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Materiali innovativi per uno sviluppo sostenibile: dal laboratorio alle applicazioni

The effect of fibres on geopolymers made using Mt. Etna volcanic ash: a preliminary study

Zafarana S. E. ([a])*, Barone G. ([a]), Occhipinti R. ([a]) & Mazzoleni P. ([a])

([a]) Department of Biological, Geological and Environmental Sciences, University of Catania, Italy

* Presenting author: sabrina.zafarana@phd.unict.it

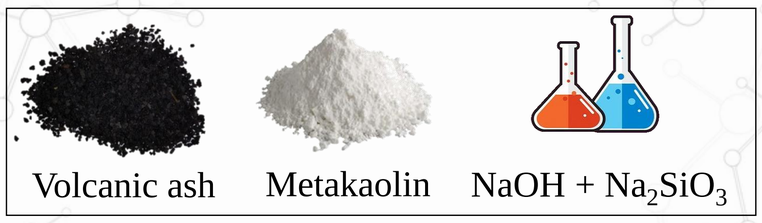
Introduction

The awareness of environmental issues has led to the development of eco-friendly materials that could combine high performance products with the possibility of the re-use of waste materials.
Geopolymers have favourable properties such as low curing temperature, recyclability and low cost of the precursors, making them a valid alternative to traditional OPC.
Despite these excellent qualities their brittle behaviour imposes constraints in structural design. To enhance the strength of the geopolymer matrix, both organic and synthetic fibres can be added to the geopolymeric matrices.
This research, funded by the PNR "Advanced Green Materials for Cultural Heritage" project aims to develop natural fibre-reinforced geopolymers for retrofitting seismic areas.

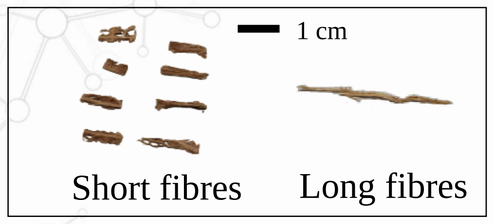
Materials

Geopolymers were prepared using formulations taken from literature [1]. The employed precursors are volcanic ash and metakaolin while the alkaline solution used was made of sodium hydroxide and sodium silicate. Then, organic prickly pear, palm tree and inorganic carbon fibres were selected and added in two different lengths: 10 mm (short) and 40/60 mm (long). Short fibres were added to the geopolymeric matrix by using a mechanical mixer while a sandwich-like disposition was chosen for the long fibres. The samples (2x2x8 cm) were cured at room temperature for 28 days.

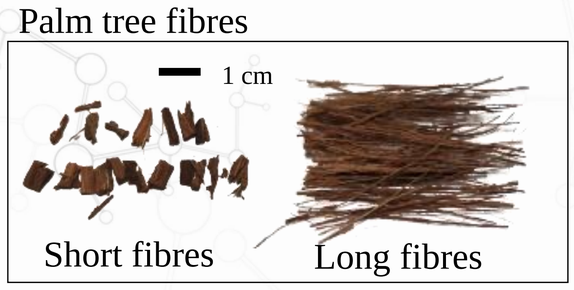
Precursors & Alkaline solution



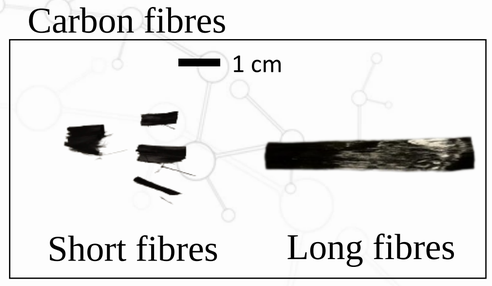
Prickly pear fibres



Palm tree fibres



Carbon fibres



Methods

Flexural and compressive strength tests were carried out in order to compare the mechanical behaviour of the samples with and without fibres. Moreover Scanning Electron Microscope (SEM) was used to evaluate the adhesion of the fibres to the geopolymeric matrix.

