Envelope Optimization

Approach to Sustainability

NBC Chapter 11: section 8

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Team

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Optimize energy performance

* Apply bio climatic architectural principles and use onsite sources and sinks
* Use of efficient envelope materials
* 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

Integrated Approach

- Bioclimatic design
- Wall optimization
  - Roof optimization
  - Fenestration optimization
- Daylight optimization
- Artificial lighting
  - Daylight integration
- HVAC
- Low energy strategies
- Building Energy Performance
Window to Wall Ratio

Wall Assembly Options

Insulation Options – Glass wool

Envelope

Insulation Options – XPS

Glazing Options

Building Envelope

- Walls / Opaque surfaces
- Roof
- Windows / Fenestration / Aperture
Walls
Thermal performance of wall

* Insulation
* High thermal mass
* Air Cavity
* High SRI coating

Walls

* Wall with insulation
  * Rigid or semi rigid blocks and boards,
  * Boards with impact or weather resistant surfaces suitable as exterior grade material,
  * Loose fill,
  * Foam and dry spray, and
  * Blankets, felts or sheets.
* Wall with high thermal mass
* Wall with Air Cavity
Walls

Wall with Air Cavity

Walls

* Wall with high SRI coating
* Reflection of incident heat
*Roof with overdeck insulation
*Cool Roofs
*Green Roof

**Building envelope: roof**

- 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...
Roofs

* Roof insulation through:
  * Use of preformed insulation materials
    * 1) Expanded polystyrene sheet.
    * 2) Extruded polystyrene sheet.
    * 3) Polyurethane/polyisocyanurate sheet.
    * 4) Perlite board.
  * In-situ application using spray applied polyurethane
  * Conventional roof insulation practices
  * Other traditional practices of roof insulation
Impact of insulation

Table 2 Typical Thermal Performance of Flat Roof Constructions

<table>
<thead>
<tr>
<th>SI No.</th>
<th>Specification of Roof</th>
<th>U Values</th>
<th>SHGC</th>
<th>VLT</th>
<th>Reduction in TR Load (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(1) W/(m² K)</td>
<td>(2) W/(m² K)</td>
<td>(3) W/(m² K)</td>
<td></td>
</tr>
<tr>
<td>i)</td>
<td>100 mm RCC</td>
<td>3.59</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii)</td>
<td>100 mm RCC + 100 mm lime concrete</td>
<td>2.78</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>iii)</td>
<td>100 mm RCC + 50 mm foam concrete + waterproofing</td>
<td>1.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>iv)</td>
<td>50 mm RCC + 25 mm expanded polystyrene</td>
<td>1.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>v)</td>
<td>50 mm expanded polystyrene + 50 mm RCC + waterproofing</td>
<td>0.62</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>vi)</td>
<td>25 mm expanded polystyrene + 50 mm RCC</td>
<td>1.09</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Building envelope optimization for Air conditioned and Non Air conditioned spaces

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Roof U-Value</th>
<th>Wall U-Value</th>
<th>Glazing View Window U-Value</th>
<th>SHGC</th>
<th>VLT</th>
<th>Reduction in TR Load (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Case</td>
<td>2.49</td>
<td>3.17</td>
<td>6.17</td>
<td>0.815</td>
<td>0.88</td>
<td></td>
</tr>
<tr>
<td>ECBC Roof Case _Over deck</td>
<td>0.36</td>
<td>3.17</td>
<td>6.17</td>
<td>0.815</td>
<td>0.88</td>
<td>1.76</td>
</tr>
<tr>
<td>ECBC Roof Case _Under deck</td>
<td>0.37</td>
<td>3.17</td>
<td>6.17</td>
<td>0.815</td>
<td>0.88</td>
<td>-0.18</td>
</tr>
<tr>
<td>Glazing optimised Case</td>
<td>2.49</td>
<td>3.17</td>
<td>1.59</td>
<td>0.28</td>
<td>0.4</td>
<td>4.20</td>
</tr>
<tr>
<td>Cumulative 1(Over Deck)</td>
<td>0.36</td>
<td>3.17</td>
<td>1.59</td>
<td>0.28</td>
<td>0.4</td>
<td>9.67</td>
</tr>
<tr>
<td>Cumulative2 (Under Deck)</td>
<td>0.37</td>
<td>3.17</td>
<td>1.59</td>
<td>0.28</td>
<td>0.4</td>
<td>7.93</td>
</tr>
</tbody>
</table>
Building envelope: roof

