A Study on Window Configuration to Enhance Daylight Performances on Working Space of an Architect's Office in Chittagong

Ali Akbar Razon

Abstract— Daylighting is a part of built forms throughout architectural history. Before the 1940s, daylight was the main light source in buildings; artificial lights supplemented the natural light. In last 20 years, artificial lighting avail the capability to transform the workplace visually exciting meeting most of the requirements of lighting for occupants. In Chittagong many office buildings are exist without window or windows. In case of having windows, the windows are not used as a source of natural light during day time. Most of the time working spaces in offices are fully dependent on artificial lighting system which may cause vision-related problems, such as eye fatigue, other health complaints related to temperatures or noise, impatient to work, fluctuation and mental problem. In some cases due to sizes and placement of windows are not capable to provide enough light or no light because of surrounding buildings and lack of sufficient distance from building to buildings. The objective of this paper is to highlight the importance of day lighting for office work and to provide or ensure more natural light in interior space of architect's office. For my research daylight intensity inside interior spaces will be simulated using Ecotect/Radiance/Daysim and will be evaluated with changing different design options (such as varying window sizes, orientations and positions) of the build form for achieving effective daylighting in interior space of the architect's office. It is expected that the outcome of the research will demonstrate use of daylight to improve human performance, to change the state for better health, and to boost work efficiency in office. The research will also demonstrate impact of daylight use on energy efficiency of buildings and work efficiency of architects at office.

Index Terms— Day lighting, artificial lighting, design process, window configuration, energy optimization, simulation, Office buildings

1 Introduction

Daylight is the combination of direct sunlight and diffuse sky light. Sun light is a full

Spectrum light and it is the light source that most closely matches human visual response. Since the human eye is accustomed to daylight, it requests less light to perform a task than in the case of electric lighting. That offers two advantages: a more comfortable view and a lower level of light required. Another positive aspect is the colour rendering. The best perception of colour is possible for light that covers all the wavelengths of the visible spectrum. Additionally, no artificial light can mimic the Variation in light spectrum that characterizes the daylight in different times of the day, Seasons and weather conditions. To sum up, natural light stimulates physiologically the human visual system and the human circadian system, benefiting people's well-being and health (Boyce et al., 2003).

All these factors improve the living quality in an environment; however, they are not the only ones. As mentioned before, there is also a psychological component that affects the well-being of people and improves their working conditions. That is why the interaction between the person, daylight and the outside world enhances the satisfaction. A view out gives knowledge of the weather, the time of day and changing events in the outside world, and it can supply relief from feelings of claustrophobia, monotony or boredom (Collins, 1975). Ne'eman and Kopkinson maintain that Occupants of windowless buildings frequently complain of deprivation and excessive enclosure, suggesting that the window is not only a source of light and fresh air but it also serves as a means of contact with the outside world. They suggest that the best size for windows, connected to the well-being of people, depends also from the size of the room and they prove that the critical minimum size of the window is in the order of one sixteenth of the floor area (Ne'eman et al., 1970).

Employees spend most of their working days inside offices, where physical conditions influence their well-being and, therefore, their working performance. An environment with uncomfortable thermal and visual conditions and with elements of psychological discomfort decreases the well-being and jeopardizes the health of employees. For example, an unsatisfactory lighting environment in office buildings is reported by between the 57% and the 66% of the cases according the study by Schuster (2006). It is also pointed out that the possibility to interact with the indoor environment, as well as an adequate contact to the outside and sufficient use of daylight, enhances user comfort and satisfaction. For this reason, big windows are strongly favoured in the work place. Moreover the use of daylight offers numerous alternatives to arrange the space and to improve the aesthetic of a building since light is an important design element.

Ali Akbar Razon is currently working as a lecturer in Department of Architecture in Premier University, Chittwagong, Bangladesh and also pursuing masters in Architecture program in Department of Architecture in Bangladesh University of Engineering and Technology (BUET), Bangladesh, PH-+8801735909262.
E-mail: razon.aust09@gmail.com

ISSN 2229-5518

2 2.BACKGROUND

2.1 Practise of using natural and artificial light in Chittagong

Daylight is one of the most important natural forces available to architects in their quest to enhance the visual quality of interior spaces. It is an abundant resource in the tropics (like Chittagong, Bangladesh), indispensable both as a primary source of illumination as well as an ingredient of drama, excitement and dynamism in the architecture and aesthetics of spaces (Ahmed & Joarder, 2007).

Of all the large cities in the country, Dhaka has the highest consumption of electricity (Sharma, 2002). After Dhaka city Chittagong city has considered the second highest consumption of electricity. Considering that finite resources of energy must be conserved in global terms (Philips, 2002), energy consciousness in the design of the luminous environment is essential. This will ideally lead to day lit office buildings, with controlled supplementary electric lighting (Bell & Burt, 2995).

In Chittagong many office buildings are exist without window or windows those are not used as a source of natural light in day time. Many buildings completely rely on artificial light during daytime. Most of the cases due to sizes and placement of windows are not capable to provide enough light or no light because of surrounding buildings and lack of sufficient distance from building to buildings. Most of the architect's office use artificial light as the main contributor to the visual environment, even though there is an abundance of daylight.

