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APPLICATION OF WASTEPAPER SLUDGE ASH AS MINERAL POWDER FOR HOT ASPHALT CONCRETE MIX

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In this article the potentiality is proven for application of wastepaper sludge ash (WSA) as mineral powder for traditional hot asphalt concrete mix. For the comparative testing in this article the traditional limestone mineral powder is used. The chemical (oxide) composition of the aggregates was studied, while that was determined by means of DRON – 3.0 diffractometer. It was ascertained that CaO is present in wastepaper sludge ash in sufficient quantity, while it provides for utilization of this waste material as an aggregate for asphalt concrete. The limestone mineral powder granulometric composition was determined and the wastepaper sludge ash was grinded by ball grinder till the appropriate granulometric composition was reached. There were studied the main physical and mechanical parameters of bitumen 70/100 to be used for formation of asphalt binder in combination with the studied mineral aggregate. There were formed the following series of traditional hot asphalt concrete mix: on limestone mineral powder, on wastepaper sludge ash, on both limestone mineral powder and wastepaper sludge ash in ratio 50/50, 30/70, 20/80 (% w/w). By means of grading curves of dense-graded continuous mixes there was designed the chip-grain carcass of asphalt concrete mix. The asphalt concrete mix was designed based on the following characteristics: hot fine-grained dense-graded asphalt concrete with residual porosity from 2 to 5 %, with quantity of chip-grains sized more than 5 mm – 35–45 % and the maximum grain-size up to 15 mm. There was determined that WSA can perform as material to be used as mineral powder for asphalt concrete mixes. According to the requirements of Ukrainian standard (DSTU B V.2.7-119:2011), the asphalt concrete with WSA is of standard condition, but the water-saturation index approaches the acceptably allowed value, while in comparison with asphalt concrete with LMP – it is higher by 55 %. Such result is due to the difference in oxide composition of the aggregates, namely lower content of products of calcareous rock in WSA. With combined application of limestone mineral powder and WSA in ratio 50/50, 30/70, 20/80 (% w/w) the water-saturation index decreases. As to the compression tensile strength and compression tensile strength after water-saturation, these indices on WSA are lower than on LMP just by 10 %. The most efficient usage of WSA, considering the studies done, can be achieved when coupled with LMP in ratio 50/50.

Key words: wastepaper sludge ash (WSA), limestone mineral powder (LMP), bitumen, hot asphalt concrete.

Introduction

At present time the most wide-spread trends for paper-production waste disposal are burial, sludge composting and incineration. Still, the most ecologically and economically attractive is usage of such waste materials in various construction composites (Bajpai, 2015). One of the forward-looking waste materials (suitable for application in the construction industry) is wastepaper savings (Frias, 2015; Segui, 2015; Ferreiro, 2013). In (Ahmad, 2013) there is stated that thermoactivated wastepaper sludge ash

(WSA) (received due to wastepaper savings incineration) possesses the binding properties and form the solidifying systems. The forward-looking is their practical application taking into account their specific structural-mechanical properties – when they are performing the role of the additional cementing materials in composite Portland-cements, mortars and dry pack mortars. Still, the review of literature has shown that the application of such approach to asphalt concrete intended for pavement of motor-roads' courses is not studied (Rahman, 2020; Pasandín, 2016; Mohammadinia, 2017).

It is generally accepted that to receive the popular type of asphalt concrete for pavement of top courses (that is, stone mastic asphalt) there is used the special stabilizing additive, which (as a rule) is produced from cellulose fiber. Still, the content of this stabilizer constitutes just about 0.3–0.5 % w/w relative to asphalt concrete. In their turn, the authors of this article proposed to use WSA as mineral powder for classical asphalt concrete. The mineral powder is more expensive than other mineral components of asphalt concrete – chips and sand (screenings), but it performs the important functions in asphalt concrete. That is: due to availability of large specific surface area (where the part of mineral powder is counted for by 90–95 % of the total surface of aggregate that comprise the asphalt concrete), the mineral powder facilitates the increase of number of contacts among the cross-linking components of asphalt concrete, fills the small voids among the larger asphalt concrete particles and have the ability to transform bitumen from volumetric state into membranous, thus creating (along with the bitumen) the asphalt binder. As a mineral powder for asphalt concrete there is traditionally used the crushed calcareous rock. As shown in (Goncharenko, 2008; Goncharenko, 2006), the activity and strength of adhesion of mineral materials with bitumen is connected with the content of oxides (cations) of alkaline, alki-earth and heavy metals. As by the influence of mineral composition of the powders upon their activity, the powders are subdivided into four groups. Attributed to the first group are the powders having high positive potential and large amount of adsorption centers in a form of cations Ca_2+ i Mg_2+ (calcite, limestone, dolomite). Attributed to the second group are the powders whose grains' surface has negative charge with large amount of adsorption centers in a form of ions O2- (quartz, kaolin, granite, silicone). Attributed to the third group are the powders having lowered negative potential, with presence on the particles' surface of the compensating cations of various valency K+, Na+, Ca_2+, Mg_2+ (mica, asbestos, gabbro, feldspar etc.). Attributed to the forth group are the powders having neutral surface (talc, graphite etc.). Taking into account the above mentioned, to apply this or that industrial waste material as a mineral powder for asphalt concrete – it shall possess the appropriate granulometric, chemical and mineralogical composition.

