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Thermal insulation, power generation, lighting and energy saving performance of heat insulation solar glass as a curtain wall application in Taiwan: A comparative experimental study

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ABSTRACT

Glass curtain walls are very popular in modern architecture due to their attractive aesthetic features and characteristic benefits such as efficient daylighting. However, current curtain wall systems are usually built via conventional fenestration products resulting to significantly greater heating and cooling demand in buildings compared to other construction types. In this respect, novel solutions are required to improve poor performance parameters of existing curtain walls. Therefore in this study, our previous research on heat insulation solar glass technology is extended to curtain walls. Two test houses having ordinary glass and novel glass curtain walls are constructed in Taiwan and experimentally investigated in terms of various performance parameters such as ultraviolet light penetration, thermal insulation, power generation, indoor lighting and energy saving efficiency. The results reveal that novel glass curtain walls have a 100% ultraviolet light blocking rate, which is of vital importance for occupants' health. Additionally, 95% of excessive thermal radiation is prevented from penetrating into the living space via novel glass curtain walls, yielding 40.8% and 46.9% mitigation in heating and cooling demand of buildings compared to ordinary glass curtain walls. Moreover, novel glass curtain walls have 24.9% better lighting efficiency as well as being capable of producing electricity to be used for lighting or any other purposes.

1. Introduction

Energy saving is of vital importance more than ever due to remarkably soaring energy prices, gradual depletion of fossil fuels and growing significance of environmental issues [1]. Renewable energy technologies are considered as the key solution to overcome energy related problems of the world [2], and hence intensive efforts are made worldwide to narrow the gap between fossil fuel based energy sources and renewables [3]. However, renewable energy resources current supply only about 14% of total world energy demand [4]. In this respect, additional decisive measures are required to mitigate total world energy consumption, and thus to halt greenhouse gas emissions which have almost doubled over the last three decades [5].

According to the latest reports by International Energy Agency [6], buildings are responsible for about 40% of total world energy use in 2014. This can be attributed to the poor thermal insulation characteristics of existing building elements [7]. Windows differ from other building components due to their significant impact on energy loss through building envelope. They tend to have notably higher overall heat transfer coefficients (*U*-value) than other building elements as reported by Cuce [8]. Current fenestration market is dominated by air or Argon filled double glazed windows due to their remarkably better thermal insulation performance compared to conventional single glazing, and well-documented fabrication process. However, their *U*-values are still very high as illustrated by Pilkington [9], and insufficient to meet the requirements of low-carbon building concepts adopted by many developed countries. As a consequence of this dramatic scenario illustrated in Table 1, heat loss through windows still accounts for about 47% of total energy loss from building envelope as recently underlined by Cuce et al. [10]. Developing energy-efficient, cost-effective and environmentally friendly window technologies is therefore important not only for retrofitting of existing buildings but also for new-build applications focusing on low/zero carbon targets.

The influence of windows on energy loss from building envelope becomes much more drastic when the window area is large like patio doors [11]. As a consequence of poor thermal insulation

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Table 1
U-values of commercial glazing products.

U-value (W/(m^2 K))	Pilkington [9]	Ref. [10]
Air filled double glazed window	2.70	2.53
Air filled double glazed window with low-e	2.00	2.10
Argon filled double glazed window with low-e	1.80	1.90

characteristics of conventional building elements notably windows [12], buildings play a crucial role in growing significance of environmental issues as reported by Bojic et al. [13]. Thermally inefficient building fabric technologies not only cause large amounts of heat loss through building envelope but also negatively affects the thermal comfort of the occupants [14]. This impact is of course expected to be massive for the buildings with glass curtain walls which are very common in modern architecture. Glass curtain wall systems provide an architecturally pleasing building. Due to aesthetic aspects and additional benefits such as efficient daylighting, they are highly preferred in commercial buildings. However, they generally have poor thermal insulation performance compared to other types of enclosure systems. In this respect, alternative solutions are needed as reported by Leskovar and Premrov [15] for fulfilling the energy requirements. There are two main reasons of this deficiency which are basically the frame impact and the glazing impact. As reported by Song et al. [16], aluminium frames are the most often used due to low density of the material which enables the construction of lightweight curtain walls. Steel frames are also widely used which can handle a large size of glass. Both frame types cause sensible energy losses through curtain walls as a result of their high thermal conductivity. However, the frame impact on energy loss in a glass curtain wall is incomparable with the glazing impact since the glazed area constitutes the greatest percentage of the construction, and has poor thermal insulation characteristics. In most cases, glass curtain walls are constructed as double glazed and equipped with low-e coating to increase the thermal resistance across the unit. However, every additional layer into the construction results in additional cost and causes deterioration of existing benefits such as increase in entire thickness, reduction in visual quality and degradation of daylighting efficiency. Moreover, these coatings might not be as effective in certain climate zones and create glare problems for adjacent buildings as reported by Kim [17]. In this respect, novel solutions are required for curtain walls to enhance their thermal insulation performance, and thus to provide large amounts energy saving both in summer and winter without affecting the architectural characteristic features of curtain walls.

Heat insulation solar glass (HISG) which has been invented by Professor Young in Taiwan [18] and recently improved in the Institute of Sustainable Energy Technologies at the University of Nottingham is such a unique solution to solve the aforesaid drawbacks of curtain walls. HISG is basically a unique application of transparent PV glazing. It is not only a good thermal insulator but also a power generator. It is a good sound insulator as well as having a self-cleaning ability through its special coating on the

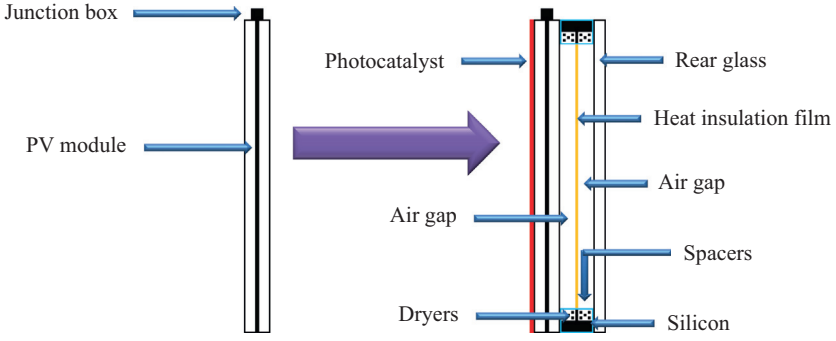

Fig. 1. Cross-sectional view of HISG with structural details.

Fig. 2. Photograph of the ordinary glass (left) and HISG (right) curtain walls.