"PARAMETRIC ANALYSIS OF RESIDENTIAL BUILDING WITH A CONTEXT TO ENERGY EFFICIENCY"

Bhavesh.N. Vekariya*1, Dr Ing A.K. Sing2, Asst. Prof. Anand Patel***3**

**1PG Student Indus University **
**2Director, IITE Indus University **
3Department of Civil Engineering Indus University
1-3Ahmedabad – 382115, Gujarat, India.

ABSTRACT: *India is witnessing a rapid increase in residential building floor space. Thus, the new residential building stock should be designed to maximize thermal comfort and to minimize energy requirements for cooling and ventilation. Building orientation is a significant design consideration, mainly about solar radiation and wind. In predominantly composite climate regions like Kutch (Hot and dry), and Chennai (warm and humid climate) which receive sunlight all year round, the building should be oriented to minimize solar gain. and maximize natural ventilation. The paper presents the integrating thermal comfort strategies, energy-efficient envelope, reduce solar heat gain and improve ventilation have been adopted in sample two bungalows of Ground plus one-story residential building model has been created on Revit architecture. The differences between in/outdoor air temperature of 2 bungalows were measured by using Revit architecture*

Keywords: *Parametric Analysis, Energy-efficiency, Thermal comfort, WWR, SHGC, U-value.*

1. Introduction

In India, Residential buildings have a large exposed façade area to built-up area ratio, resulting in the space cooling loads dominated by heat gains from the envelope. The penetration of air-conditioners in residential buildings is negligible, meaning the envelope characteristics are vital in maintaining thermal comfort. the building envelope consists of walls, roof, and fenestration (openings including windows, doors, vents, etc.). Design of building envelope influences heat gain/loss, natural ventilation, and daylighting, which, in turn, determines indoor temperatures, thermal comfort, and sensible cooling/heating demand.

The paper presents the results of integrating ventilation strategies and energy-efficient envelope in 2 residential projects located at Baladiya (Hot and dry), Chennai (warm and humid climate). The results of building energy simulation studies to understand the impact of these measures are presented. The simulations were carried out during design works conducted to recommend practical strategies for improving thermal comfort and reduce the energy required for cooling and ventilation in these building projects.

2. Objective

- To study the concept of energy efficiency with context to passive planning measure.
  To analyze a parametric model of a residential building with various iteration of passive planning measures.

3. Energy Efficient Design

Energy-efficient buildings (new construction or renovated exiting building) can be defined as a building that is designed to provide a significant decrease of energy need for heating and cooling independently of the energy and of the equipment that will be chosen to heat or cool the building.

3.1 Technique of Thermal comfort Building Envelope

1. Take suitable passive design measures for windows and walls to reduce the cooling thermal energy demand and improve thermal comfort

Measures I:- that can bring about 15%–20% reduction in cooling thermal energy demand: Use of light colors on a wall (absorptivity ≤0.4) + window shades with extended overhangs to cut off direct solar radiation on the window + insulated walls (U-value: 0.6 W/m2.K) + optimized natural ventilation.

Measures II: - that can bring about a 40%–45% reduction in cooling thermal energy demand: Package of Measures I + external movable shutters on windows.

Measures III that can bring about 50%–60% reduction in cooling thermal energy Package of Measures II + improved wall insulation (U-value: 0.5 W/m2. K) + use of double glazing in windows + better envelope air-tightness.

2. Design for adequate daylighting

Usually, 10%–15% window-to-wall ratio (WWR) in bedrooms and 30% WWR in the living room are needed to provide adequate daylighting.

3. Design the roof to reduce the cooling thermal energy demand and improve thermal comfort

Provide over-deck insulation and a highly reflective surface on the roof to minimize heat gain through the roof.

3.2 Energy-Efficient Design Strategies

Passive Design Strategies

- Building envelope
- Orientation
- Shading
- Insulation
- Daylight
- Natural ventilation
- cool roof

The main building envelope features influence the cooling thermal energy demand and thermal comfort.

