Daylight and Sustainable Architecture for Warm Humid climate

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Abstract - *Daylight has been seen as a creative element throughout architectural history, which influences the built form and the spatial quality of any building. Only that, its form or method of usage has been varied in the subsequent era in accordance to the socio economic conditions. Natural light acts as a visual element which enhances the overall perception of the space. This paper states the importance of natural light in architecture and the design criteria under which it can be efficiently utilized in the built forms, from the first step which affects the designer decision for form, proportion, location of the opening and the building orientation; especially dealing with the design criteria of Tamil Nadu region which experiences a warm humid climate where the annual temperature ranges between 38º C to 20º C, with an average humidity of 67%*

Key Words: Daylight, Design criteria, Fenestration, Interior illumination, Warm humid climate.

1.0 INTRODUCTION

The essential element that enhances the spatial quality of a building in architecture is light. Lighting plays its role over the distribution or occurrence of features such as brightness, shadows, color, their distribution and even many other aspects influencing our visual experience and taking a lead over the psychophysical well-being of the individual and the atmospheric character. This natural daylight varies with its intensity and character at various regions, according to their location with respect to the equator.

Due to the geographical location, Tamil Nadu experiences a warm humid climate. The solar radiation in this region is intense and to a great extent diffused, thus producing sky glare. Here the temperature difference is minimal, so wind is light or even non- existent for longer period.

2.0 DAYLIGHT IN ARCHITECTURE

Natural light acts as a language of communication and a medium of understanding the space by relishing over its interpretation of form, texture and color in architecture. Natural light gives an immortal identity to architecture. The manipulation of light in different ways gives a varied impression over the buildings. The extent of its availability influences the overall planning and design. To obtain a reasonable lighting, consideration over the climate, the use of the space and its speciality of visual work are taken into account. Daylight as two distinctive sources of light:

1. Sunlight - That fraction of parallel rays of solar radiation, reaching the earth's surface after certain diminution by the atmosphere (direct component)
2. Skylight - That fraction of solar radiation, reaching the earth's surface as a result of dispersion in the atmosphere. (diffused component)

Fundamental aspects of architectural lighting design:

- Aesthetic appeal – a feature important in the illumination of indoor environment.
- Ergonomic aspect - the measure of how much of function the lighting plays.
- Energy efficiency - to ensure optimum lighting in the interior, avoiding unwanted lighting or more illumination than the required task.

2.1 NEED FOR DAYLIGHT

On a practical note, daylight has the ability to satisfy biological and human need by means of its proper utilization. In general, lighting consumes about 25% - 40% of electricity in any building. Use of daylight can save or reduce it to half of its total energy consumption. It can also reduce the heating and cooling energy consumption in comparison to electrical lighting.

2.2 GOALS OF DAYLIGHT

The main goal of daylight is to bring in light deeper into the building in order to raise the illumination level and to reduce the illumination gradient across the room. The second goal deals with the reduction of direct glare of unprotected horizontal and vertical openings. The third goal is to have a control over the brightness ratio, especially caused by direct sunlight on or near the working plane. The fourth goal aims to prevent or minimize veiling reflections from skylights and high windows. By multiplying the reflections over the ceiling and wall, the light can be diffused, thus satisfying the fifth goal. The sixth goal is to utilize the aesthetic and functional potential of daylight to the fullest in spaces accompanying critical visual tasks.

2.3 NATURE OF DAYLIGHT

The daylight entering an opening can have various sources - direct sunlight, clear sky, clouds, or reflections from the ground and nearby buildings. The light from each source varies not only in quantity but also in qualities such as color, diffusion range, and efficacy. Each source of light has its own range of delivery. The two extreme conditions of daylight are overcast sky and clear sky with sunlight. Clear sky produces high illumination which is 100 to 200 times greater than the required amount of light in the indoor. Day lighting remains very high during the mid day. Under such conditions, a 1sq ft (0.6 sq m) window could illuminate over 250 sqft (23 sq m) of floor area. Even on overcast days, the same window could illuminate about 50 sqft (4.5 sq m) of floor area. Clear blue sky produces daylight of diffused form and of reduced brightness, while direct sunlight is directional and extremely bright.

