is the wheel tracking slope in mm per 10^3 load cycles; d_{5000} and d_{10000} is the rut depth after 5000 and 10000 load cycles. The experimentally obtained curves illustrate asphalt as typical visco-elasto-plastic material – the first phase has a decreasing wheel tracking slope (creep rate), whereas the second has a constant wheel tracking slope.

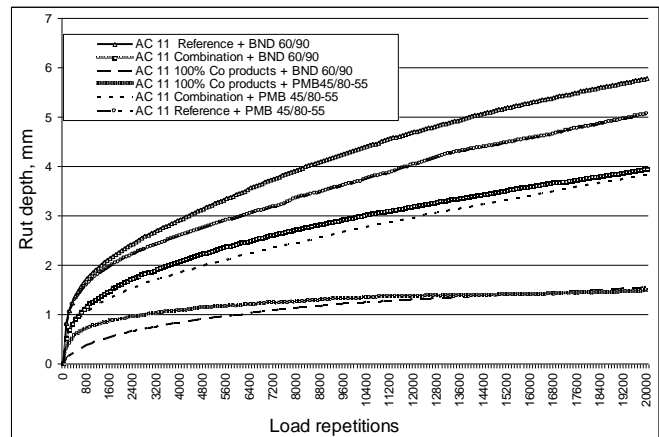


Fig 5. Wheel tracking test curves

Wheel tracking slope in Latvia has been regulated by requirements in Road Specifications 2010. All of mixtures fulfilled requirement on the category of $WTS_{AIR} 0,3$ for road with intensive traffic. The results are presented in Table 6. The largest plastic strain of 5.78 mm and highest wheel tracking slope of 0.29 mm in 1000 cycles appear in the reference mixture with unmodified bitumen. The results for reference mixture with SBS modified bitumen are only slightly better (5.05 mm and 0.2 8mm/1000 cycles). The asphalt concrete mixture which was produced entirely from co-products shows

surprisingly good resistance to permanent deformations, having an average rut depth value of 1.54 mm and wheel tracking slope of 0,12 mm/1000 cycles. The mixture with combination of co-product and conventional aggregate had somewhat worse test results: the rut depth value of 3.94 mm and the wheel tracking slope of 0.19 mm/1000 cycles. The steel slag fractions of 0/5 and 2/5 in this mixture were replaced with dolomite filler and crushed quartz sand, because of the strength and angularity the fine steel slag fractions which can cause excessive wear of the asphalt production and paving equipment. It is also important that the combination of aggregates allowed reducing the bitumen content by significant 1% (from 7% to 6%).

TABLE 6

Characteristics of wheel tracking test

	Asphalt mixes					
	Reference (natural dolomite aggregate)		Co-products (100%)		Combination of co-products and natural aggregate	
Bitumen	BND 60/90	PMB 45/80- 55	BND 60/90	PMB 45/80- 55	BND 60/90	PMB 45/80- 55
WTS _{AIR} , mm/1000cycles	0,29	0,28	0,12	0,03	0,19	0,22
RDAIR, mm	5,78	5,05	1,54	1,47	3,94	3,83
PRDAIR, %	14,45	12,63	3,85	3,68	9,85	9,58

Fatigue

Resistance to fatigue was determined at 20°C and 30Hz according to EN 12697-24. Fatigue life is defined as the number of cycles which corresponds to 50% decrease of initial stiffness modulus. This method consists in cyclic bending of prismatic specimen at constant strain amplitude. 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. Test made on mixture with BOF steel slag and dolomite sand waste showed less resistance to fatigue, compared to results for mixture made with conventional aggregates and combined mixture. The mixtures made with steel slag and local limestone in coarse portion and dolomite sand waste in sand and filler portions exhibit slightly higher fatigue resistance than the conventional mixtures. However, more extensive laboratory research is needed.

