MALAYSIAN STANDARD

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Energy efficiency and use of renewable energy for residential buildings - Code of practice

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Tel: 60 3 8318 0002
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MALAYSIA

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Foreword

This Malaysian Standard was developed by the Working Group on Architecture and Passive Design Strategy under the authority of the Industry Standards Committee on Building, Construction and Civil Engineering.

Compliance with a Malaysian Standard does not of itself confer immunity from legal obligations.

Energy efficiency and use of renewable energy for residential buildings - Code of practice

1 Scope

This code of practice gives guidance on the design, selection of materials and electrical appliances and efficient use of energy including the application of renewable energy in new and existing residential buildings.

2 Normative references

The following normative references are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the normative reference (including any amendments) applies.

MS 1020, *Thermal insulation products for buildings - Factory made mineral wool (MW) products - Specification*

MS 1525, *Energy efficiency and use of renewable energy for non-residential buildings - Code of practice*

MS 2095, *Radiant barrier and reflective insulation building materials - Specification*

MS 2574, *Minimum energy performance standards (MEPS) for domestic fan*

MS 2576, *Minimum energy performance standards (MEPS) for television*

MS 2597, *Minimum energy performance standards (MEPS) for air conditioners*

MS 2598, *Minimum energy performance standards (MEPS) for lamps*

ASTM C1371, *Standard test method for determination of emittance of materials near room temperature using portable emissometers*

ASTM E903, *Standard test method for solar absorptance, reflectance, and transmittance of materials using integrating spheres*

ASTM E1980, *Standard practice for calculating solar reflectance index of horizontal and low-sloped opaque surfaces*

ANSI/ASHRAE Standard 55, *Thermal environmental conditions for human occupancy*

Electricity Regulations 1994

3 Terms and definitions

For the purposes of this standard, the following terms and definitions apply.

3.1 ballast

A device used in conjunction with an electric-discharge lamp to cause the lamp to start, control and operate under the proper circuit conditions of voltage, current, wave form, electrode heat, etc.

3.2 building envelope

Exterior portions of a building through which thermal energy is transferred.

3.3 coefficient of performance

Ratio of the rate of net heat removal to the rate of total energy input, expressed in consistent units and under designed rating conditions.

3.4 efficiency rating label

A label which provides information of energy performance level of an equipment as specified in *Electricity Regulations 1994 (Regulation, 101A).*

3.5 emissivity (ε)

Effectiveness of the surface of a material in emitting energy as thermal radiation.

3.6 emittance

Ratio of the radiant heat flux emitted by a specimen to that emitted by a blackbody at the same temperature and under the same conditions.

3.7 illuminance

Total luminous flux incident on a surface, per unit area. It is a measure of how much the incident light illuminates the surface.

3.8 lamp

A source of spectral radiation that is detectable by the human eye. It may be a traditional electric lamp technology including incandescent, halogen, fluorescent, high intensity discharge, or a source such as light emitting diode (LED), organic light emitting diode (OLED), electroluminescence or other technologies.

3.9 minimum energy performance standards (MEPS)

Minimum level of energy efficiency which has to be met by each individual unit of the appliance.

3.10 optical transmissivity

Transmissivity is an optical property of a material, which describes how much light is transmitted through material in relation to an amount of light incident on the material.

3.11 predicted mean vote (PMV)

Predicted mean vote (PMV) refers to a thermal scale that runs from cold (-3) to hot (+3).

3.12 radiant barrier

Radiant barrier is a material that either reflects radiant heat or inhibits the emission of radiant heat.

3.13 reflectance

Ration of the intensity of reflected radiation to that of the radiation incident on a surface.

3.14 reflective insulation

An insulating material used to retard the transfer of heat by reflecting heat radiation; usually made of aluminum foil or sheets.

3.15 renewable energy

Energy from a source that is not depleted when used, such as wind or solar power.

3.16 resistive insulation

Resistive insulation, also called bulk insulation, insulates against the transfer of heat simply through its resistance to conduction.

3.17 solar absorptivity

Measure of the ability of a material to absorb solar radiation.

3.18 solar insolation

Rate of solar energy incident on a unit area with a given orientation.

3.19 solar reflectance index (SRI)

A measure of the roof's ability to reject solar heat.

3.20 solar reflectivity or reflectance

Ability of a material to reflect solar energy (reflecting solar radiation and emitting thermal radiation) from its surface back into the atmosphere.

3.21 star rating

The number of stars displayed on the energy label. The star rating is calculated from the star rating index (see Clause 5).

3.22 thermal conductivity

A material property describing the ability to conduct heat. It can also be defined as the quantity of heat transmitted through a unit thickness of a material, in a direction normal to a surface of unit area, due to a unit temperature gradient under steady state conditions. Thermal conductivity unit is W/(mK).

3.23 thermal resistance

A heat property and a measurement of a temperature difference by which an object or material resists a heat flow. Thermal resistance is the reciprocal of thermal conductivity. The thermal resistance of unit area of a material is measured by the *R*-value. *R*-value has the units of $(m^2K)/W$.

3.24 thermal transmittance

Thermal transmittance, also known as *U*-value, is the rate of transfer of heat (in watts) through one square metre of a structure divided by the difference in temperature across the structure.

4 Architectural and passive design strategies

Passive design strategies for energy efficient residential buildings are unique due to the variations in occupancy and usage pattern. Among the variable aspects are intermittent and continuous occupancy, age range, natural and/or active ventilation, and lifestyle. Most residential buildings are occupied in mixed mode ventilation (natural and active ventilation) condition.

4.1 Sustainable design approach

Designing within the contextual climate and site is the first step in optimising the benefits given by a specific environment. Design solutions should strive to achieve indoor environmental quality (IEQ) and use environmentally friendly materials of quality and durability in order to minimise waste.

A holistic architectural, engineering, site planning and landscaping approach should be used to design a habitable environment for human. For practical purposes, mixed mode strategies can be adopted to suit the variations in human activities with respect to outdoor environmental condition. For example, optimising daylighting and thermal comfort while reducing solar heat gain would be a strategy to achieve energy efficiency.

4.2 Passive design strategy

Passive design strategies mean that minimal or no mechanical or electrical means are used to achieve both indoor thermal and visual comfort and reduction in energy consumption. In order to achieve thermal and visual comfort in residential buildings in a hot-humid climate, the basic strategies are to orientate, shade, insulate, ventilate and harvest daylighting.

Residential buildings have a primary function to provide an internal and immediate outdoor environment suitable for domestic activities. The architectural passive design consideration in designing a residential building is primarily influenced by its responsiveness to its site context. The important factors that should be considered include the following:

a) site planning and orientation;

b) daylighting;

c) roof;

d) facade;

e) natural ventilation;

f) strategic landscaping; and

g) alternative/renewable energy.

4.3 Site planning and orientation

Site planning and orientation are important considerations in architectural passive design strategies. Site planning involves factors of geographical location, landform/topography, existing vegetation, wind direction, water body and adjacent development. Orientation with respect to solar insolation normally takes precedence over prevailing wind direction.

4.3.1 Site planning

Factors to be considered in site planning are:

a) geographical location (latitude, altitude, longitude);

b) land form/topography (hill, valleys);

c) existing vegetation (shading potential, channeling of wind, ambient temperature);

d) site wind condition (wind direction, speed);

e) water bodies (glare, reflection, humidity);

f) adjacent development (heat island effect, microclimate); and

g) infrastructure (accessibility, water supply, reducing carbon emission).

4.3.2 Site orientation with respect to solar insolation

The general rule for best orientation of residential buildings is to avoid facades with most openings facing east or west. Technically for buildings with rectangular plans the buildings main longitudinal orientation should be on an axis 5° northeast. On narrow sites where the east-west longitudinal orientation may not be feasible, the solutions may require other building geometries. In this case, the shading devices recommended may differ according to orientation.

The orientation of residential buildings may also contribute to the immediate microclimate of open spaces through the provision of shading and shadowing to the immediate surroundings that will in turn benefit the indoor areas adjacent to it. The microclimate information (air temperature, radiant temperature, relative humidity, air velocity and precipitation, etc.) should be analysed for the specific locality.

For link (terrace) residential buildings, the best orientation is to have the front and back facades facing north and south. However for end units, the problem with this strategy is the length of the house will be facing either east or west. As such, there is a need to introduce additional strategies such as minimising openings, covered terrace, balcony, awnings or insulation of layer in the affected walls. Refer to Table 7 for shadow angles with respect to sun position.

4.3.3 Site orientation with respect to prevailing wind direction

Generally, openings of a building should be oriented along prevailing wind direction. Wind behavior is affected by many factors; for example, trees, building and other structures on site. Therefore, it affects the natural ventilation performance of a building on site.

4.4 Daylighting

Designing to harvest daylighting should begin at the preliminary design stage.

A good daylighting system should consider the following:

a) space orientation and layout;

b) physical (shape and size) and optical properties of glazing through which daylight will transmit or penetrate;

c) internal floor, wall and ceiling surface properties (colour and reflectivity);

d) visual contrast between adjacent surfaces (e.g. between walls and ceilings); and

e) protection from visual discomfort (e.g. glare and silhouette) caused by external and internal building elements.

Conventional and innovative daylighting strategies that collect, transport and distribute light into buildings with deep floor plans and systems that reduce the need for artificial lighting without increasing solar heat gain, are recommended.

4.4.1 Daylight distribution

The simplest form of describing daylight distribution, penetration and intensity is the Daylight Factor (DF), expressed as a percentage and is limited to overcast sky condition. This is the ratio of the internal illuminance (E_{internal}) at a point in a room to the instantaneous external illuminance (E_{external}) on a horizontal surface:

$$\text{DF} = \frac{E_{\text{internal}}}{E_{\text{external}}} \times 100\ \%$$

The maximum, minimum or average DF values can be calculated using the monthly average hourly values of external illuminances as guided in Annex B, Figure B.1.

The DF will decrease as the distance from the window increases. Figure 1 shows the DF distribution along the central axis of a room for various window-to-floor-ratios (WFR), optical transmissivity of 100 % and wall reflectance of 0.8.

The internal reflectance of the surfaces in a room (such as ceiling, walls, floors and furniture) and the optical transmissivity of the window glazing will affect the internal illuminance. Similarly, shading devices and light shelves will affect the daylight factors.

The recommended minimum DF in any habitable room is not less than 2 % and the minimum WFR is 15 % (see the daylight distribution in Figure 2). For circulation areas, the minimum WFR is 10 %.

Figure 2 shows the DF distribution in room for a WFR of 15 %. The DF distribution in a room can be predicted from Figure 2 (or Table B.4 from Annex B), where *d/h* ratio is plotted against the *x/l* ratio.

where

P is a point measured on the working plane;

d is depth of *P* from window;

h is the vertical height of the window;

x is the distance of *P* from room axis; and

l is the length of window.

The *d/h* ratio is defined as the position of a point *P* on a working plane to the vertical height of the window (as in Figure 3) and the *x/l* ratio is defined as the horizontal position of the point *P* to half the length of the window. For a common working plane, *P* is a point 0.75 m from the floor.

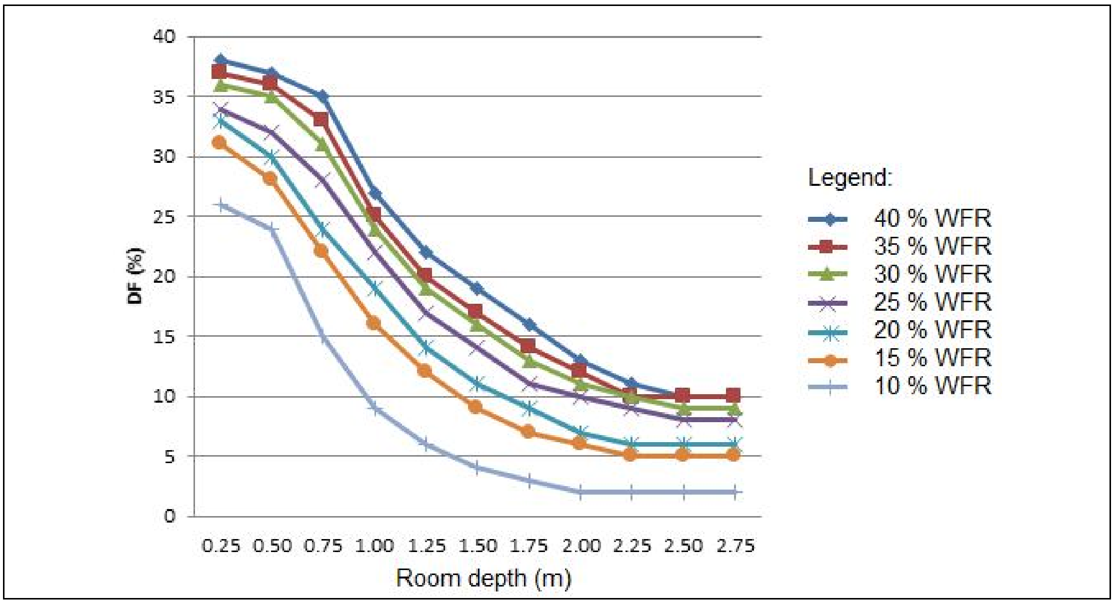


Figure 1. Effect of room depth (along central axis) on daylight factor (DF)

