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# A CRITICAL REVIEW ON HIGH RISE BUILDINGS IN THE CONTEXT OF BIO CLIMATIC DESIGN

***A case of vertical diversity in Tropical Colombo***

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## Abstract

Building envelop plays a vital role in creating comfortable indoor environments by cutting off unfavorable outdoor climatic conditions. The outdoor microclimate around a building varies creating diversified vertical climatic conditions. Yet less attention is given to the vertical climatic diversity in designing facades of tall buildings. The study critically discusses the facade design of tall buildings considering its vertical response and co-relationship to outside climatic diversity. Through a typical empirical study on randomly selected HRB in the existing context of Colombo, the Mahaweli Authority building was selected to investigate the co relationship of building design and the vertical character of its external climate. The final conclusion points out, that the designing process of HRB should pay more attention to bio climatic approach and design interventions with a better understanding on the external climatic character and its vertical diversity, rather than following typical two dimensional planning methods. This will result better and practical design outcome which will increase users satisfaction and improvements in energy saving**.**

***Keywords:*** *High-rise buildings, Bioclimatic approach, Vertical Diversity, Tropical climate*

## 1. Introduction

According to the environmental records, the building sector contributes up to 30% of global annual greenhouse gas emissions and consumes up to 40% of all energy (IPCC -2014, the fifth Assessment Report of the Intergovernmental panel on Climate Change). With the current situation of the building industry, the main objective of this study focus to identify the position of high rise buildings in urban context and its impacts on environment. According to the building form, tall buildings have more opportunity to reinvent themselves as the typology for a sustainable urban future that focused for better potential with innovative approaches forms and technologies which reduce the environmental

impact and support in challenges of the future climate change and energy consumption.

Most of the tall buildings are designed as stand-alone icons placed monotonously, rather than integrated into the urban fabric and respond to their immediate climate in respect to horizontal and vertical behavior of climate. Regardless of the often significant vertical height of these buildings, very few of them connect to the city fabric or each other at any level other than ground. But when considering about the urban fabric and the high rise buildings, there is a clear vertical zoning level according to the heights of the urban context.

Developing countries in tropical region such as Sri Lanka expand their development goals by introducing series of high rise buildings (HRB) that suddenly introduced to the urban fabric without considering climate sensitivity and environment impacts. This trend is growing continuously, creating more unfavorable conditions for humans as well as the environment. In such a context, building projects that claim benefit of such a bio climatic design approach are examined in the light of the results and practices of previously conducted researches and design projects done by Architect Ken Yeang.

The research aims at understanding the verticality in urban fabric and realizing a better environmental sensitive approach with the involvement of architecture. Bio climatic architecture is an innovative theory that integrates the man-made environment and natural environment with better mutual understand (Yeang, 1999). The main discussion of the study is based on the climate behavior and bio climatic approach of high rise buildings in urban context of Sri Lanka to create a better urban future.

The study focus on how the urban micro climate effects on the high rise buildings, horizontally as well as vertically in Tropical climate of Sri Lanka and how it is integrated with the bio climatic design approach and the vertical diversity of the built mass. Further it is aimed to identify the reasons for the lack of interest on the integration of bio climatic design applications on high rise building designs despite all developed knowledge in building technology and with practical knowledge by most of Architects or other consultant.

## 2. Bio climatic sky scrapers by Ken Yeang

Ken Yeang seeks to revision the skyscraper in terms of responsiveness to its climate and environment. There solar situation during different times of day, month and year is analyzed .this approach which aims at gaining maximum profit from alternative natural energy resources is identified as "Bioclimatic" approach, in which it is aimed to design low-energy, passive buildings with a focus on better occupant comfort and environmental sensitiveness. (Yeang, 1999). Bioclimatology, in architectural terms, is the relation between the form

of a structure, and its environmental performance in relation to its external climate.

### 2.1 Four-partial model By Victor Olgyay

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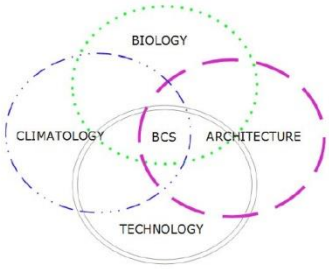



Source: (Olgyay, 1963)

*Figure 1: Victor Olgyay's Vitruvius: What is BCS*

Before the Ken Yeang's bioclimatic approach, Victor Olgyay created four-partial model introducing fundamental relationship between: climatology – biology– technology – architecture in 1963(Figure 02).

