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Editorial: Additive manufacturing in construction

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Editorial on the Research Topic
Additive manufacturing in construction

The adoption of digital solutions in construction has proved to reduce the environmental footprint in the building sector while supporting the circular economy and increasing work safety. The application of additive manufacturing (AM) [or else 3D printing (3DP)] technologies contributes to reducing material waste, simplifying resource recapture, and achieving geometrical flexibility in built design. All these features make AM particularly suitable for realizing a new generation of resource-efficient technologies in construction. Indeed, the use of computational design to create new structural forms has been limited by the conventional building production processes, which often does not allow to complete design freedom. With the advent of AM processes in construction, the use of structural optimization tools could potentially enable the realization of a new class in optimizing structures.

Various construction materials have been tested and explored to be adopted for AM processes. Thanks to the versatility and reduced cost, concrete 3DP has been largely investigated over the past decade. Recently, novel mix designs and techniques are proposed to reduce the embodied CO_2 emission of concrete structures. Mohammed et al. presented a first study on various types of agricultural waste to partially substitute sand in concrete blocks. Indeed, a cost-effective solution to reduce the CO_2 emissions produced by the concrete sector is to adopt agricultural waste, especially in developing countries. Various agricultural waste types have been tested, such as vermiculite, pistachio shells, sugarcane bagasse, and coconut husks. Experimental tests were conducted to assess the physical, mechanical, and thermal properties of cement blocks incorporated with agricultural waste to obtain results, such as water absorption capacity, density, compressive and flexural strength, and fire resistance. The results are compared with current ASTM standards for construction materials. The results revealed that concrete blocks obtained from agricultural waste could be used for non-load-bearing structural elements. The flexural strength results were satisfactory, but the durability of the block should be further investigated and improved.

Another solution to reduce the environmental impact of the construction sector is presented by the adoption of rammed earth as construction material, as proposed by Schmitz et al. The use of rammed earth in construction has a long history of traditional manufacturing, but it has been often limited by manual manufacturing processes. Recently,

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its use has been improved, thanks to the adoption of digital fabrication and automated techniques. The work presents a robotic and fully automated process for building structural wall elements called robotic rammed earth (RRE). A comprehensive experimental study was conducted to investigate the interrelation between process and material parameters and their impact on the compaction and strength of rammed earth. The results of this first investigation could be used as input data for further development of the RRE process. Future developments could see the use of on-site measurements of moisture content and density to implement a digitalized process to adjust the compaction energy during production and hence improve the robustness of the printed process.

AM techniques could assist to overcome the limitations of traditional construction methods such as formwork and labor intensity. Rennen et al. proposed a design-informed manufacturing process that merges two technologies: CNC knitted stay-in-place formwork, known as KnitCrete, and robotically applied shotcrete, known as shotcrete 3D printing (SC3DP). The framework exploits the full potential of both computational form findings with digital fabrication methods toward a new class of concrete structures. The framework is validated through a proof of concept of a pedestrian bridge. The experimental process revealed the full potential of the combined techniques but also evidenced some challenges, such as the imperfections in the SC3DP, which led to the development of an additional manufacturing technique for surface leveling. The resulting geometry closely matched the design, demonstrating the high degree of accuracy achieved through this fabrication process.

One challenge that still needs to be faced when adopting AM in construction is the reliability aspect of construction 3DP techniques. Alhussain et al. presented the development of fast and accurate data-driven models to predict and classify filament shapes based on process parameters for concrete 3DP. The models were trained on experimental data obtained to predict the geometrical features of 144 filaments based on the input process parameters. The robustness and generalizability of the models were confirmed through additional validation based on literature data, adopting various materials and setups. The use of such data-driven models could optimize efficiency, enhance quality control, and enable innovative designs. In addition, these models can be integrated into real-time control systems to adjust parameters during the printing phases.

AM techniques also offer transformative ways to realize insulating monolithic walls. Briels et al. focused on integrating thermal insulation performances into three different AM processes: selective paste intrusion (SPI), selective cement activation (SCA), and extrusion 3D concrete printing (E3DCP). The thermal insulation of AM-produced walls can be improved by i) adding lightweight aggregates to the material composition, ii) encapsulating air in a cellular structure, iii) encapsulating unbound lightweight aggregates in cavities, and iv) adding loose-fit insulation material into the structures' voids. The study is carried out through a software-based parametric design workflow, enabling parametric studies and paving the way for a design tool with performance feedback for thermal insulation. From the parametric study, all four approaches to improving the thermal insulation of AM walls can be considered effective. Adding insulation material into the cavities results to be the most effective insulation strategy among the other approaches. The workflow is presented here using one type of geometric pattern to achieve comparable results, but it can be adapted and extended for other patterns too. Furthermore, it should be extended to multi-objective and multi-disciplinary approaches, especially combining the insulating capacity with a more extensive structural integrity.

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