INNOVATIVE WINDOWS FOR ENERGY-EFFICIENT CONDOMINIUMS IN HOT AND HUMID CLIMATES

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Abstract - Dynamic window technologies aim to incorporate both passive and active designs to introduce natural daylight and ventilation into indoor spaces without increasing heat and glare. The goal is to minimize overall energy usage in condominiums with room sizes ranging from 30 to 35 square meters. This research study in Thailand focuses on several objectives: investigating energy-efficient window designs suitable for condominiums, modeling the performance of dynamic window technologies in response to solar radiation and daylight variations compared to standard windows, and calculating the potential annual energy cost savings with dynamic windows. The study recommends dynamic windows with three main components: cantilevered sun shading for sun and rain protection while maintaining views, stack effect ventilation windows to facilitate heat dissipation and airflow, and horizontal folding shutters that can be operated automatically or manually to control solar heat gain. Overall, the research suggests that implementing dynamic window technologies can lead to substantial energy cost reductions of 430,990 baht per 1000 rooms per year in medium-class condominiums in Thailand compared to traditional windows.

Keywords - Window, Condominium, Hot and Humid Climate, Dynamic Window, Window Technologies, Building Envelope, Passive Design, Active Design

I. INTRODUCTION

Most condominium residents spend almost all day with their windows closed. The modern glass façades or glass windows consume more energy to cool down the building and occupants, especially in the summer. The windows and façades are ideally made of aluminum frames. This material is valuable and highly resistant to corrosion and rust in hot and humid climates [1]. The various types of middle-class condominiums in Thailand, ranging between 30-35 square meters from 2007 to 2017. The study suggested that condominium space planning should focus on developing a system that creates natural ventilation inside the living space as much as possible [2]. In the hot climate regions, particularly in the summer, could not effectively generate natural ventilation in a room [3]. In contrast, the opening of windows could increase the indoor temperature. However, many factors influence human comfort, visual comfort, thermal comfort, and energy performance. Therefore, the relationship between thermal indoors and thermal outdoors connected through the opening of windows is considered the result of building quality and human comfort [3].

II. FIELDS OF STUDY

The energy-saving design then needs passive design strategies as an initial design process to reduce energy consumption and increase indoor thermal comfort [4]. The windows which combine mechanical controls for passive cooling with shading devices to reduce solar heat gain and optimize daylight, can make condominiums more energy efficient.

A. Shading devices

In tropical regions, direct sunlight needs to be controlled because the intensity of direct sunlight is between 5 and 10 times more than diffused sunlight [5]. To reduce the need for artificial lighting, dynamic shading devices that respond to varying daylight may be used instead of traditional ones [6]. The provision of shading using panels that can be folded vertically and horizontally, the building can be protected from the sun, heat, glare, and rain while simultaneously giving the residents some privacy. The window should have flexible controls if its components are lightweight, such as aluminum frames.

B. Stack effect ventilation window

In hot and humid climates, traditional architecture is often characterized by its emphasis on air movement. Solar heat gain (SHG) mainly occurs through the windows. In Thailand, the double-glazing windows reduce SHG more than single glazing. To encourage air movement into the building during the summer, one can relieve SHG through the window and façade accordingly [5]

C. Horizontally folding shutters.

Window shutter protection is an excellent solution relating to energy-saving purposes. Windows and translucent areas lead to significant heat losses, therefore, it is essential to reduce the energy transfer between these boundaries [7]. The horizontal folding shutter, with cantilevered sunshades, is useful in the

summer and rainy seasons in tropical regions. It allows unobstructed views from inside and outside of the building. Then the positions of the shutter should be automatically operated based on the amount of sunlight.

III.WINDOW DESIGN FOR ENERGY EFFICIENCY

There are three main components for this innovative window. First, the cantilevered sun shading is useful for the summer and rainy seasons in tropical regions, and it allows unobstructed views from the inside as well as the outside of the building in Figs. 1A and 1B. Second, the folding shutters can be operated manually or automatically via the natural light sensor attached to them in Figs. 2A. The main materials of these shutters are the basic components of windows in Thailand as perforated aluminum. The third component is the stack effect ventilation window. Typical windows in condominiums only have one sliding window that allows natural ventilation. The innovation window consists of an additional two small windows; one is located above the main sliding window, while the other is below it. According to the results in Figs. 2B, the new innovative window has a better ventilation system than the typical window because the stack effect ventilation can simulate more natural ventilation in the room.

Window materials the materials used to make dynamic windows are suggested to aluminum which is the main material used to build window parts, namely, cantilevered sun shadings, the main window frame, stack ventilation windows, and the horizontal folding shutter.

