Guidelines on Design and Construction Requirements for Energy Efficiency of Residential Buildings

2014

Foreword

The residential sector is one of the major building uses in Hong Kong. The electricity consumption in residential buildings has been increasing steadily in recent decades. Enhancing the energy performance of residential buildings forms an important part of the Government's overall strategy towards the achievement of a more environmentally friendly and sustainable built environment.

Based on a performance-based consultancy study commissioned by the Buildings Department (BD), provision of energy-efficient building envelopes and natural ventilation are found to have the highest potential in energy saving among other design and construction requirements for residential buildings. The existing Building (Energy Efficiency) Regulation (Cap 123M) and the Code of Practice for Overall Thermal Transfer Value in Buildings 1995 stipulate mandatory control on Overall Thermal Transfer Values (OTTV) for commercial buildings and hotels only, but not residential buildings. With the increasing use of air-conditioning in residential buildings, it is necessary to enhance the design of residential building envelopes so as to make them more energy efficient under air-conditioned environment. On the other hand, in view of the Hong Kong climate, natural ventilation can also be used to enhance thermal comfort in lieu of air-conditioning for residential buildings subject to other local environmental factors. The potential for natural ventilation should be exploited as much as possible for energy saving and other sustainability objectives.

These "Guidelines on Design and Construction Requirements for Energy Efficiency of Residential Buildings" aim to provide technical guidance to assist authorized persons, registered structural engineers and other relevant practitioners to design and construct residential buildings with the ultimate objective of enhancing energy efficiency. The Guidelines will be regularly reviewed and updated to keep pace with advancement in building design and technological development. The Building Authority welcomes suggestions for improving the Guidelines for enhancing the energy performance of residential buildings in general.

Buildings Department
September 2014

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 OBJECTIVE

1.1.1 The Guidelines on Design and Construction Requirements for Energy Efficiency of Residential Buildings (the Guidelines) are part of the Government's overall strategy towards the achievement of a more environmentally friendly and sustainable built environment.

1.2 SCOPE

1.2.1 Key design and construction requirements of the building fabric to reduce energy consumption during operation phase of new residential buildings are under the scope of the Guidelines.

1.2.2 The Guidelines give the assessment methods of the following two design and construction aspects for the building fabric:

- Residential Thermal Transfer Value (RTTV) that aims to control facade and roof heat gain; and
- Natural ventilation design that aims to achieve thermal comfort (NV_{TC}) without reliance on active building systems.

1.3 APPLICATION

1.3.1 The Guidelines apply to "Residential building" as defined in Section 1.4 includes domestic premises situated in a domestic building or composite building. However, domestic accommodation in a building in which the only domestic part is a place of residence, having not more than $50m^2$ of usable floor space, for caretakers or persons employed in connection with the building, will be exempted from the Guidelines.

1.3.2 Requirements of RTTV apply to all enclosed spaces of residential units, except for bathrooms and enclosed kitchens.

1.3.3 Requirements to measure the potential of NV_{TC} apply to habitable spaces of residential units.

1.4 TERMINOLOGY AND DEFINITIONS

Unless otherwise stated, words and expressions have the meaning attributed to them by the Building (Energy Efficiency) Regulation and Building (Planning) Regulations. It should also be noted that:

"Area-weighted Average Wind Velocity (AAWV)" is calculated by integrating the velocity magnitudes of the flow cells across a calculation plane and dividing by the total calculation plane area.

"Building fabric" refers to a component of any building, consisting of its roofs, walls, windows, doors, etc., but excluding any mechanical system, for controlling the flow of energy between the interior and exterior of the building.

"Cross ventilation" means the situation in which outdoor air can flow from the window opening(s) (the primary ventilation opening(s)) through a cross ventilation path and out via the other window opening(s) (the secondary ventilation opening(s)).

"External reflectance" means the percentage of daylight reflected from any external surface of any window, door, wall or roof of a building.

"Fenestration" means any glazed aperture in the building envelope.

"Field models" are based on the sub-division of the computational domain into a very large number of control volumes; they are able to give detailed information at any point of the domain. Such models incorporate the volume in question in its realistic situation with surrounding features, the surrounding features are included in the calculation domain and as such influence the result.

"Habitable space" means space for habitation including living/dining areas and bedrooms, which shall be provided with effectual means of natural lighting and ventilation under Building (Planning) Regulation 29.

"Natural ventilation for thermal comfort (NV_{TC})" facilitates the movement of fresh air through an interior space between window openings or the alike. NV_{TC} design aims to achieve thermal comfort without reliance on active building systems.

"Opaque" wall or roof means that solid part of the wall or roof which is not part of the fenestration.

"Primary ventilation openings" include any prescribed windows or primary openings meeting the requirements in Diagrams F and G of Practice Note for Authorized Persons, Registered Structural Engineers and Registered Geotechnical Engineers (PNAP) APP-130; and the said windows should face the External Plane (EXP) or the Secondary Window Plane (SWP) subject to any part of the windows not more than 1.5m away from the EXP or via Notional Plan (NP) to EXP. EXP, SWP and NP are defined in Sections 3.2 and 3.3.

"Residential building" means to include domestic premises for habitation in a domestic building or composite building. It includes hostel, dormitory or other room or premises provided for housing or lodging of pupils of any school out of school hours, but does not include hospital, residential care home for the elderly, residential care home for the disabled, and any hotel and guesthouse which has the meaning assigned it by section 2 of the Hotel and Guesthouse Accommodation Ordinance (Cap. 349).

"Residential Thermal Transfer Value (RTTV)" means, as regards a residential building, the amount, expressed in watts per square meter (W/m^2), of heat transferred through that building envelope and calculated having regard to factors such as the area of the building envelope, the material used in its construction, thermal properties of the material, orientation of the building, the area of the openings in the building envelope and the shading effect of projections from the building envelope.

"Secondary ventilation openings" include any prescribed windows, secondary openings meeting the requirements in Diagram G of PNAP APP-130, or window openings which are located at an external wall and facing a re-entrant meeting the requirements in Section 3.2.2; and the said windows should face the EXP / SWP or via NP to EXP / SWP. EXP, SWP and NP are defined in Section 3.2.

"Window to Wall Ratio (WWR)" is defined as the ratio of glazed areas to gross wall areas of building envelope of all enclosed spaces of residential units, except for bathrooms and enclosed kitchens.

"Visible Light Transmittance" means the percentage of visible radiation of light that is transmitted through a glazing panel.

"Zone models" describe a fluid flow within a discrete zone or room; they split the zone in question in distinct control volumes where calculations are performed. Zone models are not considered as accurate as field models.

2 CONTROL OF RESIDENTIAL THERMAL TRANSFER VALUE (RTTV)

2.1 GENERAL PRINCIPLES

2.1.1 General Approach

As RTTV measures the potential energy performance associated with the building envelope of a residential building, controlling the RTTV will reduce heat transfer through the building envelope and thus the electricity required for air-conditioning.

This approach will allow authorized persons, registered structural engineers and other persons responsible for the design of buildings with design flexibility to innovate and vary important envelope components such as type of glazing, window size, external shading to windows, wall color and wall type to meet targeted RTTV criteria.

The overall RTTV for external walls and roofs of a residential building shall be calculated based on the methodology set out in Section 2. The RTTVs shall not exceed the maximum values specified in Section 2.1.2 to limit the heat transfer through façades and roof and consequently limit the heat which must be removed by mechanical cooling systems or natural means. The maximum RTTVs specified should apply to the overall external walls as described in Section 2.1.6 or roofs, as the case may be, on average and do not apply to any individual wall or roof.

Artificial lighting consumes electricity and creates heat. This increases the cooling load of a building and in turn increases energy consumption. Consequently, when determining the size and location of windows as well as choice of glass in the envelope of a building, efforts should be made to provide as much natural lighting into the building as possible. For example, with glazing, the visible light transmittance should be acknowledged in addition to its thermal transmittance properties (i.e. RTTV) as daylight can supplement artificial lighting and consequently reduce the cooling load.

2.1.2 Maximum RTTVs

The overall RTTV of external walls and roof of a residential building as described in Section 2.1.6 should not exceed 14 W/m^2 and 4 W/m^2 respectively.

2.1.3 Assumptions

The concept of RTTV is based on the assumption that each residential unit in a building is completely enclosed when air-conditioning is turned on according to local climatic conditions, default air-conditioner operation and occupancy patterns.

Default air-conditioner operation and occupancy patterns of the habitable spaces of residential buildings as defined in the BEAM Plus green building certification system of the Hong Kong Green Building Council and BEAM Society have been adopted in the RTTV methodology.

2.1.4 Key Difference between RTTV and OTTV Control

The Building (Energy Efficiency) Regulation, which has come into effect since 1995, governs heat transfer through building envelopes of commercial and hotel buildings, but not residential buildings and the residents' recreational facilities. There are similarities between RTTV and OTTV control. However, the fundamental difference between RTTV and OTTV is that, the RTTV methodology assumes that residential units are not mechanically cooled from November to March inclusive while the OTTV assumes space-conditioning is required within a commercial building or hotel throughout the year primarily during the day.

2.1.5 Effective Measures to Improve RTTV Performance

The following measures will be effective in improving RTTV performance:

- Siting a building to avoid extensive glazed facades with westerly aspects;
- Introducing external shades to window areas to reduce solar heat gain;
- Appropriate sizing and locations of windows for natural daylighting while avoiding excessive solar heat gain; and
- Appropriate choice of windows with a low thermal transmittance characteristic.

2.1.6 External Walls and Roofs to be Included in RTTV Calculations

External walls and roofs of all enclosed spaces of residential units shall be included in the RTTV calculations, except those of bathrooms and enclosed kitchens.

2.1.7 Exclusions

In the RTTV formulation, the following factors are not taken into account:

- Internal shading devices, such as draperies and blinds;
- Solar reflection or shading from adjacent buildings; and
- Other measures include more extensive use of energy-efficient building services equipment and appliances, e.g. energy-saving lamps, low-loss luminaries and high-efficiency air-conditioning and more sophisticated building services control systems.

2.2 RTTV$_{wall}$ CALCULATIONS

The RTTV$_{wall}$ of external walls considers 3 elements of heat transfer:

- Heat conduction through opaque walls
- Heat conduction through glazing and window frames
- Solar radiation through glazing

The RTTV$_{wall}$ of the external walls of a residential unit should be calculated using the following formula:

$$RTTV_{wall} = 3.57(1-WWR)\, U_w\, \alpha\, G_w + 0.64(WWR)\, U_f\, G_w + 41.75(WWR)(SC)(ESC)\, G_w$$

Where:

WWR	=	Window to wall ratio
U_w	=	U-value of the wall (W/m^{2}K)
α	=	Absorptivity of the wall
U_f	=	U-value of the glazing (W/m^{2}K)
G_w	=	Wall orientation factor
SC	=	Shading Coefficient
ESC	=	Shading Coefficient of external shades

Where more than one type of material or fenestration is used, RTTV$_{wall}$ should be calculated for each element and combined as per the relative areas of each. This is calculated as follows:

$$\begin{aligned} RTTV_{wall} = \ & ((3.57(A_{w1}U_{w1}\alpha_{w1} + A_{w2}U_{w2}\alpha_{w2} + \ldots + A_{wn}U_{wn}\alpha_{wn})/A_0) + \\ & (0.64(A_{f1}U_{f1} + A_{f2}U_{f2} + \ldots + A_{fn}U_{fn})/A_0) + \\ & (41.75(A_{f1}SC_{f1}ESC_{f1} + A_{f2}SC_{f2}ESC_{f2} + \ldots + A_{fn}SC_{fn}ESC_{fn})/A_0))(G_w) \end{aligned}$$

Where:

A_o	=	Total gross wall area (m^2)
A_{w1}, A_{w2}, A_{wn}	=	Areas of different walls (m^2)
U_{w1}, U_{w2}, U_{wn}	=	U-values of different walls (W/m^{2}K)
α_{w1}, α_{w2}, α_{wn}	=	Absorptivity of different walls
A_{f1}, A_{f2}, A_{fn}	=	Areas of different fenestration (m^2)
U_{f1},U_{f2}, U_{fn}	=	U-values of different fenestration (W/m^{2}K)
SC_{f1},SC_{f2}, SC_{fn}	=	Shading Coefficient of different fenestration
ESC_{f1},ESC_{f2}, ESC_{fn}	=	Shading Coefficient of external shades of different fenestration

Areas of openings at external walls for accommodating air-conditioning (A/C) units, meeting the following requirements will not be counted in RTTV calculations:

- with A/C units installed; or
- with opaque infill panels installed if A/C units are not installed.

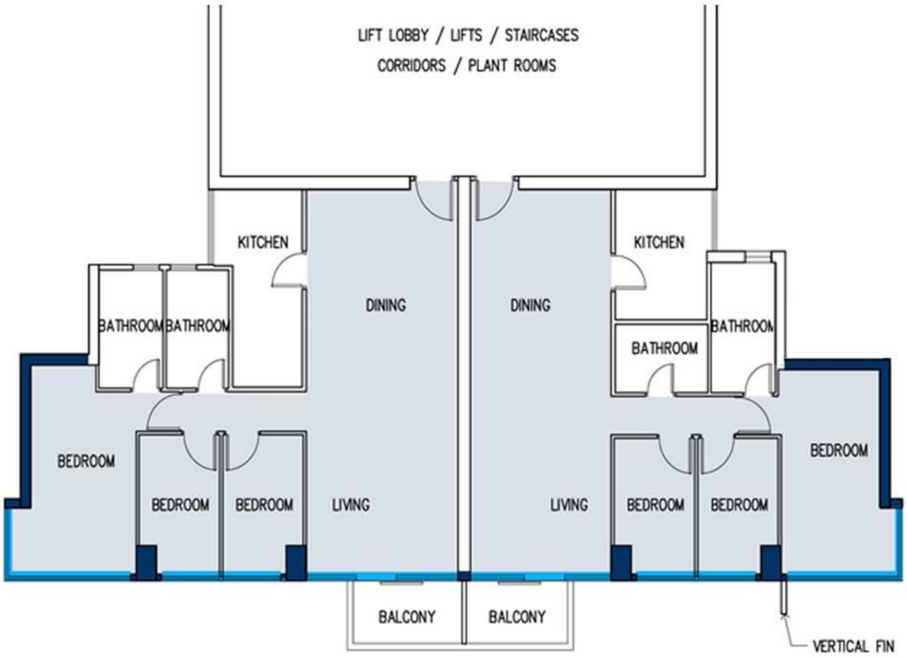


Figure 1 Wall Areas (highlighted in blue and dark blue) to be included in $RTTV_{wall}$ calculations

2.3 $RTTV_{roof}$ CALCULATIONS

The $RTTV_{roof}$ of roofs considers 3 elements of heat transfer:

- Heat conduction through opaque roof.
- Heat conduction through glazed skylights and associated frames
- Solar radiation through glazed skylights

This takes into account the combined effect of U-values, absorptivity, skylight area, skylight shading coefficient and slope orientation. This is calculated by:

$$RTTV_{roof} = 3.47(1-SRR)U_r \alpha_r G_s + 0.40(SRR)U_{sl} G_s + 41.10(SRR)(SC_r) G_s$$

Where:

U_r	=	U-value of the roof (W/m^2K)
α_r	=	Absorptivity of the roof
G_s	=	Roof orientation factor
SRR	=	Skylight to Roof Ratio
U_{sl}	=	U-value of the skylight glazing (W/m^2K)
SC_r	=	Shading Coefficient of the skylight glazing

If a roof is shaded, the effect of the shading can be calculated by the following performance method:

1. Construct a baseline model of a barely compliant roof with no shading.
2. Construct a design model including the real construction and an accurate representation of the shading.
3. Calculate the total heat transfer through the roof into the building from April to October 24 hours a day for both cases.
4. Assume the room(s) adjacent to the roof is/are cooled constantly to 22°C.
5. The performance of the shaded system must be better than the baseline.
6. Exclude all shading that is not a permanent architectural feature of the building in question.
7. The requirements for applicable simulation tools are listed in **Appendix II**.

