ARCHITECTURAL AND PASSIVE DESIGN STRATEGIES
CLIMATE CHANGE
HOW MUCH WE CONCERN?
worldwide buildings consume

17% of fresh water consumption
worldwide buildings consume **25%** of wood harvest
worldwide building consume 40% - 50% of raw materials used
worldwide buildings consume

30% - 40% of energy use
worldwide buildings contribute
33% of CO2 emissions
How important of 1 degree?  
Up 1 degreeC

Coral Reefs Destroy

Species Extinction

Island Nations Underwater
How important of 1 degree?

Up 2 degreeC

Greenland Melt

Polar Bear Extinct

Water Supply Affected
How important of 1 degree?
Up 3 degreeC

Environmental Refugees
Food Shortage
Amazon Collapse
a simple step, a brighter future.
UNDERSTAND OUR CLIMATE

A clear understand of Malaysian climate enables designers to design buildings that benefit from the climate conditions.
THE 4 ELEMENTS

- SUN
- RAIN
- WIND
- GREENERY

- HEAT GAIN
- DAY-LIGHTING
Optimising daylighting and thermal comfort while reducing solar heat gain would be a strategy to achieve energy efficiency.
Passive design strategies mean that **minimal** or **no mechanical** or **no electrical** means are used to achieve both **indoor thermal** and **visual comfort** and **reduction** in energy consumption.

- to orientate
- to shade
- to insulate
- to ventilate
- to harvest daylighting
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:

- Site planning & orientation
- Daylighting
- Roof
- Facade
- Natural Ventilation
- Strategic Landscaping
Site planning & orientation

Factors to be considered in site planning:

- geometrical location (latitude, altitude, longitude)
- land form / topography (hill, valleys)
- existing vegetation (shading potential, channeling of wind, ambient temperature)
- site wind condition (wind direction, speed)
- water bodies (glare, reflection, humidity)
- adjacent development (heat island effect, microclimate)
- infrastructure (accessibility, water supply, reducing carbon emission)
The general rule for best orientation of residential buildings is to avoid facades with most openings facing east or west. On narrow sites where east-west longitudinal orientation may not be feasible, the solutions may require other building geometries e.g. shading devices.

The orientation of residential buildings contribute to the immediate microclimate that will in turn benefit the indoor areas e.g. air temperature, radiant temperature, relative humidity, air velocity, etc.

Site orientation with respect to prevailing wind direction.
Site planning & orientation

Incorrect Orientation

Correct Orientation
Daylighting

Designing to harvest daylighting should begin at the preliminary design stage. A good daylighting system should consider the following:

- space orientation and layout
- **physical** (shape and size) and **optical** properties of glazing
  - internal floor, wall and ceiling surface properties (colour and reflectivity)
  - visual contrast between adjacent surfaces (e.g. between walls and ceilings)
  - protection from visual discomfort (e.g. glare)

To collect, transport and distribute light into buildings that reduce the need for artificial lighting without increasing solar heat gain.
Daylighting

Daylight Factor (DF)

– ratio of the internal illuminance ($E_{\text{internal}}$) at a point in a room to the instantaneous external illuminance ($E_{\text{external}}$) on a horizontal surface.

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

DF will decrease as the distance from the window increases.
Case: 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.
Daylighting

The recommended minimum DF in any habitable room is **not less than 2%** and the **minimum WFR is 15%**. For circulation areas, the minimum WFR is 10%.
Daylighting

Table 1. Illumination levels in rooms

<table>
<thead>
<tr>
<th>Area</th>
<th>Recommended lux</th>
</tr>
</thead>
<tbody>
<tr>
<td>Living room</td>
<td>200</td>
</tr>
<tr>
<td>Dining room</td>
<td>250</td>
</tr>
<tr>
<td>Kitchen</td>
<td>250</td>
</tr>
<tr>
<td>Bedroom</td>
<td>180</td>
</tr>
<tr>
<td>Bathroom</td>
<td>150</td>
</tr>
</tbody>
</table>

Table 2. Useful daylight illuminance (UDI) range

<table>
<thead>
<tr>
<th>Description</th>
<th>Lux</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within the range defined as useful</td>
<td>100 to 2000</td>
</tr>
<tr>
<td>Below the useful range</td>
<td>&lt; 200</td>
</tr>
<tr>
<td>Exceed the useful range</td>
<td>&gt; 2000</td>
</tr>
</tbody>
</table>

Illuminances above 2000 lux will cause glare, visual and thermal discomfort.
Daylighting
Sun-path diagram shows the solar altitude in the equatorial region is high throughout the year. It is a major source of heat gain during the day and heat loss via night-time cooling.

