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HIGH-STRENGTH CONCRETE USING EAF AND AOD SLAGS AS AGGREGATES

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Abstract

Currently stainless steel slag (EAF and AOD) are only used as aggregates in road construction. A part of this steel slag is not valued and has to be treated as waste. The search of other ways of valorisation would contribute to a reduction in the amount of landfilled waste. In this study the use of stainless steel slag (sss) as aggregate in high-strength concretes is evaluated. Compared to concrete made of natural aggregates (silico-calcareous), concretes made of stainless steel slag aggregates have better mechanical properties. The durability and expansion characteristics of these concretes are acceptable for construction use.

Introduction

The aim of this study is to investigate the opportunity to substitute in concrete natural aggregates with stainless steel slag aggregates (EAF slag and stabilised AOD slag). Six different concretes containing EAF slag coarse aggregate, AOD slag coarse aggregate or mixed EAF-AOD slag coarse aggregate are designed. Mechanical and stability properties of these concretes are measured and compared to high-strength concrete made of silico-calcareous (sc) coarse aggregate.

Materials

Stainless steel slag aggregates

EAF slag and stabilised AOD slag appear like solid blocks and then are reduced to conventional aggregate size by appropriate crushing (according EN 12620). Compared to silico-calcareous (sc) aggregates, stainless steel slag (sss) aggregates have higher crushing strength. The results of the Los Angeles test show lower coefficients and the apparent specific gravity of these (sss) aggregates is higher (Table 1). Water absorption was also determined and its higher value must be taken into account in the design of the concrete mixture.

Table 1: Physical properties of the aggregates

	Natural aggregates	EAF slag aggregates	Stabilised AOD slag aggregates
Apparent specific gravity	2.46	2.79	2.83
Water absorption (%)	0.98	2.57	2.96
Los Angeles coefficient (%)	30	23	16

Mix composition

Seven types of high-concretes are designed. They differ in composition in coarse aggregates. One concrete contains only (sc) aggregates (reference concrete), three concrete formulations are composed, in volume percent, of 50 vol% (sc) aggregates and 50 vol% (sss) aggregates (EAF, AOD or EAF + AOD); the last three concrete are made of 100 vol% (sss) aggregates (EAF, AOD or EAF +AOD). The mix compositions of these concretes are presented in Table 2.

Table 2: Mix composition of concretes made of stainless steel slag (sss) aggregates

		EAF slag		AOD slag		EAF and AOD	
Vol.% slag		50%	100%	50%	100%	50%	100%
Cement content (kg/m^3)		500	500	500	500	500	500
Coarse aggregate (kg/m^3)	SC	526	0	526	0	526	0
	EAF slag	592	1183	0	0	237	474
	AOD slag	0	0	600	1200	360	720
Fine aggregate (kg/m^3) SC		649	649	649	649	649	649
Water (kg/m^3)		150	150	150	150	150	150
slump test (mm)		190	190	190	190	190	190

Experimental method

Several properties were measured on concrete samples: apparent density, compressive strength, tensile strength and dynamic modulus of elasticity. Porosity and gas permeability were also tested, in order to assess the durability of the studied concrete. At last, expansion of concrete was measured. Mechanical tests were carried out on 16 x 32 cm specimens, according to EN 12390. Dynamic elastic modulus was measured by ultrasound wave propagation method. These tests were made at 28, 90 and 365 days. Gas permeability and porosity were measured according to the AFPC-AFREM method when expansion test is based on NF P 18-454 standard. Expansion test consists in measuring longitudinal deformations of concrete prismatic samples stored in water.

Results and discussions

Mechanical properties of concrete with stainless steel slag aggregates

Concretes with EAF and AOD slag aggregates are denser than those with natural aggregates: apparent density of (sc) aggregates concrete is 2.42 whereas the apparent densities of (sss) concrete vary from 2.60 to 2.64, increasing with the proportion of the slag aggregates in the concrete.