2.4 CALCULATION OF COMPONENT COEFFICIENTS AND PARAMETERS OF RTTV

2.4.1 Thermal transmittance of opaque construction (U)

Opaque walls and roofs usually involve a composite of materials. As long as the opaque walls or roofs of the same material composition on the same elevation or roof, it is acceptable to use the mean / weighted average of wall / roof thickness for RTTV calculation. The thermal transmittance of an opaque wall or roof should be derived by the following formula:

$$U = 1 / (R_i + x_1/k_1 + x_2/k_2 + \ldots + x_n/k_n + R_a + R_o)$$

Where:

x_1, x_2, x_n	=	Thickness of building materials of the wall or roof or part thereof (m)
k_1, k_2, k_n	=	Thermal conductivity of the building materials (W/mK) (Table 1)
R_i	=	Surface film resistance of internal surface of the wall or roof (m^2K/W) (Table 2)
R_o	=	Surface film resistance of external surface of the wall or roof (m^2K/W) (Table 2)
R_a	=	Air space resistance (m^2K/W) (Table 3)

Component coefficients and parameters of thermal transmittance

The component coefficient and parameters used in calculating the thermal transmittance of opaque construction should be assessed as follows:

(a) Thermal conductivity of building materials (k)

The thermal conductivity of the building materials of walls and roofs should be obtained from Table 1.

Table 1 Material Properties for U-value Calculations

Material	Thermal Conductivity (k) (W/mK)
Asphalt, mastic with 20% grit	1.15
Boards	
a) cork	0.042
b) hardboard high density	0.144
c) mineral fibre	0.053
d) plasterboard	0.16
Brick (common)	0.95
Concrete	
a) normal weight aggregate	2.16
b) lightweight aggregate	0.44
c) flat roof tiles or slabs	1.10
Glass	1.05
Mosaic tile	1.5
Insulating materials	
a) glass fiber mat or quilt	0.035
b) mineral wool felt	0.039
c) polystyrene expanded	0.034
d) polyurethane foam	0.026
Metals typical	
a) aluminum alloy	160
b) copper commercial	200
c) steel, carbon	50
Plaster/render	
a) gypsum	0.38
b) gypsum, sand aggregate	0.53
c) cement/sand	0.72
Screeding	
a) cement sand	0.72
b) terrazzo	1.59
Stone	
a) granite	2.9
b) marble	2.0

Note: If other materials are used, the thermal conductivity values should be subject to the acceptance of the Building Authority and the source of information from which the thermal conductivity values are obtained should be submitted for his consideration for this purpose.

(b) Surface film resistance for walls and roofs (R_i, R_o)

The surface film resistance for walls and roofs should be obtained from Table 2.

Table 2 Surface Film Resistance for Walls and Roofs

Type of surface	**Surface film resistance m²K/W**
Surface film resistance for walls	
a) Internal surface (R_i)	0.120
b) External surface (R_o)	0.044
Surface film resistance for roofs	
a) Internal surface (R_i)	
(i) Flat roof	0.162
(ii) Sloped roof 22.5 °	0.148
(iii) Sloped roof 45 °	0.133
b) External surface (R_o)	0.055

Note: As the inner surface of wall construction is typically not yet determined at the time when an occupation permit is issued, the internal film resistance is standardized for all situations. The external film resistance is also standardized as it is largely dominated by natural convective flows (e.g. external wind, etc) and is less affected by emissivity value.

(c) Air space resistance for walls and roofs (R_a)

The air space resistance for walls and roofs should be obtained from Table 3 and the emissivity should be referred to Table 4.

Table 3 Air Space Resistance for Walls and Roofs

Type of air space	Air space resistance (Ra) m²K/W					
	5mm	**10mm**	**20mm**	**50mm**	**75mm**	**100mm or more**
Air space resistance for walls						
Vertical air space (heat flows horizontally)						
a) Emissivity (0.5 and above)	0.110	0.123	0.148	0.153	0.156	0.160
b) Emissivity (below 0.5)	0.250	0.359	0.578	0.589	0.597	0.606
Air space resistance for roofs						
Horizontal air space (heat flows downward)						
a) Emissivity **α** (0.5 and above)						
(i) horizontal air space	0.110	0.123	0.148	0.158	0.166	0.174
(ii) sloped air space 22.5°	0.110	0.123	0.148	0.154	0.160	0.165
(iii) sloped air space 45°	0.110	0.123	0.148	0.152	0.155	0.158
b) Emissivity **α** (below 0.5)						
(i) horizontal air space	0.250	0.357	0.572	0.891	1.157	1.423
(ii) sloped air space 22.5°	0.250	0.357	0.571	0.768	0.931	1.095
(iii) sloped air space 45°	0.250	0.357	0.570	0.644	0.706	0.768

Note: A sloped air space is the air-gap between a sloped roof and a sloped structure underneath.

Table 4 Emissivity of Materials

Material	Emissivity
Aluminium (Anodised), Copper (Anodised), Glass, Paint (Zinc), Polyvinylchloride (PVC), Tile, Varnish, Cement Mortar, Screed, Concrete	0.5 and above
Aluminium (Polished/ Dull/ Roughly Polished), Copper (Polished/ Dull), Zinc (Polished/ Oxidized), Paint (Aluminum), Steel (Un-oxidized/ Polished/ Stainless)	below 0.5

2.4.2 **Absorptivity (α)**

Energy simulation studies for Hong Kong have shown that the external surface and color of walls and roofs, and therefore their absorptivity, have a significant effect on air-conditioning energy used. This should be included in the heat gain calculation as a multiplication constant to the equivalent temperature difference. The absorptivity for wall and roof surfaces should be obtained from Table 5.

Table 5 Absorptivity for Wall and Roof Surfaces[1]

Material	α	**Paint/Tile (gloss)**	α	**Paint/Tile (matt)**	α
Black spandrel glass	1.0	Black / Dark Green / Dark Grey / Dark Blue	0.9	Black	1.0
Red brick / Bituminous felt / Blue grey slate / Brown concrete	0.9	Brown / Green / Light Grey	0.8	Dark Grey / Dark Brown	0.9
Tarnished copper / Wood / Asphalt	0.8	Red	0.7	Brown / Red	0.8
Uncolored concrete	0.7	Orange / Yellow	0.5	Green / Orange / Yellow	0.6
Light buff brick / White marble	0.6	Light Green / Blue	0.4	Light Green / Blue	0.5
Granite / Stainless Steel / Aluminum	0.5	Silver / White	0.3	White	0.3
Aluminum paint / Bituminous felt aluminized	0.4				
Polished copper / Gravel	0.3				
Polished aluminum / Bare wet soil	0.2				
Turf / Tinned surface	0.1				
Tree / Shrub	0.0				

Note: Absorptivity for other materials or surfaces should be subject to the acceptance of the Building Authority and the source of information from which the absorptivity values are obtained should be submitted for his acceptance prior to the application for consent to the commencement of the superstructure works.

[1] Adopted from Code of Practice for Overall Thermal Transfer Value in Buildings 1995 with additional data of turf / tree / shrub on green roofs.

2.4.3 **Shading coefficient of fenestration (SC)**

The shading coefficient of fenestration is the ratio of the solar heat gain through a particular type of glass under a specific set of conditions to the solar heat gain through double strength sheet clear glass under the same conditions. Allowances for Hong Kong's latitude and solar effects have been taken into account in the solar factor and therefore the shading coefficient of glass published by glass manufacturers in Hong Kong or overseas can be used without modification provided that the calculations have been based on a normal angle of incidence. The normal angle of incidence is defined as the angle between the sun's rays irradiated on a surface and the line perpendicular to this surface.

2.4.4 **Shading Coefficient of external shades (ESC_1)**

Shading of windows is of paramount importance in reducing solar heat gain to the building. The shading can be provided by projections over the window, at the side of the window, or a combination of both. For the purpose of simplicity in RTTV calculations, the shading effect should be taken into account as External Shading Coefficient ESC_1 which should be assessed as follows or ESC_2 as described in Section 2.5.3.

(a) Overhang projections to windows

The Shading Coefficient for overhang projections to windows should be obtained from Table 6 according to the overhang projection factor (OPF) and the orientation of the window. The OPF should be calculated as follows:

OPF = A / B

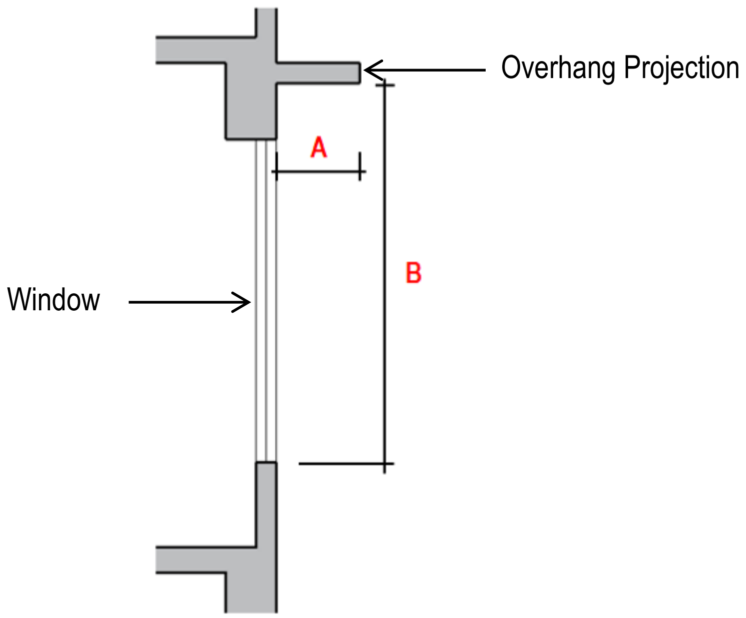


Figure 2 Overhang Projection

Table 6 Shading Coefficient for Overhang Projections to Windows

OPF	**External Shading Coefficient for Overhang Projections to Windows (ESC_1)**				
	N	**NE/NW**	**E/W**	**SE/SW**	**S**
0	1.000	1.000	1.000	1.000	1.000
0.05	0.983	0.951	0.965	0.958	0.949
0.1	0.975	0.913	0.931	0.918	0.898
0.15	0.970	0.884	0.896	0.879	0.849
0.2	0.967	0.862	0.864	0.843	0.802
0.25	0.965	0.844	0.834	0.807	0.766
0.3	0.964	0.830	0.806	0.776	0.733
0.35	0.963	0.818	0.780	0.747	0.711
0.4	0.962	0.809	0.755	0.722	0.691
0.45	0.961	0.800	0.732	0.698	0.671
0.5	0.960	0.795	0.714	0.679	0.651
0.55	0.960	0.789	0.698	0.661	0.632
0.6	0.960	0.784	0.682	0.646	0.612
0.65	0.960	0.780	0.666	0.633	0.592
0.7	0.960	0.776	0.652	0.621	0.572
0.75	0.959	0.772	0.642	0.612	0.560
0.8	0.959	0.769	0.631	0.603	0.555
0.85	0.959	0.766	0.622	0.596	0.551
0.9	0.959	0.765	0.615	0.589	0.549
0.95	0.959	0.764	0.608	0.583	0.548
1	0.958	0.764	0.602	0.577	0.546

Notes:

i. Should the OPF value fall in between increments, adopt the coefficient related to the next larger OPF value.

ii. OPF values above 1.0 are considered to produce too great an error in estimation. As such, any values above this should be taken as 1.0.

iii. When facade directions fall between the above cardinal points, the closest should be chosen.

(b) Side-fin projections to windows

For single side-fin projection, the Shading Coefficient should be obtained from Tables 7 and 8 according to the side-fin projection factor (SPF) and the orientation of the window. The SPF should be calculated as follows:

SPF = C / D

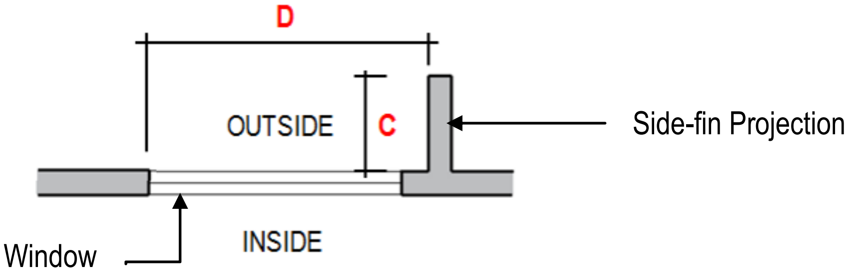


Figure 3 Side-fin Projection on the Right of Window

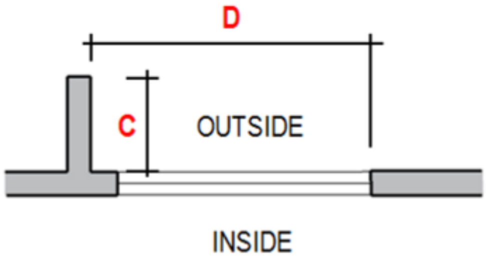


Figure 4 Side-fin Projection on the Left of Window

For a window with 2 side-fins in different length, the SPF should be calculated as follows:

$$\mathbf{ESC_{total} = 1 - [(1 - ESC_{left}) + (1 - ESC_{right})]}$$

Where ESC_{right} refers to Table 7 with SPF = E1 / F1;
ESC_{left} refers to Table 8 with SPF = E2 / F2;

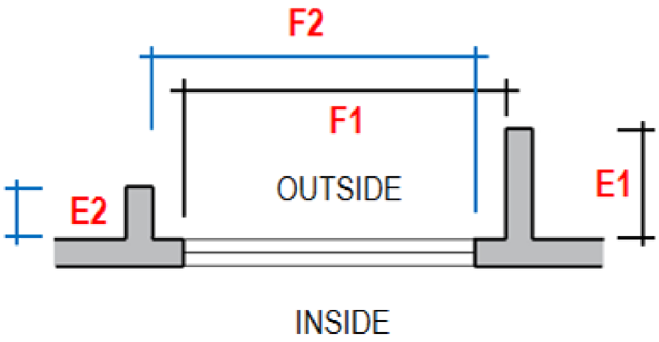


Figure 5 Side-fin Projections in Different Length on the Left and Right of Window

Table 7 Shading Coefficient for Side-fin Projections on the Right of Windows

Looking Out from the Building – Side-fin on the Right								
SPF	**External Shading Coefficient for Side-fin Projections to Windows (ESC_1)**							
	N	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.05	0.994	0.973	0.989	0.995	0.984	0.989	0.998	0.996
0.1	0.989	0.946	0.979	0.990	0.968	0.978	0.997	0.991
0.15	0.984	0.921	0.969	0.984	0.954	0.967	0.995	0.988
0.2	0.980	0.903	0.958	0.979	0.942	0.956	0.994	0.988
0.25	0.979	0.887	0.948	0.974	0.931	0.944	0.992	0.988
0.3	0.978	0.873	0.938	0.969	0.920	0.933	0.991	0.988
0.35	0.977	0.859	0.927	0.964	0.910	0.922	0.989	0.988
0.4	0.977	0.849	0.917	0.961	0.901	0.911	0.988	0.988
0.45	0.977	0.840	0.909	0.957	0.892	0.900	0.986	0.988
0.5	0.977	0.832	0.901	0.954	0.885	0.889	0.985	0.988
0.55	0.977	0.824	0.893	0.950	0.878	0.879	0.983	0.988
0.6	0.977	0.817	0.885	0.947	0.872	0.869	0.982	0.988
0.65	0.977	0.810	0.879	0.944	0.865	0.860	0.980	0.988
0.7	0.977	0.804	0.872	0.941	0.860	0.852	0.979	0.988
0.75	0.977	0.799	0.865	0.938	0.856	0.845	0.977	0.988
0.8	0.977	0.795	0.859	0.935	0.852	0.840	0.976	0.988
0.85	0.977	0.790	0.852	0.932	0.848	0.835	0.974	0.988
0.9	0.977	0.786	0.847	0.929	0.844	0.830	0.973	0.988
0.95	0.977	0.783	0.842	0.928	0.840	0.825	0.971	0.988
1	0.977	0.780	0.838	0.926	0.837	0.821	0.970	0.988
1.05	0.977	0.777	0.833	0.925	0.834	0.816	0.968	0.988
1.1	0.977	0.774	0.829	0.924	0.831	0.811	0.967	0.988
1.15	0.977	0.771	0.824	0.922	0.829	0.807	0.965	0.988
1.2	0.977	0.768	0.820	0.921	0.827	0.803	0.964	0.988
1.25	0.977	0.765	0.815	0.920	0.825	0.800	0.962	0.988
1.3	0.977	0.762	0.811	0.918	0.823	0.796	0.961	0.988
1.35	0.977	0.760	0.806	0.917	0.821	0.792	0.959	0.988
1.4	0.977	0.759	0.802	0.916	0.820	0.788	0.958	0.988
1.45	0.977	0.758	0.798	0.914	0.818	0.785	0.956	0.988
1.5	0.977	0.758	0.795	0.913	0.816	0.782	0.955	0.988

Notes:

i. SPF values above 1.5 are considered to produce too great an error in estimation. As such any values above this should be taken as 1.5.

ii. Should the SPF value fall in between increments, adopt the coefficient related to the next larger SPF value.

iii. When facade directions fall between the above cardinal points, the closest should be chosen.

