INTRODUCTION

The current pattern of urban development in Mumbai has led to a high density vertical sprawl of settlements. Most of these high-rise residential buildings are designed mainly to consume FSI (Floor Space Index) neglecting their suitability as living environments for human beings.

The current building design is a stereotype having uniform opening sizes and shading devices on all the levels throughout the facade of the building, unmindful of the site surroundings, sun path and wind pattern. Building designs tend to overlook standards of natural factors like daylighting, ventilation, thermal comfort and noise level to achieve a comfortable indoor environment required for various activity areas like living rooms, bedrooms, study rooms, and kitchens.

Healthy and comfortable indoor environments are essential for a sustained quality of life. Indoor Environmental Quality (IEQ) depends on parameters like thermal comfort, Indoor Air Quality (IAQ), lighting quality, noise and so on. The environmental performance of a building is good only if IEQ is maintained above the minimum acceptable levels. Incorporating these standards in high-rise residential buildings will help in providing a comfortable living environment for the residents and this in turn will ensure a safe, healthy and energy-efficient building.

Resulting from these thoughts, this research is based on studying parameters like Daylight and Noise in the existing tall residential buildings of Mumbai.

OBJECTIVES OF THE RESEARCH

- To compare the natural parameters of daylighting and noise at different heights in tall residential buildings.
- To compare and evaluate the selected parameters with building standards.
- To compare the effect of elevation on the selected individual flats.
- To compare the readings taken on site with computer simulated models

METHODOLOGY

The research was conducted in five tall residential buildings of Mumbai with self-contained flats of 1BHK / 2 BHK / 3 BHK. They were categorised as buildings abutting a main traffic road, buildings among complex of buildings and buildings abutting a railway track.

The buildings selected were:

<table>
<thead>
<tr>
<th>Buildings</th>
<th>No of floors</th>
<th>Category</th>
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</thead>
<tbody>
<tr>
<td>Building A</td>
<td>G + 11 storey</td>
<td>Building abutting a main traffic road</td>
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<tr>
<td>Building B</td>
<td>G + 14 storey</td>
<td>Building abutting a main traffic road</td>
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<tr>
<td>Building C</td>
<td>G + 9 storey</td>
<td>Building abutting a main traffic road</td>
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<tr>
<td>Building D</td>
<td>G + 15 storey</td>
<td>Building among complex of buildings</td>
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<tr>
<td>Building E</td>
<td>G + 20 storey</td>
<td>Building abutting a railway track</td>
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</tbody>
</table>
main traffic road, buildings among complex of buildings and buildings abutting a railway track.

Six flats were selected in each of these buildings - two each on lower, middle and upper level. The two flats on each floor had to be differently oriented. Thus, the study is based on readings in these 30 flats.

Readings of daylighting and noise were taken in all the rooms of the flats at morning (9 to 11 am), afternoon (12 to 2 pm) and evening (4 to 6 pm) for three weeks.

The daylighting was measured with a luxmeter just outside the window and at every 1 m distance from the window, inside for each of the rooms. The colour, furniture clutter, opening sizes and the size of the room were noted.

With the help of a decibel meter, the noise at the center of each of the rooms was noted.

The substantial data thus collected was then tabulated and represented in graphs for comparative analysis.

**OBSERVATIONS & CONCLUSIONS**

**Daylight**

Barring a few exceptions, similar rooms on higher floors recorded higher outdoor illuminance - this can be accorded to the lesser number of barriers for light on higher floors. The building face with shading devices promotes or obstructs the incident light depending on its form and angle. These factors affect the incident light on a window opening.

Daylight factor is the ratio of indoor illuminance to outdoor illuminance, expressed in percentage. The daylight factor depends on the size and location of the openings, the furniture clutter, the color of the walls and size of the room. Thus, a higher daylight factor can be aimed at to compensate for faces that receive less sunlight.

Light is governed by the inverse-square law - the intensity of light reduces in proportion to the square of the distance from the source. For indoors this source is the window. This fact was reiterated by the readings (discounting the minor deviations caused by interior finishes).

The use of ducts as elevation treatment outside the toilet areas obstructs penetration of daylight thereby necessitating the use of artificial lighting.

The orientation of the rooms in tall buildings is important. The rooms facing the south and west receive tremendous amount of glare and heat in the afternoon and evenings. To counter these, the opening sizes and the shading devices need to be worked out well on these faces.

