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Micro-Oculi Facades as a Sustainable Urban Facade

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Abstract : We live in an era that faces global challenges of climate changes and resource depletion. With the rapid urbanization and growing energy consumption in the built environment, building facades become ever more important in architectural practice and environmental stewardship. Furthermore, building facade undergoes complex dynamics of social, cultural, environmental and technological changes. Kinetic facades have drawn attention of architects, designers, and engineers in the field of adaptable, responsive and interactive architecture since 1980's. Materials and building technologies have gradually evolved to address the technical implications of kinetic facades. The kinetic façade is becoming an independent system of the building, transforming the design methodology to sustainable building solutions. Accordingly, there is a need for a new design methodology to guide the design of a kinetic façade and evaluate its sustainable performance. The research objectives are two-fold: First, to establish a new design methodology for kinetic facades and second, to develop a micro-oculi façade system and assess its performance using the established design method. The design approach to the micro-oculi facade is comprised of 1) façade geometry optimization and 2) dynamic building energy simulation. The façade geometry optimization utilizes multi-objective optimization process, aiming to balance the quantitative and qualitative performances to address the sustainability of the built environment. The dynamic building energy simulation was carried out using EnergyPlus and Radiance simulation engines with scripted interfaces. The micro-oculi office was compared with an office tower with a glass façade in accordance with ASHRAE 90.1 2013 to understand its energy efficiency. The micro-oculi facade is constructed with an array of circular frames attached to a pair of micro-shades called a micro-oculus. The micro-oculi are encapsulated between two glass panes to protect kinetic mechanisms with longevity. The micro-oculus incorporates rotating gears that transmit the power to adjacent micro-oculi to minimize the number of mechanical parts. The micro-oculus rotates around its center axis with a step size of 15deg depending on the sun's position while maximizing daylighting potentials and view-outs. A 2 ft by 2ft prototyping was undertaken to identify operational challenges and material implications of the micro-oculi facade. In this research, a systematic design methodology was proposed, that integrates multi-objectives of kinetic façade design criteria and whole building energy performance simulation within a holistic design process. This design methodology is expected to encourage multidisciplinary collaborations between designers and engineers to collaborate issues of the energy efficiency, daylighting performance and user experience during design phases. The preliminary energy simulation indicated that compared to a glass façade, the micro-oculi façade showed energy savings due to its improved thermal properties, daylighting attributes, and dynamic solar performance across the day and seasons. It is expected that the micro oculi façade provides a cost-effective, environmentally-friendly, sustainable, and aesthetically pleasing alternative to glass facades. Recommendations for future studies include lab testing to validate the simulated data of energy and optical properties of the micro-oculi façade. A 1:1 performance mock-up of the micro-oculi façade can suggest in-depth understanding of long-term operability and new development opportunities applicable for urban façade applications.

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