Bulletin of the *Transilvania* University of Brasov • Vol. 11 (60) Special Issue No. 1 - 2018
Series I: Engineering Sciences

STEELWORKS SLAG AGGREGATE IN ASPHALT MIXTURES

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Abstract: *In recent years studies on environmental quality have shown that the steel industry is one of the industries whose activity involves significant consumption of natural resources and energy, is also generating waste that due to the recovery potential can be transformed into by-products. This paper will present some experimental data on the development of asphalt mixtures with steelworks slag aggregate. For this two recipes of asphalt mixtures were made (BA16, BAD22.4) for which laboratory determinations were made and have been set the main physicomechanical properties of these mixtures. The results of this analysis highlighted the real possibility of using these aggregates as building materials used in asphalt mixtures for roads and streets.*

Key words: *synthetic, asphalt mixtures, steelworks*

1. Introduction

In recent years studies on environmental quality have shown that the steel industry is one of the industries whose activity involves significant consumption of natural resources and energy, is also generating waste that due to the recovery potential can be transformed into by-products. Experience has shown that recovery by recycling organic waste has both an ecological motivation as well as an economic motivation. Therefore, speaking about waste as a source of profit should be considered both aspects: environmental and economic benefits. It was found, especially in developed countries with concerns to limit the waste industry, the steelworks slag remaining after extraction of ferrous scrap, sorted and cleaned of impurities, successfully replace natural aggregates specific to road construction works.

2. Laboratory Tests

The papers will be handed in the standard form described herein in electronic format.

Steelworks slag aggregates are used primarily in foundation layers or base layers of road structures, but can be used also in asphalt layers, replacing the classic chippings. To

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support this information laboratory tests were made at the Faculty of Civil Engineering from Iasi, on two asphalt mixtures used mainly in technical class roads III ... V, namely: BA16, BAD22.4 [2]. Aggregates that is used in the preparation of asphalt mixtures are natural and artificial aggregates, according to SR EN 13043-2003 and AND 605-2016. To achieve these asphalt mixtures recipes were needed the following sorts of aggregates: crushed slag aggregate 0-4 mm, crushed slag aggregate 4-8 mm, crushed slag aggregate 8-16 mm,16-22.4 mm, natural sand 0-4 mm, limestone filler. Given the granularity of each aggregate, which results from laboratory tests, were established the following percent of aggregates for achieving the asphalt recipes, according to Table 1.

The percentages of aggregates used to produce asphalt mixes recipes Table 1

Aggregate / Recipe	BA16	BAD22,4
Limestone filler (%)	9.00	5.00
natural sand 0-4 mm (%)	12.00	14.00
crushed slag aggregate 0-4 mm (%)	31.00	14.00
crushed slag aggregate 4-8 mm (%)	24.00	15.00
crushed slag aggregate 8-16 mm (%)	24.00	28.00
crushed slag aggregate 16-22.4 mm (%)	0	24.00

The asphalt concrete was prepared with bitumen D50 / 70, corresponding bitumen hot climates - whose main characteristics are shown in Table 2.

Bitumen characteristics Table 2

Bitumen characteristics D50/70	Values obtained in the laboratory:	SR EN12591-2009
Penetration at +25°C, 1/10 mm	66	66…70
Softening point (I.B.), °C	51.8	49…55
Penetration Index I.P.	-0.158	-1.5…+0.7

Determination of density mix asphalt was performed according to SR EN 12697-6 / 2012 - Bituminous mixtures - Test methods for hot mix asphalt - Determination of apparent density of bituminous recipes. This test is used to determine the apparent density of bituminous specimen after compaction. The test method is applicable to laboratory compacted recipes. Apparent density is the mass per unit volume, including air voids, of the test specimen at a known temperature. Apparent density of compacted bituminous specimen is derived to initial recipes mass and volume. The mass of the

recipes is obtained by weighing it in the dry air. Water with a known density at temperatures of 25^0C attempt must be regarded as 997.1 kg / m^3.

Density values obtained are shown in Table 3.

Values of type recipes densities Marshall Table 3

Bitumen percentage %	Bitumen type	ρ_a, kg/m3
BA 16		
5.00	D 50/70	2.644
5.25		2.646
5.50		2.649
5.75		2.671
6.00		2.683
6.25		2.680
BAD 22.4		
4.75	D 50/70	2.637
5.00		2.639
5.25		2.634

The method of determining water absorption is according to AND 605 – 2016 Revised - Hot asphalt mixtures. Technical conditions for designing, preparing and putting into operation (Annex B). Water absorption is the amount of water absorbed by a test piece immersed in water for three hours at a vacuum of 15-20 mm Hg, then for 2 hours at atmospheric pressure in the same water. Water absorption is conclusive specimens with fine pores and could not be determined experimentally on specimens with large pores. Water absorption values are shown in Table 4.

Water absorption values of type specimens Marshall Table 4

Bitumen percentage %	Bitumen type	ρ_a, kg/m^3	Water absorption , %
BA 16			
5.00	D 50/70	2.644	4.630
5.25		2.646	4.233
5.50		2.649	2.138
5.75		2.671	0.952
6.00		2.683	0.724
6.25		2.680	0.632
BAD 22.4			
4.75	D 50/70	2.637	4.172
5.00		2.639	3.785
5.25		2.634	3.129

Method of Marshall recipes swelling is done according to STAS 1338-2-87 – "Bituminous and bituminous surfacing made hot. Methods for determining and testing". The goal is to determine the harmful effects of some components of natural aggregates susceptible to swelling, such as clay. The values in the range of swelling in 7,14, 21 and 28 days type Marshall recipes are shown in Table 5.

