Abstract

Residential units with natural lighting are considered to be very important due to its effects on the luminous comfort of occupants. This design issue is more challenging when it comes to an urban multi-storey residential building, where environmental and spatial design requirements have to be balanced. With its limitations in area and natural resources, urban areas have a high housing density. As a result, the quality of natural day lighting in the residential buildings becomes questionable. This is because architects are under constant pressure from the developers and clients to design multi-unit residential buildings with maximum space utilization, in the face of rising land prices and scarcity. Single square foot too cannot be compromised on any conditions. Thus, the challenge is to achieve comfortable luminous levels with respect to daylight for all the rooms habitable on the lower floors that are overshadowed by adjacent structures. This depends on some internal factors such as size and position of the windows, the depth and shape of the rooms and the colors of the internal surface, and some external factors such as light reflected from the ground and opposite obstruction. The aim of the paper is to explore the Luminous Comfort with respect to daylighting for urban multi-storey residential building in warm-humid climate - A case analysis in Chennai.
climate. For making this study, daylight was measured using physical instrument in an urban multi-storey residential building in warm humid climate and the recorded data was compared with the standards as prescribed. To also find the suitable luminous comfort level with respect to user preference through a questionnaire survey and from the tabulated results give design recommendations that helps in improving the luminous comfort level in urban multi-storey building. This study was conducted in winter season (October - December) months of a year where the direct solar luminance and sky luminance are comparatively lesser than summer season (April-June) months of a year.

1. AIM OF THE STUDY
In recent years there have been a number of fruitful studies concerned with providing better quality daylighting. Also there are various researches about daylighting simulations focusing on enhancing natural lighting indoors. However, there is a lack of such studies considering the luminous comfort in a built environment in warm-humid climate. The scope of this study can be summarized as:
- Highlighting the importance of daylighting design of multi-storeyed residential buildings in warm humid climate
- To justify that luminous comfort is a result of the interaction between daylighting and human behaviour, and that satisfaction with daylighting is the most important factor in determining the level of luminous comfort.
- This study will assist policy-makers in establishing appropriate guidelines and standards.
- The results will also help planners and architects implement more effective daylighting and provide residents with better luminous environments.

2. METHODOLOGY
The research is carried out using qualitative approach in the following steps:
- Physical measurement
- Questionnaire Survey
2.1 Physical Measurement
The luminous level in the living environment is measured with the help of physical instrument - Lux Meter.
Lux is a measurement of the overall intensity of light within an environment for any given area or distance from the source or lux is the amount of light in an environments perceived by the human eye. In other words, the lux is a unit of measurement of brightness, or more accurately, illuminance. The illumination is how level of luminous flux is falling on a surface area. The luminous flux is visible component that is defined in radiant flux (light power) divided by relative sensitivity of human eyes over the visible spectrum. This means the Lux is well fit to light level from sense of human eyes. Lux is ultimately derives from the candela, the standard unit of measurement for the power of light. A
candela is a fixed amount, roughly equivalent to the brightness of one candle. While the candela is a unit of energy, it has an equivalent unit known as the lumen, which measures the same light in terms of its perception by the human eye.

2.2 How to Measure Lighting Levels?
Measuring lighting or the illumination of an environment requires the use of an incident Lux meter or foot-candle meter. A lux meter is a device for measuring brightness. It specifically measures the intensity with which the brightness appears to the human eye. This is different than measurements of the actual light energy produced by or reflected from an object or light source. A lux meter works by using a photo cell to capture light. The meter then converts this light to an electrical current. Measuring this current allows the device to calculate the lux value of the light it captured. The lux light meter’s calculation of illuminance is done by using the Point Source process. The measure of the lux light meter varies depending on the light’s intensity and distance. If a point source has no reflections, a portion of the produced light reaches a surface.

2.3 Questionnaire Survey
The survey was conducted during October and December months of 2017, where the participants are questioned in person to collect data on both the resident’s objective living conditions and their subjective levels of luminous comfort. The questions were determined according to the survey objectives and other references.

Figure 1: Methodology of Questionnaire Survey
The questionnaire as shown in the fig 1 consists of five parts.

- The first part includes the general information about the resident’s age, gender, floor level and about the space in the house which they spend their maximum hours during day time. Based on the space mentioned, the remaining parts of the questions were answered by the resident’s only for that particular space.
- The second part involves objective questions about their physical living environment such as area of the room, orientation and window area.
- The third part is concerned about the experience based on daylight. The resident’s were asked to assess their abundance of daylight time, perception of uniform distribution of light and their level of satisfaction with day lighting.
- The fourth part involves questions about the troubles due to sunlight/daylight such as thermal discomfort, glare, fading object and external shading devices to investigate the resident’s about the subjective feeling towards daylight.
- The fifth part comprised of questions regarding the behavioral aspects of the resident’s, namely, the kind of activities performed in the room, purpose of using internal shading, time duration and type of artificial light used to understand about the overall satisfaction with their luminous environment.

