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FACTORS AFFECTING THE LUMINANCE VALUES OF AN APARTMENT IN COMPOSITE CLIMATE

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Abstract: *The internal layout is very much responsible for the increase in the penetration of useful daylight in the habitable spaces. These lighting units are responsible in cumulating the lighting load of a building. This paper deals with the comparative study including two cases of different apartments in the same city and climate, oriented in the same direction, elaborating the factors over which variation in the lighting units depends and the comparison with the standards. The aim of the study is to elucidate the parameters on which the values of Daylighting depend upon in a composite climate for a residential unit. The readings were recorded with the aid of a lux meter at the time between 3pm to 4pm on a summer day.*

Index Terms **–** Internal layout, Daylight, Openings, Window to Wall ratio, Energy Reduction.

1. Introduction

Energy efficiency involves using less energy to do the same work, i.e. eliminating energy waste. Energy efficiency offers several benefits, including reduced economic and household costs, reduced greenhouse gas emissions, and reduced need for energy imports. Residential buildings currently account for about 37.5% of energy consumption and significant carbon emissions, with most of this energy used for cooling. Simply said, usage of lesser energy to perform the same task can be defined as energy efficiency.

Due to rapid urbanization, we observe that the vertical expansion of the residential units is quite prominent and the most commonly compromised parameter of the structure is the orientation. Orientation is a dependent factor, on the location of a building in relation to seasonal variations in the sun's path as well as prevailing winds and thermal comfort and visual comfort is achieved by the aid of taking these parameters into account. Due to identity crisis of each tower, if the orientation of each unit/ block isn't climatically suitable as it should be, then the problems add up while planning the internal layout of such towers, where the location of the internal spaces either has to be compromised due to such restrictions and formation of dark patches or zones can be observed which are eliminated by artificial lighting, eventually increasing the energy consumption.

The interior layout of an apartment building can help reduce the dependency on artificial lightning which means more usage of daylight hence minimizes the building's overall energy consumption.

2. Theoretical framework

A comparative analysis of the where the constant elements are location, climate and orientation approximately same area are taken and are judged as per the recommended values for lighting that are specified in the standards (SP Vol. 41 HANDBOOK ON FUNCTIONAL REQUIREMENTS OF BUILDINGS-PART 4, Dec 1995). The variable elements are the internal layout, and fenestrations. The

analysis is carried out by examining the luminance values (lux) recorded by a lux meter on a clear sunny day between the times 3pm-4pm.

3. Literature Review

The overconsumption of energy is a major issue that a lot of countries and there is ongoing research to reduce this consumption. Energy Efficiency can be achieved through various factors and one can succeed by altering these factors in various permutations and combinations.

The preventive measures for having better daylight factor are orientation, layout design, WWR and glazing material, but in these preventive measures sometimes the orientation is still interdependent on the climate, the site proportion and surroundings. The independent factors are internal layout and envelope design. (Balaras, Droutsa, Argiriou, & Asimakopoulos, 1999) The secondary data analysis also helped in defining the methodology of the research as well, where most of the scholars opted research-based method (Latief, Berawi, Koesalamwardi, Riantini, & Petroceany, 2017) (Ruohomäki, Andra, & Raivio, 2020) but some of them opted for simulation-based (Hasibuan, Lianto, Siwi, & S, 2020) (Zakiah, 2020) The climate the majority of the research for energy reduction has been conducted in either tropical climates or moderate climate, observed in countries like Thailand, Indonesia, India – Delhi, and Lucknow.

3.1 Efficient Lighting Design – Efficient lighting if seen from a broader aspect can be easily achieved by maximum utilization of daylight and smart usage of artificial lighting.

3.1.1 Daylight - Daylighting is the controlled inlet of direct sunlight, diffused lighting, and natural light into a building to reduce energy consumption by lighting. With a direct linkage to dynamic, inconsistent outdoor lighting patterns, daylight helps create a productive environment and visually stimulating for building occupants, while reducing the overall energy cost of a building by one-third. When it comes to lighting the energy-saving concept of tropical climates, all experts have agreed that the use of natural light is essential. When it comes to artificial lighting, some experts have suggested that the use of LED bulbs, Low-E fixtures, and Energy Star lighting systems is suitable for evenings. (Latief, Berawi, Koesalamwardi, Riantini, & Petroceany, 2017) found that instead of expensive LED lighting, wired CFL lighting is suitable for optimal brightness while saving material costs and energy.

