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Microstructure, durability and mechanical properties of mortars prepared using ternary binders with addition of slag, fly ash and limestone

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

Introduction

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Eco-friendly cement-based materials

- More sustainable cement industry → Increase the use of eco-friendly materials
- Eco-friendly cements:
    - Lower content of clinker replaced by additions
    - Blast furnace slag, fly ash and limestone
    - Improvement of properties of cement-based materials
- Ternary binders:
    - Clinker partially replaced by two additions
    - Synergetic effect of both additions
    - Promising research field for improving sustainability of cement industry
    - Their manufacture is still very low, at least in Spain

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Objetives

To study the influence at short hardening times

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Ternary binders with standardized additions

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Microstructure

Durability

Mechanical properties

Mortars with ternary and binary binders

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%)
  - S series → CEM I 42,5 R (70%) + ground granulated blast furnace slag (30%)
  - V series → CEM I 42,5 R (70%) + fly ash (30%)
  - SL series → CEM I 42,5 R (70%) + ground granulated blast furnace slag (15%) + limestone (15%)
  - SV series → CEM I 42,5 R (70%) + ground granulated blast furnace slag (15%) + fly ash (15%)
  - VL series → CEM I 42,5 R (70%) + fly ash (15%) + limestone (15%)

Samples preparation

- Materials (mortars):
  - Water to binder ratio = 0.5
  - Fine aggregate to cement ratio = 3
  - Mortars were stored under optimum laboratory condition (20^{o}C and 95% RH) until the testing age (28 hardening days)
- Samples:
  - Cylindrical → 5 cm diameter and 6 cm height
  - Cylindrical → 10 cm diameter and 22 cm height
  - Prismatic → 4 cm x 4 cm x 16 cm

Experimental techniques

Influence at short hardening times produced by ternary binders with standardized additions

Mercury intrusion porosimetry

Non-destructive electrical resistivity

Microstructure

Mechanical properties

Compressive strength

Durability

Absorption after immersion

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

Mercury intrusion porosimetry

- Poremaster-60 GT porosimeter
- Total porosity
- Pore size distributions
- Percentage of Hg retained at the end of the test
- Pieces taken from cylindrical specimens 5 cm diameter and 6 cm height

Non-destructive electrical resistivity

- Wenner four-point test
- Provides data about pore connectivity
- Spanish standard UNE 83988-2
- Cylinders 10 cm diameter and 22 cm height

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Absorption after immersion

- ASTM Standard C642-06
- Pieces taken from cylindrical specimens 5 cm diameter and 6 cm height

Compressive strength

- Spanish and European standard UNE-EN 1015-11
- Prismatic samples 4 cm x 4 cm x 16 cm