Table 8 Shading Coefficient for Side-fin Projections on the Left of Windows

Looking Out from the Building – Side-fin on the Left								
SPF	External Shading Coefficient for Side-fin Projections to Windows (ESC_1)							
	N	NE	E	SE	S	SW	W	NW
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.05	0.994	0.996	0.998	0.989	0.984	0.995	0.989	0.973
0.1	0.989	0.991	0.997	0.978	0.968	0.990	0.979	0.946
0.15	0.984	0.988	0.995	0.967	0.954	0.984	0.969	0.921
0.2	0.980	0.988	0.994	0.956	0.942	0.979	0.958	0.903
0.25	0.979	0.988	0.992	0.944	0.931	0.974	0.948	0.887
0.3	0.978	0.988	0.991	0.933	0.920	0.969	0.938	0.873
0.35	0.977	0.988	0.989	0.922	0.910	0.964	0.927	0.859
0.4	0.977	0.988	0.988	0.911	0.901	0.961	0.917	0.849
0.45	0.977	0.988	0.986	0.900	0.892	0.957	0.909	0.840
0.5	0.977	0.988	0.985	0.889	0.885	0.954	0.901	0.832
0.55	0.977	0.988	0.983	0.879	0.878	0.950	0.893	0.824
0.6	0.977	0.988	0.982	0.869	0.872	0.947	0.885	0.817
0.65	0.977	0.988	0.980	0.860	0.865	0.944	0.879	0.810
0.7	0.977	0.988	0.979	0.852	0.860	0.941	0.872	0.804
0.75	0.977	0.988	0.977	0.845	0.856	0.938	0.865	0.799
0.8	0.977	0.988	0.976	0.840	0.852	0.935	0.859	0.795
0.85	0.977	0.988	0.974	0.835	0.848	0.932	0.852	0.790
0.9	0.977	0.988	0.973	0.830	0.844	0.929	0.847	0.786
0.95	0.977	0.988	0.971	0.825	0.840	0.928	0.842	0.783
1	0.977	0.988	0.970	0.821	0.837	0.926	0.838	0.780
1.05	0.977	0.988	0.968	0.816	0.834	0.925	0.833	0.777
1.1	0.977	0.988	0.967	0.811	0.831	0.924	0.829	0.774
1.15	0.977	0.988	0.965	0.807	0.829	0.922	0.824	0.771
1.2	0.977	0.988	0.964	0.803	0.827	0.921	0.820	0.768
1.25	0.977	0.988	0.962	0.800	0.825	0.920	0.815	0.765
1.3	0.977	0.988	0.961	0.796	0.823	0.918	0.811	0.762
1.35	0.977	0.988	0.959	0.792	0.821	0.917	0.806	0.760
1.4	0.977	0.988	0.958	0.788	0.820	0.916	0.802	0.759
1.45	0.977	0.988	0.956	0.785	0.818	0.914	0.798	0.758
1.5	0.977	0.988	0.955	0.782	0.816	0.913	0.795	0.758

Notes:

i. SPF values above 1.5 are considered to produce too great an error in estimation. As such, any values above this should be taken as 1.5.

ii. Should the SPF value fall in between increments, adopt the coefficient related to the next larger SPF value.

iii. When facade directions fall between the above cardinal points, the closest should be chosen.

2.4.5 Combination of Overhang and Side-fin Projections

For windows with both overhang and side-fin projections each Shading Coefficient should be calculated separately as described in Section 2.4.4(a) and (b) and multiplied together and then used as the Shading Coefficient in the RTTV calculations.

$$\mathbf{ESC_{total}} = \mathbf{ESC_{overhang}} \times \mathbf{ESC_{sidefin}}$$

2.4.6 Complex Shading Devices

For situations where the shading device is neither a simple horizontal nor vertical shade, in other words not covered by Section 2.4.4, the user should refer to the methodology given in Section 2.5.3 to calculate the effective ESC.

2.4.7 Wall Orientation Factor (Gw) & Roof Orientation Factor (Gs)

The orientation factor is a measure of the amount of solar radiation that is received in a specific orientation. Table 9 below highlights these for Hong Kong's climate over a period from April to October when air-conditioning is normally required. When walls or roofs are sloped, the surface can be resolved into vertical and horizontal components.

Table 9 Orientation Factors

Wall Orientation Factor (Gw)							
North	NE	East	SE	South	SW	West	NW
0.790	0.924	1.072	1.051	0.975	1.092	1.131	0.965
Roof Orientation Factor (Gs)							
2.16							

Note: i.When facade directions fall between the above cardinal points, the closest should be chosen.

ii.When roofs or facades are slopped (not horizontal or vertical), the orientation factor is calculated by linearly interpolating between the Roof Orientation Factor and the appropriate Wall Orientation Factor which is determined by the direction the slope faces.

If the wall or window is curved, the eight primary orientations are segmented as follows and the area of the curved surface calculated for each of the primary orientations:

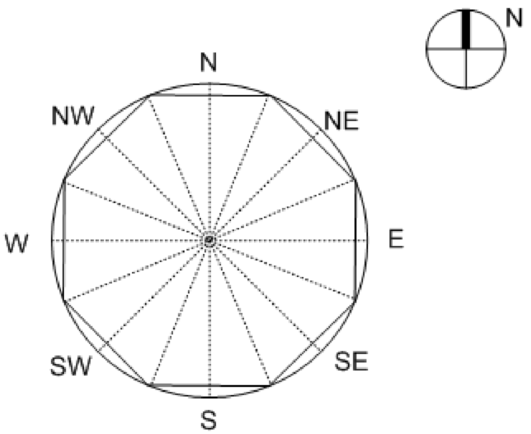


Figure 6 Primary Orientations in RTTV Calculation

2.5 EFFECTIVE SHADING

2.5.1 **Overhang Projection(s)**

(a) Single Fin

(i) Length **A** of an overhanging projection should be equal to or less than 1.5m measured from the external wall surface.

(ii) To ensure the effectiveness of long projection (projecting more than 500mm on facades facing North (NNW to NNE) or more than 750mm on facades facing other orientations, the OPF should not be less than 0.2 or 0.5 respectively, assuming that the sun shade is solid or effectively opaque (refer 2.5.1 (c)).

(iii) For sun shades within re-entrant less than 4.5m, the projection length **A** should not be more than 500mm.

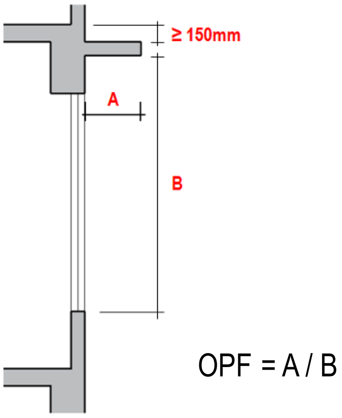


Figure 7 Overhang Projection with Single Fin

(b) Multiple Fins

(i) For multiple fins, the smallest OPF (i.e. A2 / B2) should fulfill requirements in Section 2.5.1(a)(i) and (ii).

(ii) Free area should be ≥ 2/3, [i.e. (h1 + h2 + h3) / H ≥ 2/3]; free area should also consider the combined effect of both horizontal and vertical projections.

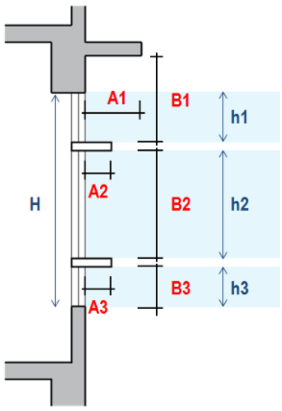


Figure 8 Overhang Projection with Multiple Fins

(c) Detail Design

(i) Projection is considered to be solid or 'effectively opaque' if **X** and **Y** are vertically aligned and **θ** < 90°.

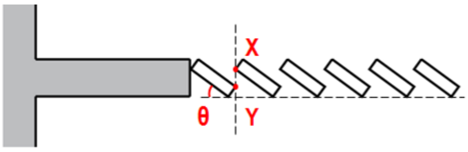


Figure 9 Effectively Opaque Projection for Overhangs

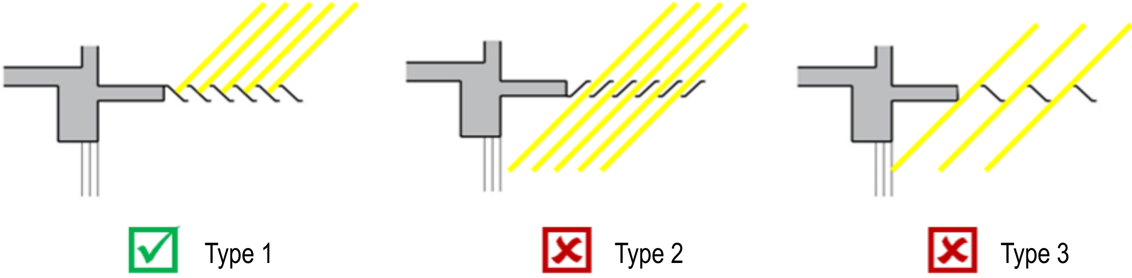


Figure 10 Examples of Projections: Only Type 1 is an effectively opaque projection

(ii) If the projection on facades is not effectively opaque or of unconventional design, a quantitative assessment shall be carried out to demonstrate that the proposed design shall meet the equivalent performance of a solid or effectively opaque projection having a minimum OPF of 0.2 and 0.5 for facades facing North (NNW to NNE) and other orientations respectively, and comply with the requirement as per Section 2.4.7.

(iii) The top projection has a **minimum drop 150mm** from the adjacent internal space.

2.5.2 **Side-fin Projection(s)**

(a) Single Fin

(i) Length **C** of a side-fin projection should be equal to or less than 1.5m measured from the external wall surface.

(ii) To ensure the effectiveness of long projection (projecting more than 500mm on facades facing North (NNW to NNE) or more than 750mm on facades facing other orientations, the SPF should not be less than 0.2 or 0.5 respectively, assuming that the sun shade is solid or effectively opaque (refer 2.5.2 (c)).

(iii) For sun shades within re-entrant less than 4.5m, the projection length **C** should not be more than 500mm.

SPF = C / D

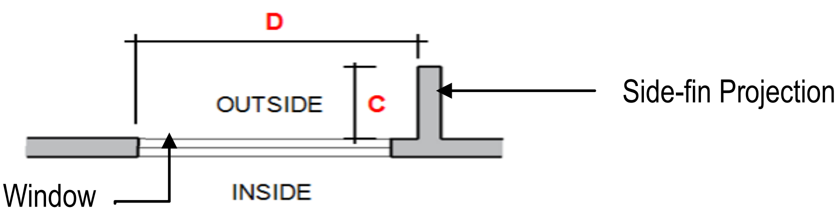


Figure 11 Side-fin Projection on the Right of Window

(b) Multiple Fins

(i) For multiple fins, the smallest SPF (i.e. C2 / D2) should fulfill requirements in Section 2.5.2(a)(i) and (ii).

(ii) Free area should be ≥ 2/3, [i.e. (w1 + w2 + w3) / W ≥ 2/3]; free area should also consider the combined effect of both horizontal and vertical projections.

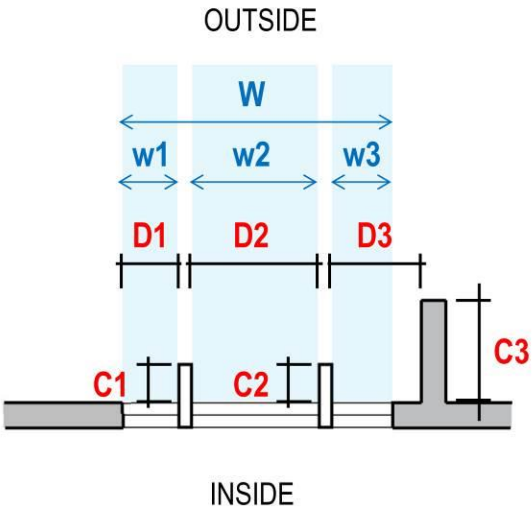


Figure 12 Side-fin Projection with Multiple Fins

(c) Detail Design

(i) Projection is considered to be solid or 'effectively opaque' if **U** and **V** are vertically aligned or P and Q are horizontally aligned; and **α or β** < 90°.

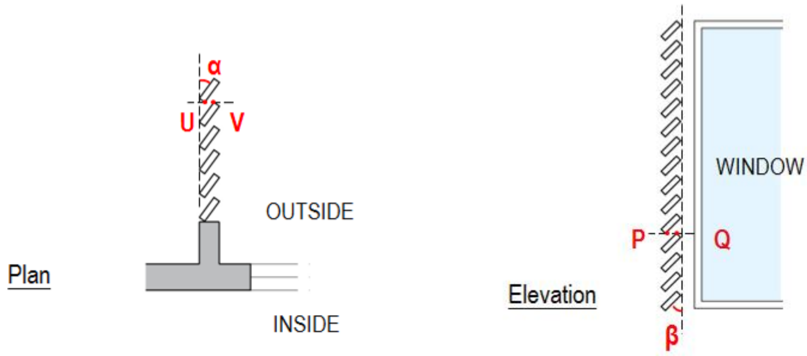


Figure 13 Effectively Opaque Projection for Side-fins

(ii) If the projection on facades is not effectively opaque or of unconventional design, a quantitative assessment shall be carried out to demonstrate that the proposed design shall meet the equivalent performance of a solid or effectively opaque projection having a minimum SPF of 0.2 and 0.5 for facades facing North (NNW to NNE) and other orientations respectively, and comply with the requirement as per Section 2.4.7.

2.5.3 **Complex Shading Devices and Building Self-shading (ESC_2)**

For shading situations not covered in Section 2.4, the following alternative methodology can be used to estimate the External Shading Coefficient. This calculation methodology can be applied to:

1. Complex Shading Devices
2. Self-Shading by built form of the building under examination

Self shading factors can be calculated according to following equation:

$$ESC = (\sum Er \cdot I_D + I_d)/(\sum I_D + I_d)$$

ESC is the External Shading Coefficient described in the $RTTV_{wall}$ equation

Where

- $Er = Ae/A$ is the fraction of area exposed to direct solar radiation
- I_D is the direct solar radiation for a specific time given in the table below
- I_d is the diffuse solar radiation for a specific time given in the table below

To calculate the shading coefficient ESC for any day, the hourly solar heat gain can be computed and summed up for the daylight hours. The total solar heat gain is then divided by the sum of the total radiation, I_D+I_d.

For calculating the ESC of a building, theoretically, the computation according to 7 months (from April to October) can be calculated. However, for simplicity, 4 typical days throughout the period are selected to represent the solar activity within the period of interest.

Depending on the complexity of the shading situation, computational simulation may be needed to calculate A_e.

Hourly solar data for 4 typical days throughout the period from April to October are listed in Tables 10 to 14. Demonstration of complex shading calculation and delineation of an alternative method for External Shading Coefficient calculation using simulation software are in **Appendix II**.

