ABSTRACT

Energy usage for building is very significant and has been on the climb from year to year especially with the growing number of buildings to cope with the development and ever growing population. With the usage of air conditioning in most buildings nowadays contributing up to 40% of total building energy use in most countries, it is becoming worrying and measure need to be taken to tackle this effect. In Singapore, studies have shown the total energy use for cooling for a building range from 45.1% up to 73% of the total building energy usage which is even more alarming. Thus Envelope Thermal Transfer Value (ETTV) was introduced as a tool to regulate and measure the building heat gain.

This dissertation proposes a methodology to utilize and generate the relationship between ETTV and Total Cooling Energy (E_c) consumption using a case study. Using a medium scale mixed development building in Singapore as case study; the ETTV value & its corresponding E_c is calculated and stimulated using Carrier's E-20 program respectively. It was found that the ETTV value for the variation of glass used range from 39.89 W/m^2 to 55.81 W/m^2 with translates to 4.73% reduction in ETTV value for each 0.1 SC-Value drop for Window to Wall Ratio (WWR) of only 0.29. It was also found that each W/m^2 of ETTV value increases the E_c by 0.65 kW with the selected air conditioning system with COP of 3. Although the findings are specific to the case study building, it is significant as medium scale mixed developments is the most sought after and constructed buildings in Singapore. Nevertheless with the findings, proper measures to set and review the permissible ETTV value range to ensure the energy usage of building can be managed more efficiently.

ABSTRAK

Penggunaan tenaga oleh bangunan kini semakin meningkat dengan peningkatan jumlah bangunan baru bagi menangani jumlah populasi semakin meningkat. Dengan penggunaan penghawa dingin dalam hampir semua bangunan kini mencecah 40% daripada jumlah penggunaan tenaga bangunan, ia makin membimbangkan dan langkah pembetulan perlu diambil. Di Singapura, kajian mendapati bahawa jumlah penggunaan tenaga untuk penyejukan sesebuah bangunan adalah dalam julat 45.1% hingga 73% daripada jumlah penggunaan tenaga banguanan. Maka sistem Sampul Pemindahan Nilai Terma (ETTV) telah diperkenalkan sebagai salah satu langkah untuk mengukur jumlah penyerapan haba oleh bangunan.

Berdasarkan kertas kerja ini, satu kaedah untuk mengguna dan menghubung-kaitkan ETTV dan Jumlah Tenaga Penyejukan (E_c) dengan menggunakan satu contoh kes kajian. Dengan menggunakan sebuah bangunan perkembangan campuran skala sederhana di Singapura sebagai contoh kajian kes ini, nilai ETTV bangunan dan E_c akan dikira dan disimulasi dengan penggunaan perisai Carrier E-20 untuk semua konfigurasi cermin bangunan. Daripada keputusan yang diperolehi, didapati bahawa nilai ETTV untuk variasi cermin yang digunakan adalah dalam julat 39.89 W/m^2 to 55.81 W/m^2 yang bermaksud 4.73% penurunan nilai ETTV bagi setiap penurunan 0.1 nilai SC untuk nilai ratio Cermin kepada Dinding (WWR) 0.29 sahaja. Selain itu, juga didapati bahawa untuk setiap peningkatan W/m^2 nilai ETTV, nilai E_c akan meningkat sebanyak 0.65 kW dengan system penghawa dingin yang telah ditetapkan dengan nilai kecekapan (COP) 3. Walaupun keputusan yang diperolehi hanya sah untuk contoh kes kajian, ia masih penting bagi pembangunan yang sama. Selain itu, langkah yang sepatutnya boleh diambil dengan menentukan julat nilai ETTV supaya jumlah penggunaan tenaga sebuah bangunan dikawal dengan lebih cekap.