3.1.2 Window-to-Wall Ratio- Windows and openings can have a major effect on the performance of a building, and the window-to-wall ratio (WWR) represents the portion of an exterior wall made up of fenestrations. This ratio is responsible for the radiation and light intake during the day (Troup, Phillips , Eckelman, & Fannon, 2019). One of the authors states to minimize heat gain when there is sufficient sunlight inside the building, Mahoney's table recommends a window-to-wall ratio of 15-20% in north and south walls. The solar path diagram of the city reveals that the sun's rays are oriented almost 90 degrees in the east and west directions, hence the maximum openings should be north and south as it's very difficult to shade the prior placement of the openings. (Bano & Tahseen, 2017)

3.2 Layout Design- The author's recommendation after study is compact layouts or individual rooms around a medium-sized courtyard, and Lucknow's native architecture teaches the same. A patio with sloping rooms facilitates ventilation and shades windows facing the patio. It also provides an open space inside for seating in the evening in summer and during the day in winter (Bano & Tahseen, 2017). The ideal case scenario for naturally light space was two lateral windows with a total width of 3-4 meters in a 6m wide room. (Reena Roy, 2020).

4. Standards for the parameters

ECBC: Energy Conservation Building Codes, NBC & SP Vol 41: National Building Codes

4.1 Daylight- Sufficient sunlight in frequently used parts of the house reduces the need for artificial lighting. Tropical climate zone Sunlight is abundant throughout the year and its effective use enhances the energy efficiency of daily life. Visible light transmittance (VLT) is the ratio of total transmitted light to total incident light. This is a measure of the light that has passed through the material in the visible part of the spectrum. According to ECBC "Useful Daylight Illuminance - UDI" is the percentage of annual sunshine hours at a particular point on a work surface 0.8 m above the finished floor that receives 100 to 2,000 lux of sunlight. 90% of indoor lighting equipment in

buildings or building areas over 300 m2 should be equipped with automated controls. (Bureau of Energy Efficiency, PRESCRIPTIVE REQUIREMENTS - WWR, 2016). As per NBC chapter 11, at least 25% of the permanently used area of a building has a minimum daylight coefficient of 2% or provides sufficient daylight as described in SP 41:1987 Handbook of Building Functional Requirements. (NBC-Approach to sustainability, 2016). The SP Vol. 41 specifies the luminance values in Lux for each space. The illumination on a horizontal plane outdoors due to the entire sky at the design time is 8 000 lux and that due to the sky and the sun is 16 000 lux. The clear design sky basis holds good for any orientation of the building and ensures adequate daylight indoors for about 90 percent of the daytime working hours. In between the morning and evening solar altitudes of 15", the indoor illumination increases as the sun goes up in the sky and also as it approaches the windows. (SP Vol. 41 HANDBOOK ON FUNCTIONAL REQUIREMENTS OF BUILDINGS-PART 4, Dec 1995) According to NBC part 11, *"Day-lighting and window design Day lighting is utilization of light from the sun and sky to augment or replace electric light. Appropriate fenestration and lighting controls can be used to modulate daylight admittance and to reduce electric lighting, while meeting the occupants' visual comfort"* (NBC-Approach to sustainability, 2016).

Table 1: Visible Light Transmittance depending upon WWR

Window-to-wall ratio (WWR)[16]	Minimum VLT [17]
0–0.30	0.27
0.31–0.40	0.20
0.41–0.50	0.16
0.51–0.60	0.13
0.61–0.70	0.11

SOURCE Bureau of Indian Standards (BIS). 2016. National Building Code of India 2016. New Delhi: BIS.