Table 10 Hourly Solar Data (N Elevation) for 4 Typical Days from April to October

N	17-Apr					22-Jun				
Time	Alt	Azi	IT	ID	Id	Alt	Azi	IT	ID	Id
6	0	0	0	0	0	3	66	17	3	14
7	12	84	13	0	13	16	71	62	13	49
8	26	90	28	0	28	30	75	111	22	89
9	40	96	59	0	59	43	78	159	35	124
10	54	104	78	0	78	57	81	164	21	143
11	67	118	88	0	88	70	83	168	9	159
12	77	155	100	0	100	84	78	163	10	153
13	75	218	102	0	102	82	280	158	4	154
14	64	246	95	0	95	68	278	148	16	132
15	51	259	62	0	62	54	280	136	16	120
16	37	266	25	0	25	41	282	85	8	77
17	23	272	10	0	10	27	286	48	7	41
18	9	277	0	0	0	14	290	18	5	13

N	11-Sep					28-Oct				
Time	Alt	Azi	IT	ID	Id	Alt	Azi	IT	ID	Id
6	0	0	0	0	0	0	0	0	0	0
7	11	89	16	0	16	7	107	7	0	7
8	25	95	50	0	50	20	114	30	0	30
9	39	102	106	0	106	32	123	70	0	70
10	52	112	130	0	130	43	136	107	0	107
11	64	129	146	0	146	51	153	118	0	118
12	72	164	151	0	151	55	177	115	0	115
13	70	211	130	0	130	53	202	106	0	106
14	60	238	127	0	127	45	221	97	0	97
15	48	252	103	0	103	35	235	77	0	77
16	34	260	72	0	72	23	244	44	0	44
17	20	267	32	0	32	10	251	0	0	0
18	6	273	0	0	0	0	0	0	0	0

Table 11 Hourly Solar Data (NE / NW Elevation) for 4 Typical Days from April to October

NE/NW	17-Apr					22-Jun				
Time	Alt	Azi	IT	ID	Id	Alt	Azi	IT	ID	Id
6	0	0	0	0	0	3	66	22	0	22
7	12	84	81	0	81	16	71	79	0	79
8	26	90	134	0	134	30	75	140	0	140
9	40	96	188	0	188	43	78	198	0	198
10	54	104	166	0	166	57	81	227	0	227
11	67	118	186	0	186	70	83	253	0	253
12	77	155	261	0	261	84	78	243	0	243
13	75	218	359	110	249	82	280	459	214	245
14	64	246	376	152	224	68	278	523	312	211
15	51	259	376	191	185	54	280	348	158	190
16	37	266	295	161	134	41	282	173	51	122
17	23	272	110	45	65	27	286	91	26	65
18	9	277	0	0	0	14	290	34	13	21

NE/NW	11-Sep					28-Oct				
Time	Alt	Azi	IT	ID	Id	Alt	Azi	IT	ID	Id
6	0	0	0	0	0	0	0	0	0	0
7	11	89	27	0	27	7	107	47	0	47
8	25	95	83	0	83	20	114	119	0	119
9	39	102	175	0	175	32	123	165	0	165
10	52	112	215	0	215	43	136	192	0	192
11	64	129	241	0	241	51	153	207	0	207
12	72	164	250	0	250	55	177	204	0	204
13	70	211	215	0	215	53	202	205	0	205
14	60	238	325	114	211	45	221	154	0	154
15	48	252	316	145	171	35	235	308	183	125
16	34	260	271	152	119	23	244	278	209	69
17	20	267	112	59	53	10	251	0	0	0
18	6	273	0	0	0	0	0	0	0	0

Note:
1. For the purpose of calculating shading coefficient, the solar data for the North-East orientation can be used for the North-West orientation.

Table 12 Hourly Solar Data (E / W Elevation) for 4 Typical Days from April to October

E/W	17-Apr					22-Jun				
Time	Alt	Azi	IT	ID	Id	Alt	Azi	IT	ID	Id
6	0	0	10	0	10	3	66	14	0	14
7	12	84	40	0	40	16	71	60	0	60
8	26	90	58	0	58	30	75	81	0	81
9	40	96	86	0	86	43	78	87	0	87
10	54	104	111	0	111	57	81	122	0	122
11	67	118	154	0	154	70	83	151	0	151
12	77	155	154	0	154	84	78	146	0	146
13	75	218	183	32	151	82	280	129	6	123
14	64	246	286	162	124	68	278	310	217	93
15	51	259	301	195	106	54	280	400	312	88
16	37	266	246	165	81	41	282	339	258	81
17	23	272	135	93	42	27	286	247	192	55
18	9	277	0	0	0	14	290	88	70	18

E/W	11-Sep					28-Oct				
Time	Alt	Azi	IT	ID	Id	Alt	Azi	IT	ID	Id
6	0	0	0	0	0	0	0	0	0	0
7	11	89	37	0	37	7	107	39	0	39
8	25	95	82	0	82	20	114	68	0	68
9	39	102	106	0	106	32	123	82	0	82
10	52	112	95	0	95	43	136	106	0	106
11	64	129	137	0	137	51	153	107	0	107
12	72	164	119	0	119	55	177	99	0	99
13	70	211	194	106	88	53	202	218	139	79
14	60	238	351	267	84	45	221	330	252	78
15	48	252	372	289	83	35	235	304	228	76
16	34	260	285	218	67	23	244	202	155	47
17	20	267	79	52	27	10	251	0	0	0
18	6	273	0	0	0	0	0	0	0	0

Note:

1. For the purpose of calculating shading coefficient, the solar data for the East orientation can be used for the West orientation.

Table 13 Hourly Solar Data (SE / SW Elevation) for 4 Typical Days from April to October

SE/SW	17-Apr					22-Jun				
Time	Alt	Azi	IT	ID	Id	Alt	Azi	IT	ID	Id
6	0	0	0	0	0	3	66	14	0	14
7	12	84	40	0	40	16	71	60	0	60
8	26	90	79	0	79	30	75	81	0	81
9	40	96	110	0	110	43	78	87	0	87
10	54	104	125	0	125	57	81	122	0	122
11	67	118	138	0	138	70	83	151	0	151
12	77	155	180	40	140	84	78	146	0	146
13	75	218	240	105	135	82	280	127	4	123
14	64	246	269	141	128	68	278	225	133	92
15	51	259	256	147	109	54	280	284	196	88
16	37	266	171	94	77	41	282	227	146	81
17	23	272	78	42	36	27	286	151	96	55
18	9	277	0	0	0	14	290	53	34	19

SE/SW	11-Sep					28-Oct				
Time	Alt	Azi	IT	ID	Id	Alt	Azi	IT	ID	Id
6	0	0	0	0	0	0	0	0	0	0
7	11	89	21	0	21	7	107	22	0	22
8	25	95	66	0	66	20	114	68	0	68
9	39	102	113	0	113	32	123	98	0	98
10	52	112	136	0	136	43	136	120	2	118
11	64	129	147	0	147	51	153	173	46	127
12	72	164	185	38	147	55	177	321	225	96
13	70	211	268	176	92	53	202	376	278	98
14	60	238	351	264	87	45	221	400	308	92
15	48	252	343	251	92	35	235	346	271	75
16	34	260	252	180	72	23	244	182	138	44
17	20	267	90	56	34	10	251	0	0	0
18	6	273	0	0	0	0	0	0	0	0

Note:

1. For the purpose of calculating shading coefficient, the solar data for the South-East orientation can be used for the South-West orientation.

Table 14 Hourly Solar Data (S Elevation) for 4 Typical Days from April to October

S	17-Apr					22-Jun				
Time	Alt	Azi	IT	ID	Id	Alt	Azi	IT	ID	Id
6	0	0	0	0	0	3	66	13	0	13
7	12	84	36	0	36	16	71	48	0	48
8	26	90	81	2	79	30	75	85	0	85
9	40	96	136	25	111	43	78	119	0	119
10	54	104	192	59	133	57	81	137	0	137
11	67	118	219	71	148	70	83	152	0	152
12	77	155	232	84	148	84	78	146	0	146
13	75	218	222	78	144	82	280	148	0	148
14	64	246	179	46	133	68	278	127	0	127
15	51	259	144	35	109	54	280	115	0	115
16	37	266	77	8	69	41	282	74	0	74
17	23	272	31	0	31	27	286	40	0	40
18	9	277	0	0	0	14	290	13	0	13

S	11-Sep					28-Oct				
Time	Alt	Azi	IT	ID	Id	Alt	Azi	IT	ID	Id
6	0	0	0	0	0	0	0	0	0	0
7	11	89	44	2	42	7	107	85	54	31
8	25	95	126	45	81	20	114	182	118	64
9	39	102	181	75	106	32	123	315	234	81
10	52	112	216	90	126	43	136	394	306	88
11	64	129	253	119	134	51	153	453	366	87
12	72	164	280	151	129	55	177	450	362	88
13	70	211	255	129	126	53	202	454	368	86
14	60	238	192	69	123	45	221	363	280	83
15	48	252	143	47	96	35	235	254	185	69
16	34	260	61	9	52	23	244	116	75	41
17	20	267	14	1	13	10	251	0	0	0
18	6	273	0	0	0	0	0	0	0	0

2.6 SEPARATE CALCULATIONS FOR WALLS AND ROOFS

2.6.1 Two values are to be reported in forms in **Appendix III for submission to the Building Authority**:

- $RTTV_{wall}$
- $RTTV_{roof}$

Roofs and walls have separate calculation procedures and will have separate targets. They are not to be combined into a single overall value.

2.7 DEEMED TO SATISFY $RTTV_{WALL}$ CRITERIA

2.7.1 With respect to different facade orientations, if the building's window-to-wall ratios (WWR) and shading coefficients of facade ($SC_{facade} = SC_{glass} \times ESC_{shading\ device}$) are not more than the specified values in the following Table 15 to Table 20, the building is deemed to have complied with the $RTTV_{wall}$ criteria and, hence, is exempted from computing $RTTV_{wall}$ and submission of $RTTV_{wall}$ calculations in Section 2.2. Compliance check methods 1 & 2 based on facades facing eight different orientations or in two orientation categories are acceptable.

For simplicity, if there is any ONE external finish material applied on the facade in one orientation constituting more than 60% of the gross wall area, that material can be regarded as the dominant external finish material and its absorptivity can be taken as the average absorptivity of the facade in that orientation for the compliance check on Deemed to Satisfy $RTTV_{wall}$ Criteria.

A set of deemed to satisfy $RTTV_{wall}$ criteria compliance check for a sample residential building is demonstrated in **Appendix V for submission to the Building Authority**. The shading coefficient of facade refers to the average shading coefficient under each orientation or orientation category.

2.8 CONTROL OF VISUAL GLARE

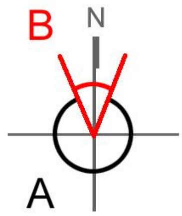
2.8.1 Glass with External Reflectance (ER_{GLASS}) exceeding 20% on any external surface of any window, door, wall or roof of a building would not be accepted for complying with the RTTV requirements.

2.9 CONTROL OF VISIBLE LIGHT TRANSMITTANCE

2.9.1 To optimize daylight penetration and ensure that an adequate amount of daylight will penetrate through the prescribed window, glazing with Visible Light Transmittance (VLT_{GLASS}) of less than 50% should not be used for the prescribed windows to comply with the requirements of the RTTV requirements. As for the glass which is installed in areas other than the prescribed windows, the visible light transmittance requirement is not applicable.

Table 15 Deemed to Satisfy $RTTV_{wall}$ Criteria for Absorptivity <= 0.4 of Opaque Wall

WWR	SC facade Shading Coefficient of Facade									
	Facade Orientation Facing									
	Compliance Check Method 1								Compliance Check Method 2	
	N	NE	E	SE	S	SW	W	NW	NNE to NNW (Category A)	NNW to NNE (Category B)
0.70	0.46	0.38	0.30	0.31	0.35	0.30	0.28	0.35	0.32	0.46
0.68	0.48	0.39	0.31	0.32	0.36	0.30	0.29	0.36	0.33	0.48
0.66	0.49	0.40	0.32	0.33	0.37	0.31	0.30	0.37	0.34	0.49
0.64	0.50	0.41	0.33	0.34	0.38	0.32	0.30	0.38	0.35	0.50
0.62	0.52	0.42	0.34	0.35	0.39	0.33	0.31	0.39	0.36	0.52
0.60	0.53	0.43	0.35	0.36	0.40	0.34	0.32	0.41	0.37	0.53
0.58	0.55	0.44	0.36	0.37	0.41	0.35	0.33	0.42	0.38	0.55
0.56	0.57	0.46	0.37	0.38	0.43	0.36	0.34	0.43	0.40	0.57
0.54	0.59	0.47	0.38	0.39	0.44	0.37	0.35	0.45	0.41	0.59
0.52	0.61	0.49	0.40	0.41	0.45	0.38	0.36	0.46	0.42	0.61
0.50	0.63	0.51	0.41	0.42	0.47	0.40	0.38	0.48	0.44	0.63
0.48	0.66	0.53	0.42	0.44	0.49	0.41	0.39	0.50	0.45	0.66
0.46	0.68	0.55	0.44	0.45	0.51	0.43	0.41	0.52	0.47	0.68
0.44	0.71	0.57	0.46	0.47	0.53	0.45	0.42	0.54	0.49	0.71
0.42	0.75	0.60	0.48	0.49	0.55	0.47	0.44	0.56	0.51	0.75
0.40	0.78	0.63	0.50	0.52	0.58	0.49	0.46	0.59	0.54	0.78
0.38	0.82	0.66	0.53	0.54	0.61	0.51	0.48	0.62	0.56	0.82
0.36	0.86	0.69	0.55	0.57	0.64	0.54	0.51	0.65	0.59	0.86
0.34	0.91	0.73	0.58	0.60	0.67	0.57	0.53	0.68	0.62	0.91
0.32	0.97	0.77	0.62	0.64	0.71	0.60	0.57	0.72	0.66	0.97
0.30	0.99	0.82	0.65	0.68	0.76	0.64	0.60	0.77	0.70	0.99
0.28	0.99	0.88	0.70	0.72	0.81	0.68	0.64	0.82	0.75	0.99
0.26	0.99	0.94	0.75	0.77	0.87	0.73	0.69	0.88	0.80	0.99
0.24	0.99	0.99	0.81	0.83	0.94	0.78	0.74	0.95	0.86	0.99
0.22	0.99	0.99	0.88	0.91	0.99	0.85	0.80	0.99	0.92	0.99
0.20	0.99	0.99	0.96	0.99	0.99	0.93	0.88	0.99	0.96	0.99



Note:
1. Orientation Category A: NNE to NNW (NNE & NNW are exclusive)
   Orientation Category B: NNW to NNE (NNW & NNE are inclusive)
2. When facade directions fall between the above cardinal points, the closest should be chosen.
3. Absorptivity stated in Table 15 to Table 20 means the average absorptivity of the external opaque wall in the same orientation.
4. If there is any ONE external finish material applied on the facade in one orientation constituting more than 60% of the gross wall area, that material can be regarded as the dominant external finish material and its absorptivity can be taken as the average absorptivity of the facade in that orientation for compliance check on Deemed to Satisfy $RTTV_{wall}$ Criteria.