Results and discussion

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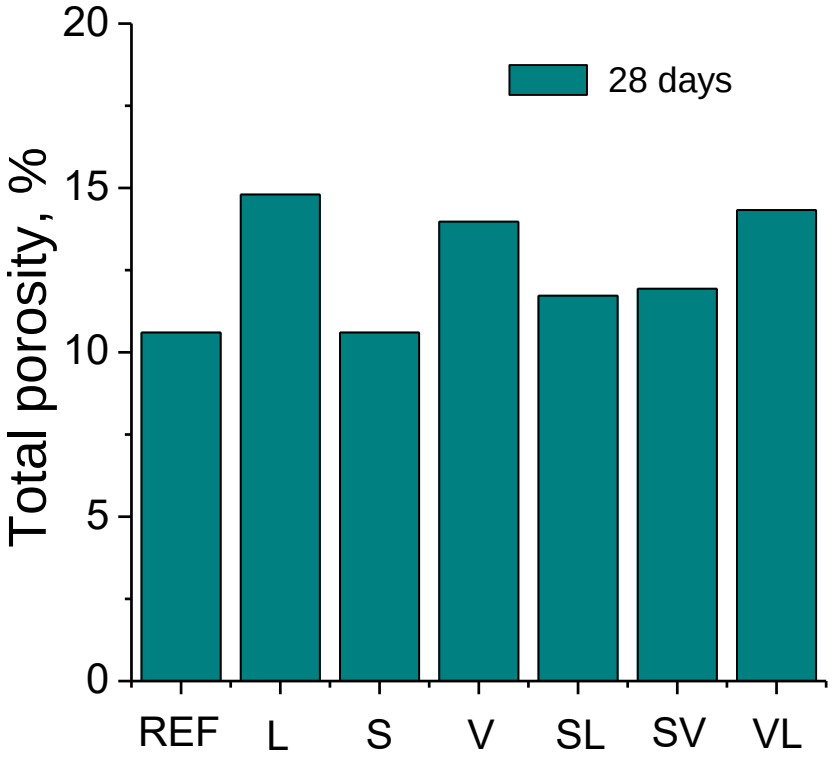
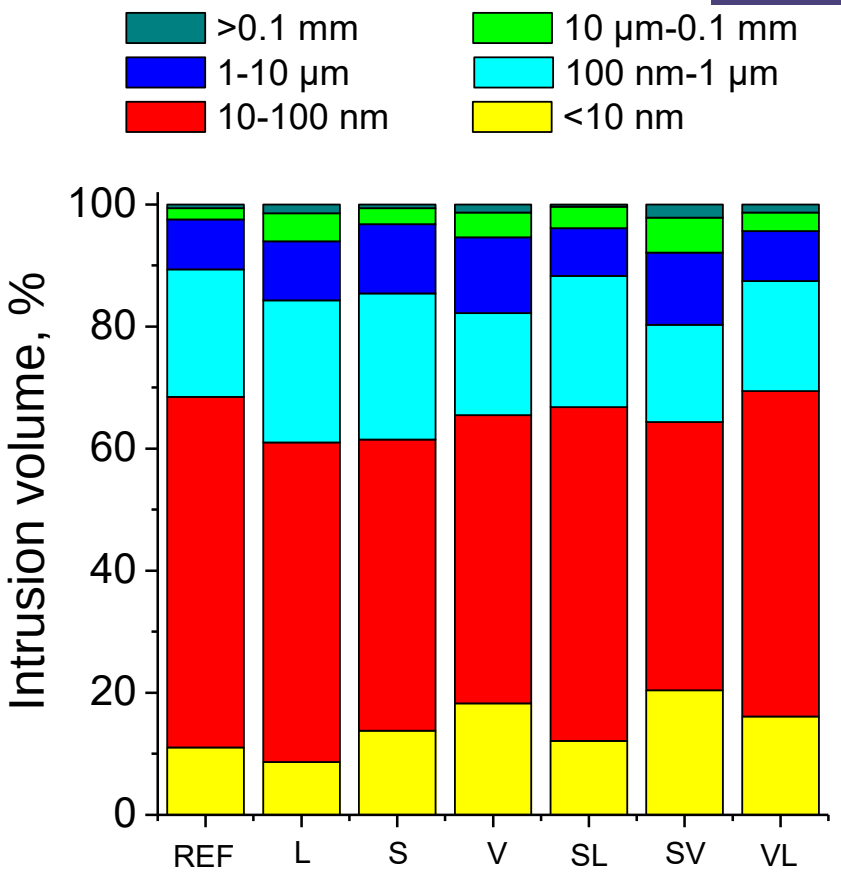
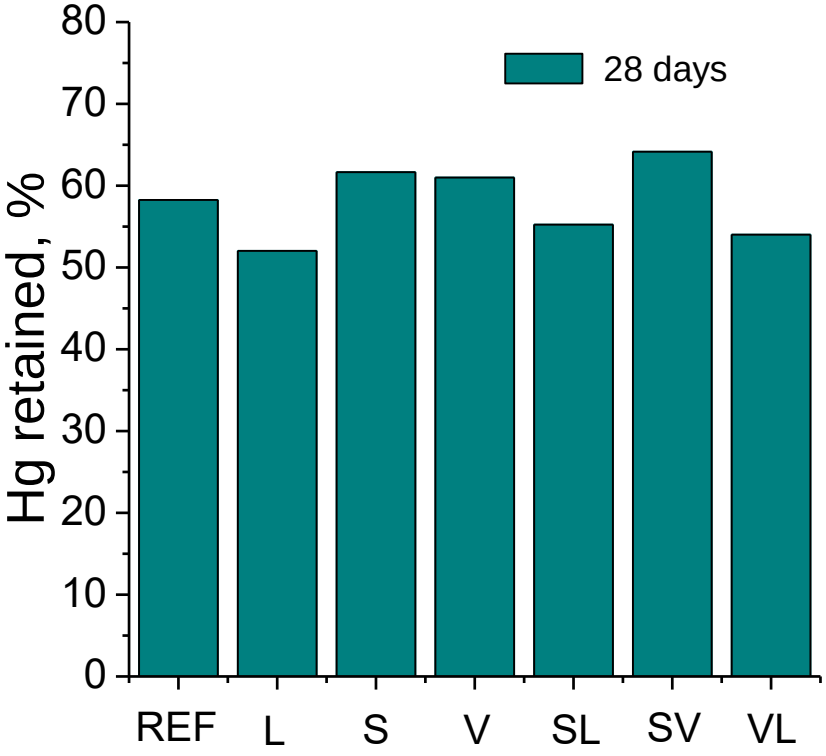
Microstructure