4.2 Glazing - Windows should let in natural light and air, but they also let in heat along with the light. Correct placement, dimensioning and detailing of windows and shade forms are therefore very important aspects in the design of solar passive buildings**.** According to the National building codes, *"Primary factors/ components of a window which have significant impact on energy and cost of the building are window size and placement, glazing, frame, shading (external and internal), and screens or Jalis. Small horizontal openings close to the floors and the ceiling are extremely effective in reducing the window area to reduce heat ingress and provide adequate daylight levels in the space. In case of larger windows, glazing selection and shading effectiveness are quite important to control glare and heat gain."* (8.1.3.1.1 Window size and placement, 2016). *"Correction for glazing where windows are glazed, the sky components obtained (from Annex A) shall be reduced by 10 to 20 percent, provided the panes are of clear and clean glass. Where glass is of the frosted (ground) type, the sky components read (from Annex A) may be reduced by 15 to 30 percent. In case of tinted or reflective glass the reduction is about 50 percent. Higher indicated correction corresponds to larger windows and/or near reference points. In the case of openings and glazing which are not vertical, suitable correction shall be taken into account."*

4.3 Layout and Design - At least 30% of open space should be preserved as softscapes (permeable surfaces of the ground). All occupied buildings must have a minimum height of 2.75 m from the floor surface to the lowest point of the ceiling (ceiling floor). The minimum clearance under beams, joints, or eaves must be 2.4 m. If there is only one room with a minimum width of 2.4 m. The living area must be at least 9.5 m², and if there are two rooms, one must have a minimum width of 9.5 m2 and the other must have a minimum width of 7.5 m2. .2 Of. 1m. (Part -3 DEVELOPMENT CONTROL RULES AND GENERALBUILDING REQUIREMENTS, 2016)

5. Case Study

5.1 Case 1 – Oranje Castle

Location- Sec-07 Gomti Nagar Extension, Shaheed Path, Lucknow, Uttar Pradesh.

Project Type- Residential 3 Bhk, 4Bhk and 5 Bhk.

Project Site Context/Setting- Urban

Number of Floors- Stilt + 17

Project Area- 7 Acres

Figure 1: Oranje Castle, Gomtinagar.

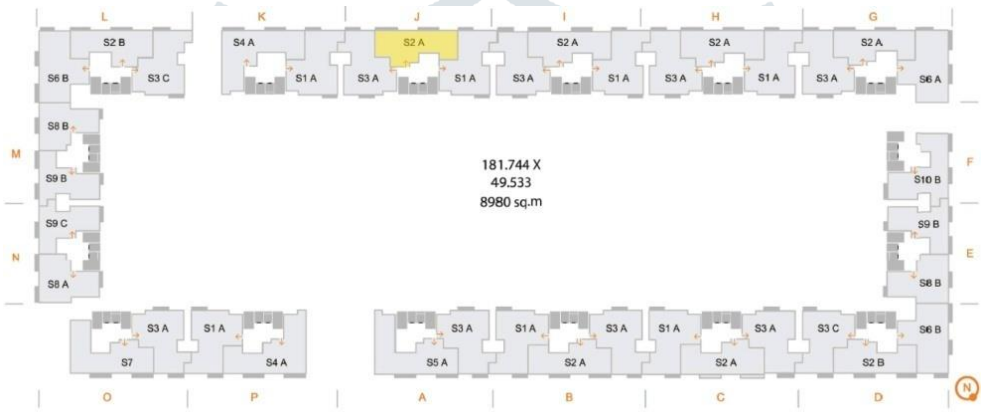

Figure 2: Key plan

The wind direction observed is east and North West. Internal layout and Planning: Compact planning with longer façade is shaded where cavity walls on exterior facades. The dimension of internal spaces is are kept less than equal to 6m hence natural light easily penetrates creating a reduction in the usage of artificial light.