### 3. Buildings in the context of tropics

In tropics, the physiological thermal requirements and the building characteristics are equal for the entire year, because the seasonal climatic variations are slight. Avoidance of excessive solar radiation and provision for moisture evaporation by breezes are the two main issues occur in constructing in hot-humid zones.

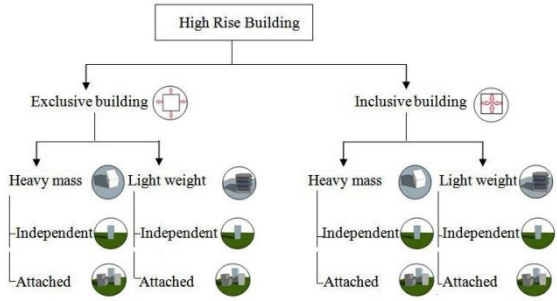
Thus the buildings in tropical context should be design to prevent heat gain, maximize heat loss and to remove any excess heat by mechanical cooling. The first two objectives can be achieved by means of 'microclimatic control' through site-layout and inner space-planning, controlling and planning air-movements, external wall and space orientation and the use of structural and constructional passive means of control.

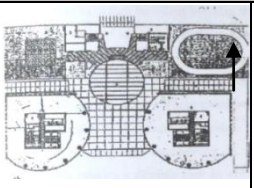
### 4. Urban Climate modification by building mass - Horizontal Vs Vertical

The placement of a building on the urban fabric influence radiative thermal, moisture and aerodynamic modification of the surrounding environment. The most important radiative effects are the decreasing in the solar radiation receipt by areas in shadow, reflection from sunlit walls, and the reduction of net long-wave cooling from surfaces near the building due both to a reduction in L↑ and to an increase in L↓ from the usually warm building. (Oke.T.R, 1998, p. 264)

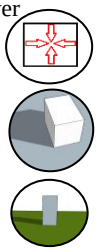
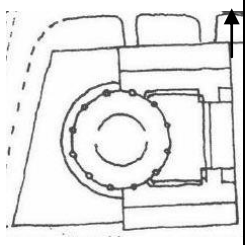
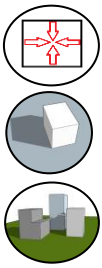
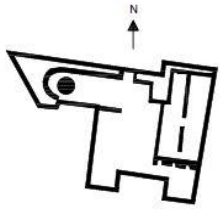
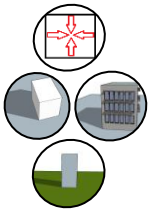
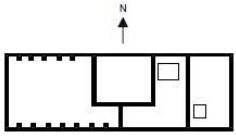
### 4.1 Empirical understanding of high rise building

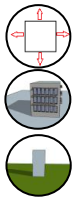
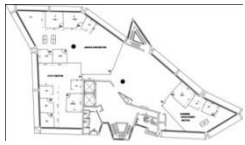
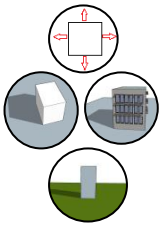
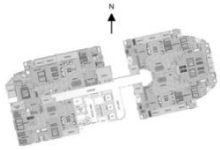
According to the building design and its respond for the outside climate of its context, buildings can be categorized. The randomly selected 12 high rise buildings, according to its primary use were examined through this process using a chart which divides the character of the building using main six keys.

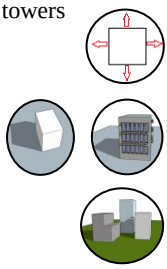
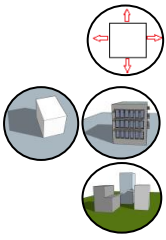
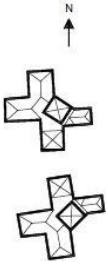
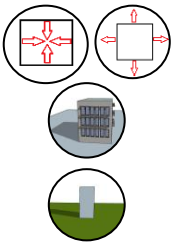




| Name/ contextual respond of building | Identification | Orientation and Plan | Special references on context of bio climatic approach |
|---|---|---|---|
| **Commercial Towers** | | | |
| 1.World trade Centre towers  |  |  39 floors | -situated in Colombo, close to set of HRB<br>-Entirely artificially ventilated and lit.<br>-Reflecting glass cladding outter envelop.<br>-Resistance to direct gain in east and west façade design. |

