MANAGEMENT OF VOLCANIC MINERAL SCRAPS: VALORIZATION INTO CONSTRUCTION MATERIALS

F. Altimari*[1](fabiana.altimari@unimore.it), I. Lancellotti[1], F. Andreola[1], H. Elsayed[2], E. Bernardo[2], B. Maggi[3], L. Barbieri[1]

[1]*Department of Engineering "Enzo Ferrari", University of Modena and Reggio Emilia, via Vivarelli, 10, 41125 Modena, Italy*

[2]*Department of Industrial Engineering, University of Padova, Via Marzolo, 9, 35131 Padova, Italy*

[3]*EuroPomice srl, Via Napo Torriani 1, 20124, Milano, Italy*

QUARRY SCRAPS PROBLEM

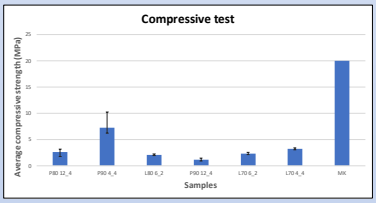
In *the Vulsini* Volcanic District (Italy) there are deposits of minerals such as pumice, lapillus and feldspathic sands of considerable commercial interest in a wide range of sectors with the exception of the extraction residue (ϕ < 3 mm), which do not find an adequate marketing and involves additional costs and charges.

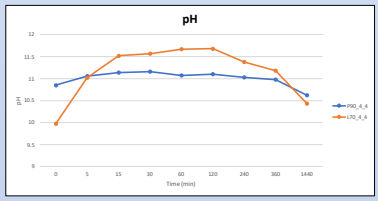
Nevertheless, the attention toward the development of new materials with specific performances and environmental friendly for both raw materials and technologies of fabrication, is of great interest. Limited to construction, one of the most expanded sector in the world, there is a great interest on lightweight materials that can also be used in niche or expanding sectors (green infrastructures such as green roofs or vertical forests, for example). Among the materials with very interesting potentialities and which can good tolerate the presence of recycling fractions we find geopolymers and expanded products (foams and aggregates).

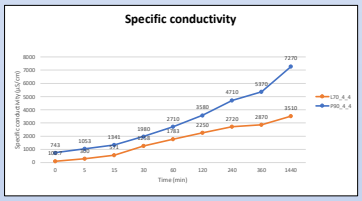
GEOPOLYMERS

The present study focused on the formulation, by cold chemical consolidation, of new products containing pumice or lapillus, in high percentages, in addition to metakaolin and activated via $NaAlO_2$ and NaOH solutions. The geopolymers obtained were characterized by means of the integrity test, to assess the behavior of the sample when totally immersed in water; the compressive strength test, performed on cubic samples of known dimensions; the measurement of pH and specific conductivity at given times, with a sample/water weight ratio of 1:10, to assess chemical stability. A geopolymer with high percentages of pumice that presented an average compression strength of 7.3 MPa, and another lapillus-containing with low resistance values were obtained. Lapillus-based geopolymer is more stable in terms of ions released in water but showed poor mechanical strength, most likely due to the lower reactivity of the starting material, having a low percentage of glass. Pumice-based geopolymer in water produced more ions than those with lapillus but showed higher compressive strength values and this could be due to a high percentage of amorphous fraction. Both samples showed rather stable pH values over time. The resulting geopolymer is porous and therefore lightweight and could be used for vertical coatings in indoor applications, partially replacing cement as a building material.

Each sample was identified with an abbreviation: the first letter indicates the raw material used, P identifies pumice and L identifies lapillus, the next two digits indicate the percentage by weight of total raw material powders used, e.g. P90 indicates 90 per cent pumice to total weight of solid components (the remaining quantity is metakaolin), the last two digits represent the quantities of reagents inserted, the first identifies sodium hydroxide and the second sodium aluminate.



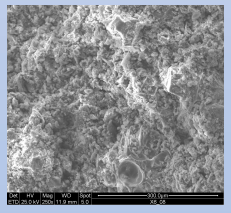




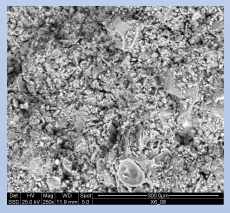
GEOPOLYMERIC MORTAR

Geopolymer mortars were produced using lapillus or Tessennano sands as aggregates, pumice or metakaolin as binders and Na_2SiO_3 and NaOH solutions as activators. Only the samples containing metakaolin were subjected to the integrity test and afterwards, to the compressive strength test with two cubic specimens with the same dimensions, the results showed an average compressive strength value of 2.57 MPa. SEM analysis shows the development of the geopolymer structure. The other samples were not tested because the polymerisation reaction had not started. The following images represent the internal structure of the geopolymer mortar made from metakaolin (binder), Tessennano sand (aggregate) and the activating solution. The presence of aggregate grains can be seen, which is better visible in BSE mode, especially at 2000x magnification.

