Chapter 3

Passive Design Measures

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Chapter 3

Passive Design Measures

3.1 Introduction

It is cost-effective to adopt passive design measures as a first step in optimising energy efficiency in commercial and residential buildings. As discussed in Chapter 1, almost 50% of energy consumption is typically used in cooling for thermal comfort in hot and humid climates. Therefore, measures discussed in this chapter should be prioritised and employed as extensively as possible. It makes sense to optimise passive cooling strategies by adopting passive design measures, which are essentially architectural. Passive design measures aim to optimise (i) passive cooling strategies, i.e. minimise heat gains in buildings; and (ii) environmental cooling through natural means such as vegetation, landscaping, and shading.

Buildings primarily provide an internal environment suitable for occupancy in buildings. Therefore, the architectural passive design should consider the building's site environment. The key passive design measures are discussed below.

3.2 Site Planning and Orientation

It is important to consider site planning and orientation in designing a new building on the green field. The primary objective of good orientation in the equatorial region is to avoid exposing building openings to intense solar radiation as the sun travels east to west. As a general rule, orientate the building layout as much as possible, such that a building's main long axis with more openings or glazing would face north to south, and the narrow ends of the building would face the east–west direction (Figure 3.1). The idea is to minimise the exposure of building openings to the east–west sun travel direction as much as possible.

The orientation of buildings can contribute to the immediate microclimate of open spaces by providing shade and shadow to the immediate surroundings that will benefit the indoor areas adjacent to it.

Figure 3.1: Long Directional Axis of Building (in Blue) Should Face North and South As Much As Possible

Source: Author.

3.3 Daylighting

Before considering efficient electrical lighting, daylight harvesting in a building should be incorporated to provide lighting requirements where possible during the daytime. Building occupants will benefit from a proper daylight harvesting design that provides a better working environment and improved energy efficiency. Conversely, improper daylight harvesting design may cause glare discomfort, excessive heat gain, increased thermal discomfort, and high energy consumption in buildings.

The simplest way to describe daylight distribution, penetration, and intensity is daylight factor (DF), expressed as a percentage. It is the ratio of the internal space illuminance ($E_{internal}$) at a point in a room to the instantaneous external illuminance ($E_{external}$) on a horizontal surface (equation 1).

$$DF = \frac{E(internal)}{\mathrm{E(external)}}\, x\ 100 \quad \text{----------------- (1)}$$

Where:

DF = daylight factor (%)

E(internal) = horizontal illumination of reference point indoor (Lux)

E(external) = horizontal illumination of unobstructed point outdoor in an overcast sky condition (Lux)

As a guide, the brightness inside a building and the associated distribution can be broadly classified by the daylight factors described in Table 3.1, based on Malaysian data given in MS1525:2019. In general, a daylight factor of 1.0–3.5 is recommended. The introduction of daylighting will save energy through energy conservation without switching on artificial electrical lighting, which would reduce lighting energy emissions that the ACMV system needs to remove.

Table 3.1: Daylight Factors and Impact

Daylight Factor	Lighting	Glare	Thermal Comfort	Appearance and Energy Implication
> 6.0	Intolerable	Intolerable	Uncomfortable	The room appears strongly daylit. Artificial lighting is rarely needed during the day, but thermal problems due to solar heat gains and glare may occur.
3.5–6.0	Tolerable	Uncomfortable	Tolerable	
1.0–3.5	Acceptable	Acceptable	Acceptable	The room appears moderately daylit. It is generally a good balance between lighting and thermal aspects. Supplementary artificial lighting may be needed in dark areas due to the effect of layout or furniture arrangement.
< 1.0	Perceptible	Imperceptible	Acceptable	The room looks gloomy; artificial lighting is needed most of the time.

Source: Department of Standards Malaysia (2019).

