Section A-Research paper

Real Time Experimental Analysis on Semi-Arid Climatic conditions through Operable Windows for Effective Thermal Comfort

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Abstract

India is one of the most interesting nations with wide range of climatic conditions which holds a maximum of 8hrs above sunlight during daytime. The Research deals with the field investigation and analysis of the Day light availability inside the office space due to opening of windows which are necessary for the natural ventilation and better thermal comfort in tropical regions usually daytime working can rely on day lighting as the working concept. The whole office space is studied by means of the instrument to know the daylight penetration through the fenestrations. The Research was carried under two conditions opening the Glass Window and closing the Glass window, in which the Results evidently showed the Opened windows had higher range of Illuminance than the closed windows. The Discussions highlighted concludes the Office environment with the Windows open could be better for Day lighting and natural ventilation for thermal comfort. The Experiment was done for three days to know the average illuminance levels and the reflections of the various planes, surface in the Indoors were noted. The Colour usage and the material finishes had an impact in the distribution of the light in the indoor. The Daylight levels reached up to 2000 lux maximum to 500 minimum and average of 700 lux was maintained all around the office with the windows opened during work as per the Guidelines of lighting which is mandatory for office working environment. The Subjective questionnaire survey conducted to the office staff and the respondents were positive and inferred they were visually comfortable and thermally satisfied due to natural ventilation when the windows were opened. The Approach of allowing the day light along with natural ventilation for comfort shall be followed in office spaces for healthy work environment.

Keywords; *Day lighting, iluminance, Operable Window, daylight in office space interiors, Fenestration, visual comfort, Thermal comfort.*

1. Introduction

The energy usage in Indian for the domestic sector rose from 80 TWh in 2000 to 186 TWh in 2012, which is 22 percent of the total electrical consumption in 2012 of the planet. [1]. India and China alone consumes 50% of energy in Asian Continent and for nearly 41% of energy is used for office illumination[15] The floor space of buildings as predicted would be 400 percent from the current scenario and may have 20 billion sqm of additional spaces of build structure [2].The construction industry is booming in India with wide expansion possibly with a rate of 38% rise in annual pricing energy consumption and 31% Rise in annual electricity consumption [3] [15]. The built-up area in the commercial sector is about 1.4 billion sqm and the predicted rise in the sector maybe up to 2.2 billion sq.m meters in the next 20 years [4].Additionally, higher expectations combined with a warmer globe will result in an increase in energy consumption, driven by an increase in cooling demand. The key is addressing human comfort through sustainable and energy-efficient building designs, notwithstanding the fact that forty percent of the stock has not yet been created.

Hotels, Hospitals, Offices, Retail, Education, and Places of Worship account for a total of 1,400 Million Square Meters in 2017 according to the commercial building stock energy modelling [5]. The analysis indicates a potential for savings between 25 and 28 percent. To forecast the growth of energy performance index (EPI) and built-up area over the next 10 and twenty years, each sector was analysed separately. The projections are included in each segment's summary results. Together, they consume approximately 71 billion megawatt-hours of electricity per year. By mid of the century the energy demand is about to increase by 50% [14]. Electricity is one of the most expensive energy sources used in buildings, and electric lighting fixtures are inefficient in converting that energy to light. [9].The daylight concepts for better productivity, incorporated in all the building sectors can provide a huge reduction in energy consumption and save us without the energy deficit and additional cost increase.

1.1 Daylight

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1.2 Daylight Harvest Studies

Daylight harvesting studies is about using an optimum amount of daylight to light a space so as to reduce the amount of electricity consumption. The main idea of this technique is to maintain the minimum recommended level for the space depending on its usage. The three tier approach has been a guideline for a good daylight harvest in any building. [10]