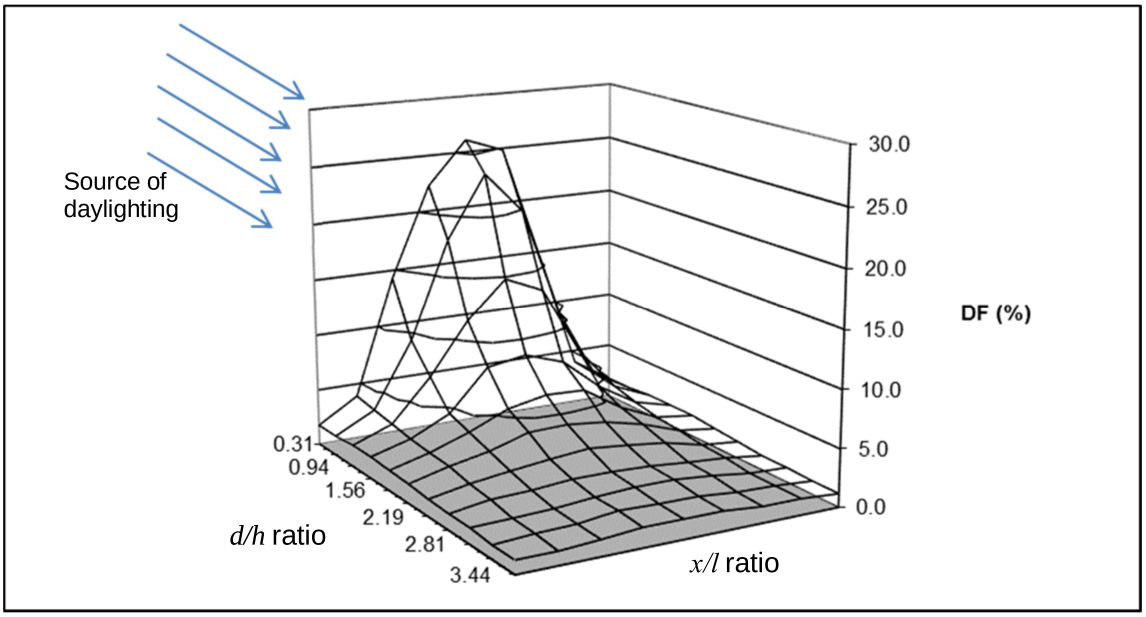
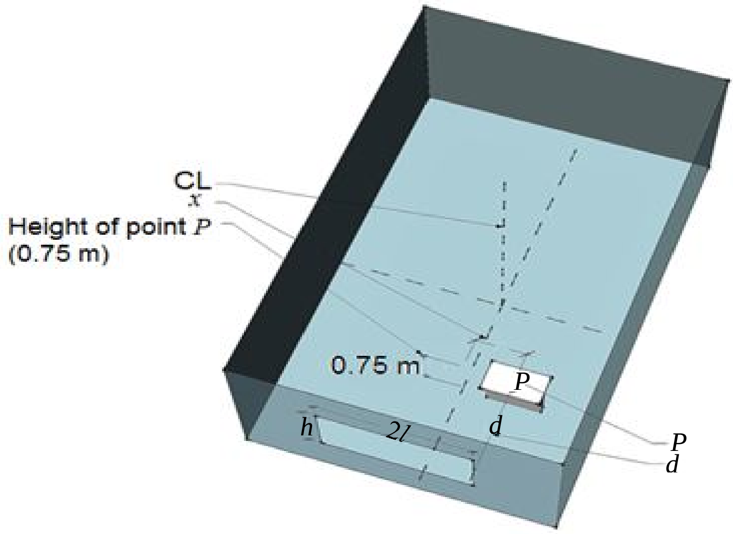
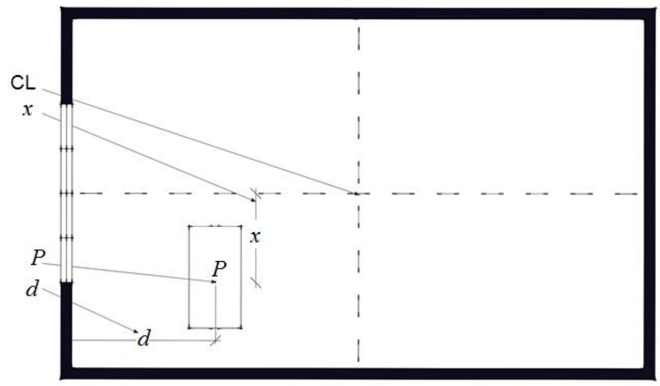


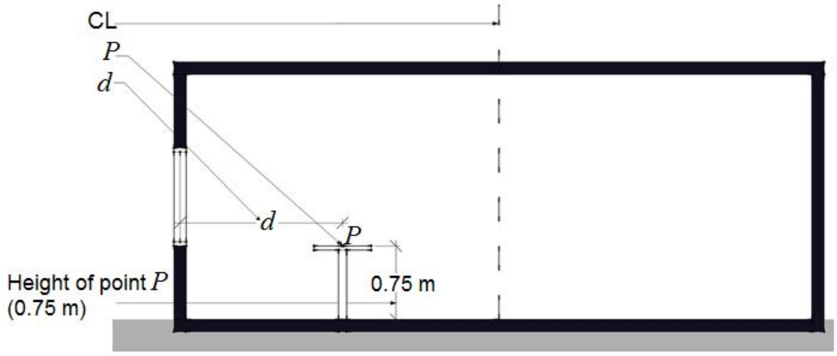
Figure 2. Daylight factor (DF) distribution for WFR 15 % in a room



3-D view



Plan view



Front view

Key

CL	=	centre line	*P*	=	point measured on working plane
x	=	distance of P from room axis	*d*	=	depth of P from window
l	=	is the length of window	*h*	=	the vertical height of the window

Figure 3. Room geometry

The recommended illumination levels in rooms are as in Table 1.

Table 1. Illumination levels in rooms

Area	Recommended lux
Living room	200
Dining room	250
Kitchen	250
Bedroom	180
Bathroom	150

The useful daylight illuminance (UDI) is another approach which draws on a range of useful level. It is defined as the annual occurrence of illuminances across the work plane where all the illuminances are within 100 lux to 2 000 lux. It is a dynamic daylight performance. UDI aims to determine when daylight levels are ‘useful’ for the occupant. The UDI scheme applied by determining the occurrence of daylight illuminances are as in Table 2.

Table 2. Useful daylight illuminance (UDI) range

Description	Lux
Within the range defined as useful	100 to 2 000
Below the useful range	< 200
Exceed the useful range	> 2 000

For residential buildings, the lower limit may not be applicable but the upper limit should be considered. Illuminances above 2 000 lux will cause glare, visual and thermal discomfort. Unlike in office or commercial buildings where lighting for productivity is of paramount importance, the minimum illuminance requirements are not as critical in residential buildings.

4.5 Roof

The roof is a component of a building envelope in the equatorial region with abundant solar radiation and precipitation. Sun-path diagram shows the solar altitude in this region is high throughout the year. Hence, the roof of low-rise buildings is the most exposed building component to the outdoor environment. It is a major source of heat gain during the day and heat loss via night-time cooling. The proportion of heat gain through the roof is 80 % via radiation. The remaining 20 % is via conduction and convection with almost equal proportion depending on the material, design and construction.

For that reason, roofs should be designed and constructed for protection against heat and rainwater. The following elements are to be considered.

4.5.1 Design

The following are recommended roof designs:

a) high pitch to drain off heavy rains;

b) large overhangs to shade the walls and openings;

c) avoid obstructions that prevent airflow along the roof surfaces, e.g. use low parapet walls or perforated screen walls;

d) double roof design;

e) roof insulation and assemblies;

f) ceiling insulation; and

g) roof ventilation.

4.5.2 Thermal properties of roofing materials

The following are considerations when selecting roofing materials:

a) Thermal conductivity - Low thermal conductivity is recommended for all roof materials.

b) Solar absorptivity - Low solar absorptivity is recommended for all roof materials.

c) Emissivity - Low emissivity of inner roof materials and insulation are recommended.

d) Solar reflectivity (SR) - High solar reflectivity of outer surface is recommended for roof finishes.

e) Solar reflectance index (SRI) - High values SRI is recommended for roof surfaces.

4.5.3 Solar reflectivity (SR) and solar reflectance index (SRI)

SRI measures the relative “steady state surface temperature” of a surface with respect to the standard white (SRI = 100) and the standard black (SRI = 0) under the standard solar and ambient conditions as specified in ASTM E1980. The calculation of SRI can be performed in compliance with the ASTM E1980 from the measured values of solar reflectivity and emissivity. Measurement for solar reflectivity and emissivity should comply with Table 3.

Table 3. Measurement for solar reflectivity and emissivity

Test method	Reference standard
Solar reflectivity	ASTM E903
Emissivity	ASTM C1371

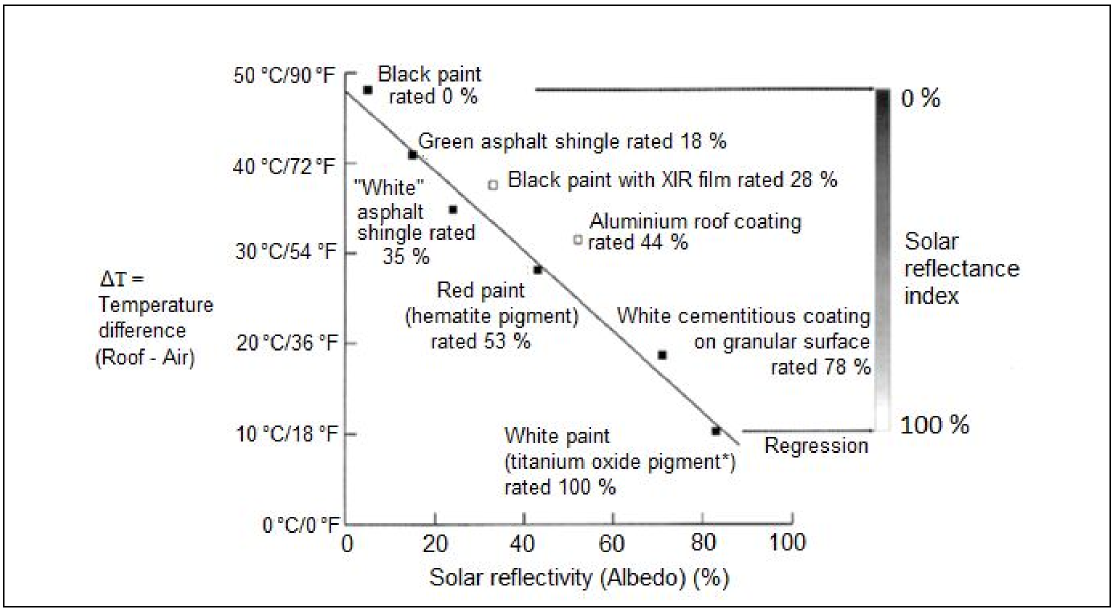


Figure 4. Solar reflectance index (SRI) of different types of roof materials and colours

Figure 4 shows the SRI of several common types of roof materials and colours with a range of albedo and temperature difference. The ΔT is temperature difference between the surface temperature of the roof and the ambient air temperature. Table 4 shows the SRI values for other types of roof materials with the respective SR and emissivity (ε).

Recommended solar reflectivity, SR value of 0.25 or higher for steep slope (> 2:12 or > 10°) roofs and 0.15 or higher with ageing. Low slope roofs require an initial SR value of 0.65 or higher and 0.50 or higher with ageing. Normally, initial SRI values for materials when newly installed is higher but will decrease after a certain ageing period as declared by manufacturer.

Table 4. SRI value by materials

Roof materials	SR	Emissivity (ε)	SRI
White asphalt shingles	0.21	0.91	21
Black asphalt shingles	0.05	0.91	1
Red clay tile	0.33	0.90	36
Red concrete tile	0.18	0.91	17
Unpainted concrete tile	0.25	0.90	25
White concrete tile	0.73	0.90	90
Galvanised steel (unpainted)	0.61	0.04	37
Aluminium	0.61	0.25	50
Siliconised white polyester over metal	0.59	0.85	69
Polyvinylidene fluoride (PVDF) white over metal	0.67	0.85	80
Black ethylene propylene diene monomer (EPDM)	0.06	0.86	-1
Grey ethylene propylene diene monomer (EPDM)	0.23	0.87	21
White ethylene propylene diene monomer (EPDM)	0.69	0.87	84
T-ethylene propylene diene monomer (EPDM)	0.81	0.92	102
Chlorosulphonated polyethylene (CSPE) synthetic rubber	0.76	0.91	95

4.5.4 Thermal properties of roof construction types

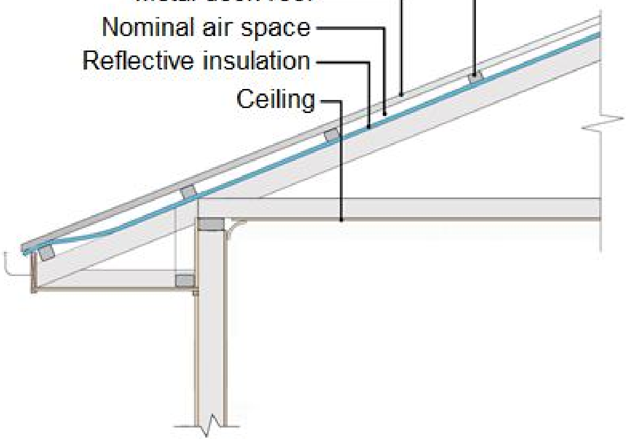
Thermal propertis of roof construction types are as follows:

a) Lightweight roof construction - Recommended to apply appropriate insulation within the lightweight roof construction. See Figure 5 a).

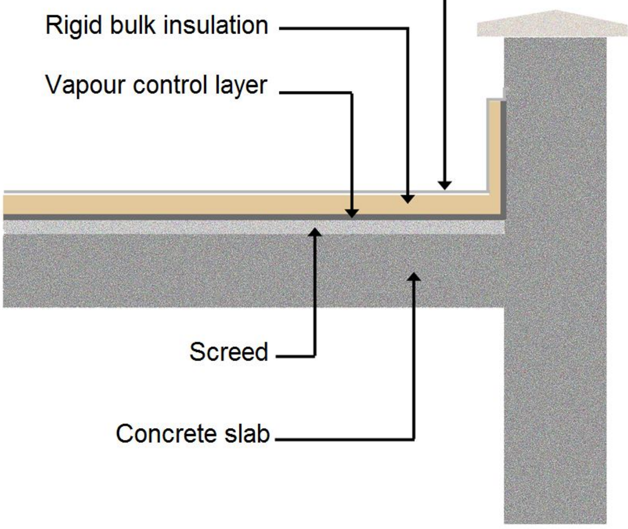
b) Heavyweight roof construction - Recommended to use sufficient insulation on the outer side of the heavyweight roof construction to mitigate heat gain. See Figure 5 b).

c) Low thermal transmittance (*U*-value) and high thermal resistance (*R*-value) - Recommended for all roof construction types.

d) Recommended *U*-value and *R*-value for roof based on construction types as in Table 5.



a) Lightweight roof construction



b) Heavyweight roof construction

Figure 5. Roof assembly

Table 5. Minimum *R*-value and maximum *U*-value for roof (W/m²K)

Roof weight group	Minimum *R*-value (m^2K/W)	Maximum *U*-value (W/m^2K)
Light (Under 50 kg/m²)	2.50	0.40
Heavy (Above 50 kg/m²)	1.67	0.60

4.5.5 Thermal insulation for roof

Thermal insulation plays an important role to reduce solar heat gain for passive cooling and decrease energy demand for active cooling of the building interior.

Thermal insulation in buildings can be categorised as 'bulk' or 'resistive insulation', 'reflective insulation' and 'radiant barrier'. Radiant barrier is defined as a reflective material facing an open air space (see Figure 5). Bulk insulation (e.g. mineral wool) is normally used for thermal insulation in walls and roofs, as well as for noise-dampening under a metal roof.

4.5.5.1 Resistive or bulk insulation insulates against the heat transfer through its resistance to conduction. It works on the principle of retarding heat transfer due to the properties of low thermal conductivity (k-value) or high thermal resistance (*R*-value). The *R*-value depends on the thickness of the material. Still air has a very low thermal conductivity and can serve as a very good resistive insulator. For bulk insulation, reference can be made to MS 1020.

