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How can a Façade design enhance daylight in office environments in temperate climates?

An energy-efficient approach toward sustainability

Mohit Attri[1]

[1] MSc Architecture and Environmental Design, University of Westminster, UK, w1827986@my.westminster.ac.uk;

Abstract: Making a structure eco-friendly and energy efficient should be one of the foremost requirements during the design phase so that it not only fulfills the needs of the present but also satisfies the demands of the future. Daylighting is one of the most critical areas to fulfil the above requirements. Recent studies highlight that in Europe, 70% of the office buildings' lighting consumption is fulfilled by electricity resulting in additional energy requirements and CO2 emissions. This paper explains the role of daylighting in achieving energy savings by presenting different shading schemes to effectively daylight the space and also tries to find a way to minimise the use of artificial lighting by using different mitigation strategies. Annual glare, UDI (Useful Daylight Illuminance) and Daylight Autonomy have been used to quantify the impact of these strategies. Euston Tower, a 70s office building is analysed as part of this Thesis to present an alternative façade retrofit proposal.
Keywords: Eco-friendly, Energy efficient, Daylight, CO2 emissions, Retrofit.

1. Introduction

Daylighting is considered one of the most precious gifts as well as a tool for an eco-friendly future. People expect good natural light in their working environment. Lighting makes an interior of a space more engaging and pleasing. People are more alert and in a better mood after being exposed to natural light which also makes them feel more rested and causes less strain on their eyes (Robbins, 1986). There is a lot of evidence to suggest that better lighting in a workplace can improve employee efficiency and effectiveness. Sixty percent of office workers surveyed (Christoffersen, 1999) said they would prefer natural light to artificial throughout at least one season of the year (Lighting Research Centre, 2014). This paper gives a theoretical and examined study of a scenario when a building receives excessive day lighting. Furthermore, this study will elaborate on the factors responsible for immoderate lighting gains and provide solutions for controlling unnecessary daylight by taking into consideration existing office buildings.

Daylight analysis will be done based on two ways. Formerly, by literature study and case study and guidelines for aspects such as solar access, climate, orientation, and obstructions. Later, a more simulation-based analysis will be presented by taking into consideration Useful daylight illuminance, Daylight autonomy, annual glare and Radiation analysis are some of them. All these methods will contribute to presenting ways to improve the indoor environment.

1.1 Hypothesis

After considering the daylight availability in an office space, three research questions were formulated after digging into a theoretical study. These questions cater to almost all the scenarios that could be possible in letting unwanted sunlight inside the space, this report examines the following questions to be fulfilled to get sufficient illuminance indoors:

- How can we achieve visual comfort in an office building?
- How can internal glare and the risk of overheating be mitigated without compromising the quality of natural light in office buildings?
- How can a responsive façade be designed to satisfy the essential illuminance inside a building?
- How does orientation affect the daylight strategies for designing shading devices?
- How does context play an important role in the shading strategies of a building?

2. Why Retrofit?

Future workplaces will be energy efficient and environmentally friendly thanks to cutting-edge design. To what extent is this even feasible, though?

Our guts tell us that tearing down run-down office buildings and replacing them with shiny new ones isn't the best course of action. When constructing something brand new, however, the embodied carbon of construction may outweigh the benefits of an efficient design and the resultant reduction in operational expenses. A total of 39% of all greenhouse gas emissions can be traced back to the real estate sector; this includes 28% from building operations and 11% from embodied carbon (the emissions caused by the use of materials and methods during construction). By bringing the structure and the building services up to the same level as a brand new building, a substantial renovation can significantly save operational carbon emissions. More than half of a building's embodied carbon emissions are linked to parts of the building that shouldn't be replaced during a significant renovation, such as the foundation, upper floors, roof, and frame.

The UK government estimates that buildings account for about two-thirds of London's total greenhouse gas emissions; since increasing energy efficiency is crucial to achieving the net-zero goal by 2050, retrofitting London's buildings is a major focus of the Mayor's Green New Deal (GND) recovery mission. In fact, a net retrofit accelerator program introduced by the mayor of London has been running for the last 10 years and they have retrofitted a total of 700+ public buildings in this period of time; and total carbon saved was 36000 tonnes. So, the future holds in choosing existing stock instead building new ones.

