CHARACTERISTICS OF IRON-SILICATE FINES AS REPLACEMENT MATERIAL IN CEMENT CONCRETE

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Introduction

This paper presents iron-silicate fines (ISF) as a by-product of the slag flotation process following smelting in the copper plant of Aurubis, Bulgaria. ISF contains mostly Fe_2O_3 in the form of fayalite (Fe_2SiO_4) and magnetite (Fe_3O_4). The use of industrial waste in building materials reduces the consumption of natural resources and results in creating environmentally friendly products.

From waste materials to mineral admixtures

Concrete is the most widely used construction material in the world[1]. It is a homogeneous composite, which contains heterogeneous materials: binder - mostly cement, aggregates (both sand and gravel), water and chemical additives. Since the aggregates make up 70% of the volume of concrete, 8-12 million tons of naturally extracted aggregates are used in its production globally every year[2]. Counteracting the decrease of natural resources, reducing the cost of construction materials and solving the problem of disposal of waste materials, generated by different industries, are the main reasons for utilising industrial waste in concrete and mortar as fine aggregates or substitutes for cement. As a major component in these materials, the type of sand reflects on the properties of the composite material, such as workability, durability, mechanical strength and weight. Substituting sand with a waste material should not reflect negatively on the properties of the composite, both in fresh and hardened state – just the opposite. That is why in the last decades, certain types of wastes are removed from that category and are successfully applied in construction as mineral admixtures.

Types of mineral admixtures in concrete production

Mineral admixtures are incorporated in cement concrete or mortar, either in the form of blended cements, such as Portland blast furnace slag cement, for example, or directly added as admixtures to the fresh mix at the time of mixing. They are also called 'Supplementary Cementing Materials' and can be divided into two groups: cementitious and pozzolanic materials. Cementitious materials have cementitious properties by themselves and pozzolanic materials exhibit cementitious properties

when combined with calcium hydroxide (lime). Many different kinds of mineral admixtures, obtained by different types of industrial production, have been used to partially or fully replace sand or cement in concrete and mortar production: steel slag, blast furnace slag, ground granulated blast furnace slag, coal bottom ash, fly ash, silica fume, copper slag, iron-silicate fines, waste foundry sand, imperial smelting furnace slag, *etc.* Most of these wastes are well-known and successfully applied in the concrete industry, except for iron-silicate fines, which are relatively unknown in the literature and in practice.

Iron-silicate fines as a fine aggregate in concrete

Iron-silicate fines (ISF) are a waste material, generated by flotation of copper slag (both by furnaces and convertors) during the metallurgic production process in the copper plant of Aurubis Bulgaria. They have physical properties similar to the ones of the fines used in concrete and mortar production. As a chemical composition ISF contain mostly ferrous and silicate oxides, together with smaller quantities of aluminium, calcium and magnesium oxides (Table 1). These oxides are formed during the process of burning of copper concentrates, delivered from copper mines. The process takes place in the smelter of the plant and consists of several stages.

Table 1: Chemical composition of iron-silicate fines

Element	Typical content	Range
Fe	46.0%	(44 ÷ 48)%
SiO_2	27.0%	(26 ÷ 28)%
Al_2O_3	3.2%	(2.7 ÷ 3.7)%
CaO	1.8%	(1.3 ÷ 2.5)%
MgO	0.7%	(0.6 ÷ 1.1)%
Cu	0.42%	(0.36 ÷0.48)%
S	0.36%	(0.25 ÷ 0.55)%

The chemical composition of ISF is determined by an X-ray radiograph (Figure 1). Visual representation of the material is obtained using SEM analysis (Figure 2). The material has dark angular particles with rough texture and irregular shape. These physical characteristics of ISF reflect positively on adhesion with other aggregates in concrete.

A scanning electron microscope equipped with energy dispersive X-ray analysis (SEM-EDX) is an important supplement to the optical microscope when examining new materials to be used in concrete and cement production. SEM-EDS analyses of ISF provide information about the particles' shape and size and the morphology of the phases constituting the fines.