IV. TESTING MODEL AND ENERGY CONSUMPTION PER YEAR OF DYNAMIC WINDOWS

A. Testing model of innovative window technologies

In order to identify the possibility of producing windows, the prototype of a dynamic window will be drawn and proved by making the prototype model in Figs. 3A, Figs. 3B and Figs. 4A. The testing model requires additional technical components: Arduino Uno as a microcontroller board, light sensors, and switches for the manual adjustment system.

B. The energy consumption per year of innovative windows

The Ministerial Regulations Prescribing the Type and Size of Buildings and Standards, Rules and Procedures for Designing Energy Conservation Buildings B.E. 2552 (2009) [8] states that the energy consumption of condominiums should be less than 211 kWh/m^2/y, the simulation of the energy consumption index of existing windows with a room area of 32.750 sqm. The results show that existing windows have energy consumption within the standard rate according to this regulation with 203.50 kWh/m^2/y.

The simulation of energy consumption index of dynamic window technologies in a 32.750 sqm room shows that dynamic window technologies have energy consumption within the standard rate according to The Ministerial Regulations Prescribing the Type and Size of Buildings and Standards, Rules and Procedures for Designing Energy Conservation Buildings B.E. 2552 (2009) with 200.21 kWh/m^2/y. When comparing existing windows and the dynamic window technologies, the new technologies consume less energy than the existing ones by 3.29 kWh/m^2/y.

V. CONCLUSION

The research found that efficient dynamic windows for hot and tropical regions should consist of three main components: cantilevered sun shading, horizontal folding shutters, and stack ventilation windows. By using passive design strategies, the cantilevered sun shading can protect against sunlight during the summer season and can also protect against heavy rain during the rainy season. The cantilevered sun shading also provides better use of a window than the traditional window as it allows occupants to open their window almost every season without obstructed views. The three aforementioned components are combined as one dynamic window, which will be a new generation of windows that help bring daylight and natural ventilation into the building without raising heat and glare. The new window will also substantially reduce the need for air conditioning and artificial light in condominiums.

In conclusion, comparisons between the total energy consumption index of a traditional window and a dynamic window in condominiums, the dynamic window technologies can save on the costs of energy consumption by 430.96 Baht/room/year, 344,792 Baht/800 rooms/year, or 430,990 Baht/1000 rooms/year based on the energy testing of a condominium with a room size of 32.75 sqm. Finally, the majority of middle-class condominiums in Thailand with a room size between 30-35 sqm can potentially apply this dynamic window technology to save energy and achieve better sun protection and ventilation inside the room.

RECOMMENDATION

With the rising demand for middle-class condominiums in Thailand, the developers should consider using a variety of folding windows for design and utility purposes. Therefore, studies on the variety of windows should also be encouraged.

