UTILISATION OF IRON-SILICATE FINES AS REPLACEMENT OF FINE AGGREGATES IN CEMENT CONCRETE PAVEMENTS

Emanuela MANOLOVA[1], Vanya STOYANOVA[2]

[1] Commercial Department, Aurubis Bulgaria, 2070 Industrial Zone, Pirdop, Bulgaria
[2] Research and Development Department, Aurubis Bulgaria, 2070 Industrial Zone, Pirdop, Bulgaria

e.manolova@aurubis.com, v.stoyanova@aurubis.com

Introduction

Iron-silicate fines (ISF), produced by a slag flotation process in the copper plant of Aurubis, Bulgaria, are presented in this article as a partial replacement of fine aggregates in concrete pavements at levels of 15, 20, 25 and 30 percent. The basic properties of the materials in fresh and hardened state are analysed. The findings show that as the ISF content increases in the concrete mix, the workability is improved. Higher percentages of ISF correspond with higher strengths. The results suggest that ISF can potentially be used as a supplementary cementitious material in concrete production, as it has a certain pozzolanic activity.

The utilisation of ISF as mineral admixtures in concrete reduces its cost and is currently considered the best ecological option for their disposal[1]. The main technological benefits of their application are improvements in almost every property of concrete and mortar. In fresh state they enhance workability, including cohesiveness and bleeding, reduce heat of hydration and water demand and affect various setting characteristics. In hardened state they reflect on the ultimate strength, reduce permeability, and improve durability against frost attack, sulphate attack resistance, alkali silica reaction, carbonation and resistance to thermal cracking[2]. Their use has been increasing during the last decades due to their economic benefits (costs and energy).

Influence of iron-silicate fines on fresh concrete mixture

ISF contain mostly Fe_2O_3 in the form of fayalite (Fe_2SiO_4) and magnetite (Fe_3O_4). Due to the small grain size (75% of the particles are between 0.0383 mm and 0.05 mm and the rest are even smaller) and moisture content (about 10%), dewatered by filter-press after flotation (Figure 1), the workability of the fresh mixture is improved. This leads to better filling up of the space between the coarser aggregates, compacting the voids and pores, less energy needed for vibration and contributes to the mechanical strength as a whole. The result is a smooth polished surface with low moisture soaking up characteristic.

Figure 1: Storage place of ISF after filter-press in the plant of Aurubis, Bulgaria

Table 1 presents 5 different concrete mix compositions for concrete pavement blocks. The first one is the reference mix, without ISF, and in the rest, there is a sand substitution of 15%, 20%, 25% and 30% ISF, respectively. Ordinary Portland cement grate 52.5 R is used together with 2 kinds of sand – natural and crushed, small fraction of crushed stone (4/12.5 mm), ISF, water and lignosulfonate chemical admixture.

Table 1: Concrete mix compositions with different percent of sand replaced by ISF

Material	Reference mix	Mix 1 (15% ISF) kg/m^3	Mix 2 (20% ISF) kg/m^3	Mix 3 (25% ISF) kg/m^3	Mix 4 (30% ISF) kg/m^3
Cement 52.5 R	355	355	355	355	355
Coarse aggregate 4/12.5 mm	810	810	810	810	810
Natural sand 0.4 mm	850	531	488	410	347
Crushed sand 0/4 mm	340	340	340	340	340
Iron-silicate fines	–	300	400	500	600
Water	145	145	145	145	145
Chemical admixture	2.1	2.1	2.1	2.1	2.1

Influence of iron-silicate fines on hardened concrete mixture

The following concrete mixes are used for producing pavements on an industrial scale by vibro-compression technology (Figure 2). After mixing all the materials, the machine casts the pavements in two layers – first the bottom one (70 mm) and then the top layer (10 mm). The duration of casting of the ready concrete mix is about 30 seconds per steel shuttering of 18 blocks. ISF are used only in the bottom layer. Then the blocks are cured in humidity chamber (at 20^{o}C and relative humidity of 50%) until the 28th day and then applied in situ. According to BNS EN 1338:2005[3] the size of the standard test sample is 197/161/80 mm.