75% solar heat gain come from roof for single storey terrace house.
For that reason, roofs should be designed and constructed for protection against heat and rainwater. The following elements are to be considered.

- high pitch to drain off heavy rains
- large overhangs to shade the walls and openings
- avoid obstructions that prevent airflow along the roof surfaces (e.g. use low parapet walls or perforated screen walls)
- double roof design
- roof insulation and assemblies
  - ceiling insulation
  - roof ventilation
Thermal properties of roofing materials

The followings are considerations when selecting roofing materials:

- **Thermal conductivity**
  - Low thermal conductivity is recommended for all roof materials

- **Solar absorptivity**
  - Low solar absorptivity is recommended for all roof materials

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

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

- **Solar reflectance index (SRI)**
  - High value SRI is recommended for roof surfaces.
### Table 4. SRI value by materials

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

Table 5. Minimum $R$-value and maximum $U$-value for roof ($W/m^2K$)

<table>
<thead>
<tr>
<th>Roof weight group</th>
<th>Minimum $R$-value ($m^2K/W$)</th>
<th>Maximum $U$-value ($W/m^2K$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light (Under 50 kg/m²)</td>
<td>2.50</td>
<td>0.40</td>
</tr>
<tr>
<td>Heavy (Above 50 kg/m²)</td>
<td>1.67</td>
<td>0.60</td>
</tr>
</tbody>
</table>

UBBL 38A (Roof Insulation)
Architectural & Passive Design Strategies

Roof

Thermal insulation for roof

a) Lightweight roof construction
Roof

Thermal insulation for roof

- Waterproofing
- Rigid bulk insulation
- Vapour control layer
- Screed
- Concrete slab

b) Heavyweight roof construction
Façade / 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.

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.
Façade / Building envelope
- Wall

**U-value** – heat transfer coefficient or thermal transmittance is used to measure how effective elements of a building fabric are as insulators. How effective the elements are preventing heat from transmitting between the inside and the outside of a building.

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.
Façade / Building envelope
- Wall

**U-value = 1 / R**

Where the thermal resistance of the layers of the element,

\[
R = \frac{\text{the thickness of each layer}}{\text{the thermal conductivity of that layer (k-value)}}
\]

<table>
<thead>
<tr>
<th>TYPE OF MATERIAL</th>
<th>THICKNESS</th>
<th>THERMAL CONDUCTIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Façade / Building envelope - Wall

### Table D.2. Typical thermal conductivity of building materials

<table>
<thead>
<tr>
<th>Typical thermal conductivity of building materials:</th>
<th>Thermal conductivity (W/mK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural and finishing materials</td>
<td></td>
</tr>
<tr>
<td>Acoustic plasterboard</td>
<td>0.25</td>
</tr>
<tr>
<td>Aerated concrete slab (500 kg/m³)</td>
<td>0.16</td>
</tr>
<tr>
<td>Aluminium</td>
<td>237</td>
</tr>
<tr>
<td>Asphalt (1 700 kg/m³)</td>
<td>0.50</td>
</tr>
<tr>
<td>Bitumen-impregnated fibreboard</td>
<td>0.05</td>
</tr>
<tr>
<td>Brickwork (outer leaf 1 700 kg/m³)</td>
<td>0.84</td>
</tr>
<tr>
<td>Brickwork (inner leaf 1 700 kg/m³)</td>
<td>0.62</td>
</tr>
<tr>
<td>Dense aggregate concrete block 1 800 kg/m³ (exposed)</td>
<td>1.21</td>
</tr>
<tr>
<td>Dense aggregate concrete block 1 800 kg/m³ (protected)</td>
<td>1.13</td>
</tr>
<tr>
<td>Calcium silicate board (600 kg/m³)</td>
<td>0.17</td>
</tr>
<tr>
<td>Concrete general</td>
<td>1.28</td>
</tr>
<tr>
<td>Cast concrete (heavyweight 2 300 kg/m³)</td>
<td>1.63</td>
</tr>
<tr>
<td>Cast concrete (dense 2 100 kg/m³ typical floor)</td>
<td>1.40</td>
</tr>
<tr>
<td>Cast concrete (dense 2 000 kg/m³ typical floor)</td>
<td>1.13</td>
</tr>
<tr>
<td>Cast concrete (medium 1 400 kg/m³)</td>
<td>0.51</td>
</tr>
<tr>
<td>Cast concrete (lightweight 1 200 kg/m³)</td>
<td>0.38</td>
</tr>
<tr>
<td>Cast concrete (lightweight 600 kg/m³)</td>
<td>0.19</td>
</tr>
<tr>
<td>Concrete slab (aerated 500 kg/m³)</td>
<td>0.16</td>
</tr>
</tbody>
</table>

