STUDY ON THE PERFORMANCE OF NATURAL AND ARTIFICIAL AGGREGATES PROVIDED BY THE EUROPEAN NORMS USED IN THE PREPARATION OF ASPHALT MIXTURES

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Rezumat. *În condițiile actuale, în care traficului rutier este în continuă creștere, o importanţă foarte mare trebuie acordată folosirii în rețetele de mixturi asfaltice a unor agregate naturale sau artificiale, ale căror caracteristici tehnice trebuie să fie testate şi să corespundă reglementărilor tehnice în vigoare, respectiv standardul SR EN 13043:2003/AC:2004 și AND 605. Această lucrare prezintă dezvoltarea şi evaluarea unor noi amestecuri de beton asfaltic tip AB31,5, care utilizează o zgură ca material de înlocuire al unui agregat natural (de carieră). Este efectuată o analiză a condiţiilor pe care trebuie să le îndeplinească agregatele naturale pentru amestecurile bituminoase şi sunt corelate performanţele agregatelor cu performanţele mixturii asfaltice.*

Abstract. *Under the current conditions of road traffic growth, particular importance should be given to the use, in the asphalt mixing recipes, of natural or artificial aggregates, whose technical characteristics have to be tested and to comply with the technical regulations in force, respectively the standard SR EN 13043: 2003 / AC: 2004 and AND 605. This paper presents the development and evaluation of a new asphalt concrete mix type AB31,5 that utilizes a sustainable slag as a replacement material of a natural aggregate (quarry aggregates). An analysis of the conditions that natural aggregates must fulfill for bituminous mixtures and the correlation between the aggregate performance and the asphalt mix performance is performed.*

Keywords: Natural aggregates, asphalt mixtures, performance.

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1. Introduction

Under the current conditions of road traffic growth, particular importance should be given to the use, in the asphalt mixing recipes, of natural or artificial aggregates, whose technical characteristics have to be tested and to comply with the current technical regulations, respectively the standard SR EN 13043: 2003 / AC: 2004 and AND 605.

Blast furnace slag is the resulting material during the casting processes of the iron. This is a non-metallic process that is obtained by melting the chemical compounds from the sterile, ash coxe and the founders.Thus, the composite organic mix has become an increasingly important topic in research from all European Union countries and around the world.

Most furnace slags can be characterized by CaO: SiO2 ratios in the range 1.0–1.3 [11].

Depending on the concentration of oxides, steel slags are divided into basic and acid. Predominant are the basic slags that can be divided according to the CaO: SiO2 ratio into:

- weakly basic slags for CaO: SiO_2 is 1.5;

- average basic slags for CaO: SiO_2 = 1.6 - 2.5;

- strongly basic slags for CaO: SiO_2> 2.5.

The most important areas in which steel slag can be used are in construction field at road construction in basic layer and subbase layer, also in construction of roads as aggregates for concrete and asphalt and construction of railways [1].

Natural quarry aggregates are natural resources of the environment that cannot be regenerated and considering the expansion of the road network it becomes imperative to look for alternative solutions for the production of high performance asphalt mixtures to meet the conditions imposed by technical standards and regulations.

Thus, there are several international studies on recipes obtained whith slag in which conventional aggregates have been replaced with slag and the results have been satisfactory [2], [3], [4], [5], [6], [7], [8], [9], [10], [12].

The conditions that the natural aggregates must fulfill refer both to the granularity class, to the content of fine parts and the quality of the fine parts but also to the shape of the coarse aggregates.

Regarding the geometric characteristics, the establishment of the granularity class is very important in the design of the asphalt mixture recipe and although the European standard provides categories of values and limits of granule content outside the granularity class that goes up to 35%, in practice in our country, it is not recommended to use some sorts of aggregates that have more than 10% granule content outside the sort. Considering that in operation the size of the aggregates but also the shape changes over time, it is necessary to impose more restrictive conditions regarding the content of granules outside the granularity class that will influence the technical characteristics of the asphalt mixture. [13], [14]

2. Experimental study

2.1 Used materials

This experimental study was performed in the INCERTRANS laboratory on the mixture AB 31.5 base 50/70, designed by the Marshall method and the 5 different types of mixing recipes with partial and total replacement of granite aggregates. The replacement percentages are those in Table 1.