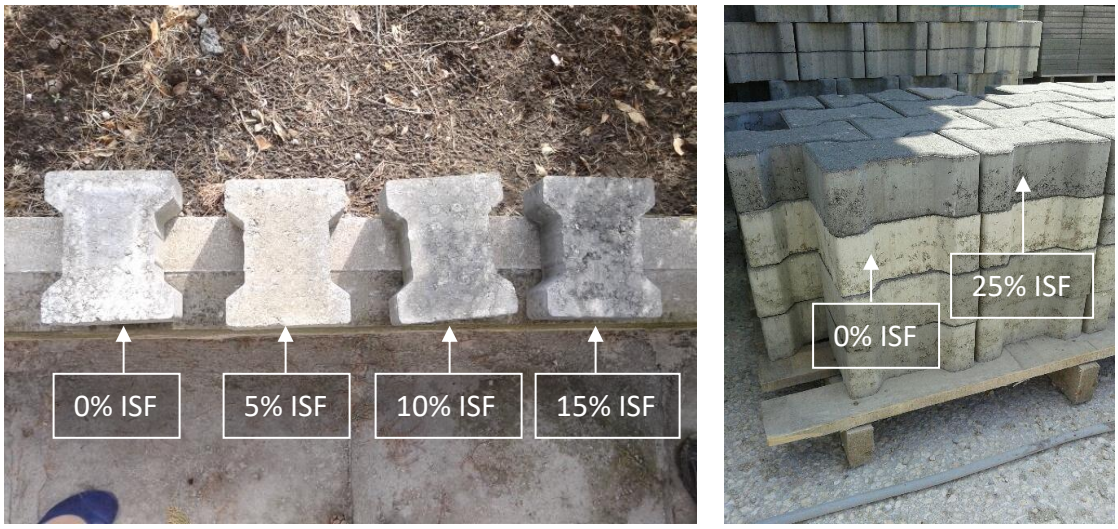

Figure 2: Cement concrete pavements with iron-silicate fines in different quantities

Flexural strength is the vital test, which proves the characteristics of ISF, regarding this kind of concrete elements. By increasing the ISF content, the flexural strength of concrete pavements increases (Table 2). The maximum strength is obtained by 25% sand substitution with ISF. As the limit value for this class of concrete is 3.6 MPa, ISF utilisation could lead to a reduction in the amount of material needed. This is due to the compacted concrete structure, even for this short production time and reduced water content. The other reason is the pozzolanic activity of ISF, proven by EN 450-1[3] and ASTM- 95[4]. At the 28th day the obtained strength activity index (SAI) of test samples with ISF is 81%, compared to reference samples with cement only, which is higher than the limit in the standard (75%). It is concluded that ISF is a pozzolanic material with certain cementitious properties in the presence of calcium hydroxide from cement hydration.

Table 2: Flexural strength of concrete pavements with different content of ISF, according to BNS EN 1338:2005

Nr	Percent sand substitution	Dimension	Test result	Value or limit
1	15%	MPa	3.7	≥3.6
2	20%	MPa	3.7	≥3.6
3	25%	MPa	4.9	≥3.6
4	30%	MPa	4.5	≥3.6

The water absorption property of a material is indicative of its total pore volume accessible to water and can be used to determine its potential durability, such as the freeze and thaw resistance[4]. Application of ISF reduces the water absorption of concrete pavements, because of the compacted structure (Table 3). The higher is the quantity of ISF, the lower is the absorption. Even at 15% sand substitution, the frost resistance of pavements is increased significantly (Table 4).

Table 3: Water absorption of concrete pavements with different content of ISF, according to BNS EN 1338:2005

Nr	Percent sand substitution	Dimension	Test result	Value or limit
1	15%	%	5.9	≤6.0
2	20%	%	5.8	≤6.0
3	25%	%	5.7	≤6.0
4	30%	%	5.7	≤6.0

Table 4: Frost resistance of concrete pavements with 15% sand substitution with ISF, according to BNS EN 1338:2005

Nr	Characteristic	Dimension	Test result	Value or limit
1	Frost resistance	kg/m^2	0.6	<1.0

Conclusions

Iron-silicate fines, as a waste material from the metallurgic production of copper of Aurubis Bulgaria, can be utilised successfully as a part of concrete innovations for a sustainable, higher strength, durability and eco-friendly concrete pavements on an industrial scale. ISF can substitute 25% of the sand used and enhance the mechanical and hydro-physical properties and improve the workability of the fresh concrete mix. Further industrial tests will be focused on concrete production with ISF as a substitute for concrete, due to the discovered pozzolanic activity and increased mechanical strength, compared to samples, in which only sand is substituted.

References

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