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RESEARCH INTO THE PROPERTIES OF POURED ASPHALT FROM ELECTRIC FURNACE SLAG AGGREGATE

Purpose. This study case shows the influence of the use of electric furnace slag as an aggregate with a high positive impact on the properties of poured asphalt (AC). Research results regarding the skid resistance, depth of surface texture, resistance to erosion, water absorption, pressure solidity, and pellets of clay have argued the fact that adding this slag to mixing eruptive aggregate indicates improvements of mechanical characteristics of poured asphalt and its surface layer.

Methodology. Preliminary preparation of the poured asphalt blend – preliminary mixture, sampling and examination of the properties – are developed in accordance with standard methods: EN 12697-27:2000, SK EN 12697-36:2003, EN 12697-2:2002+A1:2007, EN 12697-8:2003, EN 12697-34:2004+A1:2007, (Marshall Test), EN 12697-6:2004, and SIST EN 12697-2:2004.

Findings. The metallurgical industries for years have been using all their by-products, including slag, as valuable resources for the industry and especially in the construction materials industry. The use of this process by-product in the construction industry, mostly in road construction, is among the key factors in saving natural resources and preventing environmental pollution.

Originality. For the preparation of the preliminary recipe for three types of poured asphalt (AC 0/11, 0/8 and 0/5 mm), electric furnace slag and the eruptive sand with grain size from 0 to 11 mm, 0 to 8 mm and 0 to 4 mm were used.

Practical value. The use of this type of slag as an aggregate of this bituminous mixture will not only show improvement of the physical-mechanical properties of AC, but will also show high economic and environmental effects.

Keywords: *slag, electric furnace, ferronickel, nickel, poured asphalt*

Introduction. Production of ferronickel from oxide minerals is accompanied by huge amounts of slag produced in electric furnaces [1]. The projected capacities in the "Ferronickel Foundry" in Drenas are about 1,200,000 t/slag/year, over 11,000 t/Ni/year and over about 800,000 t slag/year.

In addition, there is an increase in the other wastes' quantity, mostly those made of polymer and tires. As a result, Kosovo is facing major challenges when it comes to a naturally protected environment and, in general, a sustainable economic development. In fact, environmentally irresponsible industries, especially those in Kosovo, which due to the lack of a program for the management and use of industrial waste are continuing to practise uncontrolled dumping of waste and metallurgical by-products in landfills. Environmentally friendly industries do not dump slag in landfills but use them as valuable aggregates for the industry. For example, steel slag aggregate has been used in asphaltic mixtures since the early 1970s in Canada. 10 % of steel slag has been used in sinter plants in Turkey; 90 % of steel slags have been inactive waiting in the slag storing yards for utilization [2–4].

Steel slag aggregates are hard and durable with good angular shapes and high resistance to traffic abrasion. These aggregates possess high specific gravity which increases the transportation. In addition to steel slag, electric arc furnace (EAF) has also found large use in the production of asphalt concrete. Electric arc furnace (EAF) slag is an industry-produced artificial aggregate which, after appropriate behavior, constitutes a valuable aggregate for the manufacture of wearing course in road construction industry. Many researchers have found that the benefits of this type of slag are improved deformation characteristics i.e., strength and stability, durability e.g., rough surface texture, and stripping resistance. This slag has a strong affinity to bitumen and therefore displays a greater degree of binder retention and improved skid resistance i.e., polished stone value, and others [4, 5].

