Design and Construction for Energy Efficiency of Residential Buildings in Hong Kong

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Director and Chairman of Policy & Research Committee
Hong Kong Green Building Council
2 Government buildings to achieve 5% electricity reduction target by 2020 (2014 as base); further reduction from 2020-2025 to be determined in 2019-20

- Gross Floor Area (GFA) concessions for private-sector green building projects;
- Periodic review, expand and/or tighten relevant energy-related standards:
  - Buildings Energy Efficiency Ordinance (BEOE);
  - Building (Energy Efficiency) Regulation, (B(E)ER); and
  - Energy Efficiency (Labelling of Products) Ordinance (EELPO)
- Already in existence
  - 1/7th of buildings in Hong Kong (about 6,400 buildings) participated in the $450 million Building Energy Efficiency Fund Scheme (BEEFS) programme;
  - District cooling at Kai Tak;
  - Gross Floor Area (GFA) concessions for private-sector green building projects;
  - and approximately $100 million power companies’ Eco Building Fund (CLP Power Hong Kong (CLP)) and Power Smart Fund (The Hong Kong Electric Company Limited (HEC)) for energy saving 2014-18
Sustainable Building Design Guidelines

Buildings Department, HKSAR Government
Overall Thermal Transfer Value (OTTV) standard, was first introduced in 1995 and was tightened in 2011.

Extent of Application: Commercial buildings (office, retail), and hotels

CODE OF PRACTICE

FOR

OVERALL THERMAL TRANSFER VALUE

IN BUILDINGS

1995
HK Challenges

Rising energy consumption trend in residential sector leading to increased carbon emissions

The Carbon Challenge:

Residential sector Accounting for 25% of total electricity consumption of HK (second largest sector)
1970
>1,900 Megajoule per Capita

2008
>5,300 Megajoule per Capita
HK Challenges

Humid Sub-tropical Climate

Dense Built Context

Design for Thermal Comfort

1. Air Movement
2. Solar Shading Control

Concerns about Environmental Conflicts

Air Quality
Noise Pollution
Heat Emissions etc.

Dry Bulb Temperature (°C)
Energy Use in Residential Flat

Annual Energy Use in HK in 2008 (EMSD: HK Energy End-use Data 2010)

PUBLIC
Building-Related Energy
22% [1,300 kWh/household/yr]

PRIVATE
Building-Related Energy
30% [1,900 kWh/household/yr]
Design Parameters on Building-design-related Energy Use for Residential Buildings

- Glass (SC)
- External Shading (ESC)
- Window to Wall Ratio (WWR)
- Orientation
- Absorptivity
- U-Value
- Thermal Mass
- Room Layout / Openable Window Area
- WWR / Glass (VLT) / Window Height / Room Layout

Categories:
- Envelope
- Daylight

Ventilation
Guidelines

focus on **New** residential buildings

energy efficiency / use related to design and construction of **building fabric**

energy efficiency / use in **operational phase**
Implementation

16. This practice note is applicable to all new building plans or major revision of building plans for development proposals involving residential buildings submitted to the BA for approval on or after 1 April 2015. For the avoidance of doubt, this practice note is also applicable to building plans which have been previously disapproved and are resubmitted for approval on or after 1 April 2015.

17. This practice note does not apply to alteration and addition works or change in use not resulting in a new residential building.

Effective Date: 1 April 2015
Residential Thermal Transfer Value

Natural Ventilation
Wall Areas to be included in RTTV\textsubscript{wall} calculations

External walls of the all enclosed spaces of residential units, except those of bathrooms & enclosed kitchens
Key Difference with OTTV
Default Operation and Occupancy Patterns for Residential Buildings
Independent Suitable Values for Roof and Wall

Exclusions
Internal shading devices, such as draperies and blinds;
Solar reflection or shading from adjacent developments;
and Use of energy-efficient building services equipment and appliances.
RTTV\text{wall} Calculation Formula

\[ RTTV_{\text{wall}} = [41.75 \times \text{WWR} \times \text{SC} \times \text{ESC} \times G_w] + [3.57(1-\text{WWR}) \times U_w \times \alpha \times G_w] + [0.64 \times \text{WWR} \times U_f \times G_w] \]

**Radiation Through Glazing**

- **WWR**: Window to Wall Ratio
- **G_w**: Wall Orientation Factor
- **SC**: Shading Coefficient
- **ESC**: Shading Coeff. of External Shades

**Conduction Through Opaque Wall**

- **U_w**: U-value of the opaque wall
- **α**: Absorptivity of the wall

**Conduction Through Glazing**

- **U_f**: U-value of the glazing
RTTV_{roof} Calculation Formula

\[
RTTV_{\text{roof}} = \left[41.10(SRR)(SC_r)(G_s)\right] + \left[3.47(1-SRR) U_r \alpha_r G_s\right] + \left[0.40(SRR)U_{sl}G_s\right]
\]

- **SRR**: Skylight to Roof Ratio
- **G_s**: Roof Orientation Factor
- **SC_r**: Shading Coeff. of Skylight Glazing
- **Ur**: U-value of the roof
- **\(\alpha_r\)**: Absorptivity of the roof
- **U_{sl}**: U-value of the skylight glazing
One of the pre-requisites for the granting of GFA concessions under PNAP APP-151:

\[ \text{RTTV}_{\text{Wall}} \leq 14 \text{ W/m}^2 \quad \& \quad \text{RTTV}_{\text{Roof}} \leq 4 \text{ W/m}^2 ; \]
Daylight & Glare Control