3.4 Façade Design and Building Envelope

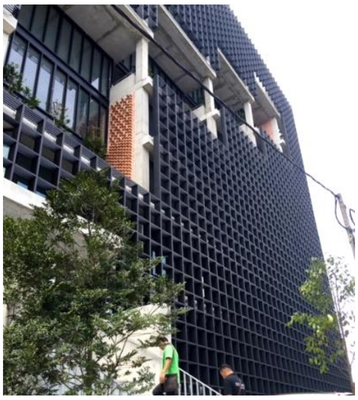
The façade design is an important part of passive design measures. This is where architects can deploy innovative ideas to minimise solar heat gains in buildings. The façade of a building is the external building envelope that determines the building's form and aesthetics. A good façade design using architectural treatments and suitable materials can help optimise daylighting and thermal comfort by minimising solar heat gains. A building envelope should be designed to block out heat into buildings via conduction and solar radiation. A properly designed envelope can greatly reduce the cooling load and, hence, the energy consumption of a building.

One way to quantify the performance of a building envelope is a design criterion known as overall thermal transfer value (OTTV). The OTTV is a useful indicator for non-air-conditioned buildings and partly non-air-conditioned buildings. The OTTV aims at achieving the design of a building envelope to reduce external heat gain and, hence, reduce the cooling load of ACMV systems. Reference is made to Section 5 of the Philippines's Guidelines on Energy Conserving Designs of Buildings (DOE, 2008) to determine the OTTV of a building envelope.

The OTTV of a building envelope is recommended not to exceed 50 W/m^2. However, this maximum value of the OTTV should be deliberated amongst stakeholders and decided by the DOE. Should the department wish to set a higher energy efficiency goal, this value can be set lower, but there will be cost implications for such a decision. For this report, the maximum OTTV value for a commercial building is set at 50 W/m^2. The OTTV is determined based on all external walls of a building. Achieving an OTTV not exceeding 50 W/m^2 can confirm that the design of the building envelope has incorporated measures to reduce external heat gain, hence, decreasing the cooling load of the ACMV system. Such effort will also result in reducing the ACMV equipment capacity.

The main façade design methods are summarised as follows:

Figure 3.2: Example of Façade Design with External Shading Devices



Source: Ar. Voon Kok Leong

Figure 3.3: Example of Egg-crate Façade Design

Source: Author.

1) Building envelope design to achieve the OTTV of external walls at 50 W/m^2 or less and roof OTTV of 25 W/m^2 or less
   a) Fenestration design and glazing selection
      i) Where possible, choose a building form and fenestration design that provide the least amount of glazing while maintaining the required aesthetic appearance of the building.
      ii) The correct selection of glazing properties can help reduce the OTTV value, reduce the cooling load, and increase energy efficiency.
      iii) As a selection guide, select glazing with a low solar heat gain coefficient (SHGC) to reduce the solar heat gain in building and high visible light transmission (VLT) to improve daylight harvesting.
      iv) It is advisable to make a balanced selection because glazing with low SHGC will likely have an unsatisfactory VLT, e.g. glazing with a VLT of less than 10% makes a building look dull from within due to the lack of daylight inside the building. For example, a high-performance low-e double glazing can get a low SHGC of less than 0.15 with a VLT of 25% or higher.
      v) As a general guide, it is possible to use the ratio of light to solar gain (VLT to SHGC, i.e. LSG [or light to solar gain]). The higher this ratio, the better it is for commercial buildings where daylight is harvested.
         - Single glazing without low-e properties has typical LSG values of 0.5 to 1.0.
         - Single glazing with low-e properties has typical LSG values of 1.05 to 1.3.
         - High-performance double glazing with low-e properties has typical values of 1.5 to 2.0.

   b) Building materials

      Suitable building materials with insulating properties can reduce a significant amount of energy consumption in a tropical climate. Outdoor air temperature is high during the daytime, while the air temperature inside air-conditioned spaces is set at 23^{0}C to 27^{0}C. Heat is conducted from the outside to the inside of a building. However, the outdoor air temperature is likely lower than the indoor air temperature during the night and early morning. Heat flow is then opposite to daytime conditions.

