OPTIMIZATION OF WINDOW DESIGN IN A HIGH-RISE RESIDENTIAL TOWNSHIP TO ACHIEVE GRIHA REQUIREMENTS FOR THERMAL AND VISUAL COMFORT

Kiriti Sahoo[1], D E V S Kiran Kumar [2], Minni Sastry[3]

[1&3]Fellow, Sustainable Habitat Division, The Energy & Resources Institute, Karnataka, India
[2]Associate Fellow, Sustainable Habitat Division, The Energy & Resources Institute, Karnataka, India

Abstract

Window design becomes critical in achieving thermal and visual comfort for buildings located in Warm–Humid climate. The paper presents the process of window design for a high-rise and dense development using software simulation tools in order to comply for GRIHA green building rating system. The impact of solar radiation and predominant wind direction on location of openings and design of external shading device are highlighted. Typical facades have been identified in order to analyses the solar insolation and to suggest the glazing requirements. Detailed and floor wise analysis is carried out for daylight and shading availability in each cluster of the apartments using dynamic simulation tools. Outdoor and indoor wind flow analysis is done using Computational Fluid Dynamics (CFD) tool of Integrated Environmental Solutions (IES-VE). Further, optimization of window design in order to achieve better air circulation and daylight requirements of GRIHA green building certification is presented. It was observed that the facades on different orientations require different treatment for shading windows and for ventilating the rooms. The research also showcases a special type of window design as a combined strategy to enhance natural ventilation and glare free daylight inside the living spaces.

KeyWords: *Shading, Day lighting, High Rise, Dense Development, Wind Flow, DF(daylight factor)*

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1. INTRODUCTION

Windows are critical in achieving visual and thermal comfort in warm and humid climate. In order to achieve appropriate window design, analysis at the building and site level should be conducted. Natural site features such as existing landscape, wind and solar paths, rainfall patterns, buffer zones and green belts should be considered while planning the buildings at site level. The project, under investigation, is a residential campus located in Guntur which is developed with minimal disturbance to the site to retain most part of the existing landscape.

2. SITE PLANNING

The three building blocks planned and constructed are 3BHK, 4BHK apartments and Club plus Transit block. Landscape design was one of the dominant features that influenced the placing and orientation of these blocks.

The buildings were designed with a central courtyard to respond to warm humid weather of the region. An hourly shadow analysis (figure 1) was carried out to observe the pattern of shadows around the buildings on typical days. The analysis showed that spacing between each of these blocks was maintained for daylight availability inside the space. The South-West Façade of 4BHK flat which was completely exposed to the sun is found critical in terms solar shading. The orientation of 3BHK, 4BHK and transit blocks was found appropriate in terms of wind flow as the longer facades were facing perpendicular to the predominant wind direction. This enhanced free air movement through the building blocks. Higher wind speeds were observed between the blocks that ensured comfortable outdoor spaces. Wind speeds found on a typical day in these spaces at 1.5m level above the ground are between 1.2 and 1.5m/s. It was also found that the wind speeds increased from 0.5m/s to 1.5m/s from the lower floor to upper floor of the buildings. Figure 2&3 illustrates the outdoor wind flow pattern observed at site level.

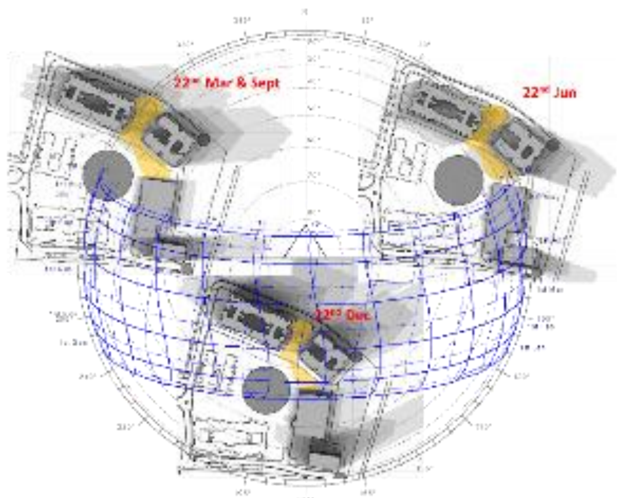


Fig 1 Hourly shadow pattern of the buildings on typical days highlighting space left building the building blocks

