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DESIGN OF ECO-EFFICIENT PRINTABLE MORTAR MIXES INCORPORATING EGGSHELL RESIDUES

Silvia Castillo Sotelo[1], Claudiane Ouellet-Plamondon[2], Miren Etxeberria Larrañaga[3], Lucas A. Hof[4*]
[1]Department of Construction Engineering, École de technologie supérieure, Montreal, Quebec, Canada and Department of Civil and Environmental Engineering, Universitat Politècnica de Catalunya (UPC-BarcelonaTech), Barcelona, Spain
[2]Department of Construction Engineering, École de technologie supérieure, Montreal, Quebec, Canada
[3]Department of Civil and Environmental Engineering, Universitat Politècnica de Catalunya (UPC-BarcelonaTech), Barcelona, Spain
[4]Department of Mechanical Engineering, École de technologie supérieure, Montreal, Quebec, Canada
*lucas.hof@etsmtl.ca

ABSTRACT

The construction industry faces a crucial challenge in its transition towards sustainability, particularly in the decarbonization of cement, a material responsible for a significant share of global CO_2 emissions. Concrete, the most widely used material in the world after water, relies heavily on cement, generating approximately 0.9 ton of CO_2 emissions per ton of cement, especially in developing countries. This substantial environmental impact has prompted research aimed at reducing the carbon footprint of cement-based materials by integrating waste-derived alternatives into construction processes.

Among these alternatives, waste eggshells have emerged as a promising substitute for cement in mortar formulations. Eggshells are primarily composed of calcium carbonate, a renewable resource with properties comparable to limestone, traditionally used in cement production. Incorporating eggshell powder into mortar reduces waste and contributes to the circular economy by minimizing natural resource extraction and industrial by-product disposal. Concurrently, additive manufacturing, also referred to as 3D printing, introduces an innovative and sustainable approach to construction, enabling the development of resource-efficient processes adaptable to various material compositions,

The objective of this research study is to develop an eco-efficient mortar mix by replacing cement with eggshell powder and evaluating its effect on key properties of printable mortars. Specifically, the study investigates the printability, mechanical performance, and long-term durability of mortar formulations containing eggshell powder. Experimental tests using a 15% substitution of cement with eggshell powder revealed that this affects both pumpability and buildability, reducing flowability and structural stability during the printing process. Hence, to counteract these challenges, higher dosages of chemical additives were required to achieve the necessary flowability and pumpability. However, at 28 days, compressive and flexural strength decreased by only 8% and 3% respectively, remaining within acceptable limits for 3D printing.

This research aligns with several United Nations Sustainable Development Goals, in particular Goal 9 (Industry, innovation, and infrastructure), Goal 11 (Sustainable Cities and Communities), and Goal 12 (Responsible Consumption and Production). By promoting waste-derived materials and reducing the environmental impact of construction processes, this study contributes to more sustainable and resilient construction practices.

The findings underscore the potential of eggshell-based mortars to support the development of 3D-printable construction materials with reduced cement content. This research highlights the importance of waste-derived materials promoting sustainable construction practices and provides practical insights into the formulation of eco-efficient printable mortars. Furthermore, these results serve as a foundation for future studies on scaling up eggshell-based printable concrete and advancing sustainable construction technologies.