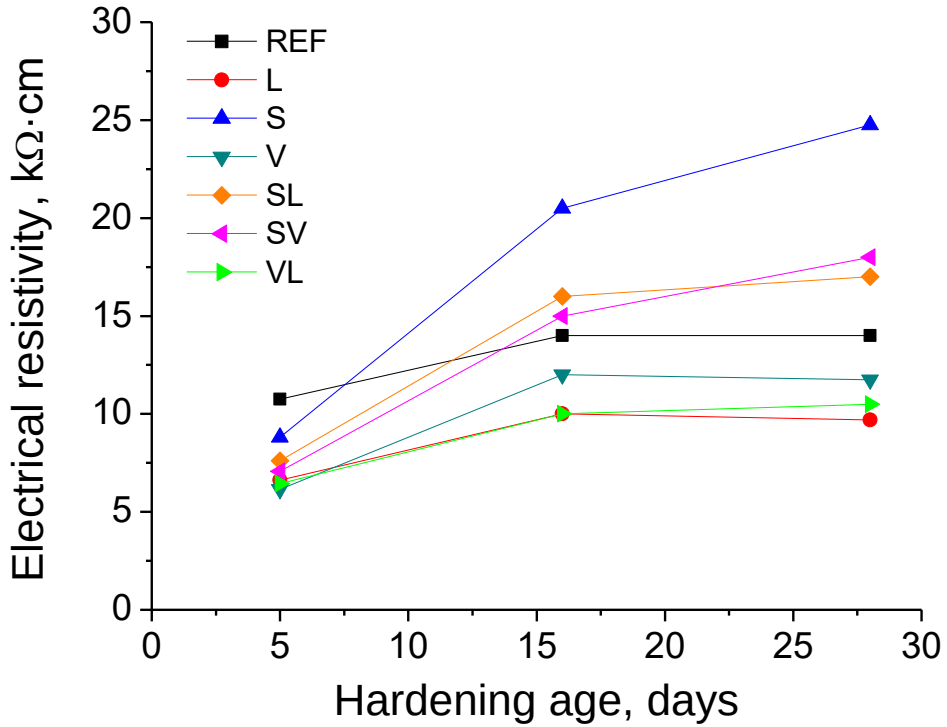




- Total porosity → Lowest for REF and S → Highest for L mortars
- Highest refinement → Series with presence of slag and fly ash
- **Especially noticeable high percentage pores <10 nm for SV**

Microstructure





- Hg retained → Higher for S, V and SV → Lowest for L mortars
- Electrical resistivity → Increasing trends for all
- **Highest electrical resistivity → Binders with slag (S, SV and SL series) → Effects of slag hydration in the short term**