4.5.5.2 Reflective insulation as defined in MS 2095 is a thermal insulation system consisting of one or more low emittance surfaces, bounding one or more enclosed air spaces with a measureable *R*-value.

Reflective insulation (e.g. aluminium foil) and radiant barrier are effective in reducing radiant heat flow into the building interior by creating reflective air spaces within wall or roof constructions. It works on the principle of reflecting and re-emitting of radiant heat due to the properties of high reflectivity (≥ 0.9) on the outer surface and low emissivity (≤ 0.1) on the inside surface.

Reflective insulation and radiant barrier are made of light materials and does not add weight to the roof structure. Both types are effective in reducing radiant heat transfer from the roof into the interior of residential buildings.

4.6 Building envelope

Exterior portions of a building through which thermal energy is transferred. Building envelope design and orientation facilitate sun shading, daylighting and possibilities of natural ventilation.

4.6.1 Design

A good building envelope design can help optimise daylighting and thermal comfort. The external wall should be designed to provide an integrated solution for the provision of view, and daylight control while minimising solar heat gain.

4.6.1.1 Window design for daylighting and natural ventilation

Windows form a fundamental component of the building envelope. They provide a relationship between the exterior and interior in the form of light, sound, air and view of the exterior. The size, shape, position and orientation of windows are designed based on intended purposes and prioritised requirements. Table 6 gives a guide for window design.

Fully openable glazed windows may be used to drive natural ventilation and maximise daylighting with high indoor illuminance. However, glazed areas can cause unwanted glare and overheating if WFR is more than 25 %. Therefore efficient shading devices systems should be in place.

Table 6. Window design

Purpose	Design recommendation
Daylighting	Optimum d/h and x/l ratios for required daylight factor. Light shelves can be used to provide reflected daylight to improve internal daylighting.
Natural ventilation	Orientation towards prevailing wind direction.
Daylighting and view	Window dimensions and sill height suited to occupant position and external features.
Daylighting and natural ventilation	Window dimensions and location should be suited to all parameters.
Sun shading	All windows should be designed with overhang or horizontal/ vertical fins to provide shading from direct sun penetration. Windows can also have projections at perimeter of openings or be recessed to provide required shading. The optimum angle of the sloped projection is 45°.

4.6.1.2 Sun shading

One of the most important aspects of building envelope design is sun shading. The basic requirement is an understanding of the sun movement in relation to the site by studying the relevant sun path diagrams. The understanding of sun path diagram is crucial for site planning and orientation as well as daylighting. For information on the sun shading design refer to Annex A.

Table 7 presents shadow angle guidelines for a preliminary design work located in Kuala Lumpur. Various tools and software are now available to work out detailed sun shading and overshadowing geometries.

Table 7. Shadow angle guidelines for Kuala Lumpur

Orientation	VSA	HSA		Remarks
		(-)	(+)	
N	65°	60°	60°	Full shading
NE	35°	-	20°	Shading from 09:30 h
E	35°	-	-	Shading from 09:00 h
SE	30°	18°	-	Shading from 09:30 h
S	60°	55°	55°	Full shading
SW	30°	-	15°	Shading until 17:00 h
W	35°	-	-	Shading until 17:00 h
NW	45°	15°	-	Full shading

Key

VSA vertical shadow angle

HSA horizontal shadow angle

External sun shading devices are more effective to achieve thermal comfort in comparison to internal sun shading devices. Horizontal louvres are recommended over vertical ones because vertical louvres reduces daylight penetration and external view.

Sun shading can be applied through the following strategies:

a) Direct solar component (direct, diffused and reflected sunlight) should be avoided by providing external and internal sun shading particularly for east-west walls [Figure 6 a)].

b) Inclusion of interlocking spaces in form of indoor-outdoor area such as a balcony. A full balcony around an end unit residential building is the best solution in providing sun shading.

c) Recess and relief to be incorporated in the building envelope.

d) External sun shading should be emphasised by providing static or moveable blinds or louvres.

e) Roof overhang is an effective external sun shading. Drop edge and sloped overhang performs better than standard overhang in providing sun shading at window and door opening. Louvred overhang and louvred drop edge provide better daylighting as compared to solid overhang and solid drop edge [Figures 6 b) and 6 c)].

f) External sun shading at window and door openings should be emphasised at all orientations and may be achieved by trellis, pergola, projections at perimeter of openings, vegetation/plants, etc. Appropriate sun shading is required for all openings at all orientations [Figure 6 d)].

g) Sun shading devices can be categorised as:

i) fixed (louvres, overhangs, fins, horizontal and vertical projection) [Figure 6 d)]; and

ii) movable/adjustable (roller blind, curtain, awning, screen).

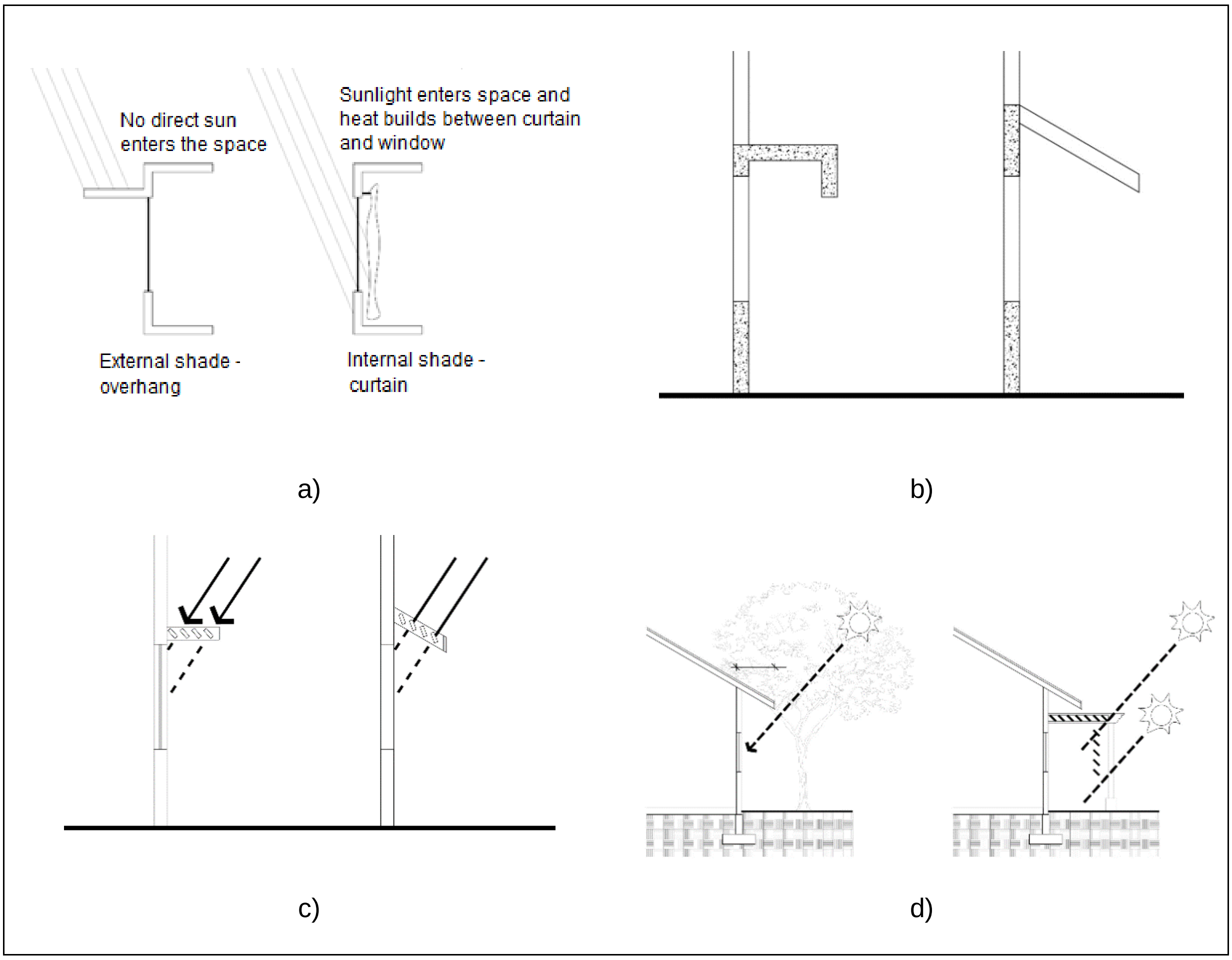


Figure 6. Sun shading devices

4.6.2 Thermal properties for wall material

U-values or sometimes referred to as heat transfer coefficients or thermal transmittances are used to measure how effective elements of a building fabric are as insulators. That is, how effective they are at preventing heat from transmitting between the inside and the outside of a building. *R*-values, which measure thermal resistance rather than thermal transmission, are often described as being the reciprocal of *U*-values, however *R*-values do not include surface heat transfers.

The lower the *U*-value of an element of a building fabric, the more slowly heat is able to transmit through it, and so the better it performs as an insulator. Very broadly, the better (i.e. lower) the *U*-value of a building fabric, the less energy is required to maintain comfortable conditions inside the building.

The *U*-value of an element (in W/m²K) can be calculated from sum of the thermal resistances (*R*-values in m²K/W) of the layers that make up the element plus its inside and outside surface thermal resistances (R_i and R_o).

$$U\text{-value} = 1 / (\Sigma R + R_i + R_o)$$

Where the thermal resistance of the layers of the element,

$$R = \frac{\text{the thickness of each layer}}{\text{the thermal conductivity of that layer (its } k\text{-value in W/m K).}}$$

Samples of thermal properties for building materials are listed in Annex D.

4.6.2.1 Solar absorptivity (α value) for surface colour

In general, the solar energy absorbed can be approximated by the surface colour. For materials, refer to manufacturer specifications as in Table 8.

Table 8. Solar absorptivity by surface colour

Surface colour	Solar absorptivity factor - Fraction of incident radiation absorbed (approximated)
White smooth surfaces	0.25 - 0.40
Grey to dark grey	0.40 - 0.50
Green, red and brown	0.50 - 0.70
Dark brown to blue	0.70 - 0.80
Dark blue to black	0.80 - 0.90

4.6.3 Overall thermal transfer value (OTTV)

The design criterion for building envelope known as overall thermal transfer value (OTTV) should be adopted. The OTTV requirement enables design of the building envelope to cut down external heat gain and hence reduce energy use to achieve better indoor thermal comfort conditions.

Refer to MS 1525 for formula and details of OTTV calculation where OTTV shall not exceed 50 W/m^2.

4.7 Natural ventilation

The purpose of ventilation is to provide:

a) thermal comfort; and

b) health.

Ventilation is the movement of air. Ventilation has three useful functions in the building sector. It is used to:

a) maintain thermal comfort of occupants by increasing the rate of evaporative and sensible heat loss from the body;

b) satisfy the fresh air needs of the occupants; and

c) cool the building mass and interior space by an exchange of warm indoor air by cooler outdoor air, when appropriate.

Natural ventilation uses natural forces of wind and buoyancy to deliver sufficient fresh air and air change to ventilate indoor spaces without active temperature controls or mechanical means. Fresh air is required in buildings to alleviate odours and improve indoor environmental quality. Provisions for naturally ventilated lobby areas, corridors, lift cores and staircases should be encouraged. This could aid compliance with the requirements from the fire authorities for smoke venting of the spaces in the event of a fire. In some of these cases, spilled air from adjacent spaces is sufficient to provide for the required air change to ventilate the space and provide thermal comfort with reduced energy consumption. Natural ventilation strategies rely on the movement of air through space to equalise pressure.

There are basically two methods for providing natural ventilation:

a) cross ventilation (wind-driven); and

b) stack ventilation (buoyancy-driven).

4.7.1 Cross ventilation

Good cross ventilation design should consider the following:

a) Orientate the building to maximise surface exposure to prevailing winds as shown in Figure 7 below.

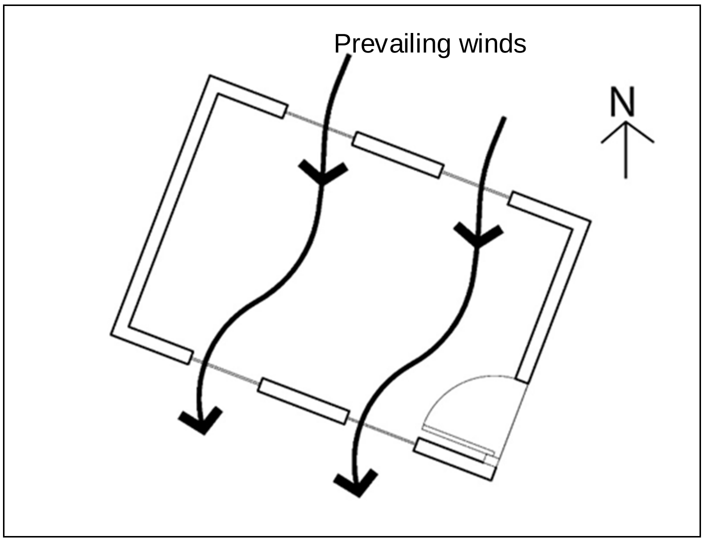


Figure 7. Surface exposure to prevailing winds

b) Provide openings on opposite walls for optimum cross ventilation effectiveness. However, if this is not possible, openings can be placed on adjacent walls.

c) Have equal inlet and outlet areas to maximise airflow.

d) Provide inlets on the windward side (pressure zone) and outlets on the leeward side (suction zone) as in Figure 8.

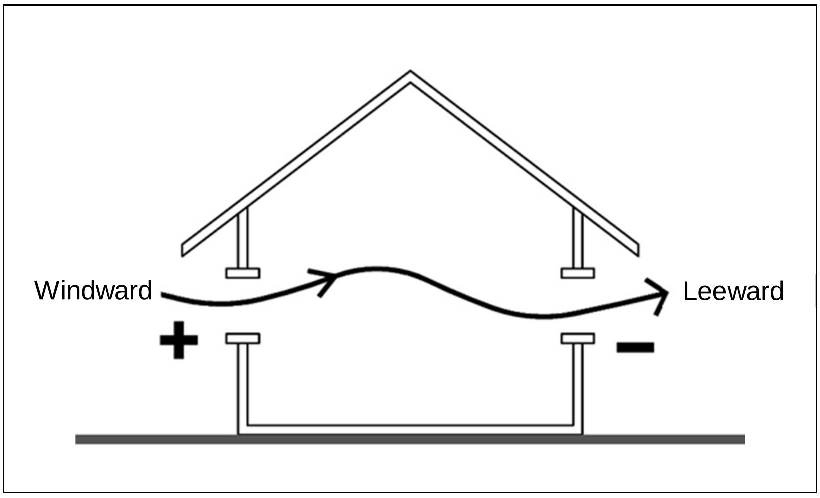


Figure 8. Wind pressure

e) Avoid obstructions between the inlets and outlets as in Figure 9.