The technological process for production of ferronickel in Drenas consists of SCHMIT rotating furnaces (5 m in diameter and 100 m in length), ELKEM electric furnace (45 MVA in power) and KRUPP vertical oxygen converters [6]. The mineral basis is exploited from two mine sites and has the following average chemical composition: Ni&Co = 1.2 %; Fe = 26.0 %; SiO_2 = 47.0 %; CaO = 2.5 %; Cr_2O_3 = 1.2 %; MgO = 11.0 %. The ferronickel is produced in electric furnaces, representing a "Melting Arc Reduction- Covered & Open Process". According to the data from the technological card of electric furnaces in New Co Ferronickeli, (XRD analysis) the metal has the following chemical composition: Ni = 15–20 %; Co = 0.6–0.8 %; Si = 2.5–4.0 %; Cr = 0.2–0.4 %; C = 0.4–0.6 %; S = 0.3–0.4 %; P = 0.15–0.2 %. While the electric furnace slag is composed by: Ni – 0.08 %; SiO_2 – 55–57 %; MgO – 10.0 %; Fe = 20.0 %; CaO = 4.0 % [7]. Further treatment phases represent de-sulfuring and refining, resulting in the final product with 25–35 % Ni. The slag produced in this foundry has a pronounced acid character. However, similar acid slags are being used more and more in the construction materials industry as intermediate or final products: roof tiles, silicate blocks, all kinds of insulating materials, asphalt concrete, and others.

This study case shows the results of testing the primary physical and chemical properties of electric furnace slag produced through the "wet method" (water granulation), whose data will be the basis for examining the possibilities of using this in construction industry. If the use of granular slag, which is located in the current Drenas landfill, was considered as an opportunity to be used as aggregates for the production of poured asphalt, AC (0/5, 0/8 and 0/11 mm), this would increase the possibility of benefiting from bituminous mixtures of high qualities. At the same time, it would be the impetus for the development of other programs related to industrial waste management, save resources and energy and through their transformation from waste into valuable aggregates would create conditions for environmental protection.

Methods. Despite the fact that nowadays, the metallurgical industries realized more than 35 % of all their slag production through the "wet method", currently there has been an advancement of slag processing methods and an increase in slag applicability in the industry. Based on the methods of processing slag according to the "wet granulation" method, we have explored the possibilities of using its materials to produce poured asphalt, AC (0/5, 0/8 and 0/11 mm) as a consumable layer for highways. This research and Preparation of the Preliminary Mixture – Preliminary Recipe and other indicators on the basis of which the study program was developed, have been carried out based on Fig. 1. Basic materials for the production of poured asphalt are presented in Table 1.

The electric furnace slag samples from "Ferronickel Foundry", were classified as 0/2 and 2–4 mm. The chemical analysis and physical properties such as water resistance, erosion and abrasion resistance, specific gravity and water absorption of these slags were tested at the factory for the production of concrete asphalt "AH-Group" Fushë Kosovë/Kosovo. The specific gravity, stability, voids, density of bitumen, void in mineral aggregate, optimum bitumen ratios, penetration and flow characteristics were measured in "AHN-Group" laboratories.

Properties of electric furnace slag in "Ferronickel Foundry" in Drenas/Kosovo. The process of melting nickel oxide ores is a slag process, as 75 % of the charge passes into slag [8, 9]. Metallurgical slag, and in this case electric furnace slag to environmentally responsible industries, today is not considered as waste, but as a valuable product for the industry. Its main physic-mechanical properties depend on its chemical composition, formation temperature and processing methods. Electric furnace slag has a very complex chemical structure, where its main components are: SiO_2, CaO, MgO, FeO, Fe_2O_3, MnO, P_2O_5, Cr_2O_3, CaS, MnS, FeS, as well as non-ferrous metals [1, 9].

SiO_2 represents the main component of electric furnace slag, which by entering combinations with oxides (CaO, FeO, MgO, MnO, etc.). CaO, MgO and FeO are the main determinants of chemical, mineralogical construction, and other properties of this type of slag (Table 2).

In general, this slag belongs to the high acidic slag group – the group characterized with up to 4.5 % acidity, the high temperature of liquid phase and the high level of aggressiveness, whereas the percentage of CaO contained in the slag plays an important role in alleviating the chemical aggressiveness, stimulating the bonding features and easing of the slag hydrating progress [9].

The main components of the produced slag are: cristobalite and trydimite, which are a high-temperature polymorph of silica (SiO_2), pseudowollastonite (α-CaO, SiO_2), wollastonite [β-(Ca, Mg)O, SiO_2], dopside [(Ca, MgO)O, MgO, $2SiO_2$], rankinite 3CaO, $2SiO_2$, merwinite (3CaO, MgO, $2SiO_2$) and nonferrous metals [1]. Slag through the discharge channels flows periodically, where during the passage under the water pressure undergoes the process of granulation [1, 7].

