DAYLIGHT DESIGN

AN ILLUSTRATOR'S STUDIO, CARDIFF

19/20-ART132
Environmental Design Application

Lucy Cadena

CONTENTS

Cardiff

THE BRIEF: Context

LOCATION: Cardiff Bay, Cardiff, United Kingdom.

- Cardiff Bay: suburban, sparse, lower chance of obstructions from other buildings

CLIMATE: Köppen-Geiger Cfb (Temperate Oceanic)*

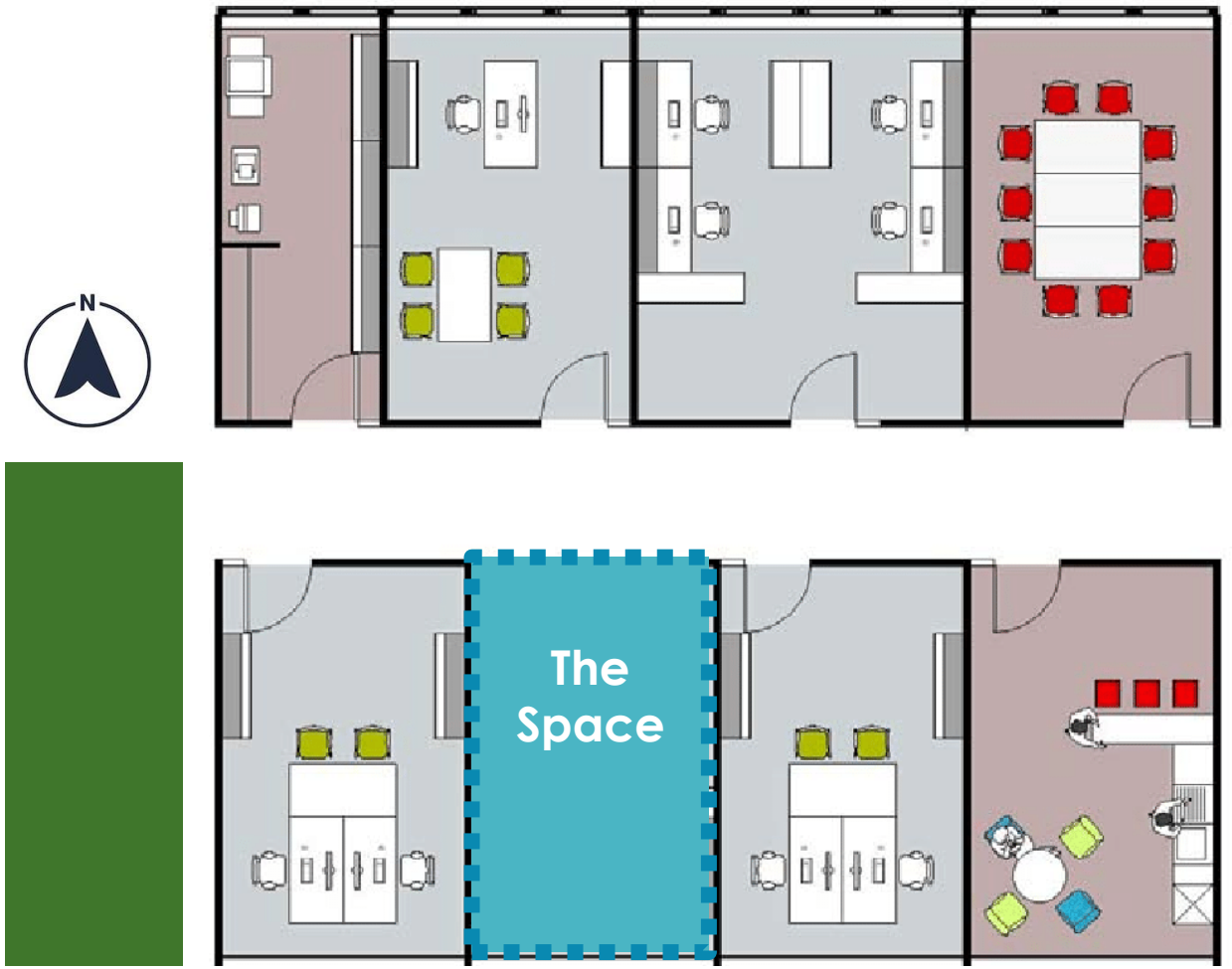
- "Often cloudy", low average sunshine hours*
- Rainiest city in the UK**

* Met Office (www.metoffice.gov.uk), Wales Climate pdf., downloaded 09.11.2019
** Data from the Met Office, 2014