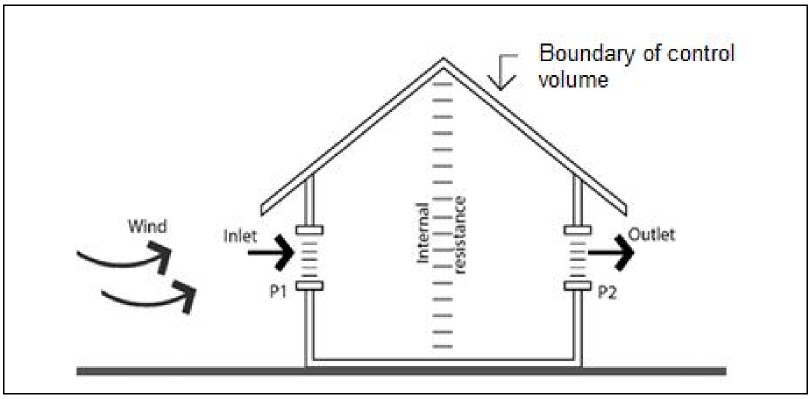


Figure 9. Inlet and outlet

f) Design outlet openings to be slightly larger than inlet openings to produce higher air velocities as in Figure 10.

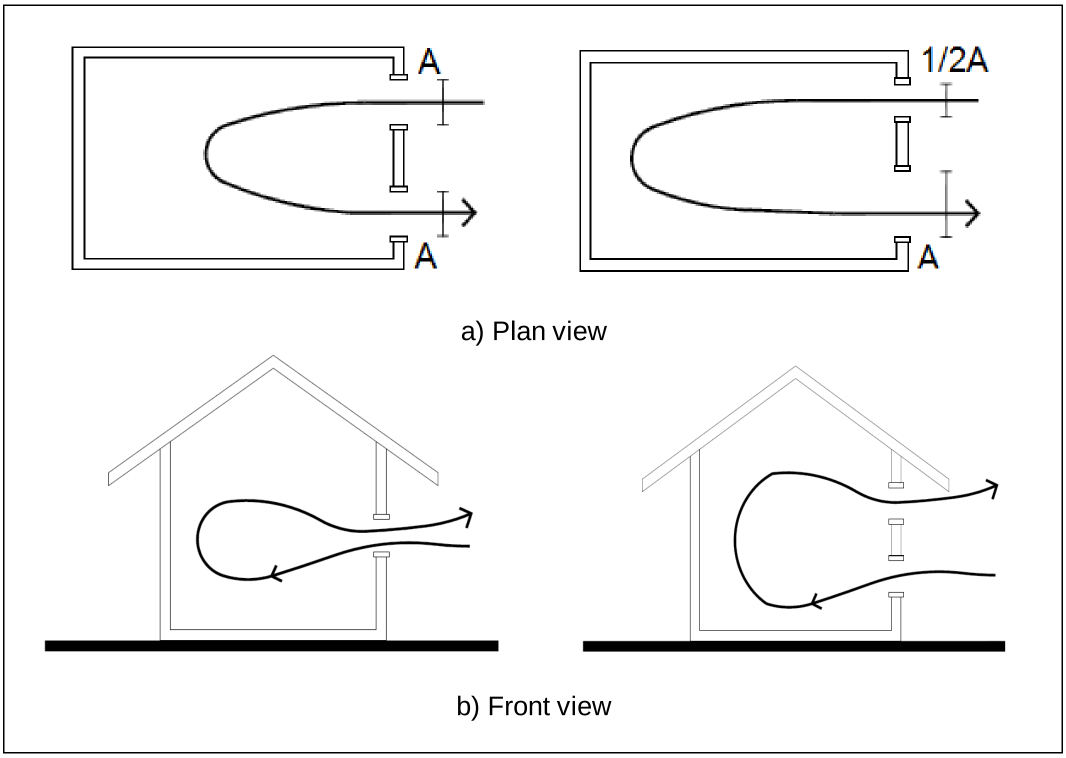


Figure 10. Single sided ventilation

g) Design openings to be easily accessible and operable by the occupants.

h) Use architectural features like wing walls and parapets to create positive and negative pressure areas to induce cross ventilation. Example is as shown in Figure 11 below.

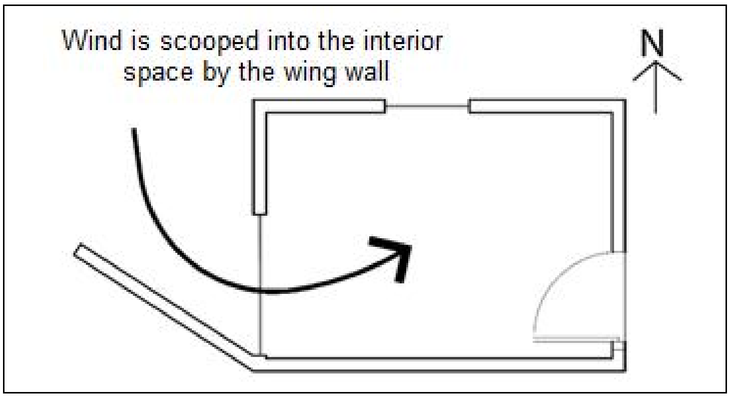


Figure 11. Wing wall to induce cross ventilation

i) Locate outlet openings on the windward side at the occupied level.

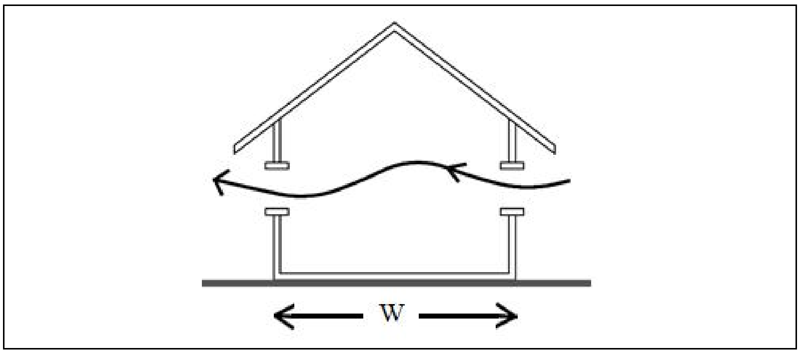


Figure 12. Cross ventilation

j) For rooms having single window at just one wall or single-sided ventilation, the effective room depth, W is or less than 6 m.

k) For cross-flow or two-sided ventilation, both window openings should be opened and the effective room depth is equal to or less than 12 m as shown in Figure 12.

l) Use good site planning, landscaping and planting strategies to cool incoming air. Example is as shown in Figure 13 below.

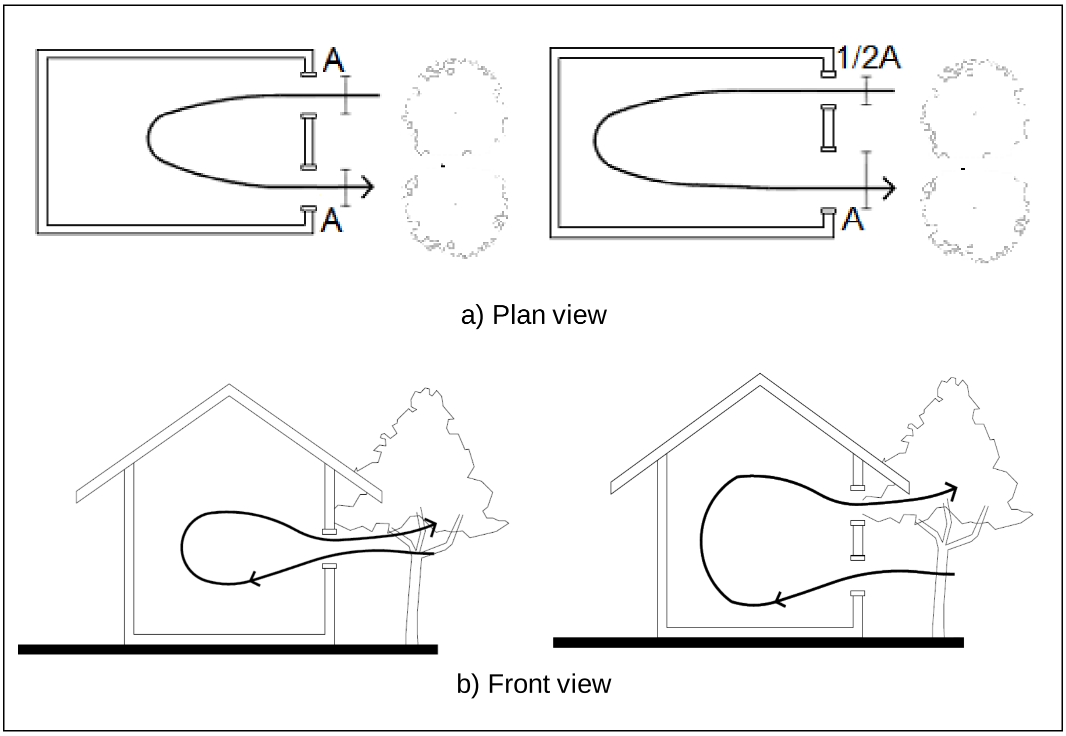


Figure 13. Planting strategy to cool incoming air

m) Trickle ventilation should be considered for night ventilation to bring in cool outside air.

4.7.2 Stack ventilation (buoyancy-driven)

A good stack ventilation should consider the following:

a) Provide at least two ventilation openings, one closer to the floor (inlet) and the other, higher in the space (outlet).

b) Maximise the vertical distance between these two sets of openings as in Figure 14. Increasing the differential height will produce better airflow.

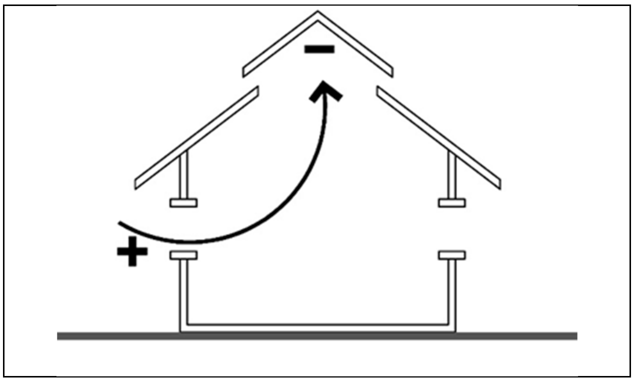


Figure 14. Vertical distances between opening

c) Provide equal inlet and outlet areas to maximise airflow.

d) Provide adequate openings in stairwells or other continuous vertical elements so that they can work as stack wells. Such spaces may be used to ventilate adjacent spaces because their stack height allows them to displace large volumes of air.

e) Use louvres on inlets to channel air intake.

The low incidence of significant wind force or low wind speeds to achieve sensible air movement for thermal comfort may necessitate additional air movement with the aid of mechanical means.

4.7.3 Air movement

Air movement affects thermal comfort. The presence of air movement enhances evaporative and convective cooling from the skin and can further increase our thermal comfort. Table 9 provides a guide on the impact of air speed on occupants' sensation.

Table 9. Impact of air speed on occupants

Air speed (m/s)	Mechanical effect	Occupant sensation
≤ 0.25	Smoke (from cigarette) indicates movement	Unnoticed, except at low air temperatures.
0.25 - 0.5	Flame from a candle flickers	Feels fresh at comfortable temperatures, but draughty at cool temperatures.
0.5 - 1.0	Loose papers may be moved. Equivalent to walking speed	Generally pleasant when comfortable or warm, but causing constant awareness of air movement.
1.0 - 1.5	Too fast for deskwork with loose papers	Acceptable in warm conditions but can be from slightly to uncomfortably draughty.
> 1.5	Equivalent to a fast walking speed	Acceptable only in very hot and humid conditions when no other relief is available. Requires corrective measures if comfort and productivity are to be maintained.

4.8 Strategic landscaping

Shading by trees and vegetation can effectively shade and reduce heat. Strategic landscaping can reduce heat gain through several processes such as shading from the sun, solar filtration at higher levels and the creation of a cooler microclimate around the building.

Creating a cooler microclimate around a building can reduce the temperature difference and maybe achieved through planning by maximising areas allocated for landscape (softscape and hardscape) and implementation of aquascape. Appropriate selection of plant types with consideration of foliage density and crown height, the choice of materials for the hardscape will help reduce the solar heat gain and reflection at the surrounding spaces.

It is recommended that the greenery area should be more than 75 % of the non-built up area. If the greenery area is less than 75 %, 50 % of the non-greenery area needs to use material with a SRI of at least 29.

4.9 Renewable energy and resources

Renewable energy (RE) is the energy which comes from natural resources such as sunlight, tide, geothermal and biomass which are naturally replenished.

In addition to passive design considerations, there are appropriate applications of RE for residential buildings such as solar energy (solar thermal and photovoltaic) and rainwater harvesting.

4.10 Thermal comfort

In naturally ventilated spaces, the thermal condition varies according to the changes in ambient conditions. This is different from the steady state model that forms the basis of predicted mean vote (PMV) model. PMV model is found to overestimate the comfort sensation in warm condition and underestimate the sensation in cold condition. Figure 15 below shows the divergence of comfort sensation as observed in the field to PMV model found in naturally ventilated spaces.

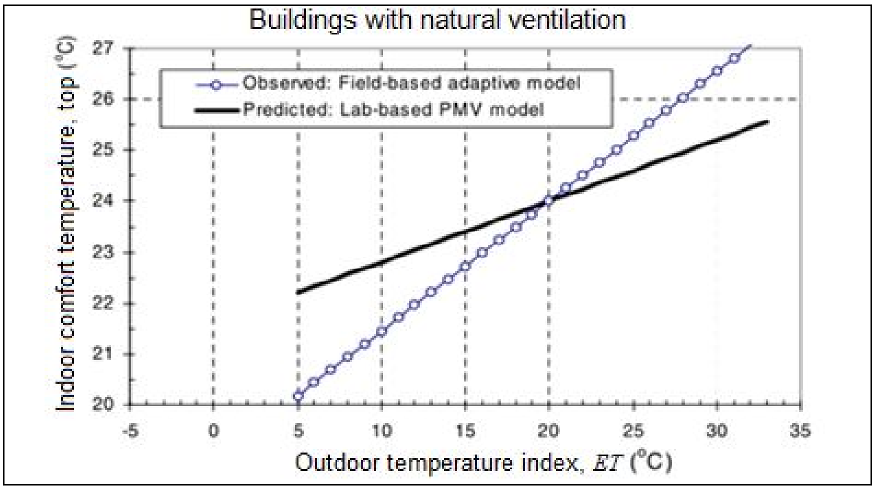


Figure 15. Divergence of actual comfort sensation observed in the field compared to PMV model prediction found in naturally ventilated spaces

The assessment of thermal comfort in naturally ventilated spaces can be done by using adaptive thermal comfort models. The adaptive thermal comfort approach is based on the fact that humans are able to adapt themselves to the environment. It may not be necessary to specify the indoor climate for a naturally ventilated building. The adaptive thermal comfort approach allows the building designer to estimate the desired indoor temperature within ± 2 °C of the standard indoor thermal comfort range. The building occupant will require manual controls to adjust the indoor climate if they find it uncomfortable. For example, opening of windows, opening or closing blinds and drawing curtains when the need arises. The controls should be operable, appropriate and effective.

