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# *Early performance of mortars prepared with binary and ternary binders exposed to a real exposure class XC4 Mediterranean climate environment*

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## Outline

1. **Introduction**
2. **Materials and methods**
3. **Results and discussion**
4. **Conclusions**

# Introduction

# Binary and ternary binders

- Development strategies for reducing the $CO_2$ emissions due to the cement manufacture → Important field of study
- Binary binders as commercial cements are common:
  - Limestone.
  - Fly ash.
  - Ground granulated blast furnace slag
- Commercial cements made with ternary binders:
  - Clinker partially replaced by two additions
  - Synergetic effect of both additions
  - Their manufacture is still very low, at least in Spain

# Real structures

- They are usually exposed to environments which differ with the laboratory conditions under generally the materials are studied

- These different conditions of real environments can affect:
    - Microstructure
    - Service properties (durability and mechanical strength)
    - Especially for cement-based materials made using binary or ternary binders.

# Objetives

**To study the short-term effects**

↓

**Exposure to real in-situ inland Mediterranean climate environment**

↙ ↘

**Microstructure**

**Mortars with different binders**

**Service properties**

**Ordinary Portland cement**

**Limestone**

**Fly ash**

**Ground granulated blast furnace slag**

# Materials and methods

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# Samples preparation

- Materials (mortars):
  - REF series → CEM I 42,5 R (100%)
  - L series → CEM I 42,5 R (70%) + limestone (30%)
  - SL series → CEM I 42,5 R (70%) + ground granulated blast furnace slag (15%) + limestone (15%)
  - VL series → CEM I 42,5 R (70%) + fly ash (15%) + limestone (15%)
  - Water to cement ratio = 0.5
  - Aggregate to cement ratio = 3
- Samples:
  - Cylindrical → 5 cm diameter and 6 cm height.
  - Prismatic → 4 cm x 4 cm x 16 cm

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# Environmental exposure conditions

- Real in-situ exposure condition
- Mediterranean climate environment
- Inland location → Orxeta town (Alicante, Spain)
- Altitude 177 m.a.s.l.
- 10 km from the coast
- Exposure class XC4 (corrosion induced by carbonation, cyclic wet and dry) defined by the Eurocode 2
- The samples were cured under an optimum condition up to 7 hardening days, when they were moved to the real in-situ environment

# Environmental exposure conditions

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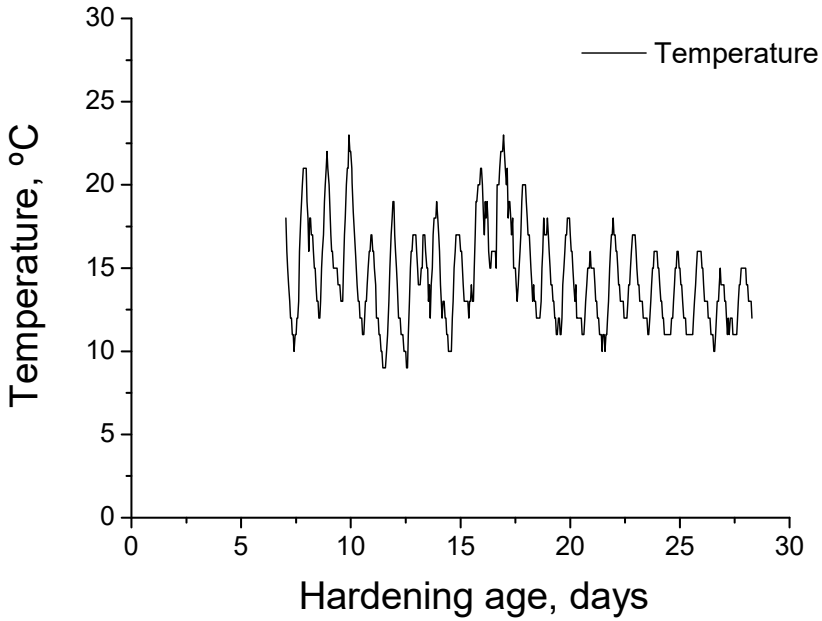