      Table 3.2 shows the difference in the energy-saving potential for wall materials with a lower coefficient of heat transfer (U-value). The estimated values given in Table 3.2 are based on an energy simulation study reported in BSEEP 2013. The simulation study model was based on a square building, without external shades and with a service core in the centre of the building. The high, medium, and low night-time baseloads refer to a night baseload of 50%, 35%, and 10% of the daytime peak load, respectively. Table 3.2 shows that the lower the wall material's U-value, the lower is the simplified energy index. This index provides an easy method to estimate the energy reduction due to the wall U-value selection in a hot and humid climate.

Table 3.2: Comparison of Estimated Energy (Electricity) Reduction of Various Wall Materials under Three Baseload Scenarios

Case	Description	ASHRAE U-value (W/m^2K)	Wall Simplified Energy Index (kWh/y per m^2 of wall area)		
			High night-time baseload	Medium night-time baseload	Low night time baseload
1	Concrete wall, 100 mm	3.40	55	32	28
2	Brick wall, 115 mm	2.82	52	30	25
3	Brick wall, 220 mm	2.16	50	27	22
4	Double brick wall with 50 mm cavity, 300 mm	1.42	48	25	20
5	Autoclave lightweight concrete, 100 mm	1.25	47	24	18
6	Autoclave lightweight concrete, 150 mm	0.94	45	22	17
7	Autoclave lightweight concrete, 200 mm	0.75	45	22	16

Source: Extracted from Public Works Department Malaysia (2013).

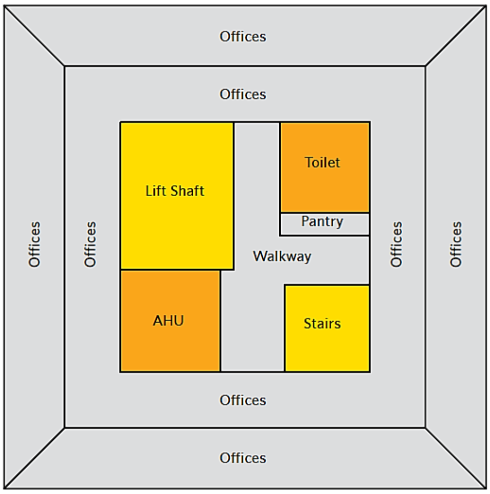
c) Core location

i) To place the service core (comprising lift core, services, etc.) to serve as a buffer zone to reduce the impact of solar radiation in the air-conditioned space of a building, e.g. core location facing the east or west. Sometimes due to other architectural considerations, it may not be possible to select an ideal core location. The designers should then consider using the next best option if the best option is not available.

ii) The objective of the core location is to increase the effectiveness of the façade design in reducing solar heat gains.

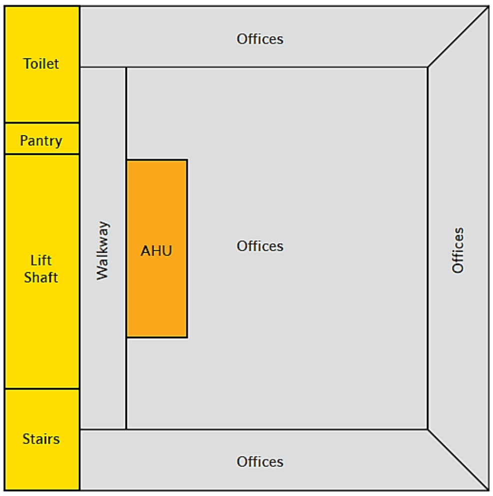
iii) Comparing Figures 3.4 and 3.5 as illustrations of a core location design, a square building with a centre core has a better view out and more glazing area; a square building with a side core facing west has less view out and less glazing area. However, in terms of solar heat gains, OTTV, and building energy performance (BEI value), the square building with a centre core facing west performs better (Figure 3.5).

Figure 3.4: Square Building Centre Core



Source: Public Works Department Malaysia (2013).

