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Alternative activation of silicomanganese slag with olive biomass fly ash to produce one-part geopolymers for a circular economy

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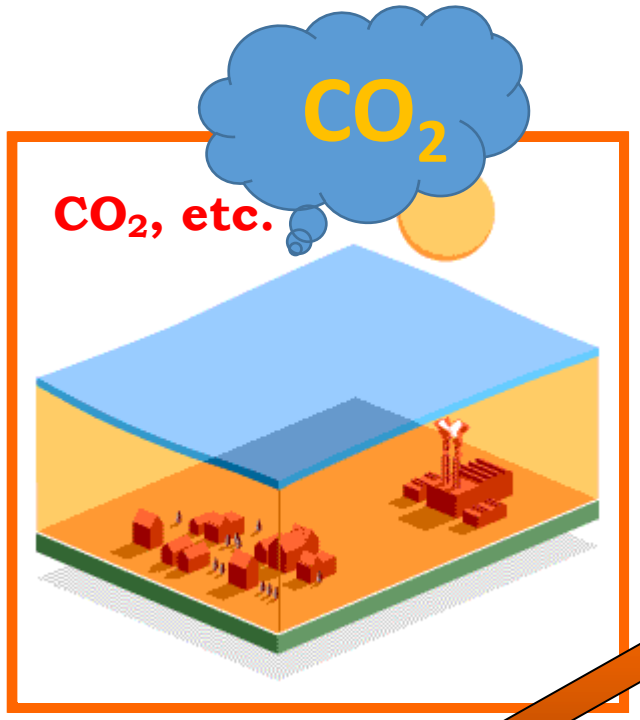
Objectives

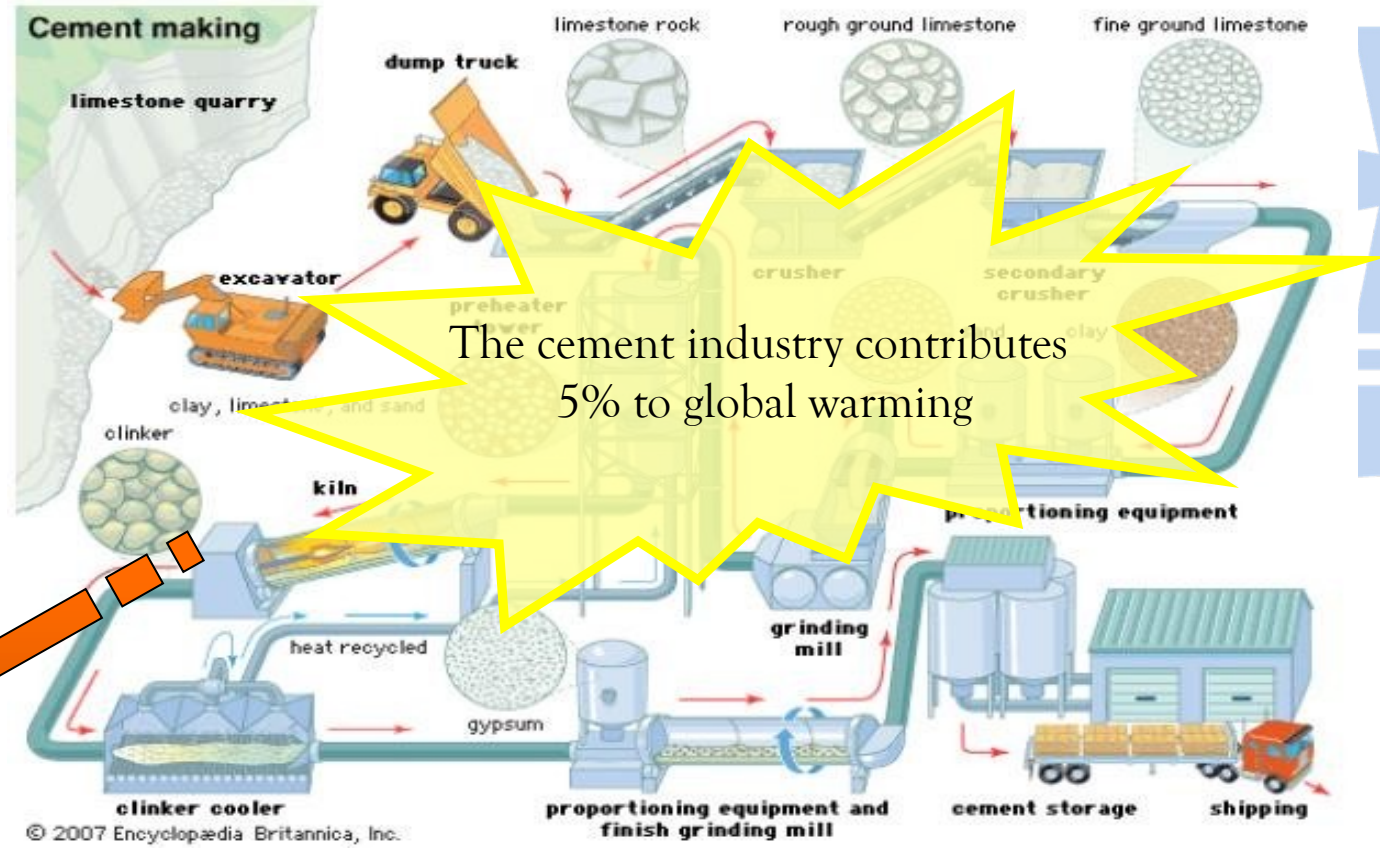
1. **Boosting the circular economy**
2. **Valorisation of industrial waste**
3. **Obtaining alternative materials to ordinary Portland cement (OPC)**
4. **Use alkaline (K) content of biomass fly ash for activator in geopolymerization process**

