Passive Design in Hot Humid Climates

Mohd. Hamdan Ahmad, PhD
Professor
Executive Director
Institute Sultan Iskandar
Universiti Teknologi Malaysia
Introduction

Buildings consumed half of the energy used daily. The energy used rise significantly due to the homogenous environment created by designers and the standardized engineering solutions. Today, most buildings tend to waste a lot of energy by not responding to the climatic conditions and comfort requirement of the inhabitants.
Introduction

- Application of advance technology and mechanical aids for cooling and comfort has also play significant roles in changing the basic design principles which we normally used to be responsive to our context – i.e. tropical climate and culture.

- Thus there is a need to re-evaluate and re-address the basic planning and design principles as designers are responsible for the energy inefficiency of the buildings they design. They must be ecological and sustainable.
Introduction

Architecture can be described from various perspectives. Historians see architecture differ than the scientist. The aristocrat and peer of the cultural realm perceived architecture more so from the cultural view points. On the other hand, the environmentalists see architecture from the environmental and bio-climatic angles.

Malay Architecture should not fall into being a trend or fashionable item. It should be dynamic to change but keeping what is local legible!
Sustainable Development:

- Sustainability applies to actions/developments that preserve the global environment and its non-renewable resources for present and future generations.
**Why Sustainable?**

Three Basic understandings:

- That our resources are limited
- That our decision may not be reversible
- That we have moral obligation for future generation

✓ **Sustainable Architecture**

The art or technology of making building with human nature relationship.

✓ **Objective of Sustainable Architecture:**

- To provide comfortable & healthy environment
- To maximize use of natural energy forces instead of mechanical aids
- To reduce energy use in building
Passive Design

- Sustainable design approach

- Passive design is design that does not require mechanical heating or cooling. It is about making the most of local conditions to make your home comfortable, affordable and sustainable.

- Passive design means designing your home for your climate. In tropical areas, lightweight materials, shade and ventilation help keep your home cool.

- MS1525:2007 Clause 4.1
  - Designing within contextual climate and site are the first steps in the reduction of energy consumption, that will result in operational cost savings.
MS1525:2007

- MS 1525 primarily deals with building energy.
- The steps towards Energy Efficient buildings are:

**PASSIVE MEASURES**

- Clause 4: Architectural and Passive Design Strategy
- Clause 5: Building Envelope

**ACTIVE MEASURES**

- Clause 6: Lighting
- Clause 7: Power System and Distribution System
- Clause 8: Air Cond and Mech Ventilation System
- Clause 9: Energy Management Control System
## Passive Design

- MS1525:2007 Clause 4 Key passive design factors

<table>
<thead>
<tr>
<th>4.1</th>
<th>Sustainable Design Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.2</td>
<td>Passive Design Strategy</td>
</tr>
<tr>
<td>4.3</td>
<td>Site Planning and Orientation</td>
</tr>
<tr>
<td>4.4</td>
<td>Daylighting</td>
</tr>
<tr>
<td>4.5</td>
<td>Façade Design</td>
</tr>
<tr>
<td>4.6</td>
<td>Natural Ventilation</td>
</tr>
<tr>
<td>4.7</td>
<td>Strategic Landscaping</td>
</tr>
</tbody>
</table>
Passive Design

- MS1525:2007 Clause 4 Key passive design factors
  - Key element of sustainable building
  - Aims to maximise comfort for people living in a home while minimising energy use and impacts on the environment
  - Making the most of renewable, natural sources of energy, such as the sun and the wind, to provide natural ventilation and lighting and to contribute to responsible energy waste.
Contextual Understanding

- Understanding context is vital in contextual responsive architecture.
- There are three major components describing context.
  - *The first is climate.*
  - *The second is culture.*
  - *The third is time (technology)*
- Understanding climate and culture must include the understanding of the site specific; the location of the site, the climatic condition of the site, the socio-cultural issues relating to the site, and the users. Time relates very much to the available and appropriate technology.
Understanding Our Tropical Climate and Thermal Comfort Criteria:

- Malaysia sits between 1-8°N latitudes, 100-119°E longitudes.
- Approximately 137km north of the Equator.
Understanding Climate