THE BRIEF: Context

- **FEATURE**
  - A shared office building
  - Cellular layout
  - 2nd floor, no obstructions to façade.
- **ORIENTATION**
  - South-facing
- **SPACE**
  - Interior dimensions: 8m (L); 4.2m (W); 3m (H)
  - One wall (the South façade) is fenestrated

The site: 2nd floor of office building (not to scale

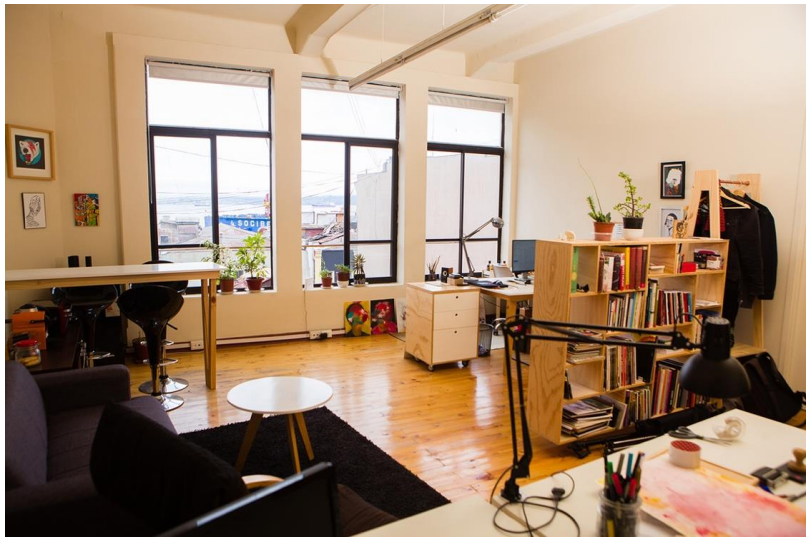


THE BRIEF: Requirements

USE

- An illustrators' studio
- **Users**: Three professional illustrators to occupy the space
- **Mediums:** pen and ink, paint on paper. Fine technical work.
- **Work surface:** desk and drawing board (working plane 0.85m above the floor, consistent with desk-based activities*). Not always horizontal (so direction & flow of light may need to be considered)
- **Time:** Daytime occupation between 09:00-17:00 Monday-Friday, all year round.

* CIBSE Society of Light and Lighting, Lighting Guide 5



An illustrator's studio in Valparaiso, Chile

An illustrator's studio in Amsterdam, Netherlands

The Brief: Requirements

Qualitative

- **Security:** not important (space is on 2nd floor of secure office building)
- **View:** a good view important for health & comfort of users
- **Privacy**: not important for the space's function

Quantitative: Amount of light

- Illuminance on task area: 750 lux*
- Daylight Factor of space:

> MINIMUM 2.5

> AVERAGE 5**

* CIBSE Society of Light and Lighting, Code for Lighting
**Randall McMullan, Environmental Science in Buidling

Quantitative: Quality of light

- Artists in the northern hemisphere prefer „Northern Light" as it is more uniform for working with colour***
- Uniformity value of at least 0.7*
- Low-medium glare

***Lighting Design: Principles, Implementation, Case Studies. Brandi, Ulrike

For reference: the SLL Code for Lighting indicates recommended illuminance levels (lux) for different room functions. I've chosen the ones whose descriptions most closely match Illustrator's Studio.

Ref No.	Type of area, task or activity	Ēm / lx (Illuminance on the task area)	UGRL (Unified Glare Rating)	Uo (Illuminance uniformity - ratio)	Special Requirements
2.27.6	Manual design, drawing patterns	750	22 (medium)	0.70	
2.30.3	Technical drawing room	750	16 (low)	0.70	
2.40.7	Art room in art school	750	19 (low)	0.70	5000 K ≤ TCP ≤ 6500 K

Light colour

Source: The Society of Light and Lighting (SLL) Code for Lighting, Norwich March 2012 - Indoor workplaces

The Brief: Requirements

Priority of main requirements:

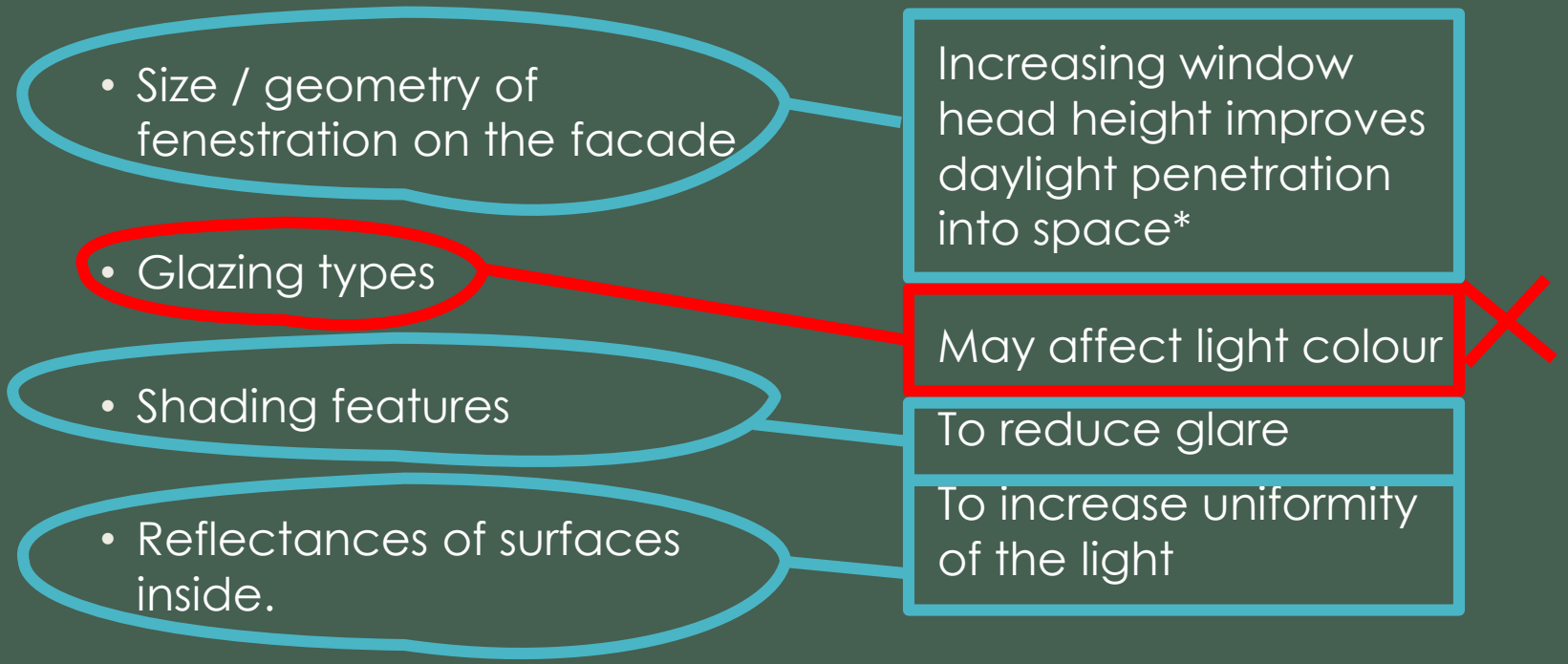
Requirement	Level required	Unit	Importance	Priority
Quality of light (uniformity)	Minimum 0.7	Min/Av DF	High	1
Quality of light (colour)	Natural!*		High	2
Quantity of light	Minimum 2.5 Av 5	DF	Medium	3
Quality of light (glare)	Low-medium	Determined by sun penetration	High	4
View	Good	-	Medium	5

*Note the colour of the light is already optimised (natural daylight) but is listed as a priority as it should not be compromised by design (eg. tinted glazing or semi-transparent shading devices)

The Brief: Constraints & Options

CONSTRAINTS on DESIGN

- Verticle glazed openings on the exterior facade only
- No other walls may be fenestrated (and no roof lights)
- No artificial light may be used



* CIBSE daylighting guide

The Data: Trends & Observations

Quality of light

- None of the models achieved daylight penetration throughout the space. As a general rule, daylighting will only penetrate to a distance of around 2.5 times the window head height.*
- The bigger the window area, the higher the uniformity value
- Still none of the models came close to achieving 0.7 uniformity (all remained under 0.2
- Group C (<6m2 window area) had the best results for quality of light

Quantity of light

- None of the models achieved the minimum required 2.5 minimum DF, or 5 average
- Again, it seemed the bigger the window area, the higher the DF readings
- None of the models achieved a minimum DF reading of even 0.4, because of the difficulty with daylight penetration – much of the room remained dark
- This also kept averages low (most below 3)
- Again, Group C had the best results.

