AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Architecture Engineering

Programming the Motion of Building Façade Materials by Controlling their Latent Passive Response

A Thesis submitted in partial fulfillment of the requirements of the degree of

Doctor of Philosophy in Architectural Engineering

Submitted by

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Statement

This thesis is submitted as a partial fulfillment of Doctor of Philosophy in Architectural Engineering Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Abstract

Typical motion mechanisms in adaptive skins compromise rigid kinematic mechanical systems with sensors, processors, and actuation devices, thus impeding the adoption of zero-energy buildings. This study is developing responsive low-cost adaptive building system that exploits latent properties of programmable materials, to passively respond to external stimulus. Composite programmable material "Hygromorphic Thermo-bimetals" H_MT_M is proposed to respond to different weather conditions, specifically Egypt. H_MT_M composite bilayer material is based on controlling both hygroscopic properties of wood that responds to variation in humidity and the difference in thermal coefficient of metals according to the variation in temperature. H_MT_M passive motion mechanism is presented as a programmable system whose bilayer motion logic is controlled through the variation in both temperature and humidity. The significance of H_MT_M composite is utilizing its infinite motion responses resulting from the hygroscopic properties of wood but is passively stimulated by the expansion of metal layer as the variation in temperature is the dominant factor in Egypt.

Despite efforts to develop working prototypes using several programmable materials, there is still no clear methodological framework for understanding and controlling the behaviour of these materials for using them for adaptive purposes. The study proposes a generative computational approach to track, analyse and program the H_MT_M motion response as a shape shifting grammar. The study presents a method to link between the material tangible interface in a sealed environmental chamber and digital interface that has image analysis software "Kinovea" that captures and analyses the material motion and its angle of curvature, and digital simulation using Grasshopper plugin and Ladybug to study the effect of H_MT_M motion responses on achieving different percentage of opening and shadow configurations in Cairo, Egypt. Shape and motion formal language grammars are used as a base to propose a generative computational approach for shape shifting materials specifically for H_MT_M to encode the effect of H_MT_M design parameters on the desired motion response.

Key words: *Adaptive facades, programmable materials, hygroscopic properties of wood, Thermo-bimetals, passive motion response, grammars*

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