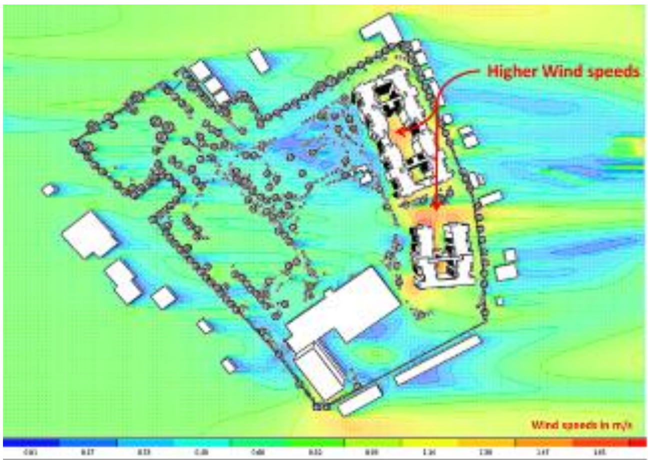


Fig 2 Outdoor wind flow pattern (horizontally) at site plan level

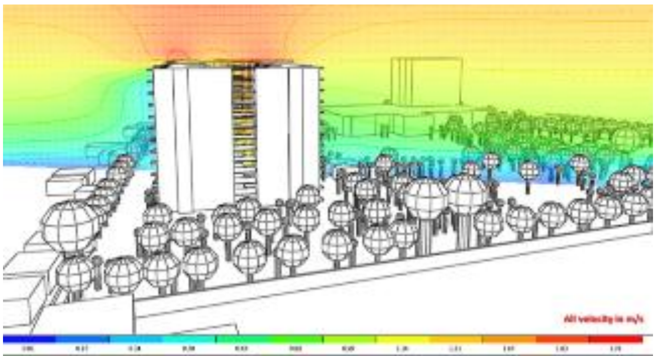


Fig 3 Outdoor wind flow pattern (Vertically) at site level

The 3BHK apartment was studied and analyzed in the context of developing a climate responsive design. Each passive strategy adopted in the building design has been discussed in detail in following sections

2. FORM AND ORIENTATION

There were eight 3-BHK units planned on each floor of G+8 3-BHK apartment. These units were clustered together and oriented towards north and south (longer sides) in order to reduce the solar exposure and thus the external heat gain (Figure 4 &5). However,this part has been detailed in the daylight analysis section.

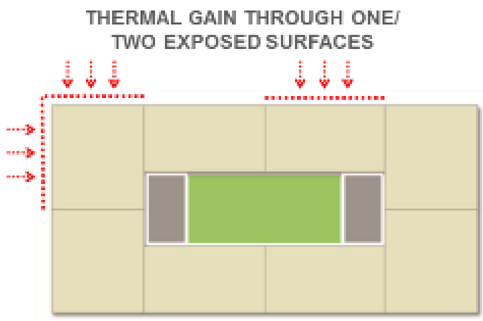


Fig 4Cluster of 3BHK units to reduce the heat gain (Courtesy: Edifice)

