

# Incorporation of wastes from the metallurgical industry in geopolymers



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# Metallurgical wastes being tested



**Steelmaking Ladle Slag (white slag)**  
**Steelmaking refractories**  
**Foundry sands**

# Steelmaking Ladle Slag



**Also called “White slag”**

**Produced in the secondary treatment of liquid steel**

**Treatment is done by adding  $\text{CaO}$ ,  $\text{CaF}_2$ ,  $\text{CaC}_2$ , Calcium aluminates, and other desulfurizing and dephosphorizing agents**

**Slag is whitish and contains  $\text{CaS}$  and  $\text{Ca}_3\text{P}_2$ , as well as Ca silico-aluminates and some, few, free lime**

**Need to be crushed and grinded**

# Steelmaking Ladle Slag

## Composition



**Ca – 46 %**

**Si – 8,5**

**S – 3,2 %**

**Mg – 2,8 %**

**Al – 1,7 %**

**Fe – 1,1 %**

**F – 0,5 %**

**Rest – oxygen, nitrogen, carbon, ...**

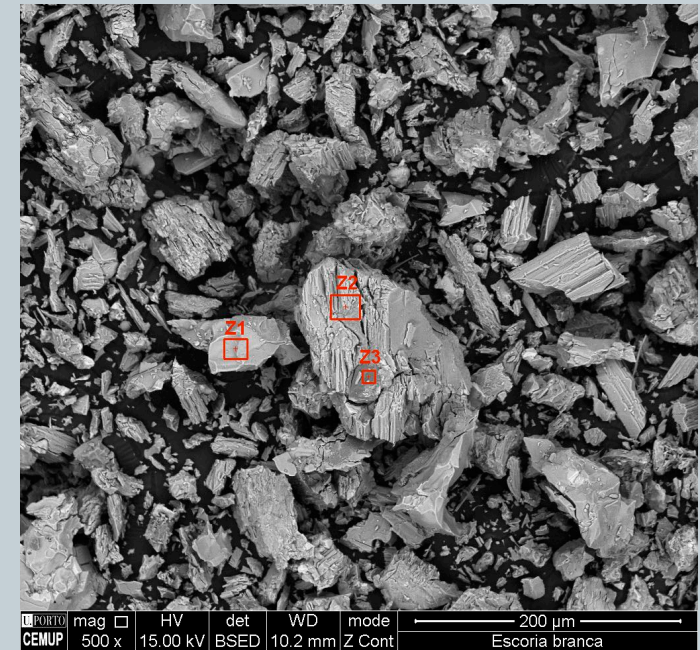
# Steelmaking Ladle Slag

## Composition



**Z<sub>1</sub> and Z<sub>2</sub> – Ca + Si + Fe + F + O**

**Z<sub>3</sub> – Mg + Ca + F + Fe + O**



# Steelmaking Refractories



**From electric arc furnace**

**Dolomitic type**

**Need to be crushed, Fe separation