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Advanced Energy Efficient Building Envelope Systems

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Preface

Building heating and cooling energy use accounts for up to 40% of the total energy consumption in developed countries. Heat losses and gains through the building envelope greatly contribute to thermal heating and cooling loads and subsequently to the overall energy performance of buildings. Several advances in building technology have been made that continue to transform building energy performance and promote new and innovative construction techniques and challenges traditional practices. In fact, some of the existing systems that are often required by energy efficiency codes and standards may not provide the optimal energy performance and indoor air quality (IAQ). For instance, leaky buildings traditionally perform very poorly in terms of energy consumption, but in general, their IAQ—as a result of the incoming outside air—is fairly good. For the sake of energy efficiency, the trend has been tighter, more effectively sealed buildings, which in turn has led to more IAQ, mold, and sick building syndrome problems. As the push for improved energy performance points designers and builders towards tighter construction, the very principle that reduces the building's energy consumption—reduced infiltration—is a net loser for indoor air quality.

In this monograph, some advanced technologies of building envelope are presented to challenge the existing paradigms for high performance buildings. Specifically, four building envelope systems are described in three chapters to showcase their ability to enhance the energy efficiency and optimize the IAQ of buildings. These advanced building envelope systems include:

- *Dynamic Insulation Materials:* These materials are assemblies that can change their thermal resistance through for instance, a controlled exchange of liquid or gaseous media, and are applied to the exterior walls and roofs of buildings. When applied and optimally controlled, these materials can save significant annual heating and cooling energy use for both residential and commercial buildings (Chapter 1).
- *Variable Reflectivity Cool roofs:* These systems are associated with coatings that can change their reflective properties over time depending on desired controlled strategies. It is well known that

static cool roofs can save energy use during cooling periods but may increase energy consumption during swing or heating seasons due to lower solar heat gains. The variable reflectivity coatings allow the reduction in heating penalty associated with conventional cool roofs (Chapter 2).

- *One-Layer Breathing Walls:* These systems provide air ventilation through the walls while recovering thermal energy. Essentially using heat exchanging mechanism, filtrated fresh air is introduced through the walls from outside to inside and is heated or cooled by the thermal energy wasted by conduction and convection with the walls (Chapter 3).
- *Multi-Layer Living Walls:* These walls utilize basic biomimetic principles to adapt to the change in climatic conditions. In particular, these climate-adaptive intelligent walls have embedded systems of air, water, and phase change material and can be controlled to maintain acceptable indoor environment under changing outdoor conditions (Chapter 3).

In all three chapters, an overview of the basic operating concepts of these advanced envelope systems is first provided. Then, their energy performance is summarized based on reported results using either experimental or modeling analyses.

It should be noted that the main goal of this monograph is to promote innovative ideas and disseminate the ongoing research and development related to the theme of sustainable buildings. It is a small contribution to the ASME initiative on Integrated and Sustainable Building Equipment and Systems (ISBES).

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Guest Editor

Abstract

This monograph presents the latest research developments of innovative building envelope systems. These systems have the ability to allow building structures to be responsive to changes in outdoor conditions to ensure comfortable indoor environment and acceptable indoor air quality at higher energy efficiency compared to conventional systems. In particular, the monograph overviews the basic operation principles and thermal performance of four technologies described in three chapters: (i) dynamic insulation materials that can change its thermal properties in order to better adapt the building envelope with its outdoor environment and reduce building heating and cooling thermal loads, (ii) variable reflectance coatings for application on roofs to lower and even eliminate the energy penalties associated with reduced solar heat gains during heating operation of buildings, (iii) single layer breathing walls to recover energy wasted from heat transmission inside the walls and provide air ventilation to indoor spaces, and (iv) multi-layer living walls to apply biomimetric principles and phase-change materials to adapt building envelope properties with the changing outdoor conditions.

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