* CIBSE Daylighting Guide

The Data: Base Case

Group C's models gave the best results for my room's requirements

Table: Group C's results

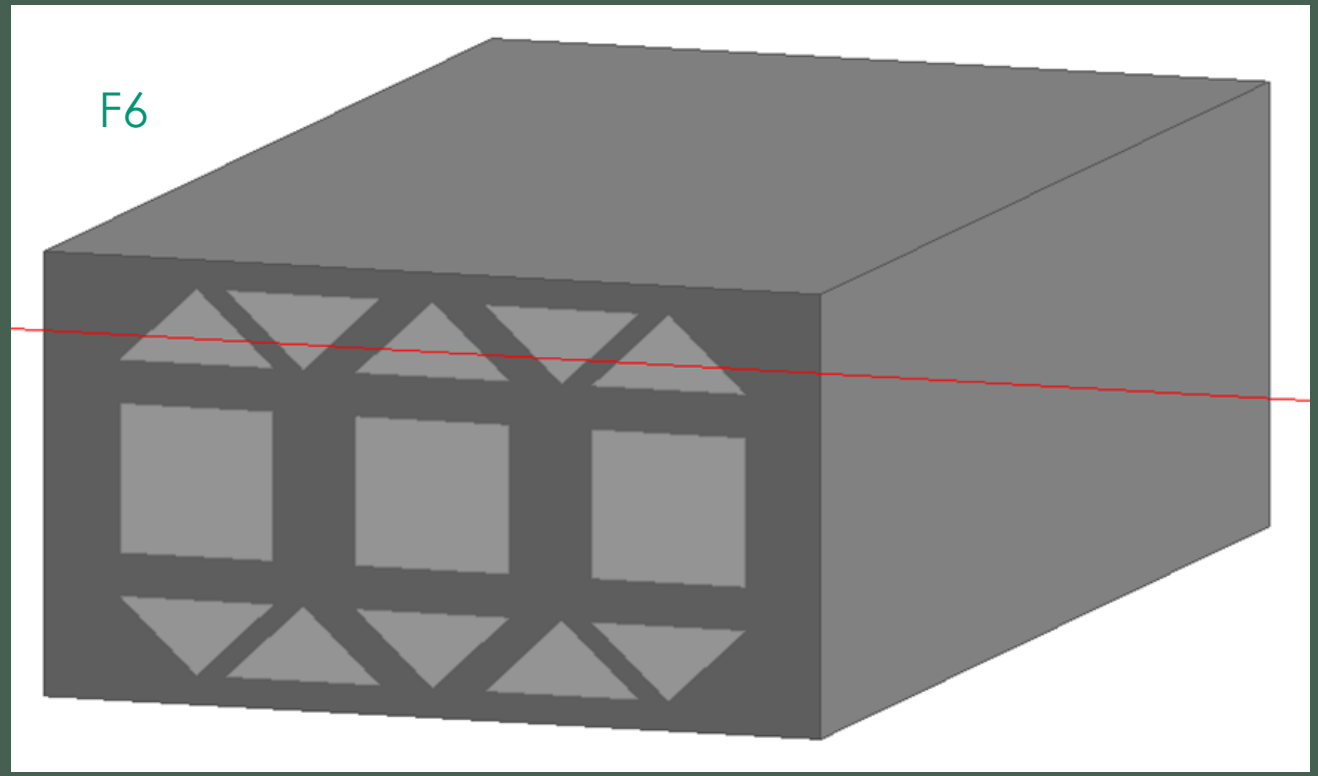
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12
Mean	2.314	1.854	2.117	3.081	2.518	2.642	2.179	1.577	2.106	2.814	2.306	1.461
Minimum	0.275	0.276	0.238	0.317	0.302	0.345	0.274	0.267	0.267	0.295	0.269	0.189
Minimum/Average	0.119	0.149	0.112	0.103	0.12	0.131	0.126	0.169	0.127	0.105	0.117	0.129

	F6	Required	Score
Av. DF	2.642	5	
Min. DF	0.345	2.5	
Min/Av	0.131	0.7	

Reminder of the required values. There is still much to be improved.

