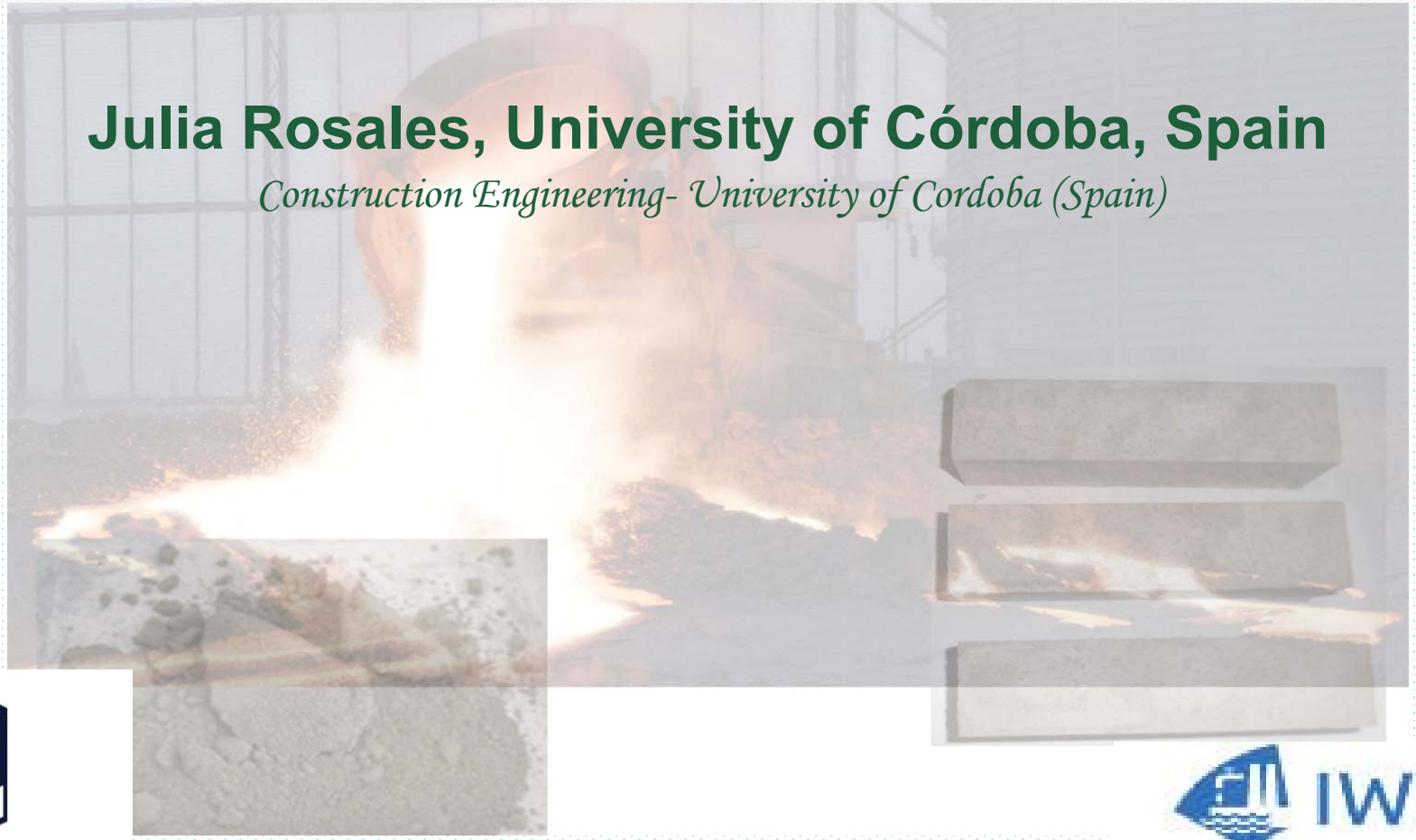
APPLICATION OF STAINLESS STEEL SLAG WASTE AS A PARTIAL REPLACEMENT TO MANUFACTURE CEMENT MORTARS



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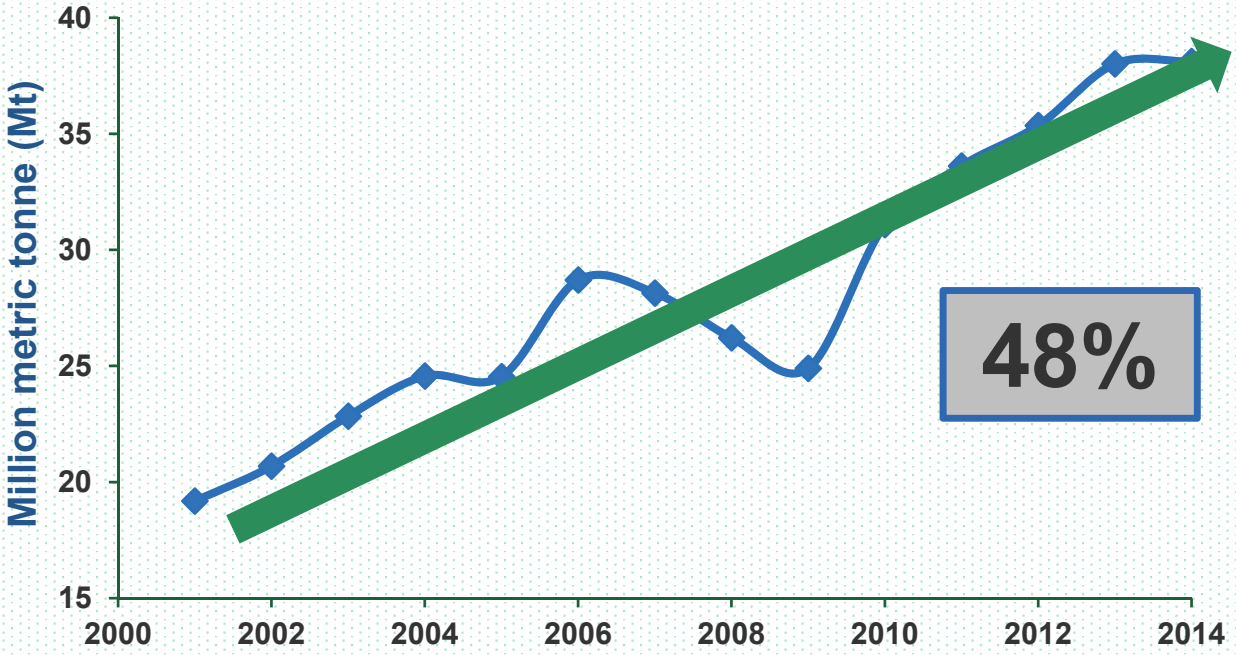
IWWATV

