Utilization of solidified industrial hazardous waste in construction: A case study

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Abstract

Utilization possibilities of solidified fractions of industrial hazardous waste obtained by mixing with inert materials in construction were investigated. Waste mineral oils, water-hydrocarbon emulsions mixture, and waste filter cakes from the physico-chemical treatment of wastewater generated by washing of patterned rollers for a printing machine, were used as models of industrial hazardous waste in the solidification process. Investigation comprised preparation of concrete and asphalt mixtures for further testing. The solidified powder was analyzed regarding the granulometric composition, while the obtained concrete samples were further subjected to compressive strength determination, whereas the asphalt mixtures were tested in the context of potential waterproofing materials. According to the obtained leaching test results, all the samples met the required conditions for further application. Compressive strength test results were in the range of 8.7 – 22.6 MPa. Still, the measured compressive strength values were lower than expected, which is explained using solidified powder fractions of smaller grain size. According to the results, it can be concluded that the investigated mixtures cannot be used for structural building elements, but their usage is recommended for elements such as pavements, roadside, path cubes, concrete haberdashery, *etc.* Asphalt mixtures showed acceptable properties in terms of mechanical, durability, and waterproofing tests.

Keywords: inertization; solidification; recycling; concrete; asphalt.

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1. INTRODUCTION

Accelerated industrial development accompanied by population growth has resulted in environmental degradation, mainly caused by the production of an increasing amount of waste with inevitable detrimental effects on human health [1]. From the Industrial Revolution to the present, the so-called "linear industrial waste management system" has been developed and utilized, which assumes that resources are abundant, accessible, and can be easily used and disposed of cheaply [2]. Today, the European Union (EU) waste management act is based on the "waste management hierarchy" principle. This act prioritizes waste management policies, as well as priorities in waste management at the operational level: prevention, preparation for reuse, recycling, reuse, and, as the least desirable option, waste disposal, *i.e.*, disposal and burning of waste without the use of energy [3,[2]. Over the last few years, waste recycling in the EU has been stimulated by appropriate regulations, while the EU legislation provides a tremendous boost to national governments in their efforts to improve recycling systems [4].

Approximately 3 billion t of all kinds of waste are generated annually worldwide [5]. The manufacturing sector (industry) generates approximately 360 Mt of waste annually, the construction sector produces 900 Mt of waste, while the water supply and energy generation sectors produce 95 Mt of waste annually [5]. Among the waste generated in the EU in 2020, 4.4 % of the total was classified as hazardous waste. Compared with 2010, another 5.1 % more hazardous waste was generated in 2020 in the EU, which is an increase in quantity from 90.8 to 95.5 Mt, with a peak in 2018 of 101.7 Mt [6]. The decline in 2020 as compared to 2018 is a result mainly due to the lower amount of combustion waste due to the lower

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usage of solid fuels such as coal, coke, and oil shale. In 2020, the share of hazardous waste in total waste generation was between 0.5 % in Romania and 12.0 % in Bulgaria. Among the non-EU member countries, Turkey recorded the highest share of hazardous waste in total waste generation (28.5 %) and was followed by North Macedonia (28.2 %), Montenegro (27.6 %), Serbia (19.3 %) and Norway (13.3 %) [6]. In 2020, a total of 9.57 Mt of waste was generated in the Republic of Serbia (RS), of which approximately 68,000 t was hazardous waste [6-8].

Hazardous waste sources include industry, thermal power plants, mining, mineral processing sites, agricultural facilities, research laboratories, and the natural environment. Hazardous waste can be in the form of solids, liquids, sludge, gases, or aerosols, and it is generated primarily by chemical production, manufacturing, and other industrial activities. It may cause damage during inadequate storage, transportation, treatment, or disposal operations. Thermal energy facilities are the largest producers of waste. Ash, slag, and dust from the boiler and fly ash from coal combustion were generated in the amount of 7.78 Mt, *i.e.* 81% of the total waste produced in RS in 2020 [9]. Other types of waste originating from thermal processes are also present in significant quantities: unprocessed slag, waste from slag processing, and solid waste based on calcium, generated in the process of desulphurizing gases. Currently, fly ash is handed over for the needs of cement production. Certain quantities of gypsum from the desulphurization process are exported, which has the status of a by-product [4]. Thermal power facilities are also the major waste producers in the RS. In contrast, in hazardous waste stream production, sludge and scone filters from the process of gas treatment containing hazardous substances, dominate in quantity (in the amount of 10,800 t), followed by excavations of land during construction activities, solidified and other waste from waste treatment plants, waste packaging, and waste from metal processing [9-12].