- Intense Heat/Solar radiation: 4.76 kWh/m² (but variable with cloud cover)
- High Air Temperature (increased yearly esp. visible in minimum air temperature) 22-34°C
- Small diurnal air temperature range: less than 10
- High humidity: >50% and very high at night
- Generally, very light winds: 0.5-3 m/s (1-6 knots)
- Cloudy Sky: >6 oktas, High Diffused Light Components (53%)
- Rainfall above global average (annual: 2600mm)
Climate Data

World Temperature Zoning

Source: www.myforecast.com
Climate Data

Kuala Lumpur/Sub., Malaysia

Latitude: 03°07'N  Longitude: 101°33'E  Elevation: 17m  Station: MS4847

Temperature: Daily High, Daily Low

Precipitation
Humidity: No Data

# Climate Data

**Kuala Lumpur, Malaysia**

<table>
<thead>
<tr>
<th>NOAA Code</th>
<th>Statistic</th>
<th>Units</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>0101</td>
<td>Temperature Mean Value</td>
<td>°F</td>
<td>79</td>
<td>79.7</td>
<td>80.2</td>
<td>80.6</td>
<td>81</td>
<td>80.6</td>
<td>79.9</td>
<td>79.9</td>
<td>79.5</td>
<td>79.3</td>
<td>79</td>
<td>78.8</td>
<td>79.8</td>
</tr>
<tr>
<td>0109</td>
<td>High Temperature Mean Daily Value</td>
<td>°F</td>
<td>89.4</td>
<td>91</td>
<td>91.6</td>
<td>91.4</td>
<td>91</td>
<td>90.5</td>
<td>89.8</td>
<td>90</td>
<td>89.4</td>
<td>89.2</td>
<td>88.5</td>
<td>88.7</td>
<td>90.1</td>
</tr>
<tr>
<td>0110</td>
<td>Low Temperature Mean Daily Value</td>
<td>°F</td>
<td>71.8</td>
<td>72.1</td>
<td>73</td>
<td>74.1</td>
<td>73.6</td>
<td>73.6</td>
<td>72.9</td>
<td>72.9</td>
<td>72.9</td>
<td>73.2</td>
<td>73.2</td>
<td>72.5</td>
<td>73</td>
</tr>
<tr>
<td>0615</td>
<td>Precipitation Mean Monthly Value</td>
<td>inches</td>
<td>6.7</td>
<td>5.9</td>
<td>9</td>
<td>11.7</td>
<td>7.5</td>
<td>5.2</td>
<td>5.3</td>
<td>6</td>
<td>7.9</td>
<td>11.2</td>
<td>11.3</td>
<td>9.4</td>
<td>8.1</td>
</tr>
<tr>
<td>0101</td>
<td>Temperature Mean Value</td>
<td>°C</td>
<td>26.1</td>
<td>26.5</td>
<td>26.8</td>
<td>27.0</td>
<td>27.2</td>
<td>27.0</td>
<td>26.6</td>
<td>26.6</td>
<td>26.4</td>
<td>26.3</td>
<td>26.1</td>
<td>26.0</td>
<td>26.55</td>
</tr>
<tr>
<td>0109</td>
<td>High Temperature Mean Daily Value</td>
<td>°C</td>
<td>31.9</td>
<td>32.8</td>
<td>33.1</td>
<td>33.0</td>
<td>32.8</td>
<td>32.5</td>
<td>32.1</td>
<td>32.2</td>
<td>31.9</td>
<td>31.8</td>
<td>31.4</td>
<td>31.5</td>
<td>32.25</td>
</tr>
<tr>
<td>0110</td>
<td>Low Temperature Mean Daily Value</td>
<td>°C</td>
<td>22.1</td>
<td>22.3</td>
<td>22.6</td>
<td>23.4</td>
<td>23.1</td>
<td>23.1</td>
<td>22.7</td>
<td>22.7</td>
<td>22.7</td>
<td>22.9</td>
<td>22.9</td>
<td>22.5</td>
<td>22.77</td>
</tr>
<tr>
<td>0615</td>
<td>Precipitation Mean Monthly Value</td>
<td>mm</td>
<td>162.8</td>
<td>144.7</td>
<td>218.4</td>
<td>284.8</td>
<td>183.9</td>
<td>126.8</td>
<td>129.2</td>
<td>145.5</td>
<td>192.0</td>
<td>272.3</td>
<td>275.4</td>
<td>230.4</td>
<td>197.18</td>
</tr>
</tbody>
</table>