- Roof receives significant solar radiation
- Roof insulation particularly important for hot climates
  - inverted earthen pots
  - insulating material e.g vermiculite insulation
  - reflective surfaces e.g broken china mosaic, reflective paints for inclined roofs

Roof

Cool Roofs (minimum solar reflectance of 0.7 and thermal emittance of 0.75)
- Roof coatings
- Broken china mosaic terracing
- Cool colours
- Traditional methods (lime wash)
## Roof

Green Roof (evapo transpiration and thermal mass)

### Wall Requirements

**Table 4.3.2 Opaque Wall Assembly U-factor and Insulation R-value Requirements**

<table>
<thead>
<tr>
<th></th>
<th>Maximum U-factor of the overall assembly (W/m²°C)</th>
<th>Minimum R-value of insulation alone (m²°C/W)</th>
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<th>Minimum R-value of insulation alone (m²°C/W)</th>
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</thead>
<tbody>
<tr>
<td>Composite</td>
<td>U-0.440</td>
<td>R-2.10</td>
<td>U-0.440</td>
<td>R-2.10</td>
</tr>
<tr>
<td>Hot and Dry</td>
<td>U-0.440</td>
<td>R-2.10</td>
<td>U-0.440</td>
<td>R-2.10</td>
</tr>
<tr>
<td>Warm and Humid</td>
<td>U-0.440</td>
<td>R-2.10</td>
<td>U-0.440</td>
<td>R-2.10</td>
</tr>
<tr>
<td>Moderate</td>
<td>U-0.431</td>
<td>R-1.80</td>
<td>U-0.397</td>
<td>R-2.00</td>
</tr>
<tr>
<td>Cold</td>
<td>U-0.369</td>
<td>R-2.20</td>
<td>U-0.352</td>
<td>R-2.35</td>
</tr>
</tbody>
</table>

### Roof Requirement

**Table 4.3.1 Roof assembly U-factor and Insulation R-value Requirements**

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<tbody>
<tr>
<td>Composite</td>
<td>U-0.261</td>
<td>R-3.5</td>
<td>U-0.409</td>
<td>R-2.1</td>
</tr>
<tr>
<td>Hot and Dry</td>
<td>U-0.261</td>
<td>R-3.5</td>
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</table>
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

Solar Heat Gain Coefficient (SHGC): SHGC refers to the ratio of the solar heat that passes through the glazing to the total incident solar radiation. The lower the SHGC, the lesser the direct incident heat gains from the glazing surfaces.
TOTAL HEAT GAIN

Why SHGC is important?

- Heat Gain due to direct solar radiation
- Amount of heat transferred due to temperature difference

SHGC

U - Value

Solar incident energy = 800 W
Temperature differential = 20º C

- SHGC of glass is = 0.3
- U Value of glass = 3.0

240 Watts
60 Watts

Total Heat Gain = 300 Watts

Source: ST.Gobain
Vertical Screening through Jalis
Fenestrations (AC and non AC spaces)

* Window sizes and heights
* Separate apertures for view and daylight
* WWR
* Glass Specifications
* Frames
* Shading Devices

Fenestrations

* Window sizes and heights
  * Height of window head
  * Sill height (height from floor to the bottom of the window)
* Use of separate apertures for view and daylight
* Window wall ratio (WWR)
Fenestrations

* Glass Specifications
  * Visible transmittance (affecting daylight),
  * Visible reflectance (affecting heat and light reflection),
  * Thermal transmittance or U value (affecting conduction heat gains),
  * Solar heat gain (affecting direct solar gain),
  * Spectrum selectivity (affecting daylight and heat gain),
  * Glazing material, and
  * Glazing colour (affecting the thermal and visual properties of glazing systems).

Fenestrations

* Shading Devices
  * External shading and screens/jalis,
  * Internal shading, and
  * Use of solar control glass.
Window Wall Ratio

- **Window-Wall-Ratio (WWR):** The Window Wall Ratio refers to the ratio of the total fenestration area to the gross wall area.
- **ECBC in a prescriptive approach recommends a maximum WWR of 60%.