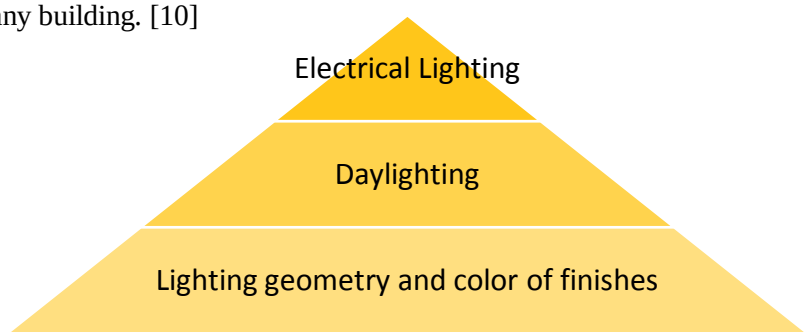

Fig 1 Three tier approach to lighting

The Daylight performance and parameters are

1.2.1 Climate

1.2.2 Latitude

1.2.3. Obstructions and Reflection on Site

1.2.4. Building Design and Geometry

1.2.5. Material Properties

1.2.6. Windows and Skylights

1.2.1. Climate

The prevailing Climatic Condition of a site helps in defining the day light designing onthe basis of available sunlight. The amount of sunshine and duration in a specific location with clear or overcast sky is a depending factor for daylight harvest in a building.

1.2.1.1 Coimbatore Climate

Coimbatore which is in the tropical zone is favorable for good daylight since the overall sunshine hours are higher in these regions. The angle of incidents of the sun also is mostly on overhead and favorable for daylight conditions. Coimbatore being an urban region with rapid development the micro climatic conditions has changed in the past decade. Most commercial buildings are just built without proper planning of daylight control. The Study Area is awarded as the seventh best city in India for living by 2020. The study area lies at 11°1′6″N 76°58′21″E in Tamil Nadu at 427 meters (1401 ft) above MSL

1.2.2 Latitude

The Latitude of a place determines the solar altitude for a particular time in a year. The altitude of the building can help in providing inputs for direct sun light into the building. This can also determine the Length of daylight available during different times of the year.

1.2.3. Obstruction and reflections on site

External reflections and Obstructions from surrounding elements can play a major role in influencing the amount of Daylight entering into a building. Roofs and Skylight elements are generally not much affected by obstacles, and they also help in increasing the amount of daylight entering a building.

1.2.4. Building Design and Geometry

The basic geometry of the building plays a major role in increasing the capacity to deliver adequate levels of day lighting in a space. When a building is linear then the idea of providing day lighting only through façade windows cannot meet the needs of the space. More window wall ratio needs to be applied. But also by this there are more chances to reach a state of visual discomfort and too much glare, hence techniques like Light Shelves or Light Wells can be adopted for better day lighting. The

amount of light received in a space is about 2H (height) on the floor surface depending on the H (Height) of the window and the obstruction factors such as sunshade, overhangs and pergolas.

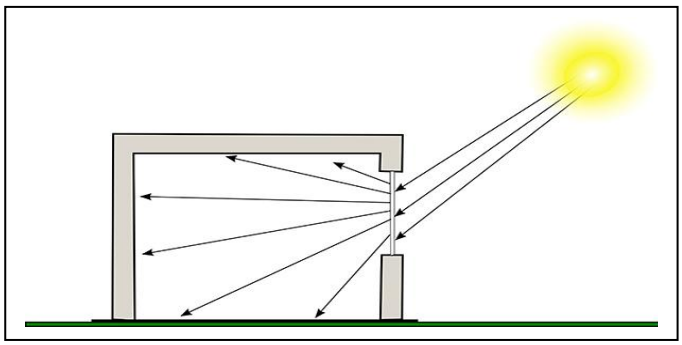

Figure 2 Daylight penetration in a building

1.2.5. Material Properties

The colour of the surface also plays a major role in lighting up a space. Dark coloured surfaces do not reflect light as much as the light surface. In places where maximum day lighting is required like office spaces, schools, residence etc. on the interior walls mostly only light coloured paints or finishes are provided in order to achieve reflective lighting into the work space. It also be noted that too much reflective lighting can also cause visual Discomfort while reading or using the space.

1.2.6. Windows and Skylights

The orientation and positioning of windows play a major role in utilizing maximum day lighting into the building. It is very important to orient the walls and windows accordingly that maximum daylight entering the building, and cutting down the irradiation. [11], thus the need for day lighting is required in all types of building for a better work environment.