2.1 Scope and Benefits of Retrofit

London keeps massive existing office building stock. If we look at the 1920s to the 1990s, a huge amount of skyscrapers was constructed in this period. Some of them are already retrofitted and some are under consideration but there is still a huge potential to reuse and modify them for life cycle and Carbon goals.

It has been estimated by the UK government that by 2023, around 20 million square feet of London's office space, or nearly 10% of the total, will be unusable due to its Energy Performance Certificate (EPC) rating of F or G. MEES regulations suggest that the minimum EPC rating for existing structures should not be less than E.

Another analysis done by Colliers shows that around 20 percent of while there are some A and B rated London office buildings, over 56% of the stock falls into the D to G rated range on the EPC scale.

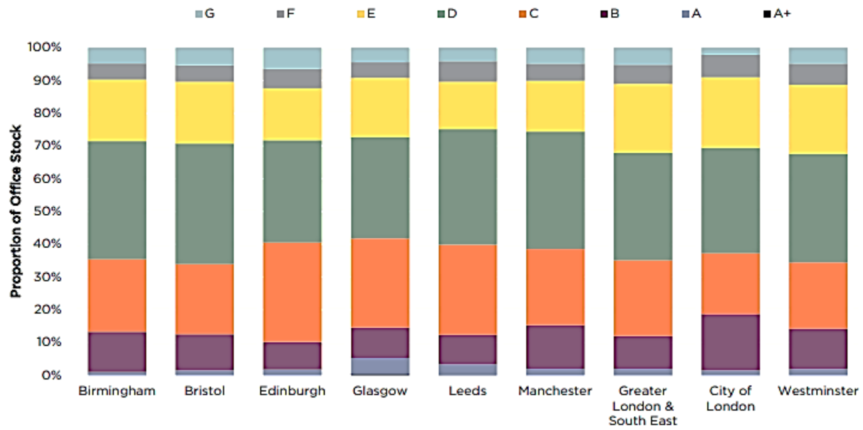

Figure 1. Colliers retrofit study

3. Preliminary Design Considerations:

A conceptual methodology regarding building Form, Height, Floor area, and glazing typology was done as the first stage. This methodology helped in deciding the right parameters to choose for the analysis part (refer to figure 2). Different guidelines and metrics from LETI, HSE, and BCO were followed to assume a "Typical" high-rise office building in London. The aim of this assumption was to cater to all the similar building typologies. Later, sun shading strategies were defined that could be used to achieve the right shading layout for different orientations. These strategies were proved in the last stage to be efficient for achieving well -daylit space by blocking direct glare and overheating and without compromising the view to outside the window.