The natural aggregates used (sorts 0-4, 4-8, 8-16, 16-31.5 mm) were granite aggregates (Table 2).

Granite, gray magmatic rock, homogeneous echigranular structure with fine-small granulation, massive and compact texture. Mineralogical composition consists of feldspar, quartz, mica.

The crushed artificial aggregates (sort 0-4, 4-8, 8-16, 16-31.5 mm) used in this study came from blast furnace slag; the other materials used were filler and bitumen D50 /70 pen.

Table 1 Recipe AC 31.5 basis 50/70

Material used, sort	Percentage [%]
granularity class 16-31.5 mm	20
granularity class 8-16 mm	18
granularity class 4-8 mm	17
granularity class 0-4 mm	40
Filler	5
Bitumen 50/70 pen	4,4

Table 2. Asphalt mixture recipe variants

Recipe variant	Natural aggregates, granularity class	Slag aggregates, larity class
A (reference)	0-4, 4-8, 8-16, 16-31,5 mm	-
B	4-8, 8-16, 16-31,5 mm	0-4 mm
C	0-4, 8-16, 16-31,5 mm	4-8 mm
D	0-4, 4-8, 16-31,5 mm	8-16 mm
E	0-4, 4-8, 8-16 mm	16-31,5 mm
P (100% slag)	-	0-4, 4-8, 8-16, 16-31,5 mm

2.2 Performed tests

For establish the physical-mechanical characteristics of the granite quarry aggregates, the following determinations were performed: the granularity of the aggregates in accordance with EN 933-1; content of fine parts in accordance with 933-1 [15]; The real density in accordance with EN 1097-5; Coarse aggregate fragmentation resistance (Los Angeles) in accordance with EN 1097-2, Micro - Deval wear resistance according to SR EN 1097-1 and frost-thaw resistance in accordance with EN 1367-2 standard. The categories of natural aggregates and slag used in this study are shown in the Table 3.

Table 3. Aggregate characteristics

Characteristics	**Aggregate Type**	
	Granite	**Blast furnace slag**
Coarse aggregate fragmentation resistance (Los Angeles)	LA_{15}	LA_{30}
Wear resistance (Micro Deval)	$M_{DE}10$	$M_{DE}15$
Resistance to freeze/thaw	MS_{18}	MS_{18}
The content of fine particles	f_3	f_3
Particle density – ρ_a (Mg/m^3) - 16/31,5 - 8/16 - 4/8 - 0/4	 2.85 2.86 2.87 2.65	 2.65 2.64 2.64 2.53

The grading curve for asphalt mixture meets EN 13108 as well as the Romanian standard requirements AND 605/2016 [16].

2.3 Samples preparation

The specimens were compacted in laboratory depending on performed tests. Thus, for Marshall Test, water absorption and IT-CY test, were manufactured cylindrical samples at Marshall Hammer for 50 blows compacting energy per side. In order to test the mixtures to water sensitivity in laboratory were produced cylindrical specimens with Ø=100.6 mm and h≈63 mm at Marshall hammer for 35 blows/side. Samples preparation and mixing were according to SR EN 12697-35 [17], [18], [19], [20]. During compaction it observed a partial crushing of slag which may be explained by slag poor resistance characteristics.

2.4. Results

Following the above laboratory tests on cylindrical samples on the 6 types of AB31.5 asphalt mixtures (A, B, C, D, E, P) the experimental results represented in figures 1-5, were obtained to emphasize the influence of the aggregate in asphalt mixture.

Figures 1 to 5 show the results obtained from the tests presented in chapter 2 according to the standard EN 13108-1 as well as within the limits imposed by the AND 605-2016 norm:

- Bulk density represented for the 6 mixtures - Figure 1;

- The water absorption represented for the 6 mixtures - Figure 2;

-The Marshall stability and index flow represented for the 6 mixtures - Figures 3 and 4;

- Water sensitivity represented for the 6 mixtures - Figure 5.

