How do Biomimetic

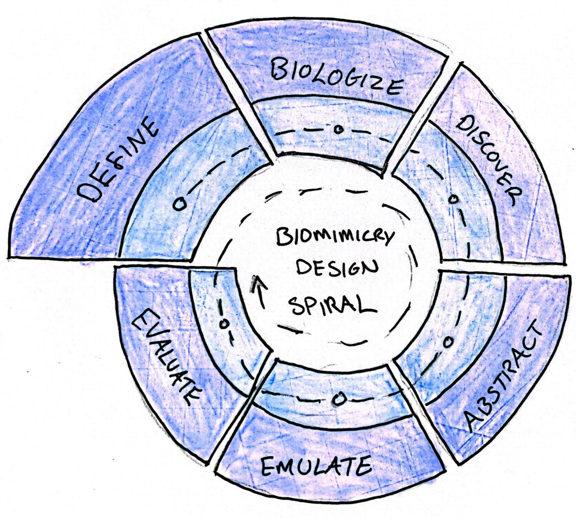
What is Biomimetic design?

Biomimetics or 'Biomimicry' is a technological-oriented design method where nature's lessons and solutions are put into practice. It is a study of natural occurrences which are then mimicked as inspiration for designs or processes with the goal of solving human problems.

An example of Biomimetic design is The National Aquatic Centre in Beijing which was designed by PTW Architects and Arup. The design was based on the way soap bubbles come together in a 12- or 14-sided cell structure.

Why is Biomimicry implemented into design?

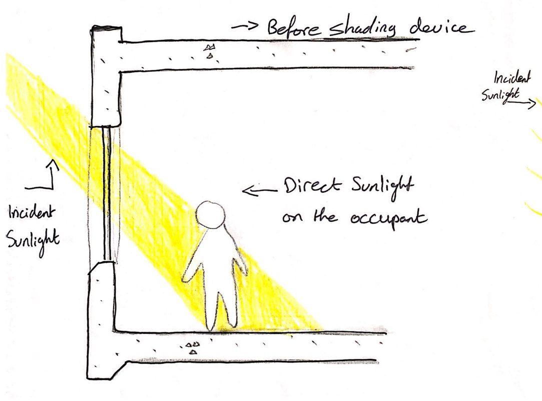
Biomimetic design is applied to construction for a variety of reasons such as optimization, creativity and collaboration to fully utilize the habitat. The whole design process is based around life's principles, which creates a culture of bottom-up building, self-assembly, optimizing rather than maximizing and embracing diversity.



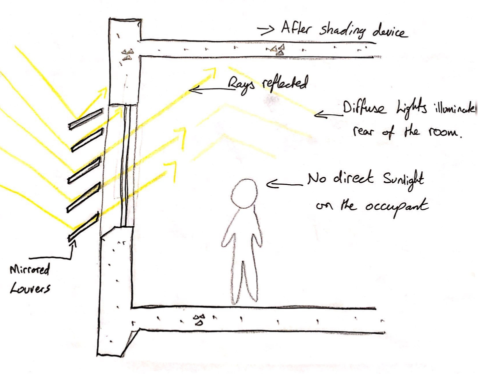
The Biomimicry Design Spiral (Hastrich, 2005)

What is the role of shading?

The traditional roles of shading systems are to improve thermal and visual comfort by reducing overheating and glare, and to provide privacy. By protecting both opaque and transparent surfaces, shading devices can be made to reduce the quantity of direct solar radiation that enters the structure.



Non-Shaded Scenario



Shaded Scenario

Aim of Study

The aim of this dissertation is to develop key considerations for biomimetic shading solutions that can be implemented into the external facade of glazed office buildings within the Irish Climate and to conclude whether or not they are needed. This will lead to design schemes for the shading solutions which will then be tested to determine if they have an impact in terms of daylight and heat gain.

Objectives of Study

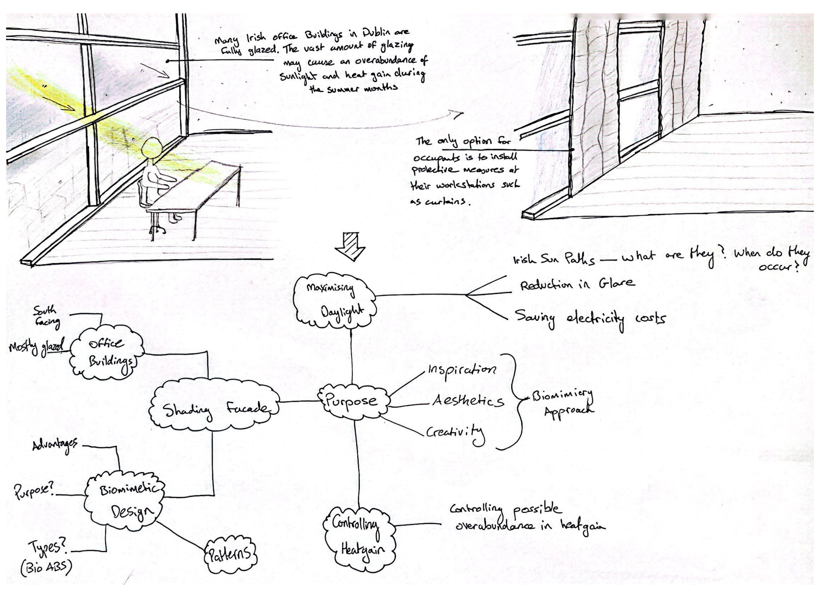
1. To investigate different types of biomimetic design and determine which are best suitable for shading solutions.
2. To justify the qualities that each biomimetic shading solution possesses and why they are chosen with comparison to to existing solutions and pattern variety.
3. To evaluate sun-paths and determine when the sun is most impactful on Irish office buildings during the course of the year for alternative orientations.
4. To investigate the impact that biomimetic shading solutions may have in terms of daylight and heat-gain within Irish Office Buildings.
5. To determine if there is a need for biomimetic shading solutions in Ireland and their overall purpose in contemporary design.

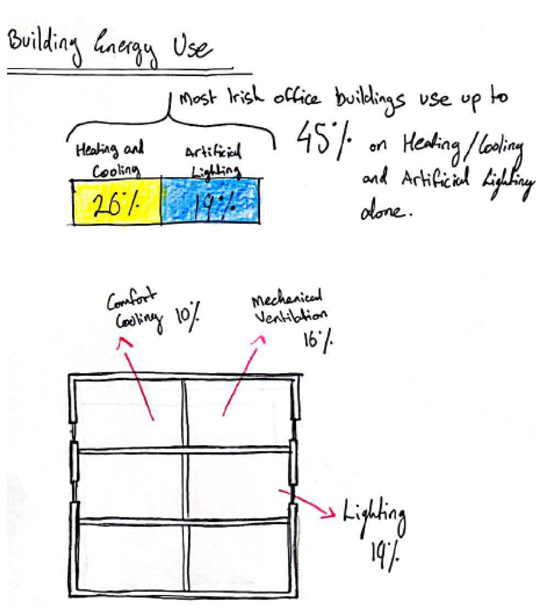
Motivation

Most new office buildings in Ireland are moderately or fully glazed, The vast amount of glazing on these buildings may cause an overabundance of sunlight and heat gain during the warmer parts of the year.

According to King D. (2010), British and Irish Office Buildings use up to 45% of building energy on artificial lighting and heating/cooling.

Shading design is a very important feature to be taken into consideration with glazed buildings and when combined with biomimetics, it can offer interesting ways to control light and radiation levels. Biomimetic design can help the construction sector learn how to develop new solutions by looking at how nature has handled particular difficulties.





Methadology

1.Desktop Research

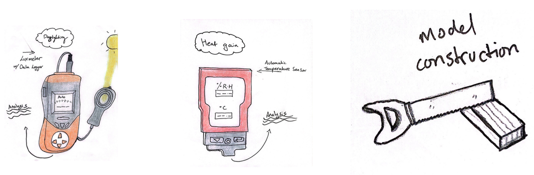
Enhanced research into current biomimetic patterns and solutions for shading devices. A total of two solutions will be looked at and tested for daylight and heat gain performance.

2. Software Testing

FenestraPro

The Exo building will be used as the project's case study. The biomimetic shading solutions will be applied to the case study building through Revit, and analysis of daylight and heat gain impact will take place through the Fenestra Pro Design Software.

3. Physical Testing



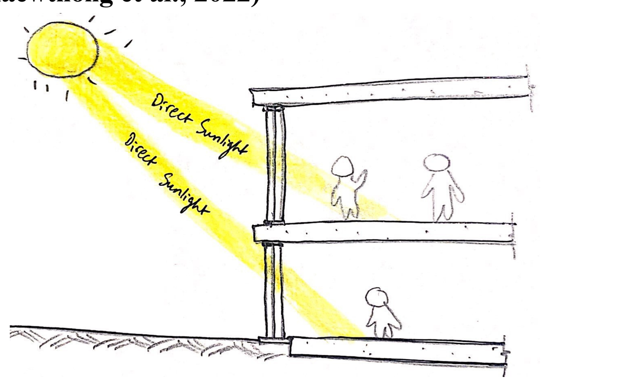
Physical testing will take place with the use of scaled prototypes representing the chosen biomimetic shading solutions. The prototypes will be used to evaluate its impact on daylight and heat gain within a small - scale enclosed office space.

4. Manual Calculation Verification

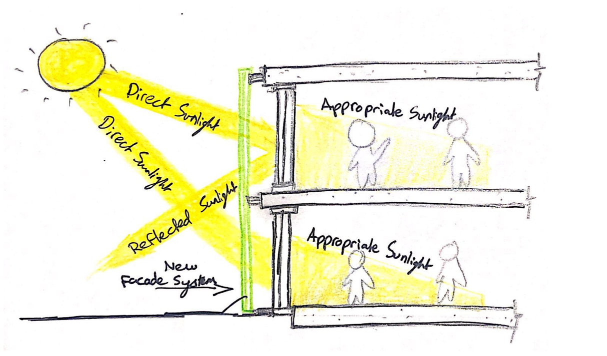
The physical tests will be validated with manual calculations such as solar load and design daylight factor %. (For existing and proposed solutions)

Literature Review

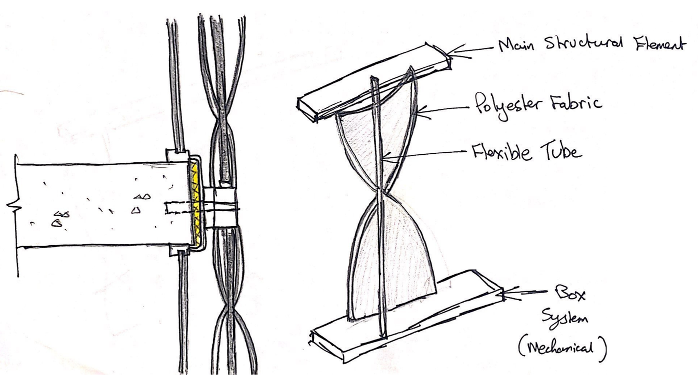
This proposal studied kinetic shading façades as means to provide suitable sunlight for interior spaces, integrated with a biomimicry approach involving mimicking a triple-identity DNA structure and photosynthetic behavior. **(Sankaewthong et al., 2022)**

