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Generative Design of Acoustical Diffuser and Absorber Elements Using Large-Scale Additive Manufacturing

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Abstract : This paper explores a generative design, simulation, and optimization workflow for the integration of acoustical diffuser and/or absorber geometry with embedded coupled Helmholtz-resonators for full-scale 3D printed building components. Large-scale additive manufacturing in conjunction with algorithmic CAD design tools enables a vast amount of control when creating geometry. This is advantageous regarding the increasing demands of comfort standards for indoor spaces and the use of more resourceful and sustainable construction methods and materials. The presented methodology highlights these new technological advancements and offers a multimodal and integrative design solution with the potential for an immediate application in the AEC-Industry. In principle, the methodology can be applied to a wide range of structural elements that can be manufactured by additive manufacturing processes. The current paper focuses on a case study of an application for a biaxial load-bearing beam grillage made of reinforced concrete, which allows for a variety of applications through the combination of additive prefabricated semi-finished parts and in-situ concrete supplementation. The semi-prefabricated parts or formwork bodies form the basic framework of the supporting structure and at the same time have acoustic absorption and diffusion properties that are precisely acoustically programmed for the space underneath the structure. To this end, a hybrid validation strategy is being explored using a digital and cross-platform simulation environment, verified with physical prototyping. The iterative workflow starts with the generation of a parametric design model for the acoustical geometry using the algorithmic visual scripting editor Grasshopper3D inside the building information modeling (BIM) software Revit. Various geometric attributes (i.e., bottleneck and cavity dimensions) of the resonator are parameterized and fed to a numerical optimization algorithm which can modify the geometry with the goal of increasing absorption at resonance and increasing the bandwidth of the effective absorption range. Using Rhino.Inside and LiveLink for Revit, the generative model was imported directly into the Multiphysics simulation environment COMSOL. The geometry was further modified and prepared for simulation in a semi-automated process. The incident and scattered pressure fields were simulated from which the surface normal absorption coefficients were calculated. This reciprocal process was repeated to further optimize the geometric parameters. Subsequently the numerical models were compared to a set of 3D concrete printed physical twin models, which were tested in a .25 m x .25 m impedance tube. The empirical results served to improve the starting parameter settings of the initial numerical model. The geometry resulting from the numerical optimization was finally returned to grasshopper for further implementation in an interdisciplinary study.

Keywords : acoustical design, additive manufacturing, computational design, multimodal optimization
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