Cooling Potential of Natural Ventilation for Affordable Housing in India

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you are here --> CONTEXT + DIGITAL MODEL ANALYSIS

BUILDING COMPONENT DESIGN

FIELD DATA COLLECTION + MODEL VERIFICATION
Context

Bhuj Earthquake: January 26, 2001

20,000 deaths / 167,000 injuries / 400,000 homes destroyed

Context
Post-Earthquake Re-Development Efforts

currently there are 74 slums in Bhuj
  • 33% of city population
  • 11,232 families

Why should thermal comfort be a primary consideration in re-development efforts?

There is a wealth of evidence indicating that housing and construction standards are almost exclusively based on technical norms, engineering knowledge and architectural design aesthetics. Consequently, standards of “adequate housing” or “sustainable housing” in the modern era tend to be informed by technological rather than health rationales, despite the fact that many housing laws have their origins in public health concerns. Similarly, building codes and national regulations governing the production and approval of buildings often tend to be vague, requiring buildings to be “safe”, to be equipped with “adequate ventilation options” or “functional heating systems”. These requirements provide little information on what the minimum standards of healthy housing are, and what characteristics need to be fulfilled to provide adequate shelter from the perspective of human health.

World Health Organization
2010 International Workshop on Housing, Health and Climate Change
Objectives
Striving for Thermally Autonomous Affordable Housing

• Understand climate requirements to maximize passive cooling potential of the building.
• Evaluate thermal performance of climate specific vernacular buildings to typical new construction.
• Evaluate thermal performance relative to an established metric that supports passive cooling strategies: ASHRAE Standard 55-2004*
• Prioritize what changes to building envelope/operation will make the most impact on thermal comfort for the least cost.

* ASHRAE Standard 55-2004 is a US standard. Another standard that was recommended is more specific to India and can be found here: http://www.sciencedirect.com/science/article/pii/S2095263513000320
One report shows that this standard consistently predicts a higher comfort temperature than that of the ASHRAE equation by 1 °C.
Vernacular Dwellings and Materials
Madhapar Mistry Settlement - Bhuj

Madhapar Mistry Settlement*

Typical House Plan*

View Through Courtyard to Street

*drawings from Shilpa Mevada’s undergraduate CEPT University thesis “Continuity and Transformation of Kutch House-Form”
Hunnarshala Foundation
Merging New + Traditional Building Techniques for Sustainable Re-Development

Earthquake Re-Construction*
Slum Free Bhuj House Typology*
High Thermal Mass Walls + Highly Insulated Roof

*photo and drawing by Hunnarshala Foundation
Building Envelope in Informal Slum and Slum Resettlements

Climate specific building knowledge rarely manifests itself in low cost housing.
Climate Consultant 5.4 Bioclimatic Chart for Bhuj
-comfort conditions possible for 72% of year using passive strategies

Main Contributors to Thermal Comfort
36% - Adaptive Comfort Ventilation
23% - Sun Shading of Windows
16% - Evaporative Cooling
14% - High Thermal Mass + Night Flush Cooling
11% - Solar Heat Gain
Digital Model Inputs
Iteration 1 – DesignBuilder – Initial Building Materials Comparison
# Building Materials Comparison without Ventilation

<table>
<thead>
<tr>
<th>NO_V</th>
<th>BRICK</th>
<th>HIGH THERMAL MASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
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<td>R4</td>
<td><img src="image3" alt="Graph" /></td>
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<td>R23</td>
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<tr>
<td>R40</td>
<td><img src="image11" alt="Graph" /></td>
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</table>
Digital Model Inputs
Iteration 2 – DesignBuilder/CoolVent – Ventilation + Building Materials Comparison
## Building Materials vs. Opening Size and Position

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
<th>Year</th>
<th>Climate</th>
<th>Comfort</th>
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</thead>
<tbody>
<tr>
<td><strong>SSV</strong></td>
<td>single-scaled ventilation</td>
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<td></td>
<td></td>
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<tr>
<td><strong>CV_1</strong></td>
<td>cross-ventilation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CV_2</strong></td>
<td>cross-ventilation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CV_3</strong></td>
<td>cross-ventilation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Children's Rooms**

- **B_R1**: single wythe brick walls
- **B_R4**: single wythe brick walls
- **B_R40**: single wythe brick walls
- **HTM_R1**: high thermal mass walls
- **HTM_R4**: high thermal mass walls
- **HTM_R40**: high thermal mass walls

### Key
- SSV = Single-Scaled Ventilation
- CV_1, CV_2, CV_3 = Cross-Ventilation
- B_R1, B_R4, B_R40 = Brick Walls
- HTM_R1, HTM_R4, HTM_R40 = High Thermal Mass

Massachusetts Institute of Technology
Building Technology Program

NATURAL VENTILATION WORKSHOP
MIT 08-20-2014
No insulation and minimal ventilation yield and indoor temperature that is typically hotter than outdoor temperature.
Indoor temperature peaks are most affected by roof insulation level.
High thermal mass moderates indoor temperature, resulting in lower daily temperatures, but higher nightly temperatures.
Building Materials vs. Opening Size and Position

Window position and increase in affective area increases AC/H and decreases nightly indoor temperatures.
Highly insulated roof further decreases indoor temperature $3^\circ$ C.
Digital Model Inputs
Iteration 3 – DesignBuilder – Annual Ventilation + Building Materials Comparison

VENTILATION SCHEDULE
- CONSTANT - windows always open
- CALCULATED - windows open if T_out < T_in

VENTILATION TYPE

DESIGN BUILDER

BHUI EPW FILE → 3m X 3m X 3m CUBE

ROOF → clay tile + rice hull insulation

BUILDING MATERIAL

WALLS
- uninsulated brick
- high thermal mass
- insulated brick

<table>
<thead>
<tr>
<th>Material</th>
<th>R value</th>
<th>RSI value</th>
<th>thickness [m]</th>
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<tbody>
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<td>1.3</td>
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<td>double wythe insulated</td>
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<tr>
<td>high thermal mass</td>
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<tr>
<td>RSI value</td>
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<table>
<thead>
<tr>
<th>open area [m²]</th>
<th>ΔH [m]</th>
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<tr>
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<tr>
<td>cross ventilation 1</td>
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</tr>
<tr>
<td>cross ventilation 2</td>
<td>1</td>
</tr>
<tr>
<td>cross ventilation 3</td>
<td>2</td>
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</table>
Iteration 3 Results
Annual Hourly Comfort Maps for 32 Materials + Ventilation Comparisons

Maps run in descending order from highest to lowest % uncomfortable hours.
Iteration 3 Results

% HOURS ABOVE 80% ACCEPTABILITY RANGE

VENTILATION
- CONSTANT
- NIGHT FLUSH

ROOF INSULATION
- R1 / RSI .156
- R4 / RSI .65
- R8 / RSI 1.33
- R40 / RSI 7

WALL MATERIAL
- 2 WYTHE BRICK
- .5m THERMAL MASS
- 1 WYTHE BRICK R8 INSULATION
- 2 WYTHE BRICK R8 INSULATION
Design Ideas and Next Steps

potential modifications to promote ventilation and decrease daily high indoor temperatures

current Slum Free Bhuj house typology
Thank you
Questions?

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