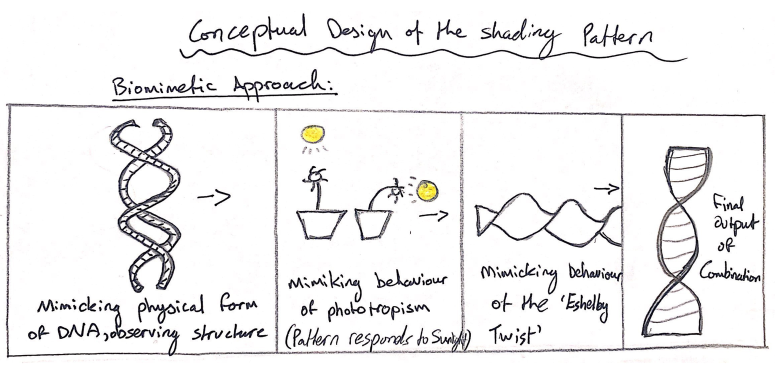


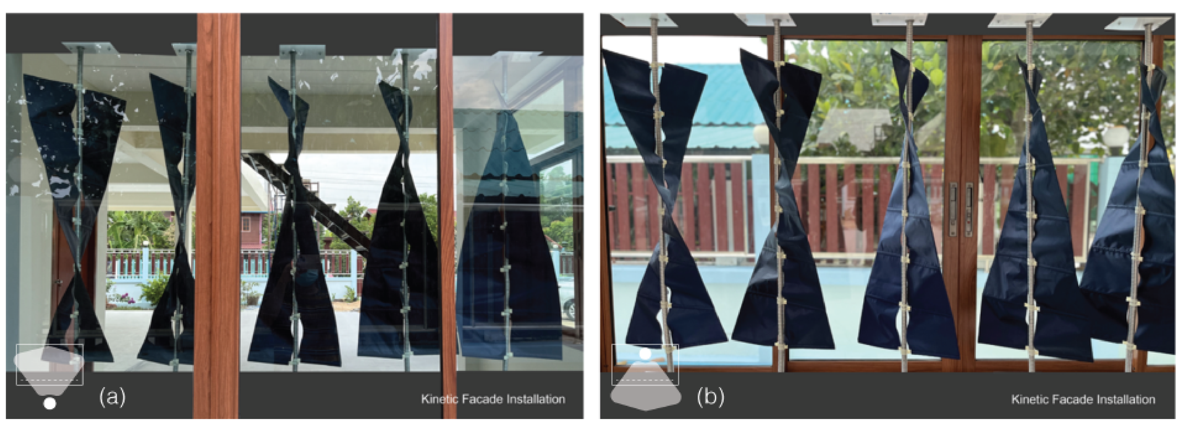
Currently many Office Buildings are designed with high amounts of glazed areas which accounts for impractical levels of daylighting and heat-gain through the summer months



The Biomimetic Facade pattern provides suitable sunlight for interior areas with high amounts of glazing. The shading pattern contributes to daylighting and heat control

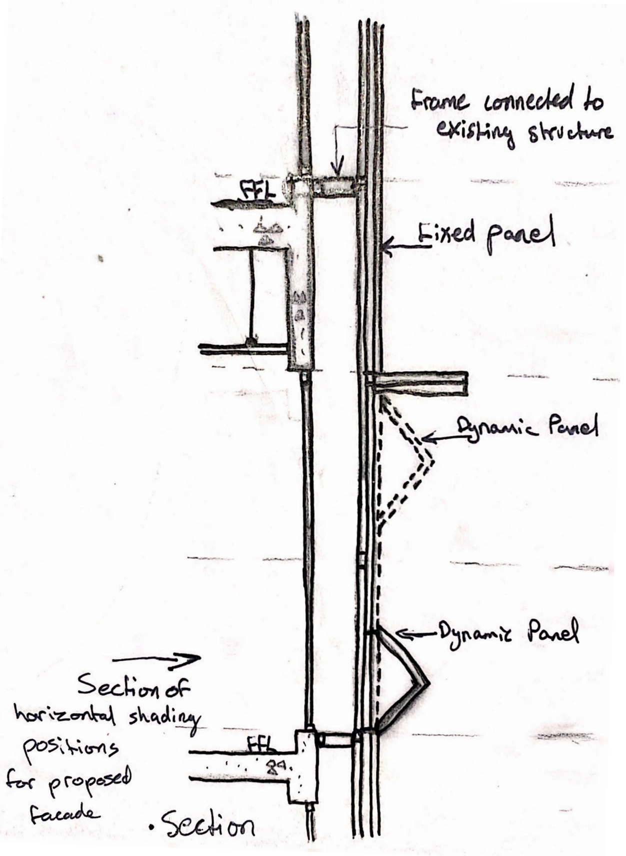


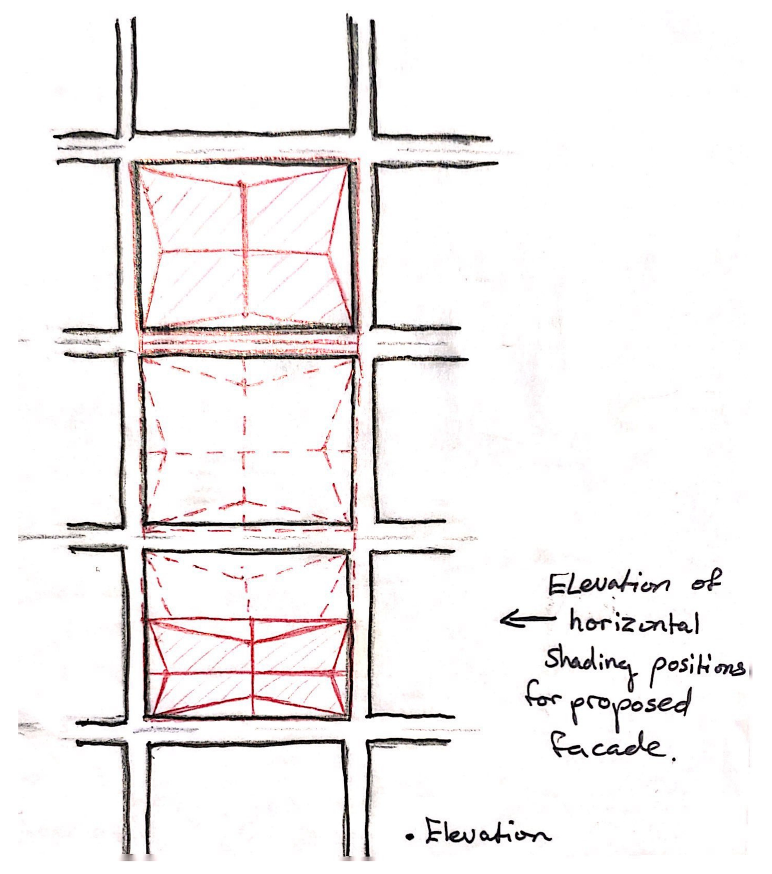


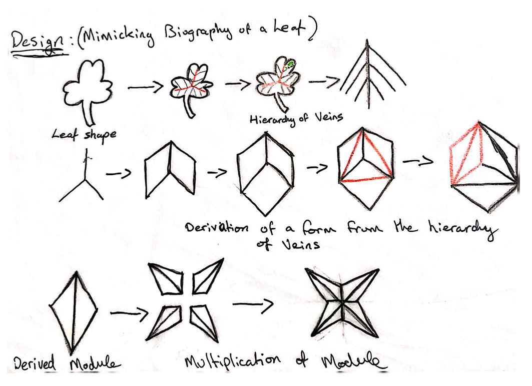


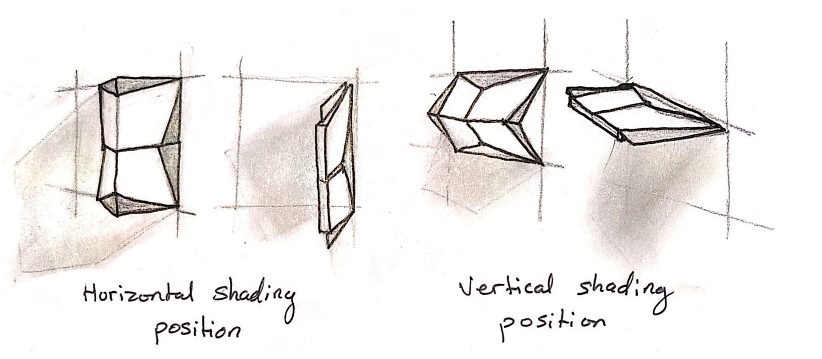
Exterior and Interior views of the biomimetic shading facade after installation. **(Sankaewthong et al., 2022)**

This study looked at the design of an adaptive biomimetic shading façade as a practical solution for enhancing energy efficiency of highly glazed buildings in the hot and humid regions. The shading module consists of four shading devices that can be folded along both horizontal and vertical axes. The design mimics the physical, physiological and adaptation properties of an 'Oxalis Oregana' leaf. **(Sheikh & Asghar, 2019)**