Introduction

Greenhouse gas emissions (GHG)



Portland cement production



The cement industry contributes 5% to global warming

$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2$$

Total CO_2 comes from:

- ✓ Limestone
- ✓~ 0.34 fuel
- ✓~ 0.10 electricity

0.59 tons de CO_2 per clinker ton

Introduction

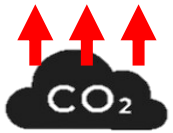
WASTE → The problem

SiMn slags in geopolymer production

- Main advantages
  - reacts readily with other raw components
  - Boost Circular economy
  - Solve an environmental problem
- Main disadvantages
  - Grinding difficult
  - Leaching problems??

Introduction

Portland cement plant



New research lines

New materials

Alkali-activated materials

Geopolymers

based on

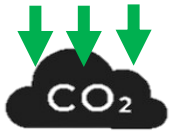
Activator

&

Precursor

Solutions of:
- Hydroxides: NaOH, KOH,
- Silicates: Na_2SiO_3, K_2SiO_3

- Natural minerals
- Waste
- Industrial by-product



Properties depend on raw materials used

Materials

- Silico-manganese slag (SiMn Slag) is generated during the production of ferroalloys with some MnO content by carbothermal reduction in electric arc furnaces (EAF)
- 1 tonne of silico-manganese ferroalloy generates 0.9-2.2 tonnes of SiMn Slags
- SiMn Slag is rich on SiO_2, CaO and MnO.
- Main mineralogical phases: akermanite ($Ca_2MgSi_2O_7$), quartz, cristobalite (SiO_2), alabandite (MnS)