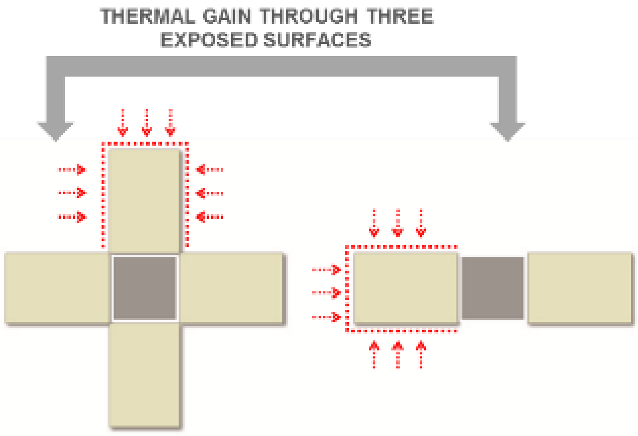


Fig 5 Cluster of 3BHK units to reduce the heat gain (Courtesy: Edifice)

Four units on each floor formed a single bay unit helping free air movement. The central courtyard planned between these single bays units helped to mutually shade the walls of the apartment and to retain the existing trees on site. Deep balconies and screens on the external facades improved self-shading of the building (Figure 6). Courtyard is shaded most part of the year which might affect the daylight in the rooms facing the courtyard.

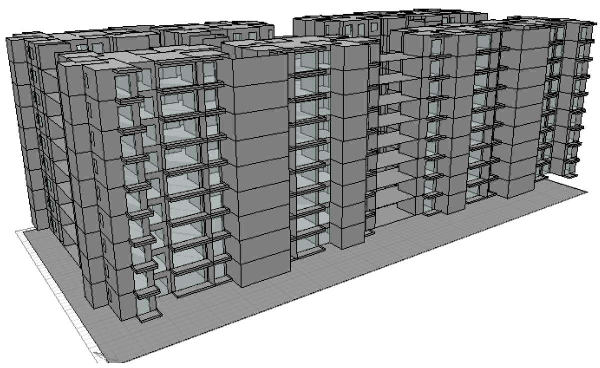


Fig 6:3-D view of the 3BHK apartment showing deep balconies on the external facades

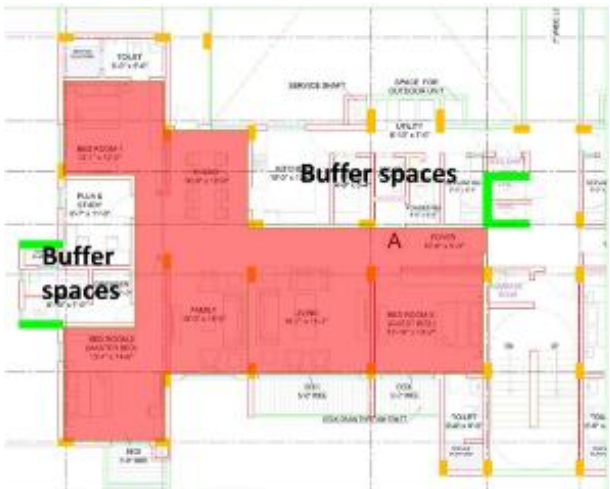
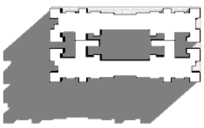
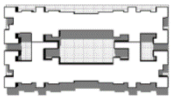
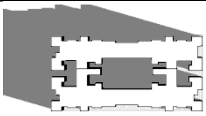
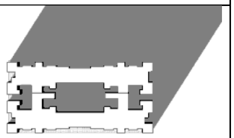