This method of slag processing (wet method) has resulted in slag which shows a low percentage of irregularly shaped granules and lack of clay balls. These two properties have significantly influenced the improvement of the quality of the aggregates, and they have enabled low water absorption, high compressive strength and other similar physical or mechanical properties, better, or similarly, than the silicate (eruptive) aggregates used in concrete asphalt [4, 10], Table 3.

According to the current granulation scheme, the slag has a composition which follows the granulometric zone of the grains with a diameter from 2 to 8 mm. This skeletal structure enables it to be used only as additional material with other silicate aggregates and show a high degree of reactivity with other aggregates and bitumen [4, 11].

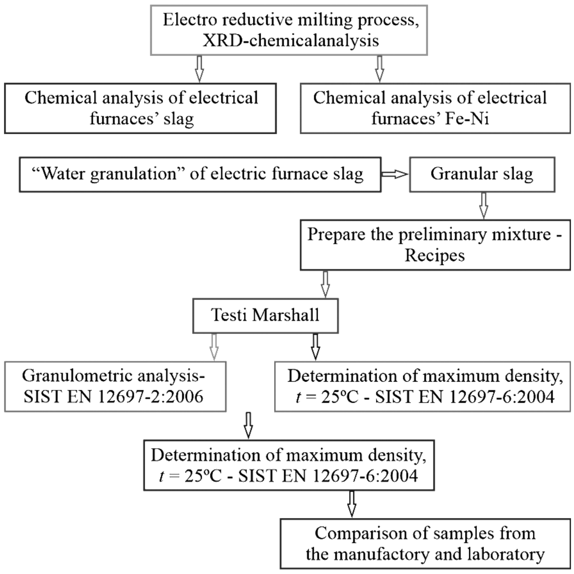

Fig. 1. Flowchart for the research methodology

Table 1

Basic materials for the production poured asphalt AC 0/5, AC 0/8 and AC 0/11 mm

Type of materials	Factions, mm	Descent	Research method
Filler	–	Macedonia	EN (933-1; 1097-4; 1097-7)
Bitum	B 50/70	ARMO SHA U.P.N. Fier	EN (1426; 1427; 1526)
Sand finesse	0/2	Arena Leposaviq	EN (933-1; 1097-2; 1097-6)
Granular EF slag	0/2	"Ferronikeli Foundry"	
Sand	2/4, 4/8, 8/11	Arena Leposaviq	EN (933-1; 1097-2; 1097-6)

Preparation of the Preliminary Mixture – Recipe for Poured Asphalt; PA (0/5, 0/8 and 0/11 mm). Poured asphalt (AC), usually has grain with diameters of 5, 8 and 11 mm (AC 0/5, 0/8 and 0/11 mm). When laying them on the road, they are not compacted by cylinders and for this reason they are called "poured asphalt".

PPM Preliminary Recipe for laboratory conditions, sampling and examination of other properties are developed in accordance with standard methods:

Table 2

The average chemical composition of the electric furnace slag*

Constituents, %	MgO	SiO_2	CaO	Cr_2O_3	MnO	Fe (tot.)	Co	Ni
K-1	9.34	58.51	9.72	1.25	0.404	13.77	0.016	0.094
K-2	9.11	55.26	8.63	1.36	0.44	16.2	0.02	0.09
K-3	8.15	60.87	12.7	0.91	0.35	11.28	0.02	0.11
K-4	7.94	62.66	11	1	–	11.86	0.01	0.08
K-5	7.59	58.78	10.7	1.28	0.39	13.24	0.01	0.08
K-6	9.23	61.46	9.94	1.42	0.44	12.76	0.02	0.08

* Source: Fe-Ni Laboratory, New Co "Ferronickel", Drenas/Kosovo

Table 3

Experimental research properties of Fe-Ni slag in "Ferronickel Foundry" Drenas/Kosovo*