3. BACKGROUND OF THE STUDY

Chennai is one of the India's densely populated cities, with many multi-storeyed and high-rise buildings. Although India is situated just south of the Tropic of Cancer and receives a lot of sunshine, the exposure of housing units to daylight can differ sharply according to factors such as floor level, orientation or external obstruction. In many cases, the degree of exposure to daylight also determines how pleasant the atmosphere is for living and home activities. In recent years there have been a number of fruitful studies concerned with providing better quality daylighting. Increased consciousness concerning comfort has aroused people's attention to their living conditions, such as thermal comfort, acoustic comfort, as well as luminous comfort. Luminous comfort is defined as the people's satisfaction with the luminous environment, as subjectively evaluated by occupants.

4. OBSERVATIONS

4.1 Sample 1
The sample was done in a gated community in Kandigai, the south part of Chennai. The building is G + 3 structure with 4 units in each floor. The orientation of the building is north facing. Using Lux meter the luminous level in the living environment is measured and it is compared with the standards (NBC). The lux level is satisfactory in the living space and the result is shown in the table 1.
4.2 Observations by Physical Instrument

Table 1: Comparison of lux level with the standards for Uni World Gated Community

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Floor</th>
<th>Space</th>
<th>Lux Level</th>
<th>NBC Standards</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ground floor</td>
<td>Living</td>
<td>450</td>
<td>500 – 1000</td>
<td>Poor</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td>Kitchen</td>
<td>120</td>
<td>150 - 500</td>
<td>Poor</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td>Bedroom</td>
<td>170</td>
<td>150 - 200</td>
<td>Medium</td>
</tr>
<tr>
<td>4</td>
<td>First floor</td>
<td>Living</td>
<td>450</td>
<td>500 – 1000</td>
<td>Poor</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Kitchen</td>
<td>120</td>
<td>150 - 500</td>
<td>Poor</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>Bedroom</td>
<td>180</td>
<td>150 - 200</td>
<td>Good</td>
</tr>
<tr>
<td>7</td>
<td>Second floor</td>
<td>Living</td>
<td>480</td>
<td>500 – 1000</td>
<td>Poor</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Kitchen</td>
<td>125</td>
<td>150 - 500</td>
<td>Poor</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Bedroom</td>
<td>187</td>
<td>150 - 200</td>
<td>Good</td>
</tr>
<tr>
<td>10</td>
<td>Third floor</td>
<td>Living</td>
<td>480</td>
<td>500 – 1000</td>
<td>Poor</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>Kitchen</td>
<td>125</td>
<td>150 - 500</td>
<td>Poor</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>Bedroom</td>
<td>187</td>
<td>150 - 200</td>
<td>Good</td>
</tr>
</tbody>
</table>

The Questionnaire survey was conducted with a sample size of 56 people. The participants belong to different age group, gender, floor level and units of the block. It was aimed to collect data on both the residents’ objective living conditions, behavior pattern and their subjective levels of luminous comfort.
4.2.1 INFERENCES
4.2.1(a) Physical Measurement
From the above table 1, lux level in the ground floor is poor when compared with the other floors. The lux level in living room is poor in all the floors because the space is provided only with the indirect lighting through the utility space. The kitchen also has poor quality of lighting because of the size and orientation of the window. The building is shaded completely by the adjacent buildings.

4.2.1(b) Questionnaire Survey
As seen from Fig 2.1 and fig 2.2, there was a significant difference in satisfaction between different age groups. The results suggest that the middle aged people tend to be more satisfied with their luminous environment than the younger generation. It may be because the middle aged people are milder towards dissatisfaction to the living environment compared to the younger people who would express their discontent more actively. Older people tend to be dissatisfied because they need a higher lighting level for their visual activities.
As seen from Fig- 2.3 nearly 80% of the residents are satisfied with the south facing windows and external shading device than those with other window orientation.

From the collected data, as shown in Fig – 2.4, fig 2.5 and fig 2.6, people use internal shading and artificial lighting in the interior mainly for privacy purpose. Thermal discomfort plays a minor role in providing internal shading.

4.3 Sample 2
The second sample was done in mathur, the north part of chennai. The parameters for the apartment selection are the same as the case study -1. The building is G + 3 structure with 4 units in each floor. The orientation of the building is south facing with the minimum setback of only 2’ on the west, 8’ on the east and 5’ on the north side. Using Lux meter the luminous level in the living environment is measured and it is compared with the standards (NBC). The lux level is satisfactory in the living space and the result is shown in the table.