2.NEED FOR THE STUDY

Daylight strategies and systems haven't always lived up to their promise as energy-saving strategies that make people more comfortable and more productive, but they haven't always worked out that way. It is always better to understand the productiveness of any model [16] which can be altered for further experimental research studies/ Quasi – Experimental Research Studies. To start, there aren't enough low-cost, high-performance lighting systems that work well. There aren't simple tools to figure out how well these advanced lighting strategies will work, and there aren't ways to make sure that daylight planning is part of the design process. Thus, it is imperative to do more experiments on day lighting. Good Lighting leads to good visibility and also the natural day lighting is human friendly specific to task [17].

Most Designers are currently ignoring the design of day lighting systems; they must devote enough attention to the design of day lighting systems during the design process. The majority of commonly used methods and design assisting tools do not provide meaningful feedback on day lighting system performance. This is true both in academia and in practice. To advance sustainable design and technology, a solution with proper empirical reference is required. As a result of this research, some novel methods of daylight harvesting can be identified and used in designs.

2.1 Daylight Strategies for an office Space

The office spaces are generally operated from 9 am to 6 pm which can be lit by means of sunlight through proper planning strategies such as space planning, form, massing, fenestrations and material choice. Nowadays the office environment mostly involves the computer based task which is generally done on a top of a desk at about 1.2 m level and the space elegance is a preferable choice of the employee. This may lead to the design of a larger office spaces which in turn may have a reduced daylight due to the larger span of work desk.

Methods must be implemented to bring in good daylight for the offices involved with larger spaces. This study will give an idea of the daylight harvest in office space and be a guideline for this region.

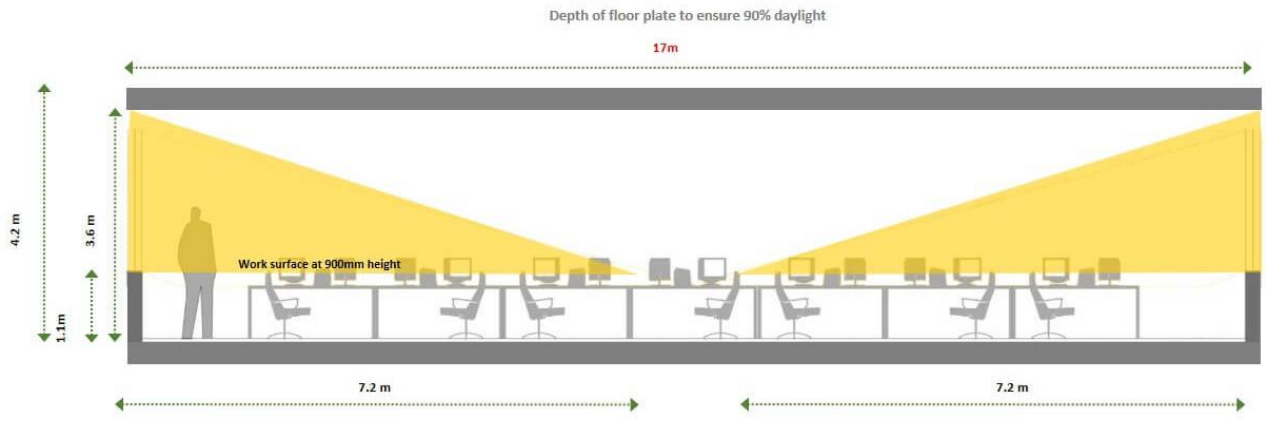

Figure 3 Day light Levels as per height of window openings

The Standard Day lighting depends on the type of Opening and the Size of the Opening in any built space. The minimum day lighting recommended for an office workspace is 350-500-750luxas per the NBC standards, which has to be followed for achieving efficient results.

3.METHODOLOGY

The experiment was carried out during the mid –summer during the month of March. Daylight Harvesting strategies were deployed to get the data, and also daylight performance parameters. Following this field study is carried out and analysed with the data collected.