- Size and location of window openings
- Shading system for windows
- Window properties
- Insulation properties of a wall
- Insulation properties of a roof
- Color and finish of exterior surfaces (walls and roofs)
- Natural ventilation
- Building air-tightness

3.3. Advantage of Energy-efficient Building.

1. **Energy and cost savings:** an energy-efficient building will have the benefit of lower energy, and maintenance costs.
2. **Lower emissions and overall environmental impact:** energy-efficient buildings have lower green building gas emissions due to their reduced reliance on fossil fuels.
3. **Better thermal comfort:** Proper designed mechanical systems and building components work together to manage comfortable indoor temperatures.
4. **Improved comfort and health:** continuous ventilation and fresh air throughout the building can lead to better well-being with occupants and as a result, a more productive workforce.

4. Methodology of Work

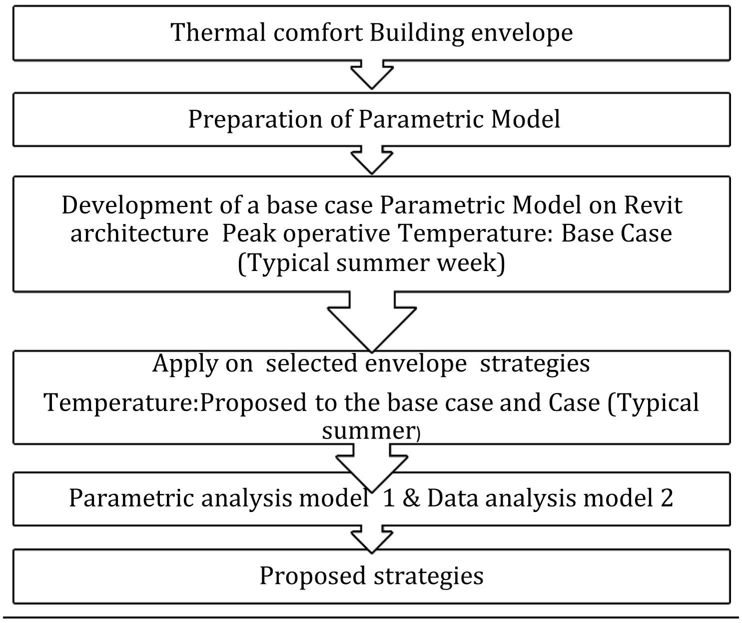

Figure 4.1: Flow chart of Methodology

5. Introduction of Parametric Model

The methodology stated here follows that adopted during a few day designs works carried out for 2 residential projects. The main purpose of the design works was to provide design recommendations for better thermal comfort and energy efficiency, specific to the requirements and limitations of the project.

1. Selection of sample bedrooms/ living room:
A sample of bedrooms/living room was selected in all 2 projects to analyses the impacts of the design recommendations. The sample bedrooms/ living rooms were selected based on their orientation, WWR, thermal comfort to account for different levels of solar and wind exposure.

2. Simulating the base case:
Energy models of the sample bedrooms/living room were developed in Revit software. Insert of the existing design is entered, details of the building envelope, and internal loads. These are non-conditioned spaces, as in residences air- conditioning is a matter of the residents' choice.

3. Simulation of the proposed envelope and ventilation, thermal comfort strategies:

Envelope and ventilation strategies are applied on the worst of the sample bedrooms/living room of the base case, i.e., like a bedroom with the highest peak operative temperature. The simulation says the peak operative temperature of the same summer day as the base case, after applying these strategies.

Strategies

1. Strategies to reduce solar heat gains through the building envelope by proper orientation, shading, and sizing of windows (external fixed and/or movable), insulation of roof and walls.

2. Strategies to improve ventilation, when desired, inside the building through window design and assisted ventilation.

3. WWR.

Table 1: Details of Internal loads of project

Parameter	Value	Unit	Schedules
Occupancy	5	persons/ bedroom/living room	Weekdays: 5 persons (9:00 pm to 6:00am) Weekends: 5 persons (11:00 pm to 7:00am) & (2:00 pm to 5:00 pm)
Lighting	28 W T-5 light (1 no.)		6:00pm to 11:00pm
Equipment	--		None

Table 2: Building Envelope Inputs for the 2 Residential Projects

	Project 1, Baladiya (Kutch)	**Project 2, Mullam (Chennai)**
Climate	(Hot and Dry)	(Warm and Humid climate)
Latitude & Longitude	N 22.30^0 E70.80^0	N 13.08^0 E80.27^0
Present Orientation of Building	**EW** orientation	**NS** orientation
Building Size	35 B X 70 L =2450 (sq. ft)	70 L X 35 B =2450(sq. ft)
External wall	230mm burnt brick with 15 mm plaster on both sides	200mm fly ash brick with 12 mm plaster on both sides
External wall (U value)	2.00 W/ m^2. K	1.90 W/ m^2.K
Floor & ceiling	**Considered Adiabatic for Intermediate Floors**	
Roof (U value)	3.70 W/ m^2.K	3.70 W/ m^2.K
Iteration	• Change in Material • Change in Building Orientation	• Change in Material • Change in Building Orientation

6. Analysis of Parametric Model

6.1 Project 1, Baladiya (Kutch)

This residential building Ground +1 story project is a story height of 10 ft" predominantly facing the **East and West** (Figure 6.1.1).

