Optimising the G-value to Deliver a Low Impact Building

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Abstract

G-value indicates the solar performance glazing, measuring the total solar radiation transmitted through glazing (CIBSE, 2014). A high level of solar transmittance can lead to excessive heat gain within the building, which will get worse in future years with the rise of climate temperatures (CIBSE, 2019). Excessive heat gain causes higher cooling loads and therefore a higher energy usage in the running of the proposed building. This report demonstrates the advantages of optimising the G-value of glazing to reduce the energy usage and carbon emissions of the building. Projects to build a high-rise office building in London will have to comply with Building regulations Part L2A and Policy S12 of the Draft New London Plan which states for a 20% reduction in CO2 emissions beyond building regulations (GLA, 2017). Optimising the G-value allows for maximum visible light to pass through the window whilst limiting the longwave radiation, therefore creating a bright productive workspace with limited heat gain through the windows. Case studies in this report show that early design stage testing of lower G-values along with optimised floor heights, orientation and ratio of the glazing on the project can lead to a low impact, sustainable building with reduced energy usage and lower carbon emissions to comply with the necessary targets. To ensure the building succeeds in reducing the energy usage, a Green Lease Agreement should be implemented by the building owner to ensure the correct usage of internal blinds and artificial lighting to allow passive design measures (including the optimisation of G-values) to work as designed throughout the life-cycle of the building.

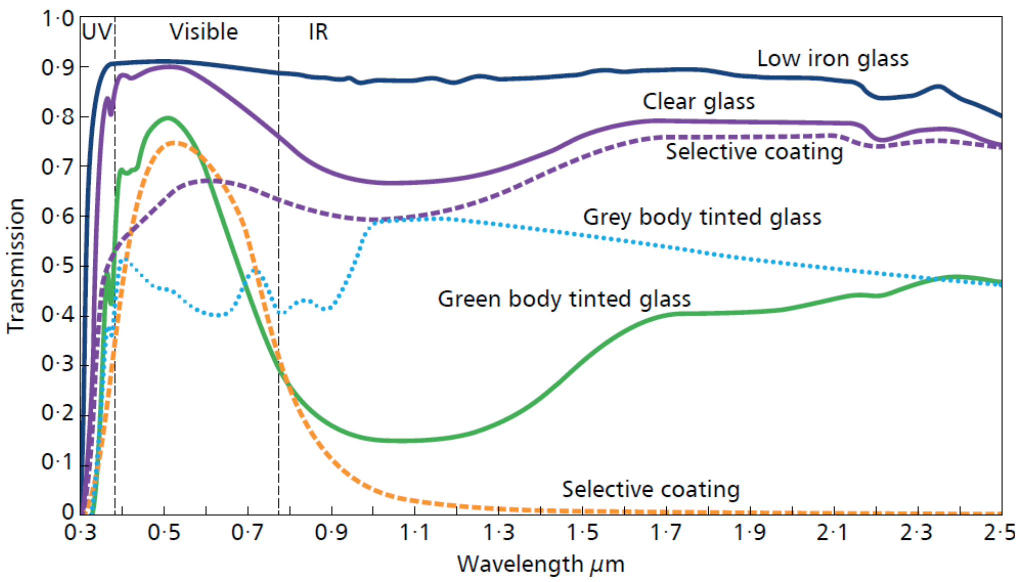

Figure 1 - Transmission of visible light for different glazing solutions. Selective coatings can have varying performance but can offer the best solution for allowing the transmission of visible light whilst blocking longer wavelength radiation (CIBSE, 2014).

Introduction

This report has been written to show the benefits of optimising the G-value of glazing at the early design stages of a high-rise office as part of a multi-use development in London. This building will have to comply with both Building Regulations Part L2A and Policy S12 in the Draft New London Plan which states a 20% reduction in CO2 emissions beyond building regulations for non-residential development (GLA, 2017). As the building is situated in London, the building will deal with a temperate climate; cold winters and warm summers that are due to get hotter following climate change (CIBSE, 2019). As office buildings are majority glazing to allow for maximum daylight and increasing productivity within the building, passive strategies need to be implemented to reduce solar internal heat gain to minimise cooling loads contributing towards a sustainable low impact building.