# Climate Data

**Kuala Lumpur, Malaysia (Jan – Sept 2011)**

<table>
<thead>
<tr>
<th></th>
<th>Max</th>
<th>Avg</th>
<th>Min</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max Temperature</td>
<td>35 °C</td>
<td>32 °C</td>
<td>24 °C</td>
<td></td>
</tr>
<tr>
<td>Mean Temperature</td>
<td>30 °C</td>
<td>28 °C</td>
<td>23 °C</td>
<td></td>
</tr>
<tr>
<td>Min Temperature</td>
<td>27 °C</td>
<td>24 °C</td>
<td>22 °C</td>
<td></td>
</tr>
<tr>
<td><strong>Degree Days</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating Degree Days</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(base 65)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling Degree Days</td>
<td>22</td>
<td>17</td>
<td>9</td>
<td>4628</td>
</tr>
<tr>
<td>(base 65)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Growing Degree Days</td>
<td>36</td>
<td>32</td>
<td>24</td>
<td>8711</td>
</tr>
<tr>
<td>(base 50)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dew Point</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dew Point</td>
<td>30 °C</td>
<td>24 °C</td>
<td>20 °C</td>
<td></td>
</tr>
<tr>
<td><strong>Precipitation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precipitation</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Snowdepth</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Wind</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>37 km/h</td>
<td>6 km/h</td>
<td>0 km/h</td>
<td></td>
</tr>
<tr>
<td>Gust Wind</td>
<td>47 km/h</td>
<td>34 km/h</td>
<td>23 km/h</td>
<td></td>
</tr>
<tr>
<td><strong>Sea Level Pressure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sea Level Pressure</td>
<td>1014 hPa</td>
<td>1009 hPa</td>
<td>1002 hPa</td>
<td></td>
</tr>
</tbody>
</table>

Source: www.wunderground.com
Climate Data

Kuala Lumpur, Malaysia (Jan – Sept 2011)

Source: www.wunderground.com
Daylight Availability in Kuala Lumpur

Global illuminance

Global diffuse illuminance
Daylight is ‘Cool’

[Diagram showing luminous efficacy comparison between different light sources: incandescent, low voltage halogen, fluorescent lamp, direct sunshine, clear sky daylight, and ‘Cool Daylight’. The diagram illustrates that ‘Cool Daylight’ has the highest efficacy (200 lumens/watt) compared to the other sources, indicating less heat and more light.]
Understanding Solar Chart/Path for Malaysia

Use Solar Chart from 0° to 8° Latitude (KL about 4°N)
Understanding Solar Path

- For Malaysia, being in the Tropical Region near the Equator, the sun is experienced from all sides of the building throughout the year
Understanding Solar Angle

- Critical exposure to sun (10.00am-4.00pm): Maximum Radiation on the Roof
- Hot evening sun (4.00-5.30pm): west wall
- Higher total solar irradiance on the East wall
- Lowest sun angle (North) at mid-day in June = 69°
- Lowest sun angle (South) at mid-day in Dec/Jan = 63°

- Lowrise Building-Roof Most Critical
- Highrise Building- Wall Most critical

Figure 3.7: The importance of orientation in avoiding solar heat gain in tropical area.

Figure 3.8: Critical cut-off angle for Malaysia on North and South walls for effective shading design.
Understanding Thermal Comfort Criteria

- Comfort Zone for Tropical Climate as suggested by Koenigsberger:

<table>
<thead>
<tr>
<th>Corrected Effective Temperature</th>
<th>22°C(CET)-27°C(CET)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Movement</td>
<td>0.15m/s-1.5m/s</td>
</tr>
</tbody>
</table>

- C.G.Webbs Equatorial Comfort Index: 25.6°C

- Adnan’s Thermal Comfort Zone: 23 – 27 °C
Olgay’s Bio-Climatic Chart
Understanding Heat Gains in Building

Qs and Qc (The effect of Solar Radiation and Heat Gain most crucial)
Sheltering Concept

- Basic Purpose of Building (Architecture):
  - To Shelter:
    - Rain
    - Sun
    - Safe and Comfortable
    - Animal and Insect

- When we design, how do we achieve this idea of ‘shelter’?
How Building Functions

- Building as ‘Climatic Risk’
  - To shelter
  - Building is not a sheet of paper within the environment
  - Building has envelope
How to Achieve Good Shelter or Basic Principle for Comfort in The Tropics

- APPRECIATE OUR CLIMATE
- THINK UMBRELLA
- UNDER SHADED TREE OR TREE CANOPY
- OPEN against ENCLOSED
- OUTDOOR-INDOOR
- IS WALL REALLY NECESSARY?
Lessons from Traditional Architectural Response: Malay House

- Large Opening
- Light Construction/light materials
- On stilts
- Open Design – Minimum partitions
The same thing applies to architecture. Traditional architecture cleverly appreciate climate which in turn become part of the cultural understanding in creating built form.