The Data: Base Case

3 Square openings 1.0 Sq.m. each & 10 Triangle openings of 0.25 Sq.m.each, placed top & bottom in South facade.



Note:

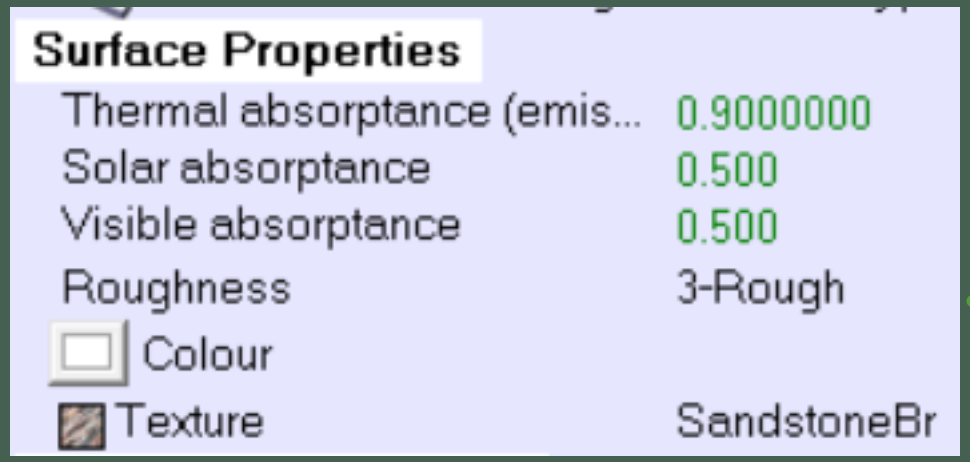
1. Group C didn't give precise placements for these openings.
2. Working plane height for Group C was 0.80m (instead of 0.85m which is what I'll be working to)

So some variation in our results might occur when modelling (shown in next slide).

The Data: Base Case

	F6	Base Case
Average DF	2.642	1.944
Min. DF	0.345	0.246
Min/Av DF	0.131	0.127

Note that there are differences between my modelled Base Case and Group C's model



Base case interior surfaces are made of Gypsum Plaster (surface reflectance 0.5). There is no shading.