Literature Review

G-value is the total solar radiation transmitted through glass (CIBSE, 2014). The G-value can be split into two components; the shortwave direct solar transmittance and the secondary longwave radiation absorbed and re-emitted into the building (CIBSE, 2019). A low G-value means that less solar radiation is being transmitted through the glazing into the building, this limits the overheating caused by solar exposure. "The performance specification for a glazing system should aim at reducing the heat losses during winter and lowering the solar gains during summer, while admitting sufficient daylight to reduce reliance on artificial lighting systems". (CIBSE, 2014, p.46). Historically, controlling the solar energy transmittance meant implementing dark tints and coloured glazing, however these blocked out all daylight and increased the use of artificial lighting and therefore the overall energy usage of the building (Lee, 2019). A modern material for optimising the G-value of glazing is spectrally selective coatings. Spectrally selective films let in the maximum amount of visible light transmittance whilst reducing the G-value, reducing solar gains in the summer and heat loss in the winter which enables reductions in the lighting and cooling energy usage within the building (Lee, 2019; CIBSE, 2014).

Increasing daylight within a building to benefit health and wellbeing can have significant negative effects on overheating for naturally ventilated spaces, or on carbon savings for fully-conditioned spaces (Gregg, 2018). By reducing the G-value of the glazing to such spaces, the prospect of overheating can be limited whilst still allowing for the maximum amount of daylight to enter the space. Nebia and Aoul (2017) show through simulations on high-rise buildings in London that the floor position, glazing ratio and orientation are main parameters to consider for overheating and daylighting design optimization. Gregg (2018) agrees that these parameters are important to look at but must be alongside optimising G-value, as a reduction in G-value from 0.5 to 0.3 can reduce carbon emissions by 3.2% on average. In the case study of No.1 Springfields office building in Manchester, the G-value was optimised in the design stage taking into account the orientation and shading of each façade to reduce energy usage within the building (Savage, 2019). It is clear that optimising the G-value is an important passive strategy to implement as part of a holistic sustainable design for a highly-glazed high-rise building.

In support of optimising the G-value, simulation testing by Wang and Arya (2019) on an office building in London showed that lowering the G-value of the glazing reduced the energy demand. Wang and Arya's (2019) testing demonstrated that decreasing the U-value (thermal insulating performance) of the glazing as building regulations suggest, only decreased energy demand on the north face of the building whereas on the south face the G-value had to be as low as 0.3 for the smaller U-value to reduce energy usage. Gregg (2018) also states that unshaded south and west faces of the building are most critical for overheating, and therefore are prime locations for optimising the G-value. This is validated by the elevations from No.1 Springfields case study in figure 2.

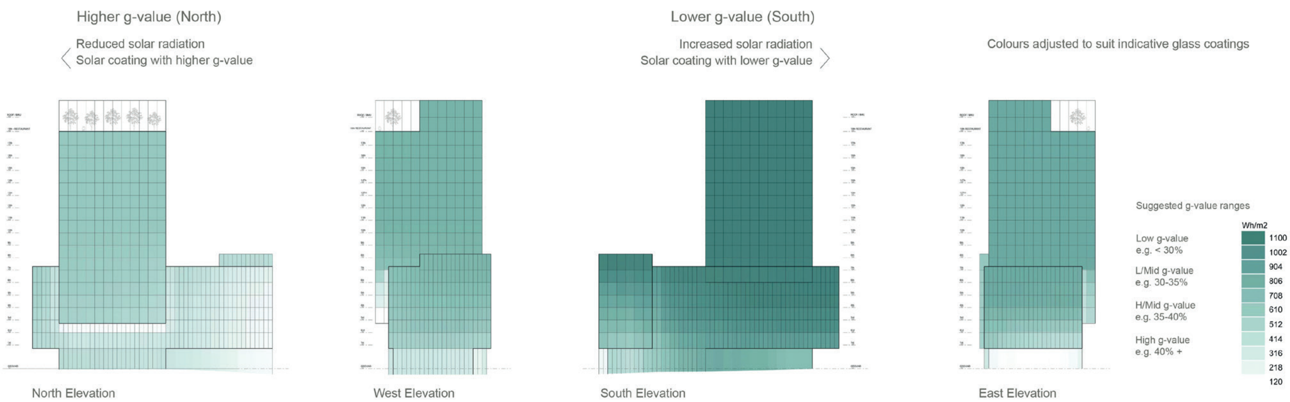

Figure 2 - Case Study: No. 1 Springfields, Manchester (Savage, 2019). The southern elevation needed the lowest G-value to block solar radiation that causes overheating, whilst the north elevation especially on the lower floor levels needed the highest G-value because there is limited solar heat gain on this façade.