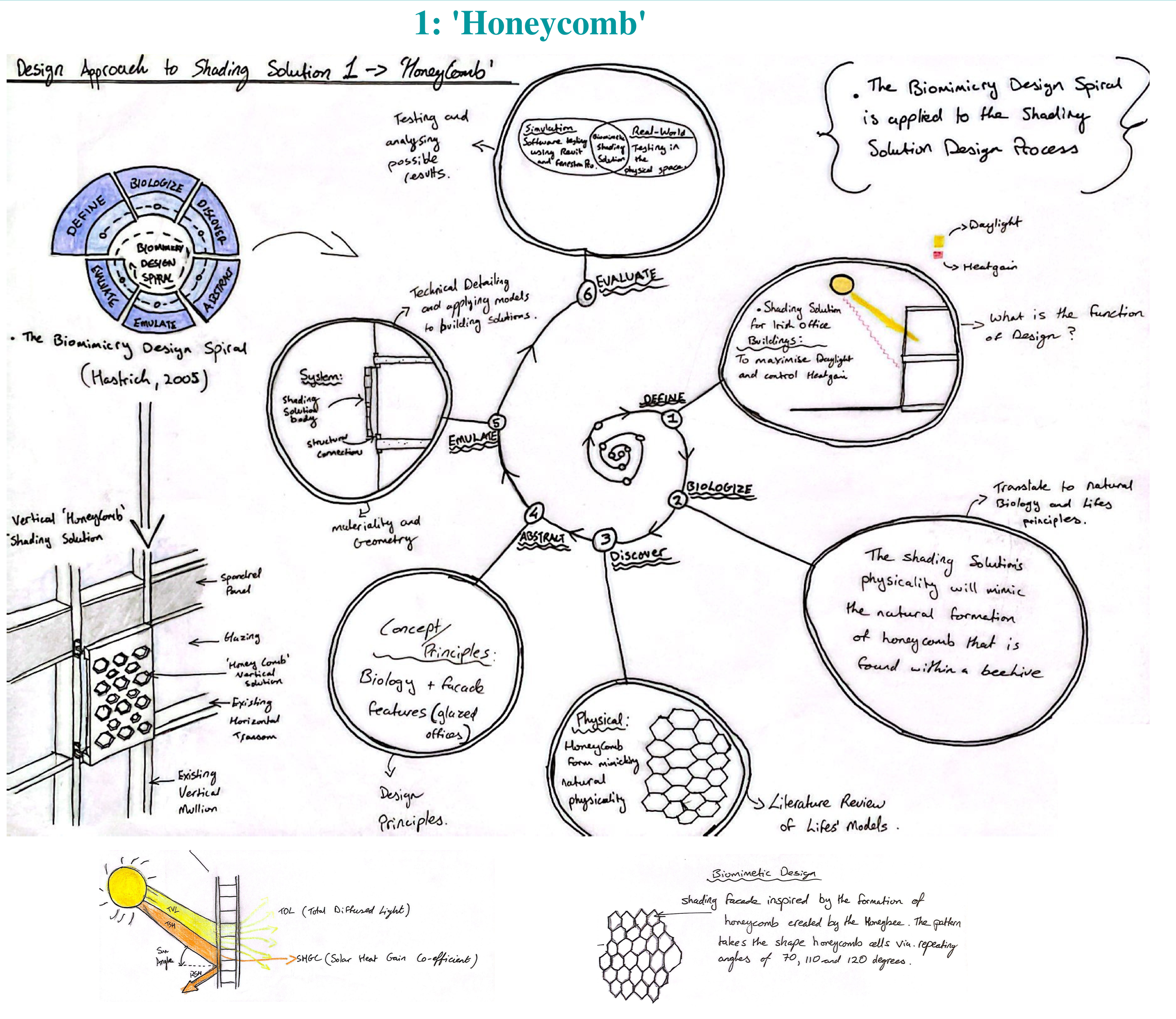




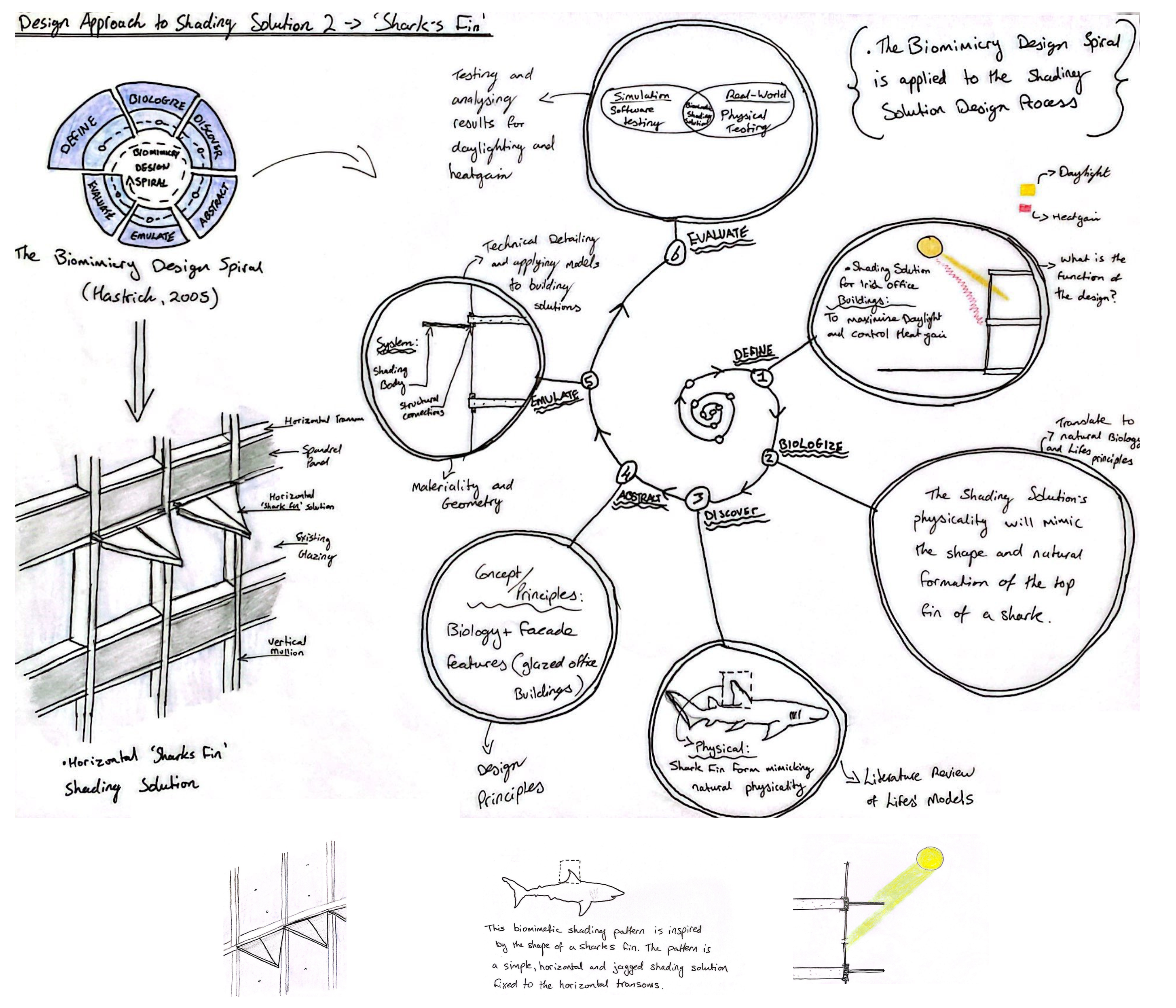


Biomimetic Shading Solutions - Evaluation and Justification

1: 'Honeycomb'



2: 'Shark's Fin'

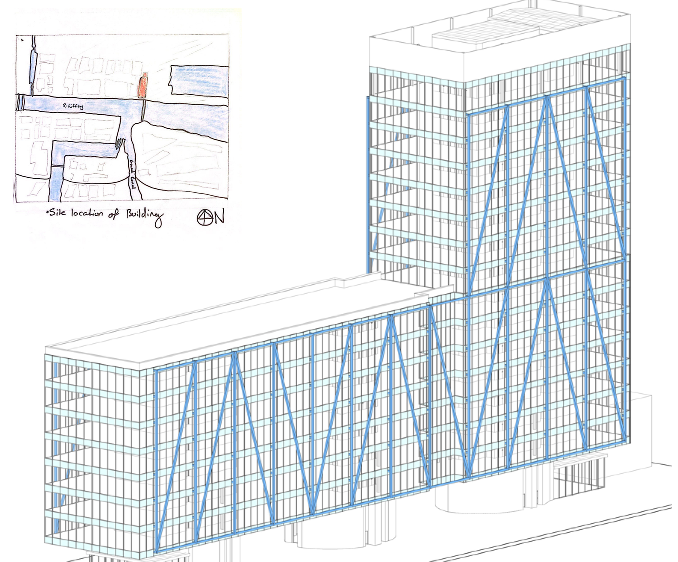


Case Study Building - The Exo Building, Dublin

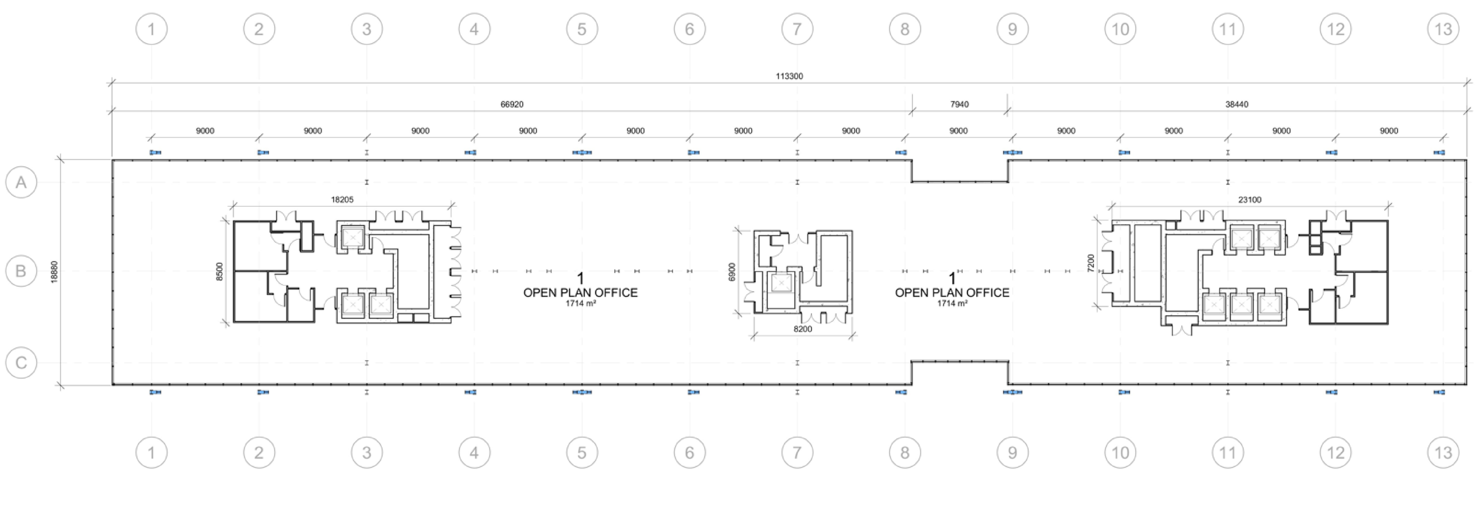
The building chosen for this study is the **Exo Building**, located at the Docklands, Dublin. The newly constructed office block is a total of 8,603.66m2 and is predominantly fully glazed with curtain walling. The glazing spans from floor to ceiling level which stands at 2.935m. The building is glazed on all four orientations.

The existing glazing consists of performance coated, argon filled, double glazed units with heat strengthened laminate inner, and annealed laminate outer to the main glazing panels and spandrel glazing panels with heat strengthened monolithic inner and annealed laminate outer - 1.5mm diameter dots on a 5.0mm pitch (as per - Exo Specification)

The building was modelled on Revit to allow for software testing of the biomimetic shading solutions in terms of impact on daylighting and heat gain.



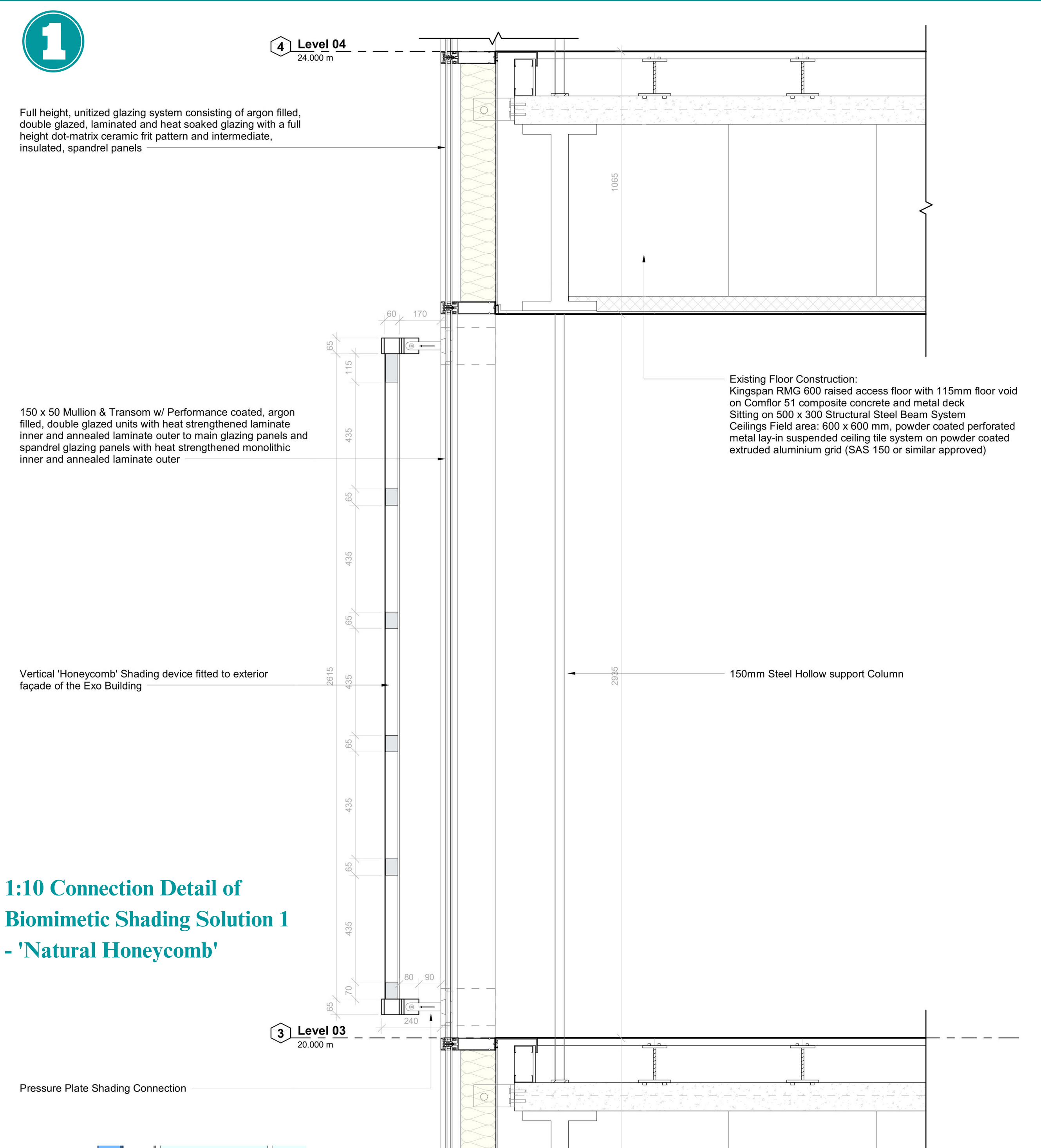
BIM Model of the Exo Building, Dublin



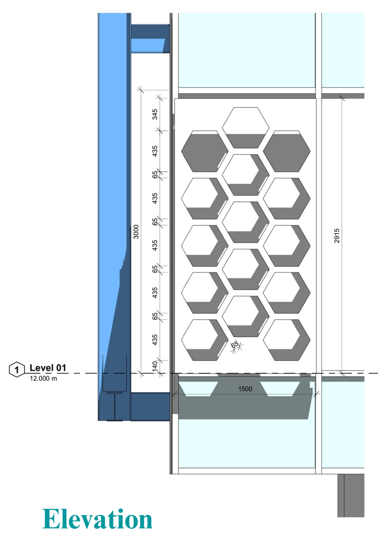
Typical Floor Plan of the Exo Building

Shading Solutions impact daylight and heat gain on glazed office building façades

