Recycling of fine industrial waste in geopolymer foam mortar for new insulation materials.

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Introduction

Recently, the interest of companies in recycling waste from the different phases of industrial operations has grown up, in the perspective of an increasingly sustainable and circular economy. Among the waste produced during the manufacture of ornamental and building materials [1], the least recyclable fractions are the **finest** ones, obtained from cutting and polishing operations, which are usually landfilled, with high economic and environmental costs for the company and the society.

In this study we tested the possibility to recycle finest inorganic waste fractions from companies dealing with ornamental stones (marbles and granites) and quartz composites. The aim is to obtain a **lightweight geopolymer mortar** for applications in the construction sector as insulation materials, taking advantage of the properties of geopolymer materials, like low thermal conductivity, good mechanical properties, low environmental impact.

Materials and methods

Two types of fine waste fractions were sampled from the company operation lines and waste deposits (**Fig.1**):

- **slurry (S):** from cutting and polishing operations of ornamental stones of various nature (marbles, limestones, travertines or granites, gneisses)
- **dust (D):** from quartz-composites cutting

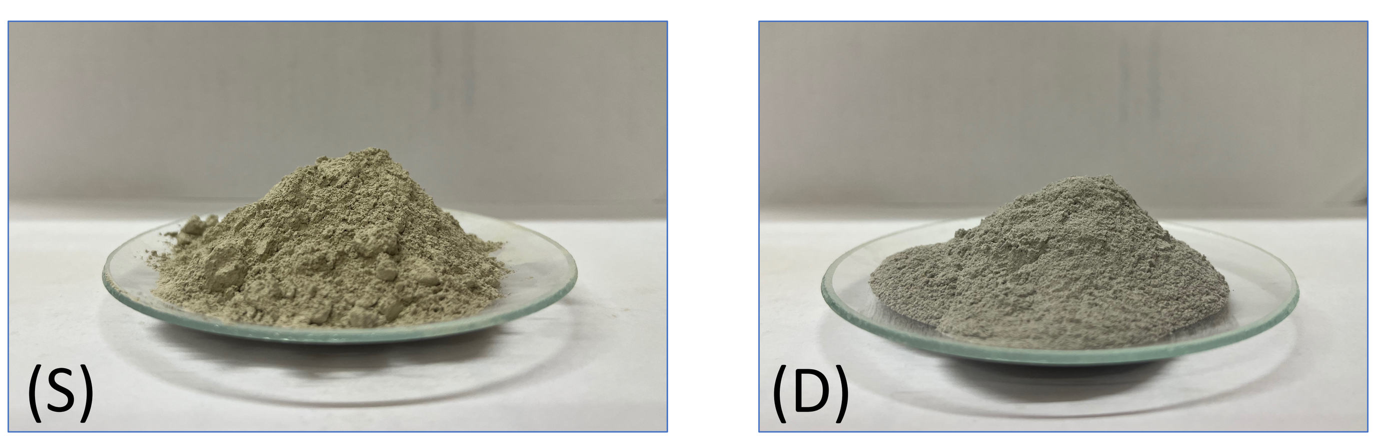

Fig.1 Finest waste fractions used in this study: slurry **(S)** and dust **(D)**.

Preliminary treatment of slurry sample (S): drying in oven at 110 °C for 24 h

Mineralogical characterization by X-Ray Powder Diffraction (XRPD) **Fig.4** and granulometric analysis by wire-mesh sieving **Fig.5**

Geopolymeric synthesis (**Fig.2**) and optical evaluation (**Fig.3**)

Physical and mechanical analysis, flexural - compressive tests (according to EN standards for cement) **Fig.7** and material density (according to ASTM C20-00) **Fig.6** were carried out for each sample;