Figure 3.5: Square Building Side Core West



Source: Public Works Department Malaysia (2013)

3.5 Natural Ventilation

Ventilation, the movement of air, has three useful functions:

1) It provides the fresh air needs of building occupants.
2) It maintains the thermal comfort of building occupants.
3) It cools down the interior building space when outdoor air is cooler.

ASHRAE Standard 62.1 – Ventilation for Acceptable Indoor Air Quality – specifies ventilation requirements. From the energy efficiency perspective, conditioning ventilation air properly is expensive, especially in hot and humid climates. It costs money to clean outdoor air, dry it, cool it, and push it into the breathing zone. Nevertheless, for health reasons, it is necessary to introduce outdoor air to air-conditioned spaces. There are particular periods, such as mornings and evenings, during which natural ventilation can cool offices and other areas with fresh air. Air flushing of building spaces may be considered during these periods. However, security, ambient exterior noise levels, outdoor air quality, outdoor air temperatures, humidity, weather conditions, etc. should also be considered.

Under the current COVID-19 pandemic situation, ASHRAE's Position Document on Infectious Aerosols recommends increased ventilation and filtration for air-conditioned spaces provided by ACMV systems because such measures can reduce the airborne concentration of COVID-19, and, thus, the risk of transmission through the air.

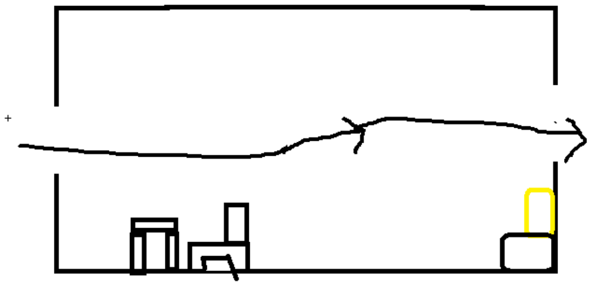
Natural ventilation uses natural forces of wind and buoyancy to deliver sufficient fresh air and air change to ventilate enclosed or semi-enclosed spaces. Natural ventilation without mechanical means should be considered in the design of common facilities – such as lobbies, corridors, staircases, toilets, and semi-enclosed parking and canteen areas – to achieve energy efficiency.

The two methods for providing natural ventilation are:

1) Cross ventilation (wind driven)

Figure 3.6 shows cross ventilation, which is wind driven across a building space through windows.

Figure 3.6: Building Section Showing Cross Ventilation

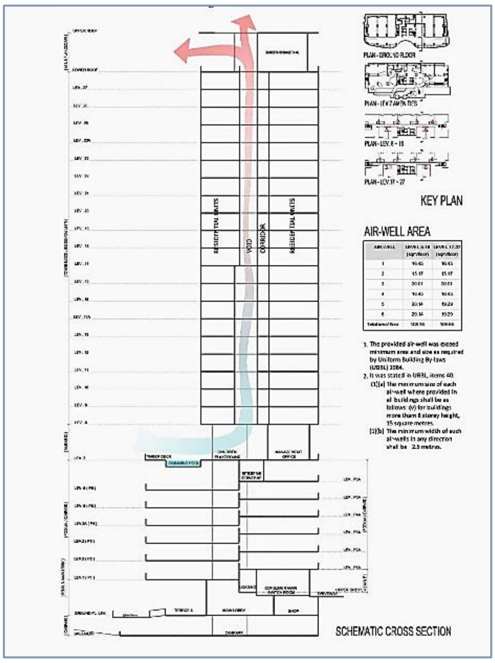


Source: Department of Standards Malaysia (2019), redrawn by Aidan Leong.

2) Stack ventilation (buoyancy driven)

Figure 3.7 shows stack ventilation, which is buoyancy-driven and is commonly incorporated in high-rise buildings through void spaces or atriums.

Figure 3.7: High-rise Building Section Showing Stack Ventilation



Source: Author.