A REVIEW ON HIGH RISE BUILDINGS IN THE CONTEXT OF BIO CLIMATIC DESIGN

| | | | |
|---|---|---|---|
| 2.BOC headquarters tower  |  |  32 floors | -Situated in Colombo, close to set of HRB,<br>-Entirely artificially ventilated and lit.<br>- Aluminium cladding and glass windows in outter envelop.<br>-Resistance to direct gain ineast and west façade design.<br>- Improper building orientation. |
| 3.HNB tower  |  |  23 floors | -Situated in Colombo, close to set of HRB,<br>-Entirely artificially ventilated and lit.<br>- Aluminum, tinted glass, clear glass cladding and cement rendered walls in outter envelop.<br>-Resistance to direct gain ineast and west façade design.<br>- Improper building orientation. |
| 4.Galadhari hotel, Colombo  |  |  32 floors | -Situated in Colombo.<br>-Light weight building, natural light and ventilation, mix use of artificial conditions.<br>-Proper building orientation |

| | | | |
|---|---|---|---|
| 5.Mahaweli Authority building  |  |  12 floors | -A bio climatic HRB located in an urban layout.<br>-Naturally lit and ventilated originally.<br>-Special climatically responsive features. |
| **Residential towers** | | | |
| 1.Empire tower  |  |  37 floors | -Situated in Colombo,<br>-Exposed to natural light and ventilation.<br>- RCC structure mixed with lightweight character.<br>-Resistance to direct gain ineast and west façade design.<br>- Improper building orientation. |
| 2.Iceland residencies  |  |  31 floors | -Situated in Colombo<br>-Mix mode operation<br>-Exposed balconies<br>-RCC Structure with a character of light weight character.<br>-Proper building orientation |

| | | | |
|---|---|---|---|
| 3.Havloc city towers  |  |  22 floors | -Situated in Colombo, close to set of HRB,<br>-Partly naturally ventilated and lit.<br>-Exposed balconies and transitional spaces<br>-RCC Structure with a character of light weight character.<br>-Partly proper building orientation |
| 4. Royal Park tower  |  |  25 floors | -Situated in Colombo, close to set of HRB,<br>-Partly naturally ventilated and lit.<br>-Exposed balconies and transitional spaces<br>-RCC Structure with a character of light weight character.<br>-Improper building orientation. |
| 5.monarch residencies  |  |  30 floors | -Situated in Colombo, close to set of HRB,<br>-Partly naturally ventilated and lit.<br>-Exposed balconies and transitional spaces<br>-RCC Structure with a character of light weight character.<br>-Improper building orientation. |

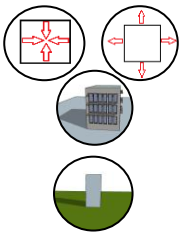
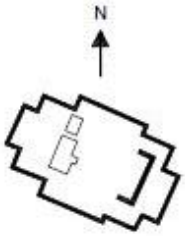
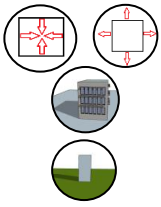
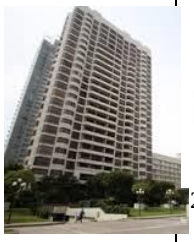
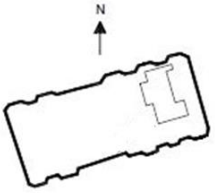
| **Mixed use towers** | | | |
|---|---|---|---|
| 1.Hilton residencies  |  |  34 floors | -Situated in Colombo,as a mix use develpment<br>-Partly naturally ventilated and lit.<br>-Exposed balconies and transitional spaces<br>-RCC Structure with a light weight character.<br>-Improper building orientation. |
| 2.Crescat residencies  |  |  25 floors | -Situated in Colombo,as a mix use develpment<br>-Partly naturally ventilated and lit.<br>-Exposed balconies and transitional spaces<br>-RCC Structure with a light weight character.<br>-Improper building orientation. |

*Table 01: Classification of building design according to its co-relationship for the outside climate (Detail empirical analysis of High rise buildings In Sri LankaSource: Author*

## Analysis

The analysis highlights the less consideration of microclimate and the effect of climatic conditions to the building interiors and the impact of building construction to its surrounding environment. Further no concern has been given to the vertical diversity of microclimate to address the needs of each level to create more occupant friendly interiors. Rather the building facades are repeated in almost all the buildings. All the cases showcased the negligence of thermal landscape of building interiors and the microclimatic features. Majority

of the buildings designs have followed typical floor plans considering only the function.