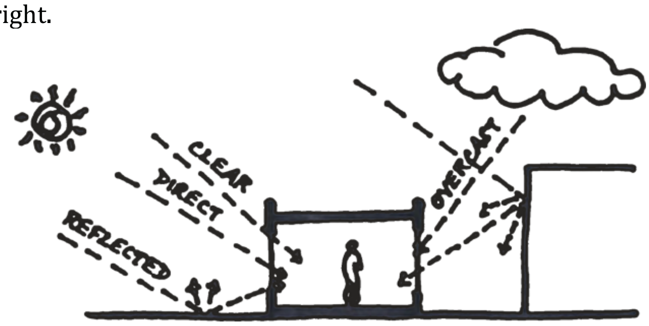

Fig -1: Sources of daylight

Positioning and material selection in the interior of building helps to illuminate by light reflectance. The reflectance factor of various materials is shown in table-1.

Table -1: Reflectance factor for various materials

Material	Reflectance (Percent)
Aluminum, reflector	90 – 98
Aluminum, polished	70 – 85
Asphalt	10
Brick, red	25 – 45
Concrete	30 – 50
Glass Clear or tinted Reflective	7 20 – 40
Grass Dark green Dry	10 35
Mirror (glass)	80 – 90
Paint Black White	4 70 – 90
Porcelain enamel (white)	60 – 90
Snow	60 – 75
Stone	5 – 50
Vegetation, average	25
Wood	5 – 40

In the building interior, the ceiling has got the most important light reflecting surface. High reflectance paints and ceiling tiles with 0.90 or high reflectance values are available, which when designed or positioned towards the daylight source, creates a brighter indoor environment.

Light reflecting proportions in the building interior are in the range as follows- Ceilings: > 90% , Walls: 50-70%, Floors: 20-40% and Furnishings: 25-45%.

2.4 DAYLIGHT FACTOR Vs DAYLIGHT AVAILABILITY

The daylight factor is a very common and easy method used to measure the quality of daylight in a room/building under an overcast sky. The higher the DF, the more is the availability of natural light. Expressed as:

$$\mathbf{DF = (E_i / E_o) \times 100\%}$$

E_i - Illuminance due to daylight at a point on the indoor working plane.

E_o - Simultaneous outdoor illuminance on a horizontal plane from an unobstructed hemisphere of sky.

The E_{in} illuminance can be considered as the sum of three different illuminances:

- The light received directly from the sky(sky component) (E_D)
- The light received directly by reflection from buildings and obstructions outside the room. (E_{ER})
- The light received directly by reflection from surfaces inside the room. (E_{IR})

Hence, the daylight factor can be expressed as the sum of three components:

$$\mathbf{DF = DC + ERC + IRC}$$

DC - Direct component
ERC - Externally reflected component
IRC - Internally reflected component

Table -2: Average daylight factor

Average DF	Appearance	Energy implications
< 2%	room looks gloomy	Electric lighting needed most of the day
2% to 5%	Predominantly day lit appearance,but supplementary artificial lighting is	Good balance between lighting and thermal aspects

	needed.	
> 5%	Room appears strongly day lit	At Daytime electric lighting is rarely needed, but potential for thermal problems due to overheating in summer and heat losses in winter

Daylight availability is defined as the ratio between the indoor and outdoor illuminance levels. It is more or less similar to daylight factor. The availability of daylight is calculated under the actual sky conditions, which also includes clear and intermediate skies.

Table -3: Minimum daylight factors

Type of space	**Daylight factor (%)**
Art studios, galleries	4 – 6
Factories, laboratories	3 – 5
Offices, classrooms, gymnasiums, kitchens	2
Lobbies, lounges, living rooms, churches	1
Corridors, bedrooms	0.5

Over cast sky condition is the presence of completely cloudy sky (100% covered) and clear sky is denoted by having less than 30% of clouds covering the sky or no clouds

2.5 DAYLIGHT STRATEGIES:

Availability of daylight and its utilization to the fullest in architectural buildings greatly depends on various aspects such as the orientation of the building, its form, the position of the opening and its type, allocation of zones (planning), and the quality of the interior in relation to the material, color and use, which also includes the elements present.

In warm humid climate the luminance available is approximately 7000 cd/sq.m. Since the cloud cover is about 60% - 70% more diffused light is available.

