DESIGN AND TECHNOLOGY. PEOPLE, SYSTEMS, ENVIRONMENT

DENERG/CRT - Additive manufacturing for building envelopes: Exploring the potential of multi-level/multi-domain computational design workflow

Funded By	Dipartimento DENERG FONDAZIONE CRT CASSA DI RISPARMIO DI TORINO [P.iva/CF:06655250014]

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Context of the research activity	The development of new manufacturing techniques (i.e. additive manufacturing) for building envelopes which allows a more efficient usage of materials (in terms of quantity needed to achieve a desired effect) compared with traditional construction techniques, has boosted the need to take advantage of computational design to generate optimised complex functionalised shapes. Performance based aspect related to energy efficiency and IEQ (i.e. thermal, acoustics, lighting, indoor air quality) are rarely taken into consideration and combined with mechanical properties and printing process optimisation. In this scenario the application of the so-called "Integrated Computational Materials Engineering (ICME)", which is widely adopted in other sectors like the automotive one, could represent a very important step-forward.

	The design of high-quality and sustainable building envelope components and system represents nowadays a challenging task for designers who are invited on the one hand to respond by developing deep knowledge and analysis in specific domain (structural, environmental, energy, manufacturing…) and on the other hand to keep a multidisciplinary vision of all the domains involved. This last aspect is relevant since the physical domains are often mutually dependent and the optimization of a single feature could potentially lead to an alteration of the others. So, the best solution always corresponds to a negotiation between the different domains. This iterative approach slows the design process and rarely corresponds to a real optimal design. The development of new manufacturing techniques (i.e. additive manufacturing) for buildings which allows a more efficient usage of materials (in terms of quantity needed to achieve a desired effect) compared with traditional construction techniques has boosted the need to take advantage

Objectives	of computational design to generate optimised complex functionalised shapes that take into consideration at least two domains, namely the printing process and the mechanical properties. However, other physical domains i.e. thermal performance aspects, daylight performance aspects etc. are rarely taken into consideration when combined with the others, even if are fundamental aspects for the design of building envelope elements. So, the need to exploit computational design tools to optimize 3D printed building components considering also the latter domains is needed. In this scenario of emerging manufacturing process, the application of the so-called "Integrated Computational Materials Engineering (ICME)", which is widely adopted in other industries like the automotive one, could be very important and represent a hot topic, since it potentially allows the integration of simulation tools encompassing different scales (from the micro/nano scale of the material physical processes, to the architectural scale of the design of the building envelope element, to the building performance scale), but also different physical domain (structural, thermal, daylight etc.). Moreover, it could allow to relate production and supply chain issues with final component performance. The aim of this research is to explore the potential of the ICME concept to the building sector, applied to additive manufactured building components. To this aim, a digital workflow need to be established, combining different building performance simulation tools (at different scales) with computational design tools, and allowing exchange of information among different physical domains and scales of simulations. The workflow will be tested and validated on different case studies, concerning the design of highly efficient building envelope materials and components, up to the evaluation of their performance at whole building level. As a result, the research will explore the potential of such a framework in different use scenarios, while at the end the developed ICME (multiscale and Multiphysics) workflow will be made available to the scientific community and validated / improved by the feedback of the early users. Part of the PhD activity is carried out within the project PRIN 2022 "CHaracterisation Of Innovative and Sustainable Insulating Solutions – CHOISIS", as far as the following lines of research are concerned: - the development of procedures and metrics for the hygrothermal characterisation, under steady state and transient state, of novel solutions at material/components scale, mainly when featuring a moisture buffering behaviour; - the development and validation of a simulation framework, based on experimental data, aimed at supporting designers/manufacturers in the optimisation process.

Skills and competencies for the development of the activity	It is required that the applicants have good knowledge on: - Advanced building envelope materials for energy efficiency and indoor environmental quality - Performance based design - Parametric design through Grasshopper for Rhinoceros - Tools for multi-objective optimisation, analytics, physics engines for interactive simulation, optimisation and form-finding within Grasshopper. - Technical process for 3D printing of ceramic materials through "Liquid Deposition Modelling" (LDM); - Buildings Energy simulation and Finite Element (FEM) methods Skills in spoken and written English and Italian