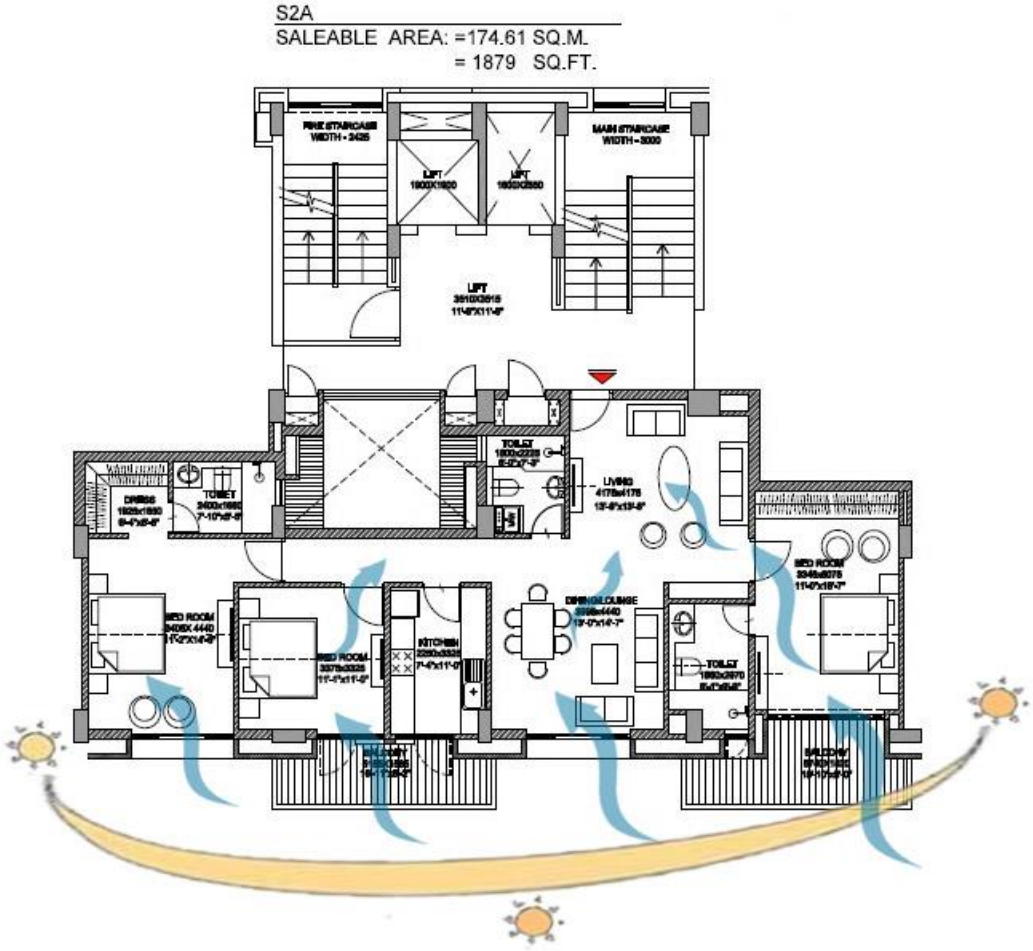

Figure 3:3BHK Apartment Layout

The internal layout of this particular apartment is compact and has the longer facade exposed to the southern direction to capture daylight which is beneficial for the winter months of the year. The provision of balconies are only on the southern façades to promote ventilation and avoided on the east and the west façade to reduce glare factor, which is double height to capture daylight and cuts the summer sun but acts as winter decks. The core is located on the northern façade and the staircase is open on one end hence it is helpful in cross ventilation of the apartment.

Table 2: Luminance data of internal spaces

Parameter	Maximum (Centre)	Minimum (Corner*)	Comments
Entrance	250	175	Capturing North light from the core area that is defused and since the plan depth is >5m the space is lit by the south facing opening.
Living/ Lounge	430	250	Plan depth is less than 6 meters thus areas are naturally lit.
Dining	450	250	Living and dining area common.
Kitchen	550	290	The kitchen is South facing and readings taken were between 3pm to 4pm
Dress/Store	130	90	No opening in the dress/ store defused light from room.
Toilets/ Bathroom	140	90	The washrooms have a ventilator opening in shafts.
Corridor	180	100	Staircase north façade open helping is illuminating the core/ corridor area.
Bedroom 1	900	450	South façade opening with no projection but recessed windows due to cavity wall. 450 value near bed head.
Bedroom 2	750	400	17’ Projection of balcony reduces luminance
Bedroom 3	650	350	18’ Projection of balcony reduces luminance but the opening size is larger hence not much difference was observed.

*In bedrooms the corner value is near the bed head. Values above 1000 lux are considered as glare.

The table above describes the illumination difference in the centre of the spaces and the corner, basically describing the maximum and the minimum lux values in the internal layout. This table helps in identifying that every space and corner is well-lit, according to NBC (STANDARDS, Dec 1995) standards of usable daylight for residence is 100 lux for bedrooms in general where as it specifies 200 lux over bed heads and while living spaces require 150 lux while non-habitable spaces like corridors, washrooms, and store areas require 70 lux to 100 lux respectively. All the readings of the tables were recorded between 3 pm to 4 pm.