and grinded**

## **Composition**

**CaO – 70 %**

**MgO – 24 %**

**SiO<sub>2</sub> – 2 %**

**Fe – 1 %**

**S – 1 %**

# Foundry Sand



**From making steel foundry molds (green sand)**

**Contains mainly quartz, with small amounts of clays, carbon, and iron (metallic and oxides)**

## Composition

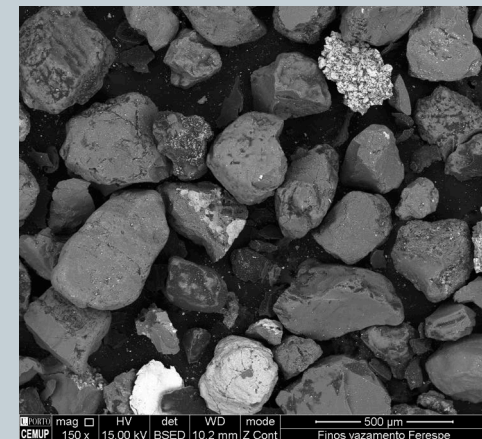
**$\text{SiO}_2$  - 93 %**

**$\text{Al}_2\text{O}_3$  - 2 %**

**$\text{Fe}_2\text{O}_3$  - 2 %**

**$\text{ZrO}_2$  - 1 %**

**$\text{Fe}_0$  - 1%**



# Testing



**Based on system Fly Ash + Sodium Silicate + Caustic Soda**

**Aggregate: feldspatic sand**

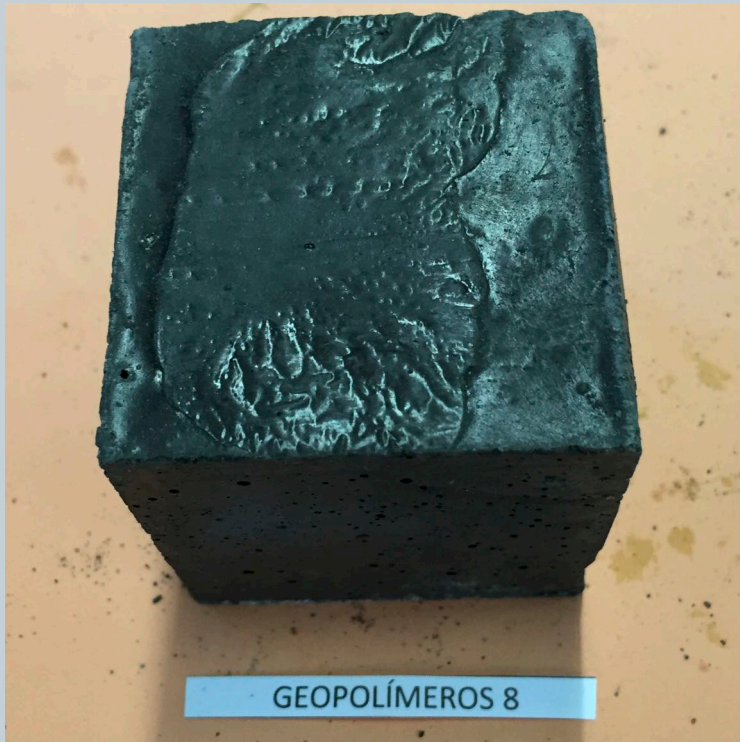
**Making 5 x 5 x 5 cm cubes**

**Compression resistance measured at 7 and 28 days**

**Incorporation of different amounts of wastes, to test effect on compression resistance**



# Testing



# Testing



## Employed materials

### Class F Fly Ash composition

**SiO<sub>2</sub> - 52,3 %**  
**Al<sub>2</sub>O<sub>3</sub> - 21,9 %**  
**Fe<sub>2</sub>O<sub>3</sub> - 11,5 %**  
**K<sub>2</sub>O - 2,8 %**  
**CaO - 2,1 %**  
**MgO - 1,9 %**  
**Na<sub>2</sub>O - 1,7 %**  
**TiO<sub>2</sub> - 1,5 %**  
**C - 1,9 %**

# Testing

## Fly ash

(SEM, BSED)

