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Steel waste valorisation - Steel Slag Waste Effect on Concrete Shrinkage

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Environmental impact of the Building Industry

Consumption of more than 40% of the energy

The European Union yearly produces 180 million tons of C&DW

Depletion of more than 50% of natural resources

On average each citizen produces 480 kg of C&DW per year

Production of 50% of the global waste

Environmental impact cement and concrete industry

Considering the continuous increase of cement production, it is estimated that, nowadays, cement and concrete industry are responsible for about 7% to 8% of global CO_2 emissions

The main problems in the iron and steel industry concerns the by-products waste, which must be properly processed or reused to promote environmental sustainability. One of these by products is steel slag

The cement substitution with slag strategy achieves two goals:
raw materials consumption reduction and waste management.

Early and longterm shrinkage control

Advances in concrete technology over the past several years have led to use of concretes with a very low W/C. In these mixtures, autogenous shrinkage becomes a dominant factor for cracking control

A better control of early and longterm shrinkage will promote good performance of the concrete structure during its service-life increasing durability.

Reducing shrinkage cracking is very important for: Behavior in service; Resistance; **Durability and Sustainability**.

Research group

"Use of Industrial, Construction and/or Demolition Waste for the Construction of Structural and Non-Structural Concrete" (TEP-951), from the University of Cadiz

This paper presents the results of the shrinkage (autogenous and total) of two concrete mixtures, produced with two different slags (GGBFS and LFS). They are part of a wider program, intended to elaborate a standard guide, with focus on the use of steel slag as a cement replacer in concrete mixtures, for infrastructure buildings, based on its chemical composition and mechanical behavior.

- Cement: Portland Cement CEM I 52.5 R
- Aggregates: Crushed limestone. Size ratio: fine aggregate (sand) 0/2, medium aggregate (sand) 0/4, and gravel 4/16
- Water: domestic tap water
- Additive: Superplasticizer. Concrete additive: UNE EN 934-2.
- Ground granulated blast furnace slag (GGBFS) with mechanical processing: the material is crushed in the factory itself until reaching a maximum size of 0.063mm, thus, it doesn’t require sieving
- Unprocessed ladle furnace slag (LFS). These slags have been screened in the laboratory below 0.063mm sieve. The fraction obtained through sieving was 23%

Slag Origin/Chemical Composition	SiO_2 %	AL_2O_3 %	Fe_2O_3 %	CaO %	MgO %	Σ others %
Cement	20–22	4–8	4-6	55–60	2-3	2-15
GGBFS	32-36	11-12	0.3-1.5	40-42	7-8	1-9.7
LFS	20-23	8-10	0.5-2	55-60	7-10	4.5-9

Materials	Ref [kg/m^3]	25GGBFS [kg/m^3]	25LFS [kg/m^3]
Cement I 52,5 R	300	225	225
GGBFS	---	75	---
LFS	---	---	75
Sand 0-2	305.1	305.1	305.1
Sand 0-4	711.8	711.8	711.8
Gravel 4 -16	1016.9	1016.9	1016.9
Water	150	150	150
Admixture	3.9	3.9	3.9
Water / Powder ratio	0.5	0.5	0.5

The preparation of specimens was performed according to NP EN 196-1, in a room with a temperature of 20±2ºC and relative humidity of 55±5%, but using a different mixture proportion and coarse aggregates.
The test specimens were compacted mechanically.
The removal of moulds took place about 4h after mixing. This time delay was defined as the minimum necessary time to ensure concrete strength between 2MPa and 5MPa, in order to avoid specimens damage due to moulds removal.