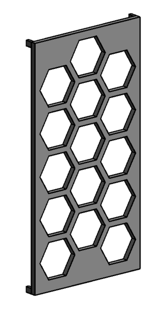
1



1:10 Connection Detail of Biomimetic Shading Solution 1 - 'Natural Honeycomb'

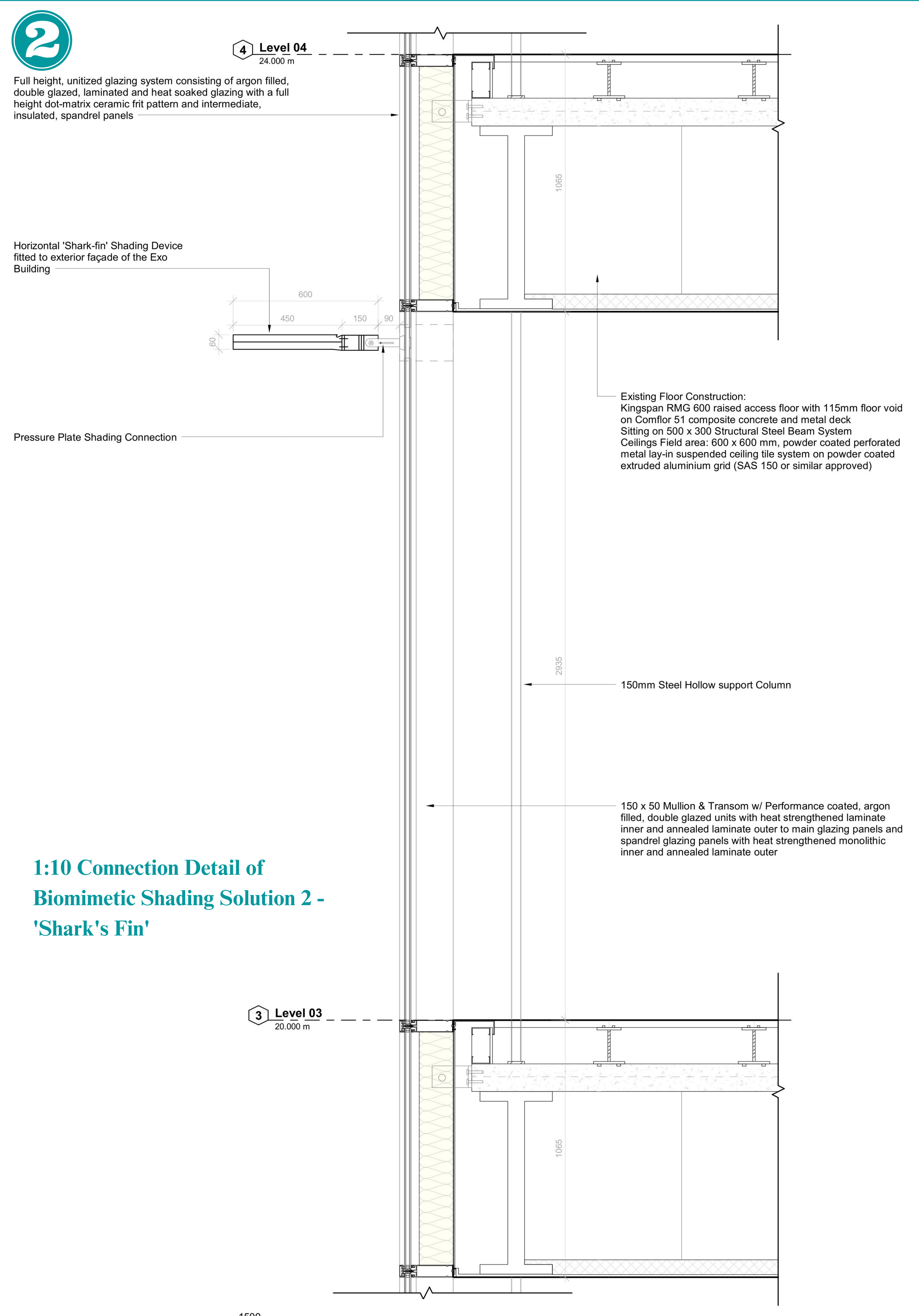


Elevation

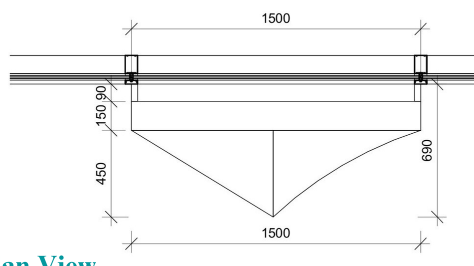


3D View

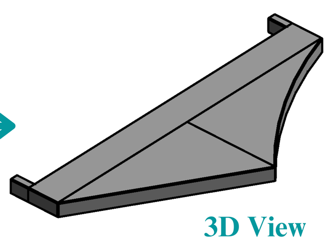
2



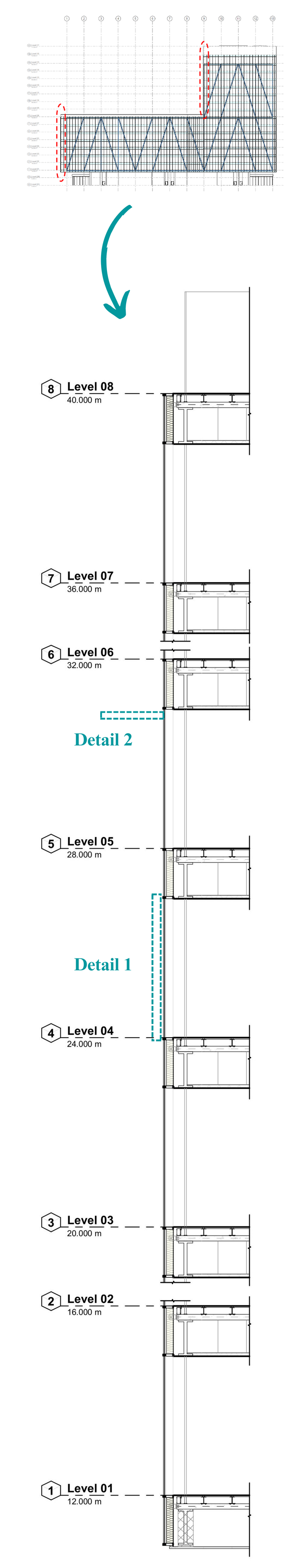
1:10 Connection Detail of Biomimetic Shading Solution 2 - 'Shark's Fin'



Plan View



3D View



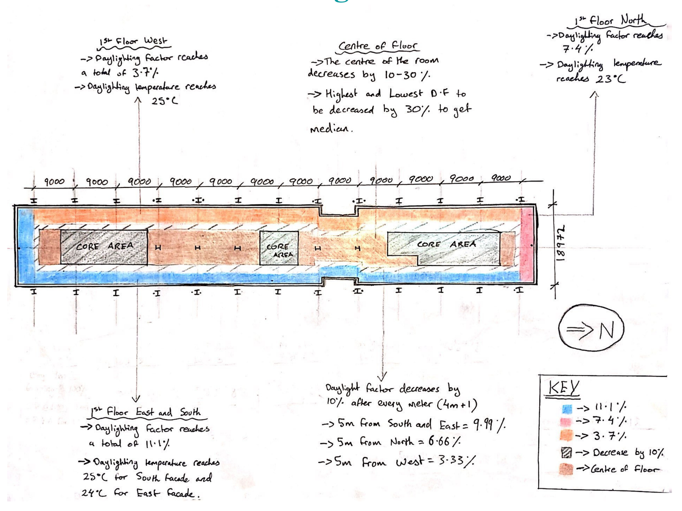
Section of Detailing - South Facade of the Exo Building

Existing Figures of Case Study Building with no shading

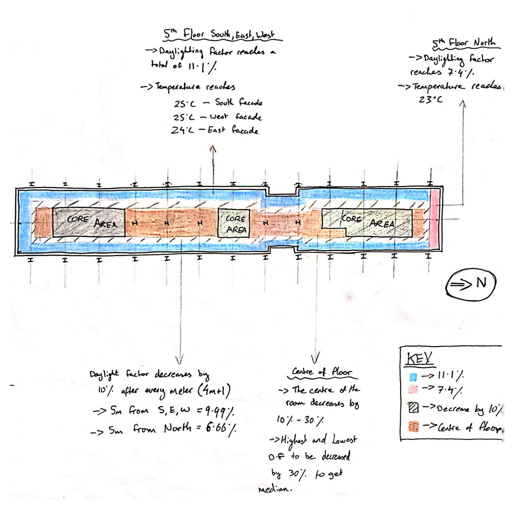
The case study building was taken into consideration to determine its existing daylight factor percentage and existing internal solar loads. Presently, there is no form of shading utilized on the Exo Building, so these figures will act as a daylight and heat-gain baseline. The daylight % figures were calculated as a result of following the **'Environmental Design Guide for naturally ventilated and daylit offices'** and were tested using the '4m Depth and Heavyweight' tables.

The Solar Heat Load was also calculated for the 1st and 9th floor of the building using manual calculations for Average Solar Heat Load per Unit Floor. This was done for all four facade orientations.