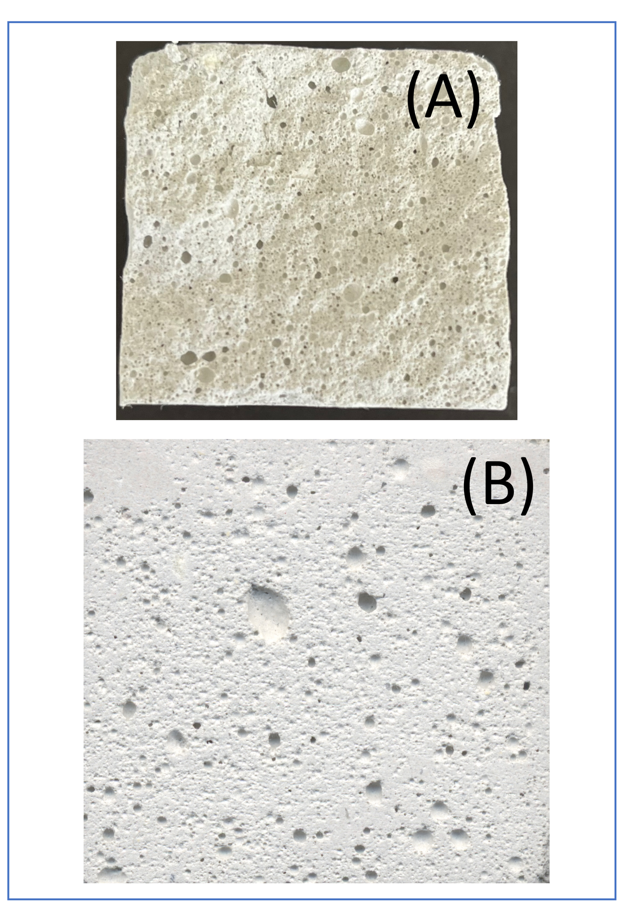

Fig.3 SGP2 **(A)** and polished surface **(B)**.