Research	Research method by SK-EN	Research results	Condition for quality under stand. SK-EN
Specific measures in fresh condition, g/cm^3	12697-6	2.6–2.8	2000–3000
Specific measures in dry condition, g/cm^3	12697-6	2.6–2.8	2000–3000
Receiving water (%) for $\phi = 0/2$ mm	12697-8	1.05–1.08	is not described
Volume measures in friable condition, g/m^3	12697-6	1.4932	is not described
Volume measures in compressed condition, g/m^3	12697-6	1.5871	is not described
Pressure solidity, MPa	in dry condition	237–240	min. 16080
	in fresh condition	224	min.12864
Equivalent fractions	12697-1	82.5	min. 60 the crushed min. 70 natural
Equivalent fractions < 0.063 mm. Equivalent fractions < 0.09 mm	12697-1	0.7 1.8	< 5 % natural < 10 % the crushed

* Source: Laboratory for asphalt "B & A & M" Maribor, Tomasicevo 36

- EN 12697-27:2000 – Bituminous mixtures – Test methods for hot mix asphalt – Part 27: Sampling;
- EN 12697-2:2002 +A1:2007 – Bituminous mixtures – Test method for hot mix asphalt – Part 2: Determination of particle size distribution;
- EVS-EN 12697-5:2002+A1:2007 – Bituminous mixtures – Test methods for hot mix asphalt – Part 5: Determination of the maximum density CONSOLIDATED TEXT;
- EN 12697-8:2003 – Bituminous mixtures – Test methods for hot mix asphalt – Part 8: Determination of void characteristics of bituminous specimens;
- EN 12697-18:2004 – Bituminous mixtures – Test methods for hot mix asphalt – Part 18: Binder drainage;
- EN 12697-34:2004+A1:2007 – Bituminous mixtures – Test methods for hot mix asphalt – Part 34: Marshall test;
– SIST EN 12697-10:2002/AC:2007 – Bituminous mixtures – Test methods for hot mix asphalt – Part 10: Compatibility;
- EN 12697-22:2003+A1:2007 – Bituminous mixtures – Test methods for hot mix asphalt – Part 22: Wheel tracking.

Such quality of AC (poured asphalt) is expected to provide high resistance to the prevailing road conditions and other favorable physical-mechanical properties of the asphalt layer. In Table 4, the recipe for poured asphalt – AC (0/5, 0/8 and 0 /11 mm) designed according to PPM is presented.

Experimental examination of the mechanical-physical properties of the group of samples of preliminary recipes with dimensions 7.07, 7.07, 7.07 cm of poured asphalt were performed in accordance with EN 12697-34:2004 + A1:2007 (Marshall Test) and technical specifications for this type of asphalt (Table 5).

Based on its chemical and mineralogical composition, this type of slag represents a material suitable for producing poured asphalt and other construction materials. The process of production is relatively simple and does not require any special technology and is accompanied by low production cost.

Table 4

Preliminary preparation of mixture – Preliminary Recipe AC (0/5, 0/8 and 0/11) mm B50/70

Materials	Recipe for poured asphalt (%)								
	AC 0/5 mm			AC 0/8 mm			AC 0/11 mm		
Samps	AC1	AC2	AC3	AC4	AC5	AC6	AC7	AC8	AC9
Concentration of bitumen, %	8.5	8.0	7.5	8.0	7.0	6.7	8.0	6.8	6.5
Filler, % m/m	26.5	28	29.5	24	25.5	26.3	22	24	26
Sand finesse 0/2, % m/m	32	31	30	28	30.5	32	27	27	28
Granular EF slag 0/2, % m/m	32	31	30	28	30.5	32	27	27	28
Sand 2/4, % m/m	28	28.5	29	22	21	19	15	15	14
Sand 4/8, % m/m	5.0	4.5	4.0	13	12	12	12	13	12
Sand 8/11.2, % m/m	–	–	–	5	4	4	11	10.2	9
Sand 11.2/16, % m/m	–	–	–	–	–	–	5	4	4.5

