Integration of Energy Efficiency Through Architectural Design

Presentation by TERI

10th June, 2010
Development of Environmental Building Guidelines & Regulations to Achieve Energy Efficiency in Bangalore City

The framework comprises of 9 Sections. These are mentioned below:

- **Solar passive design integration in new buildings.**
- **Provide roof treatment to cut heat gains.**
- **Window design for day lighting, ventilation and to reduce solar heat gains.**
- Energy Efficient Artificial lighting & Renewable energy based external lighting
- Energy efficient air conditioning design for buildings.
- Use of BEE labelled equipments and appliances to achieve energy efficiency in new and existing buildings.
- Solar water heating systems for residential and commercial buildings.
- Energy efficient electrical systems for building
- Perform mandatory energy audit for existing commercial buildings with connected load in cases of 500kW or 600KVA and reduce energy consumption by 20% over previous year.

... the technic for achieving thermal and visual comfort in buildings with optimum use of energy/natural resources

They all say they are doing it!! How do I do it??????
Optimize energy performance - Methodology

- Apply bio climatic architectural principles and use onsite sources and sinks
- Relax design criteria to reduce demand
- Use efficient lighting, equipment, space conditioning, water heating systems and effective controls.
- Use renewable forms of energy to meet a part of consumption.

.....Integrated design process
Energy-efficient buildings in India

Overview

Climatic zones

- Cold and sunny
- Cold and cloudy
- Composite
- Hot and dry
- Moderate
- Warm and humid

**Moderate**

Climatic conditions usually fall in the favourable range throughout the year. Annual mean maximum is 28° while annual mean minimum is 18°. Relative humidity varies from 20% to 55% in dry periods to 55% to 90% in the monsoon.
Psychometric Chart showing comfort zone & passive techniques to extend the comfort band for Bangalore

Psychrometric Chart
Location: Bangalore,
Frequency: 1st January to 31st December
Weekday Times: 00:00-24:00 Hrs
Weekend Times: 00:00-24:00 Hrs
Barometric Pressure: 101.36 kPa
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SELECTED DESIGN TECHNIQUES:
1. exposed mass + night-purge ventilation
2. natural ventilation
Bioclimatic architectural principles

To respond to the climate analysis

- Site planning/Landscaping
- Orientation
- Positioning of windows, shading
- Selection of materials for wall, roof, windows, including insulation
- Optimized Building envelope
- Passive cooling – Advanced techniques
- Day lighting
Landscaping to moderate microclimate temperature, provide shade, provide wind buffer
Orientation

- Daylight availability

- Sun path diagram, to keep away the sun and reduce external heat gains
Sun path for Bangalore

Bangalore
Latitude = 13°
Longitude = 77.6°
Solar Radiation Analysis – Orientation Optimization

Average daily solar radiation received on North orientation facade
Solar Radiation Analysis – Orientation Optimization

Average daily solar radiation received on South orientation facade
Solar Radiation Analysis – Orientation Optimization

Average daily solar radiation received on East orientation facade
Solar Radiation Analysis – Orientation Optimization

Average daily solar radiation received on West orientation facade
Building Form / surface to volume ratio

Buildings that are compact and have low S/V ratio are preferred.
Optimization of Building Envelope

- Windows / Fenestration / Aperture
- Walls / Opaque surfaces
- Roof
Fenestration and shading devices

- Windows are most vulnerable to heat gains and losses.

- Heat gain through glazed surfaces determined by the direct gain component (defined by shading coefficient) and U-value

- Window size and location should be determined by:
  - Orientation
  - Daylight requirement
  - Glazing type
  - external shading
  - wind direction
  - Thermal comfort
Total Heat Gain

Electromagnetic Spectrum at Terrestrial Level

TOTAL HEAT GAIN

Heat Gain due to direct solar radiation

Amount of heat Transferred due to temperature difference

UV  Visible  Near Infra Red  Far Infra Red

.25  .38  .78  2.60  50 microns
Solar incident energy = 800 W
Temperature differential = 20° C

