CHALLENGES IN PASSIVE BUILDING DESIGN
Outline/Agenda

- Introduction
- Vernacular buildings
- The design process
  - Climate
  - Psychrometric Chart
  - Strategies (Solar, Wind, Light)
- Other Parameters: Program & Occupancy pattern
- Conclusion: Passive/Active
Buildings, Energy & Climate

• Evidence shows that humans are changing the climate and that buildings are generating a considerable percentage of the greenhouse gas emissions that are responsible for this change.

• This is the most important environmental threat affecting the earth today.

• In order to reduce the detrimental effect of buildings on the environment, buildings must be designed, built and renovated so that they are sensitive to and harmonious with the environment.
Buildings, Energy & Climate

• Main intent is to create spaces that are more comfortable and require less energy to cool and heat.

• Issues affecting the sensation of comfort include:

1. EQUIPMENT HEAT GAINS
2. SOLAR GAIN
3. HUMIDITY
4. VENTILATION
5. INFILTRATION
6. OCCUPANTS
7. THERMAL TRANSMITTANCE
8. GLAZING AREA AND QUALITY
9. SURFACE TEMPERATURES
10. THERMAL MASS
11. EXTERNAL TEMPERATURE
12. INTERNAL AIR TEMPERATURE
A climate responsive approach to architectural design includes the integration of the following parameters during the different design phases:

- Orientation
- Massing
- Thermal zoning
- Wind flow
- Shading
- Materials’ specification
Vernacular buildings

• **Vernacular** architecture is an architectural style that is designed based on local needs, availability of construction materials and reflecting local traditions.

• The study of the vernacular (evolving over different time intervals) addresses the context as follows:

  ➢ Climate  
  • Sun  
  • Wind  
  • Precipitation  
  • Humidity  

  ➢ Topography and Geology  
  ➢ Methods of construction: resourceful use of materials and technology  
  ➢ Vegetation  
  ➢ Animals
Traditional Houses

- **Main Characteristics:**
  - Relationship to site
  - Thermal mass
  - Shading strategy
  - Size and position of openings / Ventilation
Traditional Houses

- Indoor/outdoor relationship
- Vegetation
- Orientation of entrance
- Materials
Climate – Clim’ate

“(region with certain) conditions of temperature, dryness, wind, light, etc.”

*oxford dictionary*

Climate encompasses the statistics of the following items in a given region over long periods of time:

- Temperature,
- Humidity,
- Atmospheric Pressure,
- Wind,
- Rainfall,
- Atmospheric Particle Count,
- Numerous other meteorological elements
PSYCHROMETRIC CHART / DESIGN STRATEGIES

Psychometric Chart

- Weather
- Comfort Zone (Baseline)
- + Thermal Mass
- + Natural Ventilation
- + Mass + Night Purging

4th HVAC Contracting Conference “Bridging the Gap Between Design, Construction and Facility Management”
SOLAR GEOMETRY

Understanding Solar Geometry is essential in order to:

1. Orient Buildings properly;
2. Apply passive design strategies (shading devices) in summer and in winter;
3. Appreciate seasonal changes in buildings and their surroundings, use the Sun to animate Architecture.
total solar radiation incident = total direct + total diffuse + ground reflected
The volume to surface ratio can be associated with energy efficiency whereby compact volumes tend to be more energy efficient.
Form and Solar Radiation

- **Area - 3m x 5m**
  - $A = 15 \text{ m}^2$
  - $V = 52.5 \text{ m}^3$
  - $EA = 71 \text{ m}^2$

- **Area = 2m x 7.5m**
  - $A = 15 \text{ m}^2$
  - $V = 52.5 \text{ m}^3$
  - $EA = 81.5 \text{ m}^2$

- **Radius = 2.2m**
  - $A = 15 \text{ m}^2$
  - $V = 52.5 \text{ m}^3$
  - $EA = 63 \text{ m}^2$

- **Radii = 1.8m, 2.2m**
  - $A \text{ at base} = 15 \text{ m}^2$
  - $V = 44 \text{ m}^3$
  - $EA = 55 \text{ m}^2$
Form and Solar Radiation

Solar insolation based on orientation and angle
Courtyards

Proportion of negative spaces with respect to solar incidence

A square courtyard that has a height to width ratio of 1 to 1 will have an incident radiation fraction (IRF) of about 45% solar radiation falling on the walls and the floor.