Table -4: Average illumination level

Spaces	**Illumination (lux)**
Hall	500 – 1000
Kitchen	150 - 500
Dining	150 - 300
Bedroom	150 - 200
Bath room	150 - 300
Class room	150 - 300
Workshop	100 – 400 (general) 300 – 400 (task)
Office	500
Conference room	300
Auditoria	150 - 200
Internal corridors, stairwell, entrance and elevator lobby	150 - 200
Parking Bays & Driving Lanes	75(indoor) 10 – 20 (outdoor)
Computer workstation	300 - 500
Library	150 - 300
Museum & gallery	300
Cafeteria	100

2.6 BUILDING DESIGNS TO BRING DAYLIGHT INSIDE

2.6.1 DAYLIGHT PENETRATION

On the basis of standards, a window can provide an illumination to a depth of about 1.5 times the distance between the floor and the top of the window with the help of natural light. Use of elements such as light shelves or other reflector systems can increase the distance to two or more times than the standard depth. Lighting penetration depth depends on the height of the window. As a common fact, a properly designed daylight is more effective within the first 25 feet from the vertical opening.

2.6.2 FENESTRATIONS

In architecture, fenestration refers to the arrangement, proportion, design of window, skylight and door system within a building which acts as a means of admitting solar radiation for natural lighting, referred to as day lighting.

Fenestrations can be broadly classified into two main types:

- Side lighting [windows]
- Top lighting [skylight]

I - Side Lighting:

The vertical fenestration introduced to the building tends to produce light that can be too bright causing glare, where provision of desirable view makes it acceptable. Side light aperture can be measured by calculating the Window-to-Wall Ratio (WWR) or Window-to-Floor Ratio (WFR). While calculating, only the transparent part of the window (i.e) the "net glazing area" is taken into count (usually 80% of the gross window area). Whether it is the calculation of wall ratio (exterior height) or floor ratio, the total surface area is considered. The calculation involves the multiplication of the Visible Light Transmittance (VLT) with Window-to-Floor Ratio (WFR). Calculated as,

0.15 < VLT x WFR < 0.18 and **0.20 < WWR < 0.30** (Preferably 0.24)

II - Top Lighting:

Buildings with large floor area or with many subsequent floors can be benefited using top lighting. Skylights, clerestories, monitor, and saw tooth roofs are categorised under top lighting types. In comparison, horizontal roof light can facilitate lighting to an extent of about three times greater than that of vertical lighting. Maximum roof light area can be limited to 12% of the floor area to reduce excessive heat gains. For rectangular skylighting, **Area of one skylight = (Floor to Ceiling Height x 1.5)^2 x target SRR** (Skylight-to-Roof Ratio). It is recommended that the percentage should be within 3%-6% and for tubular skylight it shall be 1%-2%.

A) Skylight:
Installation of skylight is best done by using diffused skylight to prevent direct sunrays which causes bright spots. Percentages of skylight area can be restricted to 5%-6% of the roof area. They may be of various forms or shapes (domed, horizontal or slightly sloping glazed openings)

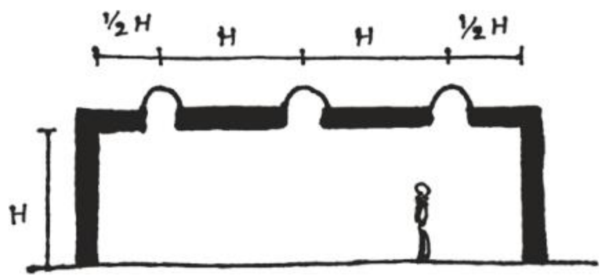

Fig -3: Recommended spacing for skylights without windows is given as a function of ceiling height.

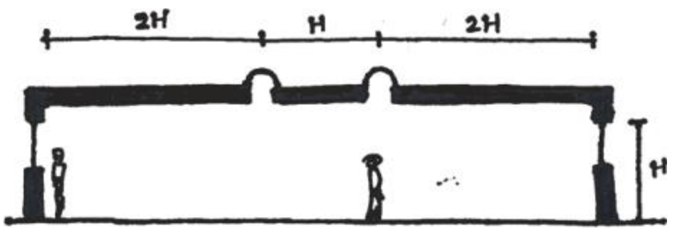

Fig -2: Recommended spacing for skylights with high windows as a function of ceiling height.

B) Clerestory Window:
These are vertical glazing, located high overhead. South facing clerestories can be shaded with overhangs when properly designed. North clerestory (angled clerestory) can reflect light deep into the room. It is usually best to have clerestories face either north or south, depending on the climate.

