

Mineralized spent lime from ceramic tiles industry as a new route for low carbon cements in a circular economy perspective

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CCS4CER project

The Carbon Capture, Storage and CO₂ Mineralization for the Ceramic Industry (CCS4CER) project, coordinated by the Ceramic Center and funded by the European PR-FESR funds of the Emilia-Romagna region, aims to address a dual need in the ceramic sector by:

- enable hard-to-abate industries through technologies for CO₂ capture and storage;
- evaluate which technologies can be implemented on an industrial scale for capturing carbon dioxide.

A mineralization process has been developed to reduce emissions, such as those from ceramic tiles industry, also assessing the possibility of using the mineralized product for the production of low-carbon mortars.



Materials and methods

From a previous characterization of 35 spent limes sampled from 14 ceramic tile companies, **one was selected as representative**. This sample was subjected to mineralization process (by CIRI-FRAME, University of Bologna).

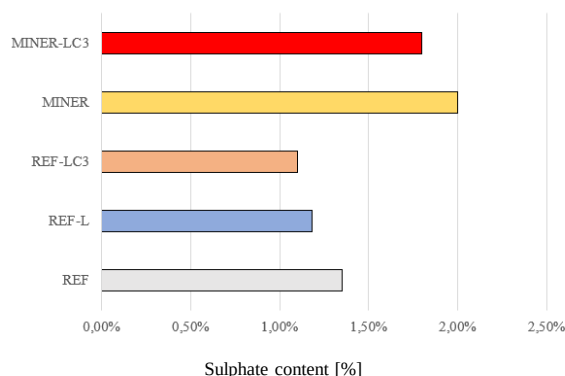
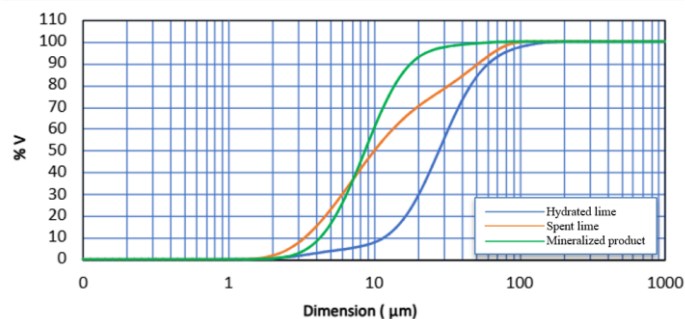
To obtain a comprehensive overview, the selected spent lime and the resulting mineralized product were compared with the original hydrated lime through: **particle size analysis** (Mastersizer 2000, Malvern), **leaching tests** with eluate analysis (Avio 550 Max, Perkin Elmer; 761 Compact IC, Metrohm), **XRD analysis** (model 1820, Philips).

The following **mortars** were prepared:

- **REF**: commercial limestone OPC (CEM II-B/L 32.5R) with 34% CaCO₃;
- **REF-L**: OPC CEM I 52.5 R blended with 34% calcium carbonate;
- **REF-LC3**: limestone calcined clay cement (OPC CEM I 52.5 R + calcined clay + 16% CaCO₃);
- **MINER**: OPC CEM I 52.5 R blended with 34% mineralized product;
- **MINER-LC3**: LC3 system (OPC CEM I 52.5 R + calcined clay + 16% mineralized product).

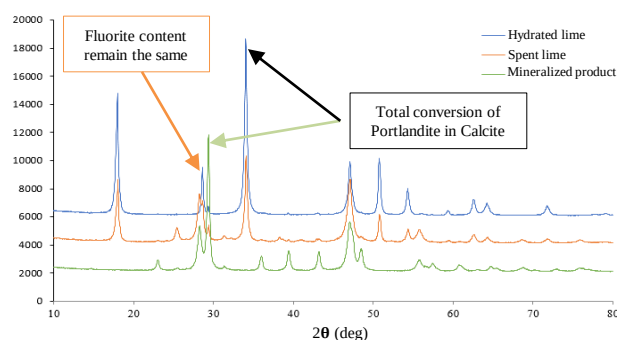
All mortars were prepared according to UNI EN 196-1 (450 g cement, 225 g deionized water, 1350 g standardized CEN sand). For mortars containing the mineralized product, an acrylic additive (0,8-1% w/w) was added to achieve comparable workability with the references.

After 28 days of curing, **compressive strength** (Amsler-Wolpert) and **water absorption** (UNI 7699) were measured. Additionally, in accordance with UNI EN 196-2 and UNI EN 196-3, **initial setting time**, **delayed expansion**, and **sulphate content** were determined.



Abstract

In the Italian ceramic tile industry, spent lime is classified as hazardous waste and commonly landfilled. This study examines the CO₂-mineralization as a route to transform exhaust lime into a non-hazardous filler for low-carbon mortars. Within the CCS4CER project, coordinated by Centro Ceramico and funded by the PR-FESR program of Emilia-Romagna Region, exhaust lime was subjected to CO₂ mineralization and characterized by different techniques. Results confirmed the carbonation of residual portlandite, while the leaching of hazardous pollutants was strongly reduced. The mineralized product was used to formulate two cements: a limestone Portland cement and a limestone calcined clay cement (LC3), with 34% and 16% of mineralized product, respectively. Mortars prepared with the new cements showed compressive strength comparable or even higher than commercial ones, without any significant effect on water absorption, setting time, soundness test and sulphate content.



Results and discussion

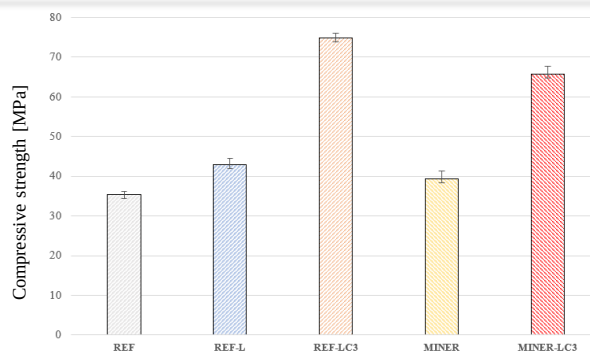
Particle size analysis shows a **progressive reduction** in particle size from hydrated lime to the mineralized product, likely due to physico-chemical transformations occurring during the mineralization process.

At the same time, XRD patterns confirm the **complete transformation** of the Portlandite phase (which is also a significant phase in spent lime) into Calcite phase during the mineralization process, as well as the substantial stability of the Fluorite phase.

Leaching tests (EN 12457) also show a **significant reduction** in heavy metals and soluble ion content in the eluate from spent lime to mineralized product.

Compressive strength tests show that MINER and MINER-LC3 have values **comparable** to the reference samples, confirming the possibility of using the mineralized product as a limestone substitute in cement formulations.

Water absorption tests, initial setting time, soundness, and sulphate content show values slightly higher than the references, but **still fully compliant** with the limits imposed by the EN 197-1 standard for the respective strength classes.



Conclusions and future perspectives

Mortars containing mineralized product showed compressive strengths comparable to the references, confirming the CO₂ capture capability and the possibility of its use as a filler for eco-cements. Further tests (such as initial setting time, water absorption etc.) carried out confirm its suitability for use in low-carbon formulations. Future developments will focus on additional characterization of the mineralized products, but the overall results indicate the potential of spent lime as a resource for circular construction materials with reduced environmental impact.