Method Adopted for understanding the day light performance

3.1 Measuring Instrument

The Measuring instrument used for the Experiment was a Lux meter (HTC Instrument Lx-101) which measures up to 2, 00,000lux.It has a sensor and gives results digitally. The readings given by the lux meter are in units of Lux which is the Illuminance of the Space. The Illuminance is the amount of light received on a surface with the addition of Sky component, externally reflected component and the internally reflected component. The level of Illuminance may vary as per the Surface and colour of the Surroundings.[12]

Figure 4 Luxmeter

3.2 Field study

Location and its features

A commercial office was chosen in Coimbatore for the study and Analysis. This Office building is located near residential layout abutting to the main road andfunctionsfrom9.00Amto5.00 Pm for6 days a week. The Office building (fig 5) is rectangular in shape and it is oriented as east - west longer axis and windows evenly distributed all around the Building.

The floor plan is a basic rectangular shaped on a plot of size 63’0” (19 m) x 35’0” (10 m) with a setback of about 5’0” (1.5m) on all 4 sides. The total built up area is about 1500 sft(139 sq.m) attached with acarporchof12’0” (3.6m) length on the front. The Building gets sufficient daylight during the Day due to the larger windows which is useful for the Productive work of the Employer during the Day. The entrance door (fig 6) was made of full glass door which admits god daylight.

It has around 8 people working in it all day. Since it functions to be an electrical consultancy office space, it has many energy conservation techniques like Solar Panels, Windmills, and Green House on the terrace etc is included in the design. These techniques indeed help in the reduction of heat gain by machines, inside the building. Though Air-conditioning systems where installed in the building the need for it was lesser. The fan-forced ventilation is all that was required to push out the heat generated by the machines-computers in the workspace.

The Interior Finishes (fig 7 and 8) of the office were mostly finished with combination of the Brown colour dark bands and light colour Beige laminate for the Partition and tables which gives a better reflection of the Daylight all around. The Interior Lobby was finished with the false ceiling with the white colour. Although there are a lot of windows with sufficient day light the glare factor was one of the major concerns for the table task.

