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DEVELOPMENT OF SUSTAINABLE 3D PRINTABLE TERNARY COMPOSITE

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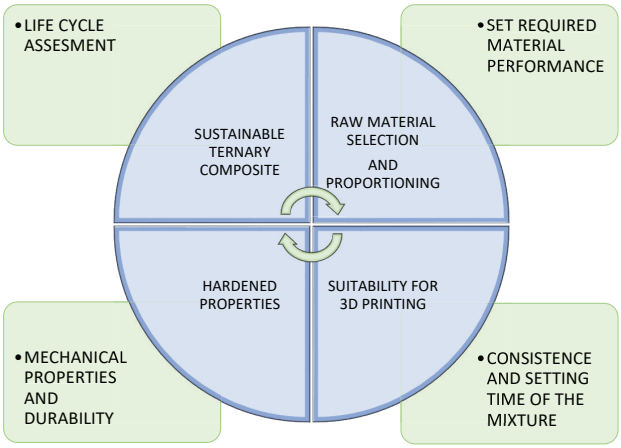
Abstract – 3D printing technology has the potential to reduce construction waste through its controlled manufacturing process and optimized material consumption, making it a promising sustainable construction approach with reduced environmental impact. However, current 3D printed structures often have a high carbon footprint due to the large amounts of fine-grained primary materials used in mortar composites. Most efforts to develop 3D printed structures are associated with concrete and Portland cement-based materials. This research presents an innovative approach for the reuse of gypsum to develop a material suitable for 3D printing, with the goal to industrialize the usage of waste gypsum in civil engineering. The objective of this study is to develop a sustainable gypsum-cement-pozzolanic (GCP) ternary binder composite, incorporating recycled industrial waste gypsum materials such as construction demolition waste gypsum (CDG), along with Portland cement and secondary pozzolanic materials. The GCP ternary composite combines the desired properties of gypsum, such as fast setting time, with those of Portland cement, which offers high final strength. The addition of a pozzolanic component is essential to ensure the chemical stability of this ternary system. As part of this study, ternary composites were designed and tested for their mechanical properties, durability, and suitability for 3D printing. Development and optimization of the ternary composite was carried out as a loop of procedures (see figure). Through these optimization procedures, a range of mixtures with necessary properties for 3D printing was found. To ensure sustainability and to assess the environmental impact of the mixtures, life cycle assessment (LCA) was performed. The LCA of GCP composites showed at least 1.5 times lower embodied energy and carbon dioxide emissions compared to Portland cement-based mortars. This is without considering avoided emissions from the end-of-life stage of gypsum waste, as well as higher technical properties that make GCP composites superior to regular cement composites. Considering these factors, GCP composites exhibit even lower emissions and are considered a viable alternative to Portland cement-based mortars.

Keywords – Additive manufacturing; Life Cycle Assessment; recycled gypsum; sustainability; ternary composite; waste materials



Optimization of the GCP ternary mixture.

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