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The use of building performance simulation to support architectural design: a case study

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Abstract

Considering the complex interaction between energy performance, lighting, acoustic and thermal comfort in contemporary design, building performance simulation [BPS] shall play a key role in addressing decision making process and technical choices towards optimized configuration during the whole design phase.
The paper reports the outcomes of a case study – performed in the framework of Ma Final Design Lab at the Department of Architecture, University of Bologna – where BPS was adopted from the very beginning as a tool to support the design process from the concept validation to the final architectural configuration to fit with passive house standards.

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Keywords: CFD; Energy efficiency; Sustainable design; Middle-East architecture; Design process; Building Simulation; Iteratively process; Solar Decathlon Middle East

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1. Introduction

Architectural forms are typically defined by a number of different aspects including typological, technological, functional, environmental features that are managed according to a hierarchical organization according to the designers' ability and the context the object is related with. When high energy performance standards are expected, the interaction between these features is often increased in complexity and multiple effects can influence the result. In order to optimize the thermal and energy behavior, designers need to achieve a balance between the physical-geometrical features of the building itself and the adopted technological solutions and equipment.

In conventional design processes the building energy performance is commonly assessed when most of the key architectural features of a building are fixed. Software for Building Performance Simulation (BPS) offers the chance to achieve more precise evaluations applying Computer Fluid Dynamic (CFD) principles, typically used in the automotive design, in the building sector. The tool is typically adopted to assess the system performances when a specific design is fixed using feedback to correct technical features and details with no significant impacts on the architectural shaping phase. New design scenario could be preliminary evaluated instead if CFD is used from early stage to properly consider the dynamic behavior of the building embedded in its environment including an effective visualization of indoor ventilation fluxes, air temperature variation, etc.

2. Objectives

The paper reports the outcome of a design process where CFD was adopted from the very beginning to drive the project in optimizing architectural and technological response to quite extreme climate conditions. The potential of the computational software is used as an operative tool to support environmental control while optimizing architectural forms. The research work was developed according to three main steps: 1) definition of the passive solutions (natural ventilation, evaporative cooling, stack effect and cross-ventilation) fitting with the project purpose according to environmental and climate conditions of the assigned site; 2) review of traditional and more recent solutions belonging to the specific region to be used as references for the project; 3) definition of design concepts to be validated and further developed. Once each single concept was defined, it was entered into an iterative validation process using BPS: the architectural concept was translated into a model reproducing all the specific features and tested especially for what concerned natural ventilation using computational fluid dynamics (CFD). The simulations' feedback was used to correct and calibrate the model (and re-configure the concept) to increase the overall performance. The process was iterated until the results matched with the expected performance level.

The purpose was on one side to test BPS as a design tool (and not simply as a way to assess the behavior deriving from a pre-defined technical solution) and on the other to experiment an innovative training process at academic level. A relevant result was indeed the capacity to reduce the gap between the expected performance level fixed at the beginning and the real achievable level once the final configuration was definitely shaped.

The process was also aimed to combine the instinctive and creative side of the design process with a more conscious knowledge of the related environmental effects while varying the architectural configuration.

3. Context and case study

The study was developed as a Master Degree Final Thesis, recently discussed at University of Bologna, Department of Architecture [DA]. The project assumes as initial brief the rules of Solar Decathlon Middle East [1] competition that will take place in Dubai during 2018. The initiative is a contest open to University teams from all over the world with the aim to design (and finally build) a highly performing prototype for a single house according to the passive standards. The study represents the preliminary project in the case DA would concretely join the competition.

The project must fulfill ten key evaluation criteria dealing with solar energy, architecture, engineering and construction, energy management, comfort condition, house functioning, sustainability, vegetation and hardscaping (hard landscape materials in the built environment structures that are incorporated into a landscape), communication and innovation. Several constraints have to be considered including site dimensions (that are 20 m length and 20 m width, with a maximum height allowed fixed in 6 m), construction process (only assembled solutions are permitted), time and logistic.