ACKNOWLEDGMENTS

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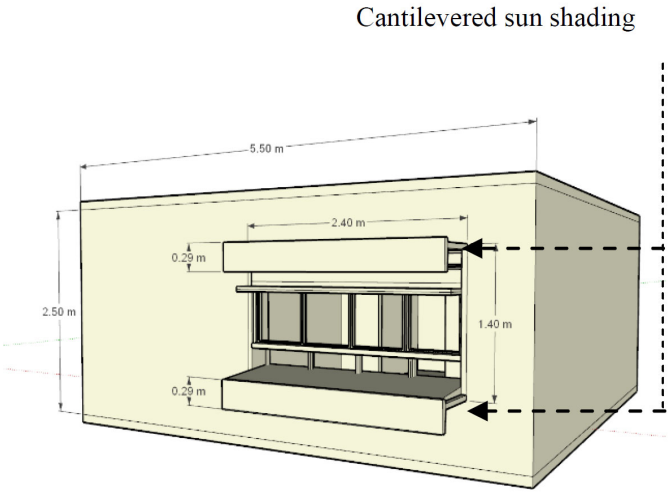
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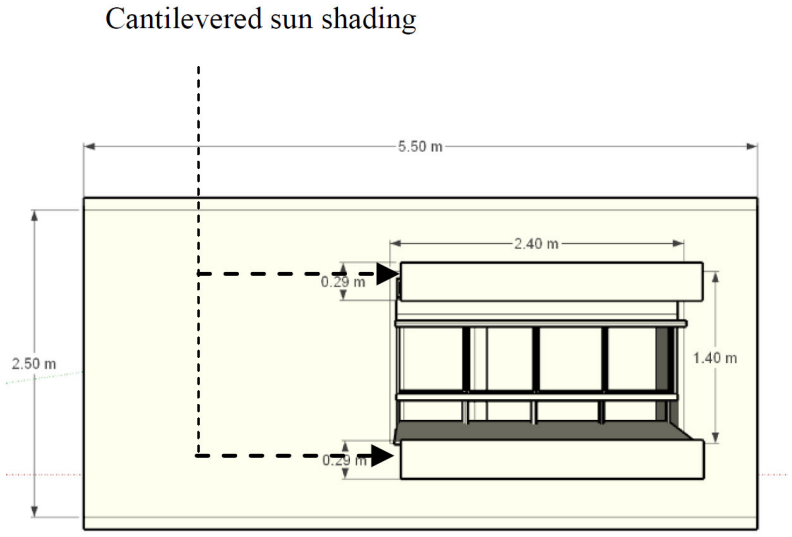
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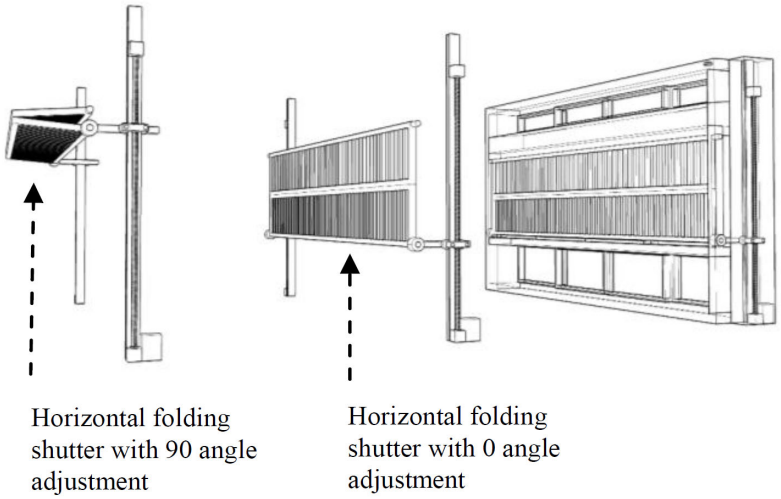
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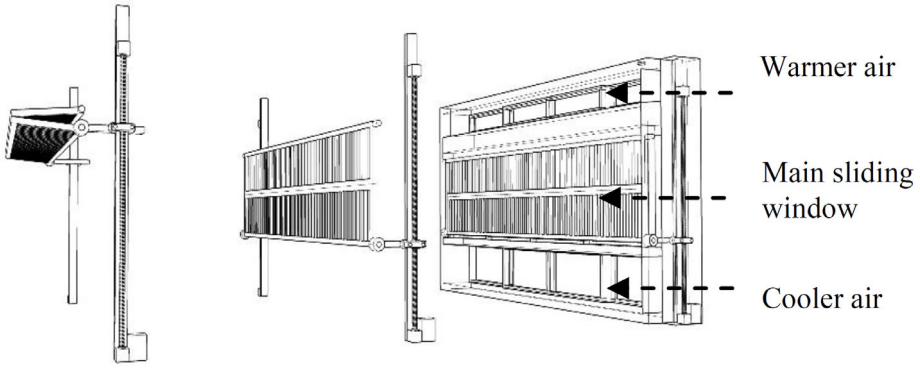
Figs.1A. Physical component of innovative windows: cantilevered sun shading



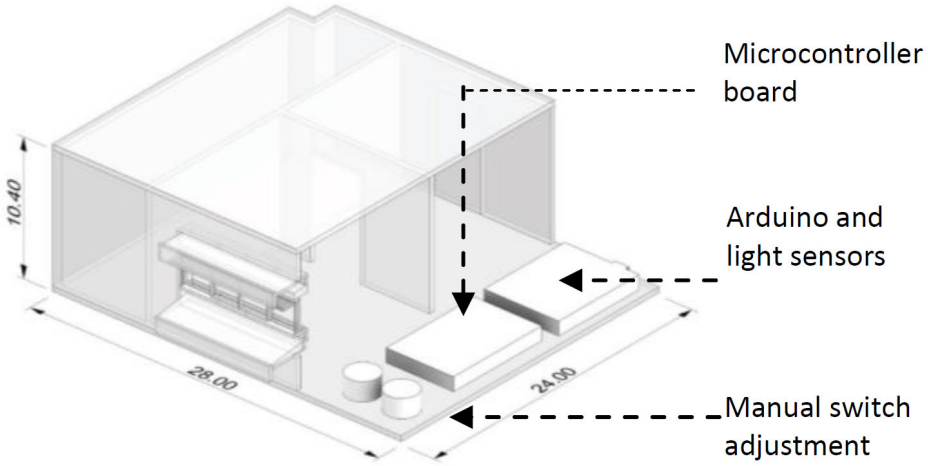
Figs.1B. Physical component of innovative windows: cantilevered sun shading