Swelling values of type recipes Marshall Table 5

Bitumen Percentage %	Bitumen type	7 days	14 days	21 days	28 days	Value STAS
BA 16						
5.00	D 50/70	0,210	0.258	0.269	0.298	max 2.0%
5.25		0.200	0.245	0.250	0.259	
5.50		0.216	0.219	0.245	0.250	
5.75		0.231	0.238	0.239	0.250	
6.00		0.250	0.255	0.259	0.261	
6.25		0.200	0.218	0.219	0.220	
BAD 22,4						
4.75	D 50/70	0.218	0.254	0.259	0.259	max 2.0%
5.00		0.230	0.236	0.259	0.270	
5.25		0.214	0.219	0.220	0.220	
5.50		0.218	0.219	0.220	0.221	

Marshall Stability Method according to SR EN 12697-34 + A1 – "Bituminous. Marshall Stability Method for warm mix asphalt". To determine the stability and flow are selected recipes of unused water absorbing. Marshall Stability values, flow, and the ratio S / I, the series of asphalt mixtures prepared in the laboratory are shown in Table 6.

For determination of physicomechanical properties of asphalt mixtures action of freeze-thaw phenomenon, were prepared in the laboratory recipes asphalt with bitumen optimal dosage determined in the laboratory, resulting in mixtures recipes BA16 and BAD22,4, according SR EN 12697-41:2006 - "Asphalt mixtures. Test methods for hot melt mixtures. Part 41: Resistance to de-icing agents". A part of the recipes were used for the determination of the phenomenon of freezing and thawing action of 28 days, while the other samples were control samples, which were tested against the swelling Marshall stability, flow index and S / I. The first recipes were subjected to 28 freeze-thaw cycles in solution Attica TZ1. This solution is a chemical flux and molasses containing NaCl solution prepared by the company "ATICA CHEMICALS SRL "[1]. The samples used were taken during freeze-thaw cycles by 10 hours at the positive (+ 18 ... +

22^{0}C) and 14 hours at negative (-21^{0}C). The results in swelling, Marshall stability flow index ratio, the ratio S / I for the samples used in the freeze-thaw action are shown in Table 7.

Value of Marshall stability values, flow, and the ratio S / I Table 6

Bitumen Percentage %	Bitumen type	S, kN	I, mm	S/I, kN/mm
BA 16				
5.00	D 50/70	16.0	3.44	2.48
5.25		15.1	3.84	3.93
5.50		11.6	4.42	2.62
5.75		16.4	5.08	3.22
6.00		13.5	5.22	2.59
6.25		11.5	5.59	2.05
BAD 22.4				
4.75	D 50/70	12.5	4.02	3.11
5.00		15.1	4.15	3.64
5.25		13.6	4.30	3.16

Recipes Atika TZ1 at 28 days Table 7

Mixtures	Recipes Atika TZ1 at 28 days			
	Swelling, %	Stability (S) at 60 ^{0}C, kN, mm	Flow index (I), mm	Rate S/I, kN/mm
BA16	0.285	10.9	4.29	2.54
BAD 22.4	0.280	8.9	3.40	2.62

Comparative measurements were carried out on the recipes of the blank to determine the swelling at 28 days, the Marshall stability, rate of flow or S / I. The results obtained are shown in Table 8.

Blank recipes at 28 days Table 8

Mixtures	Blank recipes at 28 days			
	Swelling, %	Stability (S) at 60 ^{0}C, kN, mm	Flow index (I), mm	Rate S/I, kN/mm
BA 16	0.270	12.1	4.73	2.55
BAD 22.4	0.275	9.7	3.43	2.83

3. Conclusion

Looking at the two last tables, it can be concluded that crushed the steelworks slag aggregates used to produce asphalt mixtures did not changesignificantly after 28 freeze-thaw cycles. Mean values of the swelling, Marshall stability, flow, are substantially the same and after trying to freeze-thaw action. Use of steelworks slag aggregates in the road technology leads to numerous technical and economic advantages for both the user and the manufacturer:

- diversification of road construction materials;
- reducing construction costs by replacing natural aggregates;
- elimination of waste disposal dumps made from steel mills and therefore environmental protection;
- properties of steelworks slag aggregates allow the road construction without affecting the environment at weather factors (rain, freezing-thawing).

Ensuring the service life of roads safe and comfortable, due to texture that provides roughness and high resistance to skidding. In terms of laboratory testing can be concluded the following:

- percentages of steelworks slag aggregate used in asphalt mixtures making follow the recommendations of AND 605-2016;
- optimum binder content was determined taking into account asphalt mixture density, water absorption, stability and swelling of the Marshall specimens; resulted dosage in the preparation of bituminous asphalt mixtures with steelworks slag aggregate is generally lower than the recommended dosage for a classical mixture;
- bulk density of the asphalt mixture varies between 2.6 and 2.7 kg/m3, being higher than the bulk density of a classical mixture.

The difference is made by the higher density of steelworks slag aggregates compared to the density of natural aggregates;

- swelling values determined on Marshall specimens at intervals of 7, 14, 21 and 28 days are lower than the maximum required;
- in the laboratory tests for determining Marshall stability can be observed that the values of stability S, flow I and the S / I ratio is less than the maximum imposed by the standard;
- after testing the freeze-thaw phenomenon, after the 28 freeze-thaw cycles, it was found that the differences between a witness mixture with steelworks slag aggregates and a mixture with steelworks slag aggregates treated with a solution of Attica TZ1, does not present significant differences in terms of swelling and Marshall stability.

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