Base case simulation results: The base case simulation was carried out for 3 bedrooms/ 2 living rooms of a building in different orientations Bedroom/ living room with north façade exposed with window.

1. Bedroom/ living room with south façade exposed with window
2. Corner Bedroom with south and west façade exposed with the window on the south façade
3. Bedroom/living room with south and west façade exposed with window and glass door on west façade

Energy simulation was carried out in all 3 bedrooms and 2 living rooms to calculate peak operative temperature inside the building on a typical summer day. On the ground floor, there was a temperature difference of around 5°C between the coolest bedroom (~34°C Bedrooms 1 & living room 1) and the hottest bedroom (38.4°C in Bedroom 2 & 3 & living room 2).

- The first-floor bedrooms & living room had higher inside temperatures than the corresponding bedrooms/ living room on the ground floor. The temperature difference between the coolest and hottest bedrooms (37.9°C and 40.4°C in Bedrooms 2&3, and living room 2 respectively) of the top floor is around 2.5°C (figure 6.1.2)

- On the ground floors, the walls and windows contribute most of the heat gains, depending upon the orientation. On the top floor, the heat gain from the roof is most controlling.

Figure: - 6.1.1 Project 1, Baladiya.

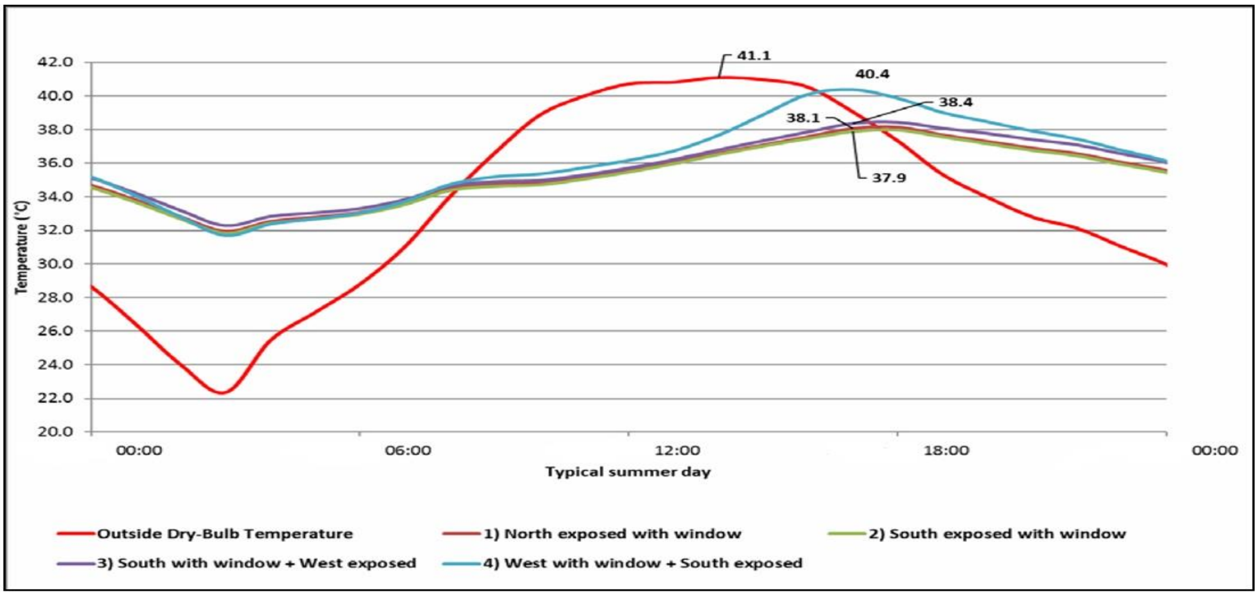

Figure 6.1.2: Peak operative temperatures for the base case on a typical summer day on the first floor (Project 1, Baladiya)