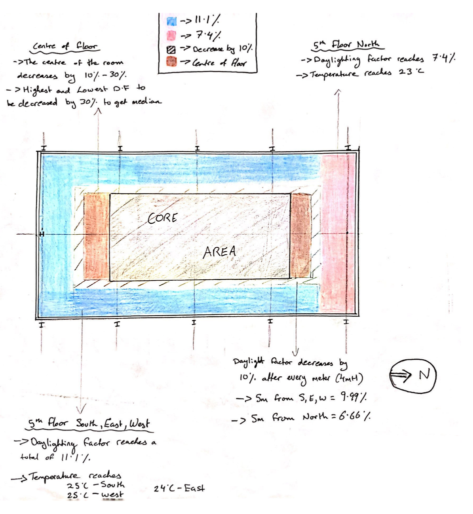
The Exo Building - First Floor



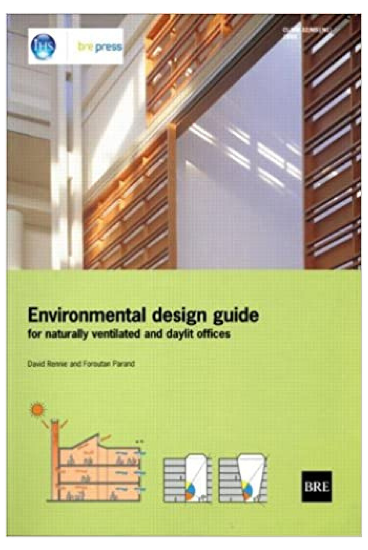
The Exo Building - Fifth Floor

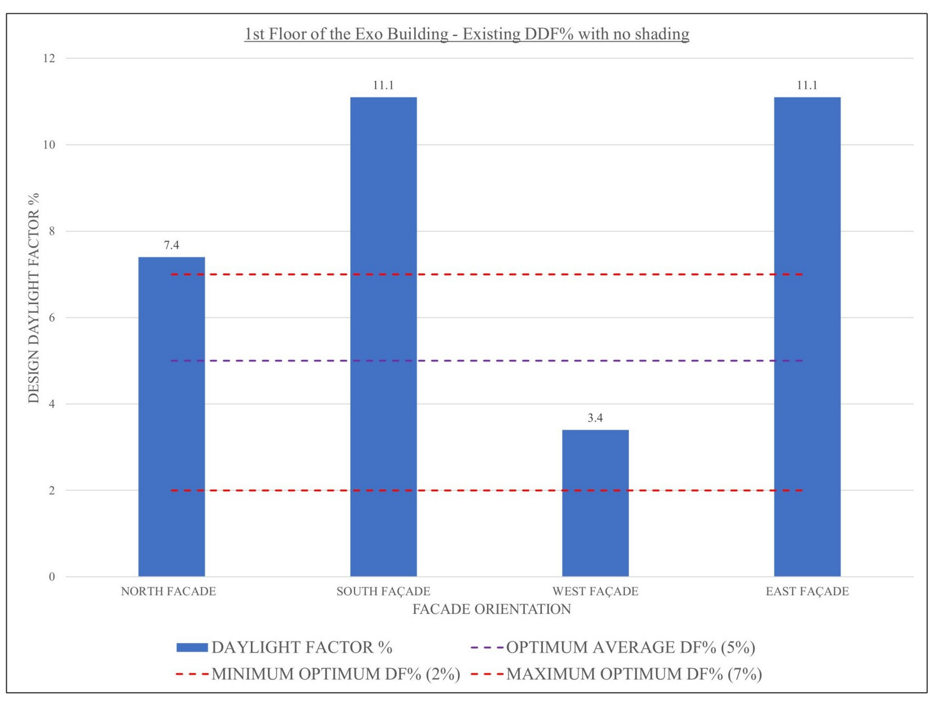


The Exo Building - Ninth Floor



Existing Daylight Factor %

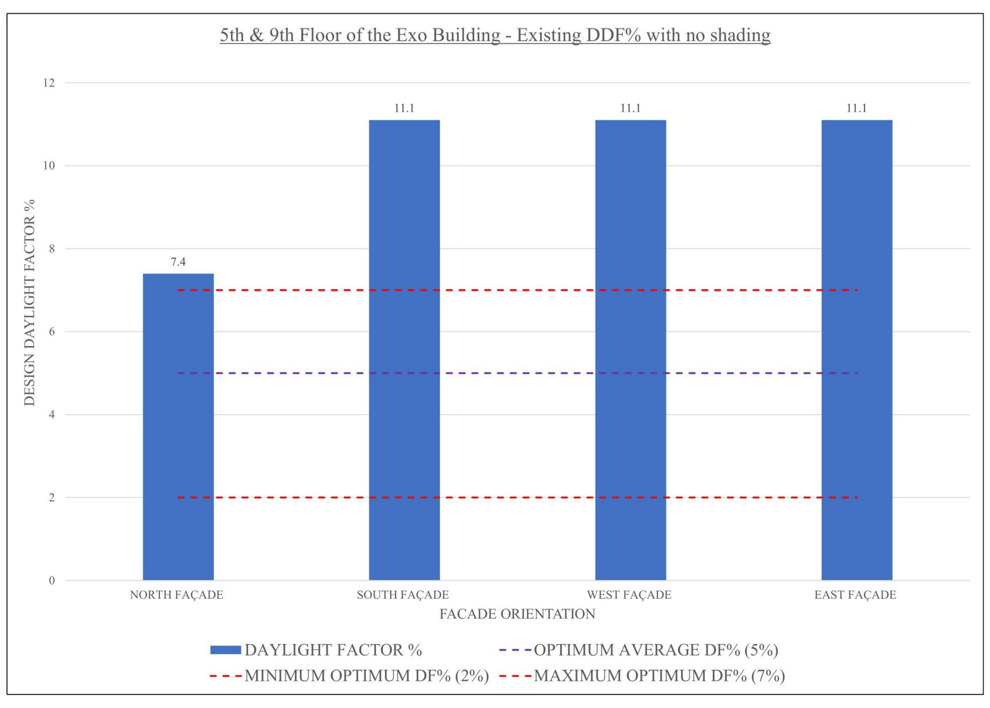




OPTIMUM
2 - 7%

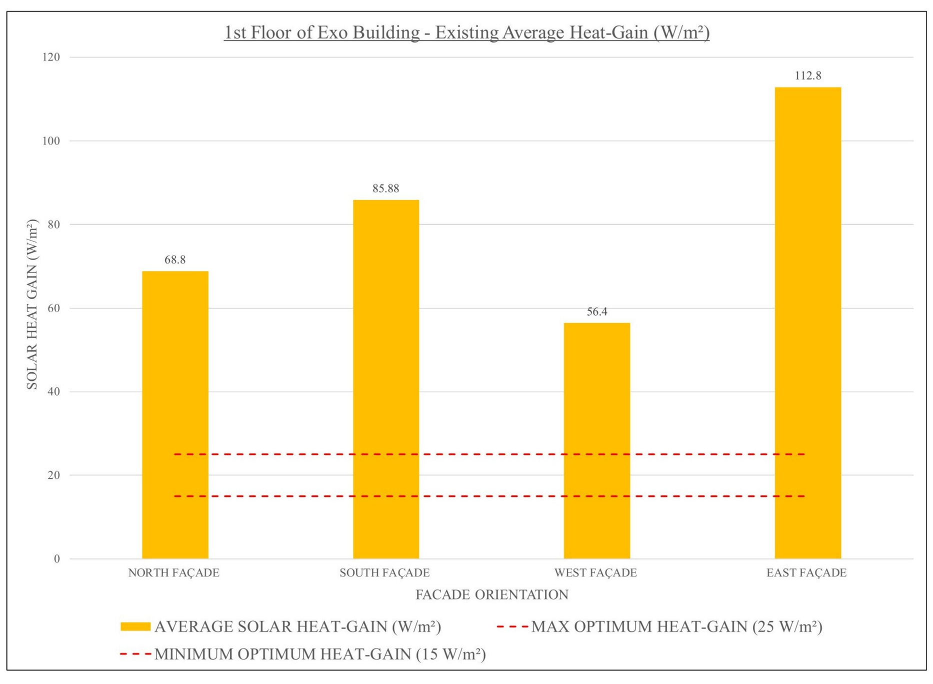
10.17%
Average

TOO HIGH!



Existing Solar Heat Loads

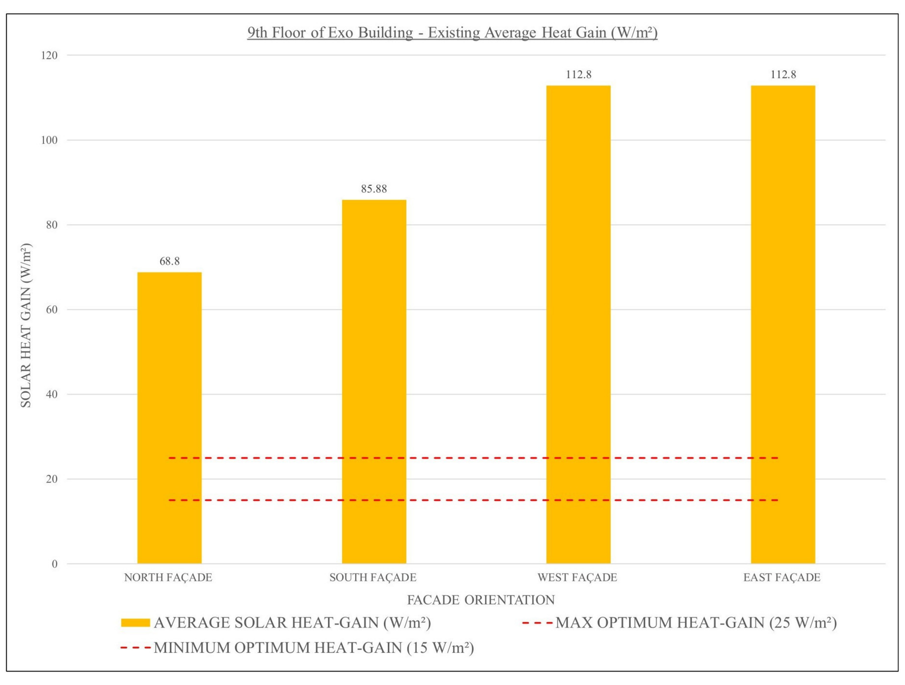
Average Solar Heat Load per Unit Floor (W/m²) = (Area of Glazing x Glazing Factor x Shading Factor x Average Solar Load) / Area of Zone



OPTIMUM
15 - 25W/m2

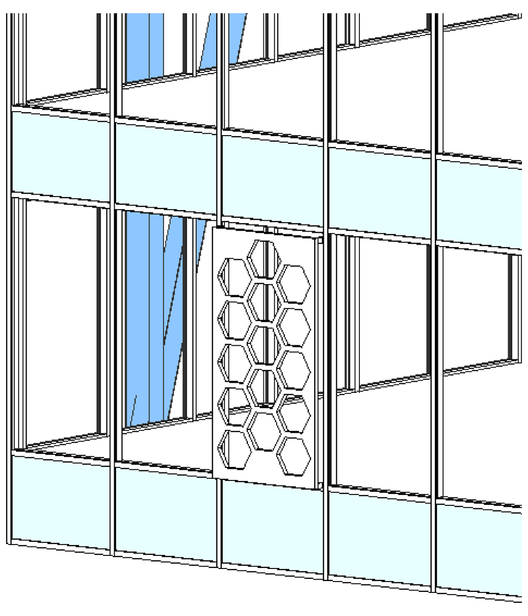
95.07 W/m2
Average

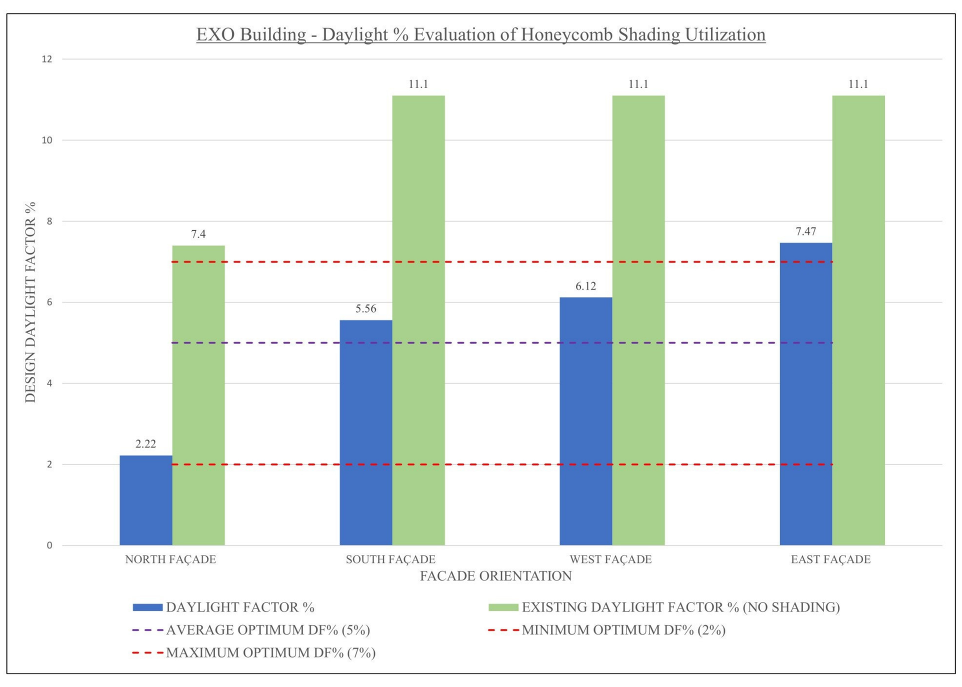
TOO HIGH!

