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Structural and Physical Aspects of Construction Engineering

Shape Design and Analysis of Adaptive Structures

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Abstract

Architecture is mostly perceived as a static, unchanging and rigid element without an ability to react to the changing environment around it and the specific conditions of its location. The digital approach to architectural design has already shown that it is possible to create architectural prototypes that react to the external inputs by changes in their material properties or even in the shape. The conventional, stationary architecture is not able to react to the environmental factors, nor to the changing needs of building occupants, which brings architects, designers, and engineers to the issue of movement in architecture. This paper describes selected adaptive materials and structures used in architecture. An adaptive shape is designed and analyzed using a combination of 3D modeling tool Rhinoceros and the visual algorithmic plug-in Grasshopper, together with the extension for Grasshopper, Kangaroo. The wind simulation is made in the Flow Design.

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Keywords: Parametric Design; Environment; Smart Materials; Adaptive Structures; Grasshopper plug-in; Flow Design

1. Introduction

The potential of digital design tools is exploited to a large extent to examine possibilities for developing of progressive architectural shapes and structures. Computer simulations can determine the energy consumption, the optimization of the material and therefore the overall form of the architecture. The architecture of tomorrow might be able to morph as a reaction to the changing live loads or environmental fluctuations. The change itself can happen in the structure of the material that is exposed to the effects of the environment, or in the overall architectural form.

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2. Shape changing smart materials

2.1. Adaptability in nature

Nature provides great examples of short-term adaptations to the environmental changes. Tree cones, for instance, respond to the changes of relative humidity in the air [1]. Tree cone scales are folding when dried to release seeds, while in the wet environment, the scales close-up.

2.2. Smart materials – shape changes influenced by changes in humidity

The adaptive mechanisms in nature, especially the hygroscopic properties of wood, are a great inspiration for designers and artists in their responsive designs. Achim Menges Architects have developed a climate responsive pavilion called HygroScope [2]. It is made of thin wooden sheets with a different grain directionality. The installation is responding, without any use of additional technology, to different levels of humidity in the air by slight changes in the inner structure of the material (Fig. 1).

The properties of the responsive wood that can support the circulation of humid air in its environment were verified in the project called Loop [3]. By designing a suitable shape and the spatial organization of the wood paneling using a computer simulation, the authors were able to achieve a much higher performance of the air circulation (Fig. 2).

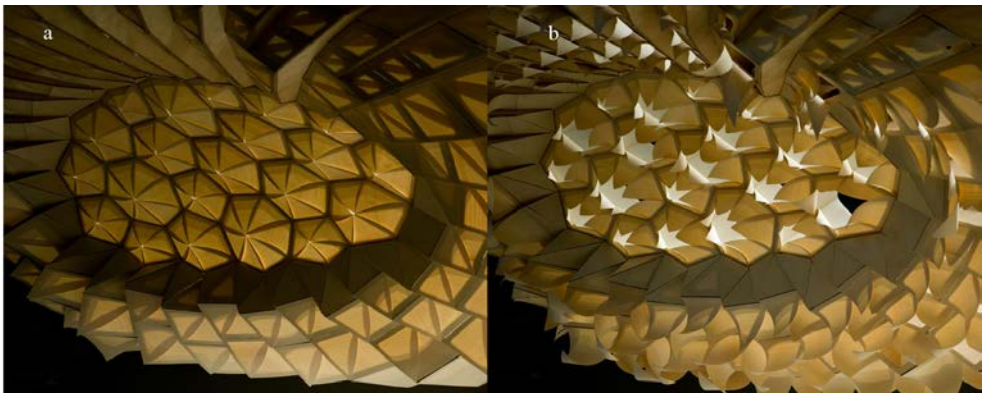

Fig. 1. (a) Closed apertures by high environmental humidity; (b) Opened apertures by low environmental humidity.

Fig. 2. Shape design of the climate responsive pavilion.