STAINLESS STEEL PRODUCTION

INTRODUCTION

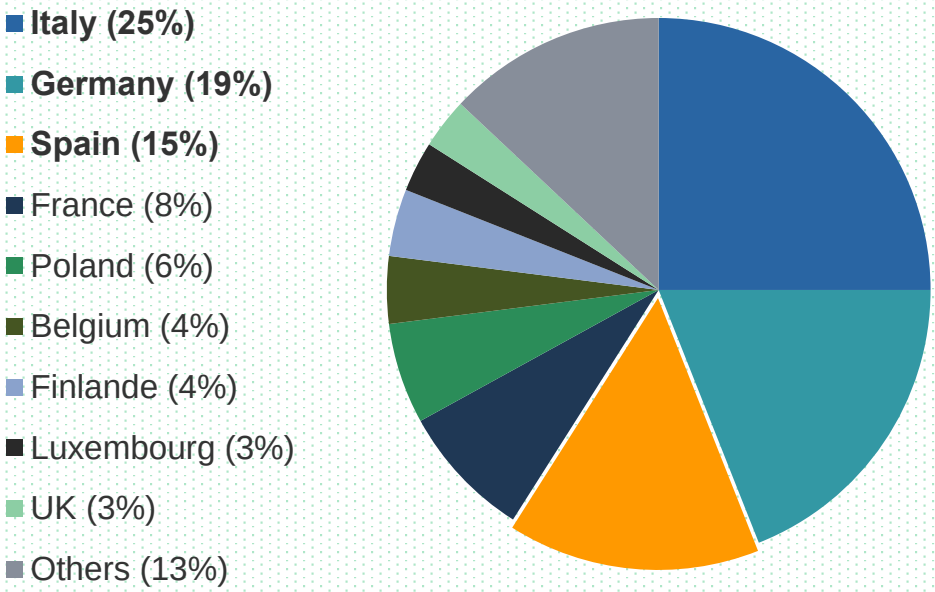


2014

1st ASIA (71%)

2nd EUROPE (21%)

3rd AMERICA (8%)

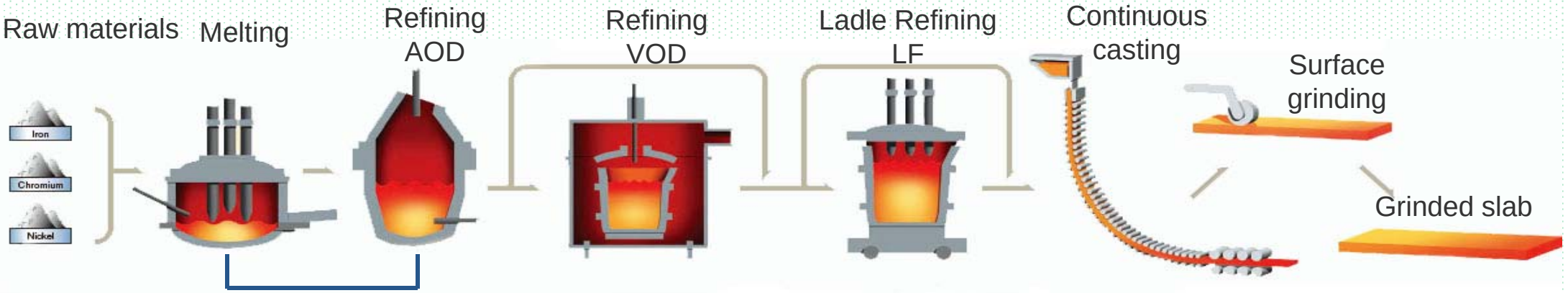


Spain 3rd European producer

International Stainless Steel Forum, 2014
World Steel Asociation, 2013

STAINLESS STEEL MANUFACTURING PROCESS

INTRODUCTION



20% Raw Materials

WASTE — **85% Waste** → **LANDFILL**

AGGREGATES **SLAG**

VALORISATION

AGGREGATES

AGRICULTURE
- Soil improvement

CONSTRUCTION
- Road base
- Concrete
- Addition to Clinker

SLAG

AGRICULTURE
- Soil improvement

TREATING WASTEWATER

CONSTRUCTION
- Soil-cement
- Concrete
- CEMENT MORTAR

WASTE UTILIZATION

LESS USE OF NATURAL RESOURCES

SUSTAINABILITY

OBJETIVES

Few research related to stainless steel slag waste for use as a substitute for cement