For example, the construction technology depicted the available technology at that time but somehow illustrated an accurate prediction of controlling, filtering and responding to outdoor climate.

The outdoor expressions were responding to the exposure of the building surfaces or envelopes and their aesthetic effect to the sunlight and even the sky condition.
When we discussed about the Malay Traditional Architecture, the picture that comes to our mind is a traditional kampong house that sits comfortably within its surrounding.

Pitch roof to block the heat from the sun and shed the rain when it pours. The facades are recessed, Long roof overhangs. Large openings that allow maximum ventilation. Walls are operable or open-able allowing flexibility of uses and function from comfort to visual and privacy. Raised floor making no contact with the ground, allowing natural ventilation and avoiding conduction of heat from the ground. The sleeping areas face east and front verandah always avoiding facing west. They are loosely arranged allowing good air movements around building.

The surrounding enhances the sheltering from the hot sun having trees indirectly as natural filter. The indoor is as open plan as possible, with loosely arrange furniture creating transparency of light and ease the natural ventilation.

The interior sometime is visually gloomy providing sense of coolness against the hot outside environment.

The Malay Traditional Architecture is a reflection of careful understanding of our people towards their environment even without architect! This is implicit language that we normally misplaced.
Traditional Chinese Shop-house Architecture Response

- Internal Courtyards
- Multiple Air-wells.

Traditional Colonial Architecture Response

- High Ceiling
- Corridor/porch around building
Building Materials

- Traditional Malay houses use lightweight construction of wood and other natural materials. The lightweight construction of low thermal capacity holds little heat and cools adequately at night. The attap roof is an excellent thermal insulator. Glazed areas are seldom found in the traditional Malay house.

- Modern housing estate houses use bricks, tiles, concrete and other materials of high thermal capacity. These materials store up heat and reradiate it into the house, causing considerable discomfort. Glazed areas are usually abundant in these houses.

Layout

- Traditional Malay houses are randomly arranged. This ensures that wind velocity in the houses in the latter path of the wind will not be substantially reduced.

- Rigid patterns in the arrangement of housing estates houses create barriers that block the passage of wind to the houses in the latter path of the wind.

Ventilation of Roof Spaces

- Roof spaces in the traditional Malay house are properly ventilated by the provision of ventilation joints and panels in the roof construction.

- Roof spaces in the housing estate house are insulated by trapped air instead of being ventilated. Such construction requires a high ceiling to be effective.

Vegetation

- The use of coconut trees and other tall trees in the kampong not only provides good shade but also does not block the passage of winds at the house level.

- Often, because of the limited size of the compound of the housing estate house and the need to provide privacy, only hedges and small trees are planted. Thus the passage of winds at the house level is often reduced considerably.
Cross Ventilation
- The elongated open plans of the traditional Malay house allow easy passage of air and good cross ventilation. There are minimal interior partitions in the Malay house which restrict air movement in the house.
- Plans of housing estate houses are of more complicated shapes, and the partitioning of the house into different rooms and areas restrict air movement and cross ventilation in the house.

Wind Velocity Gradient
- The velocity of wind increases with altitude. The traditional Malay house on stilts capture winds of higher velocity at a higher level. This is especially vital in areas where there are plant cover on the ground which restricts air movement.
- The housing estate house at ground level receives wind of lower velocity. Hedges and solid fences built around the house to provide privacy often block winds and create steeper wind velocity gradient.

Ventilation at Body Level
- The body level is the most vital area for ventilation for comfort. The traditional Malay house allows ventilation at the body level by having many full-length fully openable windows and doors at body level.
- Ventilation in the housing estate house is often only directed at the upper part of the body because windows and other openings are located at higher levels to provide privacy.