In line with the waste management hierarchy, which highlights the reuse and recycling of waste, in particular, both in the EU and the RS, research is still being carried out regarding the reuse of waste in the process of making construction products containing certain amounts of waste. This research pursues the line of reusing the waste in creation of certain types of concrete products or asphalt, containing waste components [13-16]. Reusing waste contributes to preservation of natural resources, production profitability, and the development of recyclingmarket, through the placement of new products intended for the construction industry, possibly exhibiting better shaping abilities and better properties in terms of mass reduction, water-impermeability, hydro-thermal and acoustic insulation, fire resistance, *etc.* [17]. Moreover, the so-called supplementary cementitious materials reduce the amount of spent Portland cement in mortar and concrete, thus reducing the greenhouse effect [18]. In addition to the C–H structure, many types of hydrocarbon-based industrial waste materials usually contain elements such as oxygen, nitrogen, sulfur, phosphorus, chlorine, and heavy metals. Due to the presence of these elements, this waste is classified as hazardous waste material and has to be solidified to obtain inert dry hydrophobic powder for further use.

This research examined the possibility of further use of inertized or solidified industrial hazardous waste as fillers or fine aggregates in construction and road sub-base materials, *i.e*., in concrete and asphalt mixtures that would be competitive in the market, as they are made of recycled materials. According to the authors' knowledge based on literature, there is scarce literature data concerning the utilization of solidificates in the concrete and asphalt mixtures [15]. However, previous investigations were based mainly on the use of concrete products made from construction waste, *i.e*. recycled aggregates [18].

The hazardous waste inertization, *i.e*. reducing its hazardous characteristics, includes fraction solidification (congestion and hardening) and waste stabilization [19-20]. Through this process, waste is physically bound or thickened into monolithic solid mass of high structural integrity. At the same time, stabilization is a process used to reduce the hazardous potential of waste by turning pollutants into the least melting, least immobile, or least toxic form [20]. The C–H waste solidification method is one of the most used techniques available to ultimately care for waste in an environmentally acceptable and safe manner, in line with the rules of the chemical and technological trade.

Solidification/stabilization is accepted as a well-established disposal technique for hazardous waste. In hazardous waste management, solidification/stabilization is a term typically used to designate a technology employing additives to alter hazardous waste and make it non-hazardous or acceptable for current land disposal requirements.

2. EXPERIMENTAL

Two types of industrial hazardous waste were utilized:

1. A mixture of waste oils and oil emulsions after the filtration process, index number 120107*/120109*/190207*, the Catalog of waste [10], which represent the products of the oil emulsion purification process from the ultrafiltration plant at the Holding company "FAM-DMB", ltd., Car engine factory "21. May", in Rakovica, Belgrade, Serbia.
2. Waste generated by washing in the UV machine in the PVC plant and waste filter cakes from the physical and chemical treatment of wastewater generated by washing the patterned rollers for a printing machine of the PVC plant, index number 190813*/190206, the Catalog of waste [10], from the company "Tarkett" ltd., BačkaPalanka, Serbia.

The reaction mixture for the solidification process consisted of a maximum of 20 wt.% organic phase composed of a mixture of waste oils and oil emulsions and 40 wt% of dry matter from the waste filter cake from the physico-chemical treatment of wastewater (created by washing patterned rollers for a printing machine in the PVC plant), called together as C–H-waste and 40 wt.% water, which is one of the basic components for ongoing exothermic reactions.

The waste inertization process (reducing the hazardous characteristics of hazardous waste) included solidification (thickening) and waste stabilization. In the process of solidification, a chemical reaction occurs and the formation of a stable, organo-Ca (Ca–C–H) lattice into which various ligands from the C–H-waste material are permanently incorporated/bonded. The product of the reaction is a qualitatively new inert, *i.e*. stabilized material in solid form, which, according to its chemical composition, is a mixture of organo-Ca hydrophobic (water-insoluble) salts, *i.e.* solidificate.