Principal objetive: study of cement replacement by different percentages of stainless steel slags crushed and without crushed for making mortars to determine the optimal replacement rate to increase the economic value of stainless steel slag waste and decrease the cement content

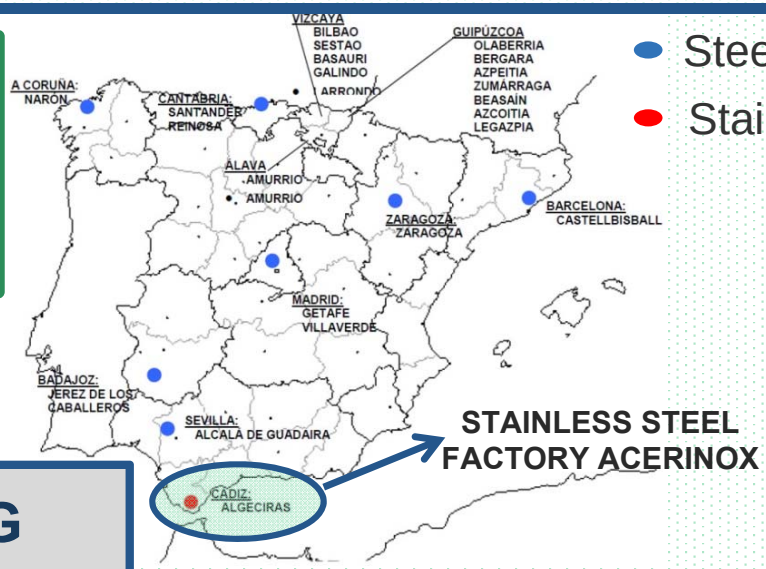
TREATMENT AND PROCESSING OF SW

- Study the cementitious properties
- Analysis of environmental effects through leaching test
- Study the effect on the compressive strength, flexural and shrinkage
- Application of multivariate analysis methods

STAINLESS STEEL SLAG WASTE AS CEMENT REPLACEMENT IN MORTAR

RESEARCH DESIGN

SW



- Steel
- Stainless Steel

PROCESSING

- **SW** — Unprocessed
- **SW-C** — Crushed - Sieved

10%CEM
20%CEM
30%CEM

REPLACEMENT

MANUFACTURE OF MORTAR

COMPRESSIVE STRENGTH
FLEXURAL STRENGTH
SHRINKAGE
MULTIVARIATE ANALYSIS

OXIDE COMPOSITION
LEACHING

STAINLESS STEEL SLAG WASTE AS CEMENT REPLACEMENT IN MORTAR

MATERIALS AND EXPERIMENTAL METHODS

CHEMICAL ANALYSIS

- **X-ray fluorescence (XRF)** *(UNE-EN 196-2)*
- **Leaching test** *(UNE- EN 12457-3)*

MECHANICAL ANALYSIS

- **Compressive Strength** ***1-7-28-90 DAYS*** *(UNE-EN 196-1)*
- **Fexural Strength** ***1-7-28-90 DAYS*** *(UNE-EN 196-1)*
- **Shrinkage** ***1-7-14-28-56-90 DAYS*** *(UNE-83831)*

SW

SW-C

CEM

Standardized Sand + Water

SW
REPLACEMENT
10% 20% 30%

SW-C
REPLACEMENT
10% 20% 30%

CONTROL

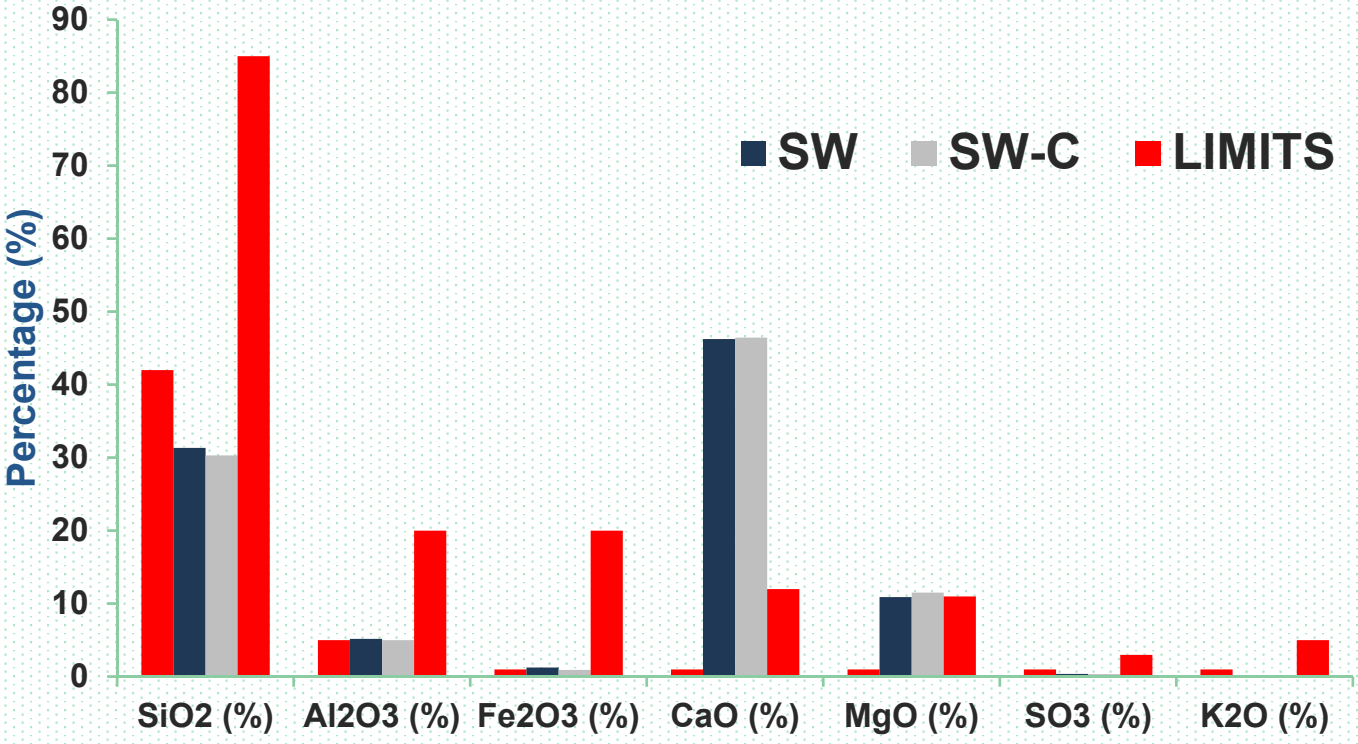
X-RAY FLUORESCENCE (XRF)