Orientation
- Traditional Malay houses are often oriented to face Mecca (i.e., in an east-west direction) for religious reasons. The east-west orientation minimizes areas exposed to solar radiation.
- For profit motives, housing estate houses often disregard orientation for minimizing solar radiation and the orientation of the houses often becomes a jigsaw puzzle of fitting the most units into the site within permissible densities.
Overhangs and Exposed Vertical Areas

- Large overhangs and the low exposed vertical areas (windows and walls) in the traditional Malay house provide good protection against driving rain, provide good shading, and allow the windows to be left open most of the time for ventilation.
- The higher and larger exposed vertical areas of the windows in the modern house are often penetrated by direct sunlight and cause considerable discomfort. The walls which act as direct sun-shading devices get heated up and in the evenings reradiate heat into the interior areas.

Glare

- Glare in the traditional Malay house is controlled by large roof overhangs and low windows which exclude the open skies from the visual field. Glare is also lessened by the less reflective natural ground covers and wooden walls of neighbouring houses.
- Glare is usually more evident in the housing estate house due to the open skies which are not excluded from the visual field because of the use of bigger and higher unshaded windows. Glare from paved concrete areas and brightly lit exterior walls of other houses also causes considerable discomfort.

Lighting Level

- The traditional Malay house tends to be underlighted. This gives the psychological effect of coolness. The underlighting, however, can be remedied by artificial lighting.
- Lighting levels in the housing estate house are generally higher than the lighting levels in the traditional Malay house because of the use of lighter coloured paints and the location of windows at higher levels. In fact there is a tendency towards overlighting and uncontrolled glare.
Design Strategy for Tropical Climate:

a. The Must/Primary: Avoiding Heat from Direct Sunlight
b. The Plus/Secondary: Natural Ventilation
c. The Extra: Induced Ventilation
d. The Unnecessary: Mechanical Aids/Controls for Remedy
Envelope Design Principles

Building envelope’ is a term used to describe the roof, walls, windows, floors and internal walls of a home. Its performance in modifying or filtering climatic extremes is greatly improved by passive design.

1. Roof design
2. Wall design
3. Floor design

**INTERNAL COMFORT**
Roof Design

- Must act as umbrella
- Provide Good Shade
- Reflective
- Good Insulation
- Ventilated Roof
- Discharge Trapped Hot Air
Wall Design

- Selective Wall – Why you must have wall? Privacy, security, view, ventilation, daylight, sunlight, transition?
- Shaded Wall – breathing, allow ventilation
- Exposed Wall – barrier, reduce heat: absorbance, radiation, transmission
- Materials Selection
Earth-bags?
Floor Design

- Reduce contact with hot ground
- Raised Floor
- Cooled Floor – Air or water cooled
- Air gap – used recycle tire
- Floor Finishes
Outdoor Design

- Landscape
- Water bed/pond
Harnessing Environment (potential)

- Solar Energy
- Day-lighting
- Recycling Rain Water
Case study

ST DIAMOND BUILDING (MALAYSIAN ENERGY COMMISSION)

Solar Geometry

The solar path was used to sculpt the building geometry. The 25° tilt angle of the facades ensures that North and South facades are fully self-shaded during the hottest mid-day hours. For the East and the West facades, the tilting façade helps to reduce the solar impact by 41%.

The tilted glazing admits more of the desirable diffuse light reflected off the landscape for glare free daylighting use in the building.
Architecture is too substantial to become an artifact. Architecture is about life, a public art that will have to be experienced by people.

Architecture must fit to context.

We can put Traditional Architecture into a frozen state or place into a protected inheritance of past excellence under heritage acts for future generation to appreciate. We can turn many of our heritages into museums.

But what is more important is to continuously sustain the fundamental nature that is the language of climatic understanding into contemporary solution.
CONCLUSION

If one traces the evolution of architecture of a country that include change due to colonial influence such as Indonesia and Malaysia, the architecture is still chiefly manifesting response to climate than the foreign cultural influence.
Could it be Corbusier machine for living?

Or is the organic Wright idea right?

What about our own bio-climatic idea of Dr Ken Yeang?

Can we still cling to the application of batik, songket and ukiran on our facades or tengkolok and songkok on top of buildings?
What I sense is that our contemporary architecture has gone to war with nature!

We must aspire that our next attempt is an act of friendly rekindle with our surrounding.

Explore the implicit language of Malay Architecture, and integrate the explicit.

Let’s pray it will work!
Thanks, and may the competition becomes a successful example of sustainable project!