The 28-days compressive strength of natural aggregate concrete is 67 MPa. When EAF slag or stabilised AOD slag are used as coarse aggregates, the mean value of the compressive strength is 73 MPa, showing an increase of 9.0% (Figure 1). Standard deviation of these data is ± 3 MPa. In addition to their higher strength, (sss) aggregates have a crushed shape, a rough surface and a higher porosity, which provide a better adhesion between them and the cement paste. Tensile strength and dynamic modulus of elasticity also increase when natural aggregates are replaced with slag aggregates. The increase in dynamic modulus is of 10% when EAF slag coarse aggregate is used and of 20% when concrete are only made of stabilised AOD slag coarse aggregate.

Durability characteristics of concrete with stainless steel slag aggregates

Porosity and gas permeability increase with the proportion of the (sss) aggregates in the concrete. However, their values remain under the maximum values recommended for a building construction, with a 30 to 50 years service-life, till 50 to 100 years for some class of environment[3]. Gas permeability reaches 2.3 x 10^{-16} m^2 for the total substitution of silico-calcareous coarse aggregate by EAF slag one.

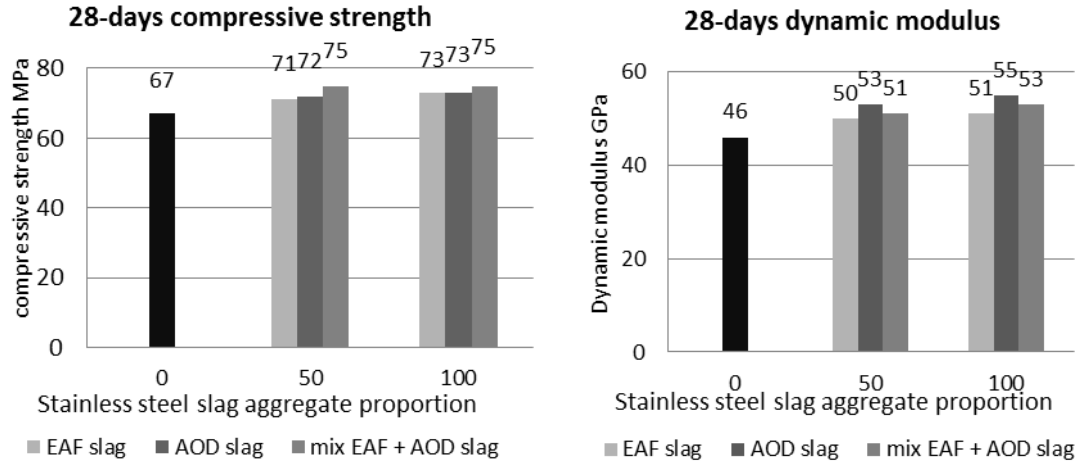

Figure 1: Compressive strength and dynamic of concretes

Table 3: Durability indicators of concretes

Aggregates	Porosity (%)	Gas permeability ($x10^{-16}$ m^2)
Silico-calcareous	9.93	0.9
EAF slag	12.40	2.3
Stabilised AOD slag	12.12	2.0
EAF slag + Stabilised AOD slag	12.36	2.2

Concretes with EAF slag aggregates have the same expansion behaviour as concrete made of silico-calcareous aggregates. AOD concretes have a slightly higher expansion. AOD slag contains free MgO whose hydration provides a volume increase. It may explain the higher expansion of concrete made of AOD slag aggregate. It can also be noted that AOD slag aggregates allow compensating the 28-days concrete's shrinkage. Concrete made of only AOD slag and mixed EAF-AOD slag present similar expansion behaviour. However, according FD 18-456 standard, expansions of all concretes are below required limits. EAF and AOD slags may be used as aggregates to make a concrete for a 30 to 50 years service-life of a building construction, till 50 to 100 years for some class of environment.

Table 4: Expansion of concrete with stainless steel slag aggregates

Aggregates	at 28 days (%)	at 90 days (%)
Natural aggregates	- 0,016	- 0,003
EAF slag	- 0,010	0,002
Stabilised AOD slag	0,001	0,015
EAF slag + Stabilised AOD slag	- 0,002	0,012

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