Sunlight pentration map

March 21

Up to 4.5m depth from facade

08:00

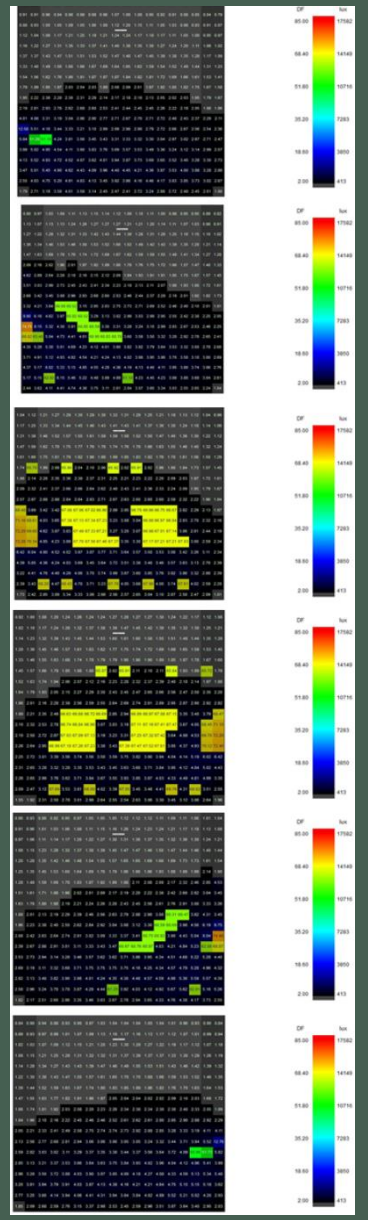
09:00

11:00

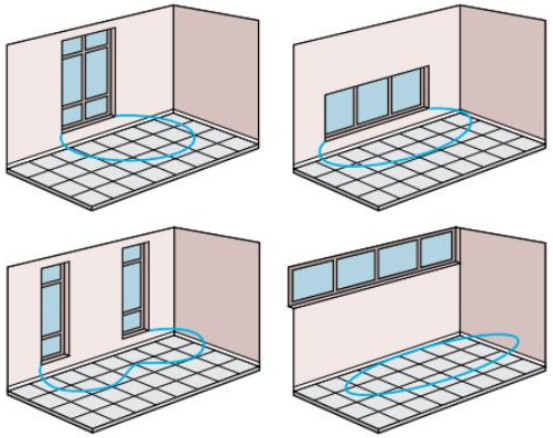
13:00

15:00

16:00



Effect of window height on daylight penetration*

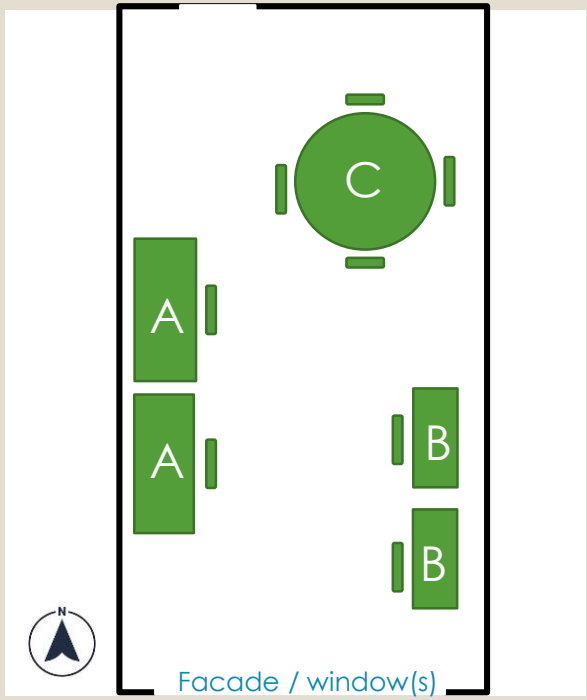


Design variables:

1. Size & Geometry
2. Reflectances
3. Shading

Plan of studio

Interior layout
- A = Drawing board
- B = Desk
- C = Table



*CIBSE Daylighting Guide

The Design: Methodology

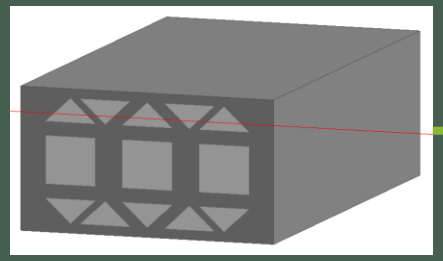
- Experimenting with 3 variables
- Focusing on DF, time of day/year not important
- However, to look at glare (4th priority), I will refer to different times of day on March 21 (spring solstice) as this time has equal length of day/night and daylight hours are around average for the year
- We can already be sure that for some times of the year & day (eg winter, past 4pm) artificial light will be required