Table 5

Investigation of physical-mechanical properties of poured asphalts prepared from eruptive sand and granular EF slag

Properties:	Criteria according to sdand.		Research results			
	Strong asphalt poured	Asphalt poured	Eruptive sand	EF slag	Eruptive sand	EF slag
Gaps to min. mix, % v/v	max. 18	max. 22	–	–	–	–
Water absorption, % v/v	max. 1.0	max. 1.0	–	–	–	–
Penetration, mm (52.5 kg/5 cm^2/40 °C/30 min)						
Transient traffic	1–6	1–6	4.3	4.2	4.3	4.2
Emplacement	1–4	1–4	3.7	3.9	3.9	3.6
Easy for cycling and running	max. 15	max. 15	11	11	11	11
Density, kg/m^3	2000–3000	2000–3000	2670	2800	2675	2830

Results. Landfill of Fe-Ni slag with a volume over 2.6 mil. m^3, which due to the lack of management and irrational use of resources and energy, has become an environmental hotspot in the Republic of Kosovo for years. Uncontrolled dumping of metallurgical slag and other industrial waste has turned them into reproductive pollutants and very environmentally disturbing. This landfill being exposed to rain and wind in addition to being very capable of emitting polluting elements, at the same time is reflecting a bad image and has become one of the obstacles to sustainable development.

Looking at the current ferronickel manufacturing practices in the "Ferronickel Foundry", over 1 million tons of Ni oxide ore are processed within a year, of which over 75 % goes to slag [2, 4]. At the same time, as estimated from the study data, the use of electric furnace slag as aggregate in the preliminary recipes of poured asphalt, in addition to guaranteeing the most advanced quality of the product, this would be followed by lower production costs, saving mineral reserves and energy and protecting the environment. Thus, the replacement of traditional aggregates, as it may be, andesites, basalts and other eruptive aggregates would eliminate the costs associated with exploration, drilling and mining, excavation, washing, homogenization and costs associated with environmental protection.

The electric furnace slag produced in Drenas belongs to the group of acidic slags, with main components: SiO_2, CaO, FeO and MgO (Fig. 2). Its relatively high acidic character represents a rather limiting factor for the direct use in construction industry, but this does not prevent it from being used for bituminous mixes.

SiO_2 and CaO are two of the main oxides which determine most of the physical and mechanical characteristics of electric furnace slag. The percentage of SiO_2 and CaO contained in the slag plays an important role in regulating the ratios between the glassy and amorphous phases, in alleviating the chemical aggressiveness, stimulating the bonding features and easing of the slag hydrating process. According to sources from the literature [1, 12]; for example, where the SiO_2/CaO ratio is greater than 2.0, as is the case with electro-arc melting in electric furnaces in the Drenas "smelter", the lowest eutectic temperature is at ≈ 1790 °C. However, the iron oxide plays an important role, significantly reducing the temperature of reaction products [13]. However, a slag with high Fe concentration has a negative impact on producing construction materials based on such slag.

The determination of the concentration of bitumen, filler and mineral mixture of poured asphalt, AC (0/5, 0/8 and 0/11) mm B50/70, was realized through the separation of the participating fractions with the system "Infra Test Asphaltanalizator", Figs. 3–5.

In particular, in circumstances where bivalent iron could be transformed into the trivalent iron, such a transformation would have negative effects on bonding capacities, as well as on other mechanical and physical features of the final product. SiO_2/CaO + MgO ratio is the main determinant of mineralogical construction and other properties of slag. However, unfavorable ratio between glass and crystalline phases and high

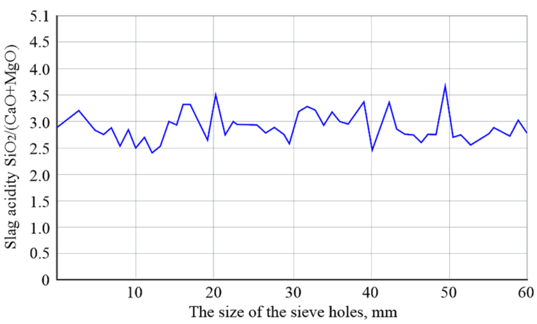

Fig. 2. Acidic character of the investigated slag (Source: Fe-Ni Laboratory, New Co "Ferronickel", Drenas/Kosovo)