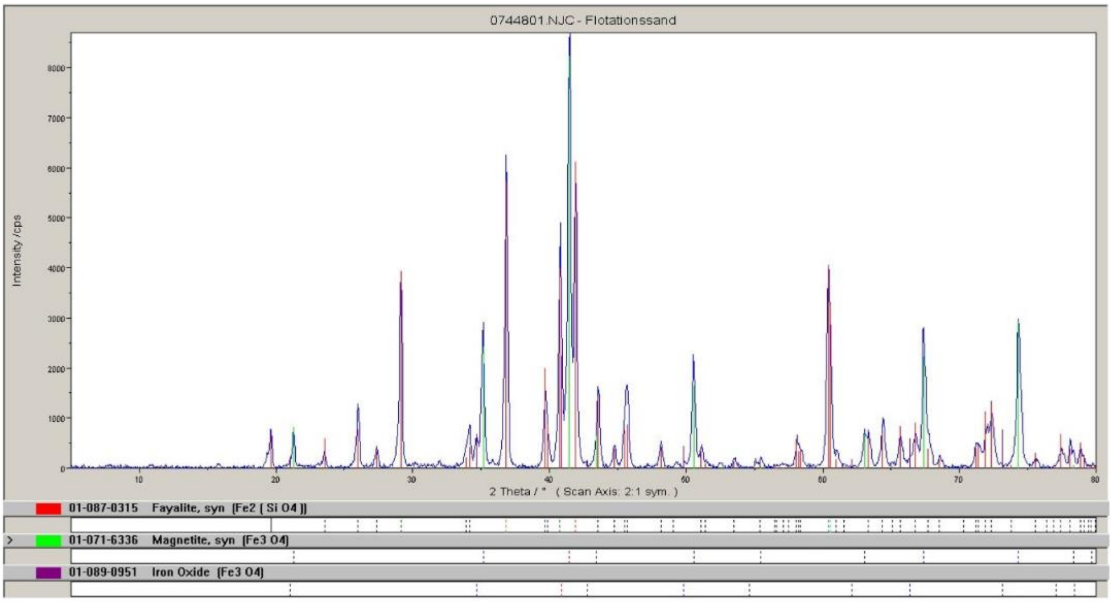

Figure 1: X-ray diffraction pattern of iron-silicate fines

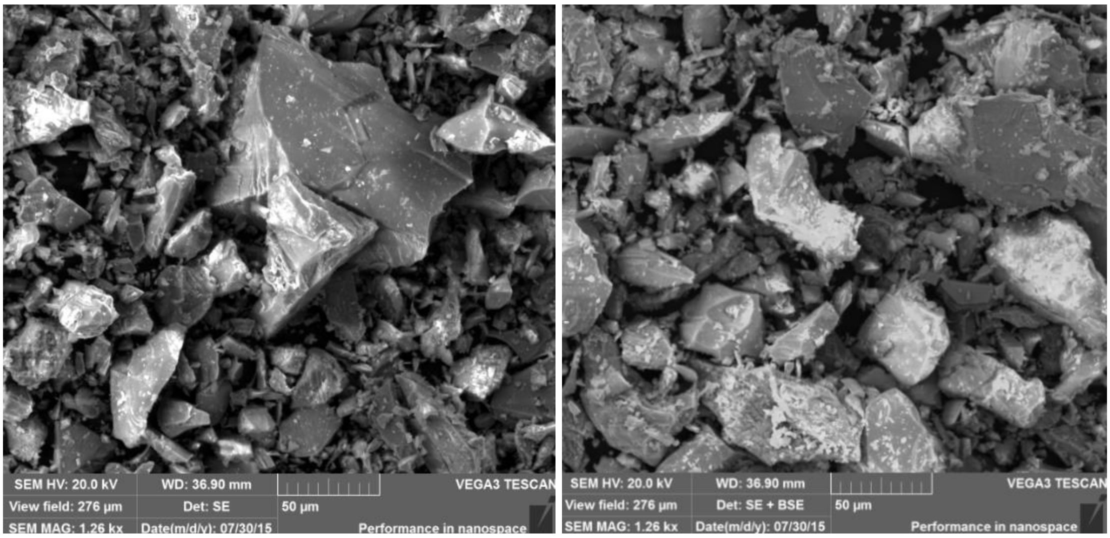

Figure 2: SEM of iron-silicate fines

The particle size distribution of ISF is about 75% particles between 0.0383 mm and 0.05 mm and 24% smaller particles with size between 0.0041 mm and 0.0383 mm (Figure 3). The specific density of the material, based on BNS EN 1097-6, is found to be 3.8 g/cm^3, which is close to the densities of 3.91 g/cm^3, reported by other copper slag producers[3,4]. The loose bulk density of ISF, according to BNS EN 1097-3, is determined to be 1.83 g/cm^3, which is relatively high for this type of material. This is due to the heavy weight of ferrous oxides in the composition and the smaller grain size compared to other kinds of copper slags generated by the industry, but also to all kinds of wastes in general.

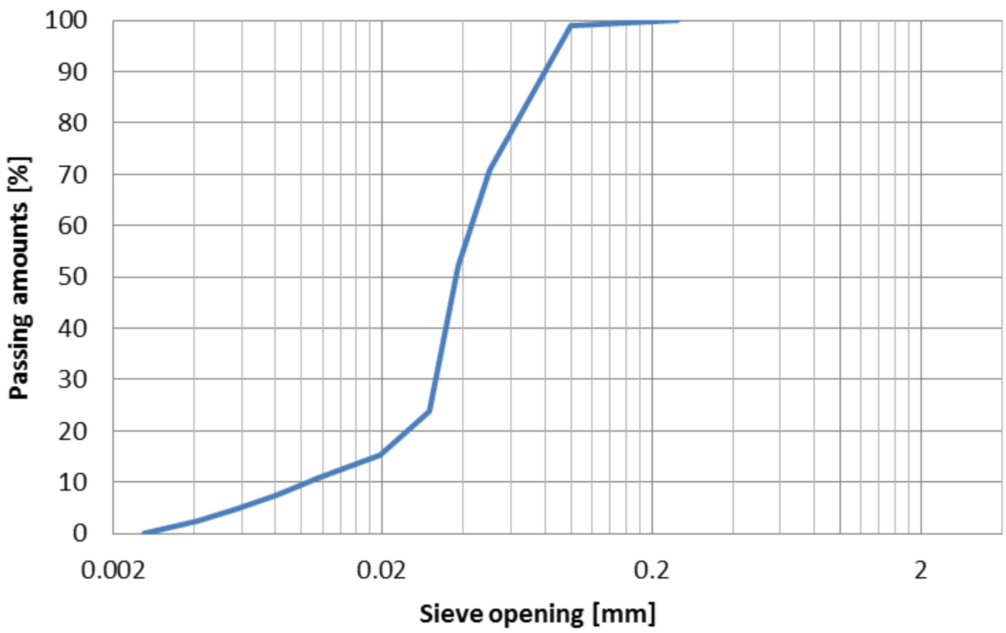

Figure 3: Particle size distribution of iron-silicate fines

Conclusions

The physical and chemical characteristics of ISF do not differ from those of other waste materials used in concrete production, which makes it a perspective material in that field of application. As a new material, it should first be tested in a laboratory and then on an industrial scale. Different tests related to sand and cement substitution will prove the presence or absence of pozzolanic activity of ISF. The use of ISF in concrete will open up new undiscovered areas of their application and will partially solve the problem of their deposition.

References

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