2.2 Aim and objectives

The findings of survey will help to identify some problems on window configuration, window size, sill height, lintel height etc. Survey shows that lighting design in general is a neglected aspect of the overall design of spaces. Most of the cases it is found that the popular practice is against the common strategies of daylight. Survey also indicate that there is a considerable potential for more daylight inclusion into offices by some simple modification of the existing window pattern or window size and awareness about day lighting issues during the design phase. The main objective of this paper is to provide or ensure more natural light in interior space of architect's office especially the working spaces. The paper tried to draw simple recommendation that can be applied easily in any time from design phase to even after occupancy. It is desired that these recommendations will develop the luminous environment of offices under daylight.

2.3 Scope and limitation of the work

Only following the Window size and position recommended in this paper is not enough to ensure proper daylight in the workstation. There are some limitations because some other variables are interlinked with this window configurations for example window directions, shading devices, venetian blinds, glazing types, louvers, building surroundings , room height etc. The basic learning from this paper is for the architects and the designers to concern about daylight when designing the office buildings (especially workstation).

3 RESEARCH METHOD

3.1 Literature Review

At the beginning, literature review of daylight intensity inside interior spaces will be studied with changing different design options (such as varying window sizes, orientations and positions) of the build form for achieving effective day lighting in interior space of the architect's office.

3.2 Field Survey

This work started with a physical survey on an Architect's offices located in Chittagong to explore the current lighting practice and to identify key design issues where daylight could broadly enhance the luminous environment for offices. During survey, importance was given on the surrounding context and external and internal elements of the offices that directly affect daylight inclusion into the office interiors and the overall luminous environment. The findings of the survey helped to identify some specific problems and potentials of using daylight in Architect's office in the context of Chittagong city. The items covered in the survey are:

- ☐Office time duration/ office hours.
- ☐Details of windows (type, material, sill, lintel, shading, internal blinds,)
- ☐Window size and orientation
- ☐Site surroundings and other element beside the office.

3.3 ECOTECT/RADIANCE/DAYSIM Analysis

In this research DAYSIM, that use dynamic Climate-Based Daylight Modelling (CBDM) method (Mardaljevic, 2006), was used to calculate DA, UDI>2000 and annual illumination profile for the case space. Both RADIANCE and DAYSIM have been validated comprehensively and successfully for day lighting analysis (Reinhart et al., 2001). ECOTECT was used as the modelling interface to launch DAYSIM program. Introduction and changes of windows orientation and positions and varying window sizes were done in ECOTECT. The location of core test plane sensor (test point) was then fixed at the working area, where the architects are working in the table and using computers and drawing table. To analyse performance metrics, the same annual illuminance profile was used based on DAYSIM calculations. Figure shows 1 the flow diagram of parametric simulation study followed in this research.

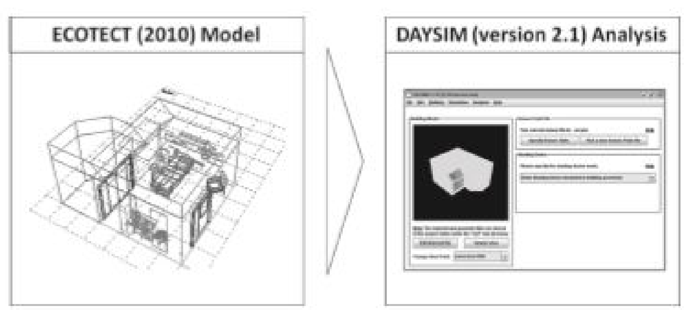

Figure 1: Flow diagram of parametric simulation study.

4 LITERATURE SYNTHESIS

4.1. Window configurations

The design of openings becomes much more complex in climates with clear and sunny sky. Configuration of openings can modify the intensity and distribution of daylight to create appropriate luminous environments (Leslie, R., 2003). The configuration of windows is dealt with in greater detail in the following.

- Side lighting; although the most common way to introduce daylight into a space is via side openings, a critical issue in side lit spaces with a single aspect, common in offices, is the fact that daylight contributions are not uniform, falling off rapidly as one moves away from the opening(Baker, N., Steemers, K., 2014).

- Window location; the intensity and distribution of daylight improves with higher glazing positions (Baker, N., Steemers, K., 2014).

- Window to wall ratio (WWR); the daylight distribution is also affected by greater areas of openings, extending daylight zone (Baker,N., Steemers, K., 2014).

4.2 Standards

According to BNBC the recommended values of illuminance for offices are

- General office – 300 lux
- Board, Drawings – 450 lux

For Architects office the recommended illuminance value is 450 lux in working space. Working area is the most important part in Architect's office where enough light is necessary for drawing or other works.