CEMENTITIOUS PROPERTIES SW AND SW-C

CHEMICAL PROPERTIES

RESULTS

	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	SO_3 (%)	K_2O (%)
SW	31,34	5,18	1,25	46,26	10,90	0,37	0,00
SW-C	30,31	5,01	0,93	46,45	11,51	0,36	0,00



Chemical composition limits pozzolanic materials (Calleja, J. 1985)

CHEMICAL COMPOSITION SIMILAR

- **CLINKER**
- **CONVENTIONAL FLY ASH**

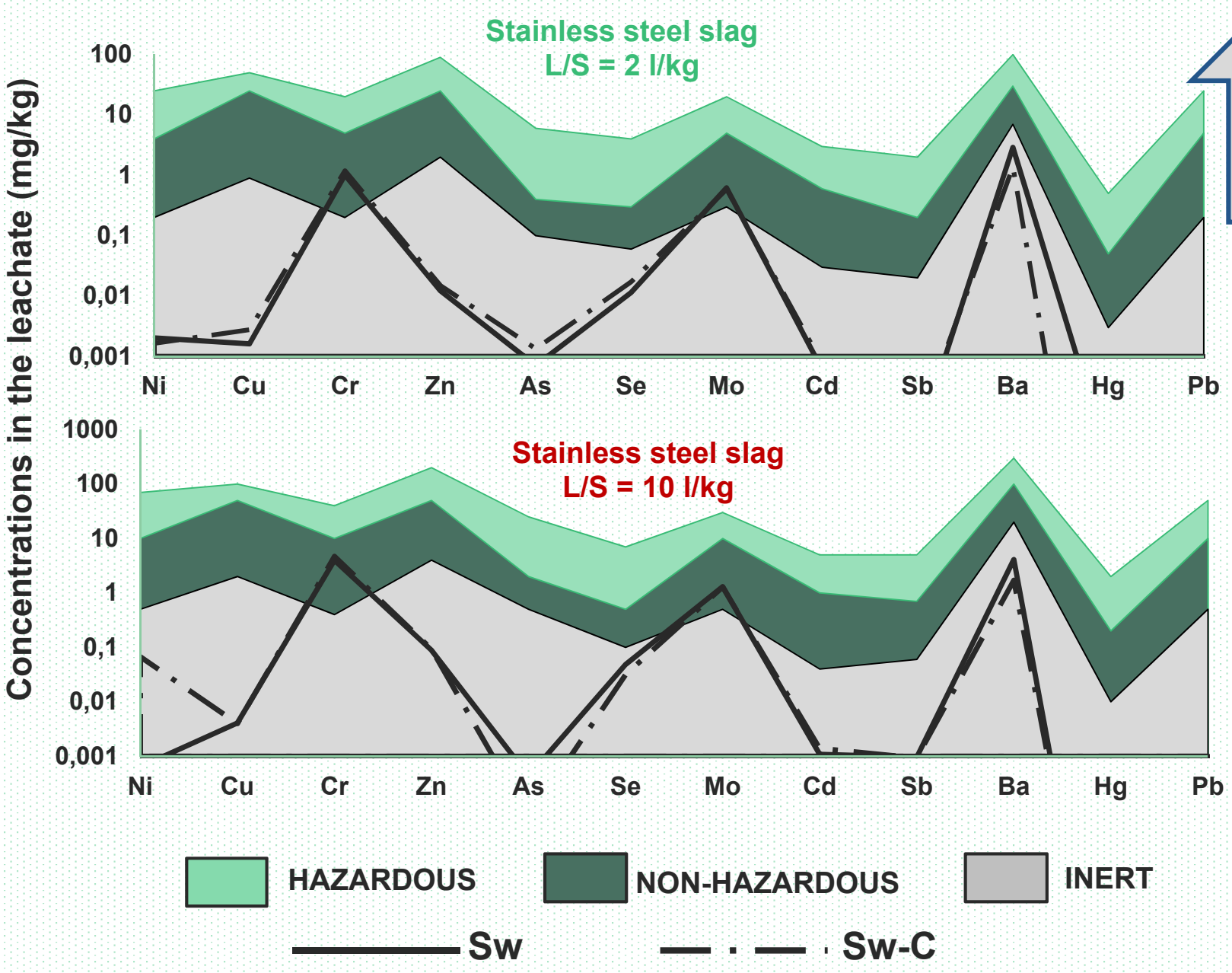
POZZOLANIC REACTION CHARACTERISTICS

LEACHING TEST

HEAVY METALS LEACHATE BY SW AND SW-C

CHEMICAL PROPERTIES

RESULTS



CHROMIUM

MOLYBDENUM

Classification	
L/S=2	
SW	Non hazardous
SW-C	Non hazardous
L/S=10	
SW	Non hazardous
SW-C	Non hazardous