Fig 7:Unit plan shows buffer spaces around the major living spaces

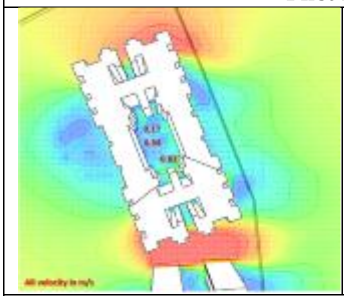
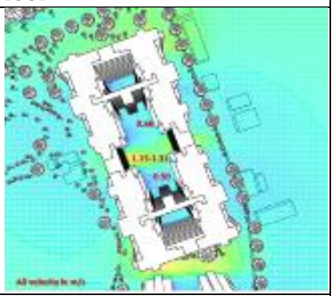
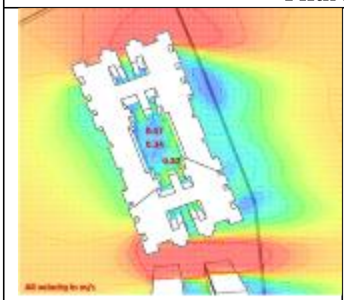
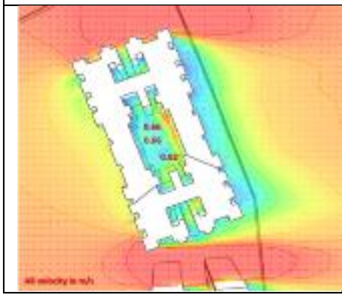
The interior layout of the unit showed that there were good buffer spaces around the major living space of the building (Figure 7). It is also observed that the interior spaces were open plan in nature with less number of partitions for better daylight distribution and air movement. Table 1, shows the shadow analysis of 3BHK at different times on typical days of a year.

Table -1: Shadow Analysis for 3BHK Apartment

09:00	12:00	16:00
22ndJune		
		
22ndMarch & Sept		
		
22nd December		
		

The building was also simulated using air flow analysis tool. In the initial concept design, when there was no stilt floor planned for 3BHK, very lower wind speeds were observed in the courtyard spaces as well as around the building. So, it was recommended to add a stilt floor for better air movement and wind velocities in the building.

Table – 2: Floor wise wind flow pattern in 3BHK before and after stilt floor is added

Before	After
First Floor	
	
Fifth Floor	
	
Ninth Floor	
	

It was also recommended to increase the width of the courtyard to enhance comfort in semi open spaces of the building. Table 2 shows the floor wise air flow pattern and wind velocities observed in 3BHK before and after the stilt floor was added.

3. WINDOW TO WALL RATIO

Size of the window openings is important to reduce the external heat gains and to reduce the energy demand for air conditioning in spaces. It is also important in providing daylight spaces so that there would be minimal demand on artificial lighting. The window to wall ratio (WWR) was calculated for the buildings for each orientation and presented in table 3. The window area on north and south orientations were higher compared to other two orientations which was good in terms of daylight availability. The overall window to wall ratio of 3BHK has been observed as 18% which was found appropriate in the hot climate of Guntur.

Table – 3: Window to wall ratio (WWR) for 3BHK

Orientation	WWR (%)
North	22.4
South	22.4
East	10.3
West	10.3
Overall	18

4. SHADING ANALYSIS

One of the mandatory compliance clauses of GRIHA is, to show that the effective solar heat gain coefficient (SHGC) of fenestration which meets the maximum SHGC requirement prescribed by ECBC. The Maximum SHGC recommended by ECBC for warm humid climate is 0.25. Below calculation presents the SHGC required for the glazing in the current fenestration design (DW2 in Living) in order to achieve 0.25.

4.1 Effective SHGC Calculation

Projection Factor (for Horizontal Overhang)

= Depth of Horizontal Overhang /window height

= 1950mm/2450mm= 0.8

Approx. Projection Factor (for Vertical fin)

= Depth of Vertical fin/ window Width

= 1500mm/4000mm= 0.37

Average of Projection factor

= (0.8+0.37)/2

=0.58

Using Table 4.4 from Energy Conservation Building Code (ECBC), the Multiplication Factor (M) on South orientation in this case will be 0.39

Then the Effective SHGC = 0.25

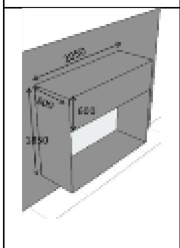
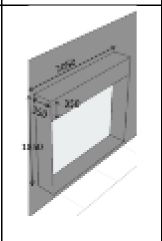
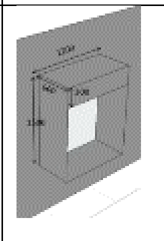
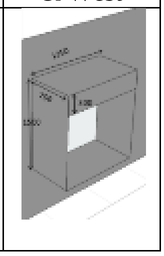
Glass SHGC * M = 0.25