Offices	
Entrance lobby and reception areas	150
Conference rooms and executive offices	300
General offices	300
Business machine operation	450
Drawing office	
General	300
Boards and tracing	450
Corridors and lift cars	70
Stairs	100
Lift landings	150
Telephone exchanges	
Manual exchange rooms (on desk)	200
Main distribution frame room	150

Fig 2: BNBC standards for offices

4.3 Daylight metrics

Over the past decade, many metrics have evolved for measuring daylight, which can be categorized into two main groups: static metrics and dynamic metrics. Static metrics (moment-in-time based metrics) include daylight factor, view to the outside, the avoidance of direct sunlight (Tregenza, 1983), uniformity, and illuminance (Perez et al, 1993) while dynamic metrics include daylight autonomy (DA), continuous daylight autonomy (cDA), useful daylight index (UDI), spatial daylight autonomy (sDA) and annual sunlight exposure (ASE). The main difference between dynamic metrics and static metrics is that they consider meteorological data, the quantity of daylight and daily and seasonal variations of daylight throughout the whole year for a given building (Reinhart et al., 2001). As we rely on measurement and simulation with static metrics, only daylight factor, uniformity, and illuminance could be applied in this study, which is discussed in the following.

- Daylight factor (DF%): DF is the simplest and the most common metric to quantify the daylight allowed by a window, as it expresses the potential illuminance inside a room in the worst possible scenario under overcast sky conditions, when there is less exterior daylight. Minimum and average daylight factor for offices have been defined as 0% and 5%, respectively (Baker,N., Steemers, K., 2014).

- Illuminance: is the amount of light falling on a surface per unit area, measured in lux (BNV. New Construction, 2012). In office room the recommended average values illuminance is 300 for general office and 450 for tracing work and drawing purpose.

5 CASE STUDY

My case study building is a residential cum office building. Ground floor is used as Architect's own office and the first floor is used as residence. My study area is the Architect's working space. The office is located in Sughandha Residential area in Chittagong. A 20 feet wide road on the East side is the main entrance of the building. The building is north-south oriented. The case study building is 2 storied. On the North and South side of the case building, there are two 6 storied buildings. And the west side there is a 4 storied building. As my case study building is surrounded by tall buildings and lack of proper set back from case building to surround building, there are scarcity of daylight inside of the office which is located in ground floor. Artificial light here replaces the day light in day time. I give more emphasized on the working area, because Architects are working here from 9 am to 5 pm. Sometimes when workloads are increased, the working hour may turn from 9 am to 8 pm or 10 pm. But maximum time the working hour is 8 hours (9 am to 5 pm). Though most of the time the employs use day time in the offices, it would expected to use daylight.

Fig 3: Google Map (Architect Office)

Fig 4: Architect Office (Align Architects)

But by surveying the office we found that the intensity of daylight in the office (especially working area) is too low, so artificial light is used in the interior spaces whole day as main source of lighting.

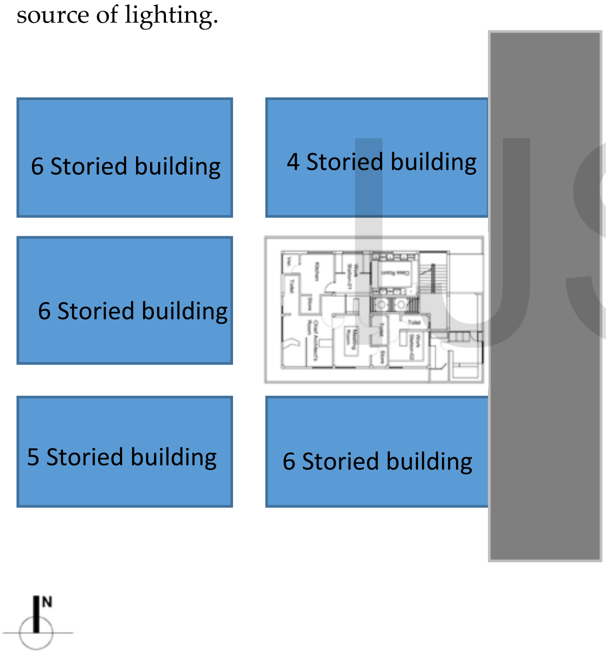

Fig 7: Site plan (Architect Office)

