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Performance rating of glass windows and glass windows with films in aspect of thermal comfort and heat transmission

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Abstract

This article is about a study on glass window and glass window with film of different types in aspect of thermal comfort and heat transmission. Different types of glass window, clear glass, tinted glass, reflective glass, double pane glass, and low-*e* glass were investigated. Films with different spectral optical properties were then adhered to the glass windows of different types and studied. The analysis was done based on the outside design weather condition which selected from 12 years of Bangkok meteorological data. Predicted percentage of dissatisfied (PPD) was selected as the thermal comfort index. The relative heat gain (RHG) based on local weather condition was selected as the heat transmission index. The PPD can be subdivided into the PPD due to surface temperature effect and the PPD due to solar radiation effect. The analysis indicated that, for most of the glass windows considered except the reflective glasses, the values of PPD due to solar radiation effect were much larger than the values of PPD due to surface temperature effect. And the most discomfort condition occurred when using a clear glass as window. Adhered films to the glass windows caused the PPD due to surface temperature effect increase and cause the PPD due to solar radiation effect decrease. It was also found that the PPD values due to solar radiation effect for glass windows and glass windows with films were varied linearly with the total transmittance of glass windows and glass windows with films. The PPD values due to surface temperature effect were varied with the total absorptance of glass windows and glass windows with films in an almost linear fashion. The heat transmission index, RHG, based on chosen design weather condition can be subdivided into the RHG due to conduction effect and RHG due to solar radiation effect. The analysis indicated that the values of RHG due to solar radiation effect were larger than the values of RHG due to conduction effect for all glass windows and glass windows with films considered in this study. Adhered film to the glass windows resulted in lowering the relative heat gain due to solar radiation in the amount corresponding to the film properties. But the film had very few effect on the relative heat gain due to conduction. The relative heat gain values were varied linearly with the total transmittances of the glass windows and glass windows with films. The relative heat gain values were also varied inversely with the absorptances of glass windows and glass windows with films in a linear fashion.

Keywords: Glass windows; Films; Thermal comfort; Heat transmission; Performance rating

1. Introduction

Large office and commercial buildings in Thailand usually have large amount of glass windows installed as the building envelopes. The glass windows are installed to serve as physical and visual connection to outsiders, as well as to make the appearance of buildings look more aesthetic. And since Thailand is located in the tropical zone near the equator. The weather is hot and humid for most of the year. Therefore, besides the advantage of the glass windows as described above, the glass windows installed in buildings in Thailand also act as a means to admit solar radiation into buildings and convert it into building heat gain and then building cooling load, respectively. Such buildings which are air conditioned will usually consume more energy from the air conditioning system to take care of the cooling load due to large amount of solar radiation passing through glass

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Nomenclature

a_k	absorptance of the outer surface of the person (standard value = 0.6)
A_T	total absorptance
e	emittance of glass
E_t	global solar radiation, W/m^2
f_{cl}	clothing area factor
f_p	projected area factor
F_{p-i}	angle factor between the person and surface i ($\sum_i^n F_{p-i} = 1$)
h_c	convective heat transfer coefficient, k cal/(h m^2 °C)
I_{dirv}	direct solar radiation striking on the vertical glass surface, W/m^2
I_{diffv}	diffuse solar radiation striking on the vertical glass surface, W/m^2
M	metabolic rate per unit body, k cal/(h m^2)
N_i	inward flowing fraction of absorbed radiation
P_a	vapor partial pressure, mmHg
PMV	predicted mean vote
PPD	predicted percentage of dissatisfied
q	solar radiation intensity passing through glass window that the person in the enclosure exposed, W/m^2
q_A	instantaneous rate of heat admission through glass window and/or glass window with film, W/m^2
Rh_k	resistance due to conductance, includes radiative affects at layer, m^2 K/W
Rk_k	resistance due to solid conductance at k layer, m^2 K/W
SC	shading coefficient
SHGC	solar heat gain coefficient
SHGF	solar heat gain factor, W/m^2
t_i	inside temperature, °C
t_j	temperature at center of glass at j layer, °C
t_o	outside temperature, °C
t_{sj}	surface temperature of the enclosure wall number j, °C
t_{sk}	surface temperature of glass at k surface, °C
T_a	Air temperature, °C
T_{cl}	Clothing surface temperature, °C
T_{herm}	hemisphere spectral glass transmittance
T_{mrt}	mean radiant temperature, °C
T_{smrt}	mean radiant temperature due to surface temperature and solar radiation, °C
T_{tmrt}	mean radiant temperature due to surface temperature, °C
$T(\theta)$	glass transmittance which dependent on incident angle
U	overall coefficient of heat transfer, W/(m^2 °C)
	Greek letters
α	absorptance of glass window and glass window with film
ε_p	emittance of the outer surface of the person (standard value = 0.97)
η	mechanical efficiency
σ	Stefan–Boltzmann constant, W/m^2 K^4
τ_T	total transmittance

windows. At the same time, Thailand has also issued the energy conservation promotion act B.E. 2535 (1992) [1] and ministry regulation on designated building B.E. 2538 (1995) [2] to control the energy usage in buildings. According to the regulation, the amount of heat gain through building envelopes (Overall Thermal Transfer Value, OTTV and Roof Thermal Transfer Value, RTTV) are limited to certain values. The regulation also enforced on the existing buildings and new buildings. Large buildings in Thailand that constructed before the regulation been issued (defined as existing buildings) usually have large amount of glass windows installed as building envelopes. And those buildings shall have the values of heat gain passing through envelopes exceeding the regulation values. Therefore those buildings have to be corrected by changing the envelope thermal properties to reduce the heat gain through the envelopes to the regulation value. The easiest way to change the building envelope properties especially on the glass windows is to adhere films on the glass windows. Data of film properties available for customer in Thailand are usually given in the form of overall values (not in function of wavelength) and the values given are usually referenced to a clear glass. But glasses used for glass windows in existing buildings can have various types, such as, clear glass, tinted glass, and reflective glass, etc. Therefore, when one wants to change the glass window properties to reduce heat transmission by adhering the film to the glass window which is not a clear glass, one cannot directly use values of the given film properties to analyze. Spectral optical properties of the individual glass and film are needed in order to find the spectral properties of glass with film. Glass windows and glass windows with films affected the building not only on thermal transmission but they also affected on thermal comfort and visual comfort. Therefore, the understanding of the thermal performance of glass windows and glass windows with films in aspect of heat transmission and thermal comfort shall be the essential things for design architects, design engineers, building owners, and officers who responsible for enforcing and issuing energy policy. This article describes the study for thermal performance rating of the glass windows and glass windows with films under local design condition.

2. Thermal comfort index and heat transmission index

Thermal comfort is defined as the condition of mind that expressed satisfaction with the thermal environment (ISO 7730 [3] and ASHRAE Standard 55 [4]). Thermal comfort