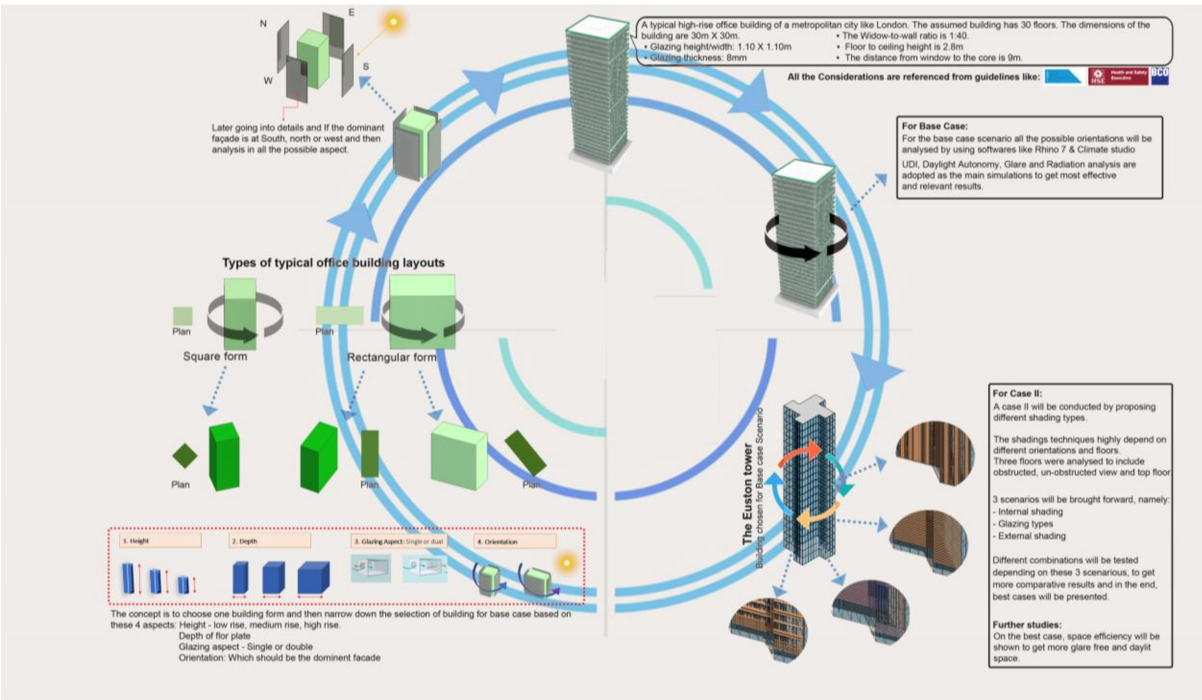

Figure 2. Conceptual Methodology

4. Base Case:

A standardised building was being proposed and an analytical approach in terms of daylighting was being conducted. The analytical approach depends on materials, UDI (Useful daylight illuminance), Daylight autonomy, and annual glare. The analytical study to test the daylight metrics is simulated by using Climate studio (a plugin of Rhino 7). Climate studio is the most accurate and fastest environmental performance analysis software for Architecture, Engineering, and construction sector.

4.1 Assumptions:

The Assumption made are based on LETI, HSE, and BCO guidelines, following steps show the recommendations of the assumption:

- The climate and city chosen for the simulation part are Temperate/London.
- The building plan being decided is square
- The dimensions of the building are 30m X 30m
- Floor to ceiling height: 2.8m (refer to section 4.2)
- Column Grid: 9.0m (refer to section 4.2)
- The number of floors: The project is mainly focusing on high-rise buildings. So, the number of floors must be more than 20 floors, i.e. 30 floors
- Window to the core: 9m (the core is assumed in the middle of the building)
- Core Area dimensions: A core element is occupancy driven. So, for a standardised building, it is kept as an approximate of 6m X 6m
- Widow-to-wall ratio: 1:40
- Glazing height/width: 1.10 X 1.10m
- Glazing thickness: 8mm

Furthermore, the test hours of a typical working individual were taken, i.e. from 9:00 to 17:00. The analysis will be focusing entirely on this time period. As for the base case scenario, the building being tested is without any context and surroundings to see the impact of direct sunlight on the test subject without being blocked by surrounding buildings. A comparative analysis being showed in between free running case and the improvement case based on daylight availability. In both the scenarios, the simulation was done on two floors, i.e. 4th and 16th.