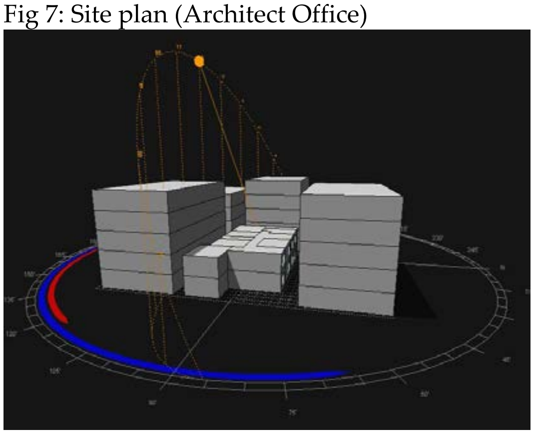

Fig 6: Ecotect Analysis of Case Study Building

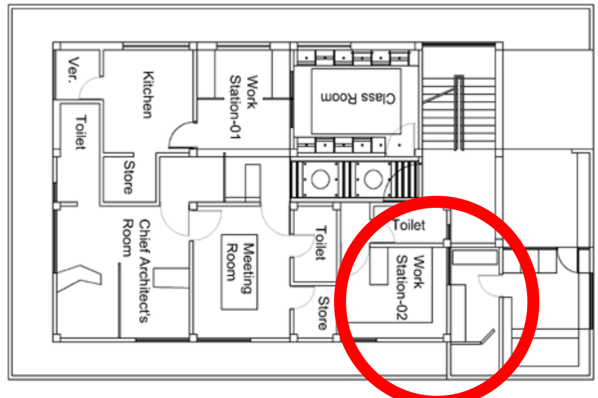

Fig 7: Ground floor plan (Architect Office)

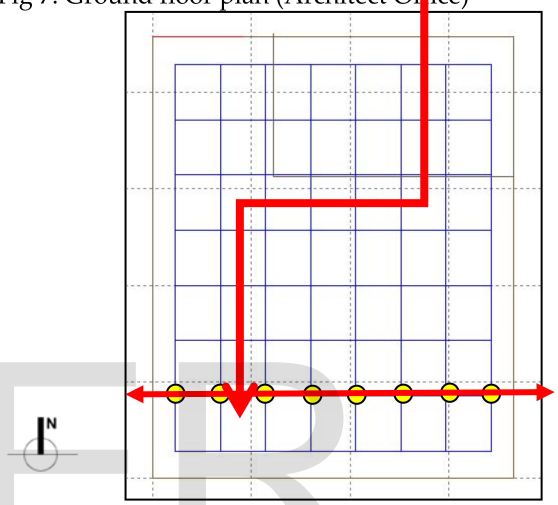

Fig 8: Analysis Grid (working area)

Fig 9: Work station (without using artificial light @ 3.00pm

Fig 10: Work station (using artificial light @ 3.00pm

6 SIMULATION STUDIES

The main objectives of the paper is focusing on the daylighting analysis. In this section, a preliminary analysis of the tools, used later to clarify the impact of window size and orientation and position is conducted. The main focus of the simulation are-

- Average daylight level on the working areas in the office.
- Number of points within acceptable illumination levels.
- Fluctuation of daylight levels from the window towards deeper spaces.
- Comparison of rendered images of the example space generated by radiance for luminance levels on the specified surface.
- Different performance metrics with Daysim to verify the annual performance data.

In the simulation study, from different types of windows I pick up three types of windows for analysis and want to identify the better illuminance level in the interior space of the working area. The existing window pattern is also analyzed in the study.

6.1 Existing Window Analysis

6.1.1 6.1.1 Radiance Simulation of existing window

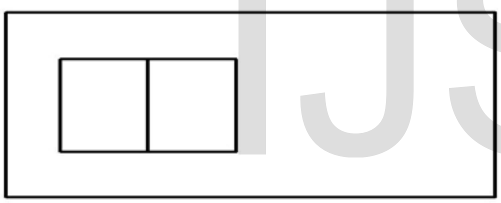

Fig 11: Existing window

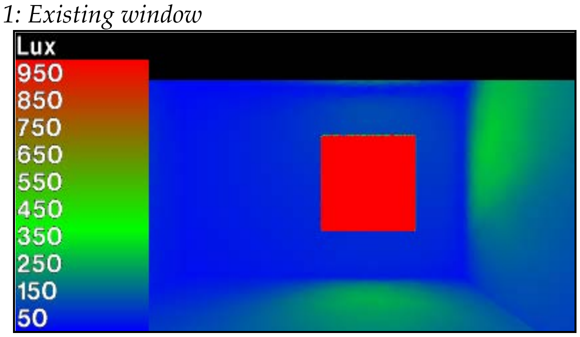

Fig 15: Radiance Analysis of existing window

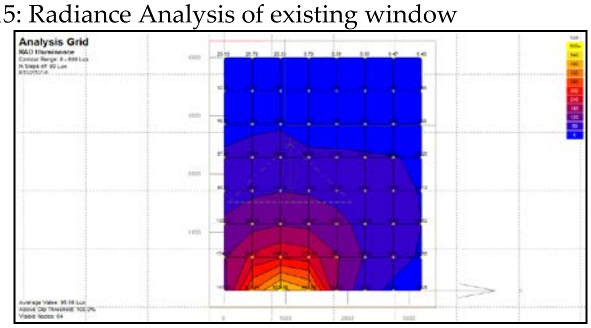

Fig 13: Daylight Analysis of existing window

6.1.2 Daysim Simulation of existing window

- Daylight Factor (DF) Analysis: 9% of all illuminance sensors have a daylight factor of 2% or higher. If the sensors are evenly distributed across 'all spaces occupied for critical visual tasks', the investigated lighting zone would not qualify for the LEED-NC 2.1 daylighting credit 8.1 as the area ratio of sensors with a daylight factor over 2% would need to be 75% or higher (see www.usgbc.org/LEED/).
- Daylight Autonomy (DA) Analysis: The daylight autonomies for all core workplane sensors lie between 0% and 75% .
- Useful Daylight Index (UDI) Analysis: The Useful Daylight Indices for the Lighting Zone are UDI<100=39%, UDI100-2000=61%, UDI>2000=0% .
- Continuous Daylight Autonomy (DAcon)and DAmax Analysis: 42% of all illuminance sensors have a DAcon above 40% . 0% of all illuminance sensors have a DAmax above 5% .
- Electric Lighting Use: The predicted annual electric lighting energy use in the investigated lighting zone is: 2.6 kWh/unit area.