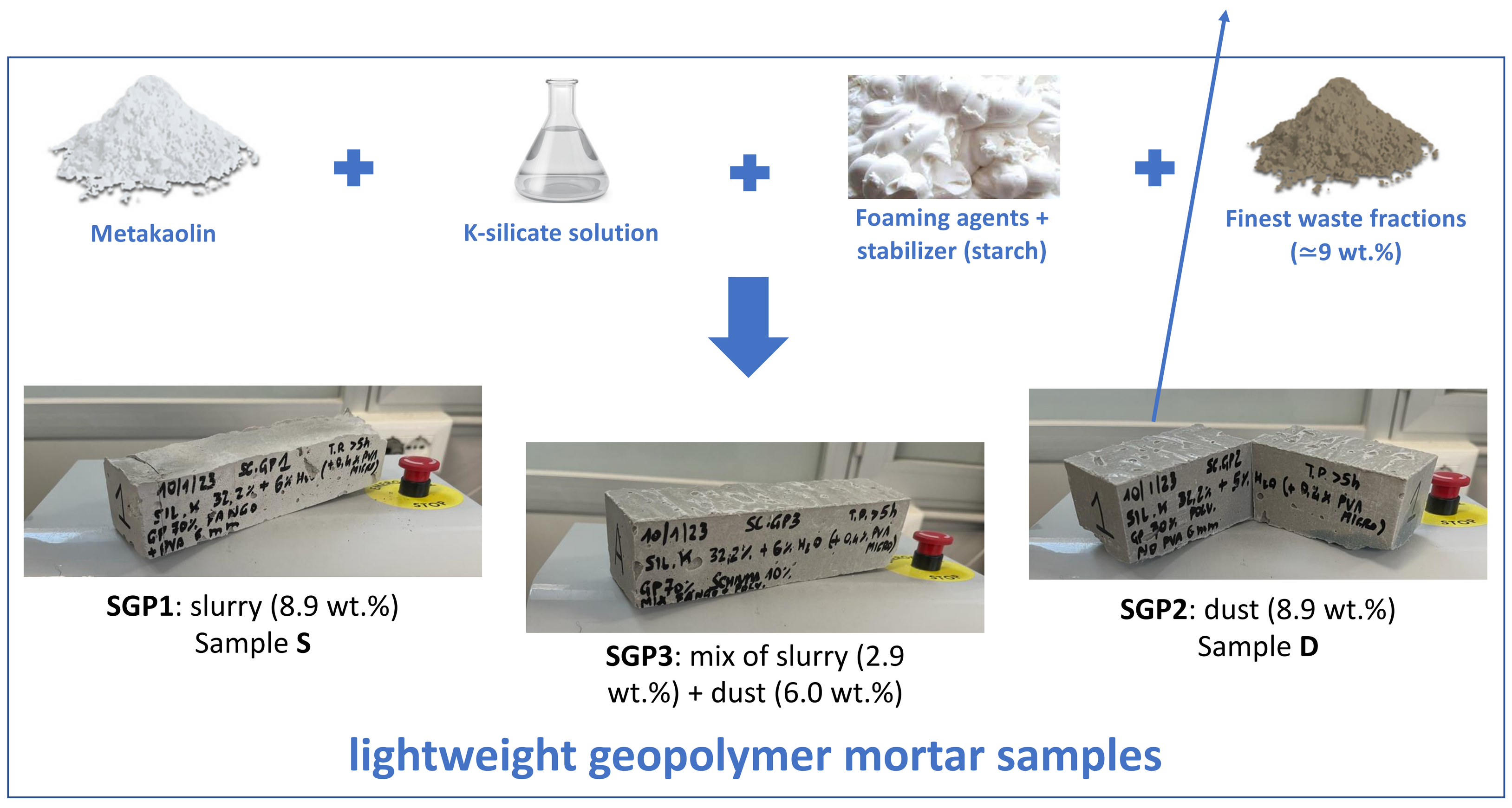

Fig.2 Synthesis of the samples.

References

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Results

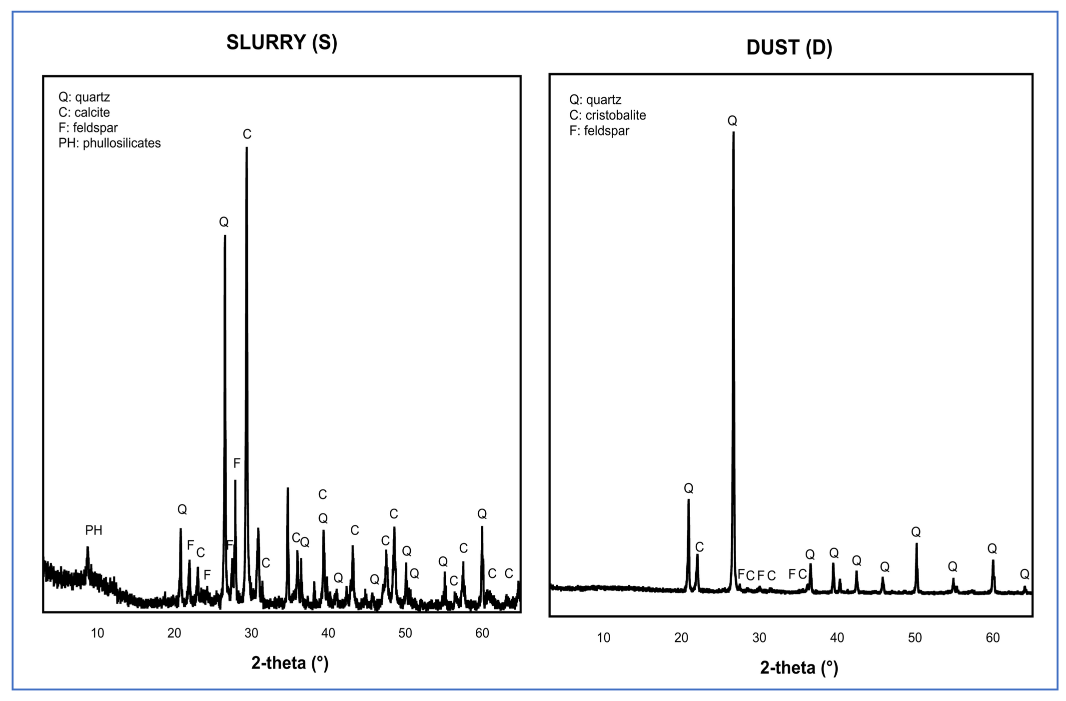

Fig.4 X-Ray Powder Diffraction analysis of Slurry (S) and Dust (D) samples

D waste was collected at the qz-composite line, as reflected in the quartz content. S waste samples have a high heterogeneity in mineral content, varying on the ornamental stones being worked in the company before the sampling, silicate (granites and gneisses) or carbonate rocks (limestones, marbles or travertines).