### Identified phases:

**Z1** - Fe - Ca - Mg oxide + some S

**Z2** -  $\text{Fe}_2\text{O}_3$

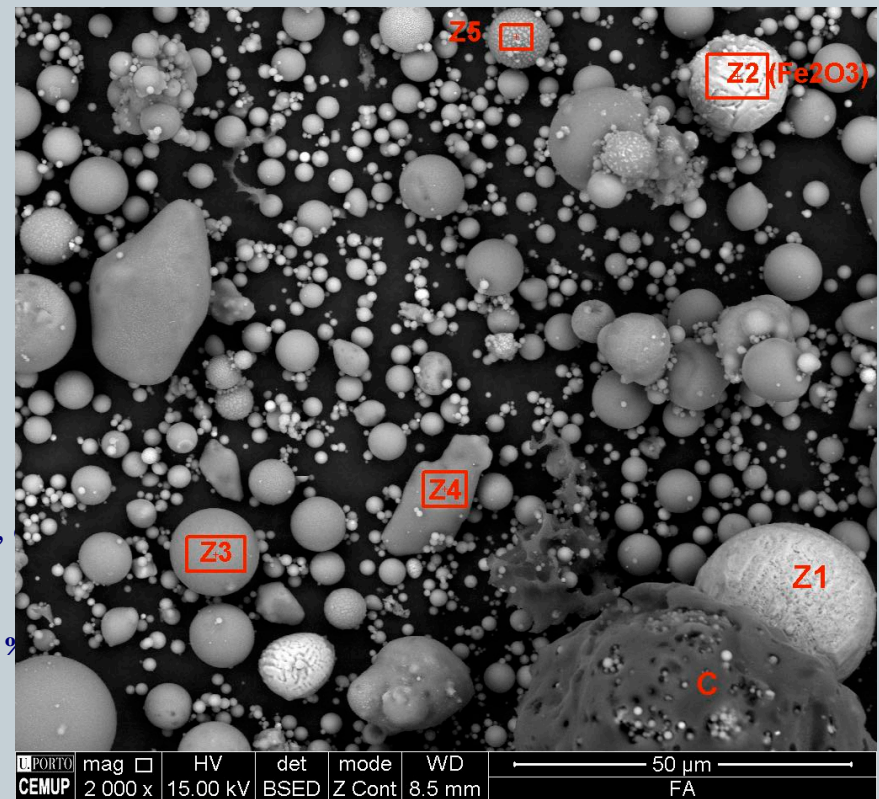
**Round "glassy" particles (Z3)**

$\text{SiO}_2$  - 57%;  $\text{Al}_2\text{O}_3$  - 30%;  $\text{MgO}$  - 3,4%;  $\text{Na}_2\text{O}$  - 2,

**Z4** -  $\text{SiO}_2$

**Round "glassy" particles (Z5)**

$\text{SiO}_2$  - 40%;  $\text{Al}_2\text{O}_3$  - 28%;  $\text{Fe}_2\text{O}_3$  - 20%;  $\text{MgO}$  - 9%



# Testing



## **Employed materials**

**Sodium Silicate R200/47 (MR  $\approx$  1,7)**

**Sodium Hydroxide 10 M**

**Natural Hydraulic Lime**

**Wastes**

# Results



## Reference samples

**Fly Ash – 24,1 %**  
**Sodium Silicate – 12,1 %**  
**NaOH 10 M – 4,8 %**  
**Lime – 2,7 %**  
**Sand – rest**

## **Compression Resistance at 28 days (curing in air, ambient temperature)**

Average of 10 tests – **24,9 MPa**  
Standard deviation – **3,5 MPa**

# Results with Ladle Slag



**Values in weight %, except for Rc (Mpa)**

FA	Silicate	NaOH	Lime	LS	Rc 28 days
24,1	12,3	4,8	2,7	0,0	24,9
24,1	12,3	4,8	0,0	2,7	21,9
24,0	12,1	4,8	0,0	5,4	26,2
23,8	12,0	4,7	0,0	7,9	23,8

# Results with Steelmaking Refractories



**Values in weight %, except for Rc (Mpa)**

FA	Silicate	NaOH	Lime	LS	SR	Rc 28 days
24,1	12,3	4,8	2,7	0,0	0,0	24,9
24,1	12,3	4,8	0,0	0,0	2,7	9,3
23,7	12,2	4,8	0,0	2,7	2,7	21,0
23,6	11,9	4,7	0,0	2,7	5,0	22,7

# Results with Foundry Sand



**Values in weight %, except for Rc (Mpa)**

FA	Silicate	NaOH	Lime	LS	FS	Rc 28 days
24,1	12,3	4,8	2,7	0,0	0,0	24,9
23,2	15,2	4,8	0,0	2,7	18,0	9,5
22,8	16,8	4,8	0,0	2,7	26,0	6,6

**Bad results, needing increase of silicate addition to be workable**



# Future work



**To test other wastes and combinations of different wastes**

**Other wastes being tested:**

Aluminum anodizing sludge  
Phosphatizing sludge  
Matrix cleaning sludge from Al extrusion  
Electric arc furnace slag  
Iron foundry slag  
Iron foundry dusts  
Waste Fly-ash (landfilled)