The portion of the glazing which lets in light is same in both cases. This is why WWR is important. The rest of the glass does not contribute to daylight, only permits more heat inside.
Optimize glazing design

- Recommended to maintain a maximum of 40% WWR
- ECBC allows up to 60% in prescriptive approach and 40% in whole building approach
- Use a combination of
  - external shading and high performance glass
  for proper solar control
  - Day lighting and glare control

Glazing Requirements
(for sun control and day lighting)

<table>
<thead>
<tr>
<th>Vertical Fenestration U-factor and SHGC Requirements (U-factor in W/m²°C)</th>
<th>WWR = 40%</th>
<th>40% &lt;WWR&lt;60%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate</td>
<td>Maximum U-factor</td>
<td>Maximum SHGC</td>
</tr>
<tr>
<td>Composite</td>
<td>3.30</td>
<td>0.25</td>
</tr>
<tr>
<td>Hot and Dry</td>
<td>3.30</td>
<td>0.25</td>
</tr>
<tr>
<td>Warm and humid</td>
<td>3.30</td>
<td>0.25</td>
</tr>
<tr>
<td>Moderate</td>
<td>6.90</td>
<td>0.40</td>
</tr>
<tr>
<td>Cold</td>
<td>3.30</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Mandatory controls for daylit areas

<table>
<thead>
<tr>
<th>Minimum VLT Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window Wall Ratio</td>
</tr>
<tr>
<td>0-0.3</td>
</tr>
<tr>
<td>0.31-0.4</td>
</tr>
<tr>
<td>0.41-0.5</td>
</tr>
<tr>
<td>0.51-0.6</td>
</tr>
<tr>
<td>0.61-0.7</td>
</tr>
</tbody>
</table>
## U-value thresholds specified in the ECBC

<table>
<thead>
<tr>
<th></th>
<th>GLASS</th>
<th>WALLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate</td>
<td>Maximum U-factor (W/sq.m.-°C)</td>
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</tr>
<tr>
<td>Moderate</td>
<td>6.9</td>
<td>Moderate</td>
</tr>
<tr>
<td>Cold</td>
<td>3.3</td>
<td>Cold</td>
</tr>
</tbody>
</table>

### Building Envelope impact on Energy Performance
Energy Efficient Envelope - Wall

Conventional case

- 9 inch Brick Wall
- 1 inch cement plaster on both sides

U Value: 0.32 btu/ft²/hr/°F

Energy Efficient Case

- 9 inch Brick Wall
- 1 inch plaster on both sides
- 3 inch Insulation

U Value: 0.07 btu/ft²/hr/°F

Energy Efficient Envelope - Roof

Conventional case

- 1 inch brick tile
- 1 inch plaster
- 4 inch brick coba
- 8 inch RCC

U Value: 0.40 btu/ft²/hr/°F

Energy Efficient Case

- 1 inch brick tile
- 3 inch insulation
- 1 inch plaster
- 4 inch brick coba
- 8 inch RCC

U Value: 0.07 btu/ft²/hr/°F
**Energy Efficient Envelope-Glass**

**Conventional case**

**U Value** - 1.087 btu/ft²/hr/degF  
SHGC – 0.815

**Energy Efficient Case**

**U Value** - 0.58 btu/ft²/hr/degF  
SHGC – 0.25 for WWR <40%

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**Impact of Efficient Envelope**

**Impact on Cooling load (TR)**

- **Base Case**: 233
- **Efficient Envelope**: 163  
  - 30 %

**Impact on EPI (kWh/m²/yr)**

- **Base Case**: 202
- **Efficient Envelope**: 168  
  - 17 %
Examples of optimized design

HAREDA, Panchkula
CESE building, IIT Kanpur

Suzlon OneEarth, Pune
Integrated Renewable Energy Technologies

Scope of ECBC

- Building Envelope
- Interior and Exterior Lighting
- Mechanical Systems
- Service Water Heating
- Electrical Power and Motors
Compliance Approaches

- Mandatory provisions to be complied
- Prescriptive method
- Whole Building Performance Method
  - (use of simulation tool)
- Trade-off option
  - (applicable to Envelope only)

Comments