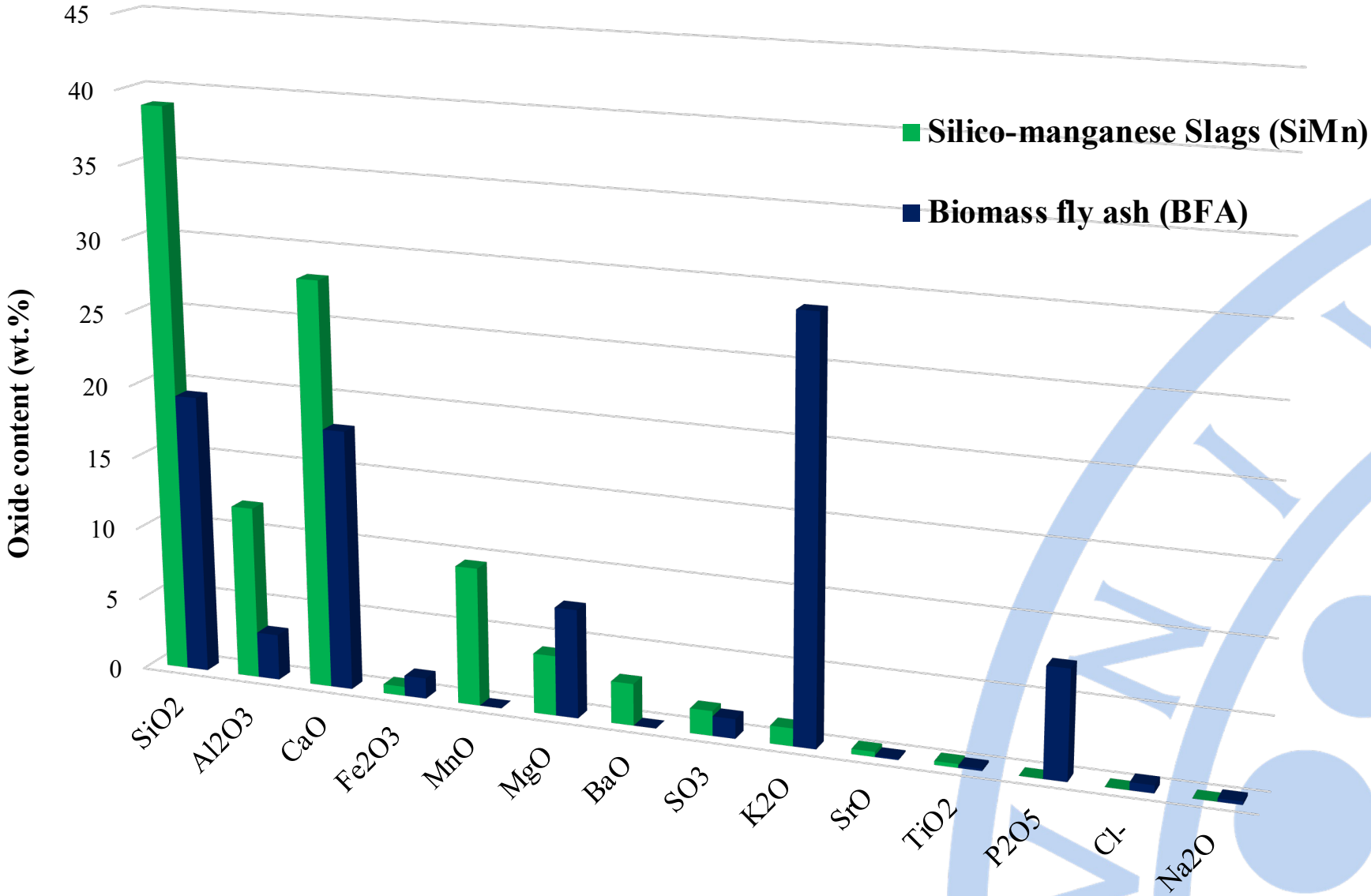
Materials

- The production of silico-manganese production in 2019 was around 162,000 tonnes = 356,000 tonnes of slags

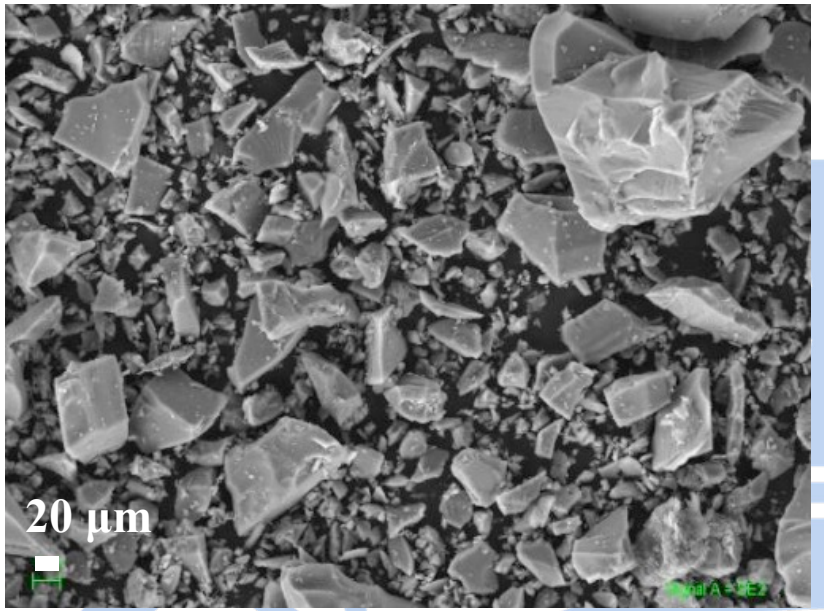
- Application in pavements layers, aggregate for concrete and filler material in embankments.