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NOMENCLATURES

Symbols	Description	Unit
$\propto$,	Diversity factors of operating hours in a day	
β	Diversity factors of operating days in a week	
γ	Ratio of the annual cooling load to envelope heat gains	
Δt	Design indoor–outdoor temperature difference	(K)
ΔT	Temperature different of outdoor and indoor condition	(K)
A	Total building envelope area	(m^2)
A_e	Exposed area of windows	
A_r	Opaque roof area	
A_{sl}	Skylight area	(m^2)
A_{f1}, A_{f2}, A_{fn}	Areas of different fenestration	(m^2)
A_o	Gross area of external wall or roof	(m^2)
A_{01}, A_{o2}, A_{on}	Gross area of the exterior wall for each orientation	(m^2)
A_{w1}, A_{w2}, A_{wn}	Areas of different opaque wall	(m^2)
b_1, b_2, b_n	Thickness of basic material	(m)
c	Load factor	
D	Number of 18.3 °C based degree day in a year	
E_c	Total Cooling Energy	(W)
E_{cl}	Total Cooling Load	(W)
E_{ac}	Annual Cooling Energy	(W)
E_{ce}	Cooling Energy	(W)

NOMENCLATURES

Symbols	Description	Unit
G	Fraction of area exposed to direct solar radiation	
I_T	Total radiation	(W/m^2)
I_D	Direct radiation	(W/m^2)
I_d	Diffuse radiation	(W/m^2)
k_1, k_2, k_n	Thermal conductivity of basic material	(W/mK)
M, J, D	March, June & December	
Q	Solar heat gain	(W)
Q_d	Degree day cooling load	(W)
Q_{env}	Average cooling load due to envelope heat gain	(W)
Q_{int}	Average internal heat load due to occupants, lights and equipment	(W)
Q_{misc}	Average miscellaneous load due to infiltration, roof and ground heat gains	(W)
R_i	Air film resistance of internal surface	(m^2K/W)
R_o	Air film resistance of external surface	(m^2K/W)
R_T	Total thermal resistance	(m^2K/W)
T_m	Daily mean temperature	(°C)
T_{ref}	Reference temperature	(°C)
U	Thermal transmittance value	(W/m^{2K})
U_f	Thermal transmittance of fenestration	(W/m^2K)
U_r	Thermal transmittance of opaque roof	(W/m^2K)
U_{sl}	Thermal transmittance of skylight	(W/m^2K)

NOMENCLATURES

Symbols	**Description**	**Unit**
U_w	Thermal transmittance of opaque wall	(W/m^2K)
U_{w1}, U_{w2}, U_{wn}	Thermal transmittance of opaque wall	(W/m^2K)
U_{f1}, U_{f2}, U_{fn}	Thermal transmittance of fenestration	(W/m^2K)

Abbreviations	**Description**	**Unit**
$ASHRAE$	American Society of Heating, Refrigerating and Air Conditioning Engineers	
BCA	Building Construction Authority	
CF	Solar Correction Factor of Fenestration	
COP	Coefficient of Performance	
$ETTV$	Envelope Building Thermal Transfer	(W/m^2)
HAP	Hourly Analysis Program	(W/m^2)
$OTTV$	Overall Thermal Transfer Value	(W/m^2)
$OTTV_{roof}$	Overall Roof Thermal Transfer Value	(W/m^2)
$OTTV_{wall}$	Overall Wall Thermal Transfer Value	(W/m^2)
$RETV$	Residential Envelope Transmittance Value	(W/m^2)
$RTTV$	Roof Thermal Transfer Value	(W/m^2)
SC	Shading Coefficient of Fenestration	
SC_1	Shading Coefficient of Glass or Effective Shading Coefficient of Glass with Solar Control Film is used on the Glass	
SC_2	Shading Coefficient of External Shading Devices	

NOMENCLATURES

Abbreviations	Description	Unit
$SC_{f1}, SC_{f2}, SC_{fn}$	Shading Coefficient of Fenestration	
SF	Solar Factor	(W/m^2)
SKR	Skylight Ratio of Roof	
TD_{eq}	Equivalent Temperature Different	
VRV	Variable Refrigerant Volume	
WWR	Window to Wall Ratio	