Glass SHGC = 0.25/0.39

Therefore Max SHGC required as per ECBC/ GRIHA in this case = 0.64

Similar results were found for DW3 (in Bedroom-2) where both horizontal and vertical shading has been provided. It was thus recommended to provide vertical shading, also for DW3 in Bedroom-3.Table 4 presents the shading recommended for W2 & W3 on West and W5 on North where currently no shading has been provided. It has a box type shading with a screen dropped down from the top horizontal member, to match the architectural design. The shading design assumes that the SHGC of glazing would be below 0.64.

Table -4: Shading design for windows in 3BHK apartment

W5 on South	W5 on North	W2 on East & West	W3 on East & West
			

This analysis concludes that the glazing with SHGC below 0.64 is suitable to meet the mandatory GRIHA requirement for 3BHK apartment.

Solar exposure analysis carried out for kitchen conveys that a special attention is required while designing shading devices for rooms facing the central courtyard. The analysis shows that the courtyard facing walls on the top two floors are exposed to the sun most part of the year.

It was recommended to shade the windows (courtyard facing) only on eighth and ninth floor in order to protect from the direct sun and on lower floors for rain protection. Figure 8 shows floor wise solar exposure condition and a schematic sketch for shading devices that were recommended on top two floors.

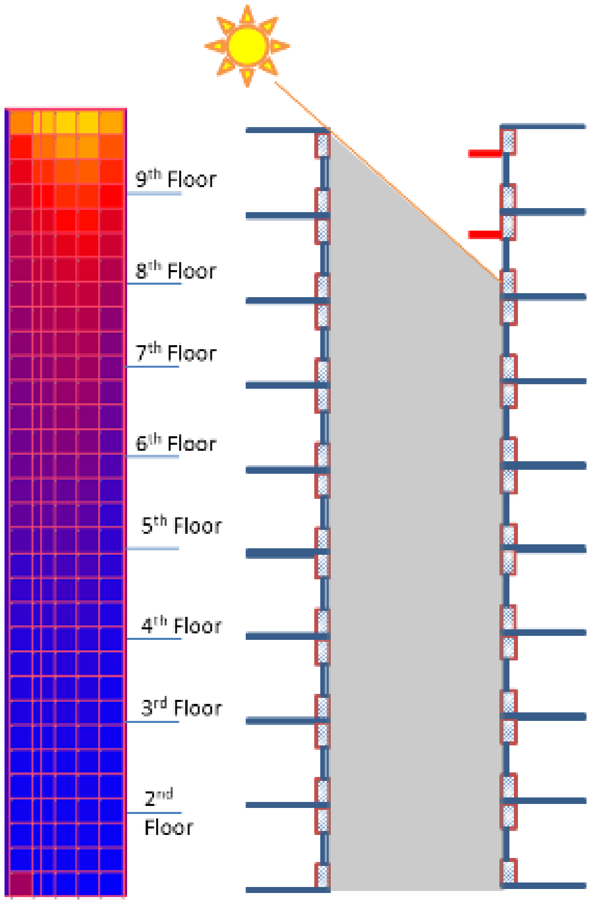


Fig 8: Floor wise solar exposure condition and schematic representation of shading design respond to the solar exposure

5. DAYLIGHT ANALYSIS

The first step in this analysis was to calculate the daylight area using formula provided in ECBC to quantify the possible daylit spaces in the building.

Based on the architectural drawings, space wise daylight area calculation has been carried out. Table 5 presents the percentage of daylit space inside 3BHK. It was observed that the total daylight area is 83% which is considered excellent for daylight integration in the building. Figure 9highlights the daylit areas calculated in a typical unit of 3BHK.