FerroAtlántica (FerroGlobe)

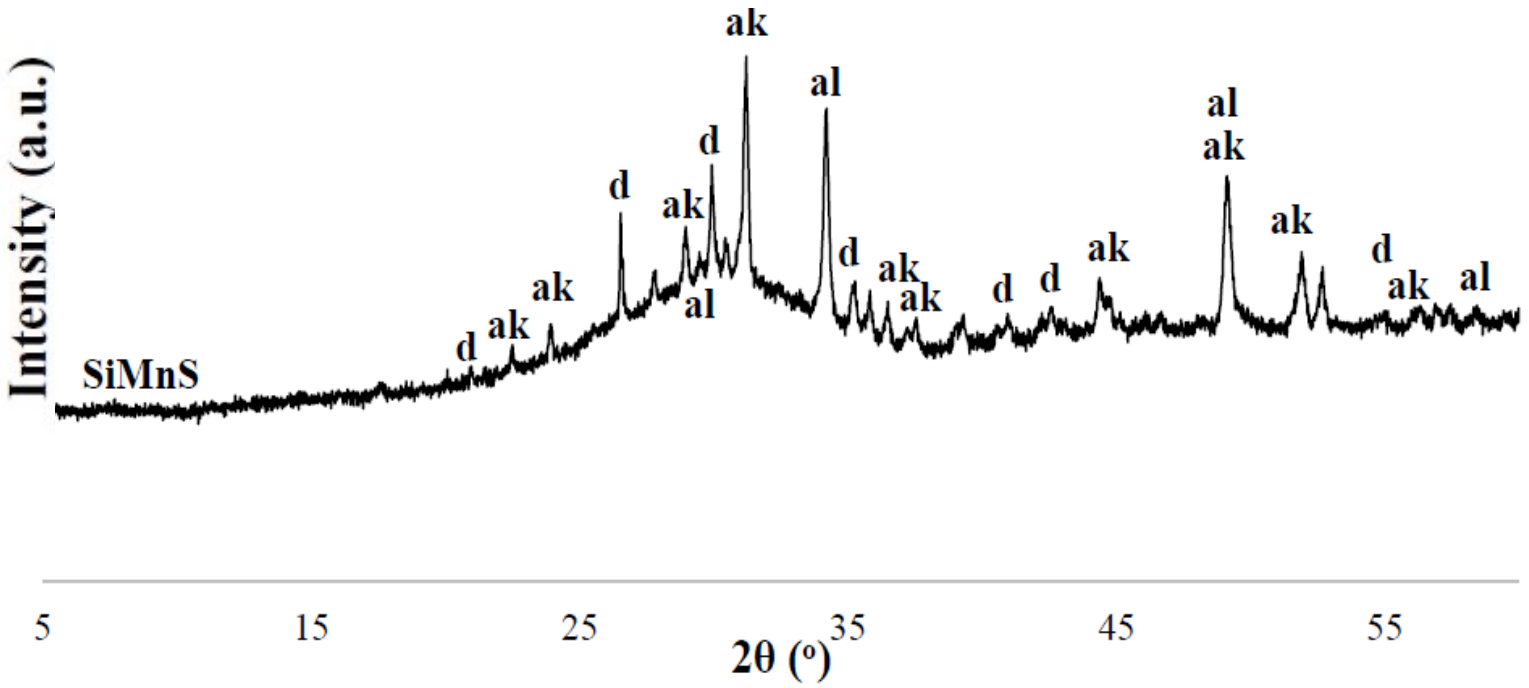
Materials


Oxide content (wt.%)
45
40
35
30
25
20
15
10
5
0
Silico-manganese Slags (SiMn)
Biomass fly ash (BFA)
SiO2
Al2O3
CaO
Fe2O3
MnO
MgO
BaO
SO3
K2O
SrO
TiO2
P2O5
Cl-
Na2O

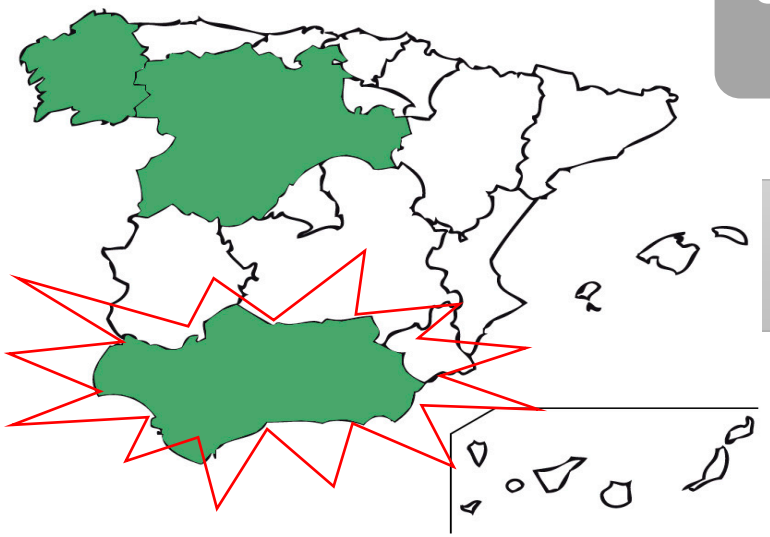
Materials



D - Diopside
ak - Akermanite
al - Alabandite

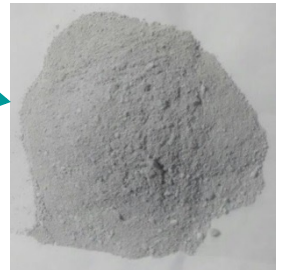


Materials



Consumption of biomass in Spain

4751 ktep GWh (2019)