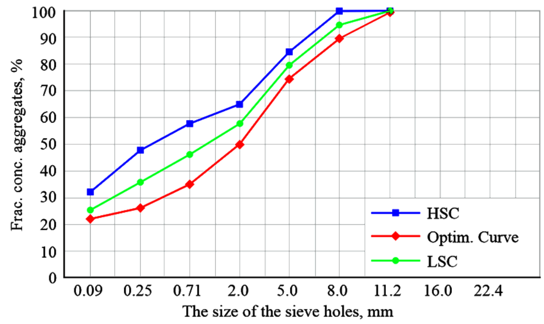

Fig. 3. Granulometric area of poured asphalt AC-0/5 mm

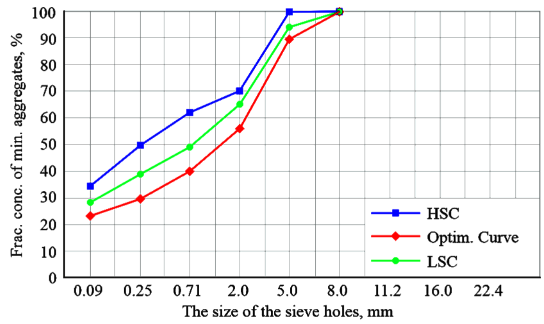

Fig. 4. Granulometric area of poured asphalt AC-0/8 mm

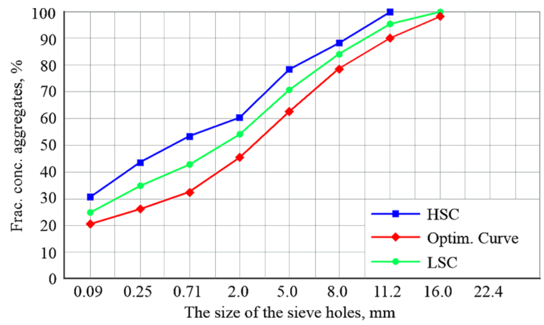

Fig. 5. Granulometric area of poured asphalt AC-0/11 mm

concentrations of fine grain have limited its application as a single element, whereas its application with other silicate aggregates would affect improvement of the majority properties of asphalt concrete.

Unlike other asphalt concretes, their layer in the paved state does not contain voids. In this case, all voids in the mineral aggregate are filled with bitumen and lime filler (while for easier paving is added a small amount of silicate filler). Poured asphalt has a fine quarry, which usually consists of 20 to 30 % gravel particles with a grain diameter of 0.09 to 2 mm and about 35–55 %; it is fine sand with a grain diameter over 2.00 mm. Tables 6, 7 show the types of poured asphalt.

After the granulometric analysis (Fig. 6), PPM-Preliminary Recipes were made (for the types of AC series (0/5, 0/8

Table 6

Type of poured asphalt

Type of mixture	Filler composition (< 0.09 mm)	Fine sand > 2 mm (criteria)	Fine sand > 2 mm (recommendation)
Strong poured asphalt	min. 20 %	40–50 %	45–50 % (50–55 %)
Poured asphalt	min. 20 %	30–40 %	35–40 % (60–65 %)

Table 7

Results from the examination of other mechanical and physical properties of B50/70 AB11s type based of EF slag, which can be reference values even for poured asphalts