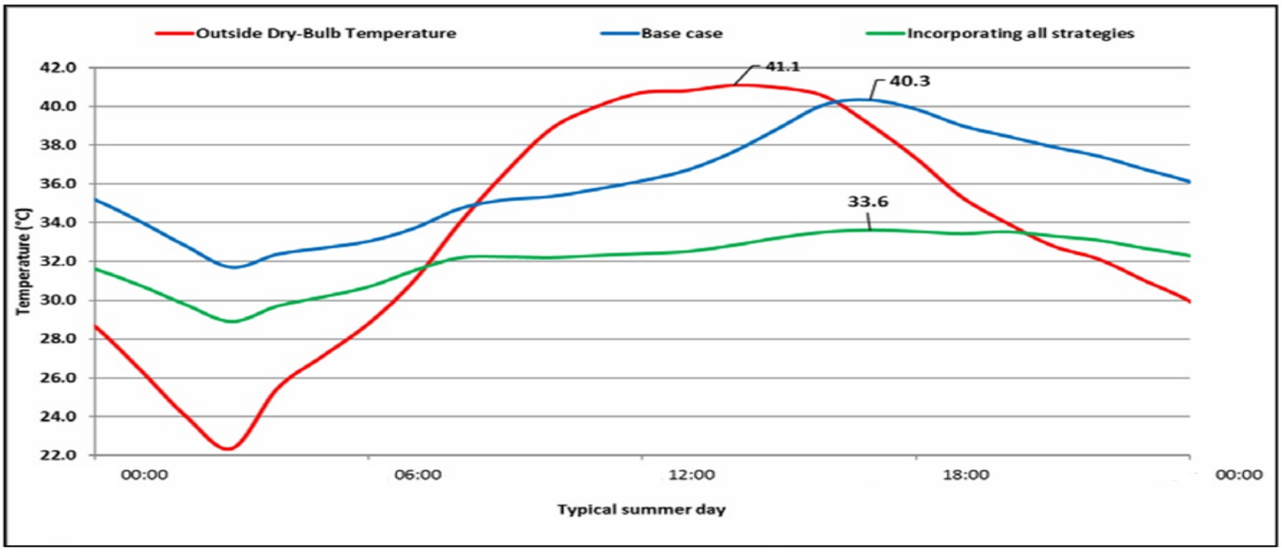

Figure 6.1.3: Peak operative temperature on building a typical summer day- in the base case & after incorporating the strategies (Project 1, Baladiya)

Proposed strategies: The following strategies were proposed:

1. Reduce WWR to 20-30 %
2. External movable shading on windows
3. 200mm thick AAC blocks for walls instead of burnt brick
4. 100mm XPS insulation on the roof

Results

These strategies were simulated for the worst of the sample bedrooms/ living room, i.e. Bedroom 2&3 (Bedroom with south and west façade exposed with window & glass door on west façade) on the top floor. It was seen that, with the above strategies, the inside temperature can be reduced by ~7°C (figure 6.1.3), bringing the peak (Figure operative temperature from 40.4°C to ~33°C. If air-conditioned, the cooling load of this bedroom will be reduced to 1/3rd of that in the base case.

6.2 Project 2, Mullam (Chennai)

This residential housing Ground +1 story project is each story height of 10 ft" predominantly facing the **North and South.** (Chennai site plan as similar site plan of Baladiya)

- Peak operative temperature in the bedroom reaches 37.8°C on a typical summer day, for a building on the windward side (Figure 6.2.1).
- For a building on the leeward side (wind speed 0 m/s), the peak operative temperature calculated on a typical summer day is 38.2°C.
- Most of the heat gains were happen through the glazed windows, which faced East-West.

