Architectural Design Optimization for Energy efficiency using Mixed-mode system: 
*Tracing the Challenges and Opportunities in a Warm-humid Climatic Context*

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Presentation Outline

- Context
- Challenges and barriers
  - Climate
  - Stakeholders
  - Simulation
  - Thermal Comfort
- Conclusion
- Acknowledgement
- References
Context

USAID ECO-III Project – Establishment of **Regional Energy Efficiency Centres (REECs)** in India

- **REEC Kolkata**
  - Home Appliances
  - West Bengal Renewable Energy Development Agency

- **REEC Nagpur**
  - Small and Medium Enterprises
  - SEE-Tech Solutions Pvt. Ltd.

- **REEC Ahmedabad**
  - Buildings
  - CEPT University

- Enhance energy efficiency awareness and **education** among energy end-users
- Facilitate showcasing and **demonstration** of energy efficient products for public at large
- **Promote development** (incubation) of energy efficient technologies
- **Encourage research** and interdisciplinary **collaboration** on energy efficiency
- **Catalyze** the development and growth of energy efficiency **market and business** in the country
Context

Energy Conservation Building Code (ECBC)

- Covers new buildings and ensures minimum energy performance requirements
- Launched by Govt. of India on 27th May, 2007
- Building components included
  - Building Envelope (Walls, Roofs, Windows)
  - Lighting (Indoor and Outdoor)
  - Heating Ventilation and Air Conditioning (HVAC) System
  - Solar Water Heating and Pumping
  - Electrical Systems (Power Factor, Transformers)
Context

Initial Design Proposal:

- Reduce solar heat gain by incorporating different external shading devices - a combination of horizontal and vertical shading devices on south and south-west facades and vertical shading devices on north and east
- Hollow brick wall with insulation to reduce conductive heat gain from outside
- High performance glazing to mitigate solar radiation
- Multiple numbers of small openings with deep overhangs on south facade and relatively larger openings on the north
Context

Building description:

- Total **built-up area: 250m²**, distributed over three floors
  - Ground floor: Demonstration
  - First floor: Training & offices
  - Second floor: Rest rooms & terrace
- Overall **WWR: 20%**
Challenges and Barriers

CLIMATE: Warm and humid

- **High temperature**
  - Mean monthly: 19-30°C
  - Maximum > 40°C
  - Low diurnal range

- **High humidity**
  - Annual average RH: 78%
  - Moisture ingress, mould growth

- **Low wind**
  - 3-7m/s for 10 months
  - 50% of the blowing wind is Calm

- **High solar radiation**
  - Annual Global average: 4100Wh/m²
Challenges and Barriers

STAKEHOLDERS: Client, Architect and Product manufacturers

- **Public undertaking**
  - Absence of clarity in the program
  - Notions of ‘Green’ building limited to a building with no air conditioning
  - Restricted possibility of experimentation with construction techniques and materials beyond the given set of specifications
  - Current specifications are outdated
  - Limited budget leads to cutting down on the short-term expenditure

- **Interaction between stakeholders**

- Unavailability of appropriate *Technological solutions* to assist path-breaking designs in energy efficiency
Challenges and Barriers

SIMULATION-based Analysis

- Simulation inputs: Schedules for occupancy, activity, systems
- Modeling of mixed-mode system: temperature bands for natural ventilation

Simulation

Energy Performance

Energy Conservation Building Code – Envelope measures

‘Zoned’ Mixed-mode design (different spaces, same time)

Thermal Comfort

‘Change-over’ Mixed-mode design (same spaces, different times)

PMV – Modified (Adaptive thermal comfort)
Optimizing Building Envelop

Reducing Internal Loads

Passive strategies

Active strategies

Wall optimization
- Insulation
- Cavity

Window optimization
- Improved glazing: reflective and low-emissivity coatings
- Improved frame

Reducing Lighting Power Density (LPD)

Reducing Equipment Power Density (EPD)

Daylight sensors

Natural Ventilation

Daylighting

Efficient Packaged AC

Solar Absorption Cooling

Dehumidifiers

Process followed for ECBC compliance, showing various ECMs

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Challenges and Barriers

THERMAL COMFORT

- Mixed-mode
- Natural ventilation
- Increased air speed

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<table>
<thead>
<tr>
<th>RUN</th>
<th>DESCRIPTION</th>
<th>HVAC</th>
<th>NAT-VENT</th>
<th>MIXED-MODE</th>
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<tbody>
<tr>
<td>1</td>
<td>Cooling setpoint 24 °C</td>
<td>On</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>2</td>
<td>Cooling setpoint 26 °C</td>
<td>On</td>
<td>Off</td>
<td>Off</td>
</tr>
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<td>3</td>
<td>Without Ceiling fans</td>
<td>Off</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>4</td>
<td>With Ceiling fans</td>
<td>Off</td>
<td>On</td>
<td>Off</td>
</tr>
</tbody>
</table>
Challenges and Barriers

THERMAL COMFORT

- **PMV**
  - Mean Air temperature
  - Mean Radiant temperature
  - Relative humidity
  - Air speed
  - Clothing
  - Activity level

- Studies have shown **PMV model to predict thermal sensations warmer than occupants actually feel in naturally ventilated spaces**
Challenges and Barriers

THERMAL COMFORT

Mathematical model of PMV + Adaptive mechanisms = Thermal Comfort

Psychological adaptation: An occupant’s past thermal experiences have an impact on his expectations of comfort

Behavioral Adaptation: People change/slow down their metabolic rate (activity) when they feel warm

Fanger & Toftum

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Challenges and Barriers

MODIFIED PMV

- Spreadsheet for calculating hourly PMV (based on ASHRAE Thermal Comfort algorithms)

- Calculation inputs:
  - Mean air temperature (Simulation hourly results)
  - Mean radiant temperature (Simulation hourly results)
  - Relative humidity (Simulation hourly results)
  - Metabolic rate: 60 W/m² (light office work)
  - Clo value: 0.75 (winters), 0.5 (summers)

- Calculated PMV → Modified PMV
  - To account for slowing down of metabolic rate: metabolic rate reduced by 6.7% (based on Fanger & Toftum PMV extension model)
  - Resultant PMV adjusted using expectancy factor ‘e’ of 0.7
PPD decreases from 50 to 35% for Modified PMV

Decrease in PPD is more significant when air movement is increased using ceiling fans – *PPD calculated using Modified PMV presents a more realistic prediction of thermal comfort in naturally ventilated spaces (with ceiling fans assisting air movement)*
PPD increases from Run 1 to Run 2 in conditioned zones due to increase in cooling setpoint.

PPD Increases (to double) from Run 1 to Run 2 in non-conditioned zones due to unavailability of Nat Vent in Run 2 – *Nat Vent is an important strategy in non-conditioned zones*

PPD decreases (to about half) from Run 3 to Run 4 due to increase in air speed in Run 4 (ceiling fans)

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Run 1 (Mixed-mode AC) and Run 4 (Nat Vent + Ceilings fans) coincide, except for peak summer months – **Air-conditioning can be avoided during the rest of the year through passive measures**
Conclusion

• **Integrated Design Process** assumes greater importance in a multi-stakeholder participation scenario

• Change of role: **Technical assistance → Facilitation**

• Keep all stakeholders in the loop

• Vary the extent of engagement at each stage

• Need for a **Thermal Comfort Model for India** - Warm-humid climate

• Significance of **Ceiling Fans in Warm-humid climate** towards improving thermal comfort
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References

Thank you

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