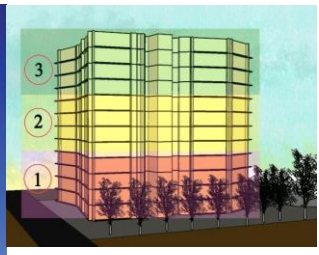
From the investigated 12 cases Mahaweli Authority building displayed better concern about the climate responsiveness in terms of bio climatic high rise design.

## 5. Selections of case studies

The nonresidential HRB Mahaweli Authority Building is selected as the case study for the field investigation. The building designed by Architect Geoffrey Bawa is globally commented in respect to bio climatic architecture in the context of high rise building.

### 5.1 Field study program

The onsite investigation comprised of two stages. Initially the selected case was studied to collect empirical data to pursue building design and main climatic approach of it. Next an in-depth investigation was conducted to study the micro climatic behavior and internal thermal environments. Through the field study air temperature, Relative humidity, and Natural lighting levels and wind velocity data of the each floor of the building was monitored in 30 minutes intervals vertically and horizontally which were then compared and analyzed. The building was classified into three levels vertically as ground, middle, upper levels and the data were obtained at three levels at the same time inclusive of all four façade of each level.




Zone – 1: First four
(1, 2, 3, 4) floors
Zone –2: Second four
(5, 6,7, 8) floors
Zone –3: Last four
(9, 10, 11 and 12) floors

*Figure 2: Mahaweli Authority Building*
*Source: (Robson D. , 2002)*

### 5.2 Built form

The building is 12 stories tall and the site was an awkward and irregular shaped and it was blocked between the Beira Lake and Hyde Park. Bawa exploited this however, in order to create a plan form which would respond aerodynamically to the prevailing winds while reducing solar gain, and which would give a maximum footprint, thus reducing the number of floors (Robson D. , 2007).

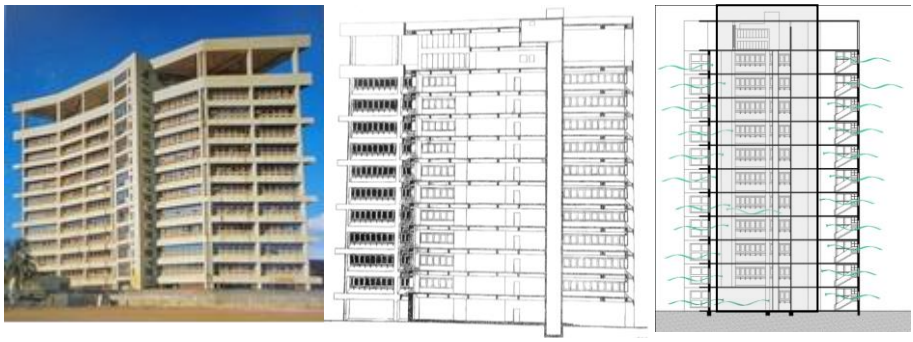
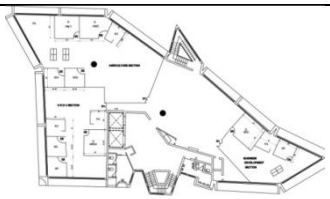
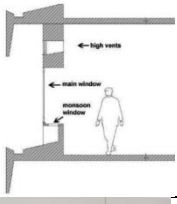
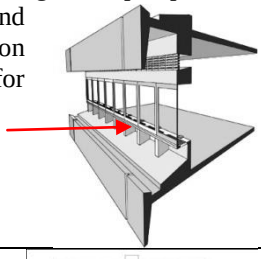
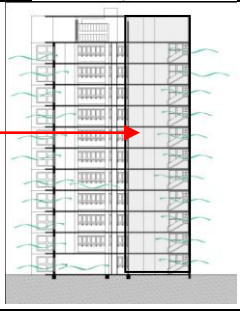


*Figure 3: Sectional elevation through the building and Cross section through the north south plain to show the natural cross ventilationSource: (Robson D. , 2002) and Author*