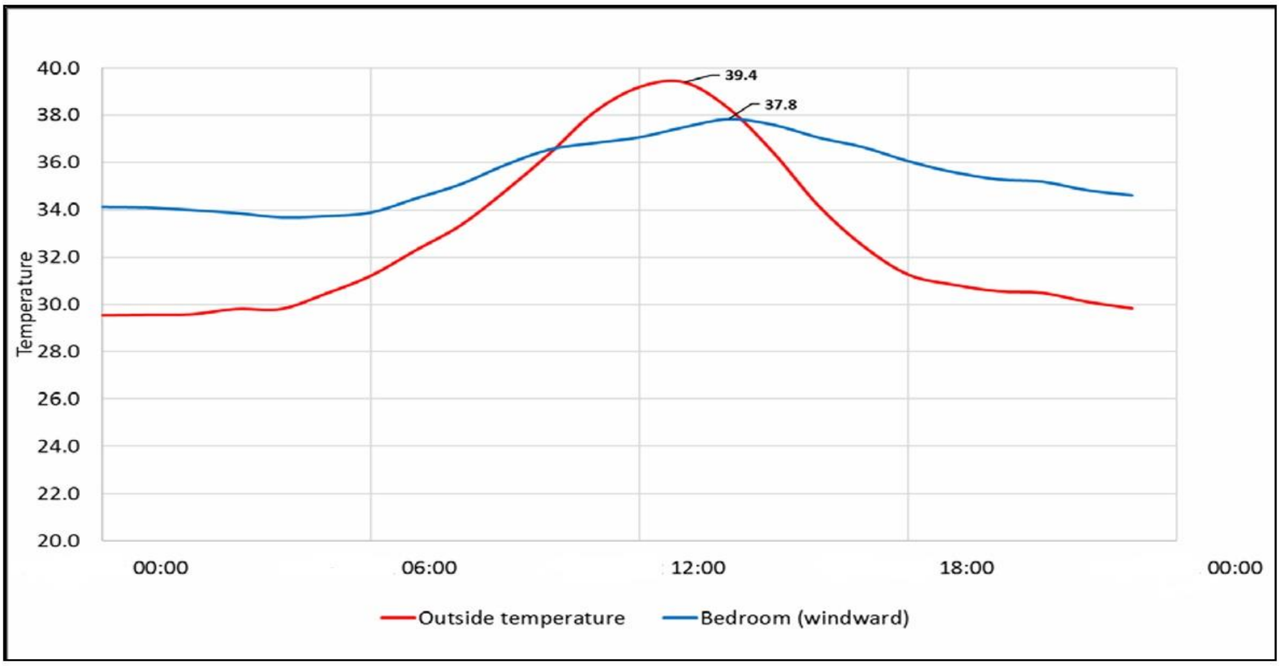

Figure:-6.2.1 Peak operative temperatures for the base case on a typical summer day in a windward facing building (Project 2, Chennai)