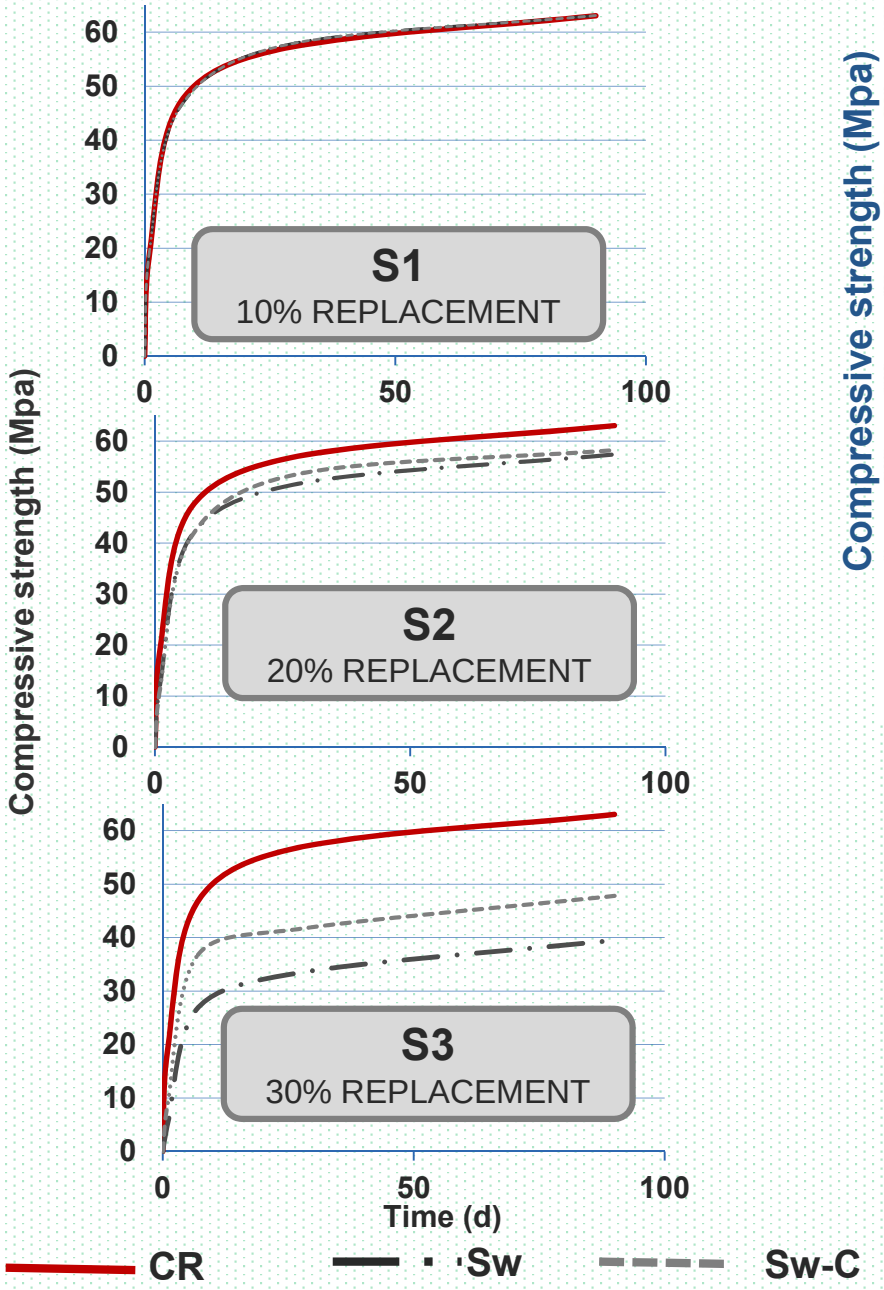
NON HAZARDOUS

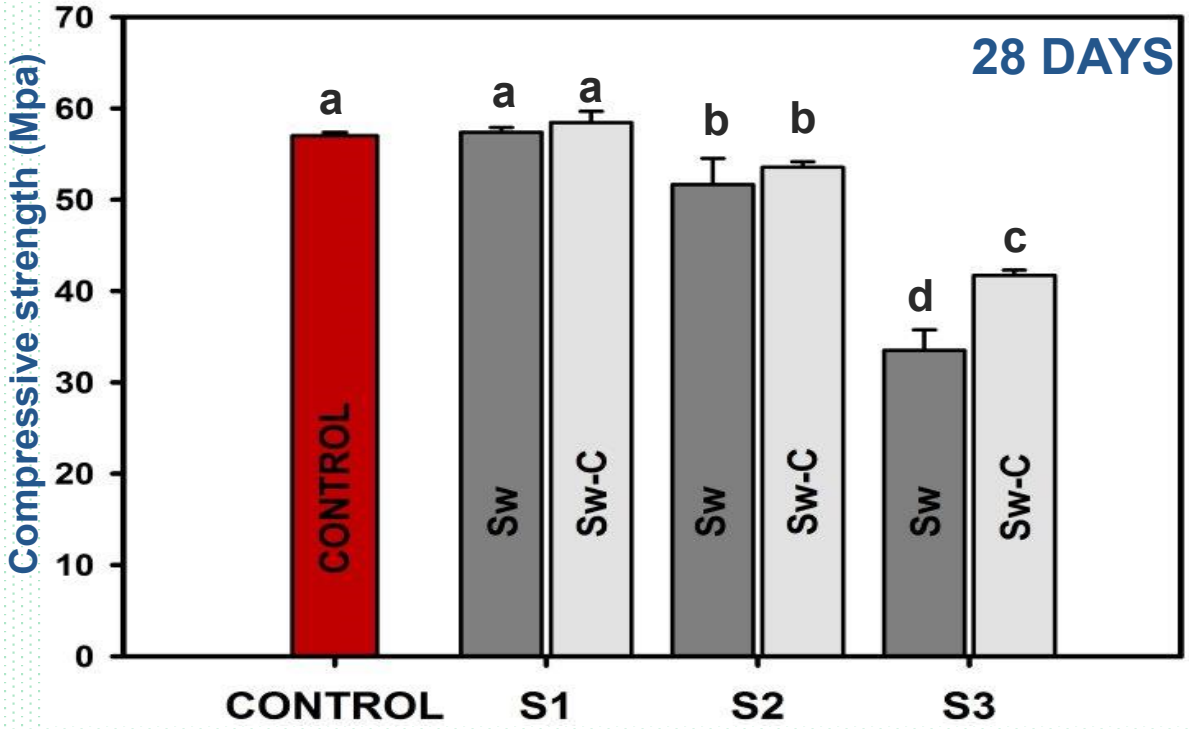
COMPRESSIVE STRENGTH

STAINLESS STEEL SLAG WASTE AS CEMENT REPLACEMENT IN MORTAR

MECHANICAL BEHAVIOR

RESULTS





LOSS OF COMPRESSIVE STRENGTH LOWER 25%

REPLACEMENT 10% Sw AND Sw-C COMPRESSIVE STRENGTH INCREASES

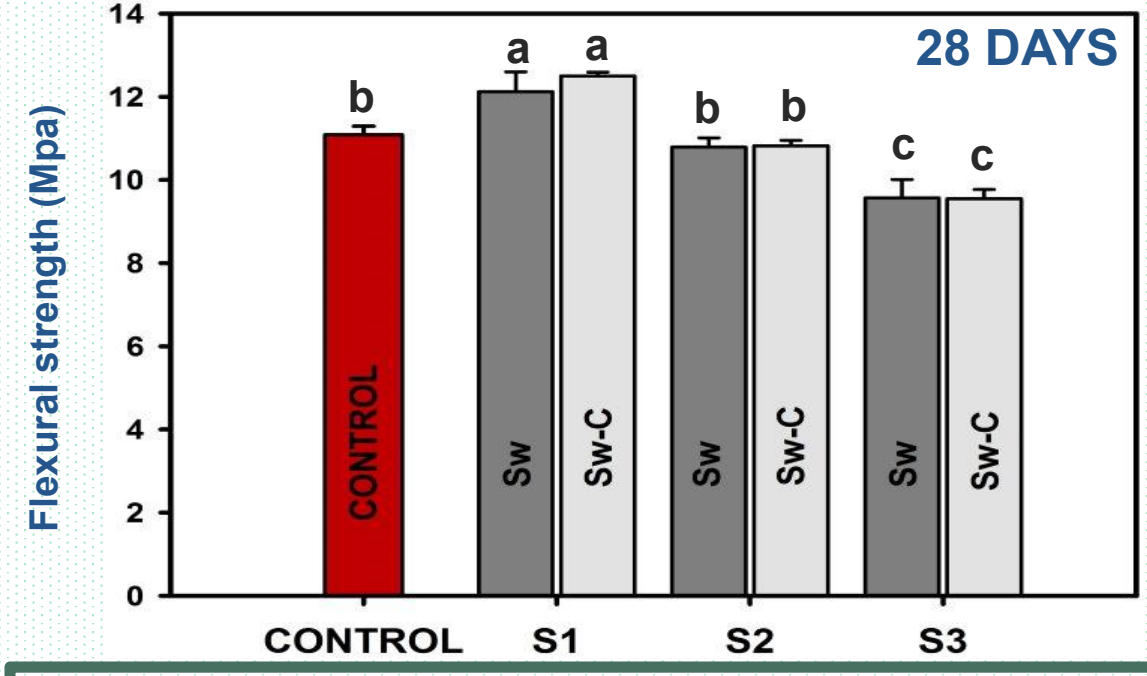
SW-C BETTER RESULTS

FLEXURAL STRENGTH