Table 16 Deemed to Satisfy $RTTV_{wall}$ Criteria for Absorptivity <= 0.5 of Opaque Wall

WWR	SC facade Shading Coefficient of Facade									
	Facade Orientation Facing									
	Compliance Check Method 1								Compliance Check Method 2	
	N	NE	E	SE	S	SW	W	NW	NNE to NNW (Category A)	NNW to NNE (Category B)
0.70	0.45	0.36	0.29	0.30	0.33	0.28	0.27	0.34	0.31	0.45
0.68	0.46	0.37	0.30	0.31	0.34	0.29	0.27	0.35	0.32	0.46
0.66	0.47	0.38	0.30	0.31	0.35	0.29	0.28	0.36	0.33	0.47
0.64	0.49	0.39	0.31	0.32	0.36	0.30	0.29	0.36	0.33	0.49
0.62	0.50	0.40	0.32	0.33	0.37	0.31	0.29	0.37	0.34	0.50
0.60	0.51	0.41	0.33	0.34	0.38	0.32	0.30	0.38	0.35	0.51
0.58	0.53	0.42	0.34	0.35	0.39	0.33	0.31	0.40	0.36	0.53
0.56	0.54	0.43	0.34	0.36	0.40	0.33	0.32	0.41	0.37	0.54
0.54	0.56	0.45	0.35	0.37	0.41	0.34	0.32	0.42	0.38	0.56
0.52	0.58	0.46	0.37	0.38	0.43	0.35	0.33	0.43	0.39	0.58
0.50	0.60	0.48	0.38	0.39	0.44	0.37	0.34	0.45	0.41	0.60
0.48	0.62	0.49	0.39	0.40	0.45	0.38	0.36	0.46	0.42	0.62
0.46	0.65	0.51	0.40	0.42	0.47	0.39	0.37	0.48	0.43	0.65
0.44	0.67	0.53	0.42	0.43	0.49	0.41	0.38	0.50	0.45	0.67
0.42	0.70	0.55	0.43	0.45	0.51	0.42	0.40	0.52	0.47	0.70
0.40	0.73	0.58	0.45	0.47	0.53	0.44	0.41	0.54	0.49	0.73
0.38	0.77	0.60	0.47	0.49	0.55	0.46	0.43	0.56	0.51	0.77
0.36	0.81	0.63	0.49	0.51	0.58	0.48	0.45	0.59	0.53	0.81
0.34	0.85	0.67	0.52	0.54	0.61	0.50	0.47	0.62	0.56	0.85
0.32	0.90	0.70	0.55	0.57	0.64	0.53	0.50	0.66	0.59	0.90
0.30	0.95	0.75	0.58	0.60	0.68	0.56	0.52	0.69	0.63	0.95
0.28	0.99	0.79	0.62	0.64	0.73	0.59	0.56	0.74	0.67	0.99
0.26	0.99	0.85	0.66	0.68	0.78	0.63	0.59	0.79	0.71	0.99
0.24	0.99	0.91	0.71	0.73	0.84	0.68	0.64	0.85	0.77	0.99
0.22	0.99	0.99	0.76	0.79	0.90	0.74	0.69	0.92	0.83	0.99
0.20	0.99	0.99	0.83	0.86	0.99	0.80	0.75	0.99	0.89	0.99

Table 17 Deemed to Satisfy $RTTV_{wall}$ Criteria for Absorptivity <= 0.6 of Opaque Wall

WWR	SC facade Shading Coefficient of Facade									
	Facade Orientation Facing									
	Compliance Check Method 1								Compliance Check Method 2	
	N	NE	E	SE	S	SW	W	NW	NNE to NNW (Category A)	NNW to NNE (Category B)
0.70	0.44	0.35	0.28	0.29	0.32	0.27	0.25	0.33	0.30	0.44
0.68	0.45	0.36	0.28	0.29	0.33	0.27	0.26	0.33	0.30	0.45
0.66	0.46	0.36	0.29	0.30	0.33	0.28	0.26	0.34	0.31	0.46
0.64	0.47	0.37	0.29	0.30	0.34	0.28	0.27	0.35	0.31	0.47
0.62	0.48	0.38	0.30	0.31	0.35	0.29	0.27	0.35	0.32	0.48
0.60	0.49	0.39	0.31	0.32	0.36	0.30	0.28	0.36	0.33	0.49
0.58	0.50	0.40	0.31	0.32	0.37	0.30	0.28	0.37	0.34	0.50
0.56	0.52	0.41	0.32	0.33	0.37	0.31	0.29	0.38	0.34	0.52
0.54	0.53	0.42	0.33	0.34	0.38	0.32	0.30	0.39	0.35	0.53
0.52	0.55	0.43	0.34	0.35	0.40	0.32	0.30	0.40	0.36	0.55
0.50	0.57	0.45	0.34	0.36	0.41	0.33	0.31	0.41	0.37	0.57
0.48	0.59	0.46	0.35	0.37	0.42	0.34	0.32	0.43	0.38	0.59
0.46	0.61	0.47	0.37	0.38	0.43	0.35	0.33	0.44	0.40	0.61
0.44	0.63	0.49	0.38	0.39	0.45	0.36	0.34	0.46	0.41	0.63
0.42	0.66	0.51	0.39	0.41	0.46	0.38	0.35	0.47	0.42	0.66
0.40	0.68	0.53	0.40	0.42	0.48	0.39	0.36	0.49	0.44	0.68
0.38	0.71	0.55	0.42	0.44	0.50	0.41	0.38	0.51	0.46	0.71
0.36	0.75	0.58	0.44	0.46	0.52	0.42	0.39	0.53	0.48	0.75
0.34	0.79	0.60	0.46	0.48	0.55	0.44	0.41	0.56	0.50	0.79
0.32	0.83	0.64	0.48	0.50	0.58	0.46	0.43	0.59	0.52	0.83
0.30	0.88	0.67	0.50	0.52	0.61	0.48	0.45	0.62	0.55	0.88
0.28	0.93	0.71	0.53	0.55	0.64	0.51	0.47	0.66	0.58	0.93
0.26	0.99	0.76	0.57	0.59	0.68	0.54	0.50	0.70	0.62	0.99
0.24	0.99	0.81	0.60	0.63	0.73	0.58	0.54	0.75	0.66	0.99
0.22	0.99	0.88	0.65	0.68	0.79	0.62	0.57	0.81	0.71	0.99
0.20	0.99	0.95	0.70	0.73	0.86	0.67	0.62	0.88	0.77	0.99

Table 18 Deemed to Satisfy $RTTV_{wall}$ Criteria for Absorptivity <= 0.7 of Opaque Wall

WWR	SC facade Shading Coefficient of Facade									
	Facade Orientation Facing									
	Compliance Check Method 1								Compliance Check Method 2	
	N	NE	E	SE	S	SW	W	NW	NNE to NNW (Category A)	NNW to NNE (Category B)
0.70	0.42	0.33	0.26	0.27	0.31	0.25	0.24	0.31	0.28	0.42
0.68	0.43	0.34	0.27	0.28	0.31	0.26	0.24	0.32	0.29	0.43
0.66	0.44	0.35	0.27	0.28	0.32	0.26	0.25	0.32	0.29	0.44
0.64	0.45	0.35	0.27	0.28	0.32	0.27	0.25	0.33	0.30	0.45
0.62	0.46	0.36	0.28	0.29	0.33	0.27	0.25	0.33	0.30	0.46
0.60	0.47	0.37	0.28	0.29	0.34	0.27	0.26	0.34	0.31	0.47
0.58	0.48	0.37	0.29	0.30	0.34	0.28	0.26	0.35	0.31	0.48
0.56	0.49	0.38	0.29	0.31	0.35	0.28	0.26	0.36	0.32	0.49
0.54	0.51	0.39	0.30	0.31	0.36	0.29	0.27	0.36	0.33	0.51
0.52	0.52	0.40	0.31	0.32	0.37	0.29	0.27	0.37	0.33	0.52
0.50	0.54	0.41	0.31	0.33	0.37	0.30	0.28	0.38	0.34	0.54
0.48	0.55	0.42	0.32	0.33	0.38	0.31	0.29	0.39	0.35	0.55
0.46	0.57	0.44	0.33	0.34	0.40	0.32	0.29	0.40	0.36	0.57
0.44	0.59	0.45	0.34	0.35	0.41	0.32	0.30	0.42	0.37	0.59
0.42	0.61	0.47	0.35	0.36	0.42	0.33	0.31	0.43	0.38	0.61
0.40	0.64	0.48	0.36	0.37	0.43	0.34	0.32	0.44	0.39	0.64
0.38	0.66	0.50	0.37	0.38	0.45	0.35	0.32	0.46	0.41	0.66
0.36	0.69	0.52	0.38	0.40	0.47	0.36	0.34	0.48	0.42	0.69
0.34	0.72	0.54	0.39	0.41	0.49	0.38	0.35	0.50	0.44	0.72
0.32	0.76	0.57	0.41	0.43	0.51	0.39	0.36	0.52	0.46	0.76
0.30	0.80	0.60	0.43	0.45	0.53	0.41	0.37	0.54	0.48	0.80
0.28	0.85	0.63	0.45	0.47	0.56	0.43	0.39	0.57	0.50	0.85
0.26	0.90	0.67	0.47	0.50	0.59	0.45	0.41	0.61	0.53	0.90
0.24	0.97	0.71	0.50	0.53	0.63	0.48	0.43	0.65	0.56	0.97
0.22	0.99	0.76	0.53	0.56	0.68	0.51	0.46	0.69	0.60	0.99
0.20	0.99	0.82	0.57	0.61	0.73	0.55	0.49	0.75	0.65	0.99

Table 19 Deemed to Satisfy $RTTV_{wall}$ Criteria for Absorptivity <= 0.8 of Opaque Wall

WWR	SC facade Shading Coefficient of Facade									
	Facade Orientation Facing									
	Compliance Check Method 1								Compliance Check Method 2	
	N	NE	E	SE	S	SW	W	NW	NNE to NNW (Category A)	NNW to NNE (Category B)
0.70	0.41	0.32	0.25	0.26	0.29	0.24	0.23	0.30	0.27	0.41
0.68	0.42	0.32	0.25	0.26	0.30	0.24	0.23	0.30	0.27	0.42
0.66	0.42	0.33	0.25	0.26	0.30	0.25	0.23	0.31	0.28	0.42
0.64	0.43	0.33	0.26	0.27	0.30	0.25	0.23	0.31	0.28	0.43
0.62	0.44	0.34	0.26	0.27	0.31	0.25	0.23	0.32	0.28	0.44
0.60	0.45	0.35	0.26	0.27	0.31	0.25	0.23	0.32	0.29	0.45
0.58	0.46	0.35	0.27	0.28	0.32	0.26	0.24	0.32	0.29	0.46
0.56	0.47	0.36	0.27	0.28	0.32	0.26	0.24	0.33	0.29	0.47
0.54	0.48	0.36	0.27	0.28	0.33	0.26	0.24	0.34	0.30	0.48
0.52	0.49	0.37	0.28	0.29	0.34	0.27	0.24	0.34	0.30	0.49
0.50	0.50	0.38	0.28	0.29	0.34	0.27	0.25	0.35	0.31	0.50
0.48	0.52	0.39	0.28	0.30	0.35	0.27	0.25	0.36	0.31	0.52
0.46	0.53	0.40	0.29	0.30	0.36	0.28	0.25	0.37	0.32	0.53
0.44	0.55	0.41	0.30	0.31	0.37	0.28	0.26	0.37	0.33	0.55
0.42	0.57	0.42	0.30	0.32	0.38	0.29	0.26	0.38	0.34	0.57
0.40	0.59	0.43	0.31	0.32	0.39	0.29	0.27	0.39	0.34	0.59
0.38	0.61	0.45	0.32	0.33	0.40	0.30	0.27	0.41	0.35	0.61
0.36	0.63	0.46	0.32	0.34	0.41	0.31	0.28	0.42	0.36	0.63
0.34	0.66	0.48	0.33	0.35	0.42	0.32	0.28	0.43	0.37	0.66
0.32	0.69	0.50	0.34	0.36	0.44	0.32	0.29	0.45	0.39	0.69
0.30	0.73	0.52	0.35	0.37	0.46	0.33	0.30	0.47	0.40	0.73
0.28	0.77	0.55	0.37	0.39	0.48	0.35	0.31	0.49	0.42	0.77
0.26	0.81	0.57	0.38	0.41	0.50	0.36	0.32	0.52	0.44	0.81
0.24	0.86	0.61	0.40	0.43	0.53	0.38	0.33	0.54	0.46	0.86
0.22	0.93	0.65	0.42	0.45	0.56	0.39	0.35	0.58	0.49	0.93
0.20	0.99	0.70	0.45	0.48	0.60	0.42	0.36	0.62	0.52	0.99

Table 20 Deemed to Satisfy $RTTV_{wall}$ Criteria for Absorptivity <= 0.9 of Opaque Wall

WWR	SC facade Shading Coefficient of Facade									
	Facade Orientation Facing									
	Compliance Check Method 1								Compliance Check Method 2	
	N	NE	E	SE	S	SW	W	NW	NNE to NNW (Category A)	NNW to NNE (Category B)
0.70	0.39	0.31	0.24	0.24	0.28	0.23	0.21	0.28	0.26	0.39
0.68	0.40	0.31	0.24	0.25	0.28	0.23	0.21	0.29	0.26	0.40
0.66	0.41	0.31	0.24	0.25	0.28	0.23	0.21	0.29	0.26	0.41
0.64	0.41	0.32	0.24	0.25	0.29	0.23	0.21	0.29	0.26	0.41
0.62	0.42	0.32	0.24	0.25	0.29	0.23	0.21	0.30	0.26	0.42
0.60	0.43	0.32	0.24	0.25	0.29	0.23	0.21	0.30	0.26	0.43
0.58	0.43	0.33	0.24	0.25	0.30	0.23	0.21	0.30	0.27	0.43
0.56	0.44	0.33	0.24	0.25	0.30	0.23	0.21	0.31	0.27	0.44
0.54	0.45	0.34	0.24	0.26	0.30	0.23	0.21	0.31	0.27	0.45
0.52	0.46	0.34	0.25	0.26	0.31	0.24	0.21	0.31	0.27	0.46
0.50	0.47	0.35	0.25	0.26	0.31	0.24	0.22	0.32	0.28	0.47
0.48	0.48	0.35	0.25	0.26	0.31	0.24	0.22	0.32	0.28	0.48
0.46	0.49	0.36	0.25	0.27	0.32	0.24	0.22	0.33	0.28	0.49
0.44	0.51	0.37	0.25	0.27	0.33	0.24	0.22	0.33	0.29	0.51
0.42	0.52	0.38	0.26	0.27	0.33	0.24	0.22	0.34	0.29	0.52
0.40	0.54	0.38	0.26	0.28	0.34	0.25	0.22	0.35	0.30	0.54
0.38	0.56	0.39	0.26	0.28	0.34	0.25	0.22	0.35	0.30	0.56
0.36	0.58	0.40	0.27	0.28	0.35	0.25	0.22	0.36	0.31	0.58
0.34	0.60	0.42	0.27	0.29	0.36	0.25	0.22	0.37	0.31	0.60
0.32	0.62	0.43	0.27	0.29	0.37	0.26	0.22	0.38	0.32	0.62
0.30	0.65	0.45	0.28	0.30	0.38	0.26	0.22	0.39	0.33	0.65
0.28	0.68	0.46	0.28	0.31	0.39	0.26	0.23	0.41	0.33	0.68
0.26	0.72	0.48	0.29	0.31	0.41	0.27	0.23	0.42	0.34	0.72
0.24	0.76	0.51	0.30	0.32	0.43	0.27	0.23	0.44	0.36	0.76
0.22	0.81	0.53	0.31	0.33	0.45	0.28	0.23	0.46	0.37	0.81
0.20	0.87	0.57	0.32	0.35	0.47	0.29	0.23	0.49	0.39	0.87

3 DESIGN FOR NATURAL VENTILATION FOR THERMAL COMFORT (NV)

3.1 GENERAL PRINCIPLES

3.1.1 General Approach

In general, natural ventilation can function well when the external temperature is below the desired internal temperature. Utilization of natural wind can reduce building energy consumption effectively by reducing the period of time where the air-conditioning system is used.

Requirements to measure the potential of natural ventilation for thermal comfort (NV_{TC}) within habitable spaces of residential units in both prescriptive and performance approaches have been set out. The assessment for the prescriptive approach should demonstrate the compliance of either cross ventilation (NV_C) requirements or single side ventilation (NV_{SS}) requirements in Sections 3.2 and 3.3 respectively.

The requirements set out here are above the minimum stipulated as the prescribed window under Regulation 30 of the Building (Planning) Regulations which is meant to ensure the health of occupants in habitable space and the like.

The dense urban form commonly found in Hong Kong always presents an extra design challenge to NV_{TC} maximization, which is largely dependent on the site aspects as well as the consideration in spatial efficiency. Local environmental conflicts such as traffic noise and outdoor air quality may make the adoption of NV_{TC} design impractical. To address these cases, an alternative performance approach with adoption of a simplified simulation method or a site specific simulation method to identify the Area-weighted Average Weighted Velocity (AAWV) in the habitable spaces. The requirements for the alternative performance approach are stipulated in Section 3.4

3.1.2 Areas to be Checked for NV_{TC} Performance

The area of habitable spaces of residential units shall be checked for NV_{TC} performance. Open kitchen within the same enclosed space of living / dining areas shall be taken into account for NV_{TC} compliance check.