Results

Mechanical tests

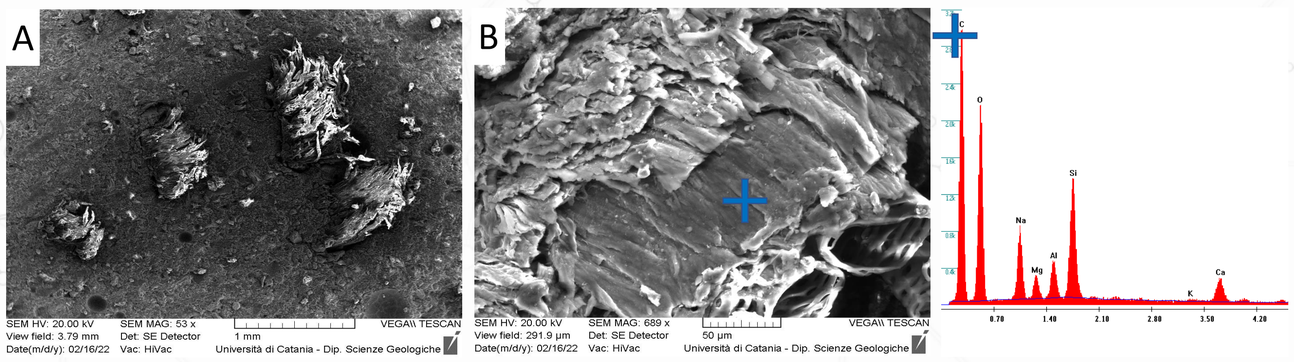
The addition of long palm and short carbon fibres to the geopolymeric matrix led to a substantial increase in flexural strength resistance if compared with samples without fibres. Otherwise prickly pear fibres negatively affected the flexural strength of the samples.

Sample	Flexural Strength [MPa]	Standard Deviation
Prickly pear (short)	5,63	0,38
Prickly pear (long)	5,06	0,60
Palm tree (short)	7,59	0,72
Palm tree (long)	12,63	3,06
Carbon (short)	23,19	3,82
Carbon (long)	8,42	2,21
Without fibres	8	-----

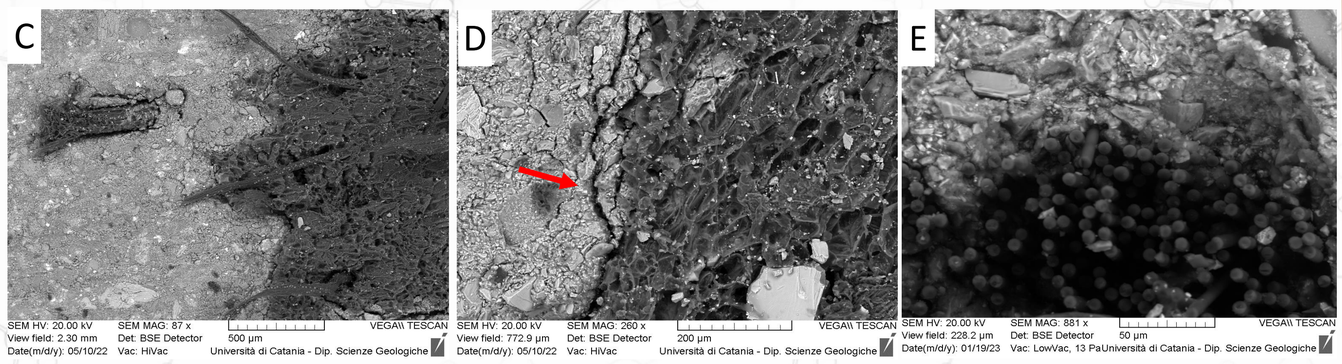
The addition of fibres brought to a drop in compressive strength resistance of about 50% if compared to geopolymer without fibres. This drop is due to the interruption of the geopolymeric structure caused by the fibres which imply a decrease in strength.

Samples	Compressive Strength [MPa]	Standard Deviation
Prickly pear (short)	22,86	5,19
Prickly pear (long)	25,44	2,68
Palm tree (short)	24,09	3,21
Palm tree (long)	23,50	5,74
Carbon (short)	38,44	3,58
Carbon (long)	24,47	0,06
Without fibres	45	-----

Scanning Electron Microscope



SEM images of samples made with prickly pear fibres (A-B). Image A shows the fibres perfectly enwrapped by the matrix. Image B shows the geopolymeric matrix on the top and the fibre on the bottom of the picture.



SEM-EDS images of samples made with palm tree (C-D) and carbon fibres (E). Image C shows a transition zone between palm tree fibres and the geopolymeric matrix. At that magnification the fibres seem to have an acceptable adhesion to the matrix. Image E, which is a magnification of image D, reports the existence of a fracture located in the geopolymeric matrix. The nature of these fractures is still under study. Image E shows a detail of the carbon fibres and the geopolymeric matrix.

Conclusion

Three types of fibres (both organic and inorganic) in different length were used to reinforce Mt. Etna volcanic ash-based geopolymers. Preliminary tests have shown that the addition of fibres enhances the flexural properties, reduces the brittle fracture and the shrinkage of the material. Otherwise, the results achieved by the compressive strength tests revealed a significant reduction in resistance due to the presence of the fibres.

References

[1] Barone, G., Caggiani, M. C., Coccato, A., Finocchiaro, C., Fugazzotto, M., Lanzafame, G., ... & Mazzoleni, P. (2020). Geopolymer production for conservation-restoration using Sicilian raw materials: feasibility studies. IOP Conf. Ser.: Mat. Sci. & Eng. 777, 012001.