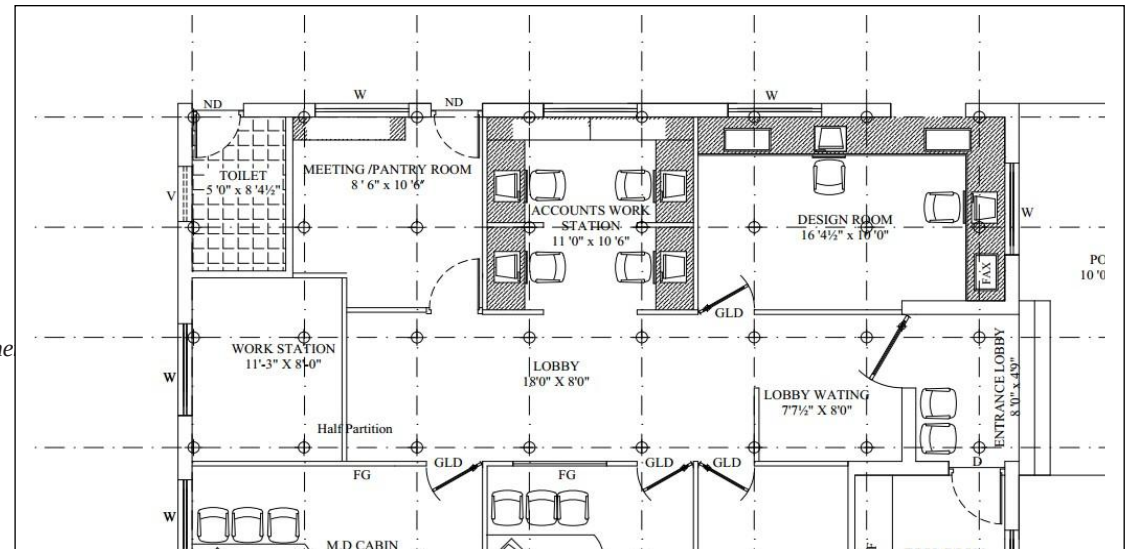

Figure 6

Figure 7

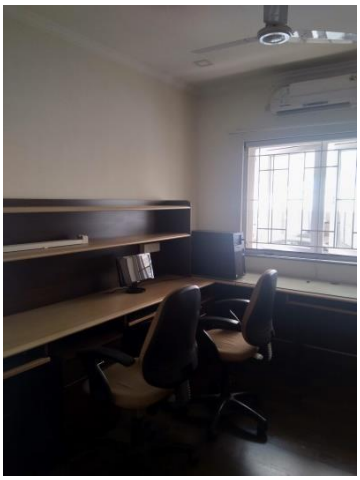

Figure 8

3.4 Field Survey

The Reading was taken on three official working days from the morning till evening. To understand the Reflection ranges and the amount of diffused transmittance due to the glass used in the windows both the readings with the Doors, windows and shutter closed and also with all of them open were considered. Normally studies such as Day lighting performance should be understood in clear manner at Controlled environment [17]. The actual impact of the direct sunlight with open windows and the other condition were understood.

3.5 Monitoring Schedule

The Daylight Readings were recorded by the Lux meter during the Three parts of the Day such as 9:00 Am, 12 :00 Noon, 2:00 PM to 4: 00 PM. The Office closed by 5:00 PM and were unable to carry out the Experiment at the end of the Day and may be considered as the limitation.

3.6 Data Collection and Analysis

Daylight Reading charts are listed as a Section for Both the Readings of the closed and open windows to get a graphical understanding of the Space lit during the particular Time. The Data collected was made a chart and analysed further for each space to get a clear understanding of the distribution of daylight.

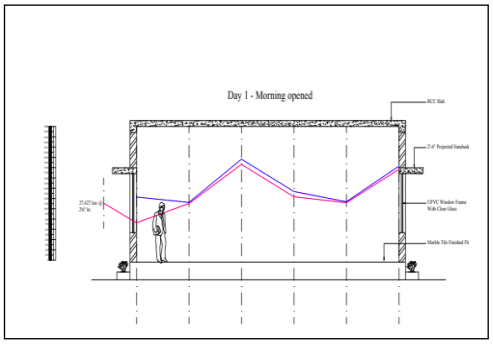

Figure 9 Typical Section showing daylight with window opened

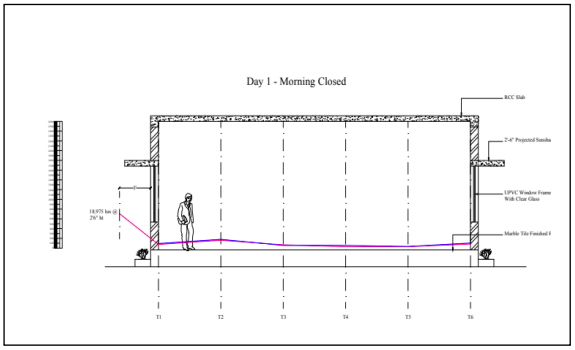

Figure 10 Typical section showing day light with window closed

The above figures (9 and 10) shown as a section of the room gives the understanding of day lighting in the office with the windows, doors and shutter closed and opened during the Morning.

The day lighting were measured as windows opened at two heights one at 2'-6"(0.75m) level will be known as Task level indicated as TL and one at a higher level of 5'-0"(1.5m) will be known as Eye level indicated as EL from the floor finish level in this paper. This measurement was done to ascertain the available lux level for the task based work and the ambient level around the indoors. Although the measurements of the illuminance were differing due to the movement of the sun, reflections, shade and other influencing factors the average level was considered as a final reading for the experiment. In figure 11 and figure 12 it is clearly showing that the lux levels at 2'6" are considerably higher while opening windows equalling to comfort range for office working environment as per the National Lighting Code 2010. Although it is evident that even while closing windows above 5' high we can able to find better lux levels in the study region.