Figure 4: Living room of Case 1

5.2 Case Study - Live – Omaxe Heights

Location: Vishesh Khand 2, Gomti Nagar, Lucknow, Uttar Pradesh.
Project Type: Residential
Project Site Context/Setting: Urban
Site Area: Site Area - 28280 sq.m
No. of Towers: 11 towers
Dimension: 237m x 160m

Figure 5:Omaxe Height

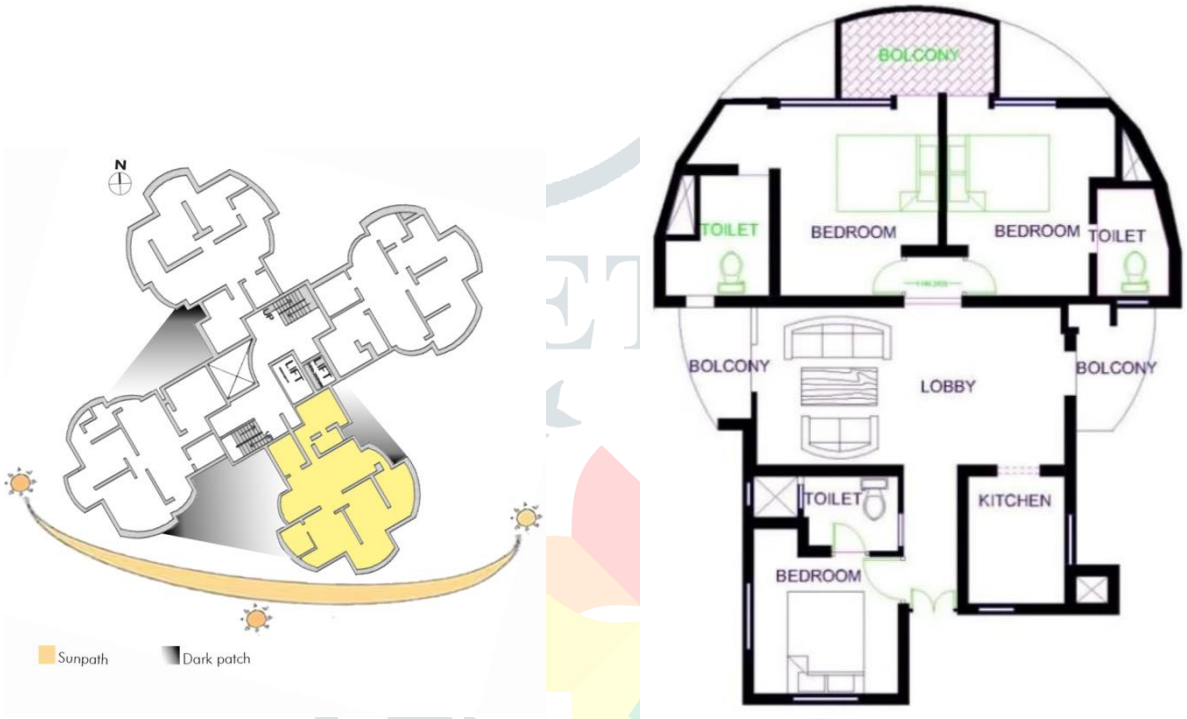

Figure 6: Typical unit plan for Omaxe Height.

The bedrooms do not have cross ventilation and most openings are not on the windward side. Plan depth of bedrooms is 5m to 4.5m hence most of the units receive defused light and are properly daylit. The units in direction North, North - East and North - West direction may not receive sunlight which may cause sick building syndrome.

Table 3: Luminance data for typical 3bhk

Parameter	Maximum (Centre)	Minimum (Corner*)	Comments
Entrance	456	250	North façade is blocked by another apartment.
Living/ Lounge	1200	882	Plan depth is less than equal to 6 meters thus areas are naturally lit along with openings on East and West Facades.
Dining	1100	850	Living and dining area common.
Kitchen	450	250	The kitchen is West facing and readings taken were between 3pm to 4pm. 250 lux over counter.
Toilets/ Bathroom	550	350	The washrooms have a ventilator opening in shafts.
Corridor	530	350	Staircase north façade open helping is illuminating the core/ corridor area.
Bedroom 1	1100	635	East façade opening with minimal projection on mutually shaded windows.
Bedroom 2	1200	860	South-East façade opening with minimal projection over half of the windows due to common balcony.
Bedroom 3	1205	850	

*In bedrooms the corner value is near the bed head. Values above 1000 lux are considered as glare.