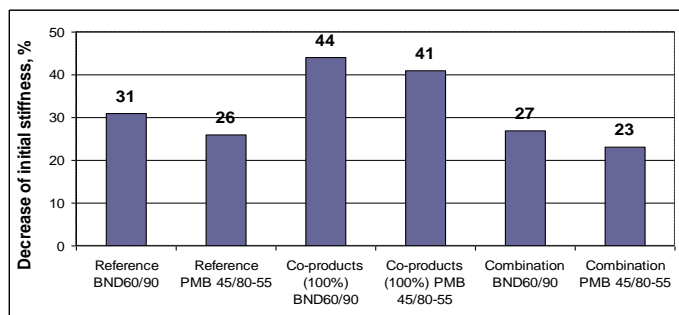


Fig. 6. Fatigue test results

CONCLUSIONS

BOF Steel slag aggregates meet the Road Specifications 2010 requirements of Latvia as a road construction aggregate. Physical and mechanical properties of steel slag aggregates are comparable with the characteristics of conventional natural aggregate usually used in transportation infrastructure. Steel slag aggregates have a high resistance to fragmentation with average LA value of 19, excellent shape (FI_2) and texture characteristics. The values of these parameters are higher than for conventional dolomite and granite aggregates that are used in Latvia. The main disadvantages of the material are high density which raise the transportation costs and large porosity that forces to use more bitumen than for conventional asphalt materials.

Dolomite sand waste meets the highest standard LVS EN 13043 category in terms of angularity, having an average value of flow coefficient of 33 which also meets the Latvian Road Specifications 2010 requirements for sand. The dolomite waste sand has a high filler content – 18.6% and therefore has to be tested for the properties of filler. The research showed high quality of this material because of low methylene blue value (MB_F 0,5), high carbonate content (CC_{90}), excellent Rigden air voids ($V_{28/38}$) and Delta ring and ball ($\Delta_{R\&B}$ 8/25) test results.

Mixture from 100% steel slag and dolomite waste sand that was prepared using unmodified bitumen BND 60/90 shows high resistance to permanent deformation $WTS_{AIR0,12}$. However this combination has high optimum binder content – 7%. Mixture from steel slag and dolomite aggregate in coarse portion and dolomite waste sand and crushed quartz sand in the sand and filler portion had a little lower resistance to permanent deformation ($WTS_{AIR0,19}$) than the mixture made only from steel slag. However the value was significantly higher than for both reference mixtures with dolomite aggregates, crushed quartz sand and limestone filler with both conventional and SBS modified bitumen - $WTS_{AIR0,29}$ and $WTS_{AIR0,28}$ respectively. This mixture with combination of conventional aggregate and co-products has also significantly lower bitumen content which lowers the production costs compared to mixtures made entirely from co-products.

The mixtures made with steel slag and local limestone in coarse portion and dolomite sand waste in sand and filler portions exhibit slightly higher fatigue resistance than the conventional mixtures. However, mixture from 100% steel slag and dolomite waste sand show less resistance to fatigue, compared to conventional mixture.

Further analysis of the effect of using waste products should involve research on the resistance to deformations at low and moderate temperatures. It must also include further optimisation of co-product and conventional aggregate in order to reduce the bitumen content while still maintaining high resistance to permanent deformation, fatigue and thermal cracking.

ACKNOWLEDGEMENT

This work has been supported by the European Regional Development Fund (ERDF) activity No.2.1.1.1. „Atbalsts

zinātnēi un pētniecībai” (support for science and research) within the project: No.2010/0254/2DP/2.1.1.1.0/10/APIA/VIAA/015.