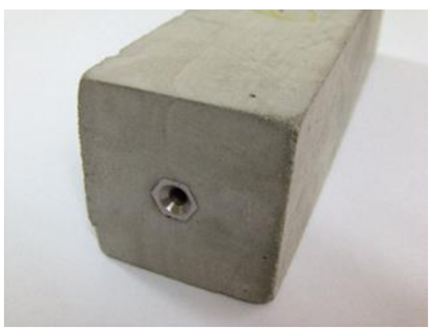
Mixtures	2 hours	3 hours	4 hours	5 hours	6 hours
Ref	0.8 MPa	2.2 MPa	3.1 MPa	6 MPa	7.6 MPa
25GGBFS	0.9 MPa	1.8 MPa	3.5 MPa	5.9 MPa	6.3 MPa
25LFS	0.9 MPa	1.9 MPa	3.2 MPa	5.8 MPa	6.4 MPa

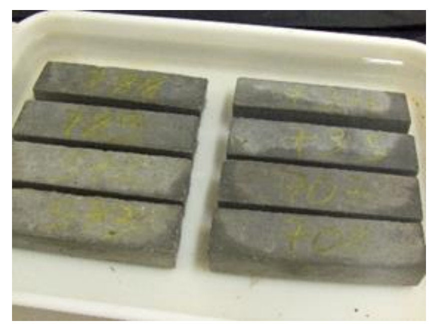
The compression strength of the Ref mixture reached 49MPa after 28 days

Subsequently, the specimens were weighed, their length was registered and, in the case of the samples used for measurement of autogenous shrinkage, they were sealed with a plastic film. Shrinkage deformations of each specimen were measured using a length comparator (sensitivity of 1 μm) and gage studs at the end sections of the concrete prisms.

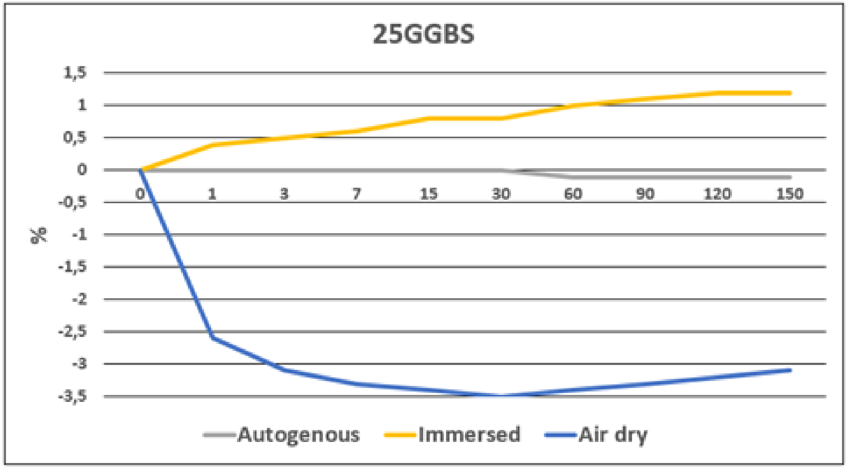
Others samples were immersed in water to control the expansion in saturated conditions.

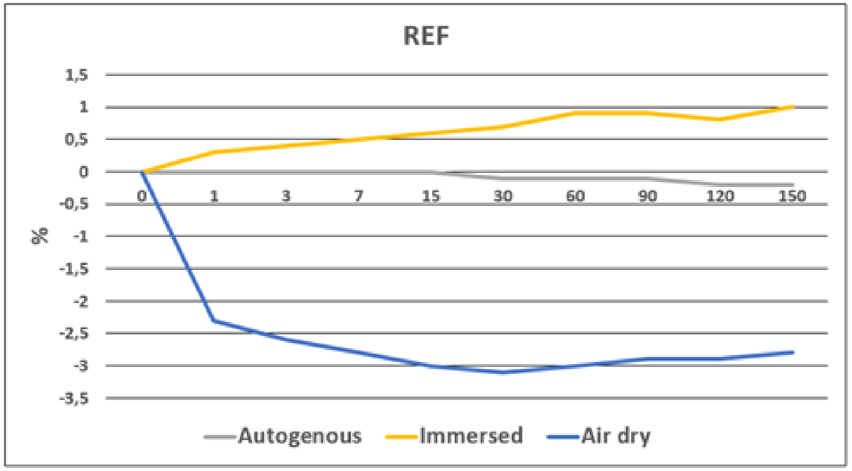
At the ages of 1, 3, 7, 14 and 28 days, and 2, 3, 4, 5 months, the samples were weighed and the length variation was measured.