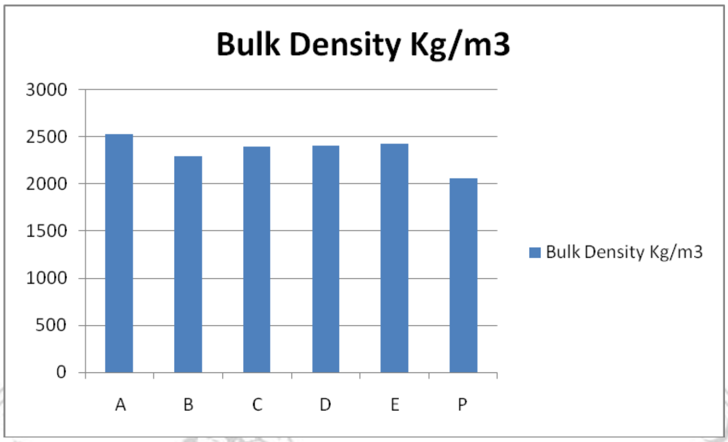

Fig. 1. Bulk density of asphalt mix

It appears from figure 1 that the values of bulk density obtained for mixture with natural aggregate is higher than that obtained for the blast furnace slag mixture. The result is explained by the fact that the density of the slag is lower than that of the granite aggregates.

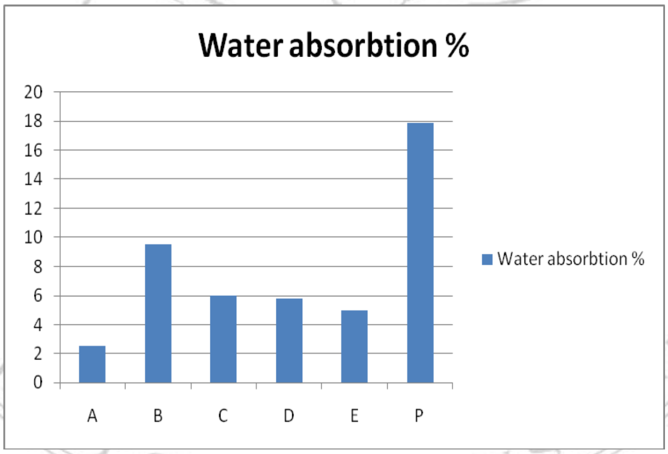

Fig. 2. The water absorption represented for the 6 mixtures

The water absorption is 2.5% at the reference mix compared to 17.9% when mixed with 100% slag (this very high value is explained by the very high porosity of the blast furnace slag).

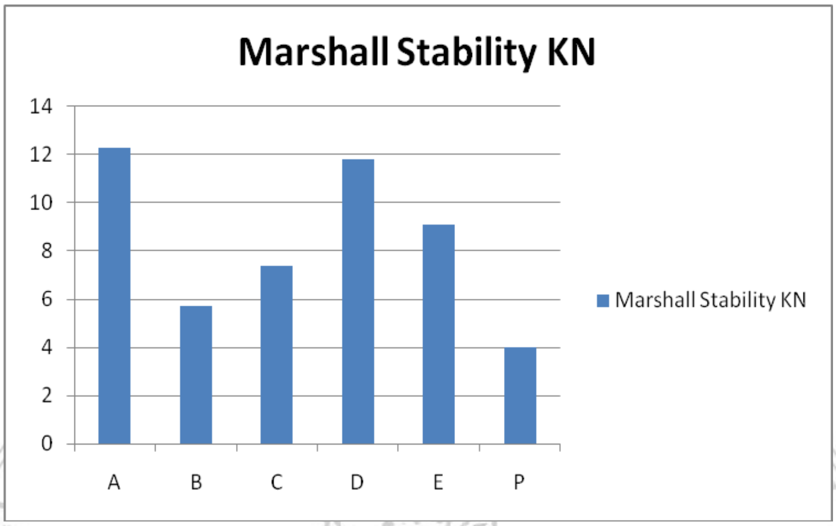

Fig. 3. Marshall stability of asphalt mix

Lower Marshall stability values have the recipe B where the 0-4 granite aggregate was replaced with the slag where the percentage was 40% but also in the recipe P where the percentage of slags was 100 %.

The recipes C, D and E had values of the Marshall stability index that were in the required minimum of 6.5 KN and maximum 13.0 KN.