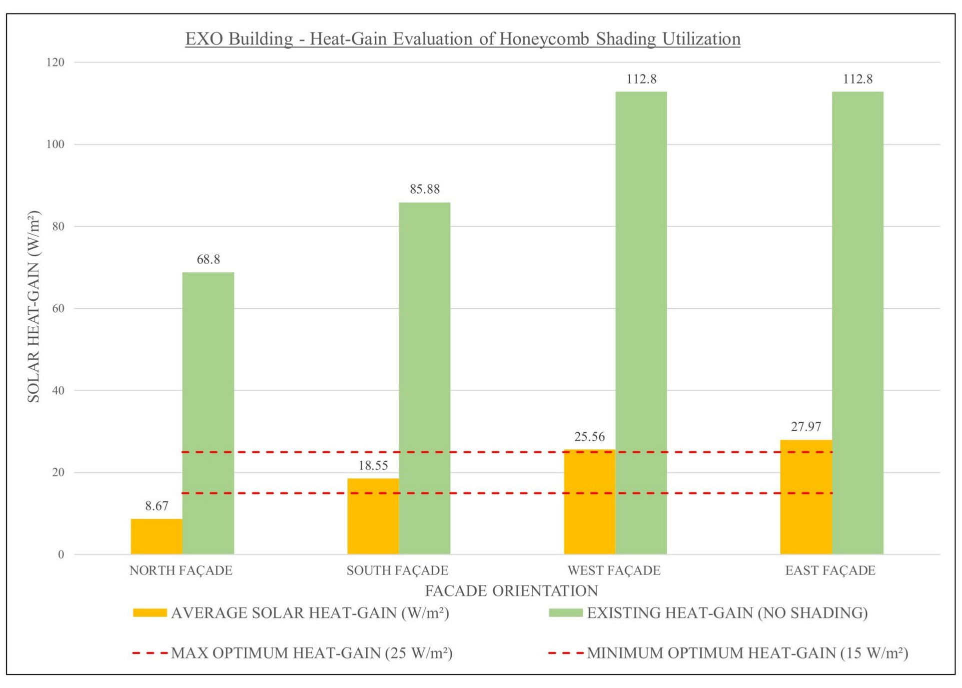


Simulation Testing - Results and Findings

Honeycomb Solution







The Honeycomb shading solution displayed relatively positive results, with the average building daylight factor % and average building heat loads falling into optimum range respectively.

Within Optimum Range

Outside Optimum Range

DAYLIGHT

5.34%
Average

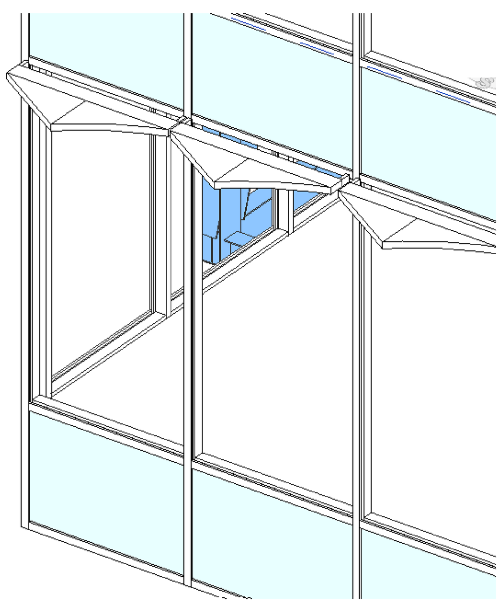
Decrease in 5.13%

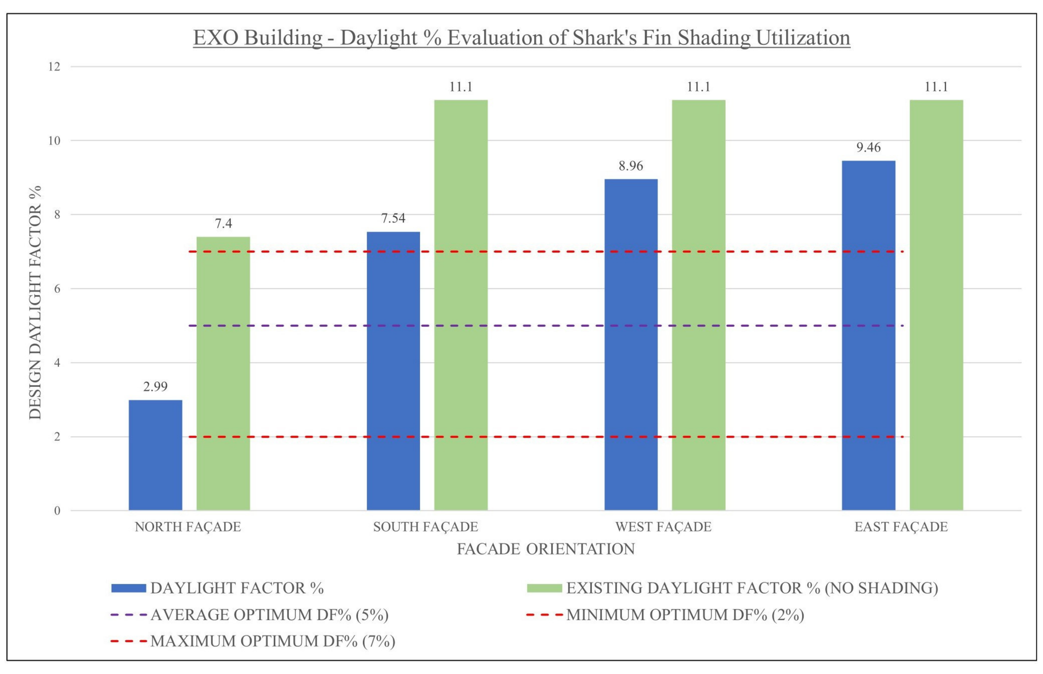
HEAT - GAIN

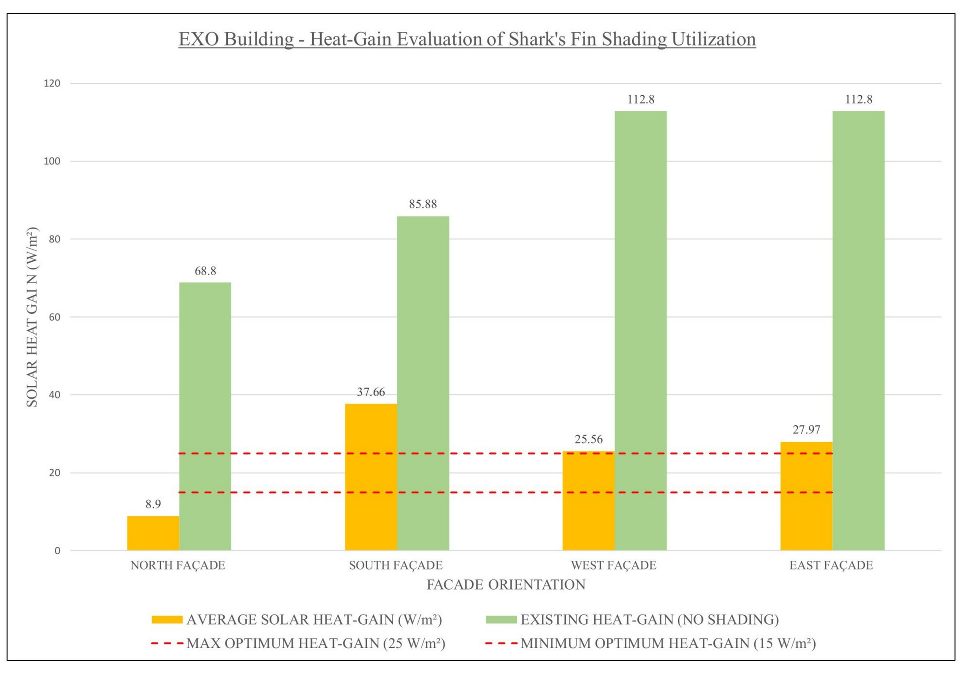
20.19 W/m2
Average

Decrease in 74.88 W/m2

Shark's Fin Solution







The Shark's Fin shading solution lowered the existing daylight levels and heat loads significantly, but was unable to produce optimum results. Factors such as sizing and shading factor may have to be taken into consideration.

DAYLIGHT

7.24%
Average

Decrease in 2.93%

HEAT - GAIN

25.02 W/m2
Average

Decrease in 70.05 W/m2

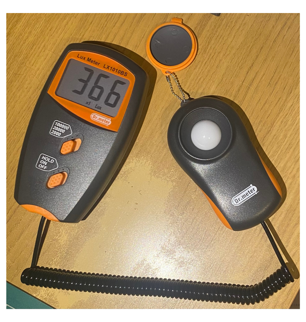
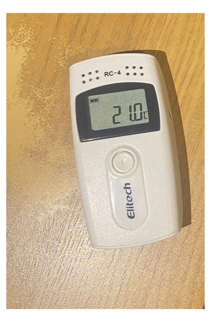
in an Irish Climate?

Sean O'Donnell
C19350201
1st Supervisor - David Palmer

Physical Testing: Preperation


Testing Location: Exterior (left) and Interior (right)

The room used for this experiment was a typical garden studio that had been renovated into a home office that was used by the occupant four days a week on average. The testing location was 4m x 3m in area, with a window head height of 2m, and contained one instance of standard double glazing that was south westerly facing. The portion of glazing that the prototypes were tested on was 1080mm tall x 500mm wide. The room in question did not use any form of mechanical heating

Equipment used for testing: Calibrated Lux Meter (left) and Temperature Sensor (Right)