Visible Light Transmittance $\geq 50\%$

Glass External Reflectance $\leq 20\%$
Incentive for Effective Sunshade

For projection ≤ 500mm (facing N [NNW to NNE]) & ≤ 750mm (facing other orientations)

* For sunshades within re-entrant less than 4.5m, the projection should not be more than 500mm

For projection > 500 and ≤ 1500mm (facing N) & > 750 and ≤ 1500mm (facing others),

- OPF not less than 0.2 or 0.5 respectively
- Not causing obstruction to prescribed windows
Complex Shading & Self-Shading

Equation:

$$\text{ESC} = \frac{\sum \text{Er} \cdot I_D + I_d}{\sum I_D + I_d}$$

**ESC**: External Shading Coefficient

**Er**: \(\frac{A_e}{A}\) is the fraction of area exposed to direct solar radiation

**I_D**: Direct solar radiation for a specific time given in tables

**I_d**: Diffuse solar radiation for a specific time given in tables
## Simplicity

### Deemed to Satisfy RTTV Criterion

<table>
<thead>
<tr>
<th>Category</th>
<th>Average Values</th>
<th>Deem to Satisfy Criteria for SC [Facade]</th>
<th>Average SC [Facade]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WWR</td>
<td>Absorptivity*</td>
<td>≤ 0.56</td>
</tr>
<tr>
<td>NNE to NNW (Category A)</td>
<td>0.38</td>
<td>0.37</td>
<td></td>
</tr>
<tr>
<td>NNW to NNE (Category B)</td>
<td>0.53</td>
<td>0.30</td>
<td>≤ 0.59</td>
</tr>
</tbody>
</table>

* Any ONE external finish material applied on the facade in one orientation constituting more than 60% of the gross wall area can be regarded as dominant and its absorptivity can be taken as the average absorptivity of the facade in that orientation for compliance check on Deemed to Satisfy RTTV\textsubscript{wall} Criteria

Facade Facing NNW to NNE (Category B)

Average WWR = 0.53
Average Absorptivity = 0.30
Average SC Facade = 0.57
RTTV
Residential Thermal Transfer Value

NV
Natural Ventilation
Adaptive Comfort Model

ASHRAE 55; CLO = 1.0
ASHRAE 55; CLO = 0.5

Ngetal 2005, Khodari 2000
Effect of Window Size
100% of rooms that comply with the prescriptive test for **Cross Ventilation** have AAWV > 0.4m/s

60% of rooms that pass with the prescriptive test for **Single-sided Ventilation** have AAWV > 0.4m/s
Cross Ventilation $N_{VC}$
Single-Sided Ventilation $NV_{ss}$

Case 1

- EXP: External Plane
- NP: Notional Plane
- $W_1 = 4.5m$
- $W_3 \geq 1m$ or width of Ventilation Openings

Single-sided Ventilation Path: 

Case 2

- EXP: External Plane
- NP: Notional Plane
- $W_1 = 4.5m$
- $W_3 \geq 1m$ or width of Ventilation Openings

Single-sided Ventilation Path:
Single-Sided Ventilation NV_{ss}

Total openable window area in aggregate

\[ \geq \text{one-fifth (1/5th)} \]

of the UFA of the room

Note: Current min. prescribed openable window area \( \geq 1/16\text{th} \) (for reference)
Heat Emissions from Air-conditioners

Required width to dissipation heat generated by AC

Width of AC Platform
1.0m 1.5m 0.75m

A/C Outdoor Units

Subject Flat

Francis Yik et al (2002) “Influence of a depth of a recessed space to flow due to air-conditioner heat rejection”
## Performance-based Approach

### Alternative Approach Methodology for NV<sub>TC</sub>

<table>
<thead>
<tr>
<th></th>
<th>Simplified Simulation Method</th>
<th>Site Specific Simulation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Process</strong></td>
<td>CFD building model to assess internal conditions with standard wind conditions</td>
<td>CFD building &amp; neighbourhood model to assess external &amp; internal conditions with realistic local wind profiling</td>
</tr>
<tr>
<td><strong>Features capture</strong></td>
<td>Building layout, building features that affect NV potential</td>
<td>Building layout, building features, neighbourhood massing / topography, local wind conditions that affect NV potential</td>
</tr>
</tbody>
</table>
Sensitivity Tests

$\text{NV}_{\text{TC}}$ Compliance Check

<table>
<thead>
<tr>
<th>$\text{NV}_c$</th>
<th>11%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{NV}_{c,\text{(at re-entrant)}}$</td>
<td>37%</td>
</tr>
<tr>
<td>$\text{NV}_{\text{SS}}$</td>
<td>34%</td>
</tr>
<tr>
<td>Overall $\text{NV}_{\text{TC}}$</td>
<td>82%</td>
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</tbody>
</table>
Potential Energy Saving

RTTV

Reduction of Cooling Energy %

Baseline: Estimated Hong Kong Average

Target 2020
Life Cycle Costing

Change of Shading Coefficient (SC)

Case 1: [WWR=0.5-0.6] & [Curtain Wall Construction]

Change of Overhanging Projection Factor (OPF)

Case 1: [WWR=0.5-0.6] & [Curtain Wall Construction]

Change of Operable Window Area

+$ +0.1~0.2%
Of total construction cost

0% ➞ 70%
Ventilated Layout %
0% ➞ 60%
0% ➞ 46%
Thank you.
Welcome your comments / questions.

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