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Environmental characterization of Foundry Waste Sand (WFS) in hot mix asphalt (HMA) mixtures

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HIGHLIGHTS

- The physical properties of waste foundry sand (WFS) it's like manufactured sand.
- Hot mix asphalt with WFS presented mechanical within the specifications criteria.
- HMA containing WFS it's environmentally inert.

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ABSTRACT

Waste foundry sand (WFS) originating in the automotive industry landed more than thirty years ago was collected in an industrial waste sanitary landfill. With this WFS, hot mix asphalt mixtures (HMA) containing this WFS were produced by replacing the fine aggregate (in this case manufactured sand) and cylindrical asphalt concrete specimens (CAC) by the Marshall method was produced. In the environmental characterization of leaching and solubilization of these HMA analysed by scanning electron microscope by dispersive X-ray spectroscopy (SEM/XSE), it was concluded that substances present in the WFS were encapsulated definitively by the HMA asphalt matrix.

1. Introduction

Non-hazardous waste is generated in industrial processes in large quantities. These materials, although not hazardous to generate a high toxicity to the environment, according to the CFR – Title 40 – Protection of environmental – Part 260–265 – Hazardous waste management (EPA RCRA Regulations, 2017) [1], must be allocated in regulated industrial waste sanitary landfills avoiding the accumulation of pathogenic substances present in this waste generating potential polluters to the surroundings of the disposal.

The Foundry Waste Sand (WFS) is the main by-product of shaped metal parts in the steel industry, waste industrial and not considered as dangerous (EPA RCRA Regulations, 2017) [1]. This industrial segment represents great economic importance in the world due to the growing demand of modern society for metallic tools and the parts used by the automobile industry.

According to the American Foundry Association (AFS, 2017) [2] the foundry process consists of the casting of metals into a ready-made mould of mineral sand which, after solidification of the metal part, the mould is broken, and the metal piece its obtained. According to the Recycled Materials Resource Centre (RMRC, 2017) [3] the sand from this mould can return to the manufacturing cycle of parts production, but after a several number of reuse this sand is

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heavily contaminated by metal particles and should be discarded in industrial waste sanitary landfills.

Considering that the production of castings in the world is around 80 million tons annually (AFS, 2017) [2] and that for witch 1 ton of cast steel produced, 600 kg of WFS are produced even with the reuse of this sand in the manufacturing of castings process (Bonet, 2003 [4]; Bina, 2002 [5]; Bonin 1995 [6]), this residue poses a major challenge to industrial waste sanitary landfills whose capacity is increasingly compromised by large amounts of WFS grounded.

In the late 90s The Casting Development Centre (TCDC, 1999) [7] with the AFS promoted a set of recommendations for the use of WFS in civil construction. This fact, has raised in researchers and research entities, new studies on the use of WFS in construction (Bina, 2002) [5]. Whether it is in low-cost concretes, landfill cover, cement additive, among others (Bina, 2002) [5], many works are aimed at inserting this residue at some stage of a civil construction project acting as an increment or aggregate without any structural damage to the project (Bina, 2002) [5]. In asphalt paving projects, such a practice could represent an opportunity to cheapen the costs these projects, as they consume enormous amounts of mineral aggregates, once are they are exhaustible natural resources, becoming more and more expensive due to increasing environmental restrictions of exploitation and mining.

The WFS, due it is an originally mineral material, has great physical similarity to the fine aggregate used in the hot mix asphalt mixtures (HMA). Usually these mixtures are used stone crushing aggregates (manufactured sand), acting with the function of interlock in mixtures of aggregates in the HMA and providing greater stability of it (AASHTO, 1994) [8].

In the literature the use of WFS from the iron and steel industry at replacement rates of 10% in mass compared to manufactured sand showed satisfactory results for light traffic routes (Recep et al., 2006) [9]. In this work a transport conditions of WFS contaminants were simulated by solubilization and leach showing that they are encapsulated in the asphalt matrix, making WFS use environmentally inert. In another study, 15–30% substitution quantities were analyzed obtaining satisfactory results of technical and environmental viability (Javed et al., 1994) [10], however as found in these studies or others in the literature (Abichou et. al., 2004 [11]; AFS-First, 2004 [12]), the WFS from landfill deposited under a soil layer is poor studied, or when it is, with rates lower than 10% and without the environmental monitoring of this in the HMA.