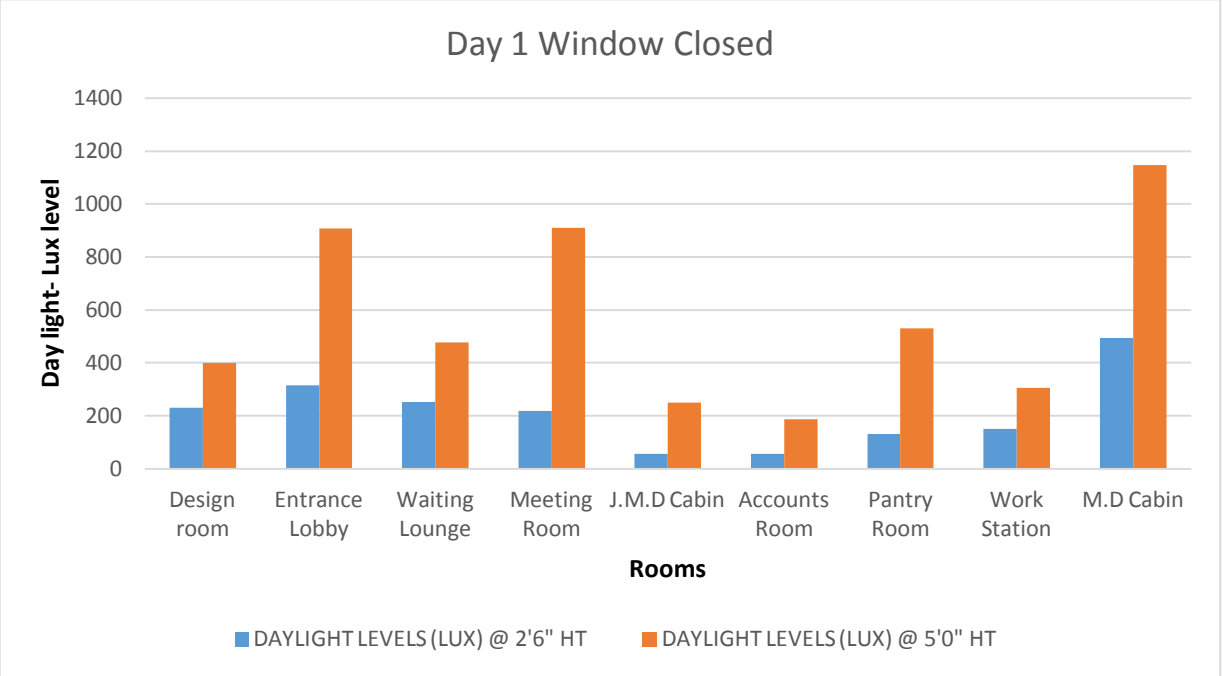

Figure 11

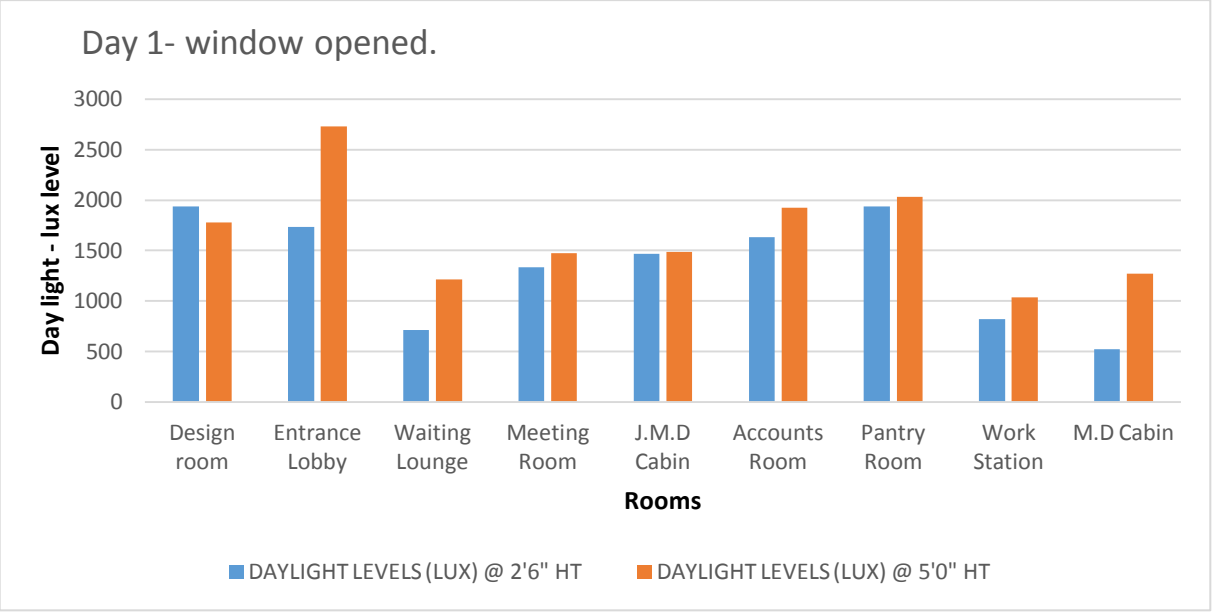

Figure 12

4. MORNING– WINDOWS OPENED AND CLOSED

The Graphs (Fig -11 and 12)above showing the illuminance of the Morning ranges with the Windows closed and Windows open gives the understanding of the variation of the day lighting in the indoors of the office. It is observed that the all the rooms were showing an illuminance level of less than

250 lux in the Morning with the windows closed at the Task level.(2'6"(0.60m)), whereas the Illuminance was high at 5'0"(1.5m)level only in few spaces. The lux levels in the morning were more than 500 lux when the windows were opened in almost all the Spaces making it suitable for a Workspace. The lux level in the workstation was lesser, which may be due to its location on the west Side of the building.