Target of this article

To determine the quantitative and qualitative influence of WSA upon the properties of hot asphalt concrete.

Techniques used

For the comparative testing there were chosen two aggregates for asphalt concrete: WSA of PJSC "Kyiv Cardboard and Paper Mill" and limestone mineral powder (LMP) produced by "Skala-Podilskii Spetscarier (Special Quarry)".

In Table 1 there is presented the chemical (oxide) composition of aggregates, which was determined by means of DRON – 3.0 diffractometer.

The analysis of Table 1 witnesses, that present in the WSA composition there is CaO (being the product of $CaCO_3$ roasting) in the sufficient quantity, while that indicates on the potentiality of using this waste material as an aggregate for asphalt concrete.

WSA consists of the particles sized nearly 10 mm. Therefore, it was grinded by means of ball grinder till the standard sizes, by which the high-quality mineral powder is characterized (please, see Table 2).

Table 1

Chemical composition of aggregates

Name of the aggregate	Name of element, % w/w							Σ
WSA	SiO_2 26.44	Al_2O_3 15.36	Fe_2O_3 1.16	CaO 49,84	MgO 2.16	SO_3 0.45	LOI 4.59	100.0
Limestone mineral powder	SiO_2 4.4	Al_2O_3 1.2	Fe_2O_3 0.7	$CaCO_3$ 85.0	$MgCO_3$ 7.7	–	1.0	100.0

Table 2

Granulometric composition of the mineral powder and WSA

Name of the aggregate	Sieves, particle residue on the sieve, % w/w						Σ
	1.25	0.63	0.315	0.14	0.071	<0.071	
WSA	0.2	0.4	1.2	8.8	7.4	82.0	100
Limestone mineral powder	0	0.1	1.2	4.7	12.9	81.1	100

As initial bitumen for asphalt concrete there was used crude-oil heavy pavement oxidized bitumen grade 70/100 from JSC Mozyr Refinery, Belarus, Gomel Region, town of Mozyr. The operation characteristics of taken bitumen are presented in Table 3. As per the tested indices, the present bitumen corresponds to the grade 70/100 according to (EN 12591; DSTU 4044). Also to produce asphalt concrete mixes there were used broken stone 10–15, 5–10 mm and chips screenings 0–5 mm (granite quarry JSC "Polonskiy Gorniy Combinat").

Table 3

Main physical and mechanical parameters of bitumen 70/100

Index	Values
Penetration at 25 °C, м$\cdot 10^{-4}$ (0.1 mm)	83
Softening point, °C	50
Ductility at 25 °C, м$\cdot 10^{-2}$ (cm)	>100

To achieve the purpose of testing there were formed the various series of the traditional hot asphalt concrete mix according to Table 4: on limestone mineral powder, on WSA, on both limestone mineral powder and WSA in ratio 50/50, 30/70, 20/80 (% w/w). By means of grading curves of dense-graded continuous mixes there was designed the chip-grain carcass of asphalt concrete mix. The asphalt concrete mix was designed based on the following characteristics: hot fine-grained dense-graded asphalt concrete with residual void content from 2 to 5 %, with quantity of chip-grains sized more than 5 mm – 35–45 % and the maximum grain-size up to 15 mm (Table 4).

Table 4

Asphalt concrete composition

Name of material	Content of material in asphalt concrete, %
Broken stone 15–10 mm	5.0
Broken stone 10–5 mm	35.0
Chips screenings, grade 5–0.63 mm	32.0
Chips screenings, grade 0.63–0.071 mm	17.0
Mineral powder	11.0
Total quantity, %	100.0
Bitumen 70/100	6.25

Physical-mechanical properties of asphalt concrete of various series are presented in Table 5. The asphalt concrete indices are accepted in accordance with (DSTU B V.2.7-119:2011) for the climate area of West Ukraine (Lviv Region).