As already mentioned, maximising daylight within the office building will reduce the reliance on artificial lighting. To build on this Loonen and Hensen (2015) state "transmittance of sunlight in the visible wavelength range not only influences solar heat gains, but also has a positive effect on visual comfort conditions". Savage (2019) also says the reason for optimising the G-value along with shading on the building was for the well-being of the occupants, maintaining views out and maximising daylight without compromising the energy performance. We can see that increasing the glazing in the office will have positive wellbeing influences on the occupants. However as we have explored, increased glazing can lead to overheating and therefore the selectivity of the proposed glazing needs to be taken into account at the design stage.

Policy S12 in the Draft New London Plan takes the requirements for building regulations Part L as baseline and states that a minimum reduction beyond this of 35% is required to meet the zero-carbon target for both residential and non-residential development combined (GLA, 2017). In Gregg's (2018, p.11) testing of overheating, carbon reductions and daylighting in relation to this target; "almost none of the naturally ventilated non-residential options simultaneously passed the criteria for carbon, daylight and overheating". He goes on to remark "a conscious trade-off may be required", indicating a balance of all three criteria maximising health and well-being within the building (Gregg, 2018, p.11). However, it is possible to achieve a 15% carbon reduction in non-residential buildings, when low G-values are used on the exposed south facing facades, along with best practice lighting design and Green Lease Agreements in place to ensure correct lighting usage by tenants (Gregg, 2018).

Reducing cooling loads in the building can have positive impacts on the annual cost of running an office building. Simulation testing of non-residential buildings in London suggested there is no correlation between the capital cost and energy efficiency of a building and therefore good design and testing on a project-by-project basis can minimise costs (Gregg, 2018). The case study from Manchester (Savage, 2019) shows that by using 23 different types of glazing with different solar coatings and shading they decreased the use of artificial lighting within the building and therefore saw a decrease in running cost. However, Wang and Arya (2019, p.11) state “Any potential savings in cost should be offset against the higher cost of providing low-G-value glazing”. Although there is an increase in cost for low G-value glazing the impact of not mitigating against overheating within workspaces can have significant negative impacts (Gregg, 2018). The simulation testing carried out by Gregg (2018) compared solutions for both shaded and exposed aspects of the building to meet the London Plan targets. “The measures for offices in shaded conditions have a cost uplift of £102/m2 compared to the baseline” due to the increased glazing ratios and dual aspect units to comply with the targets (Gregg, 2018). Whereas, achieving the targets in unshaded conditions can be done with no cost uplift (Gregg, 2018).

In summary, there are clear strengths to optimising the G-value of the glazing for energy reductions, it can:

- Limit solar overheating whilst maximising daylight,
- Therefore reduce energy usage from reduced cooling loads and use of artificial lighting,
- Create a comfortable internal environment which improves health and well-being,
- Provide greatest value to the project if implemented at the design stage with consideration to glazing orientation, ratio and floor position.

However, as seen above low G-value glazing can incur higher capital costs that need to be taken into account when calculating the cost benefits in the building life-cycle analysis.

Plan

As we have seen, optimising the G-value needs to be designed in together with the location, orientation and ratio of glazing at the early design stages of the building. To configure the best solution the concept building model will need testing; for this certain information is needed, such as:

- Precise location, in order to use correct weather data files,
- Surrounding context to determine if the building is shaded or exposed.

A primary tool such as Autodesk Insights will be sufficient whilst testing the model at RIBA Stage 2 - Concept Design where the initial massing and glazing ratios are being developed, as the properties of the glazing can be adapted in the model for each façade, which causes changes in the energy usage results from the analysis. This early stage testing can be used to inform development in the concept design of the building, leading to an optimised building that uses passive measures to limit the overheating and energy usage. For more accurate testing on cooling loads or overheating, daylighting and energy usage for RIBA Stage 3 and onwards, testing could be carried out in IES. For simulation testing to be in line with TM52 (CIBSE, 2013) the following information must be included:

- Predictions of the operative temperatures in the building,
- Realistic allowance for the use of window opening for temperature control,
- Realistic accounting for heat gains through sources such as electrical appliances and light fittings as well as solar radiation through windows.