6.2 Case 01 Analysis

6.2.1 6.2.1 Radiance Simulation of Case 01 window

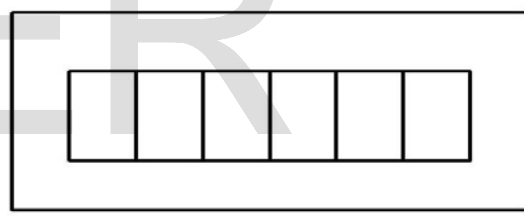

Fig 14: Proposed case 01 window

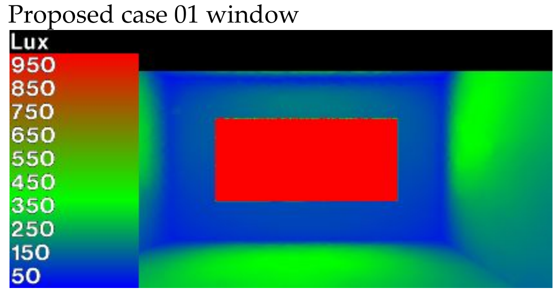

Fig 12: Radiance Analysis of case 01 window

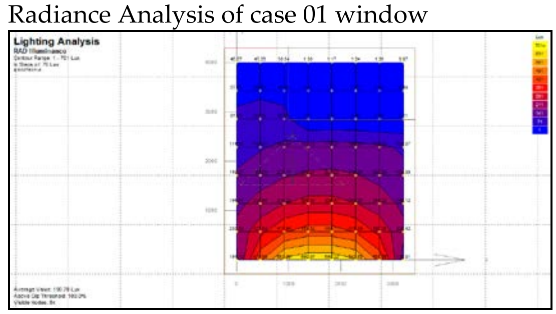

Fig 13: Daylight Analysis of case 01 window

ISSN 2229-5518

6.2.2 6.2.2 Daysim Simulation of Case 01 window

- Daylight Factor (DF) Analysis: 25% of all illuminance sensors have a daylight factor of 2% or higher. If the sensors are evenly distributed across 'all spaces occupied for critical visual tasks', the investigated lighting zone would not qualify for the LEED-NC 2.1 daylighting credit 8.1 as the area ratio of sensors with a daylight factor over 2% would need to be 75% or higher (see www.usgbc.org/LEED/).
- Daylight Autonomy (DA) Analysis: The daylight autonomies for all core workplane sensors lie between 62% and 87% .
- Useful Daylight Index (UDI) Analysis: The Useful Daylight Indices for the Lighting Zone are UDI$_{<100}$=4%, UDI$_{100\text{-}2000}$=92%, UDI$_{>2000}$=5% .
- Continuous Daylight Autonomy (DA$_{con}$)and DA$_{max}$ Analysis: 61% of all illuminance sensors have a DA$_{con}$ above 60% . 0% of all illuminance sensors have a DA $_{max}$ above 5% .
- Electric Lighting Use: The predicted annual electric lighting energy use in the investigated lighting zone is: 2.0 kWh/unit area.