### 5.3 Bio climatic approach of building design – Mahaweli Authority Building

<table>
<tr><th colspan="2">Bio climatic feature</th><th>Mahaweli Authority Building</th></tr>
<tr><td>1.Service core position</td><td>Double</td><td rowspan="2">Double core services are built on the north and south sides of the building to get maximum use of natural light and ventilation.<br><br>Two service cores at north and south with better orientation allow maximum use of natural light and ventilation.<br><br>  <br>  </td></tr>
<tr><td>2.Service core orientation</td><td>North/ south</td></tr>
</table>

<table>
<tr><td>3. Natural ventilation and Sun light for service core</td><td colspan="2">The core uses natural ventilation and lighting. The main lobby entrance was shaded as well as ventilated without mechanical effort.<br>  </td></tr>
<tr><td>4. Building Orientation</td><td colspan="2">North south orientation to minimize solar gain. The building’s overall form, structural methodology, module cores, is oriented for maximum environmental efficiency by shading against direct heat while allowing for natural daylight and ventilation.</td></tr>
<tr><td>5. Window opening placement</td><td colspan="2">Recessed and shaded windows on external façade named as ‘Monsoon window’ allowing natural ventilation in rainy season.<br>  </td></tr>
<tr><td>6. Character of the West wall</td><td>Material<br>Thickness<br>Openings/ shading</td><td>The West brick wall thickness is 12” in width<br>Recessed and shaded windows are on the west side as a response to the tropical sun path.<br>  </td></tr>
<tr><td>7.Recessed windows/Sky courts/ Balconies</td><td colspan="2">-Recessed windows at entire façade<br>-Precast ventilation grilles on the external walls shaded by overhanging floor slab with a down-hung fascia parapet.<br>-Vertical pivot windows and horizontal precast concrete ventilation slots at sill height allows for ventilation at the body level.<br>  </td></tr>
<tr><td>8.Natural ventilation strategies: Atria / Air- spaces and Wind-scoops (venture effect)</td><td colspan="2">-The walls between office space and lift lobby have high level precast ventilation holes which allows cross ventilation.<br>-lift lobby and all stair cores well lit and ventilated<br>- Basic cross ventilation air flow allowing for natural ventilation to interact with the internal cooling system.<br>  </td></tr>
</table>

| | | |
|---|---|---|
| 10. Open ground floor | Only the front part which near to the main road was planned as open plain. | |
| 11.Road and building relationship | The building is sited in a busy commercial district, facing to the main road. | |
| 12. Vertical Landscaping | No vertical landscaping was introduced to the building. | |
| 13. Floor layout | Similar design foot print of floors | |
| 14. Relationship to Urban context | The building stands alone in the site. But environmentally building act as a feature which direct the natural wind towards the road side. | |
| 15. External materials and thermal insulation | Roof (Reflective) | -Terrace open on all sides at top floor.<br>-A white cement renderd floor finish to maximize the heat reflectance.<br>  |
| | wall | Masonry work, polished cement rendered floor finish, timber window frames and concrete ventilation grills. |
| 16.Colour of the building envelop | Light blue for the east façade and elephant gray colour for the west and south facades. | |
| 17.Structure of the building | The two topmost floors of the building were shielded by a floating canopy. The office spaces were designed as open plan with a minimum number of interior columns. The terrace roof and the stilt structure of the ground floor act as buffer spaces. | |
| 18.Transitional spaces | The stairway core act as a wind scoop which provide natural ventilation for the core of the building as well as a transitional space. No balconies and terraces at the building. | |

*Table 2: Bio climatic features apply in the Mahaweli Building*

### 5.4 Identify the horizontal climatic diversity

The data was collected at twelve points were grouped in to three main groups considering the Zoning levels (Ground, Middle and Upper zone) using Anemometer, Hobo meter and light meter were compared and analyzed to identify the vertical diversity of microclimate. Data gained from four facades were also compared to identify the horizontal diversity of the climate in each floor level which was then compared vertically.