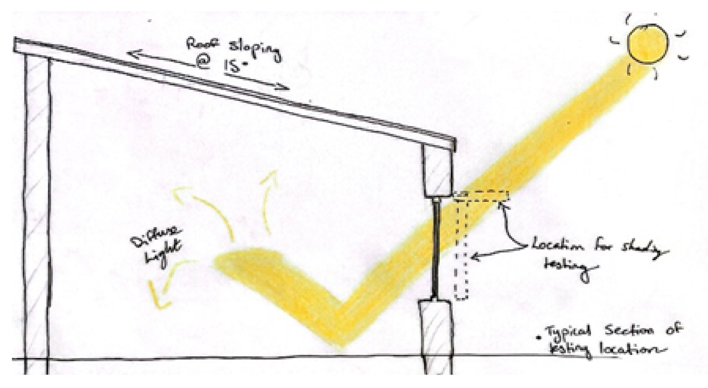
TESTING PROCESS

DAY ONE: Baseline testing with no shading

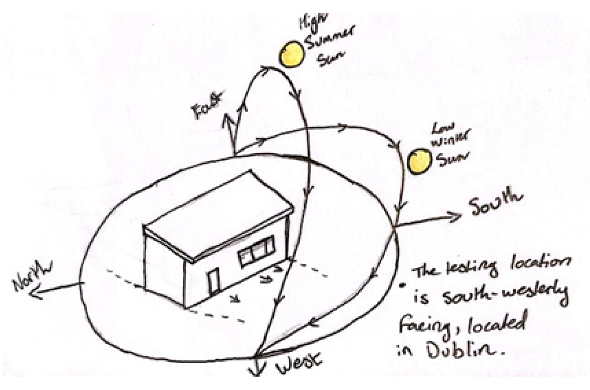
DAY TWO: Honeycomb shading solution

DAY THREE: Shark's fin shading solution

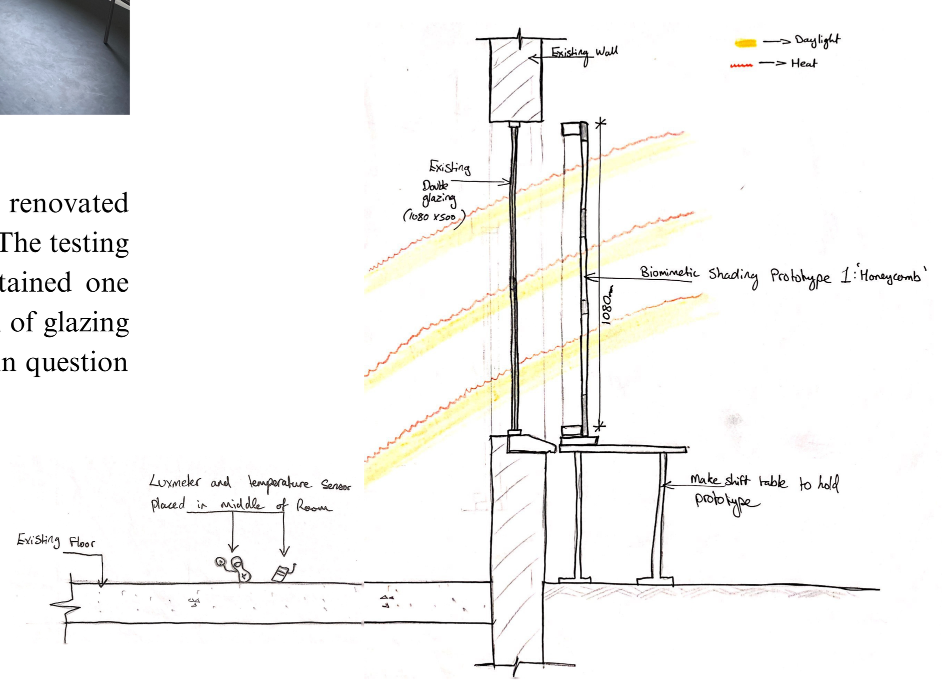
DAY FOUR: Shark's fin shading solution (adjusted to light shelf)



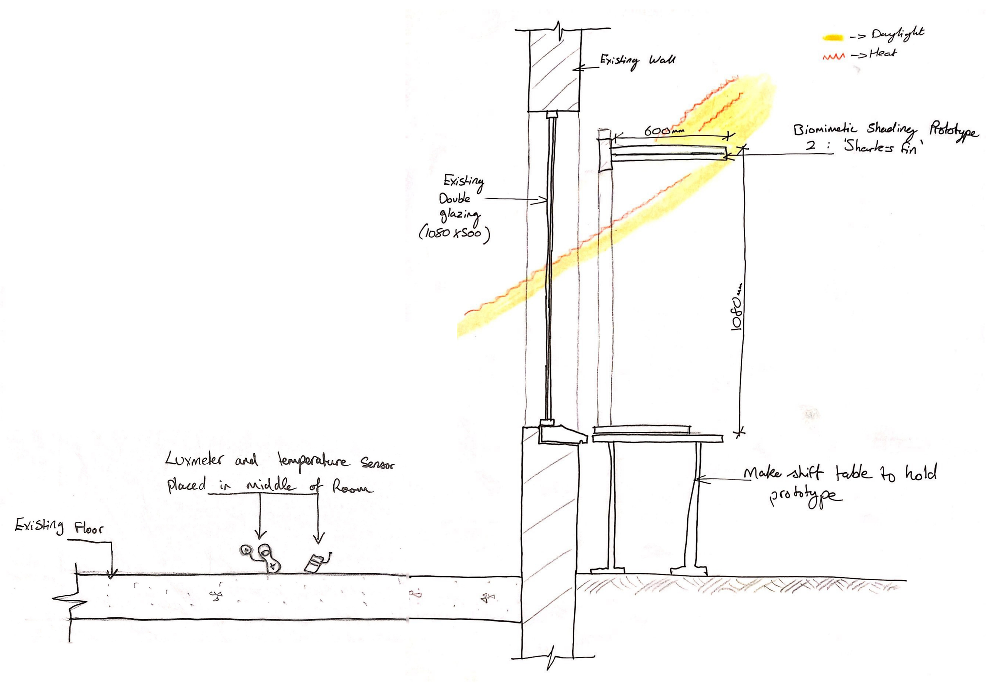
Typical section of testing location showing path of existing daylight



Orientation of testing location

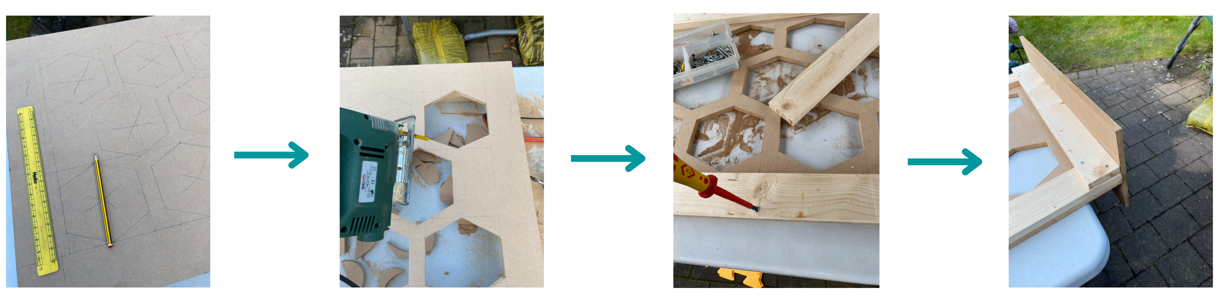


Testing Set-up showing placement of the Honeycomb shading prototype

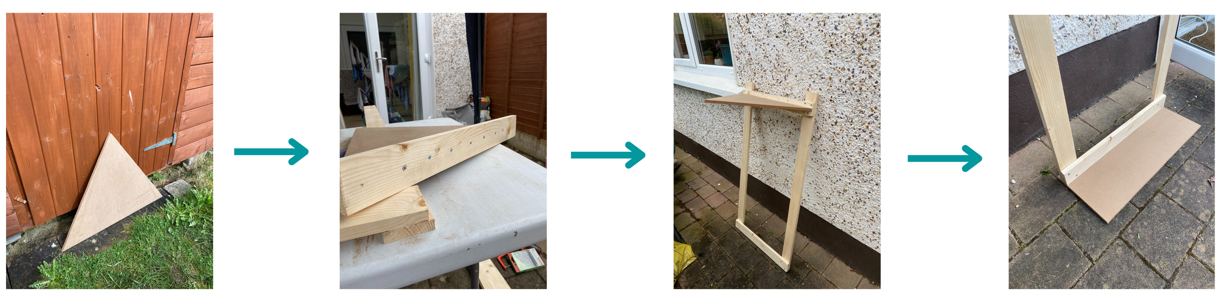


Testing Set-up showing placement of the shark's fin prototype

Prototype construction process




Honeycomb Solution

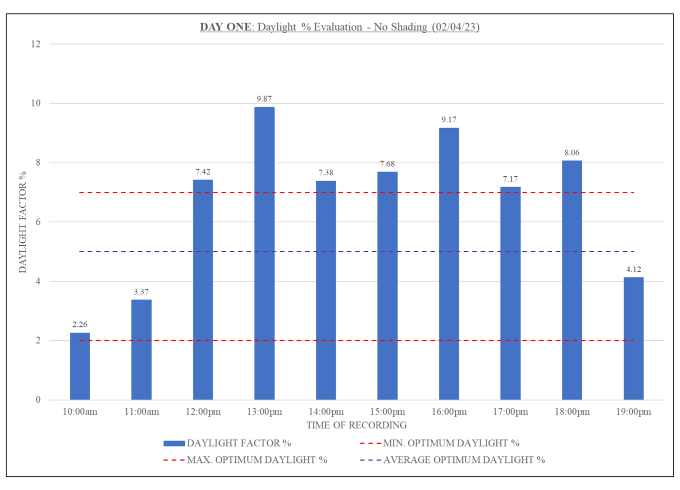



Shark's Fin Solution

Physical Testing - Results and Findings

1 DAY ONE: No Shading

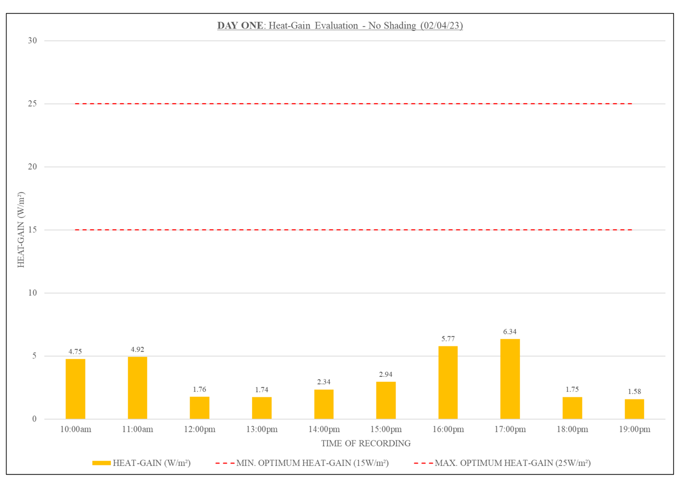
Conditions: Cloudy/Sunny



OPTIMUM 2% - 7%

DAYLIGHT FACTOR %

The baseline results indicate that the DF% was above optimum range for most of the day. The indoor lux levels were also excessively high in the late afternoon.



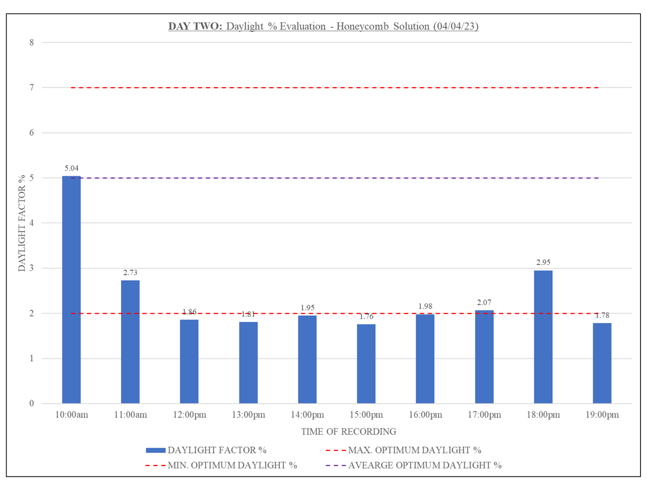
OPTIMUM 15 - 25 W/m2

HEAT - GAIN (W/m2)

Both internal heat loads and Indoor Temperature remained below optimum range throughout the day. This was due to the relatively overcast conditions.