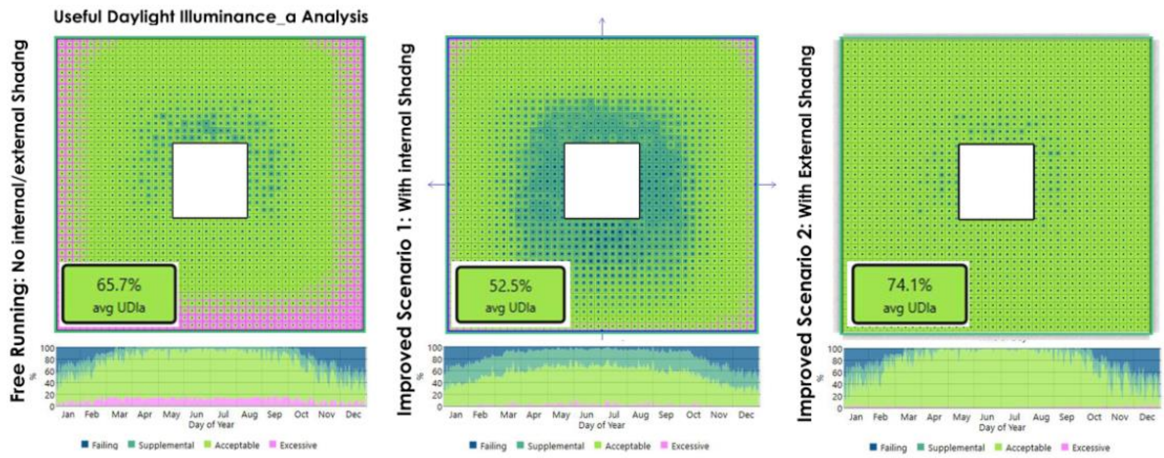

Figure 3. UDI_a at 4th Floor

Figure 3 represents the results of UDI_a on 4th Floor. The analysis shown above was based on three scenarios. The first scenario was done with No shading on the façade, the second by using Internal Blinds, and the third by proposing different shading for different orientations. As result, case three performed best by achieving the highest UDI_a. This means 74% of the floor area receives UDI autonomous (illuminance between 300 lux to 3000 lux)[2] during occupied hours for whole year.

Similarly, glare, Daylight autonomy, and Mean illuminance analysis were conducted. The conclusion was that except all the three scenarios Clear glass with External shading was

performing best. In the case of internal Blinds, a study was conducted and it was seen that in a period of the entire year, the space near the core area creates dark space during the time blinds are “ON”. Therefore, it can be said that indoor blinds are not the best case scenario for blocking excessive daylight and making a room well day-lit. This results in:
1) Use of more artificial lighting inside, i.e. high energy use (not a sustainable oriented result)
2) blocking the view out of windows, i.e. decreasing work efficiency (Robbins, 1986)
3) Poor cross-ventilation

5. CASE II (Euston Tower):

Euston Tower is a high-rise 70’s office building, located on Euston road in central London, designed by Sidney Kaye Eric Firmin & Partners. It is 36-storey, 124 metres high, and occupied by HMRC offices. The purpose of studying this building is that it sits perfectly with all the requirements and guidelines of this research project. The building has a unique shape, which is modified from a square form. The idea of choosing this building was to present a real-life scenario and apply all the studies discussed to this point and find out the most working shading strategies.

This dynamic approach will help in understanding the role of context while designing shading techniques on a building façade. Three floors were tested to get comparative results, i.e. 2nd, 16th, and 34th. The building is tilted a little towards NE. So the orientations being tested are NE, SE, SW, and SE to present different shading proposals for different facades. The shading techniques are investigated by shadow masks.

The result got from Free Running indicates the Annual glare, Useful daylight Illuminance, Daylight Autonomy, and Radiation analysis on the 2nd, 16th, and 34th floors. The unwanted disturbing daylight coming from South East and South West creates an uncomfortable environment indoors. This leads to overheating and promotes users to use internal blinds throughout the occupied hours. To get more desirable results external shades are being applied to Euston Tower in the next section. The methodological approach is kept the same as in the base case scenario. The proposed metrics of the shading techniques are shown in figure 4.

6. Conclusion:

This Research paper mentioned various questions in the beginning section of introduction, to answer all those questions a proposal was being presented. A proposal that changed the way to design an effective, efficient and responsive sun shading methodology. This methodology was designed by considering different ways of providing sun shading to a building.

By looking at the results of Case II it can be said that the proposed methodology was working precisely well. The climate-based approach helped to mitigate glare at not only different orientation but also at different floor levels. By different floors levels means, to maintain recommended daylight levels inside the workspace at different floors, a context responsive shading strategy was applied, i.e. number of overhangs and finds based on solar radiation and that lead to change in change in external shading layout from lower floors to upper floors (refer to figure 4).

This concept not only satisfy the essential illuminance inside the space but also helps us to understand how context and orientation plays an important role in the shading strategy of a building. Furthermore, based on the analytical part of the Base case and Case II it can be seen that external shading with clear glass when compared with some commonly used indoor

blinds and tinted glass, provides more desirable/recommended results in terms of visual comfort, overheating, and potential glare (refer to section 4 and 5 for detailed analysis).
So, there is no doubt in saying that the hypothesis of choosing external sun shades over internal blinds acts more reliable for achieving better daylight results.

Figure 4. Assessment methodology for right shading strategy

7. References:

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