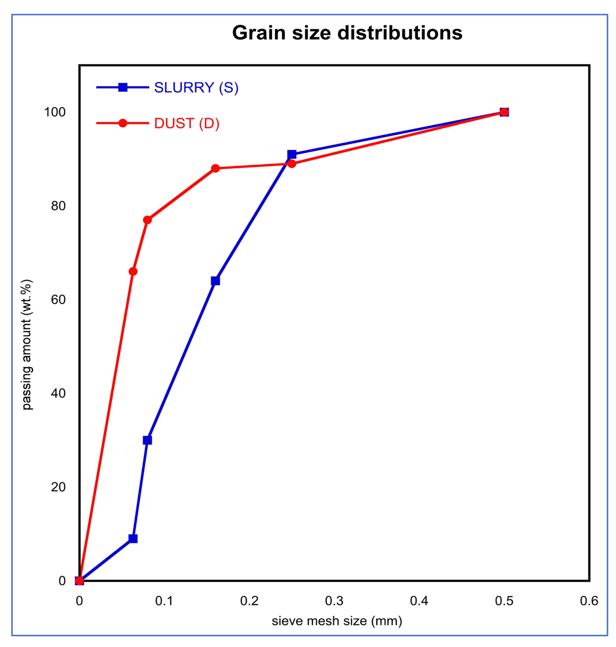

Fig.5 Grain size distribution of the two waste samples.

Particle size of waste samples is < 0.5 mm. The samples were not preliminary grinded. Only S sample, after drying in oven, was disgregated. **Fig. 5** shows that the two samples differ in grainsize distribution: D sample has a larger proportion of < 0.08 mm grainsize range compared to S, whereas in S the fractions 0.5 – 0.08 mm are more abundant than in D.

Density plot evidences the low density of the SGP samples, well below the upper limit for lightweight mortars [UNI-EN206-1:2006]. Other lightweight samples from literature, as samples made of fly-ash+crumb rubber [CR,3] and fly-ash+PET as aggregate [PET, 4] all show density higher than SGP samples. Other samples, with metakaolin + quartz sand or quartz-composites waste as aggregate from the same company [2] are shown for comparison. They all have high density, no foaming agents were used.

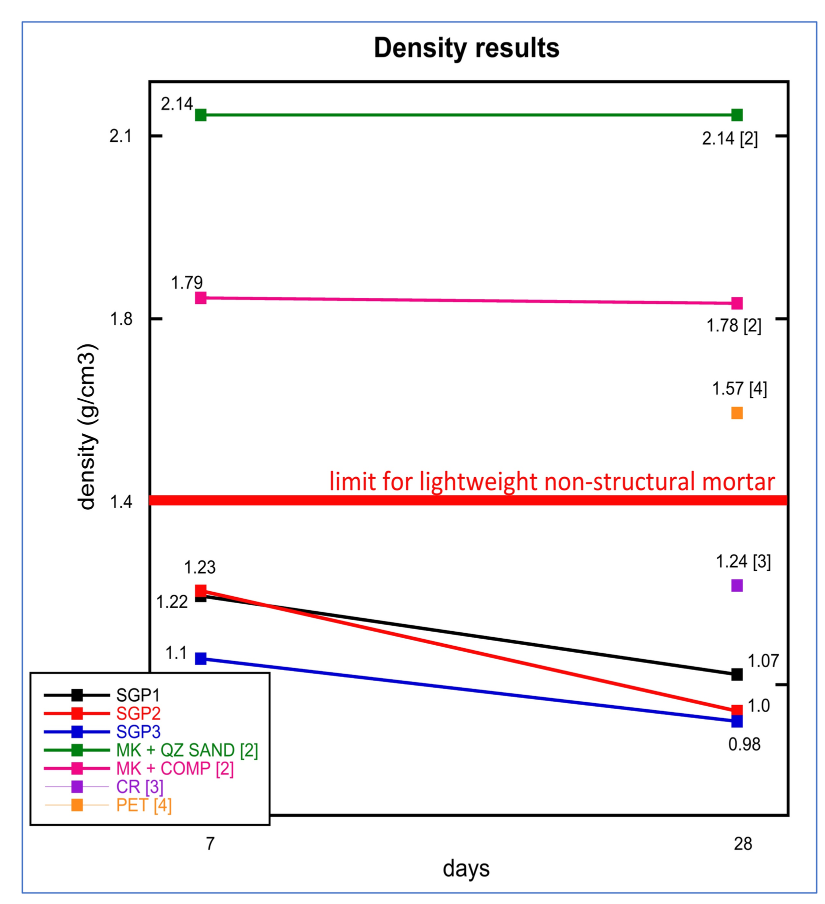

Fig.6 Densities of experimental samples at 7 and 28 days and comparison with literature data.