Energía de La Loma, S.A. (fly ash)

Experimental

The idea: one part geopolymers (use BFA as activator, high K_2O content)

SiMn slag

Biomass fly ash

Add the required amount of biomass fly ash (BFA) to ensure that we are supplying 10, 20 or 30 % K_2O per 100 grams of precursor (silico-manganese slag)

ONE-PART GEOPOLYMERS

The optimal percentage (20% FA) is compared with the geopolymers prepared with the amount of KOH necessary to have 20% K_2O in the precursor (silico-manganese slag).

Experimental

Experimental design

Precursor	Precursor (g)	H_2O (g)	Activator	Mass (g)	(%K_2O)
ESC-FA	65,0	16,25	KOH	9,11	(20)
ESC-FA	60,0	15,28	CVL	4,865	(5)
ESC-FA	50,0	13,46	CVL	8,109	(10)
ESC-FA	50,0	14,92	CVL	16,218	(20)
ESC-FA	40,0	13,10	CVL	19,462	(30)

Experimental

Geopolymerization

PRECURSOR
Material composed of Al and Si (aluminosilicate)

Room temperature
o 40-80ºC

ACTIVATOR
Alkaline solution

$$M_n(-(SiO_2)_z - AlO_2)_n * wH_2O$$

Sialato tetrahedral units

Structure formed by polymer chains

Setting and hardening

Chemical Reaction

Geopolymers

- Low emissions of CO_2 (up to 80% less than PC)
- Yields comparable to the PC
- Improved properties
  - Durability
  - Stability
  - Mechanical strength

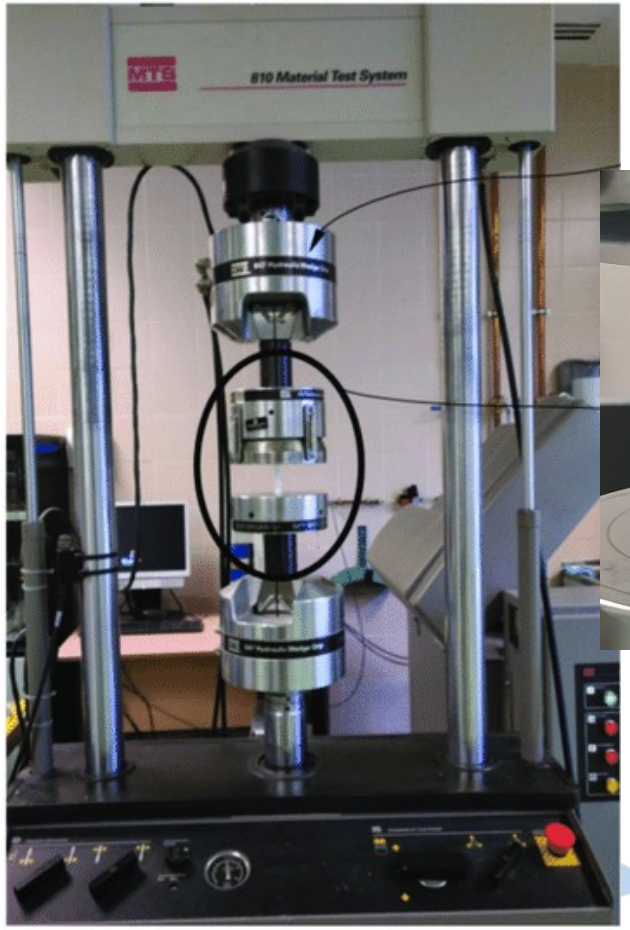
Experimental

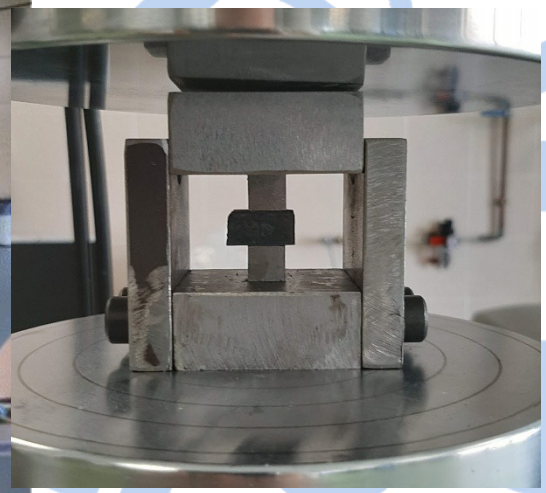
- Curing conditions:

1. Prismatic molds 10 x 10 x 60 mm
2. Curing at climatic chamber at 60°C y 98 % Relative huminity, 24 h
3. Demolding after 24 h. then curing until assay at room conditions

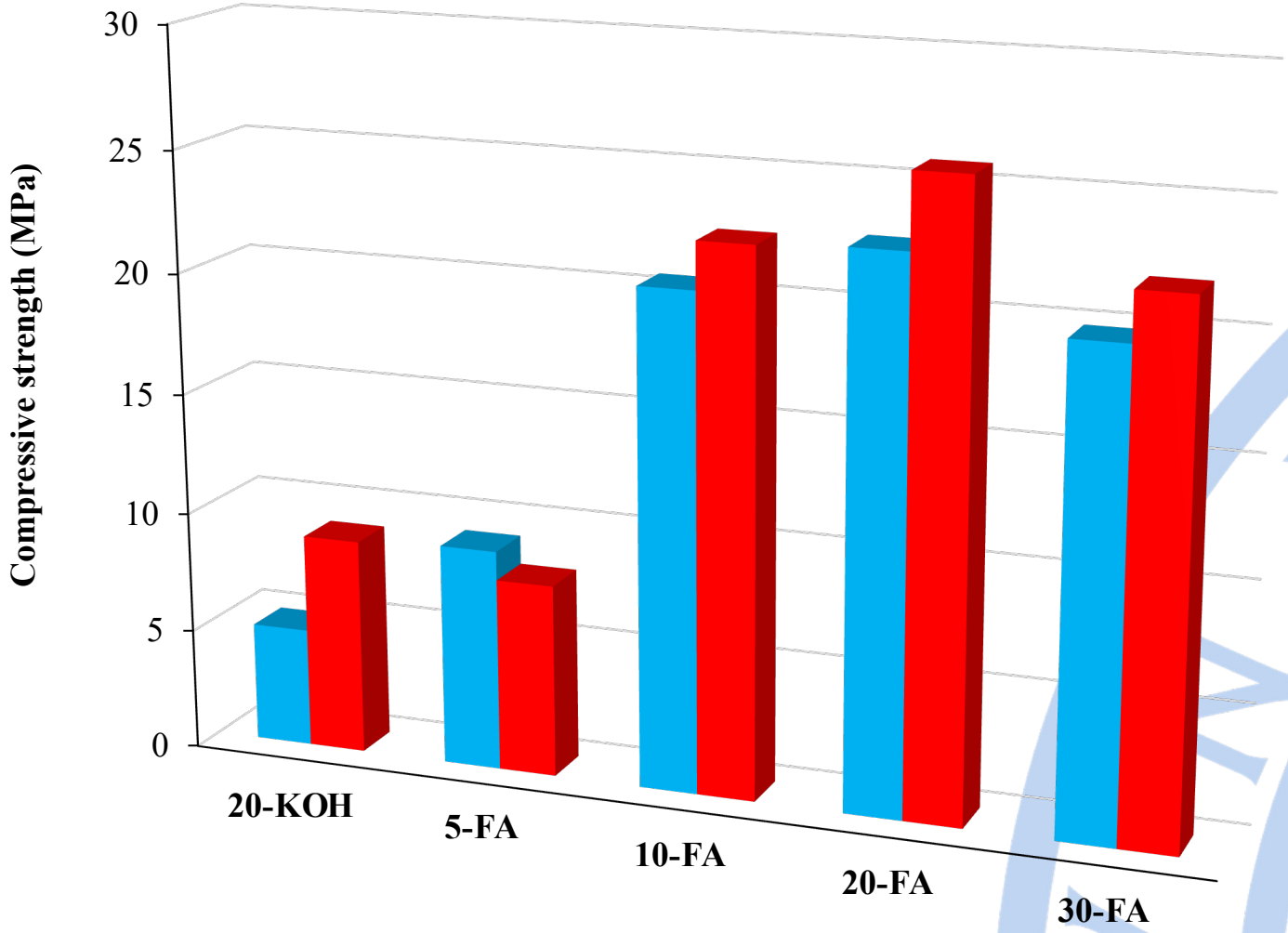
Experimental

- Essays performed:
  - Mechanical properties: compressive and flexural strength (7 and 28 days)
  - Physical properties: density, water absorption and apparent porosity (7 and 28 days)