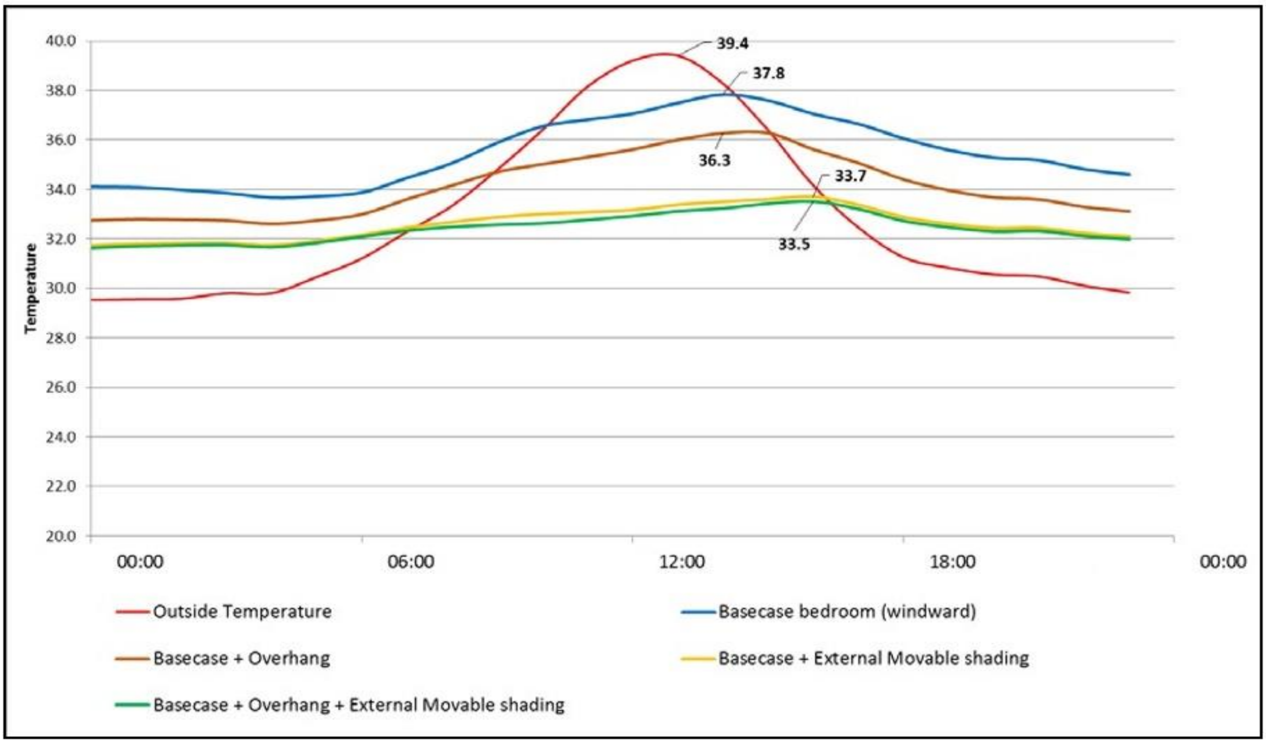

Figure: -6.2.2 Peak operative temperature of a wind-ward building on a typical summer day- in the base case and with different external shading (Project 2, Chennai)

Proposed strategies: The following strategies were

1. proposed: Shade the windows well with external movable shading and overhangs; and
2. Replace the sliding windows with casement windows to improve ventilation.

Results

The analysis shows that external movable shading has the most prominent effect in reducing inside peak temperatures and thus improving thermal comfort. While fixed shading reduces indoor temperatures by 1.5°C, external movable shading reduces it by 4.2°C (Figure6.2.2). Even for a leeward building with no wind speed, peak internal temperature is reduced by about 4°C by external movable shading. The improvement in thermal comfort due to this is also seen over the year. The number of hours in a year when the operative temperature was below 30°C is improved from 65% in the base case to 95% for the windward building and from40% to 74% for the leeward building.

7. Optimization of window-wall ratio for 2 different projects

Table 3: Building Envelope Inputs for the 2 Residential Projects

	Project 1, Baladiya (Kutch)	**Project 2, Mullam (Chennai)**
U-factor **Solar Heat Gain Coefficient (SHGC)** **Visual Light Transmittance (VLT)**	5.80 W/ m²․K 0.81 0.88	5.80 W/ m²․K 0.81 0.88
Window	Sliding Window +door	Sliding Windows +Door
Window-to-Wall Ratio (WWR) of sample bedroom/living room	• Bedroom/ living room with window: 29% Bedroom/living room with window and glass door: 43%	15%
Window operation	• 50% openable A Window opens when the inside temperature ≥outside temperature by 1°C	• 50% openable A window opens when the inside temperature ≥outside temperature by 2°C
Iteration	• Change in WWR	• Change in WWR

Table-4: Comparison of energy consumption with symmetric and asymmetric windows

Building Type	Floor	**The cooling and heating temperature set-point was taken at 24°C and 20°C respectively & Windows were provided with internal shade for glare control.** **D253933 (Double) Glazing**			
		Optimum WWR (symmetric)	Energy (symmetric)	Optimum WWR (asymmetric)	Energy (asymmetric)
		Optimum	kWh/m2-yr	(N-E-S-W)	kWh/m2-yr
70*35(sq. ft) (1:2) NS	FIRST FLOOR	25	47.6	40-25-15-20	47.3
	GROUND FLOOR	25	47.8	40-25-15-20	47.4
35*70(sq. ft) (1:2) EW	FIRST FLOOR	25	48.1	50-25-20-20	48.1
	GROUND FLOOR	25	48.2	50-25-20-20	48.1
Building Type	Floor	**S818861 (Single) Glazing**			
		Optimum WWR (symmetric)	Energy (symmetric)	Optimum WWR (asymmetric)	Energy (asymmetric)
		Optimum	kWh/m2-yr	(N-E-S-W)	kWh/m2-yr

