Multistory building envelope: Creative design and enhanced performance

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ABSTRACT
The paper presents a comparative study of three strategies in the design of the building envelope of multistory residential buildings combining enhanced energy performance and architectural innovation. The first strategy, serving as base case, employs a high performance flat façade, applied to a building of square layout. The second strategy introduces multifaceted façade geometries, comprising plates of varying tilt angles, to the same building layout, in order to assess the impact of envelope geometry on energy performance. The third approach investigates the impact on energy performance of varying building layouts as applied to flat and multifaceted facades. British Columbia (Canada) serves as location of the study, representing northern climate conditions.

For all three design approaches, the most important stage towards achieving high performance is to design an energy efficient building envelope. Comparison of energy performance of complex façade geometries to the base case, indicates that these geometrical patterns do not significantly compromise the thermal performance of the building, while enabling a considerable increase in the electricity generation potential by integrated photovoltaic systems. In folded-plate façade systems, this increase in PV potential is observed on per unit area basis as well as per total façade area. In addition, some of these façade patterns allow time spread of useful electricity generation of the BIPV systems. Combining folded façade geometry with building layouts that allow large south and near south exposure has the potential of enabling energy positive status. While the paper focuses on residential buildings, the methodology can be applied to any type of high-rise building.

1. Introduction
Building envelope design plays a significant role in the energy performance of multistory buildings. A holistic design approach of energy efficient buildings, that adopts passive strategies for building envelope design, has significant impact on improving the overall building energy performance, including large scale buildings (Sozer, 2010). A high-performance façade that integrates daylighting, shading, and natural ventilation systems, has the potential to significantly reduce energy consumed by building operations (Sadineni and et al., 2011). Moreover, building envelope forms a major factor of a building aesthetic and visual impact. Flexibility in envelope design to meet various visual and functional aspects, is an important component that can encourage architects, clients and other stakeholders to opt for one system over others. There is a need therefore to demonstrate that this flexibility of design not only does not compromise energy performance, but in fact has the potential to enhance it. There exist however some challenges in integrating energy performance considerations into more traditional architectural requirements such as aesthetics, functionality, and structure (Wingate, 2012). To meet these challenges, performance criteria need to be considered simultaneously with other architectural criteria at early design stages (Medio and Murphy, 2008).

There exists a large body of research carried out on various aspects of the envelope of different building types, including multistory buildings (Quesada et al., 2012). Most of these focus on the impact of specific components of the façade on specific and overall performance criteria of the building (such as daylighting, heating and cooling). A number of conceptual design elements of the building envelope have been identified to be implemented in planning and design of buildings. These design elements include building orientation, geometry/shape, materials of which the envelope is made, thermal resistance, window to wall area ratio, shading devices, thermal mass, renewable energy integration, and air infiltration (Hemsath, 2013; Hayter et al., 2000; Bambardekar et al., 2009; Attia et al., 2009; Samuelson et al., 2016). Research conducted on curtain wall systems and double-skin facades includes studies of heat flow, effect of shading devices, effect of tilt and size of such devices on the overall energy performance (Hwang and Tan, 2012; Knaack, 2007; Oesterle, 2001), as well as the impact of geometrical configurations of the building envelope itself on the overall energy performance and daylighting (Hachem et al., 2014; Hachem and Elsayed, 2016).

Recently, research on double-skin facades (DSF), including their thermal characteristics and performance is starting to draw more interest (Joe et al., 2014). These facade systems are comprised of two
Recent developments in solar technologies, such as building integrated photovoltaic (BIPV) systems and thermal collectors enable building envelopes to play the role of energy generators in addition to the outer skin of residential multistory buildings aimed at enhancing their energy efficiency. It presents examples of energy performance based on various design strategies, which enable flexibility in geometric and components design without compromising energy efficiency or functional comfort and enhanced aesthetic and visual opportunities.

2. Approach

The paper discusses three main strategies in the design of building skin of residential multistory buildings aimed at enhancing their energy performance. The present paper deals with residential buildings where architectural design of such building types is generally more conservative than that of office or public buildings, due largely to market constraints. The focus of the paper is thus to demonstrate a holistic approach to envelope design of residential buildings, employing various design strategies, which enable flexibility in geometric and components design without compromising energy efficiency or functional comfort and enhanced aesthetic and visual opportunities.

2.1. Assumptions

The building studied in this research is a 12-story apartment building located in the Vancouver area (BC, 49°N, Canada). Each floor is composed of 8 apartments of 90 m² floor area each, and a central service core that contains elevators, stairs, mechanical and electrical rooms. The base case has a square layout (Fig. 1) and it serves as the basis of the analysis for the first two design strategies. In the third approach the layout itself changes into other shapes, discussed below. The size of the apartments, occupancy and appliances are assumed based on existing residential blocs in the studied location (RDH, 2012), and various norms and standards.

All presented design strategies assume a modular double-skin façade system of specific characteristics as detailed below. Double-skin façade construction consists of an outer skin and inner skin separated by an air cavity, referred to as “Channel” or “corridor”, which can be designed to be closed or to allow the movement of interior or exterior air through the façade system (Arons et al., 2001).

This research assumes that the two skins are continuous over the building face and the cavity is divided horizontally at each floor plate.
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