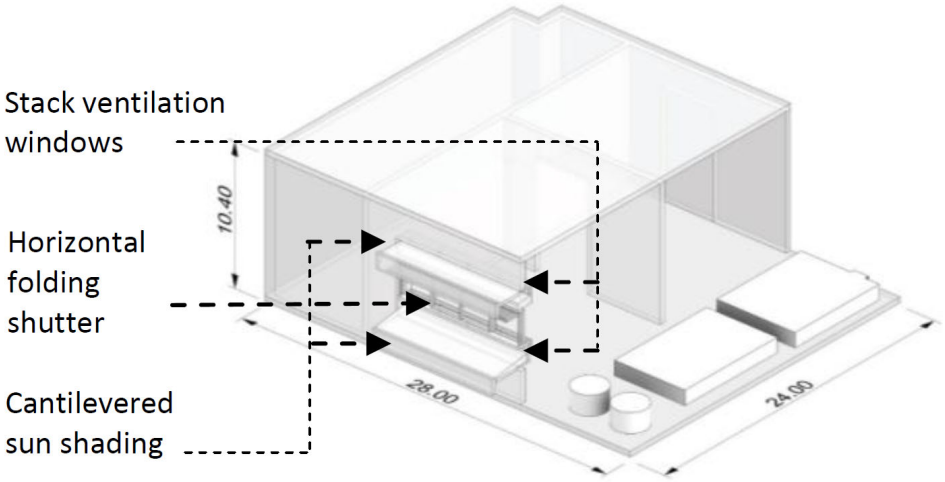
Figs.2A. Automatic horizontal folding shutter with different angles while performing as an automatic light control



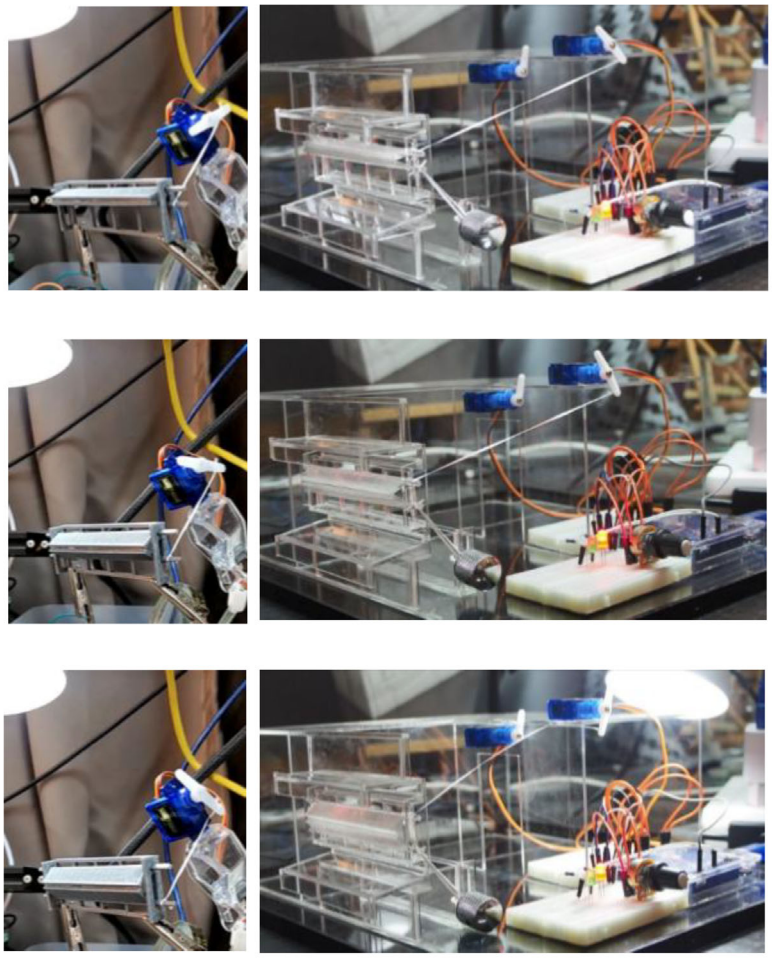
Figs.2B. Stack effect ventilation on a dynamic window



Figs.3A. Technical support of prototype model



Figs.3B. Prototype of an innovative window



Figs.4A. Prototype of a dynamic window technologies operate by automatic light control

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