3.6 Strategic Landscaping

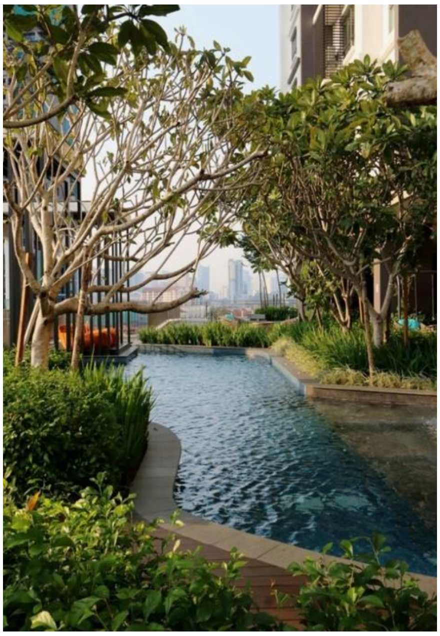
This measure is suitable for a highly urbanised area, where the surrounding area of a building is densely built up without much greenery. Strategic landscaping in a building development can reduce heat gain. Strategic landscaping aims to create a cooler microclimate around the building and reduce the urban heat island effect. The surroundings of highly urbanised and built-up areas are usually significantly warmer than the rural and less built-up areas.

Figures 3.8 and 3.9 illustrate some methods that can be deployed to create a cooler microclimate around a building:

- Maximise the area available around a building for landscape (Figure 3.9)
- Incorporate aquascape or water body (Figures 3.8 and 3.9)

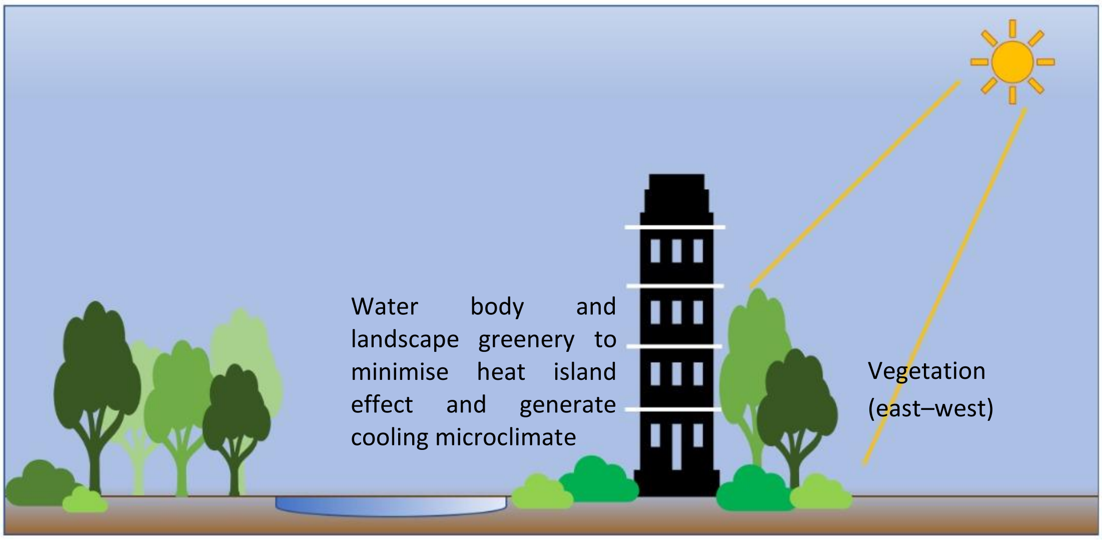
The appropriate plant types and high reflectance materials for the hardscape area will help decrease the solar absorption of the hard surfaces, hence, reducing the urban heat island effect. This can be achieved by selecting materials with a high solar reflectance index. For example, trees and shrubs near façades facing east and west can provide external shading to reduce solar heat gain into the buildings (Figure 3.9).

Figure 3.8: Illustration of Water Body and Shrubs Near Façades Facing West



Source: Author.

Figure 3.9: Illustration of Strategic Landscaping to Create a Cooler Microclimate



Source: Department of Standards Malaysia (2019), redrawn by Hayley Leong.