Earth-based composites for 3D printing: numerical design and optimisation

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ABSTRACT

Earth is one of the oldest and, until now, intensively used natural building material. Recently, the use of earth materials in contemporary buildings have aroused interest, including in Europe, mainly due to its eco-efficiency and abundance. However, making earth construction a regular building practice is a significant challenge. Thus, the scientific community needs to strengthen confidence in earth construction and adapt it to current technologies. New digital production technologies can unblock the potential of vernacular materials, such as earth, as a future building material.

This work deals with combining a very traditional building material – earth – with high-tech advancements in fabrication and application methods, the 3D printing. From the perspective of materials science, earth-based printable composites (3DPearth) mix-proportioning are critical issues, namely due to i) the requirements at fresh state; ii) the needing of adequate stabilisation; iii) the raw material natural variations asking for its characterisation.

A statistical factorial design approach was followed to reach printable 3DPearth by means of a central composite design. The 3DPearth mixtures consisted of a pre-defined range of proportions, including Turkish silty soil as the main constituent and were stabilised by a binary blend of cement and limestone, also locally available, water and superplasticiser. Slump test, Casagrande, mass loss, and mechanical strength were considered as output variables.

The empirical mathematical models revealed the influence of mixture design parameters and their coupled effects on the 3DPearth properties: deformability, shrinkage (mass loss), and compressive strength. A numerical optimisation technique was applied to the derived models to select the optimal mixture, which maximises durability and eco-efficiency simultaneously and minimises shrinkage and costs while maintaining printability.

KEY WORDS: Earth Construction, Earth materials, 3D print, DOE, sustainable construction