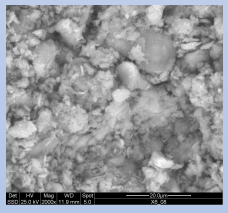
SEM image of the sample at 250x magnification captured in secondary electron (SE) mode



SEM image of the sample at 250x magnification captured in backscattered electron mode (BSE)



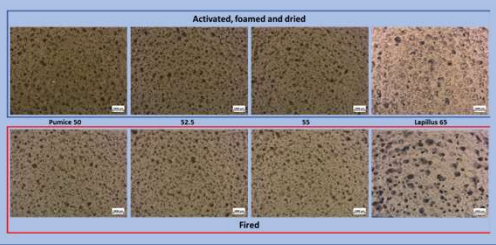
SEM image of the sample at 2000x magnification captured in BSE mode



INORGANIC FOAMS

Pumice and volcanic lapillus were easily converted into highly porous foams, by intensive mechanical stirring of suspensions in alkaline solutions, at the early stages of gelation, with the help of surfactants. Powders (<100 μm) were suspended in 3M NaOH aqueous solutions, for a solid load of 50-65 wt%, and were subjected to alkaline attack. The suspensions were first fortified with 4wt% Triton X-100 (polyoxyethylene octylphenylether - $C_{14}H_{22}O(C_2H_4O)_n$, n=9-10), then foamed by vigorous mechanical agitation (2000 rpm). The foamed gels were kept at 75°C for 72 hours, to complete polymerisation, before being unmoulded. Samples were subjected to optical stereomicroscopy, density determination (geometric density from mass/volume ratio, bulk and real density from He pycnometry on whole and powdered samples, respectively) and compression tests. The higher reactivity of pumice led to foams with far higher compressive strength than those from lapillus.

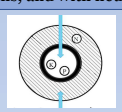
Optical stereomicroscopy images of inorganic foams from volcanic materials



Material/Solid loading	Activated, foamed and dried samples				Fired samples			
	ρ_{geom} (g/cm^3)	Total P (vol%)	Open P (vol%)	σ_{comp} (MPa)	ρ_{geom} (g/cm^3)	Total P (vol%)	Open P (vol%)	σ_{comp} (MPa)
P 50	0.65 ± 0.04	73.5	70.8	1.26 ± 0.09	0.66 ± 0.03	74.7	72.4	4.08 ± 0.16
P 52.5	0.66 ± 0.04	72.4	71.2	0.94 ± 0.06	0.64 ± 0.03	75.1	73.0	2.59 ± 0.11
P 55	0.64 ± 0.04	73.7	73.0	0.61 ± 0.04	0.59± 0.03	77.4	75.9	1.27 ± 0.09
L 65	0.60 ± 0.03	77.6	78.1	0.10 ± 0.04	0.64 ± 0.04	82.5	82.0	0.10 ± 0.03

EXPANDED CLAY AGGREGATES

Expanded clay aggregates are promising materials that maintain their characteristics over time, do not release toxic substances, do not disperse fibers or particles, do not require stabilizing treatments and are used in the agricultural, construction and road sectors and as materials with sound-absorbing performance, fire, mechanical and thermal resistance. Two groups of spherical-shaped materials were obtained by flash powder sintering at 1000 °C: a) lightweight aggregates with a draining effect based on 85 parts of mineral components (clay, pumice, lapillus) and 15 parts of porous agent (spent coffee grounds); b) a core-shell aggregate made up of selected compositions of previous matrix added with potassium carbonate and ashes of bovine bone meal, through a fertilizing glass or as they were, in the core, and degreased Black soldier fly larvae, adherent to the surface of the granulate, to create a slow release NPK fertilizer. The specimens resulted porous and light (porosity around 60%), with good capacity of water retains, and with neutral pH and conductivity values below 2 dS/m, indicating a possible use for substrate (growing layer) in roof gardens, green roofs, house gardens, etc..



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