2. 1. Solidification of industrial hazardous waste

Inertization accompanied by solidification, which impliescomplex physico-chemical and thermal dissociation process with vacuum encapsulation and primary solidification of waste material, were performed in a specially built (patented) Reactor R-210/L-210/211 (Peters, Austria) by the MID-MIX® patented technology. The reaction proceeds according to overall stoichiometric equation (1) with an energy output of Q = 3,776 MJ [20]:

$$8{,}976\text{ kg CHW} + 1{,}024\text{ kg } H_2O + 3{,}200\text{ kg CaO} = 12{,}176\text{ kg S} \quad (1)$$

where CHW and S denote C–H-waste and solidificate, respectively.

For the purposes of the further investigation, 150 kg of solidificate was prepared.

The process was semi-continuous with the retention time of materials in the reactor of about 5 min, under steering. The reactor's frequency regulator adjusts the number of revolutions in the reactor. Solidified fraction arises as a result of a physico-chemical reaction in which waste containing mixtures of different hydrocarbons (*i.e*., C–H bonds), with existing or added water molecules, reacts with dissociated elements created by the exothermal reaction with calcium oxide, which in the presence of water creates conditions for the formation of a mixed Ca–C–H-crystal lattice, also creating the calcium hydroxide and releasing heat of about 1.18 MJ kg^{-1} of calcium oxide [20]. The released heat is distributed to C–H bonds, hence the destruction of hydrocarbons, which results in the production of carbon dioxide and water, taking place at a temperature of around 100°C [20]. The total amount of released energy per kilogram of calcium oxide is sufficient to break the bonds in the benzene ring, *i.e.* the C–H structure, to evaporate almost all physically present water and achieve conditions for complete solidification of the entire mixture in the reactor. Further, released carbon dioxide can react with the calcium hydroxide and/or calcium oxide creating calcium carbonate, which remains in the solidification mixture. The temperature of the furthermost reacted solidified fraction is constantly above 100 °C, usually around 120 °C, while its cooling is very slow (about 45°C/24 h) [20].

In the process of solidification according to the MID-MIX® technology, with the mode of operation precisely selected according to the type and characteristics of waste being processed, the input waste is transformed into a whole new form of material, because each particle of waste material, helped by water vapor molecules, is encapsulated into a highly stable organo-Ca lattice and, under balanced conditions, is converted into inert stable powder, *i.e*., solidificate. Solidificate is loose powder and if there is a balanced amount of hydrocarbon waste in the treatment, solidified powder has highly hydrophobic properties.

2. 2. Preparation of concrete and asphalt mixtures

Prior to mixture preparation, the granulometric composition of solidified powder was determined according to the ISO 3310-1:2016 standard [21], at the Vibratory Sieve Shaker AS 200 (Retsch, Germany).

The obtained solidified powder was mixed in different mass ratios with other inert materials (aggregates – river aggregate in fine 0/4 mm and 4/16 mm coarse fraction (Dunavac, Serbia), limestone powder (Granit Peščar, Serbia), water, cement PC 35 M(V-L) 42,5R (Lafarge, Serbia) and bitumenEuro 70/100 (NIS, Serbia) to obtain concrete and asphalt mixtures. The composition ratios of prepared concrete mixtures are shown in Table 1.

Table 1. Composition of concrete mixtures

Sample	Content, wt. %					
	Solidified powder fraction	Aggregate, fine fraction 0/4 mm	Aggregate, coarse fraction 4/16 mm	Cement	Limestone powder	Water
Bet-1	4	31.2	20.8	40	2.6	1.4
Bet-2	6	28.8	19.2	40	2.4	3.6
Bet-3	9	27.0	18.0	38	2.2	5.8
Bet-4	13	25.2	16.8	37	2.1	5.9
Bet-5	20	22.8	15.2	33	1.9	7.1
Bet-6	27	21.6	14.4	28	1.8	7.2
Bet-7	35	19.8	13.2	22	1.6	8.4
Bet-8	42	18.0	12.0	18	1.5	8.5
Bet-9	45	15.6	10.4	17	1.3	10.7
Bet-10	50	13.8	9.2	15	1.2	10.8

In addition, possibilities of solidificate application in asphalt mixtures were examined by partially supplementing a fine fraction of aggregates (river aggregate 0/4 mm, Dunavac,Serbia) with solidified powder in asphalt mixtures (Table 2).