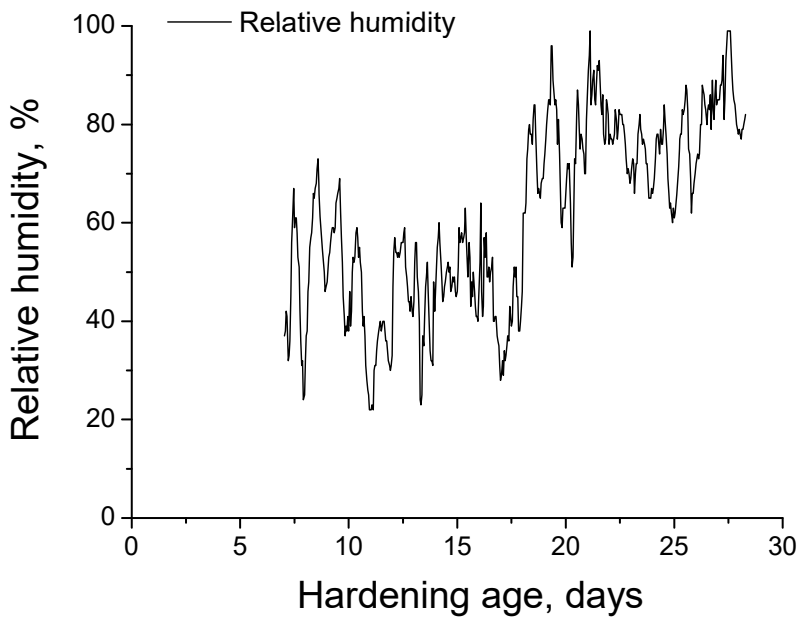


- Temperature ranged between 9°C and 23°C
- Relative humidity ranged from 22% and 99%
- 9 days rainfall (19 mm total precipitation)
- Maximum wind speed 70 km/h

# Experimental techniques

**Short-term effects of the exposure to real in-situ inland Mediterranean climate environment**

Mercury intrusion porosimetry

**Microstructure**

**Mechanical properties**

Compressive strength

**Durability**

Absorption after immersion

- **Tests performed at 28 hardening days.**

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## Mercury intrusion porosimetry

- Poremaster-60 GT porosimeter
- Total porosity
- Pore size distributions
- Pieces taken from cylindrical specimens

