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Materiali innovativi per uno sviluppo sostenibile: dal laboratorio alle applicazioni

# Strength and durability studies on Mt. Etna volcanic precursors-based geopolymers

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## Introduction

Since ancient times, pyroclastic materials from **Mt. Etna volcano** such as volcanic ash and ghiara (an iron rich paleosoil) have been used as aggregates of mortars and plasters in Catania architecture. In recent years, these volcanic pyroclastic residues have been widely employed as feedstocks in the **alkali activation process** [1, 2]. Within the project entitled "Advanced Green Materials for Cultural Heritage", local materials and industrial wastes have been valorized through the alkali activation technology. Alkali Activated Materials (AAMs) are considered as components of the future "sustainable" cement-based system in response to growing global concerns over $CO_2$ emissions from the construction sector [3].

### AIM of the WORK

In the optic of building and restoration applications, **strength and durability** of volcanic ash and ghiara-based geopolymer (binders and mortars) have been investigated in terms of structure degradation, efflorescences development and water moisture transfer after being exposed to **natural weathering** [2].

## Experimental

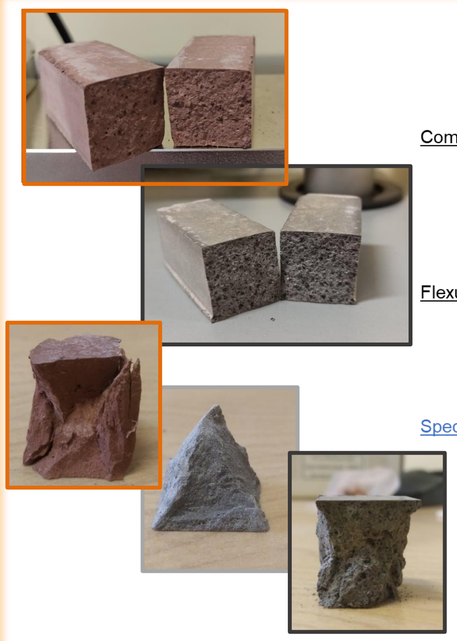
According to [2], binary mixtures of **volcanic ash/ghiara** and of commercial metakaolin (20%wt) were used as precursors. Sodium silicate and sodium hydroxide were used as alkali activators ($Na_2SiO_3$/NaOH =1.7) Two fractions of ghiara and volcanic lapilli ($2 < \phi < 0.075$ mm) were added to the binders in order to obtain **mortars**.
Samples were cured of 28 days @ 25°C.

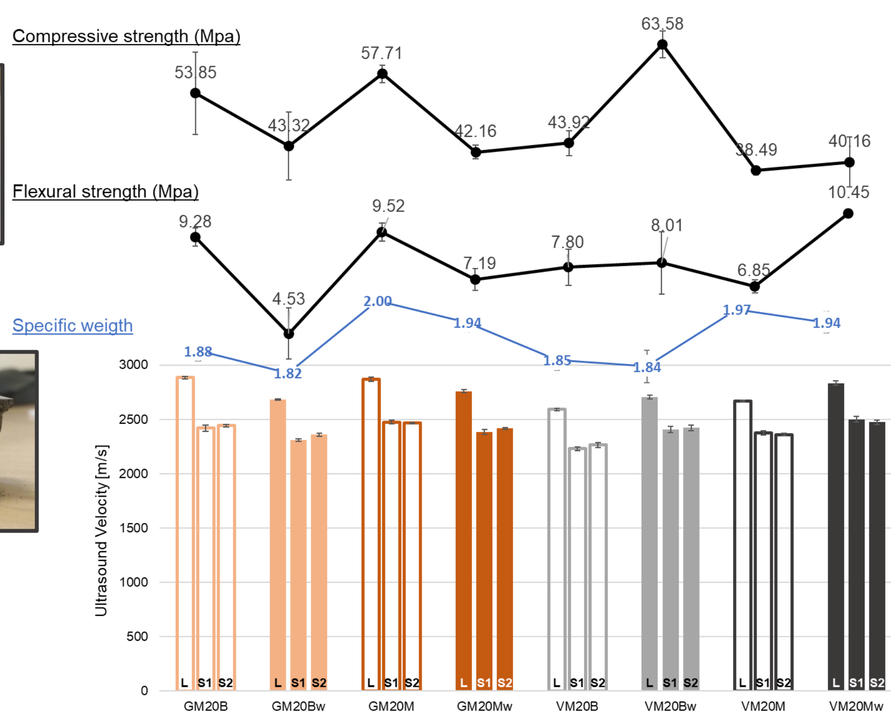
*3 replicas of each sample were exposed outdoor*


### Methods

- Compressive and Flexural strength
- Ultrasound Pulse Velocity (UPV)
- Specific weight
- Brazilian Disk (BD)
- Digital Image Correlation (DIC)
- Dynamic Vapor Sorption (DVS)

## Results






Volcanic ash-based binders
Volcanic ash-based mortars
*Ghiara* based binders
*Ghiara* based mortars
Unexposed samples
Exposed samples