Table 2. Composition of asphalt mixtures

	Content, wt.%		
	Asf-1	Asf-2	Asf-3
Solidified powder fraction	25	20	15
Aggregate, fine fraction0/4 mm	33	38	43
Aggregate, coarse fraction4/16 mm	20	20	20
Bitumen	22	22	22

2. 3. Sample preparation

The third phase of the research involved preparation of concrete samples for compressive strength determination and asphalt samples for the impact test (500 g weight impact from the height of 300 mm), cold stability (flexural test at -20 °C), water-tightness (5 bar water pressure for 1 h) and behavior in water [22].

Fresh concrete mixtures were cast into a 100 mm cubic-shaped mold according to the standard SRPS EN 12390-1:2021 [23]. Samples were made following the standard SRPS EN 12390-2:2019 [24]. Samples in the molds were dried in the air at room temperature of 20±2 °C, at a relative humidity of at least 90 %, for 24h, then arranged at a grid, 1 cm apart in water at a temperature of 20±2 °C. The water level in the container was always at least 2 cm above the sample in the mold. The compressive strength tests were performed after sample air drying for 28 days according to the standard SRPS EN 12390-3:2010 [25] by automated hydraulic press Cyber-plus Evolution (Matest, Italy). The tests were performed in duplicate, and the results are shown as mean values. The concrete cubic samples are shown in Figure 1.

Figure 1. Concrete samples made of mixtures with solidified powder

2. 4. Mixture characterization

Homogenized concrete samples and hardened asphalt mixtures were further subjected to leaching tests to assess potential impacts on the environment and toxicity characteristics.

The leaching procedure (LP) was performed according to the standard SRPS EN 12457-2 [26] for waste characterization by compliance test for leaching of granular waste materials and sludge. This is a standard mobility method for evaluating organic and inorganic substances present in liquid, solid, or multi-phase waste. The results of this test indicate a long-term leaching effect, *i.e.,* potential environmental hazard. Standards prescribe one-stage batch test at the liquid/solid ratio of 10 dm^3 kg^{-1} (10:1) for materials with high contents of solids and particle size of <4 mm (with or without decreasing particle size) [26][25]. Concrete samples and hardened asphalt mixtures were crushed by a Jaw Crusher BB 300 Mangan (Retsch, Germany), milled by a Planetary Ball Mill PBM 1-4 (Wibrotechnik, Russia) and sieved to a fraction with particle size under 4 mm by a Test Sieve (Retsch, Germany). The investigated samples were brought into contact with the distilled water during continuous stirring on the Orbital Shaker LBX ORB-PRO (Labbox, Spain) at 10 rpm at room temperature (20±2°C), with 24 h contact time, without pH control. After filtration, Pb, Cd, As, Cr, and Ni concentrations were determined by induction coupled plasma mass spectrometry at ICP-MS 7700 (Agilent, USA), according to the ISO 11885:2007 standard [27]. Tests were performed in duplicates and results were compared with the limits in the Regulation on categories, testing, and classification of waste Annex 10 [10].

After LP, liquid-liquid extraction was performed to completely dissolve possibly present organic phase. The toxicity characteristic of mixtures was estimated by the toxicity characteristic leaching procedure (TCLP) according to the standard US EPA 1311 [28]. The solid material is extracted for 18 hours with a slightly acidic fluid equal to 20 times its weight under following conditions: stirring on the Orbital ShakerLBX ORB-PRO (Labbox, Spain) at 30 rpm at room temperature (20±2°C). The possible organic phase was extracted with 20 ml diethyl ether from 100 ml TCLP liquid (extract), under defined conditions: continuous stirring on the same orbital shakerat 30 rpm and also at room temperature (20±2°C), with contact time of 18 h. The solution was evaporated to a dry residue and total hydrocarbons were determined by gas chromatography using a Gas Chromatograph 5890 Series II with Flame Ionization Detector (Hewlett Packard, USA).

3. RESULTS AND DISCUSSION

Granulometric composition of the solidified powder is presented in Figure 2.