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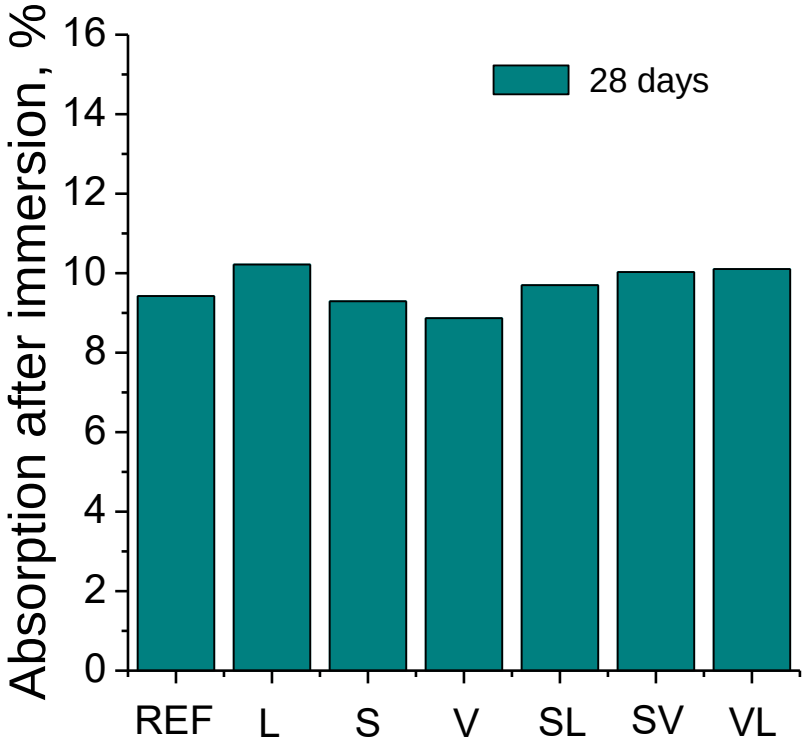
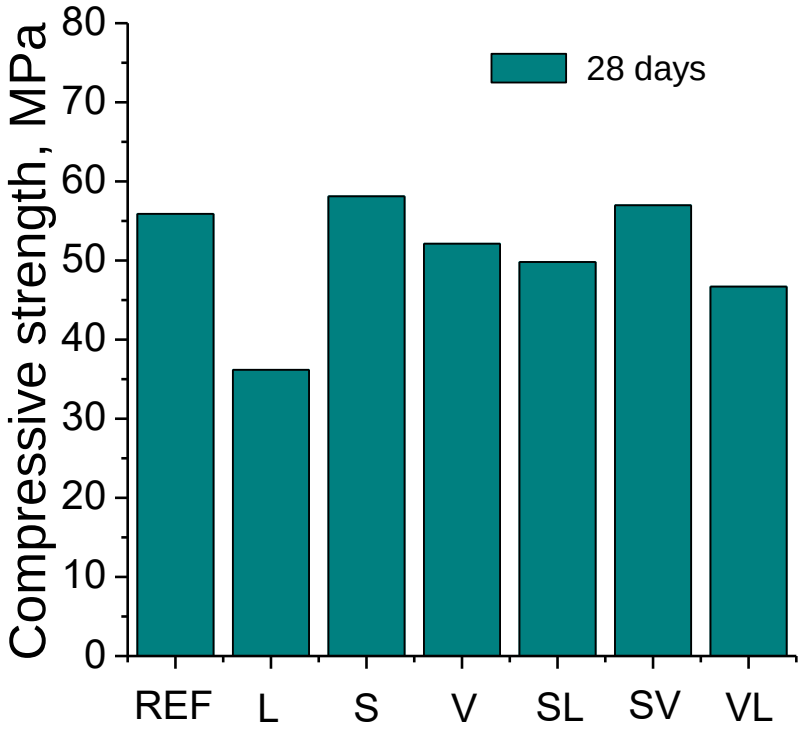
Durability and mechanical properties





- In general, relatively similar absorption for all the studied mortars
- Higher strength for REF, S and SV mortars
- **Good strength performance at 28 days of the ternary binder with both slag and fly ash (SV) → Synergetic effects of both additions**

Conclusions

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Conclusions

- The lowest total porosity values were noted for reference mortars and for those made with binary binder which only contained slag → Development of slag and clinker hydration → Series with higher content of clinker and slag
- The highest total porosity, the lowest pore refinement, the lowest electrical resistivity and the smallest compressive strength → Binary mortars with the only addition of limestone → Not an active addition
- Mortars with fly ash and slag showed higher refinement of microstructure → Especially noticeable for the ternary binder with both slag and fly ash additions → Synergetic effects of combining both additions

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Conclusions

- The absorption after immersion was relatively similar at 28 hardening days for all the mortars studied → Water absorption of the studied binders was overall adequate.

- Compressive strengths → Good performance at 28 hardening days of the ternary binder which combined slag and fly ash → Synergetic effects of slag hydration and fly ash pozzolanic reactions → Improving the strength of the material

- The addition of limestone in the ternary binders entailed a reduction of the compressive strength compared to binary binders only with slag or fly ash.

Acknowledgments

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