For naturally ventilated or non-air conditioned buildings in tropical climates, the estimated indoor temperature for human thermal comfort (Tc) is dependent on the outdoor ambient temperature. The following equation may be used to estimate the indoor comfort temperature:

$$Tc = 13.8 + 0.57To$$

where

To is the mean monthly outdoor temperature.

The ANSI/ASHRAE Standard 55 adaptive thermal comfort chart (Figure 16) shows the range of indoor operative temperature values that coincide with the mean monthly outdoor temperature. Table B.1 in Annex B is an example of typical outdoor climatic conditions (see Tables B.5 and B.6 for monthly average hourly climate data and monthly average daily solar radiation). For example, if the mean monthly outdoor temperature is 30 °C, then the range of indoor operative temperature should be between 23.6 °C and 30.8 °C for 80 % of the occupants. However, 90 % of occupants would feel comfortable within the smaller range of between 24.8 °C and 29.6 °C.

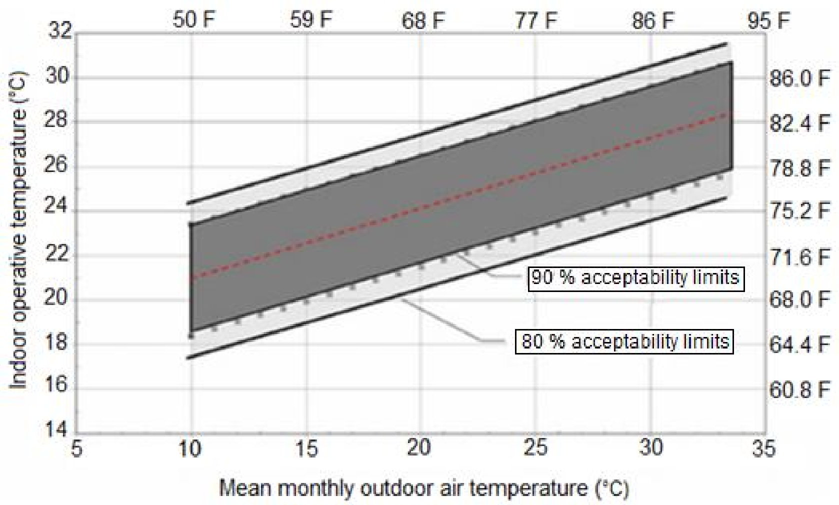


Figure 16. ANSI/ASHRAE Standard 55 adaptive thermal comfort chart

The ultimate strategy is to be able to predict the desired indoor environmental condition specifically thermal and visual comfort as well as reduction of energy consumption. This can be done by computer modelling using available and appropriate software.

5 Electrical appliances

This clause applies to the selection and use of electrical appliances for residential buildings. The appliances considered in this standard are:

a) lighting;

b) air conditioners;

c) fans;

d) refrigerators;

e) televisions; and

f) qualitative coverage on water heaters, washing machines, electric irons, microwaves, ovens/stoves.

5.1 General considerations

5.1.1 The efficiencies of appliances are based on their star ratings. Available stars are between a minimum of one (1-star, the least efficient) and a maximum of five (5-star, the most efficient).

5.1.2 The percentage of savings that can be achieved by the higher rated appliances when compared with the lower rated appliances varies for the different appliances.

5.1.3 The minimum energy performance standards (MEPS) refer to the minimum performance level for the appliance to be available in the local market. This is usually set at the 2-star category level.

5.1.4 For more energy savings, appliances with higher level star ratings should be selected.

5.1.5 Notwithstanding the requirements of 5.1.3 above, the appliances should be selected both for their energy efficiency as well as to minimise cost of ownership as far as possible. Cost of ownership includes the capital cost and the cost of energy over the equipment life time.

5.1.6 The appliance should be upgraded if more efficient models are available and if the resultant energy savings can pay back the additional cost in a relatively short period.

5.1.7 Over sizing of equipment should be avoided. The right size for the use/situation should be selected.

5.1.8 Supply system voltage has significant impact on losses. Hence, the design/optimum voltage of the equipment installed should be as close as possible to the supply voltage.

5.1.9 Appliances should be switched off or unplugged when not in use. Televisions, computers, microwaves, etc have a 'standby' mode and can use energy even when not in use.

5.2 Lighting

Energy efficient lighting is becoming more popular with the introduction of compact fluorescent lamps (CFL), induction lighting and light emitting diode (LED) lighting. In addition, fluorescent tube lamps are becoming more efficient. As some of the lighting are higher in prices, it is important to consider their energy efficiency criteria to justify their purchase.

5.2.1 Energy efficiency criteria

5.2.1.1 These criteria apply to the following products:

a) T5 and T8 double capped fluorescent lamps;

b) self-ballasted single capped CFLs for general lighting services;

c) single capped fluorescent lamps (non-integrated compact fluorescent lamps) and circular fluorescent lamps for general lighting services;

d) self-ballasted LED lamps for general lighting services; and

e) filament tungsten incandescent lamps.

5.2.1.2 The efficiency criteria is based on lamp efficacy (lumen/watt) determined in accordance to MS 2598.

5.2.2 Energy efficiency tips

Energy efficiency tips for lighting are as follows:

a) Controls such as timers and photocells save electricity by turning lights off when not in use.

b) Dimmers save electricity when used to lower light levels.

c) The curtains or shades should be kept open to use daylighting instead of turning on lights. For more privacy, light-colored, loose-weave curtains can be used to allow daylight into the room. Decorations can be done with lighter colors that reflect daylight.

5.3 Air conditioners

Use of air conditioners in residential buildings is growing fast. The price of air conditioners is also dropping, presumably by the increasing demand. Furthermore, the efficiencies of air conditioners are also increasing, making them good candidates to apply the energy efficiency criteria.

5.3.1 Energy efficiency criteria

5.3.1.1 The energy efficiency criteria is based on the energy efficiency ratio (EER) of the air conditioners determined in accordance to MS 2597.

5.3.1.2 Criteria for MEPS: The air conditioner should have at least a 2-star rating.

5.3.2 Energy efficiency tips

Energy efficiency tips for air conditioners are as follows:

a) Ensure that the air conditioners are sized correctly for the room concerned.

Cooling capacity for a room is basically the heat load in a room that has to be removed in order to achieve the desired indoor room temperature and relative humidity. Typical indoor comfort condition is taken as 24 °C at relative humidity of 55 %.

A guide on the recommended capacity of air conditioners for various room sizes is as shown in Table 10.

Table 10. Guide on recommended air conditioning capacity and room size

Area to be cooled [ft^2 (m^2)]	Capacity needed [Btu/h (hp)]
180 (17) to 260 (24)	9 000 (1)
270 (25) to 390 (36)	13 500 (1.5)
360 (33) to 520 (48)	18 000 (2)
450 (42) to 650 (60)	22 500 (2.5)
540 (50) to 770 (72)	27 000 (3)
NOTE. An airconditioner of 1 horsepower capacity will remove approximately 9 000 Btu/h of heat.	

The above estimates are for rooms of 8 ft (2.432 m) height and are based on the assumption that the premise is designed to meet the maximum OTTV of 50 W/m^2 and roof *U*-value of 0.4 W/m^2K (for light roof weight under 50 kg/m^2) or 0.6 W/m^2K (for heavy roof weight above 50 kg/m^2) as stipulated in this standard.

Adjustments will have to be made for the following situations:

i) If the room height exceeds 8 ft (2.43 m) the capacities will have to be increased by 10 % for every 1 ft (0.3 m) increase in height.

ii) If there are more than two persons who will regularly occupy the room, add 500 Btu/h for each additional person.

b) Adjust for comfortable temperature. Temperature of 24 °C to 26 °C should normally be comfortable enough.

c) Clean the air filter and the inside and outside of coil fins regularly.

d) Ensure regular servicing of the air-conditioner, including correct level of refrigerant, for optimum performance.

e) Air conditioning compressors should have access to outside air; not enclose it in garages, etc.

f) Re-circulate the inside air as far as possible instead of taking in warmer air from outside.

g) Have curtains over large glass areas, to prevent greater heat intake from outside.

h) Insulation of ceiling spaces can reduce air conditioning load drastically.

i) Avoid frequent opening of room doors.

j) Reduce air leaks from gaps between doors and the floor and from windows.

5.4 Fans

Domestic fans are widely used in domestic buildings and help create a more comfortable living environment. As they are typically used for long periods of time, they become good candidate for applying energy efficient criteria.

5.4.1 Energy efficiency criteria

5.4.1.1 The following products are excluded from these criteria:

a) ceiling fan having blade diameter size of more than 60 inch (1 500 mm);

b) pedestal, wall and desk fan having blade diameter size of more than 16 inch (400 mm);

c) decorative fans;

d) box fan;

e) ventilating fan; and

f) bladeless fan.

5.4.1.2 The criteria is based on the coefficient of performance (COP) determined in accordance to MS 2574.

5.4.1.3 Criteria for MEPS: the fan should have at least a 2-star rating.

5.4.2 Energy efficiency tips

a) If air conditioning is used, a ceiling fan will allow the thermostat setting to be raised by a few degrees with no reduction in comfort.

b) The fans should be turned off when the room is unoccupied since the fans cool people and not rooms, by creating a wind chill effect.

c) After a shower or a bath, the bathroom fan should be used to remove the heat and humidity from the bathroom/house. The laundry room might also benefit from spot ventilation. The bathroom and kitchen fans should be vented to the outside (not just to the attic).

5.5 Refrigerators

Almost all residential buildings in the country have at least one refrigerator. Refrigerators typically operate continuously throughout the day and throughout the year, making them good candidates for energy efficiency criteria to be applied.

5.5.1 Energy efficiency criteria

5.5.1.1 The energy efficiency criteria is in the form of a Star Index.

5.5.1.2 Criteria for MEPS: the refrigerator should have at least a 2-star rating.

5.5.2 Energy efficiency tips

Energy efficiency tips for refrigerators are as follows:

a) Do not place the refrigerator in a warm place, e.g. near a cooker or in direct sunlight.

b) Ensure adequate space around it for heat dissipation.

c) Keep coils at the rear of refrigerator clean.

d) Avoid unnecessary and frequent opening of refrigerator doors.

e) Defrost frozen foodstuffs in the refrigerators.

f) Check to ensure that the door gasket is in good condition by closing the door on a sheet of paper (the paper should not be able to be pulled out easily with the door closed on it).

g) If the refrigerator is not a frost-free model, check for frost in the freezer compartment. Do not let the frost exceed 6 mm of thickness. Switch off to defrost and remove excess water before restarting.

h) Allow spaces between items for good air circulation.

i) Models with more doors are better as they allow only the appropriate section to be opened.

5.6 Televisions

The size of television display panels is increasing which will result in greater consumption of energy. Notwithstanding this, the recent introduction of liquid crystal display (LCD) and light emitting diode (LED) have resulted in reduction of energy consumption by televisions. As the penetration of televisions is increasing in residential buildings, and their hours of use is increasing, they become good candidates for applying energy efficiency criteria.

5.6.1 Energy efficiency criteria

5.6.1.1 These criteria apply to the following types of televisions of sizes up to or equal to 177.8 cm (70 inch):

a) plasma;

b) liquid crystal display (LCD);

c) light emitting diode (LED); and

d) cathode ray tube (CRT) or any other display type with similar function.

5.6.1.2 The following products are excluded from these criteria:

a) television sets powered solely from batteries; and

b) front or rear projection display devices.

5.6.1.3 The energy efficiency criteria of televisions is based on the energy efficiency factor (EEF) determined in accordance to MS 2576.

5.6.1.4 Criteria for MEPS: The television should have at least a 2-star rating.

5.6.2 Energy efficiency tips

Energy efficiency tips for televisions are as follows:

a) When purchasing the television, the size and type of screen should be considered. An energy efficient 32 inch LCD television will typically use half the power of a model with a 42 inch plasma screen.

b) The television should be switched off when it is not being watched for a reasonable period of time. Switching to standby is better than leaving the television on, but it is still more energy efficient to switch it off completely.

c) The brightness of the TV should be adjusted for the room as the factory settings are typically brighter than necessary.

d) The ambient light sensor, if there is one, should be switched on, as viewing the television in a darker room with the sensor switched on can dramatically reduce power consumption by adjusting the contrast of the picture automatically.

5.7 Washing machines, electric irons, ovens/stoves, water heaters (Qualitative coverage)

5.7.1 Energy efficiency tips

5.7.1.1 Washing machines

Energy efficiency tips for washing machine are as follows:

a) Wash with full loads, as the machine uses the same amount of energy for full and part loads.

b) Do not over load the machine.

c) Choose the correct wash cycle.

d) Use optimum temperature setting and avoid hot water washing if possible.

e) Wash the clothes in cold water using cold-water detergents whenever possible.

f) Consider drying the natural way, on a clothes line, rather than using an electric dryer, as it can save energy and is recommended by clothing manufacturers for some fabrics.

5.7.1.2 Iron

Energy efficiency tips for iron are as follows:

a) Iron large batches of clothes at a time, to avoid wasting of energy for reheating the iron.

b) Setting the correct ironing temperature can save a substantial amount of energy.

c) A lighter iron will heat up faster and not hold too much heat after being switched off.

d) The iron should be turned off if the ironing activity is interrupted for a reasonable period of time.

e) Steaming uses more energy, so it should be used only when necessary. Many fabrics press well with a dry iron.

f) Sort fabrics for ironing and iron lighter fabrics on lower temperature settings first.

g) For very delicate items, turn iron off and use the remaining heat.

h) Fold washed items carefully to avoid the need for reironing where possible.

5.7.1.3 Ovens

Energy efficiency tips for oven are as follows:

a) Microwave ovens use less energy and cook faster, than conventional ovens. They are also useful for heating/reheating food, as most meals often is best served hot.

b) Preheating of ovens is normally not necessary.

c) The oven should be switched off 5 min to 10 min before normal cooking time limit to use the retained heat in the oven.

d) Keep oven doors closed. For inspection, try peeking through the oven window.

e) Thaw frozen food before cooking to save energy.

f) Plan oven meals and cook several dishes at one time to save on energy for reheating the oven.