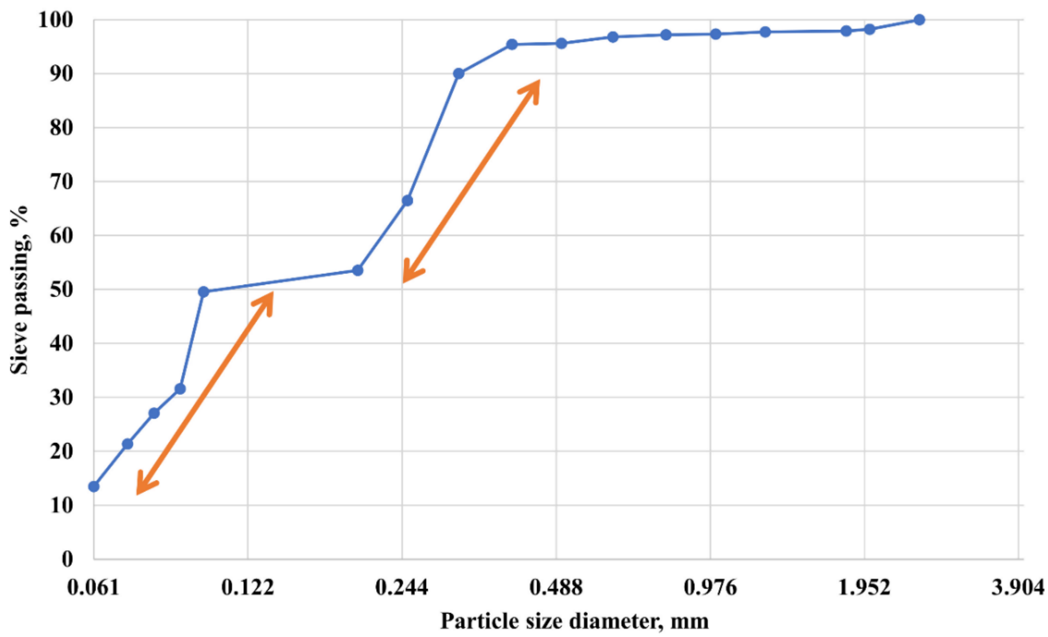

Figure 2. Granulometric composition of solidified powder fractions

As shown, if minor generalizations are applied, this composition can be considered discontinuous. Namely, particles of the fractions 0.061/0.100 mm and 0.200/0.400 mm dominantly contribute to the solidificate with 50% and 40%, respectively. Given that continuous curves are often used for producing concrete of a better quality[21][22].

The results of the compressive strength of concrete samples are shown in Table 3. along with the compressive strength of some tested materials obtained from industrial waste.

Table 3.Compressive strength results along with literature data on concrete materials supplemented with different industrial wastes (standard deviations are given in brackets)

Sample	Compressive strength, MPa
Bet-1	22.6 (0.8)
Bet-2	22.0 (0.9)
Bet-3	21.1 (0.9)
Bet-4	19.9 (0.7)
Bet-5	17.8 (0.8)
Bet-6	15.7 (0.7)
Bet-7	13.2 (0.6)
Bet-8	11.1 (0.6)
Bet-9	10.2 (0.7)
Bet-10	8.7 (0.6)
Concrete with fly ash [14]	4.5 – 17.5
Concrete with alum sludge (treated in a furnace at 200 °C) [29]	24.0 – 48.0
Concrete with Lime Stone [29]	33.0 – 53.0
Concrete with quarry dust [29]	36.0 – 65.0
Concrete with solidified wastewater treatment sludge [30]	3.9 – 5.8

The compressive strength results were in the interval of 8.7 – 22.6 MPa. Measured values were lower than expected, as explained by the presence of finer granulation in solidified powder (95.45 % of particle size <0.4 mm). Also, considering that continuous powder compositions are more favorable for better cement composites, some of the reasons for the poor behavior of the experimental mixtures can be found in the fact that the solidificate had discontinued powder composition. If a fraction of coarser granulation is used to create the sample, it is expected to gain higher compressive strength values. In particular, concrete samples that contained lower mass percentages of solidificate showed a higher strength. Therefore, samples of Bet-1, Bet-2, and Bet-3 showed satisfactory compressive strength values of over 20 MPa, bearing in mind that the typical compressive strength of Portland cement concrete varies between 20 – 40 MPa [31]. In addition, compressive strength values were still higher than in the case of some other concrete mixtures based on industrial waste (*e.g.* fly ash [14] and solidified wastewater treatment sludge [30]).