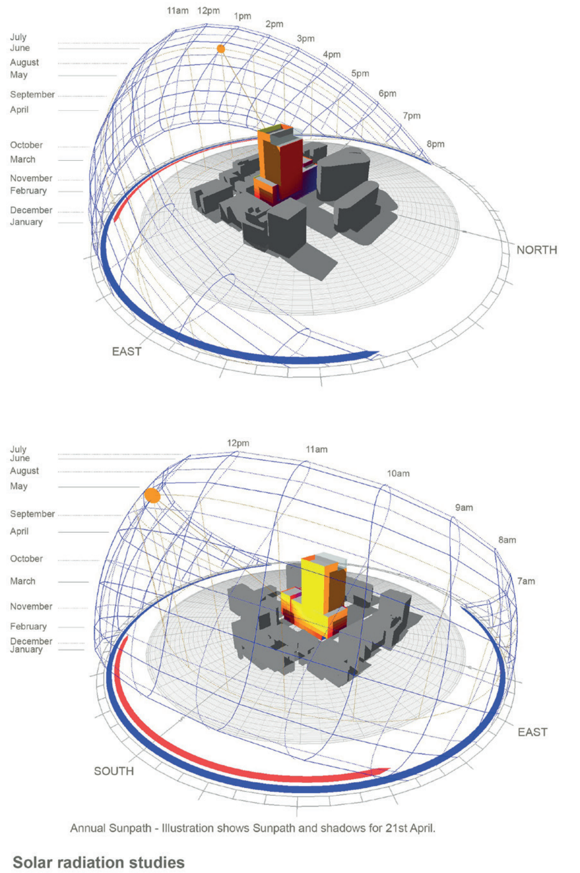

Figure 3 - Example concept stage testing from the case study: No. 1 Springfields, Manchester (Savage, 2019).

When? RIBA Stages								Who? (R)-Responsible (I)-Inform (C)-Consult (A)-Approve								
Strategic Definition	Briefing	Concept Design	Developed Design	Technical Design	Construction	Handover	In-Use	Client	Architect	BIM Manager	Civil / Structural	Mechanical Engineer	Energy Consultant	Construction Team	Commissioning Team	Facility Manager
		X	X	X			X	A	R		I		C			R

Figure 4 - Table to show roles and responsibilities for implementing this design measure.

During RIBA Stage 2 the Architect can use the basic testing tools to mock up quick building concepts using available product data for the glazing G-value. Thus the Architect is responsible at this Stage whilst they will consult and be informed by the Energy Consultant due to the size and complexity of the high-rise office building. Any developments in the design of the project will need to be approved by the Client to ensure that they agree with the design. Moving to RIBA Stage 3 and 4, the Architect may be informed by Civil Engineers for the types of glazing to be used on the building. More detailed analysis of the building would be carried out by the Energy Consultant to provide a more accurate simulation of energy usage and carbon reductions at this stage of the project.

It will also be important during RIBA Stage 7 (In-Use) of the project for the usage of internal blinds and artificial lighting to be managed correctly to allow the passive design measures to work effectively and ensure the energy usage is kept to a minimum, thus the Facility Managers would be responsible at this stage. A Green Lease Agreement will aid this management and ensure the energy usage and carbon emissions is kept to a minimum for the full life-cycle of the building (or for the duration of the contract), this is the building owners responsibility to put in place and the occupiers duty to fulfil.

Conclusion

Overheating is an issue that will only get worse in future years due to rising climate temperatures. A high-rise office building will have large expanses of glazing to maximise daylight within the workspace to improve productivity. It is therefore key to ensure that passive design measures are in place to reduce the amount of excessive solar heat gain into the building to create a comfortable working environment and reduce the amount of energy used to cool the building in warmer months. Along with orientation, floor position, and glazing ratio, the optimisation of G-value is essential for the design of the high-rise office building in reducing solar heat gain into the building. A spectrally selective glazing with a low G-value may have a higher capital cost, but this is outweighed by the reduction in running costs through the life of the building. Through optimising the G-value of the glazing holistically in the design of the building, it is likely that the 15% carbon reduction will be met to comply with Policy S12 in the Draft London Plan, and therefore will inherently comply with Part L2A building regulations. Above all, optimising the G-value allows for large expanses of glazing without compromising on energy usage or carbon consumption, and therefore will result in a modern, sustainable, and aesthetically pleasing building.

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Figure List

Figure 1 - CIBSE (2014) *Lighting Guide 10* [online]. London: The Society of Light and Lighting. Available from: https://www-ihsti-com.ezproxy.uwe.ac.uk/CIS/document/309114 [Accessed 10 March 2020].

Figure 2 - Savage, M. (2019) *In Detail: Façade Design.* Available from: https://www.simpsonhaugh.com/stories/no1sp-facade [Accessed 24 April 2020].

Figure 3 - Savage, M. (2019) *In Detail: Façade Design.* Available from: https://www.simpsonhaugh.com/stories/no1sp-facade [Accessed 24 April 2020].

Figure 4 - Author's own.