POLITECNICO DI TORINO

Honors thesis

Master of Science in Sustainable Architecture

Abstract

Ultra-lightweight extrudable foamed concrete for innovative and energy-efficient building components

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The experimental research work in this thesis concerns extrudable foamed concrete, an innovative material with great potential for use in the construction sector in the near future. This material, which can be ascribed to the category of lightweight concretes, is characterised by its high multi-functionality and versatility of use but, at the same time, thanks to its ability to develop timely green strength, it also offers the possibility of being used in automated extrusion construction processes, both in the field of prefabrication and in situ fabrication, according to the 3D Concrete Printing method. In this context, the efficiency, cost-saving and eco-sustainability benefits associated with the material can be amplified through its use in innovative products that are just as efficient, cost-effective and eco-sustainable.

Extrudable foamed concrete is a 'young' material, still little investigated in spite of its extremely high potential, and the aim of this thesis work is based on the need to carry out studies and experiments both in the laboratory and in environments which can easily be assimilated to typical production sites in the construction sector, such as production plants and construction sites.

Precisely because of these needs, this thesis work has focused on experiments carried out in the laboratory, studying the main properties of ultra-lightweight foamed concrete with extremely low density. In addition, through field experiments using a robotic arm, it was possible to design and manufacture energy-efficient, multifunctional and variable-density building components. It was also possible to study the extrusion process, which made it possible to highlight the potential, limitations and problems of both material and process.

In this thesis work, the first three chapters deal with the three basic themes that characterise the area under study, on a theoretical level and on the basis of existing literature: concrete technology and strategies for making this material more eco-sustainable; the characteristics, potential and current limits of the use of 3D Concrete Printing in the construction sector and the properties that a concrete must possess in order to be subjected to extrusion processes; the properties and potential of extrudable foamed concrete and its use in the construction sector. Subsequently, practical experiments are dealt with in Chapters 4 and 5.

The first experimental part, dealt with in Chapter 4, was carried out in the laboratory of the Department of Structural, Geotechnical and Building Engineering (DISEG) and investigated the rheological and mechanical characteristics of innovative, ultra-lightweight cement matrix materials with a fresh density in the range 162-188 kg/m^3. Thanks to the evaluations carried out both in the fresh and hardened state, it was possible to compare materials with approximately constant density but characterised by the use of two different foaming agents and the possible presence of polypropylene microfibres. The second experimental part, dealt with in Chapter 5, concerned the design and construction of extrudable foamed concrete components with variable density, intended for prefabrication or in situ fabrication, suitable for application as thermal insulation in energy efficiency measures on existing opaque vertical building envelopes. In this context, various types of components have been conceived, designed and manufactured by means of an extrusion process using a collaborative robot and in the absence of formwork, or by simple casting or extrusion carried out inside formwork of variable geometry.

In the final part of this paper, the latest considerations regarding the area under study are expressed, with particular emphasis on future scenarios in terms of research and experimentation.