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An approach to building façade design to enhance acoustic and thermal comfort at the urban microscale

Environmental noise pollution and heat stress threaten the health and well-being of the urban population. Under the challenges of increasing urbanization, urban heat island and climate change, the themes of outdoor thermal and acoustic comfort are gaining increasing research attention.

Both environmental noise levels and microclimatic conditions in urban open spaces are influenced by the morphological and material properties of the surrounding urban fabric. Therefore, architectural design, if properly conceived, can contribute to outdoor acoustic and thermal comfort in nearby urban areas. Among urban surfaces, building façades have the largest impact on thermal comfort in their surroundings and play a major role in the sound reflections occurring in urban areas. While in cities the urban fabric is often already fixed and there are limited chances to act on it, retrofit interventions of building façades are relatively common, making these elements strategic starting points to locally improve outdoor comfort and promote the well-being of the population. Nonetheless, the outdoor implications of façade design are generally overlooked, missing precious opportunities to enhance comfort conditions in urban areas.

The Ph.D. research activities aimed to shed light on some of the most relevant topics encompassing the improvement of acoustic and thermal comfort in outdoor urban spaces. The research work has investigated the methodologies that can be used to predict and optimize design proposals to improve outdoor acoustic and thermal comfort, with a focus on the role of building façades. The two themes have been addressed in parallel, ranging from the material scale to the urban microscale. The activities were mainly developed to support the definition of a methodological framework to address these topics from different standpoints, making use of laboratory and field measurements, and performance simulations.

An appropriate characterization of the material properties is essential to correctly set up the input data for performance simulations, whose outcome can orient design processes, following the performance-based design approach. Part of the research has focused on the laboratory and in-situ characterization of innovative building envelope materials, with

respect to acoustic and thermal properties. The reliability of performance simulation tools is crucial to inform design decisions in an efficient way. This aspect was investigated through a literature-based overview, and more in detail, through the comparison of simulated data with measured acquisitions in urban areas. In this framework, an evaluation of geometrical room acoustic tools i.e., Odeon ad Pachyderm, in an outdoor urban setting, and a validation study of the most well-known microclimatic simulation tool, i.e., ENVI-met, are presented. While good agreement between simulations and measurements was found for the use of room acoustic tools in an outdoor scenario, the evaluation of the microclimatic simulation program has highlighted some marked limitations in the tool's ability to correctly estimate microclimatic variables under extremely hot conditions, which may limit the reliability of the predictions. Finally, the practical application of performance simulation tools to orient design decisions was tested on both idealized scenarios and case-studies to explore the methodologies that can be followed, the complex interrelationship between the two aspects, and to highlight the potential benefits of the inclusion of outdoor comfort goals during design processes. The main contribution of this exploratory research work is to increase the knowledge on simulation approaches to estimate and improve outdoor thermal and acoustic comfort conditions by means of façade design choices, and on methodologies to assess the performance of innovative façade materials that are expected to influence, and potentially benefit, outdoor comfort conditions in their surroundings.