Table 5

Physical-mechanical properties of asphalt concrete

No	Name of index	Asphalt concrete series, % w/w					Requirements to the designed asphalt concrete
		LMP 100	WSA 100	LMP/WSA 50/50	LMP/WSA 30/70	LMP/WSA 20/80	
1	Average density, g/cm^3	2.36	2.33	2.34	2.35	2.35	–
2	Water-saturation, % by volume	1.6	2.9	2.0	2.5	2.7	Not more than 3.0
3	Compression tensile strength, MPa, at: 20 °C 50 °C	3.8 1.4	3.5 1.3	3.6 1.3	3.5 1.3	3.5 1.3	Not less than 2.7 1.3
4	Compression tensile strength, MPa, at 50 °C after water-saturation	1.2	1.1	1.2	1.2	1.2	–

When making analysis of Table 5 one can ascertain that WSA may serve as a material that may be used as a mineral powder for asphalt concrete mixes. According to the requirements (DSTU B V.2.7-119:2011), the asphalt concrete with WSA corresponds to the conditions, but the index of water-saturation approaches the acceptably allowed value, while in comparison with asphalt concrete with LMP it is higher by 55 %. Such result is caused by the difference in oxide composition of the aggregates, namely: the lower content of calcium carbonate in WSA. In conditions of combined application of limestone mineral powder and WSA in ratio 50/50, 30/70, 20/80 (% w/w) the index of water-saturation decreases. As to compression tensile strength and compression tensile strength after water-saturation, these indices on WSA are lower than on LMP just by 10 %.

Conclusions

1. There was tested the chemical (oxide) composition of the aggregates and there was determined the potentiality of wastepaper sludge ash application as a mineral powder for asphalt concrete – as far as CaO is present in its composition in the sufficient quantity.

2. The wastepaper sludge ash was grinded till the standard (for mineral powder) granulometric composition, while the components of asphalt concrete mix were also selected and tested.

3. The traditional hot asphalt concrete compositions were designed, and the influence of wastepaper sludge ash (separately and in complex with limestone mineral powder) upon the physical-technical indices of asphalt concrete was tested. There was ascertained that the wastepaper sludge ash can be used as a mineral powder for asphalt concrete – both separately and in combination with mineral powder. The most efficient usage of wastepaper sludge ash (based on the testing done) can be reached in combination with LMP in ratio 50/50.

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ВИКОРИСТАННЯ МАКУЛАТУРНОГО СКОПУ В РОЛІ МІНЕРАЛЬНОГО ПОРОШКУ ДЛЯ ГАРЯЧИХ АСФАЛЬТОБЕТОННИХ СУМІШЕЙ

У статті доведена можливість використання макулатурного скопу в ролі мінерального порошку для традиційного гарячого мінерального порошку. Досліджено хімічний (оксидний) склад наповнювачів, який визначили за допомогою дифлактометра ДРОН – 3.0. Встановлено, що у складі макулатурного скопу присутній CaO в достатній кількості, що дає можливість застосування цього відходу в ролі наповнювача для асфальтобетону. Встановлено зерновий склад мінерального порошку та розмелено за допомогою кульового млина до відповідного зернового складу макулатурний скоп. Досліджено основні фізико-механічні показники бітуму 70/100, що утворюватиме з дослідженими мінеральними наповнювачами асфальтне в'яжуче. Заформовано такі серії традиційної гарячої асфальтобетонної суміші з використанням: мінерального порошку, макулатурного скопу, на мінерального порошку та макулатурного скопу у співвідношенні 50/50, 30/70, 20/80 (% мас). Встановлюємо, що макулатурний скоп може слугувати матеріалом, що можна використовувати в ролі мінерального порошка для асфальтобетонних сумішей. Згідно з вимогами ДСТУ Б В.2.7-119:2011 асфальтобетон з макулатурним скопом є кондинційним, але показник водасичення наближається до допустимо дозволеного значення, порівняно з асфальтобетоном і з мінеральним порошком він є вищим на 55 %. Такий результат зумовлений різницею в оксидному складі наповнювачів, а саме менший вміст продуктів вапнякової породи в макулатурному скопі. За комбінованого застосування мінерального порошку та макулатурного скопу у співідношенні 50/50, 30/70, 20/80 (% мас) показник водонасичення знижується. Щодо границі міцності при стиску та границі міцності при стиску після водонасичення зразків асфальтобетону, ці показники з використання макулатурного скопу є меншими, ніж з використанням мінерального порошку лише на 10 %. Найраціональніше використання макулатурного скопу з огляду на проведені дослідження можна досягнути в поєднанні з мінеральним порошком у співвідношенні 50/50.

Ключові слова: макулатурний скоп, мінеральний порошок, бітум, гарячий асфальтобетон.