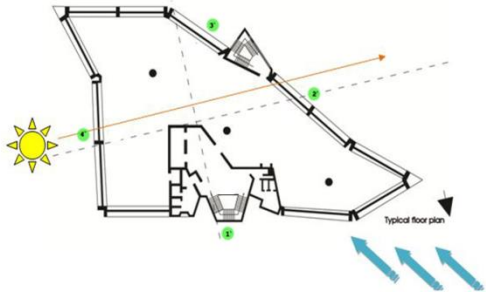
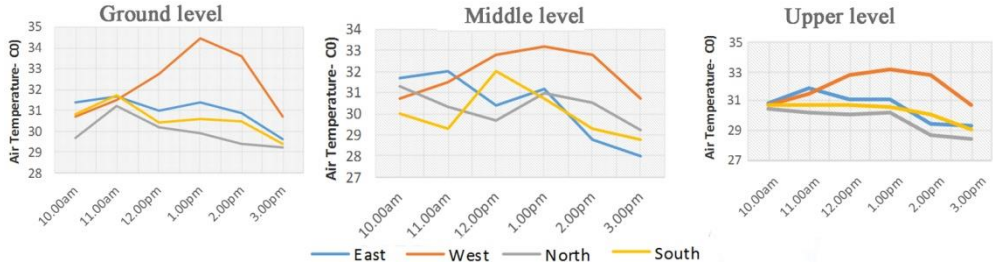


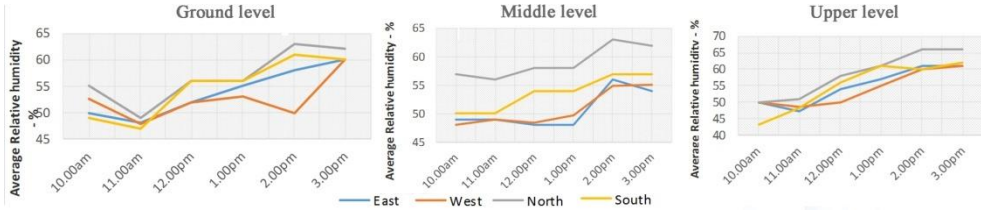

*Figure 4: Locations of measurement taken points at each level*
*Source: By Author*

## 5.5 Analysis of Data

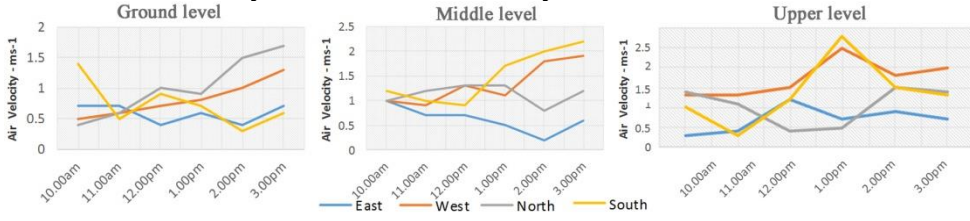
1. Horizontal diversity of Outdoor Air temperature



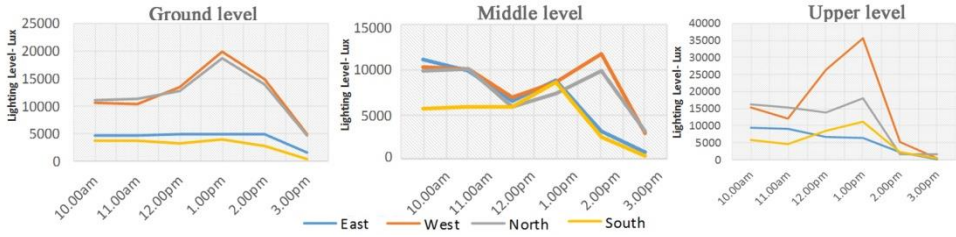

2. Horizontal diversity of Outdoor Average Relative Humidity




3. Horizontal diversity of Outdoor Air Velocity



4. Horizontal diversity of Outdoor lighting level




The collected data which were analyzed points out the horizontal variation in microclimate at each level in four facades. This suggests that the façade design of a building even at a single level has to be different to address the horizontal variation of the microclimatic conditions.