Figure 3: Layout of Mathur Gated Community
4.3.1 Observations by Physical Instrument

Table 2: Comparison of lux level with the standards for Mathur Gated Community

<table>
<thead>
<tr>
<th>Sno</th>
<th>Floor</th>
<th>Space</th>
<th>LUX Level</th>
<th>NBC Standards</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ground floor</td>
<td>Living</td>
<td>600</td>
<td>500 – 1000</td>
<td>Medium</td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td>Kitchen</td>
<td>120</td>
<td>150 - 500</td>
<td>Poor</td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td>Bedroom</td>
<td>170</td>
<td>150 - 200</td>
<td>Medium</td>
</tr>
<tr>
<td>4.</td>
<td>First floor</td>
<td>Living</td>
<td>650</td>
<td>500 – 1000</td>
<td>Medium</td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td>Kitchen</td>
<td>120</td>
<td>150 - 500</td>
<td>Poor</td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td>Bedroom</td>
<td>180</td>
<td>150 - 200</td>
<td>Good</td>
</tr>
<tr>
<td>7.</td>
<td>Second floor</td>
<td>Living</td>
<td>700</td>
<td>500 – 1000</td>
<td>Medium</td>
</tr>
<tr>
<td>8.</td>
<td></td>
<td>Kitchen</td>
<td>125</td>
<td>150 - 500</td>
<td>Poor</td>
</tr>
<tr>
<td>9.</td>
<td></td>
<td>Bedroom</td>
<td>187</td>
<td>150 - 200</td>
<td>Good</td>
</tr>
<tr>
<td>10.</td>
<td>Third floor</td>
<td>Living</td>
<td>700</td>
<td>500 – 1000</td>
<td>Medium</td>
</tr>
<tr>
<td>11.</td>
<td></td>
<td>Kitchen</td>
<td>125</td>
<td>150 - 500</td>
<td>Poor</td>
</tr>
<tr>
<td>12.</td>
<td></td>
<td>Bedroom</td>
<td>187</td>
<td>150 - 200</td>
<td>Good</td>
</tr>
</tbody>
</table>

The Questionnaire survey was conducted with a sample size of 42 people. The participants belong to different age group, gender, floor level and units of the block. It was aimed to collect data on both the residents’ objective living conditions, behavior pattern and their subjective levels of luminous comfort.

Figure 4.3.1– Age group vs Daylight Hours

Figure 4.3.2 – Age group vs Satisfactory level

Uniformity in distribution of daylight & Luminous Environment

4.4.2 Inferences

4.4.2(a) Physical Instrument
From the above table 2 the lux level in the ground floor is poor when compared with the other floors. It is mainly because of the minimum setbacks given to the building and the adjacent building is G+1 structure.

4.4.2(b) Questionnaire Survey
- As seen from Fig 3.1, 3.2 there was a significant difference in satisfaction between different age groups. The results suggest that the middle aged people tend to be more satisfied with their luminous environment than the younger generation. It may be because the middle aged people are milder towards dissatisfaction to the living environment compared to the younger people who would express their discontent more actively. Older people tend to be dissatisfied because they need a higher lighting level for their visual activities.
- As seen from Fig- 3.3, nearly 90% of the residents are satisfied with the North facing windows because the building has more setbacks in the north when compared to the south. As seen in Fig-3.4 the purpose of providing external shading device is more satisfied by the residents in living and bedroom when compared with the kitchen which mostly has windows facing south and the setbacks on the south side is comparatively less.
- From the collected data, as shown in Fig 3.5, the thermal discomfortness was high in kitchen when compared to other spaces. Fig 3.5 and 3.6 indicates people use internal shading and artificial lighting in the interior mainly to prevent heat.

5. CONCLUSION

The luminous comfort with respect to daylighting and human behavior is carried out using physical instrument and a questionnaire survey in two different multi-storey apartment in Chennai. Based on the analysis of data, the following conclusions about the factors promoting luminous comfort can be drawn.

- No statistical difference appears between genders concerning preferences for luminous comfort. Age, however has major effect on luminous comfort level, the younger people tend to be more satisfied with their luminous environment than the older people.
- Daylight hours, uniformity distribution of light, orientation of window, satisfactory level with the external shading device, thermal discomfort and sunlight hours in winter are the six factors that determine the resident’s level of satisfaction with respect to daylighting.
- Satisfaction with the quality of daylighting determines the level of luminous comfort more than behaviour related factor such as use of artificial lighting. Some 60.6% of the survey participants reported that their level of luminous comfort was the same as their level of satisfaction with daylighting.
- Behaviour factors have a significant influence on luminous comfort. People often use internal shading and artificial lighting to adjust and improve the indoor luminous
environment. Nearly 80% of the occupants Use of artificial lighting and internal shading for many hours a day is mainly because of troubles due to sunlight/daylight, activities in the room and their behaviour pattern.

The results of this study may help to generate awareness of the detailed factors involved in luminous comfort. The study also shows the importance of daylighting for peoples overall satisfaction and these findings may also assist planners and architects to implement better daylighting for housing projects and provide residents with greater luminous comfort.

6. REFERENCES
[1] National Building Code Of India – PART 8 Building Services-Section 1 Lighting And Ventilation

TO CITE THIS PAPER