6.3 Case 02 Analysis

6.3.1 Radiance Simulation of Case 02 window

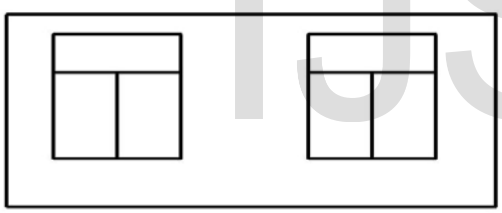

Fig 17: Proposed case 02 window

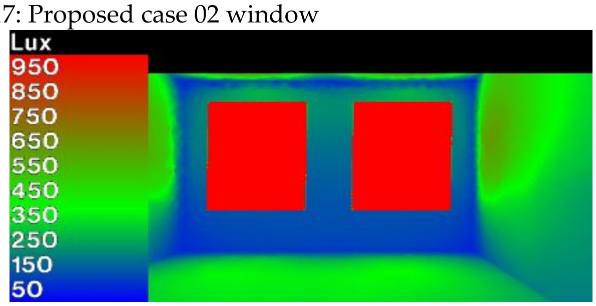

Fig 18: Radiance Analysis of case 02 window

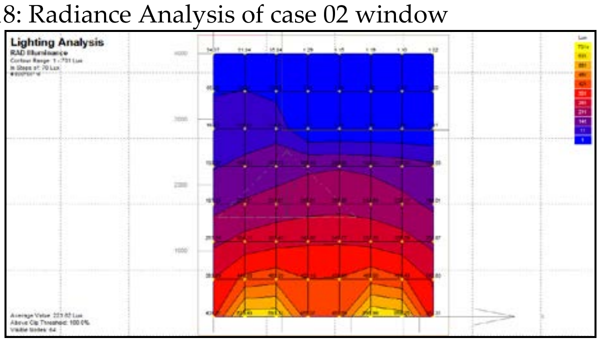

Fig 13: Daylight Analysis of case 02 window

6.3.2 Daysim Simulation of Case 02 window

- Daylight Factor (DF) Analysis: 39% of all illuminance sensors have a daylight factor of 2% or higher. If the sensors are evenly distributed across 'all spaces occupied for critical visual tasks', the investigated lighting zone would not qualify for the LEED-NC 2.1 daylighting credit 8.1 as the area ratio of sensors with a daylight factor over 2% would need to be 75% or higher (see www.usgbc.org/LEED/).
- Daylight Autonomy (DA) Analysis: The daylight autonomies for all core workplane sensors lie between 79% and 90% .
- Useful Daylight Index (UDI) Analysis: The Useful Daylight Indices for the Lighting Zone are UDI<100=2%, UDI100-2000=91%, UDI>2000=7% .
- Continuous Daylight Autonomy (DAcon)and DA-max Analysis: 63% of all illuminance sensors have a DAcon above 60% . 6% of all illuminance sensors have a DAmax above 5% .
- Electric Lighting Use: The predicted annual electric lighting energy use in the investigated lighting zone is: 1.9 kWh/unit area.

6.4 Case 03 Analysis

6.4.1 Radiance Simulation of Case 03 window

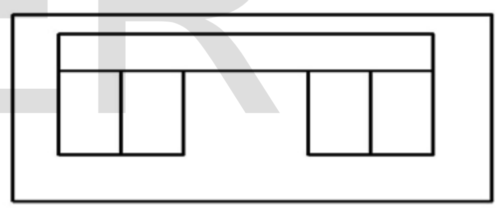

Fig 17: Proposed case 02 window

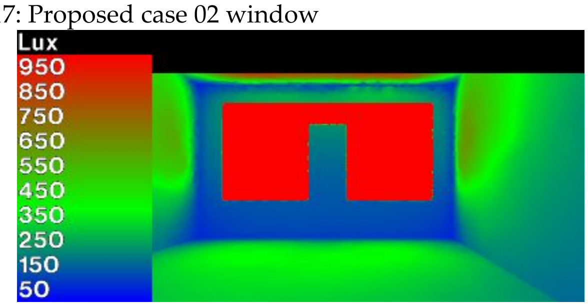

Fig 17: Radiance Analysis case 03 window

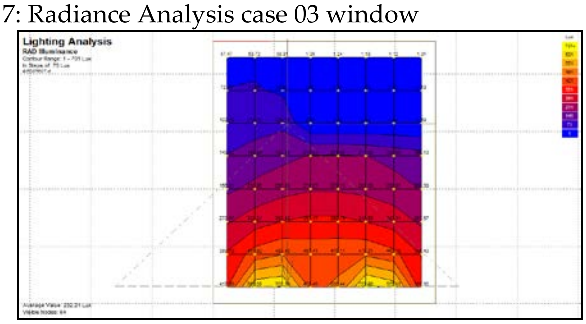

Fig 17: Daylight Analysis case 03 window

ISSN 2229-5518

6.4.2 Daysim Simulation of Case 03 window

- Daylight Factor (DF) Analysis: 45% of all illuminance sensors have a daylight factor of 2% or higher. If the sensors are evenly distributed across 'all spaces occupied for critical visual tasks', the investigated lighting zone would not qualify for the LEED-NC 2.1 daylighting credit 8.1 as the area ratio of sensors with a daylight factor over 2% would need to be 75% or higher (see www.usgbc.org/LEED/).
- Daylight Autonomy (DA) Analysis: The daylight autonomies for all core workplane sensors lie between 80% and 90% .
- Useful Daylight Index (UDI) Analysis: The Useful Daylight Indices for the Lighting Zone are $UDI_{<100}$=2%, $UDI_{100-2000}$=88%, $UDI_{>2000}$=10% .
- Continuous Daylight Autonomy (DA_{con})and DA_{max}- Analysis: 66% of all illuminance sensors have a DA_{con} above 60% . 9% of all illuminance sensors have a DA_{max} above 5%.

7 DISCUSSION

This study examined the daylight performance of an Architect's office (Working area of Architects where drawing and other works are done) with changing design options of windows (such as varying window sizes and positions) of the build form for achieving effective daylighting in interior space of the office. The south-facing office implementing the three proposed windows concept which was simulated by using Ecotect/Radiance/Daysim. Different kinds of windows have shown different day lighting levels in Simulation tools. Each proposed design options (windows) shown different daylight levels and daylight factors for each options.