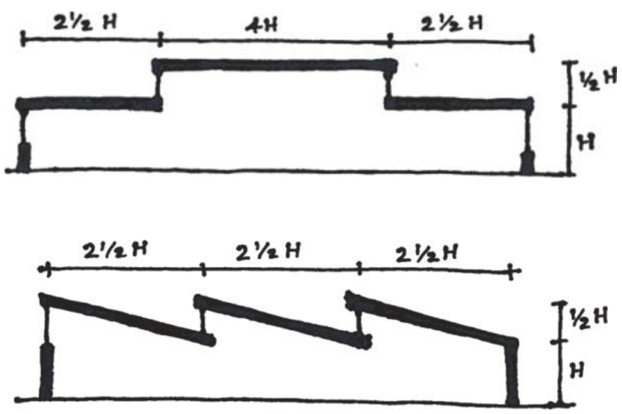

Fig -4: Typical spacing of clerestories shown as a function of ceiling height.

III - Glazing Ratio:

Glazing affords surplus amount of natural light, provided it allows unwanted summer solar gains and winter heat losses. An approximation of about 25%-50% of glazing of the external wall is recommended for proper lighting. This percentage may vary in accordance to various factors such as orientation, location, obstructions [view of sky] and activity/user requirements.

IV - Shading Devices:

Shading is considered to be an integral part of architecture which adds up to both functional and aesthetical value. Glazed openings exposed to direct sunlight should be strategically designed for solar controls, to improve building energy performance, prevent glare, increase useful daylight availability and create a sense of security. These devices can be fixed or movable in which movable can be either manual or automatic (internally or externally) shading device.

V - Shadows:

Shadows become a matter of interest. These shadows may be based on three categories, attached shadow (forming shadows on the element itself), shading (bright and dark contrast), cast shadow (shadows over other elements). The elements involved in the creation may be columns, jalli work, arches, translucent materials, etc.

3.0 DESIGN CRITERIA FOR WARM HUMID CLIMATE

Heat absorption and heat storage are avoided, and the use of low thermal mass, high reflective outer surfaces or double-skin structures is recommended. Temperature at the interior level can be maintained by the proper designing of ventilation and utilisation of air movement at increased velocity, which takes the advantage of reduction in heat and compresses the humidity level.

3.1 Settlement Planning and Design

I - Sun orientation

As the warm-humid climate zones are located near the equator, orientation of the settlements pattern should be placed preferably on southern or northern slopes. The best orientation is longer sides facing north and south directions to protect from the solar radiations. However the east and west sides should be shaded by shading devices.

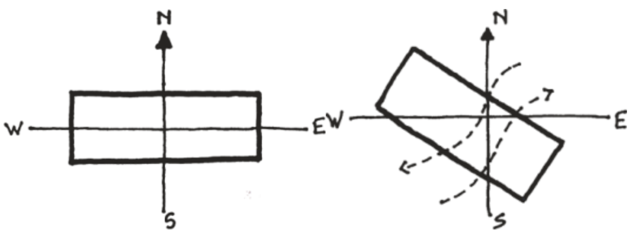

Fig -5: Optimisation of the orientation

II - Wind orientation

Primary wind direction and secondary wind direction should be considered while designing the buildings. Elongating the settlement in a line across the prevailing wind direction gives low resistance to air movement and is therefore the ideal solution. Building should be oriented along the wind direction with the longer axis intercepting the predominant wind directions.

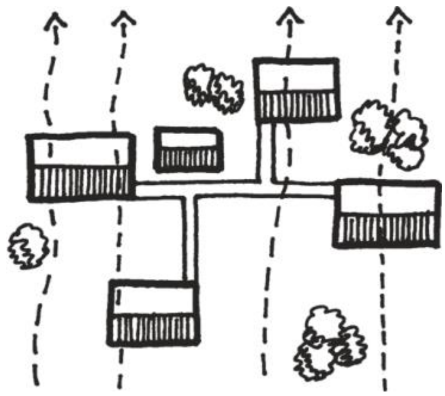

Fig -6: Building orientation along the wind direction.

Cross-ventilation acts more effective in interior spaces by enlarging the openings of the internal partitions and by providing free passage, courtyards, verandah, etc. Houses over raised platform facilitates with better ventilation. Continuous circulation of air enhances the space with appropriate temperature and humidity.

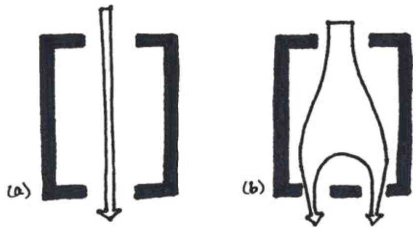

Fig -7: (a) – Good ventilation, (b) – Excellent ventilation

3.2 - Urban Form and External Space

In order to take the advantage of air circulation, an open settlement pattern is preferred, where buildings are separated with large free spaces. This pattern enhances the airflow thus facilitating proper ventilation. External public spaces are to be covered and protected for sun and rain, provided they have a proper cross-ventilation. Linear streetscapes are more advantageous for uninterrupted air movement.