When using the MID-MIX® technology, it was experimentally confirmed that solidificates are very difficult to combine in mixtures with higher water contents, because they tend to float on the sample surface due to hydrophobicity [20]. It is also important to note that when adding solidificate to concrete or asphalt mixture, empirically determined ingredients of solidificate mixture should be used to achieve the required properties of the newly acquired material [20].

After analyzing the compressive strength results, it can be noted that solidificates in the concrete samples reduce the firmness of concrete and cannot be used in construction elements. However, utilization in some other construction elements such as pavements, roadside, path cubes, concrete haberdashery, *etc.*, could be recommended. In addition to solving the problem of disposal of one part of the total quantity of waste, the usage of industrial hazardous waste in this type of building element would undoubtedly reduce the amount of non-renewable natural raw materials used in the production, while making the production process more economically acceptable.

The experimental asphalt mixtures showed negligible differences in the tests. Namely, all mixtures stayed stable without fractures under the weight impact, without cracks during the flexural test at -20 °C, and all mixtures were water-tight (after 1 h of 5 bar water pressure), while finally, these properties did not change after one week in the water [22].

The obtained results were difficult to compare with any other research due to the lack of data regarding utilization of solidificates from industrial hazardous waste in asphalt mixtures, *i.e.*, waste mineral oils and hydrocarbon-based emulsions [15,31-32]. In this regard, standardized data are lacking on the types of concrete elements containing organic types of industrial hazardous waste, and further research is needed.

The results of the LP test, implying the impact of investigated concrete and asphalt mixtures on the environment, are shown in Table 4.

Table 4. Results of LP tests expressed as heavy metal contents in leachate of samples of stabilized solidified powder in distilled water at the liquid/solid ratio of 10 dm^3 kg^{-1}(standard deviations are given in the brackets)

Concrete and asphalt materials	c (SD) / µg dm^{-3}				
	Pb	Cd	As	Cr	Ni
Bet-1	53.21 (1.10)	60.04 (1.26)	2.51 (0.06)	15.64 (0.09)	50.65 (1.20)
Bet-2	56.37 (0.64)	101.20 (1.49)	3.19 (0.03)	17.57 (0.06)	53.81 (0.81)
Bet-3	59.53 (0.75)	142.36 (1.71)	3.87 (0.04)	19.50 (0.07)	56.97 (0.98)
Bet-4	62.69 (0.95)	183.52 (0.61)	4.55 (0.03)	21.43 (0.09)	60.13 (1.00)
Bet-5	65.85 (0.98)	224.68 (2.38)	5.23 (0.03)	23.36 (0.06)	63.29 (0.96)
Bet-6	76.05 (1.19)	370.00 (2.97)	5.35 (0.04)	24.93 (0.04)	78.16 (0.92)
Bet-7	79.21 (0.93)	381.16 (1.84)	5.63 (0.03)	26.86 (0.04)	83.32 (1.00)
Bet-8	82.37 (1.34)	392.32 (2.97)	5.91 (0.05)	28.79 (0.03)	88.48 (1.00)
Bet-9	85.53 (1.58)	403.48 (3.25)	6.19 (0.04)	30.72 (0.09)	93.64 (1.02)
Bet-10	119.30 (1.89)	414.64 (2.97)	6.47 (0.03)	32.65 (0.03)	98.80 (1.08)
Asf-1	43.68 (0.91)	50.06 (1.10)	1.35 (0.03)	11.22 (0.03)	46.32 (0.99)
Asf-2	40.03 (0.79)	43.55 (0.58)	1.17 (0.02)	9.76 (0.03)	40.30 (0.92)
Asf-3	36.38 (0.54)	37.89 (0.71)	1.02 (0.02)	8.49 (0.02)	35.06 (0.88)
Reference value [10]	5000	1000	5000	5000	20000

The results of LP tests were under the prescribed values [28]. The TCLP results showed that total hydrocarbons were not detected in the tested samples, and therefore these materials do not show any toxicity characteristics. According to the obtained results, all samples meet the conditions for further applications [28].