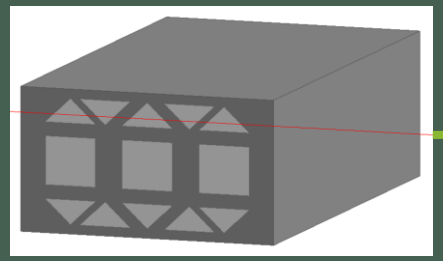
The Design: Methodology

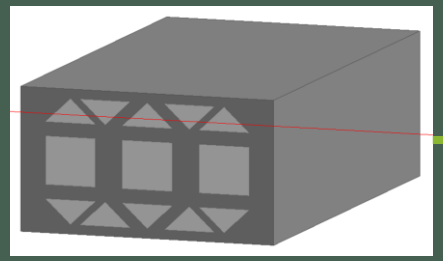
Variable 1: Size & geometry of openings

Variable 2: Internal reflectances

Variable 3: Internal shading device







V1

V2

V3

V4

V5

V6

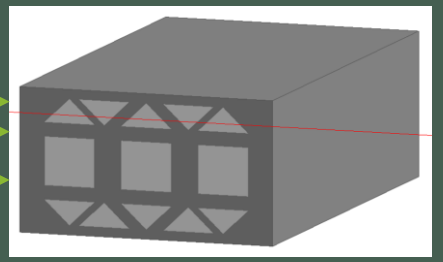
V7

V8

V9

Best versions combined

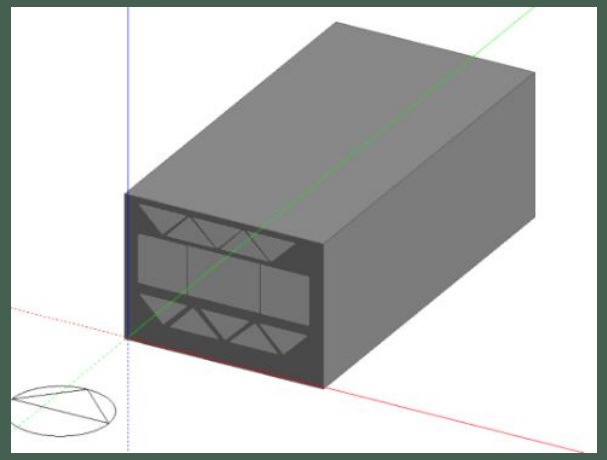
V10



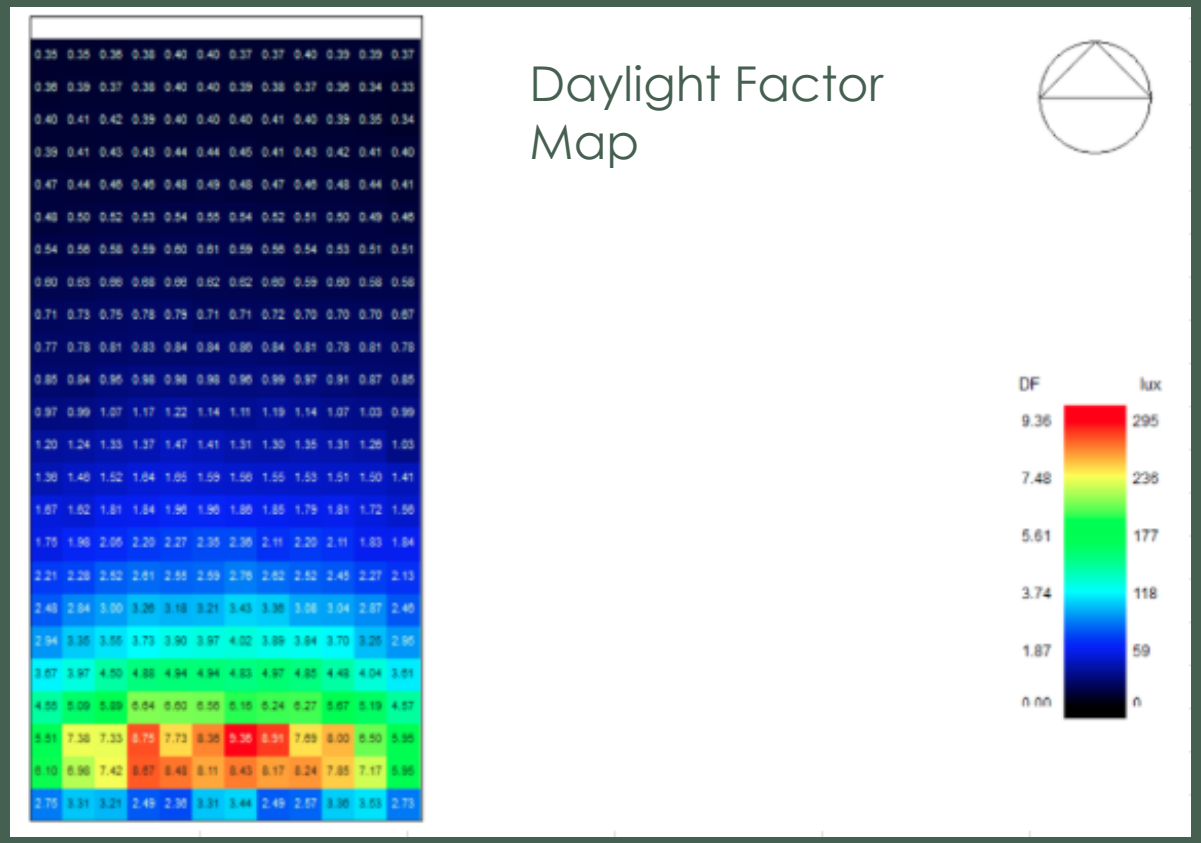
Final design

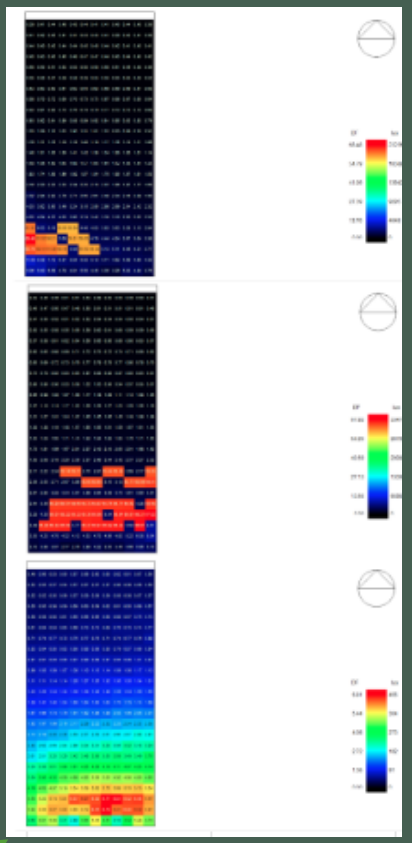
Results: Variable 1, V1

- Increased window surface area to 6m2