EcoTect energy simulation software was used to simulate the daylighting to compare with the actual readings. The computer model had similar outdoor illuminance and opening sizes as the actual room. In this example, the simulation showed the average inside illuminance as 1069.6 lux, while the actual on site reading was 318 lux (outdoor illuminance of 7,705 lux in both cases).

**Some facts from the study:**

- In 100 percent of the observations, the outdoor illuminance increased with increasing height.
- In 85 percent of the observations, the indoor illuminance increased with increasing height.
- In 59 percent of the observations, the daylight was within the National Building Code standards.

**The study for daylighting concluded:**

- The upper level floors have higher outdoor and indoor illuminance than the lower floors. In order to have higher average indoor illuminance at the lower floors the window opening sizes need to be larger.
- Illuminance is indirectly proportional to the square of the distance thus forming a curve in graphical representation.
- The surrounding adjoining buildings and the landscape elements also affect
The standards prescribed by the NBC are inadequate. Though light varies with distance, the standards do not prescribe the exact distance inside a room where the illuminance should be recorded or the time of the day that it should be recorded. The opening sizes prescribed by the standards are irrespective of the orientation of the room, the shading devices and the outdoor illuminance.

In interiors, textures and finishes of materials play a vital role for a well-lit room.

The window size is very important for a daylighting.

**NOISE**

Rooms that face the road and the railway track have higher outside and inside noise levels at the upper floors than the lower levels; this is because the high frequency sound travels long distances and reaches the top floors, while at lower levels they are absorbed and dispersed by trees and other obstructions.

The rooms that face open spaces have outside and inside noise levels higher at the lower or middle levels only. This is because the low frequency sounds of children playing do not travel far and reach intermediate levels only.

All the rooms have noise levels below the Central Pollution Control Board (CPCB) standards at all the floors in the daytime.

**The study for noise concluded:**
- The noise levels increase with the increasing height. i.e. the upper floors have higher noise levels than the lower floors. This is mainly due to high frequency sounds travelling long distances.
- The building abutting the main road and railway track have higher noise levels at the upper floors because of high frequency sounds, while building abutting minor road have higher noise levels at the lower levels or middle levels.

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**Graph showing daylighting of the living room at three levels. Note how the illuminance varies with distance from the window and at various levels**
because of low frequency sounds.

- The standards prescribed by the CPCB accept very high noise levels. In the current study, all the rooms were within the standards, though sometimes the noise seemed disturbing.
- Incorporation of good acoustic materials for sound insulation should be used in windows where the rooms are near a potential source of noise (example - railway tracks, road).

**RECOMMENDATIONS**

**Daylighting**

Building designs should focus on standards of daylighting to achieve a comfortable indoor environment required for various activity areas like living rooms, bedrooms, study rooms, and kitchens.

The openings and the shading devices at the various floors should be designed on the basis of sun path diagrams, along the façade of the building.

To provide adequate daylighting at the lower levels, windows with large opening sizes and light coloured interior finishes should be used. To avoid intense glare and heat at the upper levels, glass with anti-glarre film should be used and shading devices should be designed to obstruct direct radiation into the room.

The use of ducts as elevation treatment outside the toilet areas should be improvised to provide louvres or large openings to maximise the penetration of daylight.

The current computer simulation tools are inadequate to determine indoor illuminance in a furnished room.

**NOISE**

At planning level, good setback between the roads and the buildings should be maintained. This space should be designed with sound barriers like trees with dense canopies.

Natural topographic features within the site should be tapped well for best acoustic advantage.
Graph showing Outdoor Illuminance for all rooms, at three levels
Graph showing daylight factor for all rooms, at three levels.
Careful design within a building can also reduce the effects of noise pollution. For example, if the front of a building is exposed to traffic noise, it makes sense to locate bedrooms at the rear.

At the household level, dense materials such as brick walls, solid-core doors should be used for sound reduction.

For openings, a double glazed window with air space between the two panes should be used for sound insulation. All gaps around both doors and windows should be well sealed.

(This Paper by Ar Ruparel is based on her dissertation submitted to the Yashwantrao Chavan Maharashtra Open University in partial fulfilment towards the Masters Degree in Environmental Architecture, February 2009. She can be contacted at archruparel@gmail.com)