Other estimated values are presented as follows:

<table>
<thead>
<tr>
<th>H/W ratio</th>
<th>IRF</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>65%</td>
</tr>
<tr>
<td>1.5</td>
<td>35%</td>
</tr>
<tr>
<td>2.0</td>
<td>30%</td>
</tr>
</tbody>
</table>

The percent represent decreasing solar radiation on the walls which will result in reducing the urban heat island effect and lowering the cooling loads inside buildings.
The sun path diagram is a useful tool that allows a thorough understanding of solar altitude and azimuth.

Particular Sun Path Diagram relate to different latitude.
SUN PATH DIAGRAM

AZIMUTH / ALTITUDE

Azimuth

Altitude
SUN PATH DIAGRAM
Façade orientation (360 Degree Rotation)
SUN PATH DIAGRAM

December Animation
SUN PATH DIAGRAM

June Animation
SUN PATH DIAGRAM

Noon Animation / Year
SUN PATH DIAGRAM

Same Hour during the Year
SUN PATH DIAGRAM

During the Month
SUN  WIND  LIGHT
The prevailing wind conditions at the proposed location of the building play a significant role in its design.

Positive and negative pressure zones can be used for natural ventilation.

The position of supply and exhaust openings must be aerodynamically efficient.
A building’s massing configuration affect wind movement both inside and outside a building.

Both issues affect energy consumption because proper ventilation measures reduce the cooling loads due to natural ventilation strategies (cross, stack, night time cooling).
WIND FLOW IN BUILDINGS

• Single sided ventilation
• Cross Ventilation
• Stack ventilation and cooling tower
• Night-time cooling
Single Sided Ventilation

The incoming and outgoing wind is confined to one elevation
Cross Ventilation

The incoming and the outgoing wind relates to opposite (or adjacent) elevations
Cross Ventilation

An approximate calculation of the cooling capacity

4.155 Cross ventilation cooling capacity. Heat removed per unit floor area (based upon a 3°F [1.7°C] temperature difference) as a function of size of inlet openings and wind speed.
Cross Ventilation

Simulations based on computational fluid dynamics are very helpful to understand the patterns of wind-flow in internal and outdoor spaces.
Cross Ventilation

Do Vs Don’t

Don’t

Do
Stack Ventilation
Stack Ventilation

Different approaches and applications
Stack Ventilation
Stack Ventilation

An approximate calculation of the cooling capacity

4. Adjust stack openings and/or height as necessary to obtain desired cooling capacity.
Stack Ventilation
Wind Towers
Wind Towers
Night Ventilation of Thermal Mass
Solar Chimney
Solar Chimney

HEATING
DESIGN RECOMMENDATIONS

A number of design strategies should be understood and explored during the design process. These strategies are briefly described as follows:

• Increase perimeter daylight zone

• Extend the perimeter footprint to maximize the usable daylight area.

• Internal partitions and furniture affect the distribution of daylight.
Section showing the 2.5 rule of thumb which assumes that adequate daylight for office tasks will penetrate to a depth of 2.5 x the height of the window head above the workplane.
DESIGN RECOMMENDATIONS

Close up and interior view of a split blind system in the Lamparter Office Building near Stuttgart, Germany.
A south-facing lightshelf with blinds between the glass can reflect problematic light to the ceiling and back into the space.
DESIGN RECOMMENDATIONS

Slope ceilings to direct more light into a space.

Sloping the ceiling away from the fenestration area will help increase the surface brightness of the ceiling further into a space.

Sloping the ceiling downward from the head of the Window to the back of the room improves reflectance.
DESIGN RECOMMENDATIONS

Avoid direct beam daylight on critical visual tasks.

Poor visibility and discomfort will result if excessive brightness differences occur in the vicinity of critical visual tasks.
SUN  WIND  LIGHT

DESIGN RECOMMENDATIONS

summer day
Other Parameters

- Thermal Zoning
- Occupancy Patterns
Thermal Zoning

Example of Strategic Space Planning
Occupancy Patterns

Space usage and occupancy needs affect the spatial distribution of functions in a Project.

Spaces that are occupied from September till June (such as schools) and from 8:00 am till 3:00 pm allow for particular massing options in order to reduce cooling and heating requirements. In this case, schools (classrooms) do not require enhanced views.

Moreover, projects that have a year long continuous occupancy pattern would require a different approach.
Conclusions: Passive / Active

Passive approach (protecting from the sun) vs. active approach (harnessing the sun)
QUESTIONS?

Thank you for your attention

Nohad Boudani
Email: nohadb@inco.com.lb