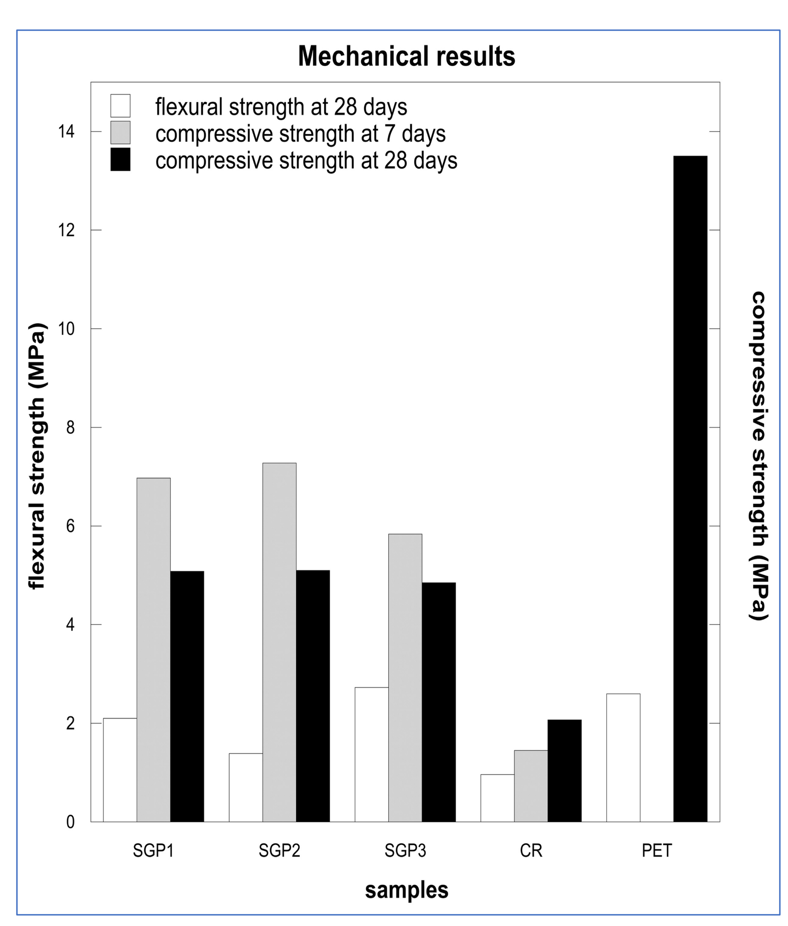

Fig.7 Flexural and compressive strengths at 7 and 28 days. Samples from literature: MK+Qz or Qz composite [2], fly-ash+crumb rubber **CR** [3], fly-ash+**PET** [4].

Mechanical tests at 7 and 28 days **(Fig. 7)** evidence that samples made with only slurry S or dust D (SGP1 and SGP2) show higher value of compressive strength at 7 days, respect to SGP3 (S plus D). At 28 days all three samples have similar values (≃ 5 MPa). SGP3 shows a better performance for flexural strength (2.7 MPa) compared to SG1 and SG2 (2.1 and 1.4 MPa), whereas SG1 is higher than SG2. Comparison with literature data show SGP samples give better results than CR (fly-ash+crumb rubber, [3]) both in flexural and compressive strength, but lower values in compressive strength compared to PET (fly-ash+PET, [4]).

Conclusions

- Density data reaches 0.98 to 1.07 g/cm^3 at 28 days for the three samples, well below the limit for lightweight mortar products (< 1.5 g/cm^3), representing a good starting point for these materials to be used as insulating panels.
- Mechanical properties tests indicate **SGP3** sample obtained good results for flexural test, comparable or higher than other literature lightweight materials.
- Experimental data revealed that the waste (**S**, **D** or **S+D** mix) can be easily mixed together, obtaining similar results in terms of density and mechanical properties. This makes the recycling of these very fine fraction easier and economically interesting for the company.
- Finest inorganic waste components could be interesting for circular economy and applications in the construction sector.