

ABSTRACT - POSTER

Development and characterization of low-carbon 3D-printed refractory inks for permanent formworks

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In the construction and refractory materials sectors, producing precast components with complex geometries often requires complex molds, resulting in high production costs, long processing times, and significant material waste. This study investigates 3D-printed permanent formworks made from low-carbon refractory inks as an alternative to conventional mold-based manufacturing, eliminating mold fabrication and demolding while enabling the production of complex-shaped components.

The development of refractory inks for 3D printing remains challenging due to their high aggregate content and relatively large particle sizes, reaching up to 3 mm, as well as the need to minimize cement content to maintain mechanical performance at high temperatures. The objective of this work is to establish a general formulation and characterization methodology applicable to a wide range of refractory materials. The particle size distribution was designed according to the Andreasen model. Two refractory formulations were developed: one containing 5 wt.% cement and another containing only 0.25 wt.% cement, using a microsilica-gel bonding system. These formulations were compared with a commercial, non-refractory construction ink containing more than 20 wt.% cement.

Several characterization methods were investigated to determine the water content required for extrusion and to assess ink printability, including manual extrusion tests, rheological measurements, mechanical testing, flow-table tests, and ultrasonic monitoring of setting. The manual extrusion test proved particularly relevant for identifying the suitable water-content range for printing, with the refractory inks showing high sensitivity to water content. The Andreasen particle size distribution model facilitated the development of extrudable and printable formulations, whereas flow-table tests were found to be unsuitable for characterizing refractory inks. Printing trials using a MiniPrinter EDU (Construction-3D), equipped with a continuous-feed extrusion system, confirmed the suitability of the proposed formulation and characterization approach for large-scale extrusion-based additive manufacturing.