7.1 Static simulation

From the radiance simulation study it is found that with the changing of the window configuration the illuminance condition enhances from existing condition in each condition. But according to standard luminous requirement case 01 performs better than others as in this case the working table is provided with 414,454,455 and 416 lux in selected 4 points which is closest to standard condition of 450 lux. Where case 02 has 462,422,424 and 465 lux and case 03 has 489,467472 and 479 Lux in selected 4 points of working table in office.

7.1 Dynamic Simulation

From the Daysim simulation the following comparison on Useful Daylight Index (UDI) Analysis is found.

From Table 1, it is seen that case 01 is performing better than other cases in terms of Useful Daylight Index (UDI) as in this case $UDI_{<100}$=4%, $UDI_{100-2000}$=92%, $UDI_{>2000}$=5%

	DAcon(%)	DAmax(%)	UDI <100 (%)	UDI 100-2000 (%)	UDI >2000(%)
Existing	42% above 40%	0% & above 5%	39%	61%	0%
Case 01	61% above 62%	0% & above 5%	4%	92%	5%
Case 02	63% above 60%	0% & above 5%	2%	91%	7%
Case 03	66% above 60%	0% & above 5%	2%	88%	10%

Table 1: Comparison of Useful Daylight Index (UDI) on analysis grid between four cases

8 CONCLUSION

Daylight is the most efficient source of light which usage should be maximize even in overcast condition. Good quality lighting condition help to improve the work performance and the user comfort. Daylight plays a crucial role in improving employs performance which is in turn largely affected by window configurations. This paper studies the effect of each window configuration on daylight performance. Further studies are encouraged in order to carry out simulations in which different window configurations are run simultaneously to obtain more optimum results. Future studies may evaluate suggested windows configurations by annual metrics to avoid glare, excessive sunlight, and visual discomfort and simultaneously provide enough daylight level.

There are some limitations because the field studies cannot take into the consideration of employs physiological, psychological, and behavioural aspects of daylight due to limitation of time. Also neglected employs visual comfort, performance and other health complaints related to temperatures or noise, impatient to work, fluctuation and mental problems. Employs preferences, satisfaction and expectations cannot be addressed through subjective measurements and questionnaires. It is expected that future studies compare subjective measurements with objective measurements to yield more user-friendly results.

9 APPENDICES

A Survey on Daylighting Potentiality in the Buildings of Chittagong, Bangladesh

1. Which "Building Types" would you prefer to study for Daylighting?

- K-Miscellaneous…Office and Residence

2. **Type Low Rise (1 side open)**
3. **Name of the building:** Dr. Rafiq Uddin Chowdhury
4. **Location :** Sughandha Residential Area, Panchlish, Chittagong
5. **Orientation:** North-South
6. **Access road:** 1 (One) **Name :** Sughandha Road **Width:** 20 feet
7. **Building length of road frontage:**36 feet
8. **Land configuration:**

West		North		East		South
40 feet		65 feet 6 inch		40 feet		65 feet 6 inch

9. **Land area:** 2622 sqft
10. **Built-up area:** 1790 sqft
11. **Number of floors:** 2 Floors
12. **Obstructions:**

	North	East	South	West
Type	Residential		Residential	Residential
Height	32 feet		62 feet	62 feet
Distance	8 feet		8 feet	10 feet
Color/ Shade	white		white	white
Overlapped area				

13. **Date of Occupancy:** 2014 - Till to date
14. **Occupancy hour:** From 10 A.M to 6 P.M, Total 8 Hour/Day
15. **Number of users:** 12 persons
16. **Total floor area:** 3400 sqft
17. **Dimensions of Activity Spaces in Surveyed building**

Space Use	Class Room	Working Area - 01	Chief Architect's Room	Meeting Room	Working Area - 02
Space dim	11′-0″x14′-0″	10′-5″x10′-6″	14′-10″x14′-1″	14′-1″x10′-10″	11′-11″x9′-8″
Window dim	6′-0″x4′-6″	6′-0″x4′-6″	6′-0″x4′-6″	6′-0″x4′-6″	4′-0″x4′-6″

18. Character of Windows in the Building:

Height			Orientation	Material	External Shading	Internal Shading
Sill	**Lintel**	**Opening**				
2′-6″	3′-0″	4′-6″	North-South	Glass, Grill	Sunset	Blinds

19. Envelop of □e building:

	Floor	Ceiling	Partition Wall	Furniture	Wall	Openings
Area	1610 sqft	1610 sqft	40 sqft	150 sqft	150 sqft	40 sqft
Material	Terrazzo	Plaster	Board	Wood	Brick	Glass Grill & Iron
Color /Shade	White	White	White	Wood	White & Yellow	White
Finishes	Terrazzo	Paint	Paint	Varnish	Paint	Paint