The pavement which is not shaded absorbs heat quickly and increases the temperature, whereas vegetal cover increases the micro climate keeping the outdoor comparatively low.

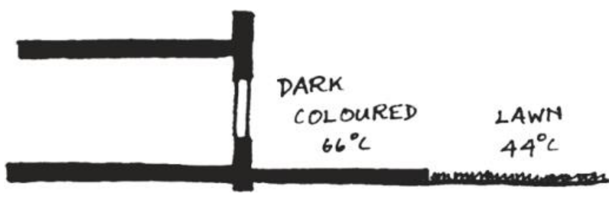

Fig -8: Temperature variation due to ground cover materials

A) Shape and volume

Forms with large surface areas are preferred to compact buildings. This favours ventilation and heat emission at night time. Two or three floors are recommended as taller buildings have too much radiant heat and also obstruct air flow to neighbouring buildings.

B) Openings and shading devices

As openings play a vital role in warm humid regions, certain criteria's are to be followed. The openings should be large enough and fully operable, equipped with flexible louvers (protection from driving rain) allowing appropriate regulation of ventilation. Fixed glass panes in openings do not satisfy any purpose.

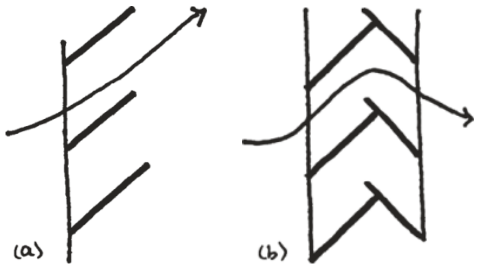

Fig -9: (a) – Ordinary louvers, (b) – Modified louvers

Jalli works can act as an alternate to windows at appropriate places as a main source of opening. Shading devices provided should be much larger as the radiation is diffused, provided it obstructs the sky and not just the sun.

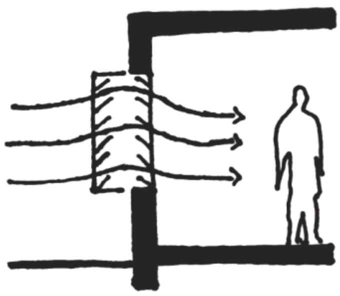

Fig -10: Inlet at lower level and outlet at higher level

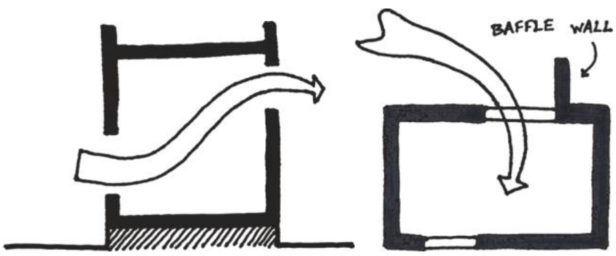

Fig -11: Baffle wall helps to drive air flow

C) Shading with vegetation

Due to the characters of solar radiation, shading devices are demanded. A low cost solution for creating a shading device is by providing vegetation rich environment, creating a micro climate. They are designed in such a way that it does not hinder the air movement.

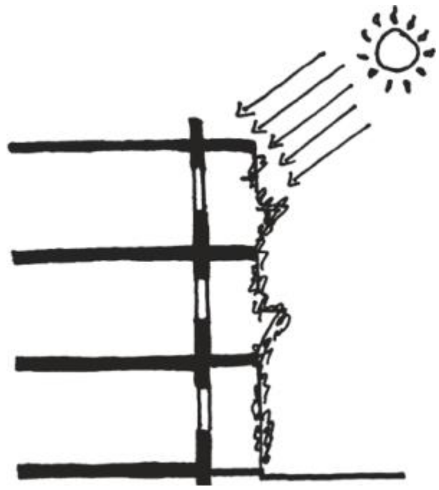

Fig -12: Green cover on balconies of multistory building

Incorporations of high trees with wide, shading canopies in landscape designing provide significant protection from solar radiation. Before reaching the buildings, air should not be allowed to pass through the unshaded pavement, as it drives in hot air.