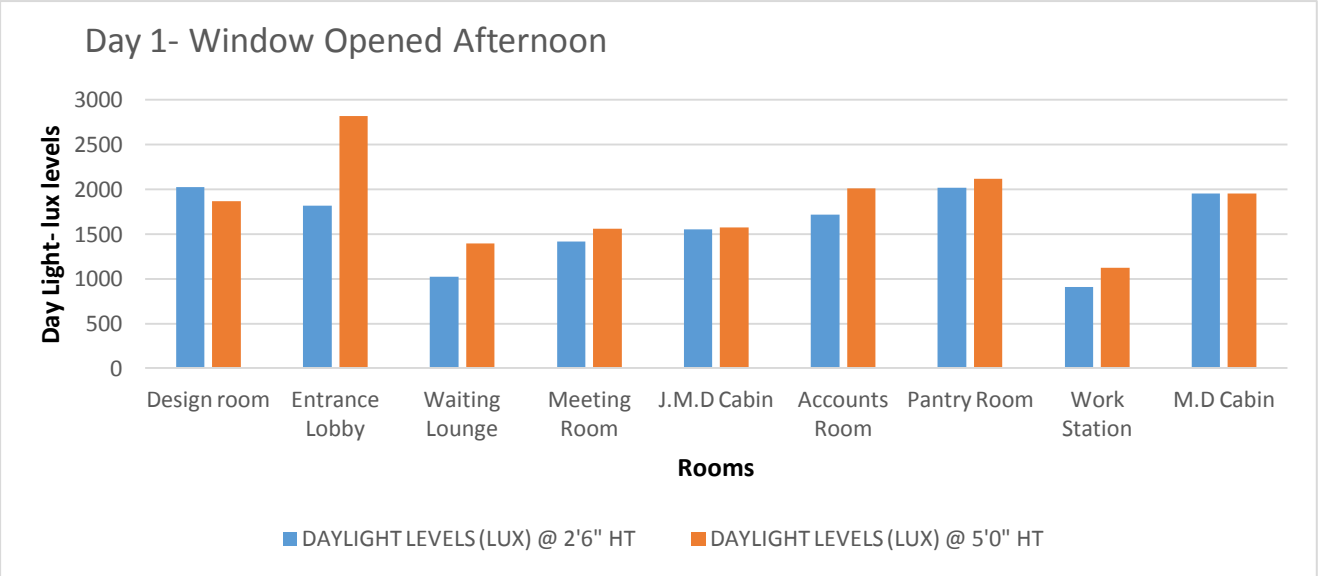

Figure 3

4.1 AFTERNOON – WINDOWS OPENED

It was noticed in graph (fig-13) evidently the two larger sized windows in the Design rooms located on the *North east corner* with windows on adjacent sides both North and east, showed a good illuminance level of about 649 to 1963lux at the TL ,which is more than the standards. The M.D.Cabin Located on the *South West* corner with the Windows on the Adjacent Side on both south and west showed illuminance levels of 1895 lux with an average of about 600 Lux at the TL and showed a higher illuminance level of about 1700 lux at the EL mostly without much variation. The Others Rooms such as Waiting lounge, JMD room, Accounts room and pantry Room showed illuminance levels varying from 743 lux to 1962 lux at the TL.

The Waiting lounge illuminance levels were always more than 500 lux on the TL and 1000 lux on the EL. The pantry room illuminance level was proportionally showing lesser illuminance in all the readings at the TL compared to the EL which was not evidently seen in all other spaces. The Entrance lobby was with the highest illuminance level of about 1758 lux in the TL and 2758 lux at the EL. The Work station

located on the West side was showing lesser illuminance of about 600 lux only at the TL than other rooms.

It can be inferred that even with the shutter and doors closed the MD Cabin, Meeting Room and Entrance Lobby all facing south have more daylight inside at 9:30am to 11:00am. Minimum day lighting happens in the design room on the North which has a neighbour building that obstructs daylight.

5. RESULTS AND DISCUSSIONS

It is evidently noticed that the illuminance levels are becoming higher due to the opening of windows during the morning and afternoon reading. The function of Windows closed in all the rooms were showing very less illuminance levels of lesser or equal to 200 lux in all the Spaces. The opening of windows not only increased the illumination ranges through reflection but also had good flow of air movement around the Building making the occupants comfortable even during the afternoon. It is always evident that the daylight performance of any building assessment leads to a better design evolution in earlier design stage through the case studies [16].