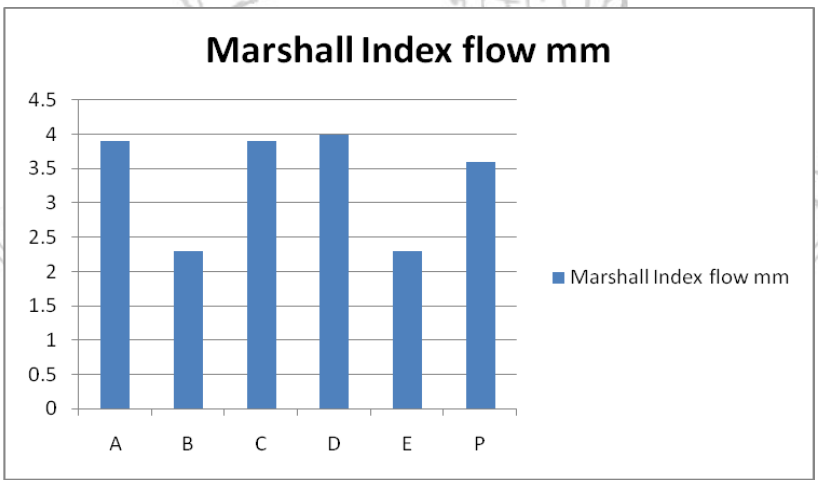

Fig. 4 Marshall index flow of asphalt mix.

The results indicate satisfactory results of the Marshall index flow in all six recipes. The values were in the required minimum of 1,5 mm and maximum 4,0 mm.

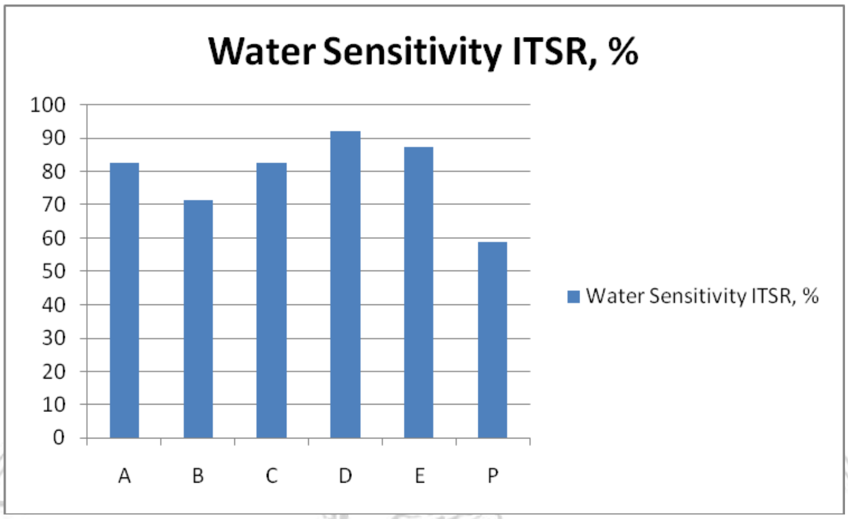

Fig. 5. Water sensitivity ITSR of asphalt mix

The results indicate that good results of ITSR in receips A,C, D, E, were obtained and the receip B and P did not meet the requirement of at least 80%.

3. Conclusions

The use of slag asphalt mixes has several important advantages for environmental protection, thus reducing existing slag deposits in our country and saving local resources.

As is known, hot mix asphalt is a building material made by a process involving the heating of natural aggregates and bitumen, mixing of the mixture, transport and putting into operation by hot compaction [AND 605-2016].

To produce asphalt mixtures, a wide variety of mineral aggregates are used.

The quantity of aggregates in asphalt mixes is almost 94-95%, so the knowledge of the mineralogical-petrographic and physical-mechanical characteristics of these aggregates can lead to the improvement of the mix properties.

The values of density obtained for mixture with natural aggregate is higher than that obtained for the blast furnace slag mixture.

The water absorption is 2.5% at the reference mix compared to 17.9% when mixed with 100% slag (this very high value is explained by the very high porosity of the blast furnace slag).

The recipes C, D and E had values of the Marshall stability index that were in the required minimum of 6.5 KN and maximum 13.0 KN. Lower Marshall stability values have the recipe B where the 0-4 granite aggregate was replaced with the slag where the percentage was 40% but also in the recipe P where the percentage of slags was 100 %.

In the future it is necessary to study other percentages of replacement of natural aggregates with slag, respectively 2 or 3 sorts and partial and not total replacement of the 0-4 mm range may lead to a better conclusion about asphalt mixing with furnace slag behavior.

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