Solar Factor of glass is: 0.3

U Value of DGU : 3

240 Watts

60 Watts

Total Heat Gain = 300 Watts

80%
Reducing Heat Gain: Tropical Countries

U Value
X
Temperature difference

Solar Factor
X
Amount of Solar Energy Incident

Reducing:
Solar Factor

Optimise Energy Performance
Solar Heat Gain Coefficient

- Aim is to minimize the solar heat gain coefficient.
  - Selection of glass
  - External shading devices
  - Combination of external shading & glass.
<table>
<thead>
<tr>
<th>Product</th>
<th>SHGC</th>
<th>U Value</th>
<th>LT (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear Glass</td>
<td>0.72</td>
<td>3.16</td>
<td>79%</td>
</tr>
<tr>
<td>Body Tinted</td>
<td>0.45</td>
<td>3.24</td>
<td>65%</td>
</tr>
<tr>
<td>Hard Coated: Solar Control</td>
<td>0.26</td>
<td>3.27</td>
<td>24%</td>
</tr>
<tr>
<td>Soft Coated: Solar Control</td>
<td>0.18</td>
<td>3.08</td>
<td>15%</td>
</tr>
<tr>
<td>Low E</td>
<td>0.56</td>
<td>2.33</td>
<td>61%</td>
</tr>
<tr>
<td>Solar Control + Low e</td>
<td>0.23</td>
<td>1.77</td>
<td>41%</td>
</tr>
</tbody>
</table>
Design External Shading Devices

Solar Angles to be cut on various cardinal directions

<table>
<thead>
<tr>
<th>Cardinal Directions</th>
<th>HSA (Horizontal Sun Angle) in Degrees</th>
<th>VSA (Vertical Solar Angle) in Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>37.8</td>
<td>79.4</td>
</tr>
<tr>
<td>East</td>
<td>-1</td>
<td>33.2</td>
</tr>
<tr>
<td>West</td>
<td>-5.9</td>
<td>58</td>
</tr>
<tr>
<td>South</td>
<td>-68.9</td>
<td>85.1</td>
</tr>
<tr>
<td>North-East (NE)</td>
<td>44</td>
<td>42.3</td>
</tr>
<tr>
<td>North-West (NW)</td>
<td>-50.9</td>
<td>68.3</td>
</tr>
<tr>
<td>South-East (SE)</td>
<td>-46</td>
<td>43.3</td>
</tr>
<tr>
<td>South-West (SW)</td>
<td>39.1</td>
<td>64</td>
</tr>
</tbody>
</table>
## Combined Impact of Glass & Shading

### Combined Impact of Glass & Shading to reduce Solar Heat Gain Coefficient

Net SHGC = SHGC\textsubscript{Glass} * M (Multiplication Factor)

<table>
<thead>
<tr>
<th>Location</th>
<th>Orientation</th>
<th>Overhang 'M' factor for the projection factor</th>
<th>Vertical Fin 'M' factor for projection factor</th>
<th>Overhang + Vertical Fin 'M' factor for projection factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Latitude 15° or greater</td>
<td>N</td>
<td>0.88 0.8 0.76 0.73</td>
<td>0.74 0.67 0.58 0.52</td>
<td>0.64 0.51 0.39 0.31</td>
</tr>
<tr>
<td></td>
<td>E/W</td>
<td>0.79 0.65 0.56 0.5</td>
<td>0.8 0.72 0.65 0.6</td>
<td>0.6 0.39 0.24 0.16</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>0.79 0.64 0.52 0.43</td>
<td>0.79 0.69 0.6 0.56</td>
<td>0.6 0.33 0.1 0.02</td>
</tr>
<tr>
<td>Less than 15° North Latitude</td>
<td>N</td>
<td>0.83 0.74 0.69 0.66</td>
<td>0.73 0.65 0.57 0.5</td>
<td>0.59 0.44 0.32 0.23</td>
</tr>
<tr>
<td></td>
<td>E/W</td>
<td>0.8 0.67 0.59 0.53</td>
<td>0.8 0.72 0.63 0.58</td>
<td>0.61 0.41 0.26 0.16</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>0.78 0.62 0.55 0.5</td>
<td>0.74 0.65 0.57 0.5</td>
<td>0.53 0.3 0.12 0.04</td>
</tr>
</tbody>
</table>
Building envelope: roof

Roof receives significant solar radiation
first principles can be fairly simple and are universal
e.g. solar heating processes which happen everywhere

sun on roof surface leads to temperature rise and temperature rise to heat transfer which occurs on both sides affecting the outdoor environment as well as room temperature below and everything gets involved…
Reduction of Heat Gains through Roof

- Green Roof Concept
- Use of high reflective material on roof top
- Thermal insulation for roof
- External shading for roof
ECBC Recommendation for Building Envelope

**Roof construction**

Maximum Recommended U-value of roof assembly for moderate climate of Bangalore is 0.409 W/m²K for daytime and 24-hr building.

**Opaque wall construction**

Maximum Recommended U-value of opaque wall for moderate climate of Bangalore is 0.440 W/m²K for daytime and 24-hr building.