5.7.1.4 Water heaters

Energy efficiency tips for water heater are as follows:

a) Instantaneous water heaters are more efficient than storage type water heaters, since storage water heaters have higher standby losses because they keep tanks full of heated water at all times and are typically located away from points of use. Where hot water use is low (e.g., kitchenettes and office restrooms), installing instantaneous water heaters can save energy. In addition, their compact size allows them to be located near the point of use, further reducing heat loss through piping.

b) Storage water heaters should be sized properly. Oversized products cost more to buy and use more energy due to excessive cycling and higher thermal energy losses.

c) Insulation blankets for storage water heaters and insulation wraps for the hot water pipes can bring down energy costs.

d) Setting a lower temperature for the heated water can also save energy. However, the temperature set should not be too low as *Legionella pneumophila*, the bacteria known to cause Legionnaires disease, can grow in water heaters.

e) Turning water heaters down or off during unoccupied periods also reduces energy use and costs, as do timers or other load control devices in buildings with time-of-use rates or demand charges.

f) Storage water heaters can be turned on for short periods (say an hour a day), as their storage capacity can give warm water for several hours after they are switched off to save on energy use.

Annex A
(informative)

Sun path diagram

A.1 Sun path diagram

Sun path diagrams show the apparent path of the sun across the sky. The position of the sun in the sky is defined by two solar angles: solar azimuth (φ) and solar altitude (β) as shown in Figure A.1. Solar azimuth is the clockwise angle between the north reference and the perpendicular projection of the sun down onto the horizontal plane. Solar altitude or also referred to as solar elevation angle is angle of the sun's position and the horizontal plane.

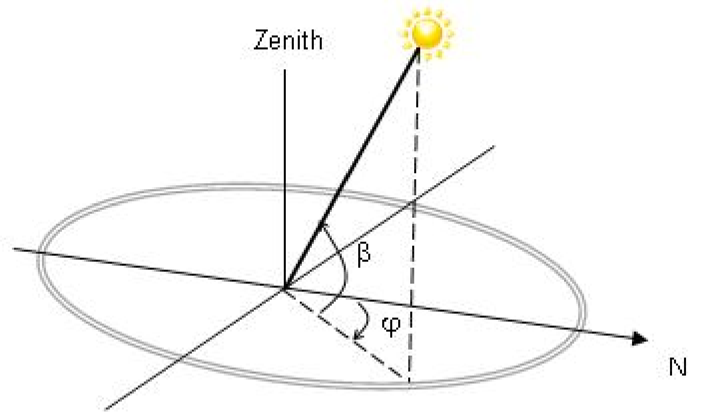


Figure A.1. Solar angles

Figure A.2 is a sun path diagram of Kuala Lumpur. The solar altitude (β) is represented by concentric lines. The solar azimuth (φ) is indicated by the scales on the outermost concentric line that also represents the horizon. The paths of the sun are represented by elliptical curves. The top elliptical curve represents the path of the sun for summer solstice (approximately Jun 21 to 22). The middle elliptical curve represents the path of the sun for March Equinox (approximately March 20 to 21) and September Equinox (approximately September 22 to 23) The bottom elliptical curve represents the path of the sun for winter solstice (approximately December 21 to 22). The vertical curves indicate the location of the sun along the path at a particular time of the day in local time.

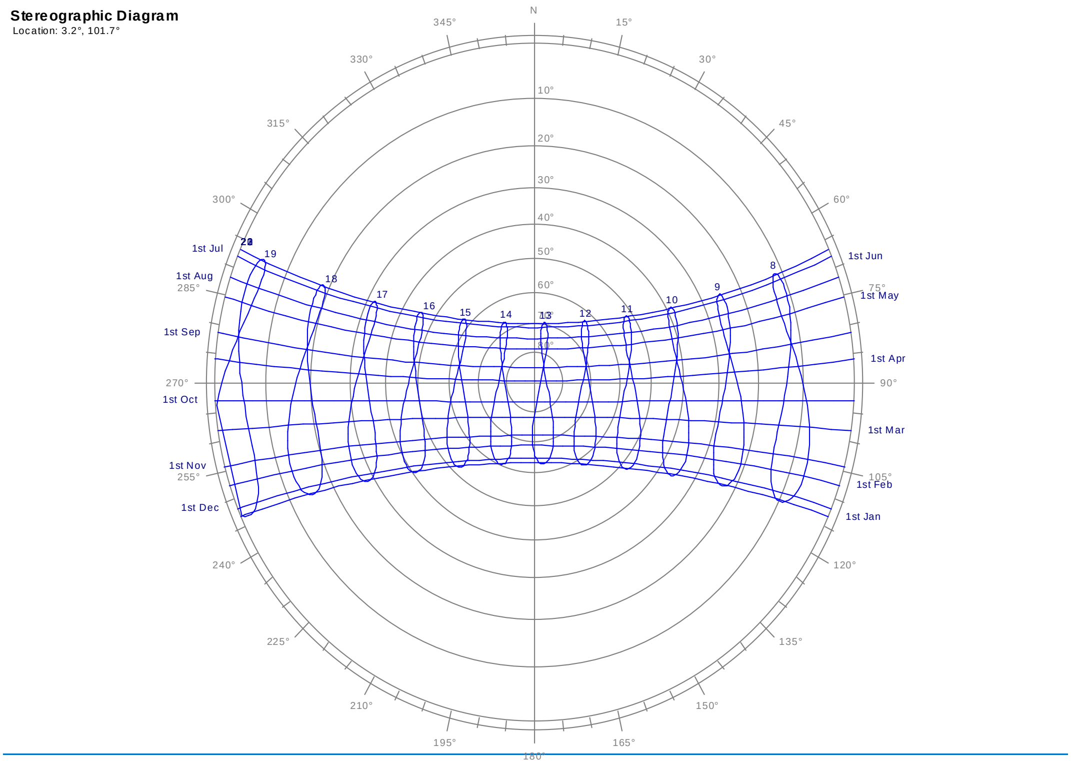


Figure A.2. Sun path diagram

In determining the best sun shading design, shadow angle protractor can be superimposed on the sun path diagram to determine the vertical shadow angle (VSA) and the horizontal shadow angle (HSA). Figure A.3 shows the superimposed shadow angle protractor on the sun path diagram for Kuala Lumpur to determine VSA and HSA for north-east (NE) façade. For each façade the critical VSA and HSA need to be determined to design the appropriate sun shading projections. Figure A.4 illustrates the various solar angles (solar altitude and solar azimuth) and shadow angles (VSA and HSA) in relation to vertical and horizontal sun shading.

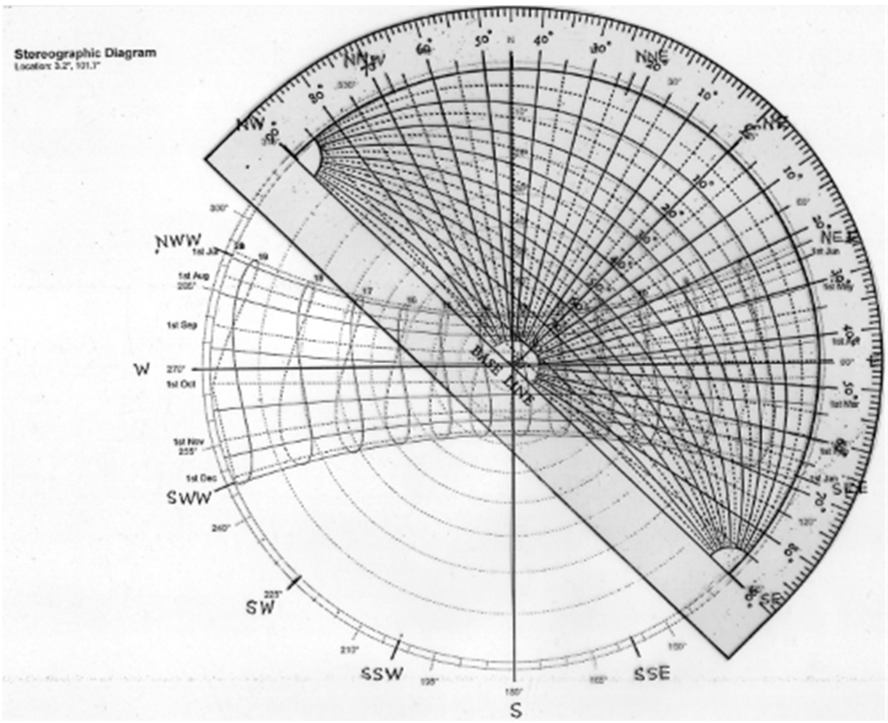
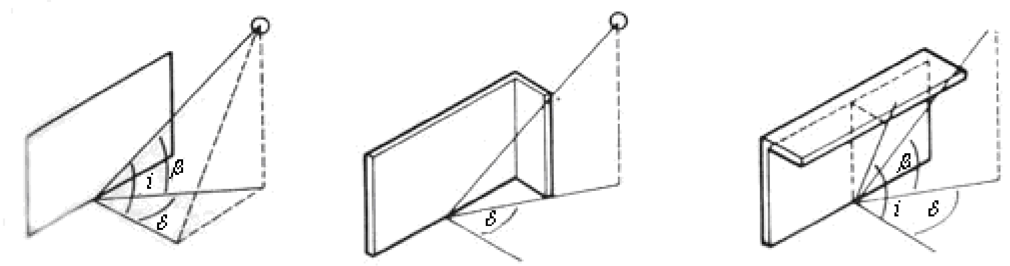


Figure A.3. Superimposed shadow angle protractor on sun path diagram



a) Solar azimuth and solar altitude

b) Altitude and HSA

c) Solar altitude, HSA and VSA

Figure A.4. Solar angles and shadow angles

Annex B
(informative)

Distribution of daylight factors

B.1 As a guide, the brightness inside a building and the associated distribution can be classified by the daylight factors as shown in Tables B.1, B.2 and B.3.

Table B.1. Daylight factors and impact

DF (%)	Lighting	Glare	Thermal comfort
> 6.0	Intolerable	Intolerable	Uncomfortable
3.5 - 6.0	Tolerable	Uncomfortable	Tolerable
1.0 - 3.5	Acceptable	Acceptable	Acceptable
< 1.0	Perceptible	Imperceptible	Acceptable

Table B.2. Internal illuminance

External (lux)	DF (%)					
	1	2	3	4	5	6
5 000	50	100	150	200	250	300
10 000	100	200	300	400	500	600
20 000	200	400	600	800	1 000	1 200
30 000	300	600	900	1 200	1 500	1 800
40 000	400	800	1 200	1 600	2 000	2 400
50 000	500	1 000	1 500	2 000	2 500	3 000
60 000	600	1 200	1 800	2 400	3 000	3 600
70 000	700	1 400	2 100	2 800	3 500	4 200
80 000	800	1 600	2 400	3 200	4 000	4 800

Table B.3. Sky conditions

Sky conditions			
Sky type	**Description**	**Cloud cover (%)**	**Sky illuminance (lux)**
Standard overcast	Sun not visible; sky covered with thick, milky white cloud	100	5 000 - 20 000
Cloudy	Sky partially covered by cloud	> 70	20 000 - 100 000
Intermediate	Sky mostly covered with 30 % to 70 % cloud	30 - 70	30 000 - 100 000
Clear blue sky	Sky with almost no cloud	< 30	50 000 - 100 000
NOTE. In general the sky type in Malaysia can be classified as intermediate.			

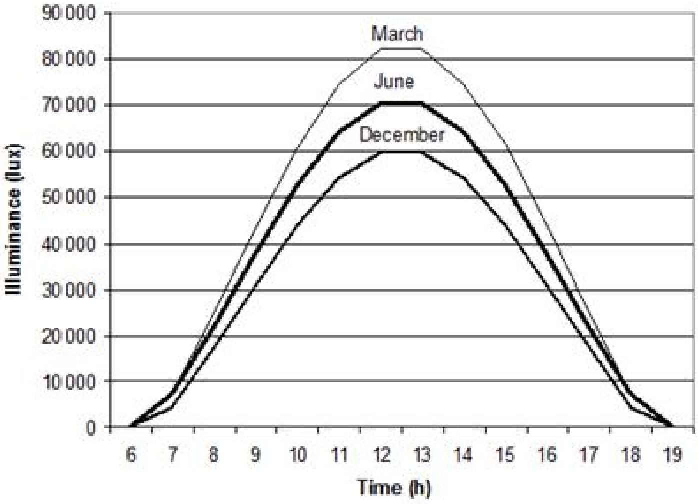


Figure B.1. Monthly average hourly illuminance in March (maximum), June (average) and December (minimum)

Table B.4. Distribution of daylight factors (%) for WFR of 15 %

d/h \ *x/l*	**0.17**	**0.11**	**0.06**	**0.03**	**0.00**	**-0.03**	**-0.06**	**-0.11**	**-0.17**
0.3	4.3	7.4	26.5	30.4	30.6	31.1	27.9	8.1	4.2
0.5	4.7	7.2	22.7	26.8	27.6	27.4	23.6	8.2	4.5
0.8	4.8	6.6	17.0	22.3	21.6	22.5	18.5	7.5	4.8
1.0	4.7	6.1	12.4	16.1	15.9	16.0	12.7	7.0	4.7
1.3	4.4	5.4	9.4	12.0	12.1	12.3	10.2	6.1	4.6
1.5	4.0	4.9	6.9	8.1	9.2	9.2	7.9	4.8	3.9
1.8	3.9	4.5	5.9	6.3	7.2	6.8	6.3	4.3	3.5
2.0	3.9	4.0	5.0	5.3	5.7	5.7	5.3	3.9	3.5
2.3	3.6	3.9	4.4	4.7	5.1	4.8	4.6	3.7	3.3
2.5	3.4	3.4	4.2	4.3	4.5	4.4	4.1	3.6	3.3
2.8	3.4	3.4	4.0	4.2	4.5	4.2	4.0	3.4	3.3

Table B.5. Monthly average hourly climate data

Parameter	**Month**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Dry bulb temperature (°C)	26.3	27.0	27.4	27.4	27.1	25.2	25.8	27.5	27.3	27.5	27.3	25.7
Wet bulb temperature (°C)	23.6	23.6	23.9	24.9	25.2	24.2	24.7	24.1	24.1	24.5	24.0	23.8
Relative humidity (%)	84	89	82	81	87	80	82	91	81	88	86	88
Wind speed (m/s)	2.4	1.0	1.7	0.6	1.3	1.6	1.6	1.0	1.0	2.4	0.8	0.6

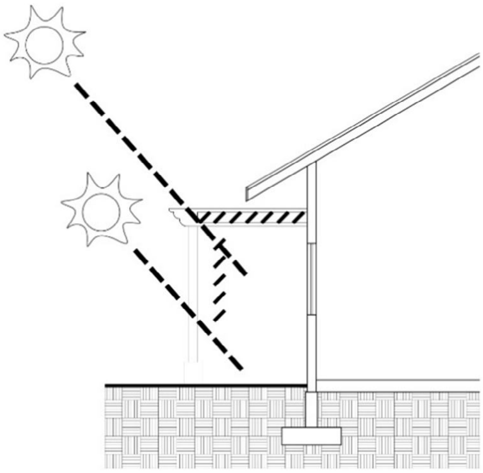
Table B.6. Monthly average daily solar radiation