REFERENCES

- [1] The European Slag Association: „EUROSLAG”, Legal status of slags. Position paper, Available: <http://www.euroslag.com> [Accessed: Aug 10, 2011].
- [2] D. Xirouchakis, V. Manolakou. *Properties of EAF Slag Produced in Greese: A Constructional Material for Sustainable Growth: 5th Internationa Conference Bituminous Mixtures and Pavements*, pp. 287–297, June 1-3, 2011, Thessaloniki, Greece.
- [3] U. Bagampadde, H. I. Al-Abdul Wahhab, S.A. Aiban. “Optimization of Steel Slag Aggregates for Bituminous Mixes in Saudi Arabia.” *Journal of Materials in Civil Engineering*, vol 11., issue 1, pp.30-35. ISSN: 0899-1561Feb. 1999.
- [4] M. Pasetto, N. Baldo. Mix Design and Performance Characterization of Bituminous Mixtures with Electric Arc Furnace Steel Slags: *5th Internationa Conference Bituminous Mixtures and Pavements*, pp. 748 – 757, 287–297, June 1-3, 2011, Thessaloniki, Greece.
- [5] A. Korjakins, S. Gaidukovs, G. Šahmenko, D. Bajāre, D. Pizele. “Investigation of Alternative Dolomite Properties and Their Application in Concrete Production”. *Scientific Proceedings of Riga Technical university. Construction Science Vol 2. Issue 9*, pp. 64-71. ISSN 1407-7329, 2008.
- [6] S. Skinskas, V.E. Gasiūniene, A. Laurinavičius, I. Podagėlis. “Lithuanian Mineral Resources, Their Reserves and Possibilities for

Their usage in Road Building”. *The Baltic Journal of Road and Bridge Engineering* 5(4), pp. 218-228., ISSN 1822-4288, 2010.

- [7] “Road Specifications 2010” approved by Order No 01.01-03/173 of the Ministry of Traffic on 7. Sept. 2009. 239 pp., Available: http://www.lvceli.lv/lv/Files/Publications/629/CELU_SPECIFIKACIJA_S_2010_GALA_REDAKCIJA_arTK_23jul09_labojumiem_grafikiem.pdf [Accessed: Aug 10, 2011].

Viktors Haritonovs Riga, Latvia (1979), Engineer (2002), Dr.sc.ing. in the field of Transport and Infrastructure, Riga Technical University (2010). Construction Science Centre Researcher at Riga Technical University
Address: Azenes Street 16/20 – 448, Riga, Latvia
Phone: +37126412568
E-mail: viktors.haritonovs@rtu.lv

Mārtiņš Zaumanis Mg.sc.ing., Riga Technical University, The Institute of Transportation, Riga, Latvia, 2010. Doctoral student and research assistant at Riga Technical University. Quality Engineer at Ltd “Union Asphalttechnik”, road construction and asphalt production company.
Phone: +371 26665537
e-mail: jeckabs@gmail.com

Guntis Brencis, Road Engineer, Riga Technical University, Head of Road Building Materials Laboratory.

Juris Smirnovs, Prof., Dr. sc. ing, Riga Technical University, The Institute of Transportation,
Address: Azenes Street 16/20, Riga, Latvia
Phone: +371 67089278

Viktors Haritonovs, Mārtiņš Zaumanis, Guntis Brencis, Juris Smirnovs. Bituminēto maisījumu īpašības, kas izgatavoti no tērauda sārņiem un dolomīta atsijām