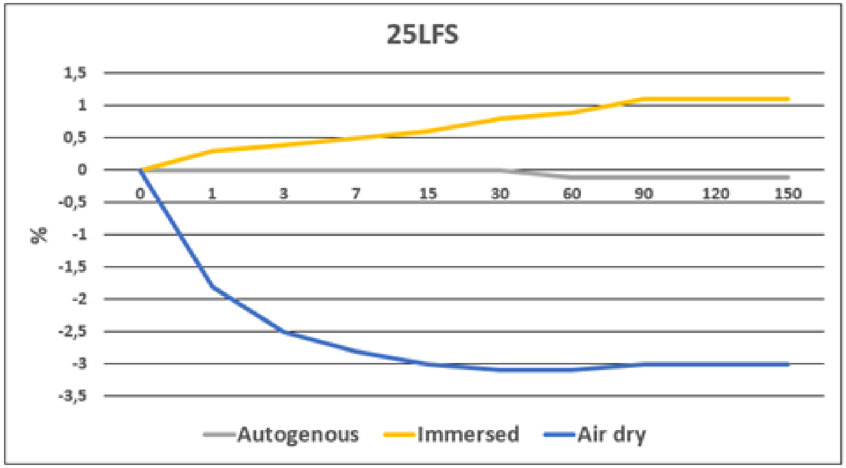




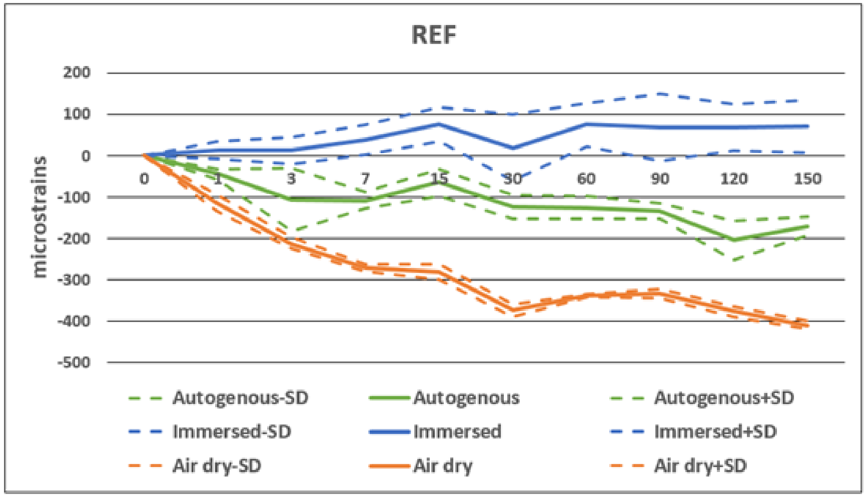
Mass change

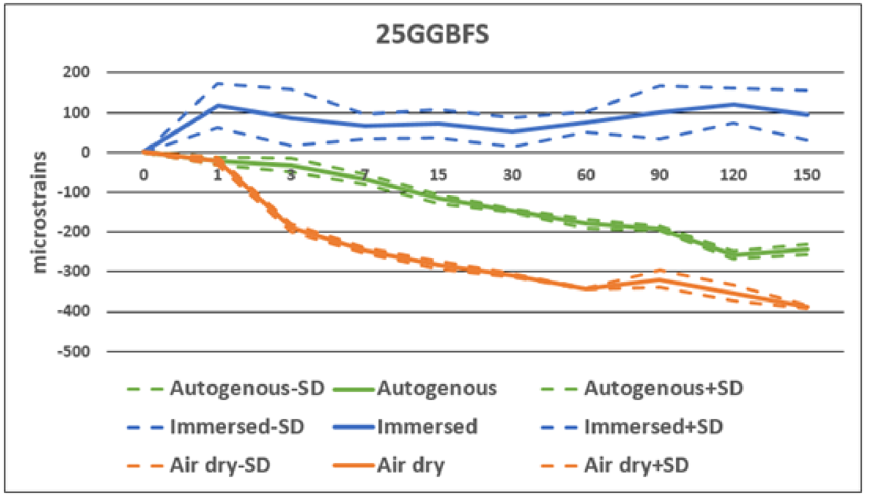

25GGBS
1,5
1
0,5
0
-0,5
-1
-1,5
-2
-2,5
-3
-3,5
%
0
1
3
7
15
30
60
90
120
150
Autogenous
Immersed
Air dry