20. **Ceiling height:** 9 feet 6 inch
21. **Average height of work plane:** 10 feet
22. **Average height of Interior partition walls:** 10 feet
23. **Electricity Supplied from :** PDB
24. **Is there any provision of own power generation system?** No
25. **Average monthly expenses due to own power generation:**
26. **Number of A.C:** No
27. **Electronic Equipment:** Fan, Light, Computer, Ips
28. **Average electricity bill per month:** 2800 tk
29. **Is there any provision of Emergency Lighting?** No
30. **Probable area that may be covered by day light:** Approximately 500 sqft
31. **Major shade / Colour of lig** White
32. **Major activities performed in the various space of the Building:** Working space & Chief Architect's Room
33. **Light Control Devices :** Switch Board

10 ACKNOWLEDGMENTS

I would like to thank all of the people who helped make this investigation possible, in particular: My Teacher- Dr. Md. Ashikur Rahman Joarder Sir for his kind information and help and also Architect Hossan Murad for extending his kind consent on conducting survey on his offices, also grateful to Architect Istiaque Ahmed, Chief Architect and CEO of Space jam, for giving me information related to my topics and providing relevant information to generate case space for simulation study. I am grateful to Mr. Mehedi Forhad, Lecturer, Department of Architecture, Port City International University, Chittagong and the Dept. of Architecture, BUET, Dhaka, Bangladesh for technical support.

REFERENCES

[1] Joarder , M.A.R and Ahmed, Z.N., Daylighting Inside Glass Boxes: Responsiveness of Interior Design to External Façade, pp. 107-124. In Khatib J. M. (ed) Architecture Anthology I: Architectural Construction, Materials and Building Technologies. Athens Institute for Education and Research. Athens, Greece, (2015).

[2] Joarder, M.A.R, Ahmed, Z.N., Price, A.D.F. and Mourshed, M.M., A Simulation Assessment of the Height of Light Shelves to Enhance Daylighting Quality in Tropical Office Buildings under Overcast Sky Conditions in Dhaka, Bangladesh. 11th IBPSA Conference and Exhibition, 27–30 July, Glasgow, UK, 1706 –1713. (2009).

[3] Tregenza, P. R. and Waters, I. M., (1983). Daylight Coefficients. Lighting Research & Technology, 15(2), pp. 65-71.

[4] Perez, R., Seals, R. and Michalsky, J., (1993). All-Weather Model for Sky Luminance Distribution – Preliminary Configuration and Validation. Solar Energy, 50(3), pp. 235-245.

[5] L. Edwards and P. Tortellini. A Literature Review of the Effects of Natural Light on Building Occupants. 1617 Cole Blvd: National Renewable Energy Laboratory, 2002

[6] Baker, N., Steemers, K., (2014). Daylight design of buildings: a handbook for architects and engineers, Routledge

[7] Timur Dogan, Prof. Christoph Reinhart, and Panagiotis Michalatos. Urban daylight simulation calculating the daylight area of urban designs. Madison, Wisconsin: Fifth National Conference of IBPSA-USA. 2012

[8] Ahmet E. Çakır. Daylight for Health and Efficiency – A new career for an old friend. ERGONOMIC Institute, Berlin.2002

[9] M. Andersen, S. Kleindienst, L. Yi, J. Lee, M. Bodart and B. Cutler. An intuitive day lighting performance analysis and optimization approach. New York: Building research and information. 2008.

[10] Leslie, R., (2003). Capturing the daylight dividend in buildings: why and how? Building and Environment, 2003, No. 2, Vol. 38, pp. 381-385.

[11] Helena Bülow Hübe. Energy-Efficient Window Systems-Effects on Energy Use and Daylight in Buildings.Sweden: Helena Bülow-Hübe and Division of Energy and Building Design. Lund University, Lund Institute of Technology, Lund. 2001.

[12] Boyce, P., Hunter, M., Howlett, O. 2003. The benefits of daylight through windows. Rensselaer Polytechnic Institute, Troy, NY.

[13] BNV. New Construction – Technical Manual, Norwegian Green Building Council and BRE Global, (SD 5066A: ISSUE 1.1), 2012, pp. 1-397 .

[14] Cantin F, Dubois MC. Daylighting metrics based on illuminance, distribution, glare and directivity, Lighting Research and Technology, 2011, No. 3, Vol. 43, pp. 291307

[15] Collins, B. 1975. Windows and People: A Literature Survey - Psychological Reaction to Environments With and Without Windows, Natural Bureau of Standards Building Science Series No. 70. Washington, D.C.: Institute of Applied Technology.

[16] Ne'eman, E., Hopkinson, RG. 1970. Critical minimum acceptable window size: a study of window design and provision of a view. Lighting Research Technology, 2(1), 17–27.

[17] Simm S, Coley D. The relationship between wall reflectance and daylight factor in real rooms, Architectural Science Review, 2011, No. 4, Vol. 54, pp. 329-334

[18] Reinhart, C., Bourgeois, D., Dubrous, F. Laouadi, A., Lopez, P., and Stelescu, O., Daylight 1-2-3 – a state-of-the-art daylighting/energy analysis, software for initial design investigations, Building Simulation, (2007).