Evaluation of the porosity of one-part alkali-activated materials based on volcanic ash and its influence on the decay by salt crystallization

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INTRODUCTION

A new approach is required to move towards a circular economy where waste is used. In this context, alkali-activated materials (AAMs) are gaining attention as a promising alternative to traditional building materials. AAMs are manufactured by the combination of a pulverized aluminosilicate precursor and an alkaline solution at low-temperature (<100°C) and can utilize natural and industrial waste precursors, making them a sustainable option for the construction industry (Provis & Van Deventer, 2014). In general, alkali-activated process aligns with the European policy of promoting an Ecological Transition towards environmental sustainability, which emphasizes the need for sustainable industrial processes and reduced exploitation of natural resources. Currently, volcanic ash has been considered a waste material with high management costs. However, in recent years, researchers have been exploring the feasibility of using volcanic ash from Mt. Etna (Italy) for building and restoration purposes in an alkaline environment. This approach involves using the ash as a two-part system with promising results in various researches (Finocchiaro et al., 2022; Fugazzotto et al., 2023). In this study, one-part volcanic ash-AAMs was analysed to evaluate the porosity and its influence on the decay by salt crystallization.

MATERIALS AND METHODS

One-part volcanic ash-AAMs samples were prepared using volcanic ash, metakaolin, sodium hydroxide and silicate at solid state. The mixing was performed using only tap water, whose mixture was used to fill cubic moulds of 4 cm in length. The investigation involved performing hydric tests (free and forced water absorption, and drying tests) according to UNE-EN 13755 and NORMAL 29/88 standards, and mercury intrusion porosimetry (MIP) using a Micromeritics Auto-pore IV 9500 porosimeter. Ultrasound was employed to assess the compactness of AAMs samples by using a Controls 58-E4800 ultrasonic pulse velocity tester. The direct method specified in accordance with the ASTM D2845 standard was utilized to measure the propagation of P-waves in the three orthogonal directions of cubic samples. Furthermore, the sample set was subjected to fifteen salt crystallization cycles to simulate the decay resulting from the dissolution and recrystallization of $Na_2SO_4 \cdot 10H_2O$ within their porous systems following the UNE-EN 12370 standard.

RESULTS

Fig. 1 shows the main results concerning the hydric (a) and MIP (b) tests. AAM-samples evidence a slow and little absorption capacity. In the step of forced water absorption, the set displays a typical behaviour of tortuous porosity (Cultrone et al., 2005). Moreover, the saturation is contrasted to a very slow drying achieved after around three weeks (Fig. 1a). The MIP results evidence an average of 2.0 (g/cm^3) of apparent density and 20% of accessible porosity, while the main pore size is ranged between 0.01 and 0.1 µm (Fig. 1b). The salt crystallization cycles do not highlight significant weight loss, despite the sample set is characterized by very low pore sizes. The ultrasound results display an average velocity of 2430 m/s, in accordance with the range found in the literature related to metakaolin-geopolymer (Ghosh et al., 2018).

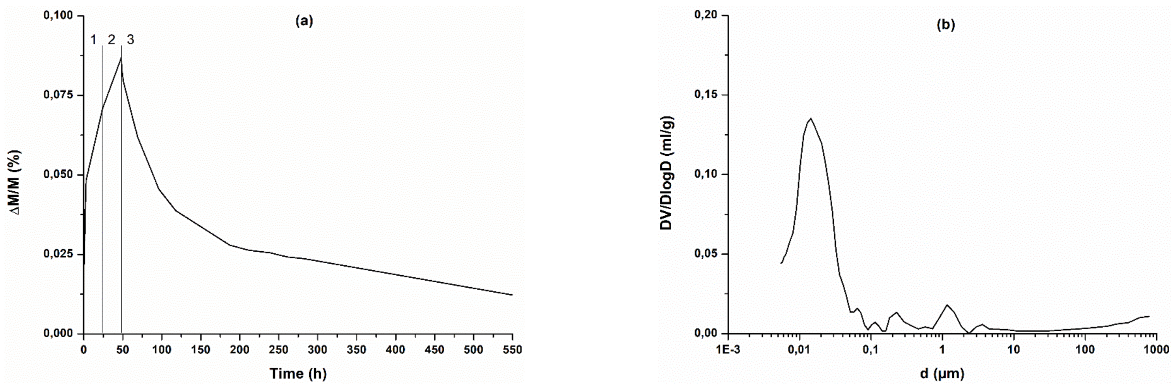

Fig 1*. Pore system of synthetized materials:* ***(a)*** *hydric and* ***(b)*** *pore size distribution results.*

CONCLUSIONS

The proposed methodological approach was useful to define the microstructural features of these synthesized materials to assess their decay behaviour. Indeed, the obtained results highlight small size of pores, confirmed, also, by the slow absorption-drying cycles recorded during the hydric tests. This behaviour can be due to the interaction of matrix's sample and water which produces the formation of a gel inside the pores which hampers the drying. The salt ageing test evidences an excellent resistance to salt crystallization. Therefore, they can represent a potential eco-friendly material for building and restoration interventions with a simplified mixing procedure contrary to the common two-part AAMs, representing thus an adding value for this material class.

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REFERENCES

ASTM D2845, Standard Test Method for Laboratory Determination of Pulse Velocities and Ultrasonic Elastic Constant of Rock, American Society for Testing and Materials, USA, 2005.

Cultrone, G., Sebastian, E., de la Torre, M.J. (2005): Mineralogical and physical behaviour of solid bricks with additives, Construction and Building Materials. **19**, 39–48. DOI: 10.1016/j.conbuildmat.2004.04.035.

Finocchiaro, C., Belfiore, C.M., Barone, G., Mazzoleni, P. (2022): IR-Thermography as a non-destructive tool to derive indirect information on the physical-mechanical behaviour of alkali activated materials, Ceram. Int. DOI: 10.1016/J.CERAMINT.2022.08.174.

Fugazzotto, M., Occhipinti, R., Caggiani, M. C., Coccato, A., Finocchiaro, C., Lanzafame, G., Mazzoleni, P., Nucatolo, G., Piacenti, G., Starinieri, S., Stroscio, A., Barone, G. (2023): Restoration feasibility study by using alkali activated mortars based on Mt. Etna volcanic ash: The case study of Monreale Cathedral (Palermo, Italy), Mater. Lett., **333**, 133626. DOI: 10.1016/J.MATLET.2022.133626.

Ghosh, R., Sagar, P.S., Kumar, A., Kumar Gupta, S., Kumar, S. (2018): Estimation of geopolymer concrete strength from ultrasonic pulse velocity (UPV) using high power pulser. Journal of Building Engineering, **16**, 39-44. DOI: 10.1016/j.jobe.2017.12.009.

NORMAL 29/88, Misura dell'indice di asciugamento (drying index), ICR-CNR, Rome, Italy, 1988.

Provis, J.L. & Van Deventer J.S.J. (2014): Alkali Activated Materials: State-of-the-art Report, RILEM TC 224-AAM. DOI: 10.1007/978-94-007-7672-2.

UNE-EN 12370, Natural Stone Test Methods. Determination of Resistance to Salt Crystallization, AENOR, Madrid, Spain, 2020.

UNE-EN 13755, Natural Stone Test Methods. Determination of Water Absorption at Atmospheric Pressure, AENOR, Madrid, Spain, 2008.