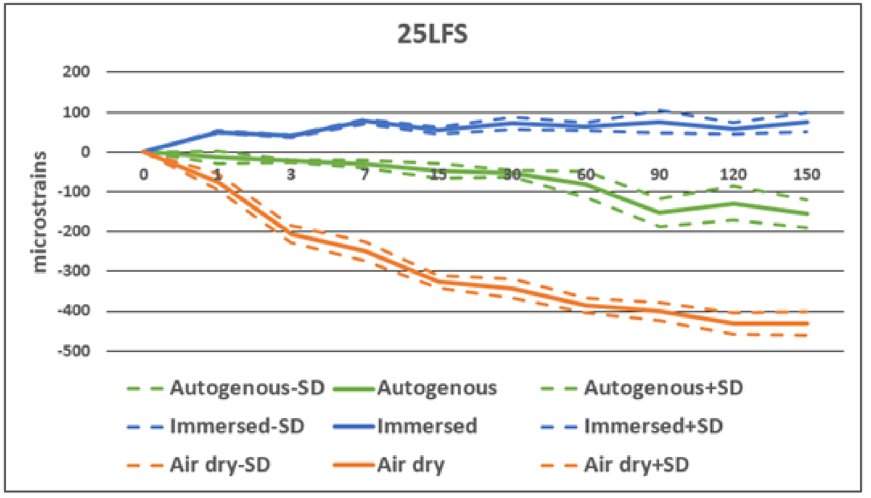

REF
1,5
1
0,5
0
-0,5
-1
-1,5
-2
-2,5
-3
-3,5
%
0
1
3
7
15
30
60
90
120
150
Autogenous
Immersed
Air dry


25LFS
1,5
1
0,5
0
-0,5
-1
-1,5
-2
-2,5
-3
-3,5
%
0
1
3
7
15
30
60
90
120
150
Autogenous
Immersed
Air dry

Shrinkage


REF
200
100
0
-100
-200
-300
-400
-500
microstrains
0
1
3
7
15
30
60
90
120
150
Autogenous-SD
Autogenous
Autogenous+SD
Immersed-SD
Immersed
Immersed+SD
Air dry-SD
Air dry
Air dry+SD


25GGBFS
200
100
0
-100
-200
-300
-400
-500
microstrains
0
1
3
7
15
30
60
90
120
150
Autogenous-SD
Autogenous
Autogenous+SD
Immersed-SD
Immersed
Immersed+SD
Air dry-SD
Air dry
Air dry+SD


25LFS
200
100
0
-100
-200
-300
-400
-500
microstrains
0
1
3
7
15
30
60
90
120
150
Autogenous-SD
Autogenous
Autogenous+SD
Immersed-SD
Immersed
Immersed+SD
Air dry-SD
Air dry
Air dry+SD

The paper presents the results of a laboratory experimental concrete shrinkage study, performed on a medium strength concrete class, when cement is partially (25%) replaced by ground granulated blast furnace slags (GGBFS) and ladle furnaces slags (LFS).

The results show that for cement substitution by slags, at least up to 25%, similar results are obtained related to total and autogenous shrinkage when compared to the reference mixture.

Also the risk of deleterious expansion in saturated conditions does not exist. This is an important aspect, as it allows these mixtures to be used in marine infrastructures.

The results hereby presented are part of a wider program, intended to elaborate a standard guide, with focus on the use of steel slag as a cement substitution in concrete mixtures, for infrastructure buildings, based on its chemical composition and mechanical behavior.

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- and "Laboratorio de Materiales de Construcción", from the "Escuela Politécnica Superior de Algeciras" of Cádiz University.

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Thank you for your attention!