Sakarā ar strauji pieaugošu satiksmes intensitāti un transportlīdzekļu ass slodzēm paaugstinās prasības Latvijas ceļu segas nestspējai. Vietējām dolomīta un grants šķembām ir ļoti zemi kvalitātes rādītāji, kuri neatbilst tehnisko noteikumu prasībām. Tāpēc Latvijā ceļu būvniecībā pārsvarā izmanto importētu pildvielu, kas palielina būvdarbu izmaksas. Tomēr Latvijā vairāku gadu garumā ir izveidojušies lieli tērauda sārņu krājumi, kas ir tērauda ražošanas industrijas blakusprodukts. Drupinot šo materiālu, iegūst vietējas izcelsmes tērauda sārņu šķembas ar augstu stiprību un labām fizikālām īpašībām. Savukārt dolomīta izstrādes karjeras izveidojušies vairāku miljonu tonnu lieli dolomīta atsiju uzkrājumi, kurus var izmantot kā netradicionālu smalku pildvielu un aizpildītāju asfaltbetona sastāvu izstrādei. Šobrīd joprojām trūkst pieredzes darbā ar asfaltbetonu, kura sastāvā ir izmantoti šie blakusprodukti. Pētījuma galvenais mērķis ir, izmantojot dolomīta atsijas un tērauda sārņus, izstrādāt asfaltbetona maisījumus ar augstām ekspluatācijas īpašībām. Pētījuma gaitā noteiktas blakusproduktu īpašības un projektētas trīs blīvā asfaltbetona AC-11 sastāvu grupas: references sastāvs no tradicionālās dolomīta pildvielas un drupinātās kvarca smilts; sastāvs tikai no blakusproduktiem un blakusproduktu un tradicionālā minerālmateriāla kombinācijas. Maisījumu izgatavošanai izmantota nemodificētā BND 60/90 un SBS modificētā saistviela. Blakusproduktu testēšanas rezultāti rāda, ka frakcionēto tērauda sārņu un dolomīta atsiju īpašības atbilst aukstām standarta LVS EN 13043 kvalitātes kategorijām. Asfaltbetona sastāvu projektēšanai izmantota Maršala metode. Deformatīvās īpašības augstās ekspluatācijas temperatūrās noteiktas, izmantojot Wheel Tracking testēšanas metodi atbilstoši standarta LVS EN 12697-22 prasībām. Analizējot iegūtos rezultātus, konstatēts, ka asfaltbetona maisījumi, kas izgatavoti tikai no blakusproduktiem vai kombinētot blakusproduktus ar tradicionālo minerālmateriālu, uzrāda augstu noturību pret risu veidošanos un atbilst vietējo tehnisko noteikumu „Ceļu specifikācija 2010” prasībām. Secināts, ka dolomīta atsijas var izmantot kā daļējo vai pilnīgo aizpildītāju un smilts frakcijas aizvietotāju, savukārt tērauda sārņus kā smalkas un rupjas pildvielas aizvietotāju. Turpmākos pētījumos jānosaka izstrādāto sastāvu deformatīvās īpašības vidējās un zemās temperatūrās.

Виктор Харитонов, Мартиньш Зауманис, Гунтис Бренцис, Юрис Смирновс. Свойства асфальтобетонных смесей с использованием металлургических шлаков и доломитных отходов

В связи с резким увеличением интенсивности дорожного движения и осевой нагрузки, на дорогах Латвии возросли требования к несущей способности дорожных одежд. Местный щебень из гранта и доломита имеет низкие показатели качества и не соответствуют техническим требованиям. Поэтому при строительстве дорог в Латвии используются импортный наполнитель, который значительно увеличивает стоимость строительных работ. Однако в Латвии за многие годы образовались большие скопления металлургических шлаков, которые являются отходами металлургической промышленности. После дробления и фракционирования этот материал показывает высокие механические и физические свойства. В свою очередь в доломитных карьерах за многие годы образовались многомиллионные накопления доломитного отсева, который можно использовать как мелкий нетрадиционный наполнитель для производства асфальтобетонных смесей. Сегодня ощущается нехватка опыта по использованию этих материалов для производства асфальтобетона и его свойств. Главной целью исследования было разработка асфальтобетонных смесей с высокими прочностными характеристиками с использованием металлургических шлаков и доломитного отсева. В процессе исследования были определены свойства производственных отходов и спроектированы три группы плотного асфальтобетона AC – 11: референтный состав из традиционного щебня и дроблёного песка, состав из отходов и комбинация отходов и традиционного материала. Для изготовления смесей использовали немодифицированный БНД60/90 и СБС модифицированный битум. Результаты тестирования показали, что фракционированные металлургические шлаки и доломитный отсев соответствуют высоким категориям качества согласно требованиям стандарта LVS EN 13043. Асфальтобетонные смеси проектировались с использованием метода Маршала. Деформационные свойства при высоких эксплуатационных температурах определены с использованием теста на колесобразование, согласно требованиям стандарта LVS EN 12697-22. Анализируя полученные результаты, констатировано, что асфальтобетонные смеси, изготовленные из отходов или в комбинации с традиционным материалом, показывают высокую устойчивость к образованию колеи и соответствуют требованиям технических условий „Ceļu specifikācijas 2010”. Сделан вывод, что доломитный отсев может быть использован как полный или частичный заменитель песчаной фракции, в свою очередь металлургические шлаки как заменитель среднего и крупного наполнителя. В дальнейших исследованиях необходимо определить деформационные свойства этих смесей при средних и низких температурах.