The WFS present in landfills is as big a problem as the periodic production by steel mills, since the areas where it is grounded are useless or unproductive areas, which occupy large physical spaces and could be in use for some economic order or social.

Therefore, there is a demand for studies that characterize the environmental behaviour of HMA containing WFS from landfill. Making mixtures according to the Marshall procedure at substitution rates over 10% in relation to the manufactured sand, proving if the encapsulation of substances present in these residues by the asphalt matrix occurs.

2. Material and method

For the development this environmental characterization a representative quantity of WFS from an industrial waste sanitary landfill was acquired by sampling. With this sample of WFS reduced for testing size, along with samples of coarse aggregates (chip 1/2″ and chip 3/8″) and fine aggregates (manufactured sand) also reduced, mixtures were performed for design asphalt binder containing asphaltic cement (AC) of stability 30/45, by the hot mix asphalt mixtures Marshall method, and moulded cylindrical specimens measuring 65.00 mm in height and 100.00 mm in diameter by mechanical compaction. The WFS (normal state sample) and HMA were submitted to Leaching and Solubilization tests with subsequent SEM/XSE analysis of the dried extracts (extracts: solutions in the aqueous phase obtained from the leaching and solubilization tests). The results of SEM/XSE analyses performed in the dry extracts of WFS and HMA were compared to determine if there were free chemicals elements in the HMA (coming from WFS) or were completely encapsulated by the asphalt matrix, constituting an environmentally inert material.

2.1. Material

2.1.1. WFS

The WFS obtained was excavated in an industrial waste sanitary landfill that complies with international solid waste storage standards (EPA RCRA Regulations, 2017) [1]. This landfill received until the late 1980s large amounts of WFS from a nearby automobile industry. After the cessation of industry activities, the WFS remained grounded until today (ie, for more than 30 years).

2.1.2. Mineral aggregates: coarse and fine aggregate

Was obtained quantities by sampling method in a mining company (located near the laboratory where the experiments were carried out) of coarse aggregate (chip 1/2″ and chip 3/8″) and fine aggregate (manufactured sand) and posteriorly reduced for testing size sufficient for the HMA used in the development of this environmental characterization.

2.1.3. Mineral filler

The Hydrated Lime was obtained of a commercial representative, supplier of the laboratory where the tests were carried out. In HMA mixtures, the mineral filler is used as an additive to increase the adhesiveness of the aggregates with the asphalt binder, in this case the Hydrated Lime ($Ca(OH)_2$).

Table 2.1
Methodologies used, according to the test methods established by the standards, in this development of this environmental characterization.

Sample materials	Experimental method	Descripting
WFS	ASTM D6009 [13]	Sampling waste piles
WFS and aggregates	ASTM C 702 [14]	Reducing samples of aggregate to testing size
WFS and aggregates	ASTM C 136 [15]	Sieve analysis of fine and coarse aggregates
WFS and fine aggregate	AASHTO T-84 [16]	Specific gravity and absorption of fine aggregate
Coarse aggregate	AASHTO T-85 [17]	Specific gravity and absorption of coarse aggregate
WFS, aggregates and AC 30/45	TLT 301 03 [18]	Mix design method for asphalt concrete pavement by marshall procedure
Cylindrical asphalt concrete specimens (CAC)	ASTM C 496M – 17 [19]	Splitting tensile strength of cylindrical concrete specimens
WSF and HMA	EPA 1311 [20]	Toxicity characteristic leaching procedure
WSF and HMA	EPA 3500c [21]	Procedure for getting of solubilized extraction of solid wastes
TCLP and dry solubilized extracts: WSF and asphalt mixtures	SEM/XSE	Images and elementary composition by SEM/XSE