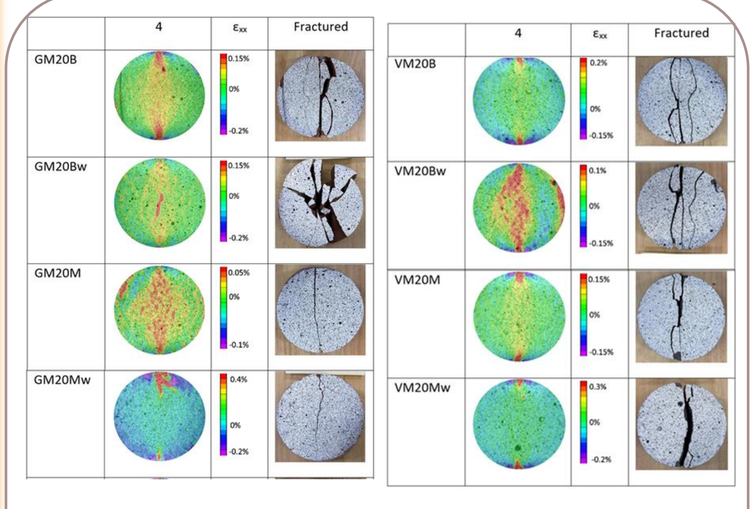
### Mechanical strength – UPV - Specific weight

In both volcanic ash and ghiara series, the relationships between the average values of UPV are consistent with those of the respective flexural and compressive strength data.

**ADDITION OF AGGREGATES:**
It does not significantly affect the mechanical strength and the specific weight values. However, the values of the **velocities recorded increase** with the addition of the aggregates that could be explained by an increase in heterogeneity.

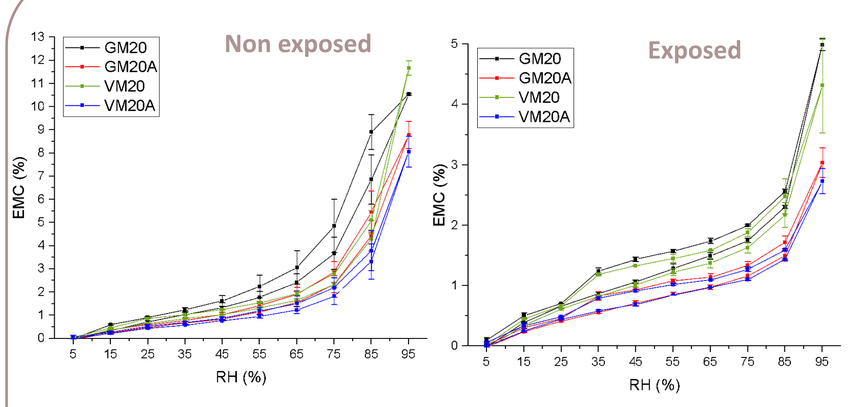
**EFFECT OF WEATHERING:**
The exposed **ash-based geopolymers** (VM series) show an increase of the mechanical strength and UPV while **ghiara-based ones** (GM series) show an opposite behavior. Despite this, the UPV values are in accordance with the flexural and compressive strength values, confirming the relation of this physical property with mechanical strength: within each series, higher UPV correspond to higher mechanical strength values, even though for some samples, high errors values must be taken into account. Moreover, for both groups (VM and GM), fresh and weathered, differences in UPV measured along the three axes (two shorter and one longer) were observed due to the attenuation caused by the anisotropy of the matrices (voids, cracks, and aggregate grains).

### Brazilian Disk Test




The comparison of the peak load and peak stress values from BD test among the different groups of samples leads to the observation that **ghiara binder performance worsens after exposure**, in accordance with UPV and compressive and flexural strength and after addition of aggregates too.

### DVS




Specific weight, UPV and mechanical strength are also strictly related to the **presence of soluble phases** (e.g. salts) that are dissolved and leached out after exposure [2], increasing the total mass amount of the non-exposed samples.
For **non-exposed samples**, the graduality of the adsorption-desorption process over time may indicate that the materials themselves are still somehow reactive and not totally stable.

For **exposed samples**, DVS measurements clearly showed how the **weathering process strongly influences the sorption-desorption properties** of the materials, reducing the maxima EMC values to less than half of what is found for unexposed samples. Looking at the EMC and RH% change over time, it can be observed that the materials after exposure have reached a higher degree of stability and are thus less reactive in presence of different relative amounts of moisture. On the other hand, from the hysteresis curves maxima, it can be inferred that the 35-55% RH, is the RH% interval to pay attention to when these materials are in use.

## Conclusions

The **innovative combination** of ultrasound pulse velocity and dynamic vapour sorption applied to the study of naturally weathered geopolymers proved **effective** to study structural properties of the materials and the moisture sorption behaviour of these building materials.
All the data collected in this study on unexposed and exposed samples seem to converge towards confirming a **better response of the volcanic ash-based geopolymers** to the natural exposure to atmospheric agents in the Catania climate, representative of hot summer Mediterranean zone, probably assisted by a better compaction of the matrix as the reaction proceeds.
Ghiara-based products, instead, already showing some mixing difficulties during their preparation, are more affected by exposure conditions.

**References:**
[1] G. Barone et al., 2021, Potentiality of the Use of Pyroclastic Volcanic Residues in the Production of Alkali Activated Material, Waste and Biomass Valorization. 12 1075–1094.
[2] R. Occhipinti, 2022, Effect of atmospheric exposure on alkali activated binders and mortars from Mt. Etna volcanic precursors, Mater. Lett. 315, 131940.
[3] J.L. Provis, 2018 Alkali-activated materials, Cem. Concr. Res. 114, 40–48.