Frontiers of Architectural Research (2015) 4, 127–145

HOSTED BY

Available online at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/foar

Frontiers of Architectural Research

RESEARCH ARTICLE

Breathing architecture: Conceptual architectural design based on the investigation into the natural ventilation of buildings

Anastasia D. Stavridou

Division of Hydraulics and Environmental Engineering, Department of Civil Engineering, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece

Received 30 September 2014; received in revised form 19 February 2015; accepted 2 March 2015

KEYWORDS
Natural ventilation of buildings;
Computational fluid dynamics;
Architectural design;
Architectural synthesis;
Air;
Concept

Abstract
This study explores architectural design by examining air, fluid mechanics, and the natural ventilation of buildings. In this context, this research introduces a new way of dealing with the process of architectural synthesis. The proposed way can be used either to create new architectural projects or to rethink existing ones. This study is supported by previous investigation into the natural ventilation of buildings via computational and laboratory simulation (Stavridou, 2011; Stavridou and Prinos, 2013). The investigation into the natural ventilation of buildings provides information and data that affect architectural design through various parameters. The parameters of architectural synthesis that are influenced and discussed in this paper are the following: (i) inspiration and analogical transfer, (ii) initial conception of the main idea using computational fluid dynamics (digital design), (iii) development of the main idea through an investigatory process toward building form optimization, and (iv) form configuration, shape investigation, and other morphogenetic prospects. This study illustrates the effect of natural ventilation research on architectural design and thus produces a new approach to the architectural design process. This approach leads to an innovative kind of architecture called "breathing architecture."

1. Introduction

The application of fluid mechanics in architecture attracts research interest because of its potential to enhance the architectural quality and environmental performance of

E-mail address: astavrid@civil.auth.gr
Peer review under responsibility of Southeast University.

http://dx.doi.org/10.1016/j.foar.2015.03.001

buildings. To achieve this conjunction between architecture and fluid mechanics, analytical investigation in both fields is necessary.

Chen (2004) explores the use of computational tools to factor wind into architectural environmental design. The study compares the available techniques used to study the wind effect in building design and illustrates several architectural indoor and outdoor environmental designs that utilize computational fluid dynamics (CFD). Weinstock and Stathopoulos (2006) discuss about advanced simulation in design and explain that the advanced physics of nonlinear behavior can be incorporated into generative computational design in exploring the dynamic changes undergone by structures and materials in response to changing conditions. The study further presents a visualization of the main wind flow parameters around a proposed building on a site in Chile. This work shows that the investigation into wind movement at the exterior environment of a building may provide interesting information on the form of the building in correlation with the building topography. Menges (2006) studies instrumental geometry and explains that parametric digital modeling alters the digital representations of architectural design from explicit geometric notation to instrumental geometric relationships. Hensel and Menges (2008) investigate the inclusive performance of built environment and efficiency versus effectiveness toward a morpho-ecological design approach. This study reveals that computational processes provide a potential for a high level of design synthesis and that analysis plays a critical role during the entire morphogenetic process. This analysis is possible not only by examining structural and environmental capacity but also by revealing the material and geometric behavioral tendencies of a system. Therefore, the instrumental contributions of tools such as CFD software are significant. Similar ideas were put forward in the study of McLean (2008), where it is stated that a creative application of CFD tools can be developed in the design process. In the above study, the analysis of “aerodynamic principles” (Bernal, 1939) and the design of surface morphologies, with which the ventilation and protection of internal climate can be achieved by designing and envisioning airflows and turbulence, appear to be an interesting prospect. In his article on architectural design and research, Weinstock, (2008a) notes that architectural designs usually need an optimal resolution of conflicting parameters. When design goes beyond existing forms, spaces, or material systems, the design can converge with research to achieve the idea of new and preserve the goal of being optimal. Leach (2009) explores digital morphogenesis and observes a shift of focus within contemporary architectural design from an architecture based on purely visual concerns toward one that is justified by its performance. The privileging of performance within the design process is described as an interest in “morphogenesis.” Rahm (2009) hails the emergence of a new “meteorological architecture,” in which the invisible takes precedence over the visible and elements such as the atmosphere, conduction of heat, and shifting weather and climate conditions are foregrounded. This research provides a new sort of creations, which consists of typologies related with meteorology and physics, articulation of air movements, transformation of water into vapor, rates of renewal of air mass, sound pressure, temperature, respiration etc.

Mathematics (Dahan-Dalmedico, 2011) and parametricism (Schumacher, 2009) can be integrated with the dynamic processes of nature (Weinstock, 2008b) to promote digital design. This creation path is directly connected to the use of computers (Woods, 2008) while its maturation may lead to the production of new forms and esthetics (Goldblatt, 2007).

Building performance (Lam and Yeang, 2009; Fisher, 2012; Hensel et al., 2012; Hygh et al., 2012; Aldawoud, 2013; Attia et al., 2013) is an important issue in the literature. The integration of support tools into the early stages of architectural design (Lam and Yeang, 2009; Attia et al., 2012; Fisher, 2012; Greenberg et al., 2013) can contribute to the optimization of form and design (Attia et al., 2012; Ihm and Krarti, 2012). CFD simulation (Da Graça et al., 2012) provides leading information for the optimization of natural ventilation and building geometry. Lomas (2007) describes how the architecture of advanced naturally ventilated buildings can be shaped by considering environmental design and ventilation. Wu et al. (2011) compare the CFD results of natural ventilation with the original design concept to verify the architect's vision of realizing the design purpose. The integration of CFD results into energy simulation (Hiyama and Kato, 2011) promotes building performance while building form and its role on energy consumption (Zerefos et al., 2012) are also determining factors for eco-performative design. Energy efficiency depends on the natural ventilation strategy of a building (Schulze and Eicker, 2013). Therefore, CFD analysis (Givens, 2011; Suárez et al., 2011; Wang et al., 2012) can be decisive in bioclimatic architecture.

The literature shows that the investigation into architectural design with consideration of the natural ventilation of buildings and with information from computational and laboratory simulations constitutes a valuable research field.

The current research provides lines of architectural synthesis induced by air, its movement, and natural ventilation, which enable a building to “breathe.” Therefore, this study examines the impact of investigating the natural ventilation of buildings on various parameters of architectural design. The parameters influenced and analyzed in this study are (i) inspiration and analogical transfer, (ii) initial conception of the main idea using CFD (digital design), (iii) development of the main idea through an investigatory process toward building form optimization, and (iv) form configuration, shape investigation, and other morphogenetic prospects. This study illustrates the effect of natural ventilation research on these parameters and thus produces a new approach to architectural design that leads to "breathing architecture".

This paper is organized as follows. First, the concept of “breathing architecture” is analyzed, and the role of the natural ventilation of buildings in this kind of architecture is introduced. Subsequently, information on the computational and laboratory simulation of the natural ventilation of buildings is provided. Then, the effect of the investigation into the natural ventilation of buildings on vital parameters of architectural design is elaborated. Figures, descriptions, and discussions accompany the analyses of each parameter. Lastly, several conclusions are derived regarding a creative view of natural ventilation, architectural design through displacement ventilation, building form optimization, morphology and contours of velocity, turbulence intensity and turbulent kinetic energy for