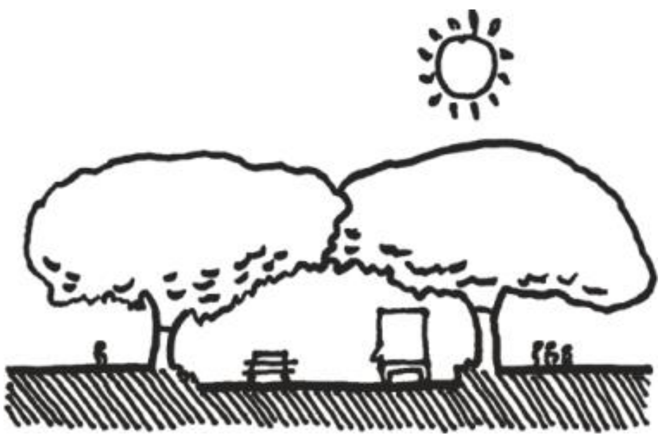

Fig -13: Canopy effect by trees

Creating landscape around the building or growing of green cover over the roof and wall (acts as a second skin) as shown in figure 12. can improve the indoor climate. They reduce the sun glare, reduces noise and dust by sound absorption and by filtering air. A stabilised micro climate is created.

4.0 SUMMARY AND RECOMMENDATIONS

Utilization of natural day light improves the quality and standard of the building in relation to the design strategies and enhances the aesthetic factor, creating a visual experience. It is an element which has an influence over the psychophysical wellbeing of an individual by the appropriate use of the natural light through fenestration, shading devices and incorporation of the perfect ratios of its characters. Considering the design criteria for warm humid climate especially in Tamil Nadu, the buildings are to be oriented in accordance to the sun and wind direction, utilizing its advantageous factor to its fullest. Water bodies are not to be added as they would tend to further increase the humidity content in the atmosphere. To encourage the air flow, the streets are to be oriented parallel to the prevailing wind direction. North – south orientation favours the blocking up of the direct solar radiation. Mutual shading can be achieved at the streetscape level by the choice of suitable road width. For uninterrupted air movement, free planning of buildings and large open spaces are recommended. The form of the building can be narrow and linear to facilitate cross ventilation. Areas with high heat and moisture content such as toilets and kitchens must be properly ventilated and can also be separated from the main structure. Open spaces such as balconies, verandahs, porches and courtyards can be increased in number. A courtyard helps to draw away the rising heat and they are to be provided with vents at higher levels. To shelter the spaces from sun and rain and to have a control over the air flow, venetian blinds and louvers can be installed. The interior and exterior surfaces can be painted with appropriate light colors and surface finishes or reflecting materials can be used to reduce heat gain of the building. The passive techniques to lower the indoor temperature are found to be cost effective.

5.0 CONCLUSION

Thus by understanding these criteria's and its proper application, enhances the spaces and creates a comfortable zone without any mechanical devices or with minimum use. While designing the buildings, both Architects and Civil engineers should take care of adequate daylight inside the building, improve the productivity levels and keep the indoor in comfortable conditions in a natural way contributing towards energy conservation and sustainable architecture.

REFERENCES

[1] BIS, National Building code of India, Bureau of Indian standards, New Delhi, 2005.

[2] Koenigsberger OH, Ingersoll TG, Mayhew Alan, Szokolay SV., Manual of tropical housing and building -climatic design. Orient longman private limited; 1975.

[3] Aravind Krishnan, Nick baker, Simas Yannas, SV Szokolay, climate responsive architecture: A design handbook for Energy efficient buildings, Mcgraw Hill Education (India) Private Limited, 2001.

[4] Norbert Lechner, Heating, cooling, lighting _ sustainable design, fourth edition

[5] Karen Kensek and Jae Yong Suk, Journal of Creative Sustainable Architecture & Built Environment, CSABE Vol. 1, November, 2011 (clear and overcast sky)

[6] http://www.beaconlightingtradeclub.com.au/media/ Assets / LUX_Levels_Chart.pdf

[7] https://www.kellwood.co.uk/led-lighting/technical/ cibse- recommended-lux-levels

[8] http://www.slideshare.net/AnanthShayan/warm-and- humid-climate-55783434?qid=ce4c727c-7712-415e- a2b9-aeb2e224f926&v=&b=&from_search=4 (design)

[9] http://collections.infocollections.org/ukedu/ en/d/Jsk02ce/3.4.html (design)

[10] https://www.noao.edu/education/QLTkit/ACTIVITY_Documents/Safety/LightLevels_outdoor+indoor.pdf (lux)

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