Table -5: Percentage of Daylight areas in a typical unit of 3BHK apartment

Living Space	Daylight Area (%)
Bedroom 2	89
Bedroom 1	88
Family Dining & Living	81
Study	65
Bedroom 3	78
Kitchen	85
Total	83

Further, a detailed daylight factor (DF) analysis is carried out for all living spaces in the apartment based on the architectural drawing. A corner unit (NE) facing smaller courtyard on one side is selected for the study. The reflectance values considered for internal surfaces like wall, roof and floor are 0.5, 0.7 and0.3 respectively. Average DF was calculated and compared with the recommended DF as per SP 41 - Handbook on Functional Requirements of Buildings BIS Code book. Table 6 presents the average DF achieved at the center of each space of 3BHK unit considering window glazing of VLT of 60%.

Table -6: Percentage of Daylight areas in a typical unit of 3BHK apartment

DF Distribution in Living Space	Avg DF using Glazing of VLT 60%	Recommended DF as per GRIHA / IS SP 41
Bedroom2	2.72	0.625
Study/ Puja room	1.74	1.9
Bedroom1	2.6	0.625
Bedroom3	1.41	0.625
Kitchen	0.81	2.5
Living and Dining	1.84	0.625

The analysis shows that the recommended daylight factor has not been met both in Kitchen as well as in Study/ Puja room. However, all other spaces were well above the recommended DF.

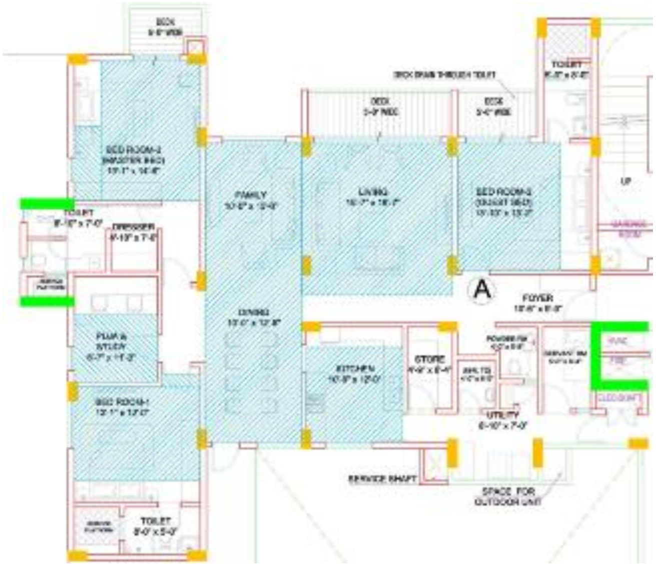


Fig 9: Living spaces highlighting possible daylit areas in typical unit of 3BHK

Various parametric runs were carried out, increasing dimensions and light transmittance properties for window glazing in Kitchen. It was found that even with full length (2mX3m) window and with 80% VLT for window glazing, kitchen on first floor doesn't meet the recommended Daylight factor. It was observed that shadow in the courtyard was affecting daylight quality in the space.

Hence, an analysis is carried out to check floor wise daylight availability and the solar exposure for kitchen wall. Figure 10 highlights the solar exposure of south walls facing courtyard as well as outside.

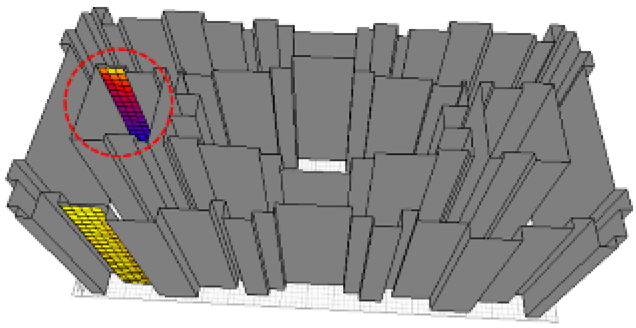


Fig 10 Solar exposure observed on south walls facing courtyard as well as outside

Table 7 presents floor wise average daylight factor (with window glazing of VLT 60%) found in kitchen. It also provides information on shading factor (% of time it is shaded) for Kitchen wall. The analysis shows that better lighting quality is present in the Kitchen on the top floors (eighth and ninth floors) as they are exposed to the sun most part of the year.