The above table shows that luminance values measured by the lux meter in the center of the room are too high as per the (STANDARDS, Dec 1995), to be utilized, rather it shall create glare during the day. It is just the corner values that are usable and match the standard lux requirement for residential standards. This is an outcome of providing window to wall ratio not as per the standards and especially in the West and the East direction where the sunrays are hitting parallel to the ground. It is observed that the same flats mirror in all direction brings a lot of issue like flats in the northern direction shall not get adequate sunlight, necessary for a healthy living.

Table 4: Comparative Analysis of Case 1 and 2

Parameter	Oranje Castle, Lucknow.		Oxame Heights, Lucknow.		Standards for Luminance value (LUX)^
Selection criteria	Direction specific layout with cross ventilation and cavity wall reducing indoor temperature.		Apartment Building with generic design mirrored in all cardinal directions		-
Entrance	250	175	456	250	150
Living/Lounge	430	250	1200	882	150
Dining	450	250	1100	850	100
Kitchen	550	290	450	250	200
Dress/Store	130	90	-	-	100
Toilets/Bathroom	140	90	550	350	100
Corridor	180	100	530	350	70
Bedroom 1	900	450	1100	635	100 (General) 300-700 (Reading tables) 200 (Dressing tables, bed heads)
Bedroom 2	750	400	1200	860	
Bedroom 3	650	350	1205	850	

^ (SP Vol. 41 HANDBOOK ON FUNCTIONAL REQUIREMENTS OF BUILDINGS-PART 4, Dec 1995)

The difference between the two cases is that the layout of the first is direction driven while the second one is a typical layout mirrored in all directions. The openings in both the cases have 6mm single clear glass. The study helps us understand how planning and the opening sizes affect the luminance values during the day.

6. Conclusion

The reduction in the energy consumption can be observed if the areas are day lit so as to reduce the usage of artificial lighting, since we know the value of luminance specified in the standards we can plan in a manner that we utilize the maximum daylight cutting out the glare. Since the climate type is composite we need to cut the summer sun and take in the winter sun to passively heat the space. Thus we shall discuss below the provision to be made while planning a space that does the above mentioned phenomenon.

a) Orientation and Layout: The orientation of the built mass should be such that the longer facade should face the north south direction to minimize the exposed surface to the West façade. Mutual Shading of different block is to be preferred. Plan depth should be less than or equal to 6m as the light penetrates the same distance when openings on one side along with reflectors. More openings on the northern face of the building capture the north light. Louvers to be provided to trap winter sun and cut the summer sun and provide protection from rain while it is beneficial if the balconies are treated as projections and deck to treat sun in the composite climate.

b) Openings and Window to Wall Ratio: The vision window area that is located above 1.0 m but below 2.2 m is usually provided with the glass with lower VLT in order to reduce glare. Window to wall ratio on a facade, correlated to the visible light transmittance of the glazing which shall not exceed 60 percent. Recessed windows on the Southern façade is preferred along with greater projections to reduce the incoming of glare as well as sun eventually heating the space, while minimal openings should be provided on the East and the West façade as the glare is the hardest to cut and the sun penetrates deep into the space leading to internal heat gain. The WWR is the maximum for the Northern façade as diffused light is the most preferred in any habitable space and for the requirement of the climate type Southern façade is equally important during winters. Light shelves and reflectors area required for the light to penetrate deeper than 6m. It is required to maintain a balance between inlet of daylight and heat gain as the solar heat gain is directly proportional to the window to wall ratio.

c) Glazing: Where balconies area treated as projection over windows tinted glass shall reduce the lux values such that the spaces shall be requiring artificial lighting at some point of the day. To reduce heat gain via glazed windows without increasing the artificial lighting indoors, can be fulfilled by providing Double-glazed Low-e Coated Glazing as it shall prevent the building from the solar heat gain.

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