If small corridors within a room are connected to the rest of the space in the room on their ends but not along their lengths, and the width of the circulation is not excessive, the circulation area can be excluded from NV_{TC} compliance check.

3.1.3 Assumptions

Doors of rooms within a residential unit are assumed to be fully opened while doors of kitchens and main entrance doors that connect to the common area (e.g. common corridor or lobby) are assumed to be fully closed. Bathroom / toilet doors are assumed to be closed unless the following requirements are met:

(i) All sanitary fitments and floor drains in a bathroom / toilet are provided with effective water seal traps. The water seal traps for floor drains should be designed in accordance with paragraph 2 of PNAP ADV-24 that can effectively avoid the loss of water seal and prevent foul air from getting into the bathroom / toilet from other floors;

(ii) The bathroom / toilet windows meet the NV_C requirements in Section 3.2 (i.e. area, cross ventilation path distance and turn limits, location, etc.); and

(iii) The openable area of the Secondary Ventilation Opening is at least 1/20 of the aggregate floor area of the habitable spaces and bathroom / toilet.

If windows are opened for natural ventilation, occupants are expected to live with the internal temperatures up to 28°C. Above this temperature, they close the windows and turn on the air-conditioner for cooling. Windows are opened and the cooling system is off so long as the internal temperature is not over 28°C.

3.1.4 Exclusions

The following factors affecting NV_{TC} potential are not taken into account:

- Assessment of wind availability for the indoor environment due to site planning and urban design factors; and
- Local environmental conflicts such as traffic noise and outdoor air quality.

3.2 CROSS VENTILATION REQUIREMENTS

3.2.1 Room Layout

Units can be considered to have good NV_C when the air flow path between facade openings is relatively unobstructed. As such, in this assessment, all windows and internal doors (excluding the main entrance and kitchen) that can be opened are assumed to be opened.

The cross ventilation path between the primary ventilation opening and secondary ventilation opening should consist of no more than two straight lines (one turn only), from the middle of one window to another. The angle of turn for the cross ventilation path at the joint of the two lines must be no greater than 90°. See Figure 14.

The cross ventilation path must be less than 12m in length for each habitable space.

If a cross ventilation path is drawn across a corridor, a notional area with 750mm width shall be included in the usable floor area required for calculation of minimum openable window area for NV_C as specified in Section 3.2.4.

Openable windows can be located in different areas of habitable spaces or on differently orientated facades of the same habitable spaces. To ensure effective NV_C for the majority of the habitable spaces, the windows on different walls should be located apart with a reasonable distance. To assess this, draw the smallest rectangular box possible that bounds the assessed area and divide the rectangular box into equal halves through the longer side. The windows must lie in different halves of the habitable space. See Figure 15.

For a room of complicated shape, the room may be subdivided into “notional rooms” of more regular shape. Each “notional room” shall be assessed individually using the same method as mentioned above and all of the “notional rooms” of a room shall comply with the relevant requirements in Section 3.2 / 3.3.

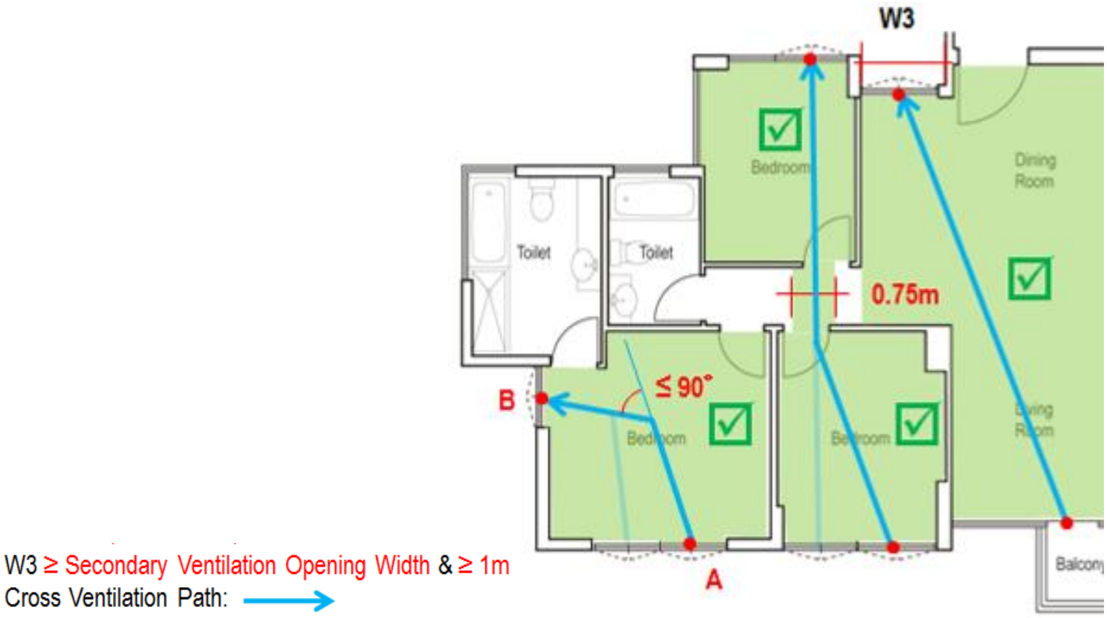


Figure 14 Openable Windows Locations and Cross Ventilation Path
(Rooms with cross ventilation potential are indicated with a tick)

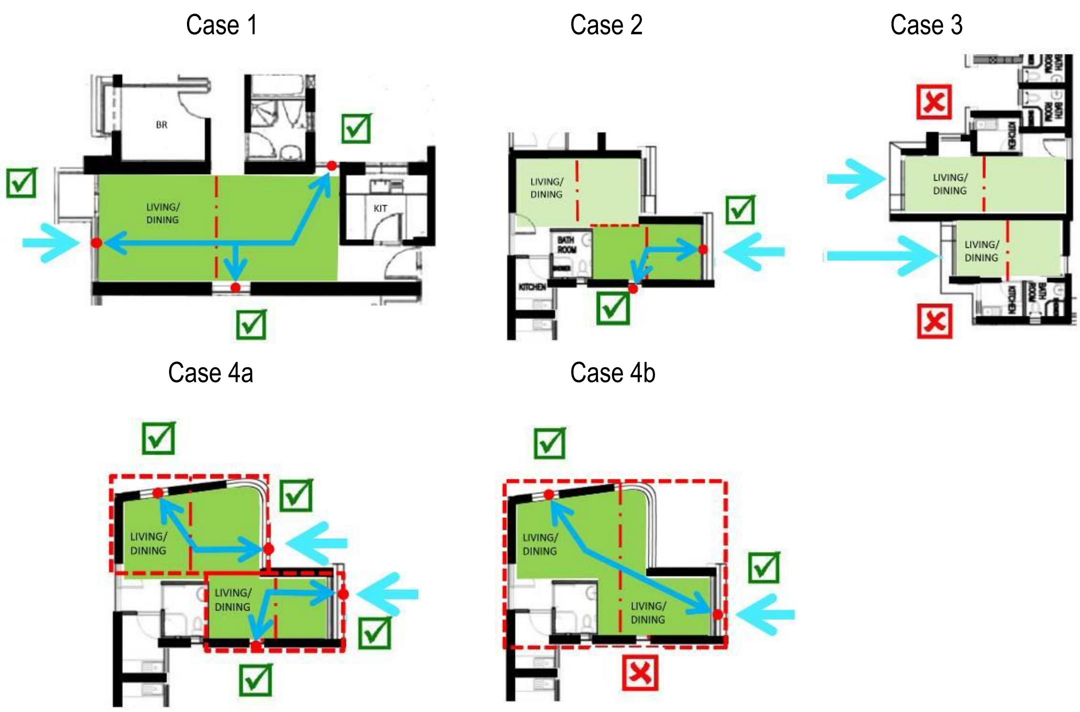


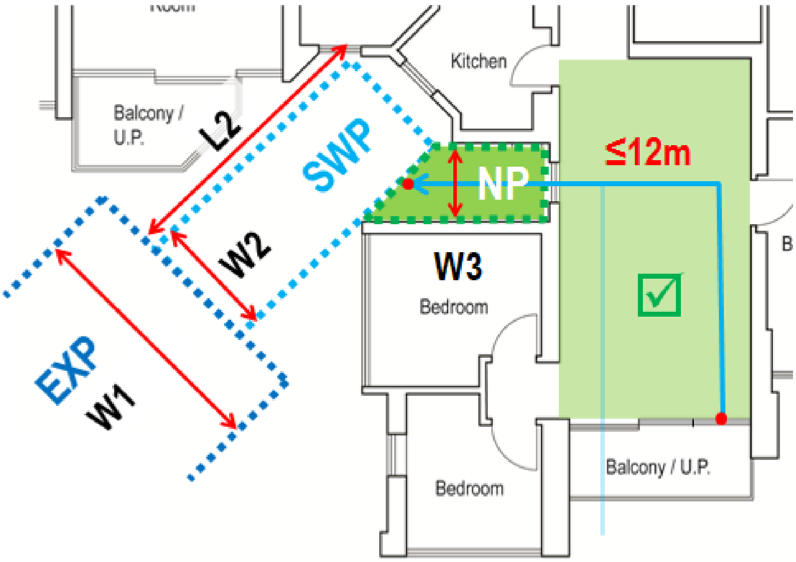
Figure 15 Openable Windows Located at Different Halves of Habitable Spaces
(Floor areas highlighted in green are taken into account for calculation of openable window area for NV_{TC})

3.2.2 **Re-entrants**

Concave areas of buildings with width greater than 4.5m will typically have similar flow characteristics to the free-stream. Hence, for the purpose of ventilation, a re-entrant begins when a concaved area has width less than 4.5m. This can be defined graphically by a plane of 4.5m wide (referred to as the External Plane (EXP)), extending from any street or notional air corridor [as defined in the PNAP APP-152] towards a concave area: the re-entrant begins where such a plane can no longer pass through. See Figure 16.

A secondary ventilation opening located in the re-entrant may still achieve satisfactory NV_C performance provided that the re-entrant is sufficiently wide and the window is located relatively close to the beginning of the re-entrant. Such an acceptable window can be defined by connecting a plane of 2.3m width and 4.5m length (referred to as Secondary Window Plane, (SWP)) to EXP. Windows that can be reached by SWP are considered acceptable secondary ventilation openings. See Figure 16. A re-entrant not more than 4 storeys is deemed to meet the requirements of SWP regardless its width and length; and hence, the entire re-entrant can be considered as SWP for NV_c assessment.

For the purpose of this assessment, the effective area of an apartment can be extended by the concept of a "notional" area. Such a notional area can be defined by connecting a Notional Plane (NP) of 1m width or equal to the width of the secondary ventilation opening, whichever is larger, from SWP / EXP to a secondary ventilation opening. If the width of a portion of NP is less than 1m, the depth of that portion of NP should not be more than its width. The maximum distance and number of turn requirements for cross ventilation paths for effective NV_C (section 3.2.1) shall be applicable NOT only within the actual residential unit, but also the notional area together. See Figure 16. NP / SWP / EXP should be vertically uncovered, except that effective sun shades (section 2.5) and amenity features including drying racks, small projecting air-conditioner platforms or hoods and window eaves protruding onto or over NP / SWP / EXP may be disregarded if the size of these features is not excessive.



EXP: External Plane
SWP: Secondary Window Plane
NP: Notional Plane
W1 = 4.5m; W2 ≥ 2.3m; L2 ≤ 4.5m
W3 ≥ Secondary Ventilation Opening Width & ≥ 1m
Cross Ventilation Path: →

Figure 16 NV Assessment for Re-entrant

3.2.3 Room Depth facing SWP

The depth of room from primary ventilation opening to secondary ventilation opening abutting the SWP should not be more than 12m.

If there is a NP between the secondary ventilation opening and the SWP, the length of the NP should be added to the depth of the room from primary ventilation opening to secondary ventilation opening. The total length shall not exceed 12m.

3.2.4 Minimum Openable Window Area to Floor Area

The total openable window size in aggregate should not be less than one-eighth (1/8th) of the usable floor area of the room. The area of the NP needs to be taken into account for the calculation of openable window area.

If the primary ventilation opening and the secondary ventilation opening are located in two rooms. The total openable window size in aggregate should not be less than one-eighth (1/8th) of the usable floor area of the rooms.

If a cross ventilation path is drawn across a corridor between two rooms, the total openable window size in aggregate should not be less than one-eighth (1/8th) of the total usable floor area of the rooms and a notional area with 750mm width of the cross ventilation path across the corridor.

If the secondary ventilation opening is located in a bathroom / toilet as described in Section 3.1.3, the area of the bathroom / toilet needs to be taken into account for the calculation of openable window area.

The aggregate size of the secondary ventilation opening(s) should preferably be not less than one-sixteenth ($1/16^{th}$) of the usable floor area of the room(s). It should not be less than one-twentieth ($1/20^{th}$) of the usable floor area of the room(s) and the notional area of corridor used as cross ventilation path if applicable.

3.3 SINGLE-SIDED VENTILATION REQUIREMENTS

3.3.1 Room Layout

Preferably two or more separated windows should be designed for NV_{SS}.

3.3.2 Room Depth

The depth of habitable spaces should not be more than 4.5m, measuring from the center of openable window. Only windows meeting the 4.5m room depth limit will be taken account for the openable area calculation. See Figure 17.

Windows for NVss shall be primary ventilation openings which either (a) face an EXP or (b) connect to an EXP via a NP. The width of NP should equal to the width of the ventilation opening or not be less than 1m, whichever is larger. For case (b), the depth of the habitable space should be measured from the meeting point of EXP and NP to the furthest corner of the space. The ventilation path should consist of no more than one turn, and the angle of turn for the ventilation path must be no greater than 90°. Windows serving as NVss for a room may either be located on the same wall or on different walls.

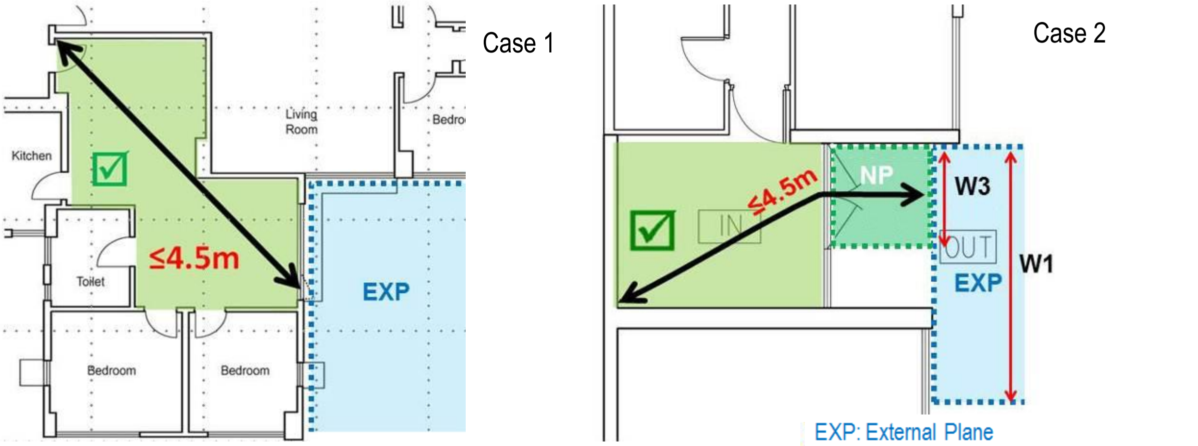


Figure 17 Maximum depth of habitable spaces for single-sided ventilation

3.3.3 Minimum Openable Window Area to Floor Area

The total openable window size in aggregate should not be less than one-fifth (1/5th) of the usable floor area of the room. The area of the NP needs to be taken into account for the calculation of openable window area.