Table -7: Floor wise average daylight factor and shading factor achieved in 3BHK Kitchen

Floor Level	DF with 60% VLT	Shading factor
1	0.81	1
5	1.46	0.68
7	2.42	0.58
8	3.12	0.48
9	3.85	0.28

3. CONCLUSIONS

Conclusions that have been drawn from the analysis discussed in the paper are listed below.

1. It is recommended to increase the width of the Kitchen window by at least 0.5m for better daylight quality in the space. It is essential to provide daylight in Kitchen, especially between 08:00hrs and 10:00hrs to reduce energy demand on artificial lighting. Daylight Autonomy (DA) calculations show how much percentage of the year, a good amount of daylight is available with the wider window recommended in the design. It was found that 26.6% of the day time in a year, lighting level of 225 lux (with 60% VLT) is present in the space on the first floor.
2. This analysis concludes that the window glazing with VLT above 60% is suitable to maintain a good daylight quality in all the spaces of 3BHK facing courtyard.
3. Table 8 provides a few glazing products (Single Glazed Units) available in the market with the recommended thermo-physical properties viz, SHGC≤0.64 and VLT≥60%.

Table -8: Glazing products with the recommended thermo physical properties

Glazing Model	Type	Colour	U Value (W/m2K)	SHGC	VLT (%)
Asahi Planibel G (hard coated)	SGU	Neutral	3.9	0.61	70
Saint Gobain Sparking Ice	SGU	Neutral	5.6	0.67	67
Pilkington Eclipse Clear (low e)	SGU	Neutral	3.8	0.62	67
Pilkington Solar E	SGU	Neutral	3.7	0.52	60
Pilkington Solar E	SGU	Neutral	3.7	0.51	59

4. Further to this, combined U-value of the fenestration was calculated with various framing materials (Table 9). This analysis helps to choose the right framing material along with glazing that would be selected in the building.

Table -9: Combined U- Value of fenestration with various framing materials

Glazing Model	U Value at the Centre of the glass (W/m2K)	Frame Type	Combined U-Value (W/m2K)
Pilkington Solar E	3.7	Vinyl	3.09
Pilkington Solar E	3.7	Aluminum (w/o Break)	3.8
Pilkington Solar E	3.7	Aluminum (with Break)	3.51

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BIOGRAPHIES

Ar. Kiriti Sahoo, a researcher and architect by profession, completed his Bachelors in Architecture from National Institute of Technology Tiruchirappalli, India and Masters of Architecture in Design and Energy Conservation from University of Arizona, Tucson in United States. His core research involves designing buildings using natural ventilation system and its effect on buildings for achieving thermal comfort. Presently, Ar. Sahoo works as Fellow in The Energy and Resources Institute, where he is researching on thermal comfort in non-air conditioned buildings using thermal simulation and computational fluid dynamics analysis.

DEVS Kiran Kumar Architect and Building Technologist; completed bachelors from Andhra University and Masters from Indian Institute of Technology Madras, has been working in the field of Green Buildings for last 6 years; Currently associated with TERI as a researcher.

Minni Sastry, Architect, with Masters in Environment & Energy Studies, specializes in passive and low energy designs to obtain Sustainable Habitats. She has been with TERI for more thn 11 years and is directing the South Regional Centre for research and policy interventions to mainstream green buildings as an Associate Director for Sustainable Habitat Division, TERI-Bangalore.