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Solar radiation (MJ/m^2)	20.97	14.59	18.81	18.69	16.72	13.28	12.16	17.69	13.56	17.37	17.61	12.12

Annex C
(informative)

Examples of mechanism to control solar penetration

Examples of mechanism to control solar penetration are shown in the following figures.


a) Appropriate overhangs

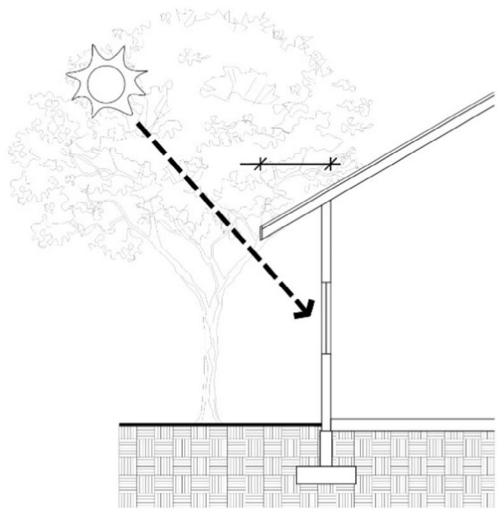

b) Exterior sun shading with trellis or projections at perimeter of openings

Figure C.1. Control of solar penetration

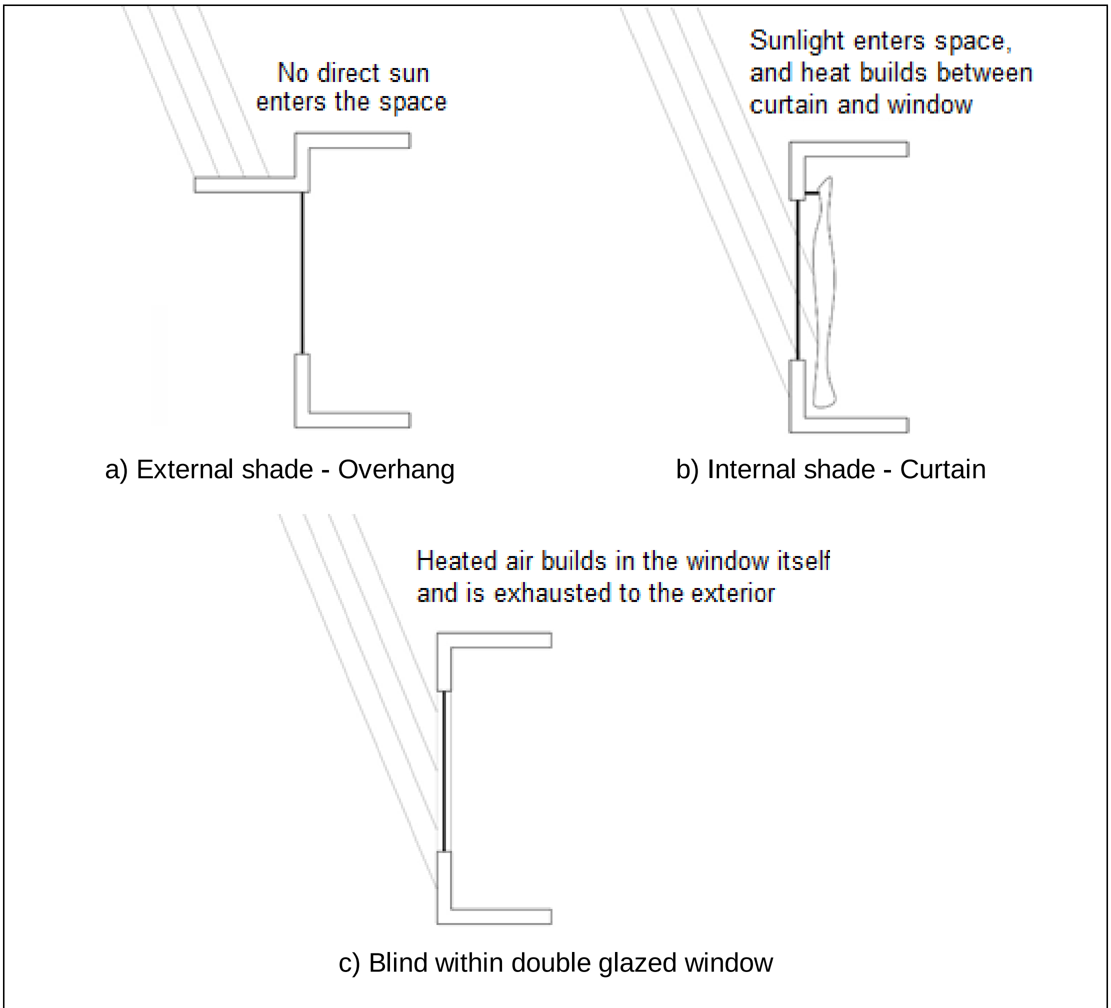


Figure C.2. Controls of solar penetration by curtain and blind

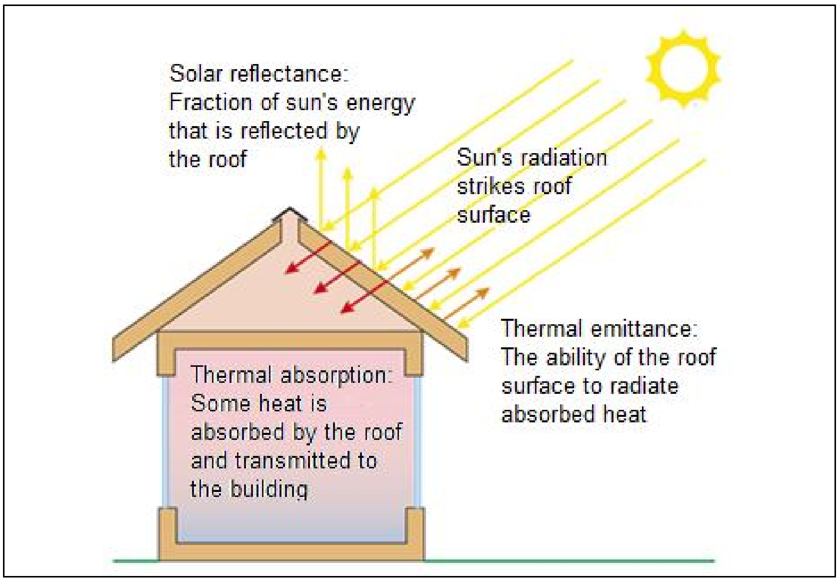


Figure C.3. The effect of solar radiation on roof surface

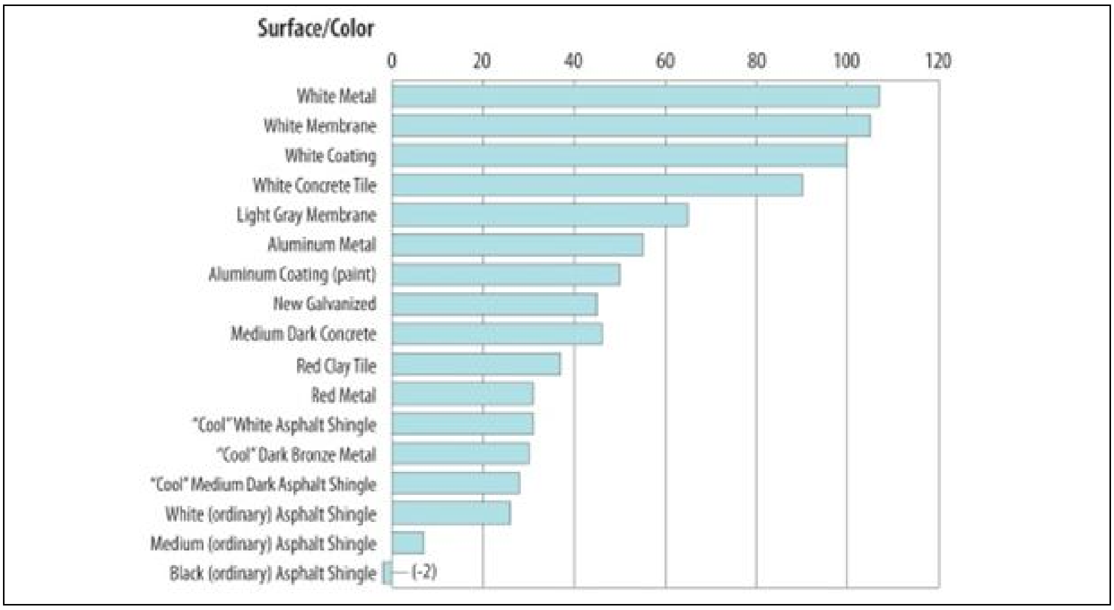


Figure C.4. SRI of various types of roofing materials and colours

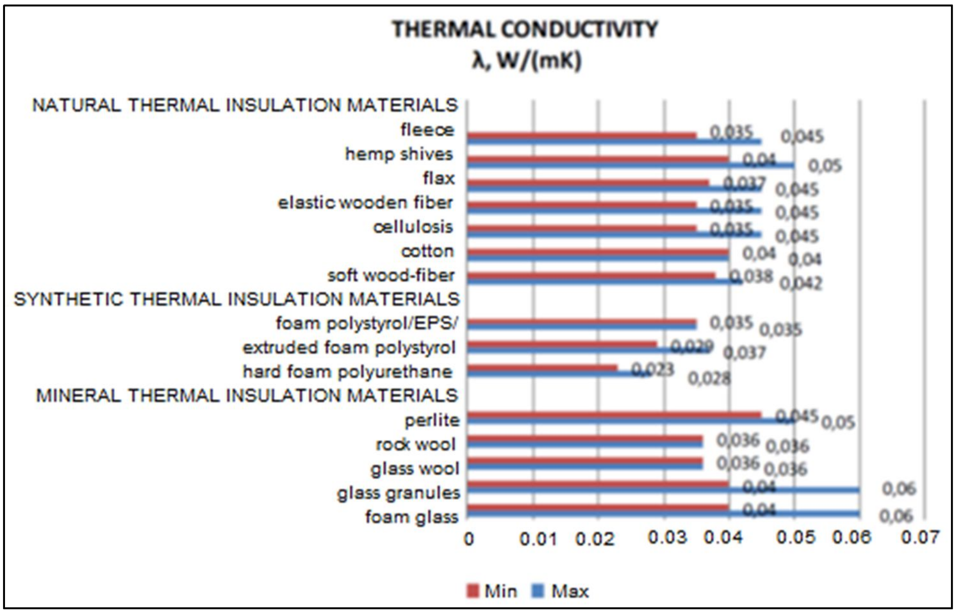


Figure C.5. Thermal conductivity for common roof and insulation materials

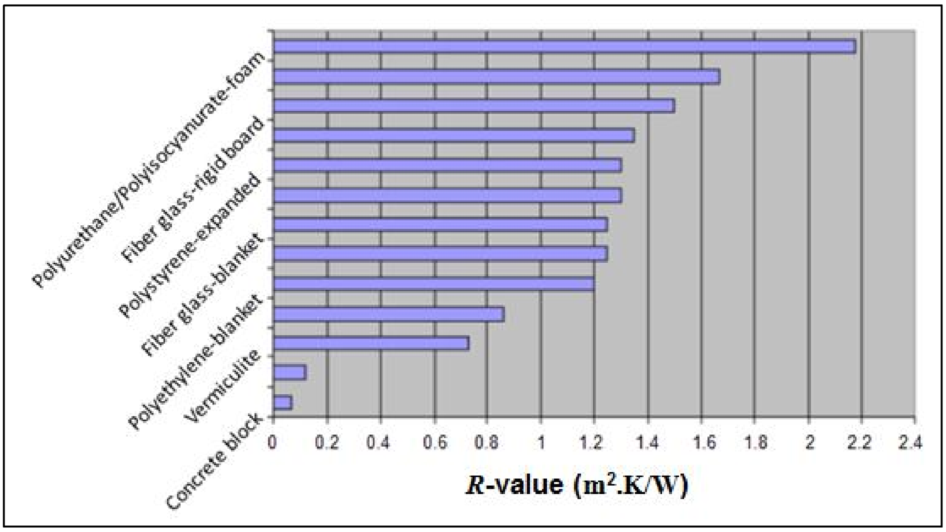


Figure C.6. *R*-value of common building materials based on 50 mm thickness

Annex D
(informative)

Thermal properties of common building materials

D.1 The following are thermal properties for common building materials.

a) Thermal conductivity - Low thermal conductivity is recommended for all roof and building materials (see Tables D.1 and D.2).

Table D.1. Thermal conductivity for roof materials

Group	Material	Specific mass (kg/m^3)	Thermal conductivity (W/mK)	
			Dry	Wet
Metal	Aluminium	2 800	204	204
	Copper	9 000	372	372
	Lead	12 250	35	35
	Steel, iron	7 800	52	52
	Zinc	7 200	110	110
Natural stone	Basalt, granite	3 000	3.5	3.5
	Bluestone, marble	2 700	2.5	2.5
	Sandstone	2 600	1.6	1.6
Masonry	Brick	1 600 - 1 900	0.6 - 0.7	0.9 - 1.2
	Sand-lime brick	1 900	0.9	1.4
		1 000 - 1 400	0.5 - 0.7	-
Concrete	Gravel concrete	2 300 - 2 500	2.0	2.0
	Light concrete	1 600 - 1 900	0.7 - 0.9	1.2 - 1.4
		1 000 - 1 300	0.35 - 0.5	0.5 - 0.8
		300 - 700	0.12 - 0.23	-
	Pumice powder concrete	1 000 - 1 400	0.35 - 0.5	0.5 - 0.95
		700 - 1 000	0.23 - 0.35	-
	Isolation concrete	300 - 700	0.12 - 0.23	-
	Cellular concrete	1 000 - 1 300	0.35 - 0.5	0.7 - 1.2
		400 - 700	0.17 - 0.23	-
	Slag concrete	1 600 - 1 900	0.45 - 0.70	0.7 - 1.0
		1 000 - 1 300	0.23 - 0.30	0.35 - 0.5
Inorganic	Asbestos cement	1 600 - 1 900	0.35 - 0.7	0.9 - 1.2
	Gypsum board	800 -1 400	0.23 - 0.45	-
	Gypsum cardboard	900	0.20	-
	Glass	2 500	0.8	0.8
	Foam glass	150	0.04	-
	Mineral wool	35 - 200	0.04	-
	Tiles	2 000	1.2	1.2
Plasters	Cement	1 900	0.9	1.5
	Lime	1 600	0.7	0.8
	Gypsum	1 300	0.5	0.8
Organic	Cork (expanded)	100 - 200	0.04 - 0.004 5	-
	Linoleum	1 200	0.17	-
	Rubber	1 200 - 1 500	0.17 - 0.3	-
	Fibre board	200 - 400	0.08 - 0.12	0.09 - 0.17