Type of processing	AB 11 surf B50/70 A3					AB 11 surf B50/70 A3 (andesite + slag)				
Research method	Bitumen properties EN 1426, 1427									
Nr. mixed. the asphalt concrete	PA1	PA2	PA3	PA4	PA5	PA1	PA2	PA3	PA4	PA5
Bitumen, % m/m	Required standard min. 8.0 (KN)									
	10.8	11.3	11.0	10.0	9.3	10.8	11.3	15.0	11.7	7.9
Bitumen density, kg/m^3	1020	1020	1020	1020	1020	1016	1016	1016	1016	1016
Filler, % m/m	6.2	6.0	6.2	6.5	6.8	5.9	7.2	7.4	7.6	8.2
Research method	Test Marshall EN 12697-34; Compression temp. (150 ± 3 °C) – 2×50 stroke									
Stability, kN	Required standard min. 8.0 (KN)									
	11.3	11.7	11.8	11.3	11.6	11.2	10.8	10.7	11.4	10.7
Fluency, mm	Required standard 2–4 (mm)									
	3.0	3.3	3.0	2.9	3.0	2.9	2.7	2.8	3.7	2.9
Coefficient of stiff, KN/mm	Required standard < 2.20 (KN/mm)									
	3.6	3.9	3.6	2.9	3.6	3.5	4.5	4.3	4.4	3.7
Max. density of asphalt, kg/m^3	2494	2496	2497	2498	2489	2499	2485	2485	2489	2497
Density mixed with mineral, kg/m^3	2398	2392	2394	2387	2379	2382	2332	2388	2383	2395
Gaps, % v/v	Required standard 4.5–5.5 % (v/v)									
	4.9	4.2	4.3	4.7	4.3	4.6	4.8	5.3	4.7	4.2
Filling the gaps with bitumen, % v/v	Required standard 66–78 % (v/v)									
	67.6	69.2	70.1	71.9	71.7	75.0	76.0	68.2	70.0	71.4
Gaps in mineral mixture, % v/v	11.6	17.4	15.9	18.5	19.4	20.4	20.0	12.0	16.6	20.3
Aggregate volume	80.3	80.6	81.1	80.5	80.6	77.6	80.4	81.2	81.2	80.5

and 0/11 mm) of the samples (3 × 3). The mixing temperature in the experimental mixer was in the intervals of 160–172 °C.

The preliminary design of the mineral mixture was developed according to the technical criteria specified according to ZTV Asphalt STB 94 (Fig. 7).

In general, the quality of electric furnace slag for the production of Fe-Ni in "Ferronickel Foundry", even according to the actual method of wet processing, if combined with other eruptive aggregates and modified bitumen in recipe for all types of asphalt concrete will have a crucial influence in terms of:

1. Stability (resistance to deforming under the influence of repeated traffic movements).

2. Sustainability (to impacts of climate conditions and vehicle carrier action during exploitation of the road).

3. Flexibility (resistance to fatigue performances under the influence of repeated movements of vehicles in low temperatures).

4. Rudeness (which is manifested as a functional indicator of road surface, expressed in macro and micro longitudinal coefficient of friction and one radial)'.

5. Noise (as an indicator of surface that has an influence on driving comfort and negative ecological effects).

6. No water penetration (which expresses the ability of the asphalt layer against penetration of water from surface layers).

7. Working capacity (for easy laying and efficient compression).

In addition to strong economic and environmental incentives, increasing the applicability of slag would have an impact on the promotion of other recycling programs and other industrial by-products as well as those of modern waste management.

On the other hand, the low alkaline character of the investigated slag represents a favorable feature in using slag as an additive material for all types of cement, particular for metallurgical cement.

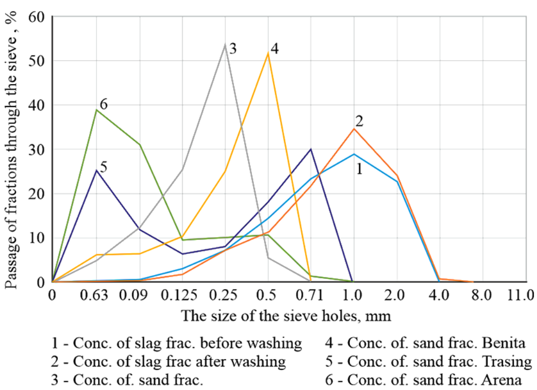

Fig. 6. Granulometric analysis of eruptive sands and EF slag of "Foundry" in Drenas