Thus it is conclusive day lighting gets affected/ minimised due to the closing of windows even if it is provided with the clear glass. The Morning and evening hours are generally comfortable, afternoon hours have higher illuminance and also higher radiation which may cause thermal discomfort. After a quick survey the occupants using the design room responded that they were comfortable with the day lighting aspects during the afternoon and evening whereas in the morning they had higher glare in the Design Room from the east side window causing a little discomfort visually. The respondents who work in the other sections feel the day lighting is sufficient for them all around the day but the glare on the task level is a little higher which causes discomfort but can be bearable Since the task mostly involves the soft skills and less of writing it was felt comfortable.

Although the day lighting is satisfactory in all spaces, afternoon ranges of illuminance were extremely high, in and few spaces caused discomfort due to irradiation. Thus, a balance between the irradiation in the indoor environments must be minimized and the illuminance level for the task must be maintained glare free. The office environment in future needs more Day lighting and natural ventilation for thermal

comfort to extensively reduce the Electrical consumption, thus the operable windows can become a favourable solution, although the factors such as dust and noise should be tackled.

5.1 Recommendations

1. Usage of curtains with projections with partial blackout/stripped options – 40% can be used for getting filtered- or diffused lights from the fenestration, and allowing the natural ventilation which can minimize the heat gain
2. Light color wooden louvers maybe an option for giving a diffused light during the afternoons and minimizing the harsh irradiation in the afternoon allowing light and ventilation.
3. Partial opening of roller blinds from top to bottom is a solution, whichcan be a manually operated as per the lighting requirement and ventilation
4. The angle of the window maybe tilted to 30° in plane to get reflected sunlight in the projected area and giving a distributed daylight conditions for the office.
5. The usage of ventilators-manually operated for diffused light and ventilation from the ceiling level
6. Manual operation / automatic operation with sensors of the Window blinds as per the sun path can minimize the irradiation and heat ingress and bring sufficient daylight.

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