4. CONCLUSION

In this work possibilities for further use of inertized, *i.e.*, solidified industrial hazardous waste were investigated with the focus on production of new building products that would be competitive on the market due to their origin from recycled materials. The inertization of hazardous waste, *i.e.*, reducing its hazardous characteristics, involves solidifycation and stabilization of waste. The method of waste solidification is one of the most used techniques available for the final care of waste in an environmentally acceptable and safe manner, following the rules of the chemical and technological trade.

The experimental part had four phases. In the first part of the research, solidification/inertization of collected samples of industrial hazardous waste was carried out: waste mineral oils and a mixture of water-hydrocarbon emulsion, as well as waste filter scones from the physical and chemical treatment of wastewater caused by washing the patterned rollers for a printing machine. Waste fractions were solidified resulting in powder that was examined regarding granulometric composition. In the next phase, the solidified powder was mixed with the necessary ingredients to make concrete and asphalt mixtures. The concrete samples were tested on compressive strength and asphalt samples on waterproofing properties. The impact of waste-based samples on the environment and their potential toxicity were carried out by the standard leaching tests: leaching procedure (LP) and the toxicity characteristic leaching procedure (TCLP).

The compressive strength results were in the interval of 8.7 to 22.6 MPa, which was lower than expected, and explained by small granulation in the solidified powder (95.45 % of particle size <0.4 mm). The granulometric composition can be considered discontinuous, which is a disadvantage in obtaining high-quality concrete. Samples with lower contents of the solidified powder (*i.e.* Bet-1, Bet-2, and Bet-3) showed satisfactory compressive strength values of over 20 MPa, bearing in mind that the typical compressive strength of Portland cement concrete varies between 20 to 40 MPa. Thus, the obtained results indicate that addition of solidificates to the concrete reduces the concrete strength, so that it cannot be exploited in structural building elements, but it is recommended for pavements, roadside, path cubes, concrete haberdashery, and similar. All of the asphalt mixtures had similar properties regarding the conducted tests (the impact test, cold stability, water-tightness, and water soaking), implying that the inertized hazardous waste does not induce adverse effects on asphalt mixtures.

The results of the LP were under the prescribed values, and the TCLP results showed that total hydrocarbons were not detectable. Hence, these kinds of recycled mixtures do not represent environmental hazard and do not show toxicity characteristics.

The obtained results indicate significant potentials of the applied procedure and waste materials for further use, but additional investigations are necessary since there is a major lack of literature data and research regarding the utilization of inertized industrial hazardous waste in concrete and asphalt mixtures.

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Upotreba solidifikovanih frakcija industrijskog opasnog otpada u niskogradnji: Studija slučaja u Republici Srbiji

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Izvod

Ispitivane su mogućnosti korišćenja solidifikovanih frakcija industrijskog opasnog otpada dobijenog njegovim mešanjem sa inertnim materijalima u građevinarstvu. Kao predstavnici industrijskog opasnog otpada u procesu solidifikacije korišćena su otpadna mineralna ulja, mešavina vodeno-ugljovodonične emulzije i otpadne filter pogačeiz fizičko-hemijskog tretmana otpadnih voda nastalih pranjem dezen valjaka na mašini za štampanje. Istraživanje je podrazumevalo pripremu betona i asfaltne mešavine za dalja ispitivanja. Utvrđen je granulometrijski sastav solidifikovanog praha, uzorci betona su dalje podvrgnuti određivanju čvrstoće na pritisak, a asfaltne mešavine su ispitivane u kontekstu hidroizolacionih materijala. Prema dobijenim rezultatima ispitivanja luženja, svi uzorci su ispunjavali potrebne uslove za dalju primenu. Rezultati ispitivanja čvrstoće na pritisak bili su u opsegu od 8,7 – 22,6 MPa. Izmerene vrednosti čvrstoće na pritisak bile su niže od očekivanih, što se objašnjava upotrebom solidifikovanih frakcija manje granulacije. Na osnovu dobijenih rezultata može se zaključiti da se ispitivane mešavine ne mogu koristiti za konstruktivne građevinske elemente, te se preporučuje njihova upotreba za građevinske elemente kao što su trotoari, ivičnjaci, kocke za staze, betonska galanterija i dr. Asfaltne mešavine su pokazale prihvatljiva svojstva u pogledu mehaničkih, ispitivanja izdržljivosti i hidroizolacije.

Ključne reči: inertizacija; solidifikacija; reciklaža; beton; asfalt