3.4 HEAT EMISSIONS FROM AIR-CONDITIONERS OF OTHER ACCOMMODATION

3.4.1 Heat emissions from air-conditioning units of a residential unit should be at least 1.5m below or horizontally apart from the following:

- ventilation openings for NV_C or NV_{SS} of other residential unit(s) adjacent to the air-conditioning units as per Figure 18 (case 1);
- ventilation openings for NV_C or NV_{SS} of other residential unit(s) in a re-entrant less than 4.5m in width as illustrated in Figure 18 (case 2) & Figure 19;
- NP for NV_C of other residential unit(s) in a re-entrant less than 4.5m in width as illustrated in Figure 18 (case 2); and
- Common boundary of an adjoining site.

If air-conditioning units are installed at the time of occupation permit application, the measurement of 1.5m shall be made between the edge of the ventilation openings / NP and the closest outer edge of air-conditioning units or the horizontal distance to the closest outer edge of the A/C platform, whichever is closer.

If air-conditioning units are not installed at the time of occupation permit application, the measurement shall be made between the edge of the ventilation openings / NP and the closest outer edge of the window openings for the installation of the air-conditioning units or the horizontal distance to the closest outer edge of the A/C platform, whichever is closer.

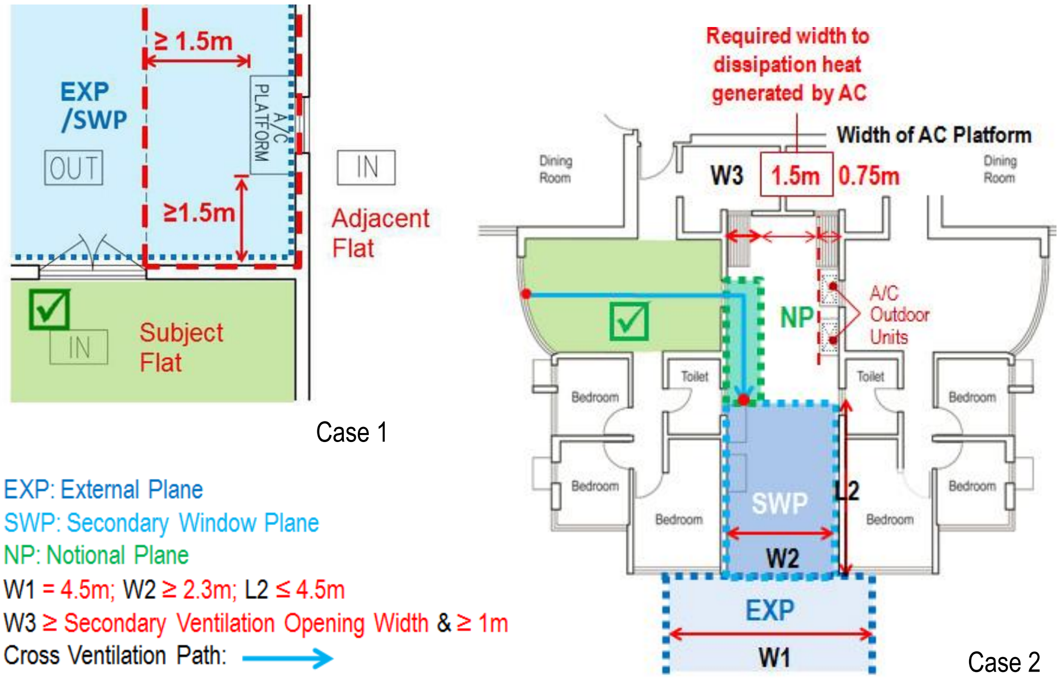
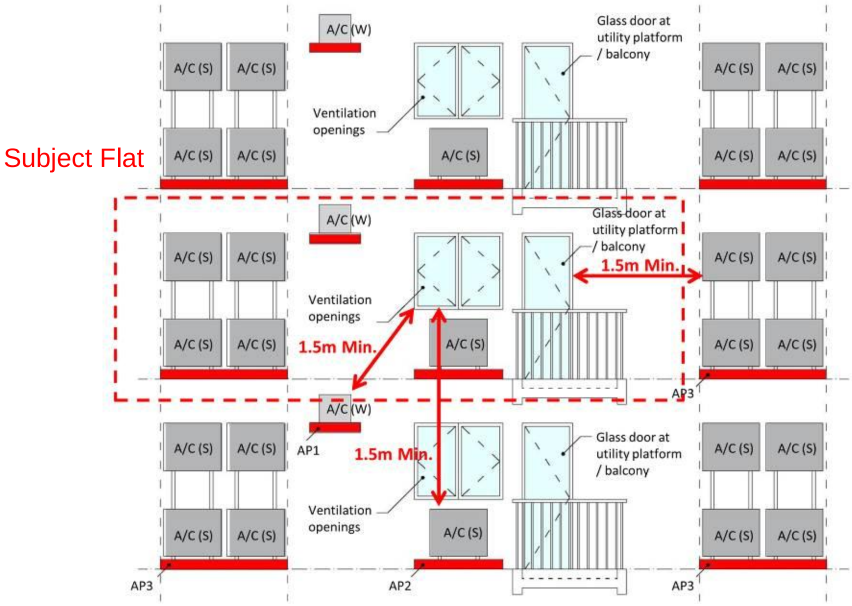


Figure 18 Heat Emissions at least 1.5m Away from Openable Windows of Adjacent Units



A/C(W): Window-type A/C unit
A/C(S): Split-type A/C unit
AP1: Air-conditioner platform for window-type air-conditioner of adjacent residential units
AP2 / AP3: Air-conditioner platform of adjacent residential units for split-type ar-conditioners

Figure 19 Locations of Air-conditioners in a Re-entrant

3.5 ALTERNATIVE PERFORMANCE-BASED APPROACH METHODOLOGY

Alternative paths to assess NV_{TC} are simplified simulation method and site specific simulation method, whether by field model or zone model, shall be undertaken to identify the AAWV in the habitable spaces. Computational Fluid Dynamic (CFD) software for all simulations should meet the requirements stipulated in the AVA methodology[2].

3.5.1 Simplified Simulation Method

The following methodology should be adopted for the simplified simulation approach:

- Wind speed of 3.0 m/s.
- There is no set requirement for the wind direction to be chosen and it should be chosen as the designer sees fit. The designer is free to choose any number of wind directions for the assessment.
- The simulated domain should include all habitable spaces, structural elements, fixed internal partitions, false ceilings/floors and wing walls.
- The model can be simplified to include envelope 'holes' which are equivalent to the opening areas should the designer feel it inappropriate to model the opened window pane in situ. The calculation for the opening areas should follow CIBSE Applications Manual AM10: 2005[3].
- The simulation should identify the AAWV from each habitable space under each wind direction.
- Toilet or bathroom doors complying with Section 3.1.3 and internal doors within a unit are assumed to be fully opened.
- Kitchen doors and entrance doors that connect to the common area within the building (e.g. lift lobbies) are assumed to be fully closed.
- The AAWV is calculated on a plane 1.2m above the average finished floor level for each space.
- A habitable space is deemed to have satisfied the requirements if the AAWV is not less than 0.4m/s under the chosen wind direction.
- All habitable spaces are calculated separately.
- Find out the percentage area of spaces which satisfy the AAWV requirements based on total habitable spaces in the building.

3.5.2 Site Specific Simulation Method

To more accurately assess NV_{TC} performance with regard to internal layouts and envelope details in the full urban context, a detailed CFD model is required to be set up as follows:

- Construct a urban model in accordance with the AVA methodology[4]:

2 Housing, Planning and Lands Bureau, Technical Circular No/ 1/06 Environment, transport and Works Bureau Technical Circular No/ 1/06 - Air Ventilation Assessments

3 CIBSE Applications Manual AM10: 2005 (Section 3.2) provides a methodology for calculating effective opening areas for different window types.

4 Housing, Planning and Lands Bureau, Technical Circular No/ 1/06 Environment, transport and Works Bureau Technical Circular No/ 1/06 - Air Ventilation Assessments

(i) Surrounding massing equal to 2 times the height of the tallest building and including any significant massing which may affect flow further outside of this zone should be included.
(ii) Surrounding topography up to 5 times away from the height of the tallest building.
(iii) Wind profile(s) for the site should be referenced from the V_∞ data developed from simulation models (e.g. MM5 and CALMET). The Power Law or Log Law using appropriate coefficients to the site conditions should be used when adapting the wind data for the site.
(iv) Choose a simulation software that at a minimum has the following specifications:
  - The ability to solve fluid flow equations for three dimensional incompressible flows at steady state on a body conforming computational grid.
  - Turbulence modeling shall be included, typical accurate modeling tools are:
    - The modified k-ε turbulence model.
    - The standard k-ω turbulence model.
    - Detached eddy simulation.
    - Large eddy simulation.
  - If other turbulence models are used, the submission must demonstrate that the tool used is "fit for the purpose". The scientific suitability, as well as the practical merits must be demonstrated.
(v) Ensure the mesh is sufficient to resolve salient flow features and capture and calculate the results accurately. Typical mesh elements are in the order of 0.5-1.0m, but specific project features should be considered.
(vi) Demonstrate that enough wind directions are chosen so that more than 75% of the probable winds directions in a typical reference year are assessed. This should start with the most probable direction and proceed accordingly.
(vii) Simulate to calculate the wind pressures at the mid level of each floor plate type on the elevations with natural ventilation openings.

- Construct an internal layout model of the units in the assessment.

(i) All internal and envelope features that may significantly influence flow must be present in the model.
(ii) Ensure the (mesh) is sufficient to resolve salient flow features and capture and calculate the results accurately. Typical mesh elements are in the order of 0.1-0.2m, but specific project features should be considered.
(iii) Toilet or bathroom doors complying with Section 3.1.3 and internal doors within a unit are assumed to be fully opened.
(iv) Kitchen doors and entrance doors that connect to the common area within the building (e.g. lift lobbies) are assumed to be fully closed.
(v) Choose a simulation software, that at a minimum has the following specification:
  - The ability to solve the fluid flow equations for three dimensional incompressible flows at steady state on a body conforming computational grid.
  - Turbulence modeling shall be included, typical accurate modeling tools are:
    - The modified k-ε turbulence model.
    - The standard k-ω turbulence model.

- Detached eddy simulation.
- Large eddy simulation.

- If other turbulence models are used, the submission must demonstrate that the tool used is "fit for the purpose". The scientific suitability, as well as the practical merits must be demonstrated.

(vi) Input the wind pressures from the urban CFD model as boundary conditions at facade openings of this internal layout model.

(vii) Run simulations to calculate the AAWV within the habitable spaces which is calculated on a plane 1.2m above the average finished floor level for each space. Find out the percentage area of spaces which satisfy the AAWV requirements based on total habitable spaces in the building.

(viii) A habitable space is deemed to have satisfied the requirements if the AAWV is not less than 0.4m/s for any wind direction.

(ix) All habitable spaces are calculated separately.

3.5.3 **Documentation Requirements for Simplified / Site Specific Simulation Methods**

The following documentation should be prepared to demonstrate compliance with the above methodology including all necessary evidence for review. The layout should be as follows:

- Executive summary
  - Background of development
  - Summary of findings
  - Conclusion from work
- Background of work and development
- Methodology
  - Description of methodology
  - Professional rationale highlighting why the computational process is adequate for the task. This should include wind settings, CFD setting, unit choice, etc.
- Images of the model
  - Assessment size
  - Local massing and size
  - Mesh views highlighting scale in comparison to building features
  - Internal layout
- Assessments settings
  - Boundary conditions
  - Software and calculation process
  - Mesh settings, including the mesh size and aspect ratio
  - Solution control and convergence criteria
- Results (details may be included as appendices)
  - External velocities plots including the surrounding and massing features
  - Graphical plots for the facade pressures highlighting different wind directions
  - Internal velocities plots including the building features
  - Tabulation of the results
- Conclusion

Appendix I

SPECTRUM OF RTTV OF SELECTED DESIGN CASES

Results of pilot studies of selected design examples have been calculated and tabulated below for $RTTV_{wall}$ and $RTTV_{roof}$ respectively to demonstrate the associated spectrum of performance.

Spectrum of $RTTV_{wall}$ of Selected Design Cases

Case	Building Design Parameters					$RTTV_{wall}$ (W/m^2)	Reference Pictures
	WWR	SC	OPF	α	Orientation		
W1A	0.55	0.53	0.8	0.58	N-S	12.44	
	Remarks: - 10mm thk. Green Tinted Glass - External finishes: white ceramic tiles						
W1B	Same as Case 1A				E-W	13.81	
W2A	0.55	0.45	0.05	0.75	N-S	13.92	
	Remarks: - Single low-e; 10+12+10mm thk. IGU - OPF for fenestrations at balcony: 0.6; rest: 0.05 - Curtain wall						
W2B	Same as Case 2A				E-W	15.29	
W3A	0.36	0.58	0.05 / 0.6	0.7	N-S	13.60	
	Remarks: - 8mm thk. Green Tinted Glass - OPF for fenestrations at balcony: 0.6; rest: 0.05 - External finishes: medium light brown ceramic tiles						
W3B	Same as Case 3A				E-W	15.33	
W4A	0.14	0.90	0.2	0.5	N-S	10.00	
	Remarks: - Clear Glass - External finishes: light coloured spray paint						
W4B	0.14	0.64	0.2	0.5	E-W	8.75	
	Remarks: - 6mm thk. Green Tinted Glass - External finishes: white ceramic tiles						

Spectrum of $RTTV_{roof}$ of Selected Design Cases

Case	Building Design Parameters			$RTTV_{roof}$ (W/m^2)	Reference Pictures
	U-value	α	% Uncovered		
R1	0.9	0.6	100	4.00	
	Remarks: - Medium grey concrete tile - Medium insulated				
R2	0.68	0.4	100	2.04	
	Remarks: - White metal roof tiles - Medium insulated (50mm mineral wool)				
R3	2.75	<0.2	100	2.06	
	Remarks: - Green roof - wet soil, no further insulation				

Appendix II

DEMONSTRATION OF COMPLEX SHADING AND SELF-SHADING CALCULATIONS AND ALTERNATIVE METHOD FOR EXTERNAL SHADING COEFFICIENT CALCULATION USING SIMULATION SOFTWARE

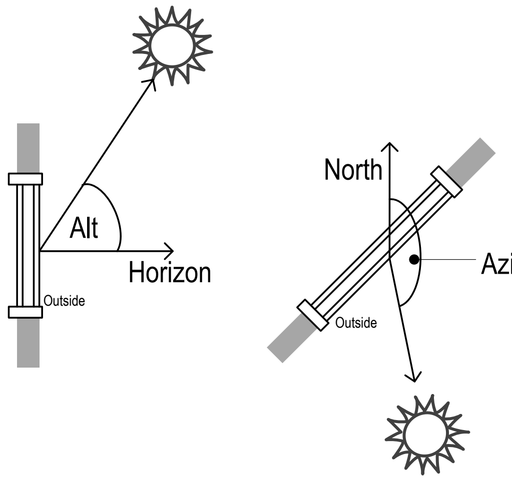
COMPLEX SHADING AND SELF-SHADING CALCULATIONS

Example – Complex Shading

The effect of complex shading can be calculated by the following method:

1. Solar data and the solar environment of Hong Kong have been considered in the preparation of these guidelines and are summarized in Table 10 – Table 14.
2. Firstly, identify the direction the glazing faces, this should then be used to select the correct table of solar data from Table 10 – Table 14 of the Guidelines.
3. The closest cardinal or inter-cardinal direction should be selected.
4. The hourly solar data, for 4 representative days, is listed for each of the eight cardinal and inter-cardinal directions. This is split into direct and diffuse solar data (Table 10 – Table 14). E.g. 28th Oct, South East and South West orientations.

