



**Politecnico
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Scuola di Dottorato ~ Doctoral School

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Doctoral Dissertation
Doctoral Program in Civil and Environmental Engineering (37th Cycle)

**Exploring 3D-printing with
lightweight foamed concrete: material
properties and potential application to
produce multifunctional building
components**

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June 10, 2025

Abstract

In the context of the ongoing pursuit of more efficient and sustainable construction processes, materials, and products – driven by the urgent need to reduce the environmental impacts, costs, and timeframes that characterize the construction sector – the innovative application of Additive Manufacturing (AM), particularly 3D Concrete Printing (3DCP) with cement-based materials such as foamed concrete, has recently attracted growing interest.

The research work presented in this PhD thesis aims to expand current knowledge and investigate the potentials, weaknesses, and specific challenges associated with the use of lightweight foamed concrete – featuring a dry density of approximately 800 kg/m^3 – in medium-scale 3DCP applications.

The research commenced with a critical review of the existing literature, which revealed a significant scarcity of studies specifically addressing this topic. In particular, no prior work was found to comprehensively investigate the full range of aspects related to the use of lightweight foamed concrete in 3D printing applications, and this clear gap in the literature underscores both the originality and the scientific relevance of the present study.

The initial phase of the experimental activity focused on the comprehensive characterization of the material in both fresh and hardened states, examining its physical, mechanical, thermal, microstructural, and durability properties. The research then shifted to a targeted application: the production of multifunctional building components. Several prototype elements were successfully printed, and their mechanical performance, particularly compressive strength, was evaluated.

In the absence of specifically defined standards for such materials and products produced using 3DCP processes, existing standards for similar or normal-weight materials were adapted. To address this regulatory gap, guidelines developed as part of an interlaboratory study on 3D-printable normal-weight concretes promoted by RILEM were followed where applicable, although adjustments were often required due to the specific characteristics of the material used.

The findings of this study contribute to the advancement of knowledge in this emerging field, shedding light on the opportunities, weaknesses, and key technical challenges that must be addressed before this technology can be implemented in real-world applications.