## Absorption after immersion

- ASTM Standard C642-06
- Pieces taken from cylindrical specimens

## Compressive strength

- Spanish and European standard UNE-EN 1015-11
- Prismatic samples

# Results and discussion

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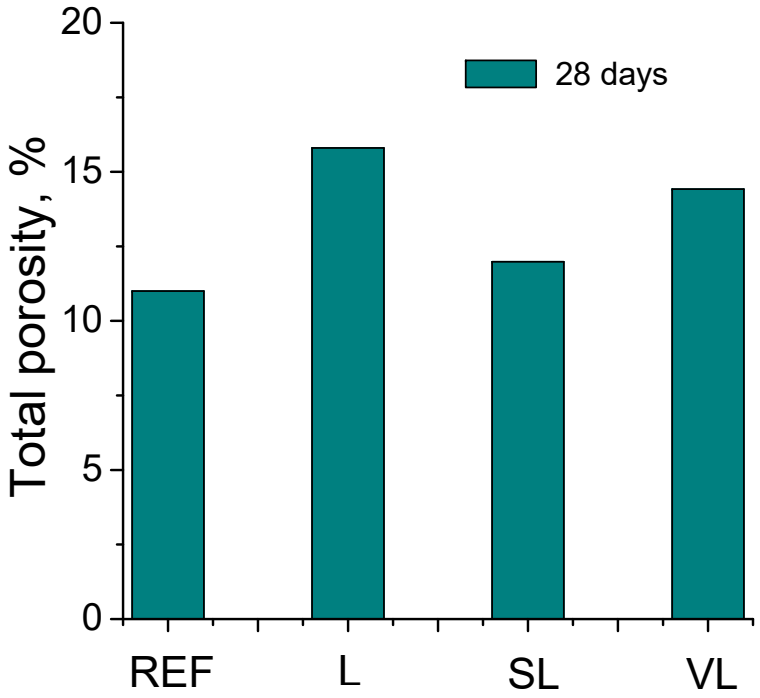
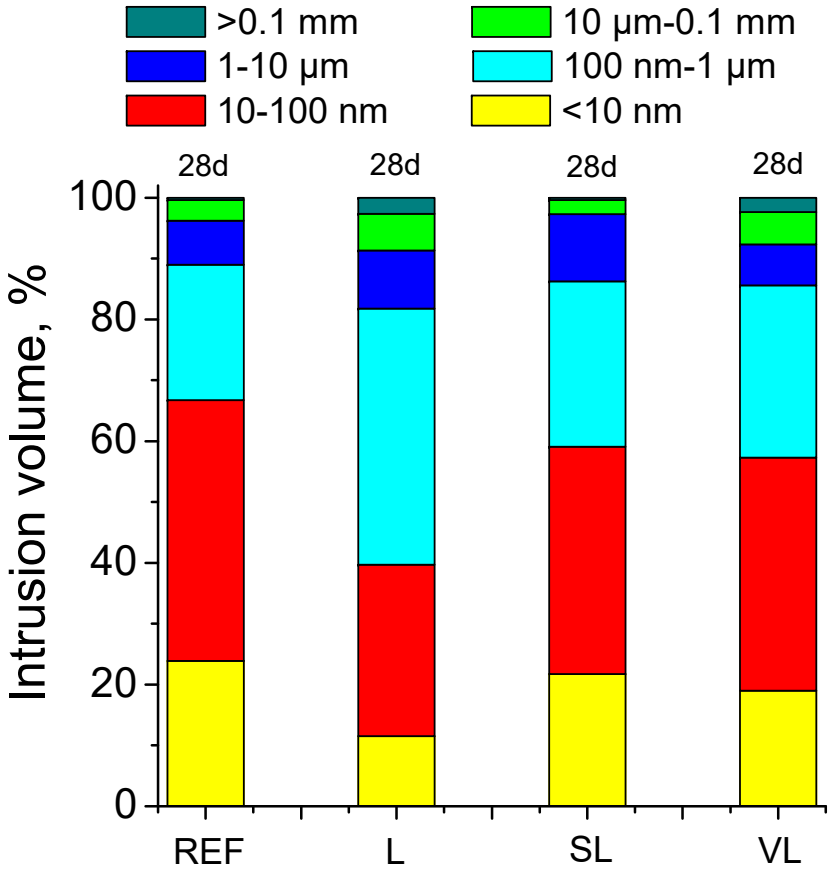
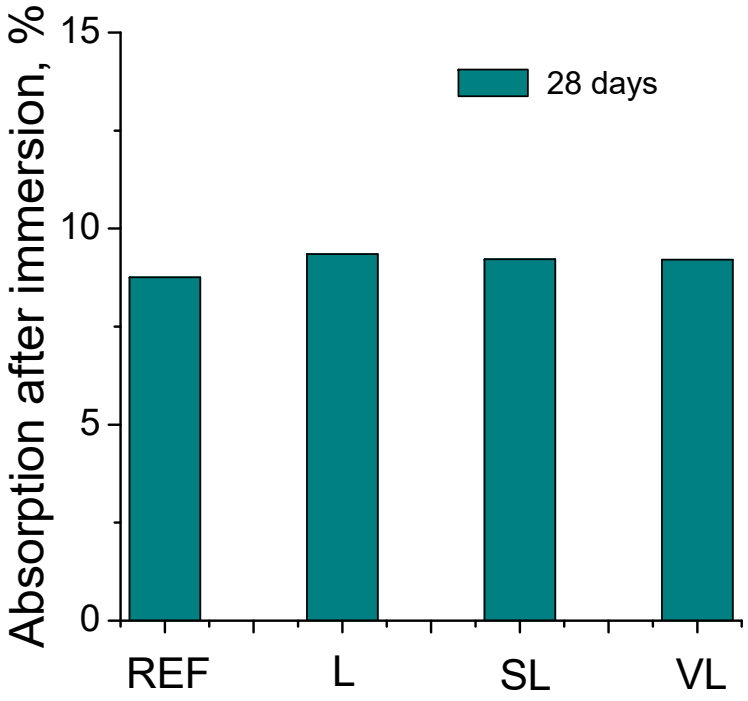
# Microstructure