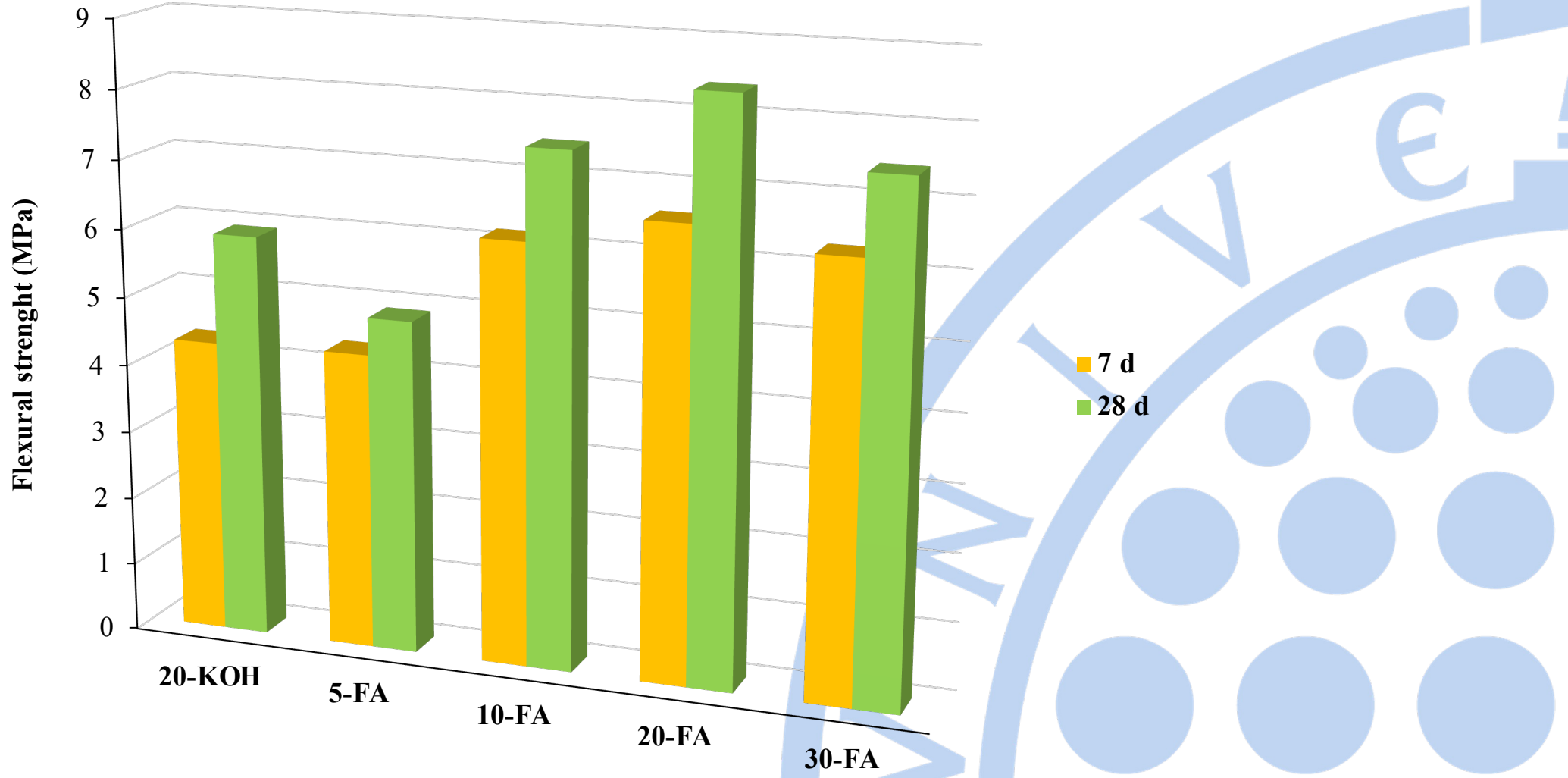




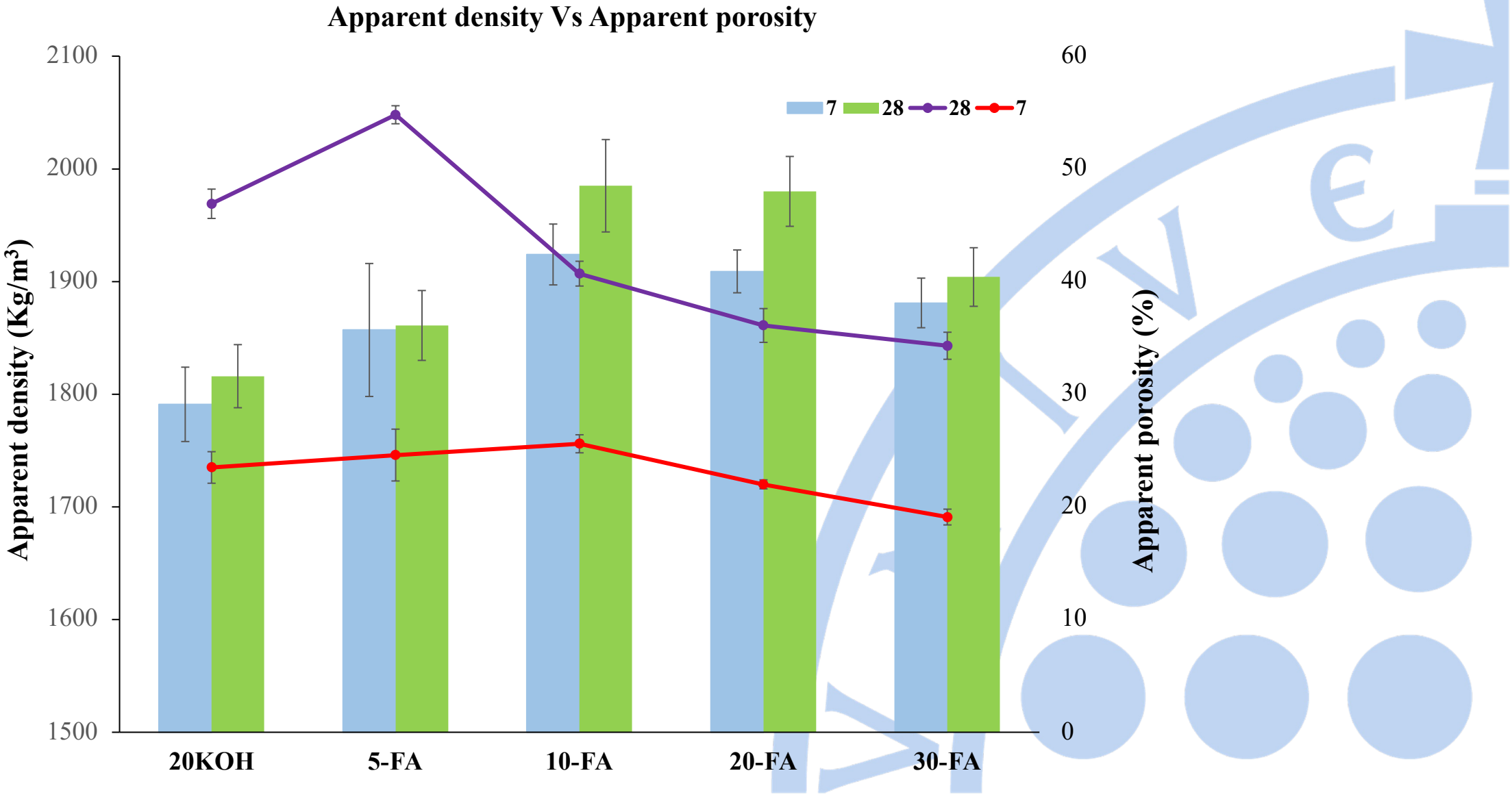
Results


Compressive strength (MPa)
30
25
20
15
10
5
0
20-KOH
5-FA
10-FA
20-FA
30-FA
7 d
28 d

Results


Flexural strenght (MPa)
9
8
7
6
5
4
3
2
1
0
20-KOH
5-FA
10-FA
20-FA
30-FA
7 d
28 d

Results


Apparent density Vs Apparent porosity
Apparent density (Kg/m³)
Apparent porosity (%)
2100
2000
1900
1800
1700
1600
1500
60
50
40
30
20
10
0
7
28
28
7
20KOH
5-FA
10-FA
20-FA
30-FA

Conclusions

- The best mechanical results were obtained for the 20-FA series for both compression and three-point bending (flexural) strength.
- This composition (20-FA) favours the formation of C-A-S-H gel, and as a consequence there is an increase in compressive strength.
- The increase of the bulk density by increasing additions of silico-manganese slag and at the same time decreasing the bulk porosity helps to increase the mechanical strength of the geopolymers.

Thank you for your attention!

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