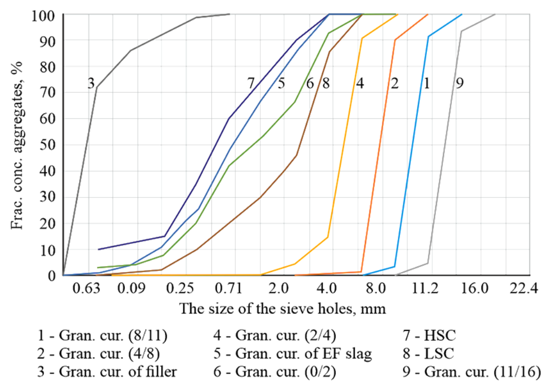

Fig. 7. Preliminary design of the mineral mixture eruptive sands and electric furnace slag according to ZTV Asphalt STB 94

Conclusions. The aim of the paper is to promote the use of the electric furnace slag produced in Drenas for the purposes of construction materials industry, with economic and environmental effects. Based on the research works published in literature and the appropriate experience gained with industrial tests, the authors of this paper carried out a systematic approach to find out how suitable is the electric furnace slag produced in Drenas for production of construction materials, particularly for production of poured asphalt. This slag represents the most important by-product for saving natural resources, economic development and environmental protection. Modifications of the slag processing about the correction of some of the chemical-physical properties of them would enable the transformation of the electric furnace slag for the production of ferronickel from a residue into aggregates valuable for the construction industry. This transformation would be a key factor in relation to advancing the properties of construction products, reducing costs for environmental maintenance, generating new jobs, reducing imports and generally increasing the gross domestic product. In this case, the application of electric furnace slag processed according to actual practice, as part of the recipe for poured asphalt AC 0/5, AC 0/8 and AC 0/11 mm would enable a product with excellent physical-mechanical and environmental attributes. The basic principle of design and choice of materials for those is to ensure a balanced ratio between stability, penetration, and stiffness, which is achieved by accurately determining the proportional ratios of the slag, eruptive aggregate and other participating components.

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Дослідження властивостей литого асфальту з електропічного шлакового заповнювача

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Мета. Дане дослідження показує вплив використання електропічного шлаку як наповнювача із сильним позитивним впливом на властивості литого асфальту (асфальтобетону, АБ). Результати досліджень, що стосуються опору ковзанню, глибини текстури поверхні, опору ерозії, гігроскопічності, міцності при стисканні та глиняних окатишів, підтвердили той факт, що додавання цього шлаку до змішувального еруптивного заповнювача вказує на покращення механічних характеристик укладеного асфальту та його поверхневого шару.

Методика. Попередня підготовка асфальтобетонної суміші – попередня суміш, відбір проб і дослідження властивостей – відбувається у відповідності до стандартних методик: EN 12697-27:2000, SK EN 12697-36:2003, EN 12697-2:2002+A1:2007, EN 12697-8:2003, EN 12697-34:2004 +A1:2007, (тест Маршалла), EN 12697-6:2004 та SIST EN 12697-2:2004.

Результати. Металургійна промисловість протягом багатьох років використовує всі свої відходи виробництва, включаючи шлак, як цінні ресурси для промисловості і, зокрема, у промисловості будівельних матеріалів. Використання побічних продуктів цього процесу в будівельній галузі, в основному в дорожньому будівництві, є одним із ключових факторів економії природних ресурсів і запобігання забрудненню навколишнього середовища.

Наукова новизна. Для приготування попередньої рецептури трьох видів литого асфальту (АБ 0/11, 0/8 і 0/5 мм) використовувалися електропічні шлаки та еруптивний пісок крупністю від 0 до 11 мм, від 0 до 8 мм та від 0 до 4 мм.

Практична значимість. Використання такого виду шлаку в якості заповнювача даної бітумної суміші не тільки покращить фізико-механічних властивостей АБ, але й покаже значний економічний та екологічний ефекти.

Ключові слова: *шлак, електропіч, феронікель, нікель, литий асфальт*

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