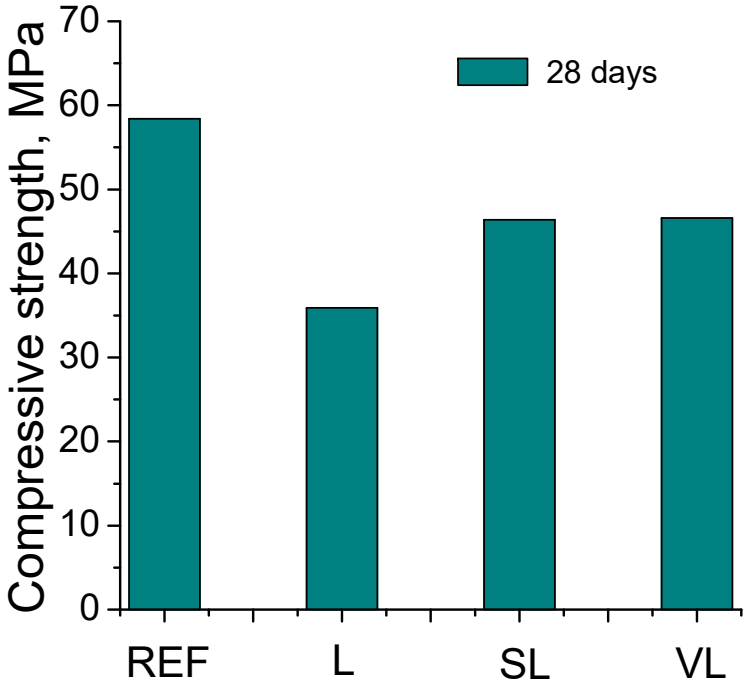



- Lowest porosity and highest pore refinemement → REF mortars
- Highest porosity and lowest pore refinemement → L mortars
- Ternary binders → **SL better than VL in terms of porosity**

# Service properties




- In general, similar absorption values for all the studied mortars
- Highest strength for REF mortars and the lowest for L ones
- Ternary binders → **Similar compressive strength for both, improving the value noted for binary binder**

# Conclusions

# Conclusions

- The greater total porosity, less pore refinement and lower compressive strength observed for L mortars with the could be due to the fact that limestone is not an active addition

- The total porosity of SL mortars showed similar total porosity to REF ones, but their microstructure was slightly less refined → Slower development of the slag hydration due to relatively low temperatures in the exposure site along the time period studied

# Conclusions

- The VL mortars showed higher total porosity and less pore refinement than reference ones → Development of fly ash pozzolanic reactions (delay respect to clinker and slag hydration) → The low environmental temperatures could also an influence.
- Absorption after immersion → Behavior of binders with additions did not differ too much compared to reference mortar at 28 hardening days
- Compressive strength of mortars prepared with the binary and ternary binders studied were lower than that noted for reference specimens

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