Table D.1. Thermal conductivity for roof materials *(continued)*

Group	Material	Specific mass (kg/m^3)	Thermal conductivity (W/mK)	
			Dry	Wet
Wood	Hardwood	800	0.17	0.23
	Softwood	550	0.14	0.17
	Plywood	700	0.17	0.23
	Hard-board	1 000	0.3	-
	Soft-board	300	0.08	-
	Chipboard	500 - 1 000	0.1 - 0.3	-
	Wood chipboard	350 - 700	0.1 - 0.2	-
Synthetics	Polyester (GPV)	1 200	0.17	-
	Polyethene, polypropene	930	0.17	-
	Polyvinyl chloride	1 400	0.17	-
Synthetic foam	Polystyrene foam, exp. (PS)	10 - 40	0.035	-
	Ditto, extruded	30 - 40	0.03	-
	Polyurethane foam (PUR)	30 - 150	0.025 - 0.035	-
	Phenol acid hard foam	25 - 200	0.035	-
	PVC-foam	20 - 50	0.035	-
Cavity isolation	Cavity wall isolation	20 - 100	0.05	-
Bituminous materials	Asphalt	2 100	0.7	-
	Bitumen	1 050	0.2	-
Water	Water	1 000	0.58	-
	Ice	900	2.2	-
	Snow, fresh	80 - 200	0.1 - 0.2	-
	Snow, old	200 - 800	0.5 - 1.8	-
Air	Air	1.2	0.023	-
Soil	Woodland soil	1 450	0.8	-
	Clay with sand	1 780	0.9	-
	Damp sandy soil	1 700	2.0	-
	Soil (dry)	1 600	0.3	-
Floor covering	Floor tiles	2 000	1.5	-
	Parquet	800	0.17 - 0.27	-
	Nylon felt carpet	0.05	-	-
	Carpet (with foam rubber)	0.09	-	-
	Cork	200	0.06 - 0.07	-
	Wool	400	0.07	-

Table D.2. Typical thermal conductivity of building materials

Typical thermal conductivity of building materials: Structural and finishing materials	**Thermal conductivity (W/mK)**
Acoustic plasterboard	0.25
Aerated concrete slab (500 kg/m^3)	0.16
Aluminium	237
Asphalt (1 700 kg/m^3)	0.50
Bitumen-impregnated fibreboard	0.05
Brickwork (outer leaf 1 700 kg/m^3)	0.84
Brickwork (inner leaf 1 700 kg/m^3)	0.62
Dense aggregate concrete block 1 800 kg/m^3 (exposed)	1.21
Dense aggregate concrete block 1 800 kg/m^3 (protected)	1.13
Calcium silicate board (600 kg/m^3)	0.17
Concrete general	1.28
Cast concrete (heavyweight 2 300 kg/m^3)	1.63
Cast concrete (dense 2 100 kg/m^3 typical floor)	1.40
Cast concrete (dense 2 000 kg/m^3 typical floor)	1.13
Cast concrete (medium 1 400 kg/m^3)	0.51
Cast concrete (lightweight 1 200 kg/m^3)	0.38
Cast concrete (lightweight 600 kg/m^3)	0.19
Concrete slab (aerated 500 kg/m^3)	0.16

NOTE. Always check manufacturers details as variations will occur depending on product and nature of materials.

b) Solar absorptivity - Low solar absorptivity is recommended for all roof materials (see Table D.3).

Table D.3. Solar absorptivity for roof materials

Material	**Solar absorptivity**
Aluminum, polished	0.30
Aluminum paint	0.20
Aluminum, anodised	0.15
Brick, glazed	0.35
Brick, common light red	0.55
Brick, common red	0.68
Brick, wire cut red	0.52
Brick, blue	0.89
Cork	0.45
Limestone, light	0.35
Limestone, dark	0.50
Linoleum, red-brown	0.84
Sandstone, light grey	0.62
Sandstone, red	0.73

Table D.3. Solar absorptivity for roof materials *(continued)*

Material	Solar absorptivity
Marble, white	0.44
Soft rubber, grey	0.65
Marble, dark	0.66
Granite, reddish	0.55
Magnesium oxide, evaporated	0.08
Graphite	0.84
Porcelain	0.50
Steel, vitreous enameled green	0.76
Steel, vitreous enameled dark red	0.81
Steel, vitreous enameled blue	0.80
Iron, galvanised new	0.64
Iron, galvanised dirty	0.92
Iron, galvanised white washed	0.22
Concrete	0.60
Copper, polished	0.18
Copper, tarnished	0.64
Lead, old	0.79
Asbestos cement, roof tiles old	0.83
Asbestos cement, roof tiles red	0.69
Asbestos slate	0.81
Asphalt roofing, new	0.91
Asphalt roofing, old	0.82
Bitumen-covered roofing sheet, brown	0.87
Slate, blue grey	0.87
Tile, clay red	0.64
Tile, concrete uncolored	0.65
Tile, concrete black	0.91
Vitreous enamel, white	0.39
White Dutch tile	0.18

c) Emissivity - Low emissivity of inner roof materials and insulation are recommended (see Table D.4).

Table D.4. Emissivity value for metals and non-metals

Metals		Non-metals	
Material	**Emissivity (ε)**	**Material**	**Emissivity (ε)**
Aluminium alloy-oxidised	0.40	Asbestos board	0.96
Aluminium-highly polished	0.04 - 0.06	Asphalt, tar, pitch	0.90 - 0.98
Aluminium-oxidised	0.11 - 0.31	Brick-red and rough	0.93
Aluminium-anodised sheet	0.55	Brick-fireclay	0.75
Brass-oxidised	0.60	Carbon-filament	0.53
Brass-polished	0.03	Carbon-lampblack	0.96
Chromium-polished	0.10 - 0.38	Cement	0.54
Copper-polished	0.02 - 0.05	Ceramic	0.90 - 0.94
Copper-heated at 600°C	0.57	Concrete	0.92 - 0.97
Gold-pure, highly polished	0.02	Frost crystals	0.98
Iron-polished	0.21	Glass	0.80 - 0.95
Iron-oxidised	0.94	Human skin	0.98
Rusted iron plate	0.65	Ice	0.96 - 0.98
Iron-rough steel plate	0.94 - 0.97	Marble polished light grey	0.90
Lead-grey and oxidised	0.28	Paints, lacquers, varnishes black lacquer	0.90 - 0.95
Mercury	0.09 - 0.12	Paints, lacquers, varnishes aluminium paints	0.55
Nickel polished	0.12	Paints, lacquers, varnishes flat black lacquer	0.96 - 0.98
Nickel oxidised	0.37 - 0.85	Paints, lacquers, varnishes white lacquer	0.95
Platinum-pure polished plate	0.05 - 0.10	Paper	0.94
Platinum-wire	0.06 - 0.16	Plastic	0.84 - 0.94
Silver-pure and polished	0.02 - 0.03	Porcelain-glazed	0.92
Stainless steel-polished	0.16	Propellant-liquid rocket engine	0.90

Table D.4. Emissivity value for metals and non-metals *(continued)*

Metals		Non-metals	
Material	**Emissivity (ε)**	**Material**	**Emissivity (ε)**
Stainless steel-oxidised	0.74 - 0.87	PVC	0.91 - 0.93
Tin-bright	0.07 - 0.08	Quartz opaque	0.75
Tungsten-filament	0.32 - 0.39	Rubber	0.95 - 0.97
Zinc-polished commercial pure	0.05	Sand	0.90
Zinc-galvanised sheet	0.23	Snow	0.96 - 1.00
-	-	Soil	0.92 - 0.95
-	-	Tape masking	0.92 - 0.95
-	-	Wallpaper	0.85 - 0.90
-	-	Water	0.95 - 0.96
-	-	Wood-planed oak	0.82 - 0.89

d) Solar reflectivity and solar reflectance index (SRI) are as in Table D.5.

Table D.5. Solar reflectance index (SRI) for typical roofing materials

Example SRI values for generic roofing materials	Solar reflectance	Infrared emittance	Temperature rise	Solar reflectance index (SRI)
Grey EPDM	0.23	0.87	68F	21
Grey asphalt shingle	0.22	0.91	67F	22
Unpainted cement tile	0.25	0.90	65F	25
White granular surface bitumen	0.26	0.92	63F	28
Red clay tile	0.33	0.90	58F	36
Light gravel on built-up roof	0.34	0.90	57F	37
Aluminium	0.61	0.25	48F	56
White coated gravel on built up roof	0.65	0.90	28F	79
White coating on metal roof	0.67	0.85	28F	82
White EPDM	0.69	0.87	25F	84
White cement tile	0.73	0.90	21F	90
White coating-1, coat, 8 mills	0.80	0.91	14F	100
PVC white	0.83	0.92	11F	104
White coating-2, coats, 20 mills	0.85	0.91	9F	107

e) Example calculation of typical roof assemblies using common building material for roof reinforced concrete roof is as in Tables D.6 and D.7.

Table D.6. Example of *U*-value calculation (for reinforced concrete roof based on 4.6.2)

For concrete roof tiles with 50 mm fiber glass insulation:			
Component (outside to inside)	**Thickness (T) (mm)**	**Conductivity (k) [w/(m.K)]**	**Resistance (T/C)**
Outside solar absorption	-	-	0.700
Outside surface resistance	-	-	0.055
Roof tile	12	0.836	0.014
Fiberglass	50	0.035	1.429
Air space	-	-	1.095
Asbestos free ceiling board	12	0.108	0.111
Inside surface resistance	-	-	0.148
Total thermal resistance	-	-	**2.852**
***U*-value (W/m^{2}K)**			**0.351**

Table D.7. Calculation of typical roof construction in Malaysia yields the following typical *U*-value

No	**Roof construction type**	**Insulation**	***U*-value W/m²K**	**Compliance with Table 5**
1.	Lightweight roof with metal deck	100 mm (f/g)	0.23	✓
2.	Lightweight roof with roof tile	NIL	0.7	✗
3.	Lightweight roof with roof tile	50 mm (f/g)	0.35	✓
4.	Lightweight roof with roof tile	75 mm (f/g)	0.28	✓
5.	Lightweight roof with roof tile	100 mm (f/g)	0.23	✓
6.	Heavyweight reinforced concrete roof slab 100 mm	NIL	2.9	✗
7.	Heavyweight reinforced concrete roof slab 100 mm	100 mm (p/u)	0.34	✓

Key

f/g is fiber glass

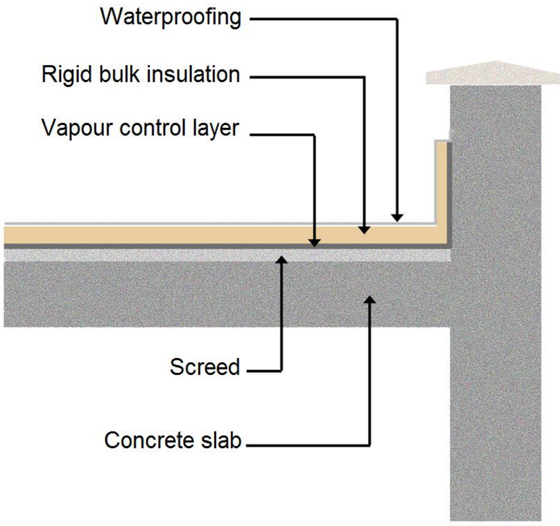
p/u is polyurethane

NOTE. See Figure D.1 for calculated *U*-value of typical roof construction.

a) Lightweight roof

Comprising of timber or steel frame, ceiling board, air space and roof tiles or metal decking.

f/g = fiber glass



b) Heavyweight reinforced concrete roof

Comprising of reinforced concrete slab with bitumen or water proofing layer.

p/u = polyurethane, an insulation layer incorporated into the reinforced concrete slab.

Figure D.1. Calculated *U*-value of typical roof construction

D.2 Properties of typical building material

Example calculation of typical roof and wall assemblies using common building material is as in Tables D.8 and D.9. For example on calculated *U*-value of typical wall construction, refer to Figure D.2.

Table D.8. Example of calculation for roof

Brick wall:			
Component (outside to inside)	**Thickness (T) (mm)**	**Conductivity (k) [w/(m.K)]**	**Resistance (T/k)**
Outside solar absorption	-	-	0.400
Outside surface resistance	-	-	0.044
Cement sand plaster	6	0.533	0.011
Brickwall (dry)	140	0.3	0.467
Cement sand plaster	6	0.533	0.011
Inside surface resistance	-	-	0.120
Total thermal resistance	-	-	**0.653**
***U*-value (W/m^{2}K)**			**1.531**

Table D.9. Example of *U*-value calculation (for brick wall based on 4.6.2)

No.	**Wall construction type**	***U*-value W/m²K**
1.	150 mm wall with 125 mm clay bricks 12 mm screed both sides	2.7
2.	200 mm wall with 175 mm clay bricks 12 mm screed both sides	2.3
3.	150 mm wall with 125 mm cement sand bricks 12 mm screed both sides	3.1
4.	150 mm wall with 140 mm aerated cement blocks 6 mm screed both sides	1.5

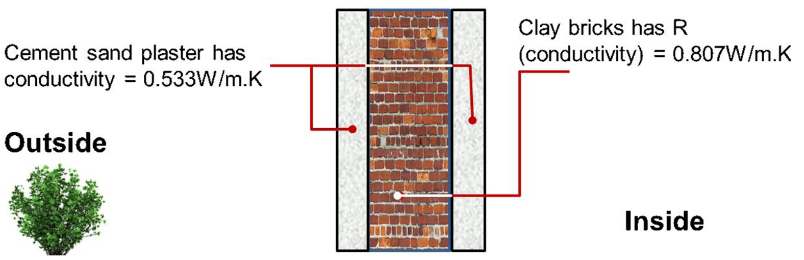


Figure D.2. Calculated *U*-values of typical wall construction

Acknowledgements

Members of Technical Committee on Energy Efficiency of Buildings (Passive)

Prof Ir Dr KS Kannan (Chairman)	Universiti Teknologi Malaysia
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Co-opted member

Mr Deep Kumar/ Ms Marina Yong	Building Sector Energy Efficiency Project (BSEEP), Jabatan Kerja Raya

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Ms Nadiah Mohamed (Secretary)	SIRIM Berhad
Ir H P Looi	Building Sector Energy Efficiency Project (BSEEP), Jabatan Kerja Raya
Dato' Prof Emeritus Ar Dr Elias@ Ilias Salleh/ Dr Noor Hanita Abdul Majid/ Dr Zuraini Denan/ Dr Aliyah Nur Zafirah Sanusi	International Islamic University Malaysia
Dr Ar Lim Chin Haw	Universiti Kebangsaan Malaysia
Dr Mohamad Fakri Zaky Jaafar	Universiti Putra Malaysia
Prof Dr Azni Zain Ahmed/ Dr Nor Zaini Ikrom Zakaria/ Prof Sr Dr Md Najib Ibrahim	Universiti Teknologi MARA