STAINLESS STEEL SLAG WASTE AS CEMENT REPLACEMENT IN MORTAR

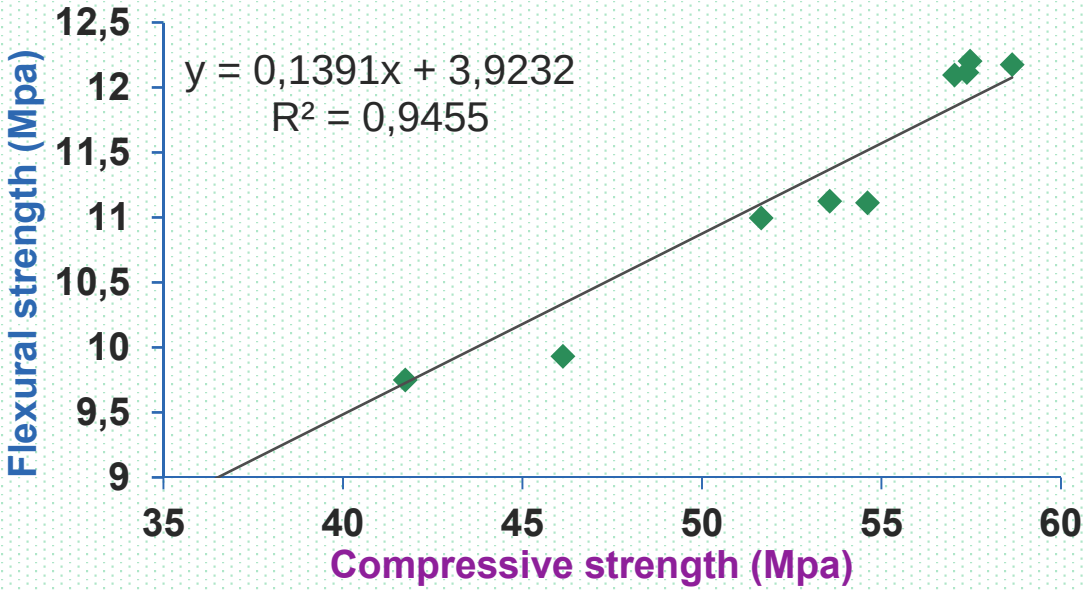
MECHANICAL BEHAVIOR

RESULTS



LOSS OF FLEXURAL STRENGTH LOWER 15%

REPLACEMENT 10% Sw AND Sw-C FLEXURAL STRENGTH INCREASES



FLEXURAL STRENGTH *VS* COMPRESIVE STRENGTH

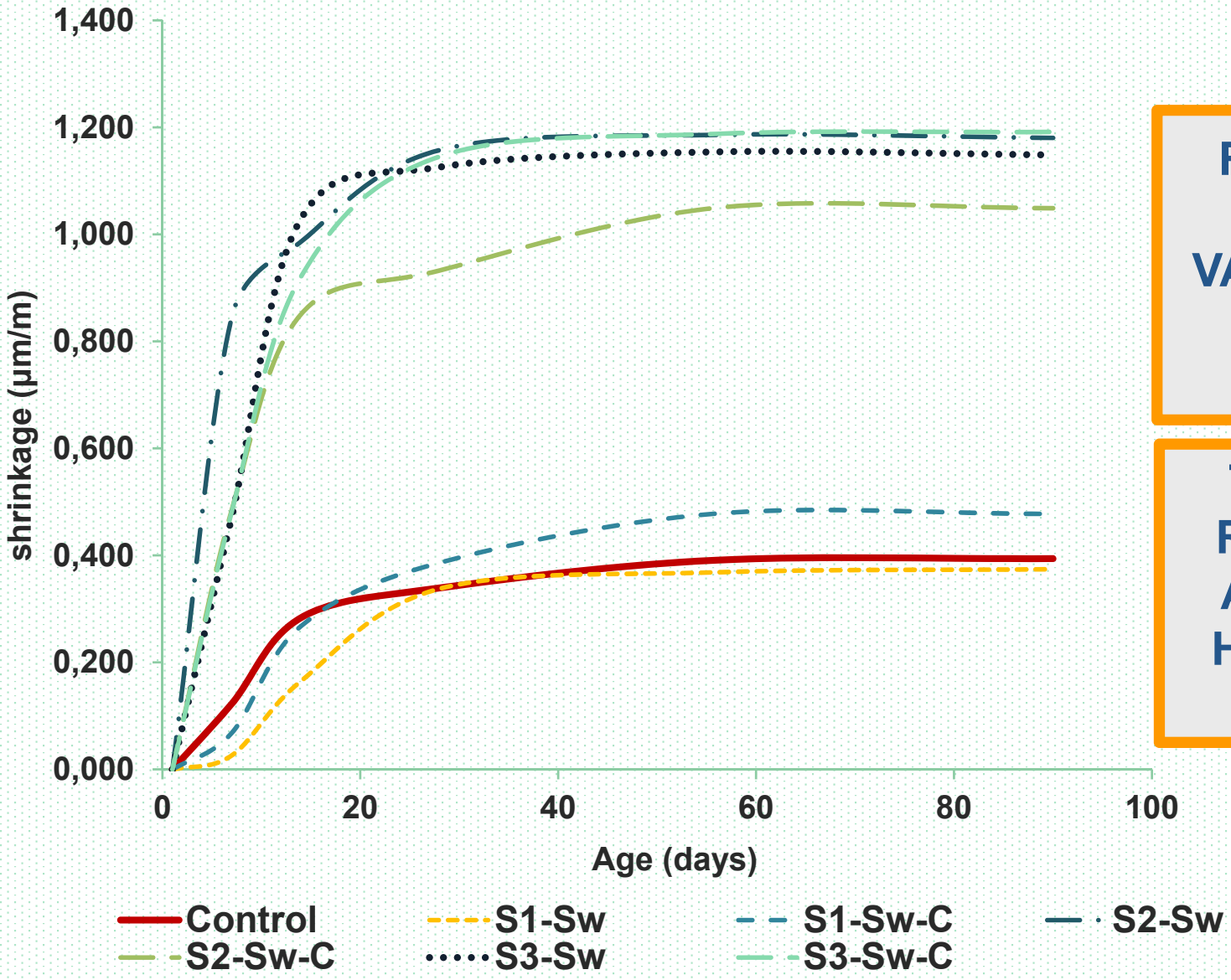
HIGH POSITIVE CORRELATION AMONG THE COMPRESSIVE STRENGTH AND FLEXURAL STRENGTH

SHRINKAGE

STAINLESS STEEL SLAG WASTE AS CEMENT REPLACEMENT IN MORTAR

MECHANICAL BEHAVIOR

RESULTS



REPLACEMENT 10% Sw AND Sw-C PRESENT VALUES OF RETRACTION SIMILAR THAT THE CONTROL

THE MORTARS WITH A REPLACEMENT OF 20% AND 30% Sw AND Sw-C HAVE HIGH SHRINKAGE VALUES

The mechanical behavior of mortars must be analyzed as a whole (Compressive Strength, Flexural Strength and Shrinkage)