**Vertical fenestration**

Maximum Recommended U-value of vertical fenestration for moderate climate of Bangalore is 6.90 W/m²K and maximum SHGC for WWR <=40% is 0.40, for 40%<WWR<=60%, maximum SHGC recommended is 0.30.
External Shading of Building Envelope in Bangalore

Shading of East & West walls

Shading of Roof

Life Cycle Cost Analysis for building envelope options
Daylight harvesting in CII-Godrej Green business centre building reduced 50% lighting energy consumption.
Factors affecting daylight integration

- Height to Separation Ratio between buildings.
- Window Wall Ratio (WWR)
- Visible Light Transmittance of Glass
Daylight integration in buildings

Residential naturally ventilated buildings

<table>
<thead>
<tr>
<th>H/S ratios (height to separation between buildings)</th>
<th>Minimum WWR (%) required for adequate day lighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:5</td>
<td>10</td>
</tr>
<tr>
<td>1:4</td>
<td>10</td>
</tr>
<tr>
<td>1:3</td>
<td>10</td>
</tr>
<tr>
<td>1:2</td>
<td>20</td>
</tr>
<tr>
<td>1:1</td>
<td>20</td>
</tr>
<tr>
<td>2:1</td>
<td>50</td>
</tr>
<tr>
<td>3:1</td>
<td>60</td>
</tr>
</tbody>
</table>

Commercial Naturally ventilated buildings

<table>
<thead>
<tr>
<th>H/S ratio (height to separation between buildings)</th>
<th>Minimum WWR (%) required for adequate day lighting</th>
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<tr>
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</tr>
<tr>
<td>1:1</td>
<td>20</td>
</tr>
</tbody>
</table>
Innovative daylight systems

*Fig 20: Light shelf for better distribution of daylight*

*Fig 23: Light well type*

*Fig 22: Movable louver*

*Fig 30: Typical light pipe*
Conclusions from Building envelope

- Optimization of Window design is crucial to achieve energy efficiency in buildings

- Optimization of roof is crucial to achieve energy efficiency in buildings
Passive cooling techniques to achieve thermal comfort

Natural Ventilation

Evaporative cooling
Passive cooling techniques - Ventilation

- The wall towards the south is made into a blank wall, allowing the breeze to flow over the building, which in turn creates a negative pressure and starts pulling fresh air from north into the building. Ventilation is enhanced by solar chimneys and vents.
Integration of Passive Architectural Building Design Concepts in Building Regulations of Bangalore City
Mandatory Clause: (Bye law section 3.2.11)
All exposed roof in air conditioned spaces and naturally ventilated spaces shall comply with the ECBC 2007 requirement or shall be shaded.

What is ECBC roof
ECBC roofs are insulated roof, with high solar reflectance.

Roof assembly U-factor requirements as per ECBC 2007

<table>
<thead>
<tr>
<th>Climate zone</th>
<th>24-Hour use buildings Hospitals, Hotels, Call centres etc.</th>
<th>Daytime use buildings Other building Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate</td>
<td>Maximum U-factor of the overall assembly (W/m²K)</td>
<td>Maximum U-factor of the overall assembly(W/m²K)</td>
</tr>
<tr>
<td></td>
<td>U-0.409</td>
<td>U-409</td>
</tr>
</tbody>
</table>
Integration in Building bye law - Guideline on Window design

**Mandatory Clause:** (Bye law section 3.3, (e))

In air conditioned spaces, windows should comply with the ECBC requirement in terms of U-value and SHGC (Solar Heat Gain Coefficient).

**Vertical fenestration U factor and SHGC Requirement as per ECBC 2007**

<table>
<thead>
<tr>
<th>Climate</th>
<th>Maximum U-factor (W/m²-K)</th>
<th>Maximum SHGC for WWR ≤ 40%</th>
<th>Maximum SHGC for 40%&lt;WWR≤60%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate</td>
<td>6.9</td>
<td>0.4</td>
<td>0.3</td>
</tr>
</tbody>
</table>

In naturally ventilated buildings, windows should be shaded to cut down summer sun and for protection against rains.
Guidelines on Solar Passive Architectural Design

Benefits:
In air conditioned buildings -
Through ECBC compliant or shaded roof & window, annual energy saving potential is between 10-15%. Pay back period is less than 5 years. Increase in initial cost 1 – 1.5 %.

Naturally ventilated build –
Through ECBC compliant or shaded roof & shaded window, discomfort hours in the year are less than 10% and temperature difference in peak summers of such buildings are about 1 – 2 deg C lower.
Thank you