SE/SW	28-Oct				
Time	Alt	Azi	IT	ID	Id
6	0	0	0	0	0
7	7	107	22	0	22
8	20	114	68	0	68
9	32	123	98	0	98
10	43	136	120	2	118
11	51	153	173	46	127
12	55	177	321	225	96
13	53	202	376	278	98
14	45	221	400	308	92
15	35	235	346	271	75
16	23	244	182	138	44
17	0	0	0	0	0
18	0	0	0	0	0

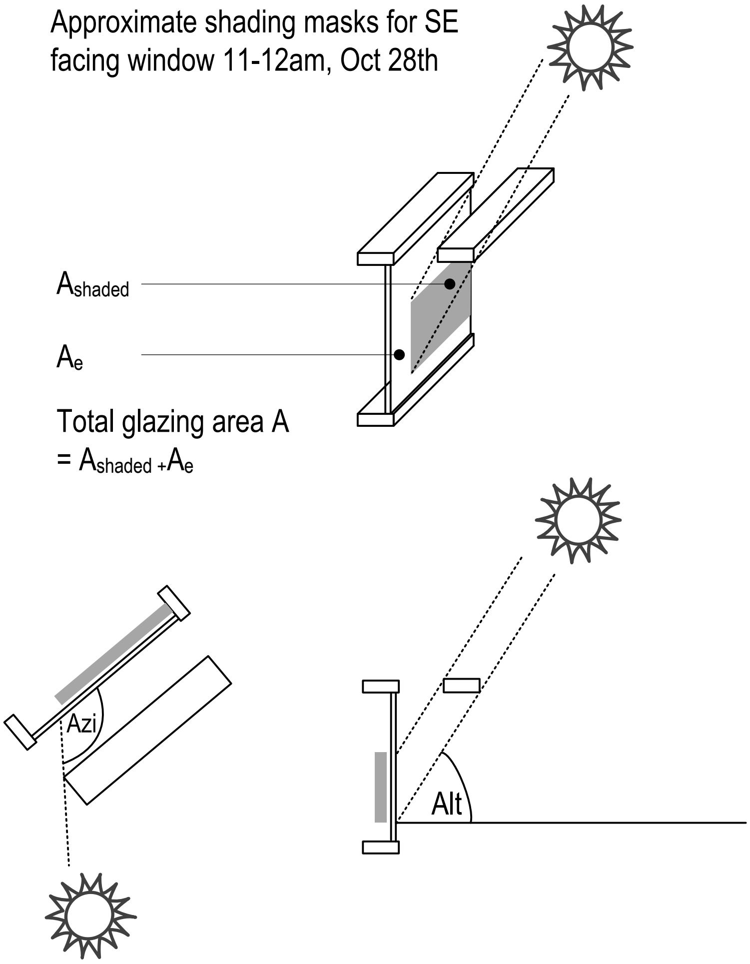


Total radiation (IT) =
Direct Radiation (ID) + Diffuse Radiation (Id)

5. To calculate the effect of shading, at any point in time, the fraction of the glazing exposed to direct radiation must be calculated – Er.

$$Er = A_e/A$$

Where Ae is the glazing area exposed to direct solar radiation and A is the total glazing area.



6. A_e is calculated through the application of simple geometric principles for each hour of the day to give Er values.
7. When Er is multiplied by I_D, ($Er \cdot I_D$), the amount of direct radiation that strikes the glazing at that hour of the day is given.
8. This is added to the total amount of diffuse radiation (I_d) in that hour.
9. The hourly values of shaded direct radiation ($Er \cdot I_D$), and total diffuse radiation (I_d) are summed for each hour of the day to give the total radiation that falls on the glazing during that day:

   Solar radiation that falls on a shaded window = $\mathbf{\sum Er \cdot I_D + I_d}$

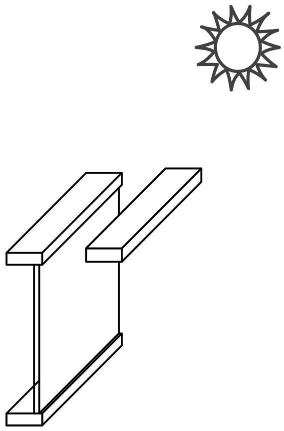
10. The total radiation that falls on an obstructed glazing during a day is given by:

    Solar radiation that falls on an un-shaded window = $\mathbf{\sum(I_D + I_d)}$

11. These values are calculated for the four days according to the tabulated solar data to give a representation of the total radiation that falls on the glazing during the residential cooling period.
12. The shading factor or ESC is the proportion of the two summations:

    The shading factor, $\mathbf{ESC = (\sum Er \cdot I_D + I_d)/\sum(I_D + I_d)}$

13. Steps 1-12 are shown in the following table for a typical day, values approximate the below sketch:



SE/SW	28-Oct				
Time	**Alt**	**Azi**	**IT**	**ID**	**Id**
6	0	0	0	0	0
7	7	107	22	0	22
8	20	114	68	0	68
9	32	123	98	0	98
10	43	136	120	2	118
11	51	153	173	46	127
12	55	177	321	225	96
13	53	202	376	278	98
14	45	221	400	308	92
15	35	235	346	271	75
16	23	244	182	138	44
17	0	0	0	0	0
18	0	0	0	0	0

	Er*	Er×ID	Id	Er*ID+Id	ID+Id
	1.00	0	0	0	0
	1.00	0	22	22	22
	1.00	0	68	68	68
	1.00	0	98	98	98
	1.00	2	118	120	120
	0.95	43.7	127	171	173
	0.85	191.25	96	287	321
	0.70	194.6	98	293	376
	0.64	197.12	92	289	400
	0.70	189.7	75	265	346
	0.80	110.4	44	154	182
	0.90	0	0	0	0
	0.95	0	0	0	0
	Total October	929	838	1767	2106

....

(Similar tabulation carried out for April, June & September)

....

Total April	416*	1117	1533	1686
Total June	447*	1119	1566	1728
Total September	707*	1007	1714	1972
Total Cooling Seaon	2499	4081	6580	7492

* indicative values for demonstration only

Therefore,

ESC = $(\sum Er \cdot I_D + Id)/\sum(I_D + Id)$

ESC = 6580 / 7492

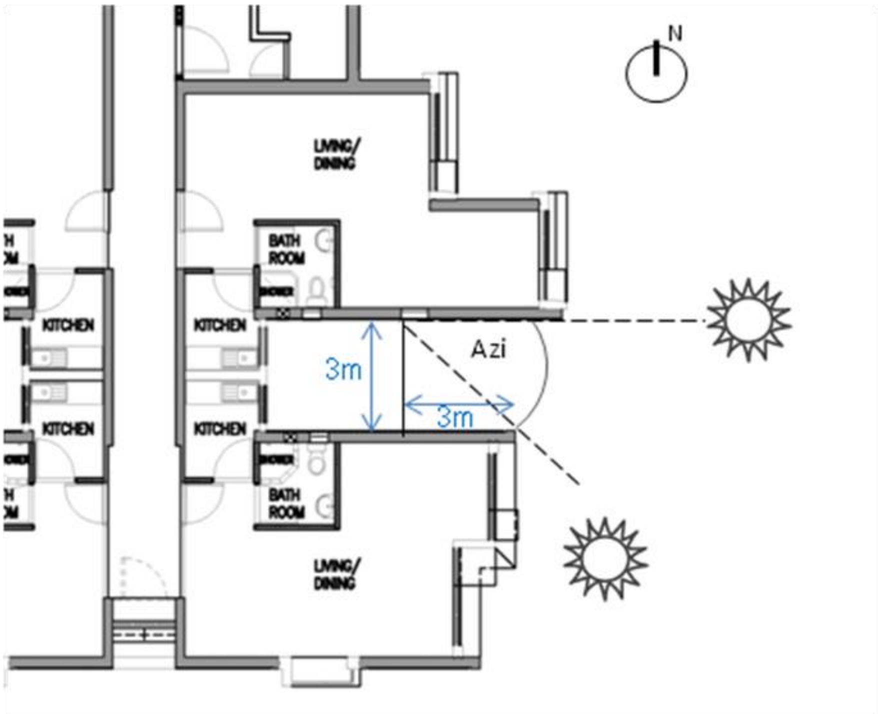
ESC = <u>**0.88**</u>

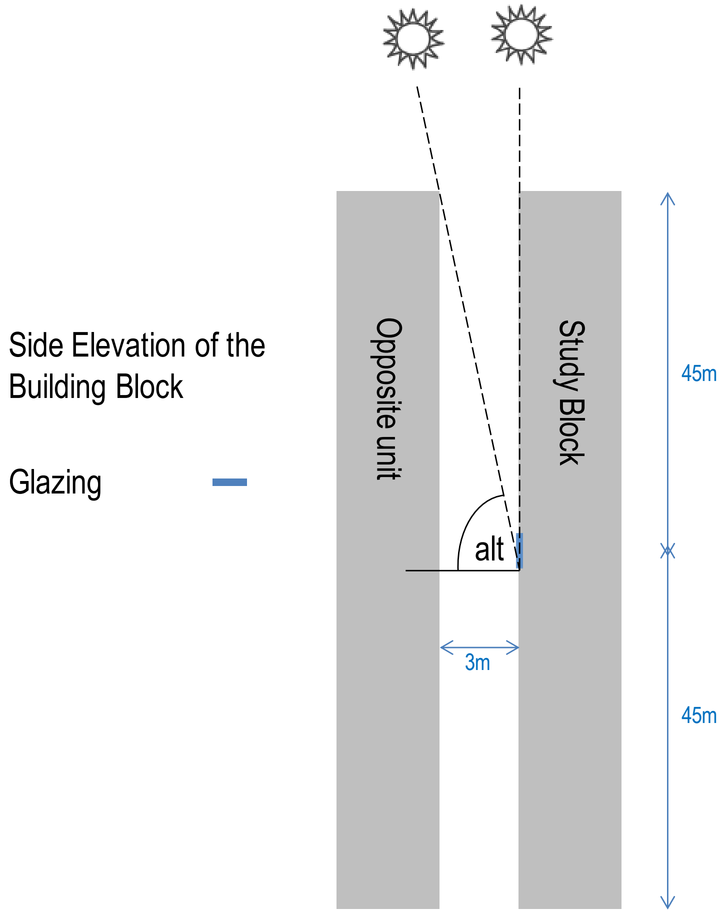
Example – Self Shading

The methodology presented for complex shading should be applied for self shading, with the following point taken into account:

i. The direct solar radiation is calculated based on the geometry of the mid floor unit.

The self-shading effect on glazing in the re-entrance area is examined in this example. This is a 30 story block and the window in question is 1m in height and width, mid way up the wall.





For the representative solar data for south facing windows, the proportion of the window that is shaded is calculated for each hour and the ESC calculated as per the equation:

$$\mathbf{ESC = (\sum Er \cdot I_D + I_d)/\sum(I_D + I_d)}$$

In this case:

- For 90º < solar azimuths < 135º the glazing is fully exposed to direct solar radiation - Er= 1,
- For solar azimuths > 146º the glazing is fully shaded from direct solar radiation – Er = 0,
- For 135º ≤ solar azimuths ≤ 146º the proportion of the shaded window should be calculated to give Er.
- For solar altitudes > 86.1º in conjunction with solar azimuths > 141º the glazing the glazing may experience direct solar radiation and the proportion of the shaded window should be calculated to give Er.

The tables below are constructed based on the relevant solar tables, for south facing glazing, given in these guidelines. When Er > 0, the glazing receives direct solar radiation.

S	17-Apr						22-Jun					
Time	Solar altitude	Solar azimuth	ID	Id	Er	Q=Er*ID+ Id	Solar altitude	Solar azimuth	ID	Id	Er	Q=Er*ID+ Id
6	0	0	0	0	0	0	3	66	0	13	0	13
7	12	84	0	36	0	36	16	71	0	48	0	48
8	26	90	2	79	0	79	30	75	0	85	0	85
9	40	96	25	111	1	136	43	78	0	119	0	119
10	54	104	59	133	1	192	57	81	0	137	0	137
11	67	118	71	148	1	219	70	83	0	152	0	152
12	77	155	84	148	0	148	84	78	0	146	0	146
13	75	218	78	144	0	144	82	280	0	148	0	148
14	64	246	46	133	0	133	68	278	0	127	0	127
15	51	259	35	109	0	109	54	280	0	115	0	115
16	37	266	8	69	0	69	41	282	0	74	0	74
17	23	272	0	31	0	31	27	286	0	40	0	40
18	9	277	0	0	0	0	14	290	0	13	0	13
	SUM(Er*ID+Id)		1296				SUM(Er*ID+Id)		1217			
	sum(Id+ID)		1549				sum(Id+ID)		1217			
	SC(Day)		0.837				SC(Day)		1.000			

S	11-Sep						28-Oct					
Time	Solar	Solar	ID	Id	Er	Q=Er*ID+	Solar	Solar	ID	Id	Er	Q=Er*ID+
6	0	0	0	0	0	0	0	0	0	0	0	0
7	11	89	2	42	0	42	7	107	54	31	1	85
8	25	95	45	81	1	126	20	114	118	64	1	182
9	39	102	75	106	1	181	32	123	234	81	1	315
10	52	112	90	126	1	216	43	136	306	88	0.09	116
11	64	129	119	134	1	253	51	153	366	87	0	87
12	72	164	151	129	0	129	55	177	362	88	0	88
13	70	211	129	126	0	126	53	202	368	86	0	86
14	60	238	69	123	0	123	45	221	280	83	0	83
15	48	252	47	96	0	96	35	235	185	69	0	69
16	34	260	9	52	0	52	23	244	75	41	0	41
17	20	267	1	13	0	13	10	252	0	0	0	0
18	6	273	0	0	0	0	0	0	0	0	0	0
	SUM(Er*ID+Id)		1357				SUM(Er*ID+Id)		1152			
	sum(Id+ID)		1765				sum(Id+ID)		3066			
	SC(Day)		0.769				SC(Day)		0.376			

Therefore:

ESC = $(\sum Er\cdot I_D+I_d)/\sum(I_D+I_d)$

ESC = (1296+1217+1357+1152)/(1549+1217+1765+3066) = **0.661**

ALTERNATIVE METHOD FOR EXTERNAL SHADING COEFFICIENT CALCULATION USING SIMULATION SOFTWARE

The External Shading Coefficient (ESC) of shading can be calculated by the following method:

1. Construct a baseline model of the glazing system with no shading;
2. Construct a design model of the glazing system and an accurate representation of the shading;
3. For both cases calculate the area-integrated incoming solar flux (irradiance) or solar power on the outer pane of the glazing from April to October, 24hrs a day should be calculated.
4. The $ESC=(\sum ID_{(shaded)} + Id_{(shaded)})/(\sum ID_{(unshaded)} + Id_{(unshaded)})$ or $ESC = (\sum solar\ flux_{(shaded)})/(\sum solar\ flux_{(un\text{-}shaded)})$
5. This can then be inputted into the RTTV calculation.

Notes:

i. Exclude all shading that is not a permanent architectural feature of the building in question.

ii. The solar data must be based on a typical year weather file for Hong Kong, for instance - CityUHK-45007 -- WMO#450070 Typical year file Hong Kong originally in IWEC format spreadsheet jointly developed by Dr TT Chow and ALS Chan of the City University of Hong Kong.

iii. The software should have the following capabilities:

   a. Accurately model building and shading system geometry;
   b. Accurately predict the passage of solar energy through shading systems *should they be semi opaque*;
   c. Utilize climate data based on solar time;
   d. Accurately predict quantities of direct and diffuse irradiation and the resultant solar flux;
   e. Calculate the area-integrated incoming solar flux (irradiance) or solar power in a given period of time.

iv. Typically software that can carry out the above calculation are: (note that this list is not exhaustive and other software can be considered)

   a. Autodesk Ecotect;
   b. Integrated Environment Solutions , VE-Pro;
   c. Radiance simulation tools;
   d. EnergyPlus

Appendix III

STANDARD FORMS OF RTTV CALCULATIONS

Appendix IV

SAMPLE OF RTTV REPORT / CALCULATIONS FOR A RESIDENTIAL BUILDING

Appendix V

SAMPLE OF RTTV REPORT / CALCULATIONS FOR DEEMED TO SATISFY $RTTV_{WALL}$ CRITERIA FOR COMPLIANCE CHECK FOR A RESIDENTIAL BUILDING

Appendix VI

SAMPLE OF NV_{TC} COMPLIANCE CHECK FOR A RESIDENTIAL BUILDING LAYOUT