Multivariate analysis: a useful tool to evaluate the influence of addition of slag waste in the mechanical behavior

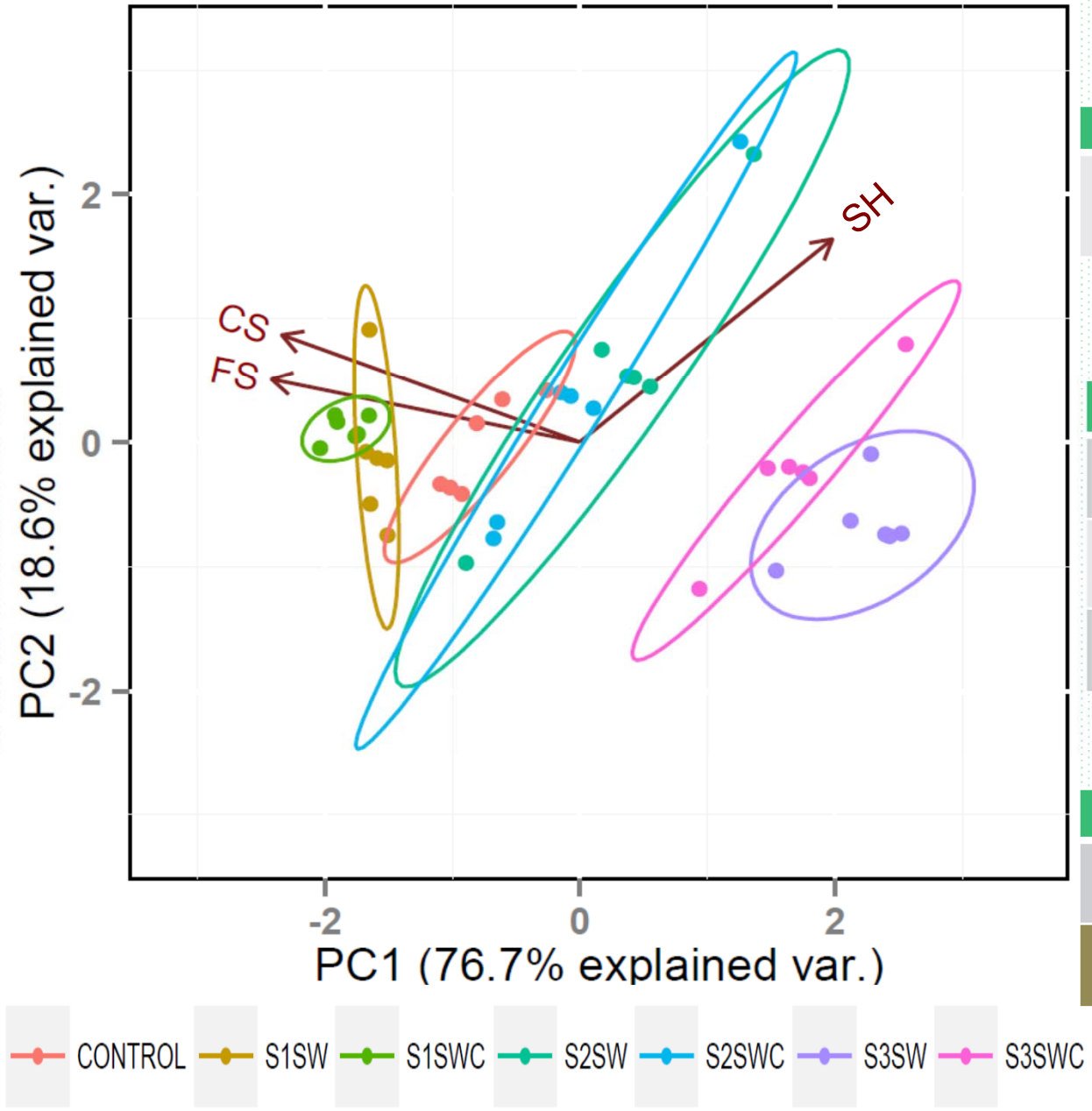
MULTIVARIATE ANALYSIS METHODS

- **Ordination Analysis.** Principal Components Analysis (PCA)
- Multivariate Analysis of Variance (MANOVAs)

SAS 9.4

MULTIVARIATE ANALYSIS

RESULTS



MANOVAs

	Pillai	approx F	Pr(>F)	
Mechanical behavior *vs* All treatment	1,86	9,53	< 0,0001 ***	DIFFERENT

Control *vs* Replacement Series

	Pillai	approx F	Pr(>F)
Control *vs* S1	0,6775	23,11	< 0,0001 ***
Control *vs* S2	0,6279	18,56	< 0,0001 ***
Control *vs* S3	0,9691	345,75	< 0,0001 ***

Unprocessed *vs* Crushed

	Pillai	approx F	Pr(>F)
SW *vs* SW-C	0,7037	26,12	< 0,0001 ***
S2SW vs S2SW-C	0,1827	2,46	0,08

DIFFERENTS

CONCLUSIONS

- The cement replacement by stainless steel slag waste provides an increased in compressive and flexural strength for 10% substitution respect to the control. For stainless steel slag waste crushed we are observed better results. For mortars manufactured with this percentage, the retractions are similar to the control mortar.

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THANKS FOR YOUR ATTENTION

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