## 5. 6 Assessment of vertical climatic character

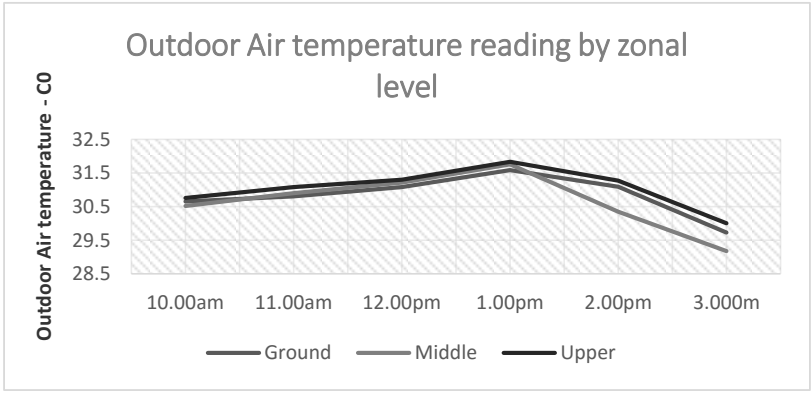



*Table 3: Vertical character of outdoor Air temperature*
*Source: By Author*

By analyzing the graph it is clear that the outdoor air temperature was slightly vary with the height of the building but the fraction of impact is negligible because of the minor lags between measurements. When compare each levels,

Ground to middle level air temperature varies by $1C^0$
Middle to Upper level air temperature varies by $0.5C^0$

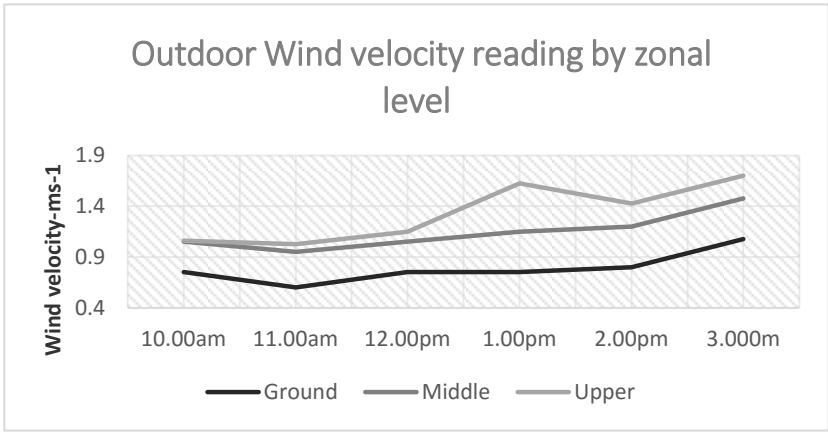



*Table 4: Vertical character of Wind velocity Source: By Author*

According to the graph, the ground levels experience the less air movement and the amount of wind floor was increasing with the height. Ground to middle level wind velocity varies (increase) by 0.3ms$^{-1}$
Middle to Upper level wind velocity varies (increase) by 0.1ms$^{-1}$

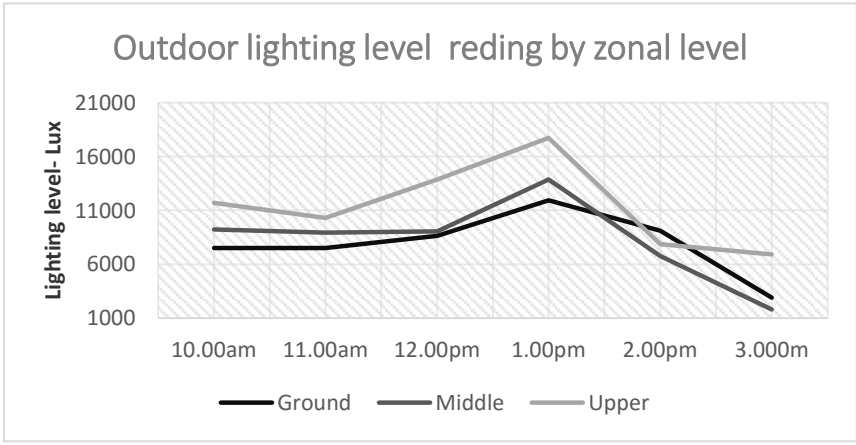



*Table 5: Vertical character of lighting level*
*Source: By Author*

According to the graph, the ground levels experience the less amount of light condition with compare to the middle and upper floors. When compare to each levels,

Ground to middle level lighting level varies (increase) by 1500 lux
Middle to Upper level lighting level varies (increase) by 2500lux

(With the height of the building there is a considerable variation in lighting level in each level).

## Conclusion

The field investigation data analysis clearly points out that in different vertical levels the outdoor climatic conditions and their effect on each level vary. Thus the design of high rise buildings has to address this vertical diversity in climatic conditions in order to design tall buildings that are thermally comfortable for the occupants in each level. The façade design, openings, shading and etc. of each level should address the vertical climate rather than being monotonous.

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