2 DAY TWO: Honeycomb Solution

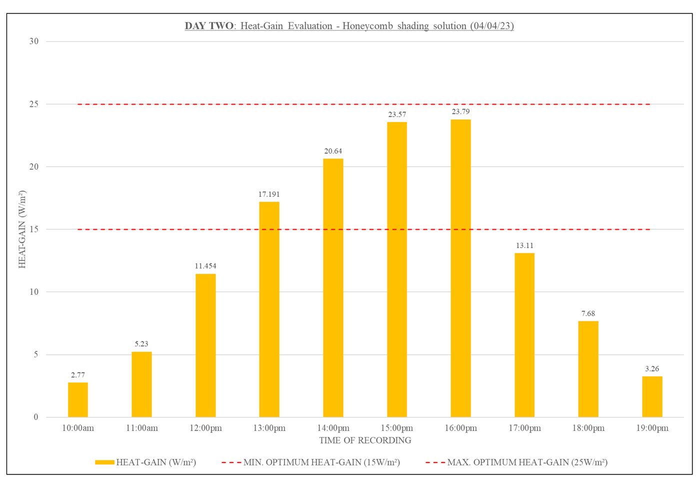
Conditions: Very Sunny



OPTIMUM 2% - 7%

DAYLIGHT FACTOR %

The honeycomb shading solution lowered the DF% significantly, however most of the day was below optimum range.



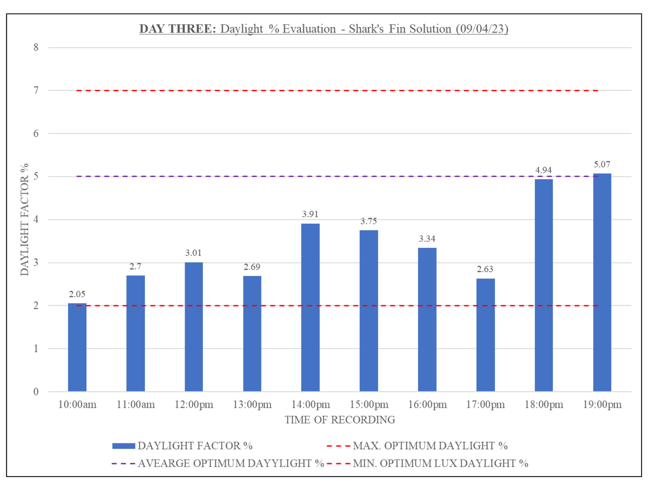
OPTIMUM 15 - 25 W/m2

HEAT - GAIN (W/m2)

The higher outdoor temperature on this day resulted in a rise in the internal heat-loads, with 1-4pm being within optimum range as a result of the honeycomb shading solution.

3 DAY THREE: Shark's Fin Solution

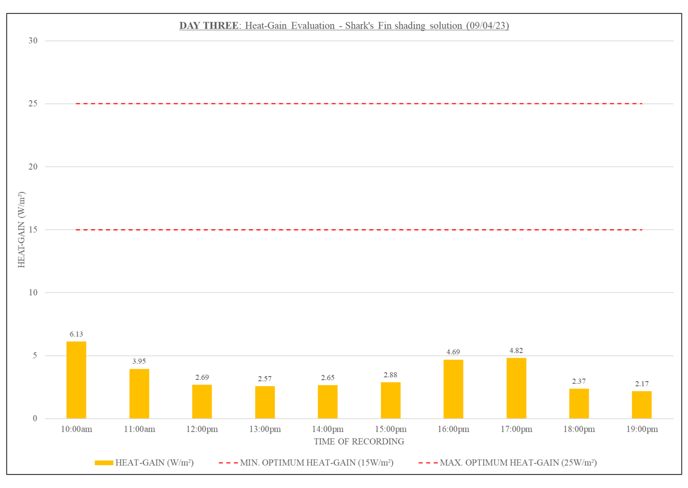
Conditions: Cloudy/Sunny



OPTIMUM 2% - 7%

DAYLIGHT FACTOR %

The shark's fin canopy allowed for optimum DF% for the whole day.



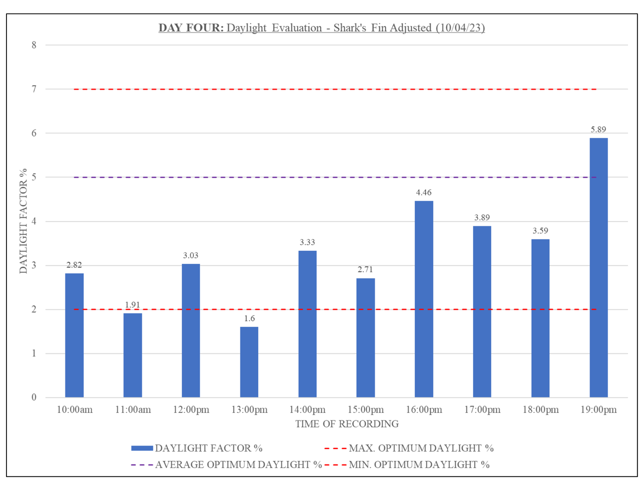
OPTIMUM 15 - 25 W/m2

HEAT - GAIN (W/m2)

The shark's fin canopy was unable to improve internal heat-gain, with the solar loads falling well below optimum range throughout the day.

4 DAY FOUR: Shark's Fin (Adjusted)

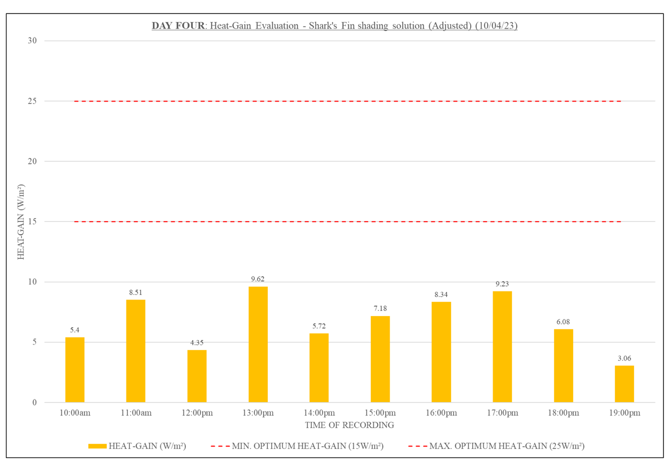
Conditions: Cloudy/Sunny



OPTIMUM 2% - 7%

DAYLIGHT FACTOR %

The adjusted shark's fin allowed for optimum DF% for the whole day except for 11am and 1pm.



OPTIMUM 15 - 25 W/m2

HEAT - GAIN (W/m2)

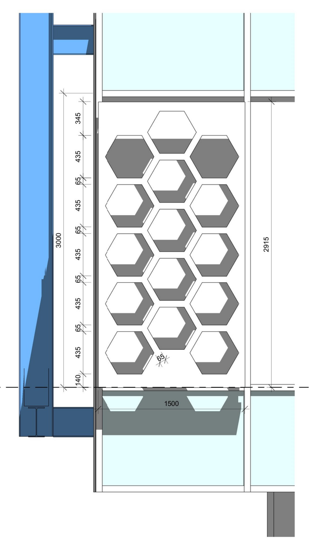
Similarly to Day Three, the adjusted shark's fin solution was unable to keep the internal heat-gain within optimum range throughout the day

Analysis and Conclusion

KEY FINDINGS

Honeycomb Shading Solution

Simulation Testing



Outputs

The larger scale simulation tests were more successful than the smaller scale physical tests. This was most likely due to a different **percentage coverage**, as the physical prototype covered more glazing area than the shading device on the case study building. The Solar Heat Gain Co-efficient of each of the glazing types may also play a factor in this situation.

Physical Testing

Simulation Testing

The results of the simulation testing showed a positive decrease of annual daylight % and heat-gain levels, with both falling within optimum range for all four orientations.

DAYLIGHT FACTOR %

SOLAR HEAT-GAIN

DAYLIGHT FACTOR %

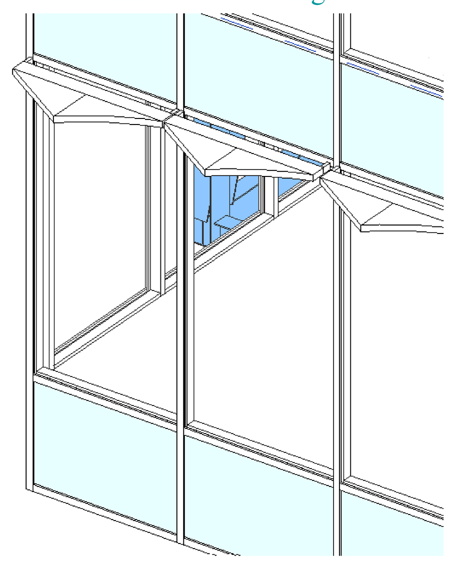
SOLAR HEAT-GAIN

Physical Testing

The results of the physical testing showed that the prototype was unable to maintain optimum DF% and optimum solar loads throughout the day.

Shark's Fin Shading Solution

Simulation Testing



Outputs

The smaller scale physical tests maintained a better overall DF% than the simulation. Both tests were unable to provide optimum solar heat results. This was most likely due to a difference between the shading factors of both devices relative to the glazing area. The Solar Heat Gain Co-efficient of each of the glazing types may also play a factor in this situation.

Physical Testing


Simulation Testing

The results of the simulation testing showed a significant decrease of both the annual DF% and Solar Heat-Gain, but both instances remained slightly above optimum levels for all four orientations.

DAYLIGHT FACTOR %

SOLAR HEAT-GAIN

DAYLIGHT FACTOR %

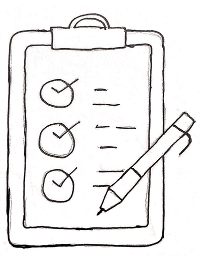
SOLAR HEAT-GAIN

Physical Testing

Both variations of the shark's fin shading prototype were successful in maintaining optimum hourly Daylight % but were unsuccessful in producing optimum hourly internal solar heat loads.

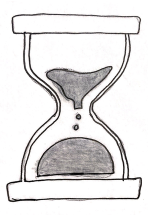
CONCLUSION

A greater knowledge of biomimetic shading and its impact on daylighting and heat-gain has been gained throughout the course of this study as a result of obtaining valuable information from the literature review and the utilization of quantitative methodology. It is clear from the results that both shading solutions that were used throughout the study had an effect on office environments, although some better than others due to design consideration and scale point of views. It proves that the type of biomimetic design has an impact on the way it performs when integrated into the glazed façade of a building. The data allows us to hypothesize that biomimetic shading may only be used as a type of aesthetic within a façade, as various different designs can show different results.

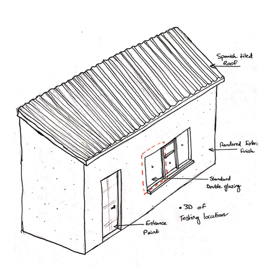


LIMITATIONS

There were limitations present during the physical testing phase of this study.

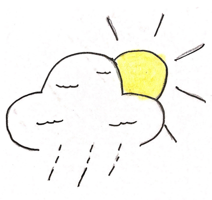


Due to time constraints during the course of this dissertation, the physical testing was limited to four days. This was to allow for at least a day to test all scenarios.



The room was glazed on the south-westerly façade alone, therefore only the south-westerly orientation could be evaluated.

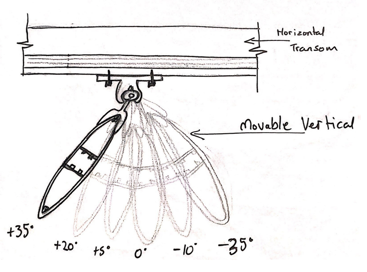
Different weather conditions were present during these tests, which had an effect on the results produced.



FURTHER RESEARCH

Large Scale Physical Testing

Physical Testing on a larger scale may lead to more accurate results on a commercial office block in a real-life environment.



Movable/Dynamic Shading Devices

Movable biomimetic shading solutions may be tested to evaluate response to light emitted by different Irish sun patterns. This would involve appropriate materiality and geometry to suit an Irish Climate