NOTE. Always check manufacturers details as variations will occur depending on product and nature of materials.
Windows form a fundamental component of the building envelope. Windows provide a relationship between the exterior and interior in the form of light, sound, air and view of the exterior. Fully openable glazed windows may be used to drive natural ventilation and maximise daylighting with high indoor illuminance.

Glazed areas can cause unwanted glare and overheating if WFR is more than 25%.
### Façade / Building envelope - Window

**Table 6. Window design**

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Design recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daylighting</td>
<td>Optimum $d/h$ and $x/l$ ratios for required daylight factor. Light shelves can be used to provide reflected daylight to improve internal daylighting.</td>
</tr>
<tr>
<td>Natural ventilation</td>
<td>Orientation towards prevailing wind direction.</td>
</tr>
<tr>
<td>Daylighting and view</td>
<td>Window dimensions and sill height suited to occupant position and external features.</td>
</tr>
<tr>
<td>Daylighting and natural ventilation</td>
<td>Window dimensions and location should be suited to all parameters.</td>
</tr>
<tr>
<td>Sun shading</td>
<td>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°.</td>
</tr>
</tbody>
</table>
Façade / Building envelope
- Sun Shading

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.
Façade / Building envelope - Sun Shading

Sun shading can be applied through the following strategies:

• **Direct solar component** (direct, diffused and reflected sunlight) should be avoided by providing external and internal sun shading particularly for east-west walls.

• Inclusion of **interlocking spaces** in form of indoor-outdoor area such as a balcony.

• **Recess and relief** to be incorporated in the building envelope.

• External sun shading should be emphasised by providing static or moveable blinds or louvres.
Façade / Building envelope
- Sun Shading

Sun shading can be applied through the following strategies:

- **Roof overhang** is an effective sun shading.
- **External sun shading** at window and door openings should be emphasised at **all orientations**.

Sun shading devices can be categorised as:

- fixed (louvres, overhangs, fins, horizontal and vertical projection)
- movable / adjustable (roller blind, curtain, awning, screen)
Façade / Building envelope  
- Sun Shading
Façade / Building envelope
- Sun Shading
Façade / Building envelope
- Sun Shading
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 for formula and details of OTTV calculation where **OTTV shall not exceed 50W/m2.**
Façade / Building envelope - OTTV

OVERALL THERMAL TRANSFER VALUE (OTTV)
Natural Ventilation

Ventilation is the movement of air. Ventilation had 3 useful functions in the building sector.

- **maintain thermal comfort** of occupants (by increasing the rate of evaporative and sensible heat loss from the body)
- **satisfy** the **fresh air needs** of the occupants
- **cool the building mass and interior space** (by an exchange of warm indoor air with cooler outdoor air)

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.
Natural Ventilation

Basically, there are two methods for providing natural ventilation:

- **cross ventilation** (wind-driven)
- **stack ventilation** (buoyancy-driven)
Natural Ventilation

Cross Ventilation

- Single Opening
- Two Openings - Same Wall
- Two Openings - With Wings
- Two Openings - Adjacent Walls
- Two Openings - Opposite Walls
Natural Ventilation

Cross Ventilation

Single Opening

Two Openings

Three Openings

Four Openings
Natural Ventilation

Cross Ventilation

No cross-ventilation from windows

Windows formed above door to create cross-ventilation
Natural Ventilation

Stack Ventilation
Natural Ventilation

Stack Ventilation
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
- creation of a cooler microclimate around the building
Strategic Landscaping

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.

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 materials with SRI of at least 29.
Strategic Landscaping
Strategic Landscaping
Site planning & orientation
Daylighting
Roof
Facade
Natural Ventilation
Strategic Landscaping
ARCHITECTURAL AND PASSIVE DESIGN STRATEGIES

Thank you