70*35 (sq. ft) (1:2) NS	FIRST FLOOR	10	49.7	20-10-5-10	49.4
	GROUND FLOOR	15	50.4	35-15-5-10	50.0
35*70 (sq. ft) (1:2) EW	FIRST FLOOR	10	50.9	20-10-5-10	50.5
	GROUND FLOOR	10	51.4	20-10-10-10	51.2
Building Type	Floor	**S475556 (Single) Glazing**			
		Optimum WWR (symmetric)	Energy (symmetric)	Optimum WWR (asymmetric)	Energy (asymmetric)
		Optimum	kWh/m2-yr	(N-E-S-W)	kWh/m2-yr
70*35(sq. ft) (1:2) NS	FIRST FLOOR	15	49.4	25-10-10-10	49.1
	GROUND FLOOR	20	49.8	35-15-10-15	49.3
35*70(sq. ft) (1:2) EW	FIRST FLOOR	15	50.5	30-15-10-10	49.7
	GROUND FLOOR	15	50.6	30-15-15-10	50.2

For single-layer glass (S475556) shown in Table-4, the optimum WWR came out to be 30-40%, 15%, 10%, and 10% on an average for north, east, west, and south facade respectively. For double glass assembly shown in Table-4, the optimum value for WWR reached 40%-60% on the north, 25% on the east, 20% on the west, and 15% on the south.

Results

Now, analyzing the results, it could be identified that in general the ground floor allows a higher optimum WWR. This difference of results for the ground and top floor was governed by two parameters, the difference in HVAC sizing for both floors and the ground reflectivity. The higher HVAC sizing due to the effect of a roof on the top floor resulted in greater CFM (cubic feet per minute of air moving) leading to higher convective heat gain through windows, thus favoring a smaller window. In another way, the optimum Window to wall ratio effect on distributing the windows symmetrically on all four sides of the building came to be quite less as compared to independent distribution. The comparison of energy consumption (Lighting, HVAC) between two cases (one with optimum.

Symmetrical distribution and other with optimum independent distribution) is shown in Table-4.

Proposed suggestions

These results can be visualized that considering an optimized asymmetric window distribution proves much better than symmetric distribution.

CONCLUSIONS

The experience from these 3 projects shows that a reduction in peak operative temperatures in a range of 4 - 7°C is possible by implementing a few key envelope and ventilation strategies.

·Reducing window-to-wall ratio where required;
· Providing fixed shading: Fixed horizontal shading for the south and north façade can reduce direct solar radiation from entering the building from these facades.
· External movable shading: External movable shades are the most effective in cutting solar gains from windows.
· Roof insulation: A large reduction in heat gains is possible for the first floor with roof insulation.
· Wall Insulation: Wall insulation works best in regions when the diurnal temperature range is high like in Baladiya, but not in Chennai.
· Casement windows (100% openable) instead of sliding windows (50% openable) for better natural ventilation potential

The total energy consumption and WWR straight away bring out the essential for an optimization-based approach in determining the most efficient opening size for a particular glazing type, orientation, and type of building. It's not only the type of glazing (i.e. thermally efficient glazing recommended by ECBC) that need to be emphasized for better building performance but observation should also be given to the WWR that is being adopted for various directions, various floors, and different types of glass. Independent distribution of glazing on the four directions should be preferred rather than symmetric distribution as it can be identified that the optimized WWR for the latter case is much lower. With this, a higher Window to wall ratio can be afforded in few directions for better aesthetics and outside view, as compared to symmetric distribution and that too without compromising with savings, but in fact, increase it.

Abbreviation

WWR: - Window to Wall Ratio
SHGC: -Solar Heat Gain Coefficient
U-value: -Thermal Transmittance
W/ M^2. K: -Watts per meter square -Kelvin
HVAC: -Heating Ventilation and Air-Conditioning

REFERENCES

BEEP. 2016. "Design Guidelines for Energy Efficient Residential Buildings - Warm-Humid Climate".

NITI Aayog. 2015. India Energy Security Scenarios. Retrieved from http://www.indiaenergy.gov.in/

BEEP. 2014. "Design Guidelines for Energy Efficient Multi-Story Residential Buildings- Composite & Hot- Dry Climates".

Y. Feng, H. Yang, Defining the area ratio of window to a wall in ''Design standard for energy-efficiency of residential buildings in hot summer and cold winter zone'', Journal of Xi'an University of Architecture and Technology 33 (2001) 348–351.

Y.B. Hou, X.Z. Fu, Affection of WWR on energy consumption in the region of hot summer and cold winter, Architecture Technology 10 (2002) 661–662.