- Raised height of windows



	V1
Av DF	2.146
Min DF	0.326
Min/Av DF	0.152

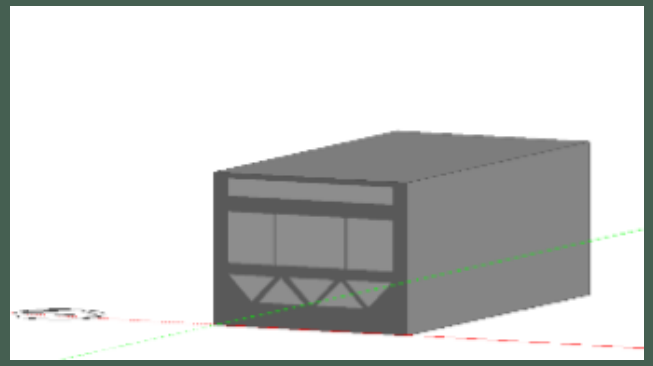




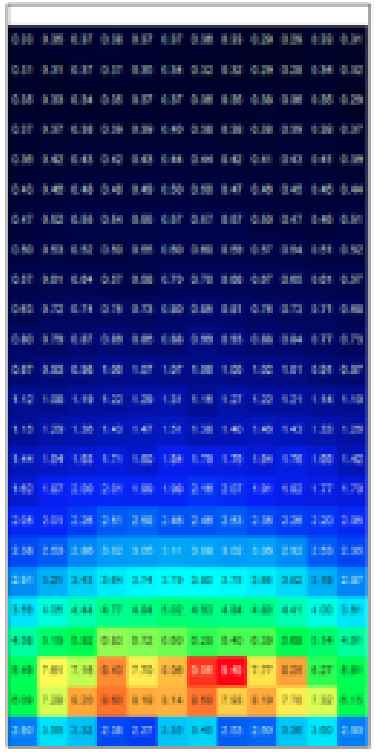
Sun penetration map at 09:00, 13:00 and 17:00 on 21 March

Results: Variable 1, V2

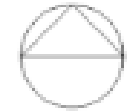
- Changed window shape at top
- Raised height of top window
- 6m2 area

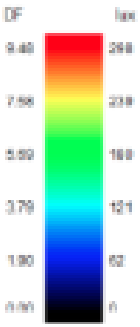


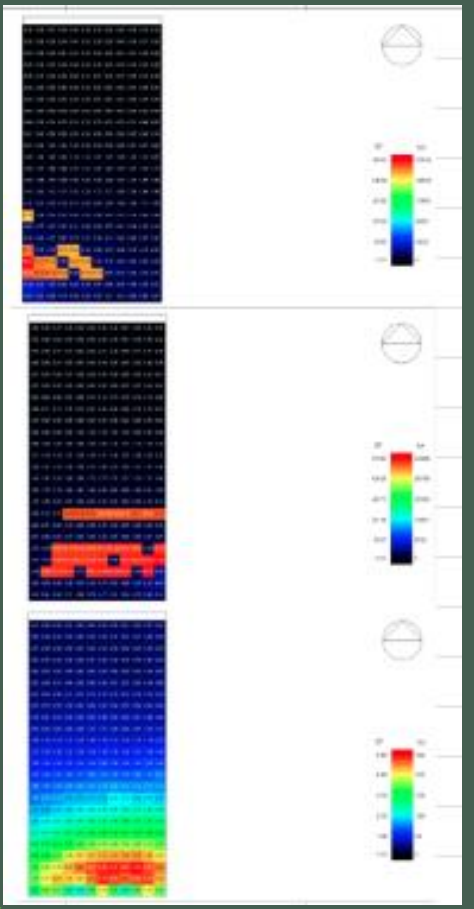
	V2
Av DF	2.077
Min DF	0.284
Min/Av DF	0.136



Daylight Factor Map



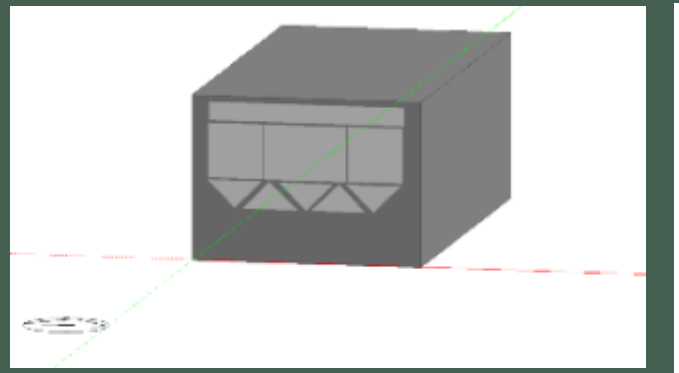




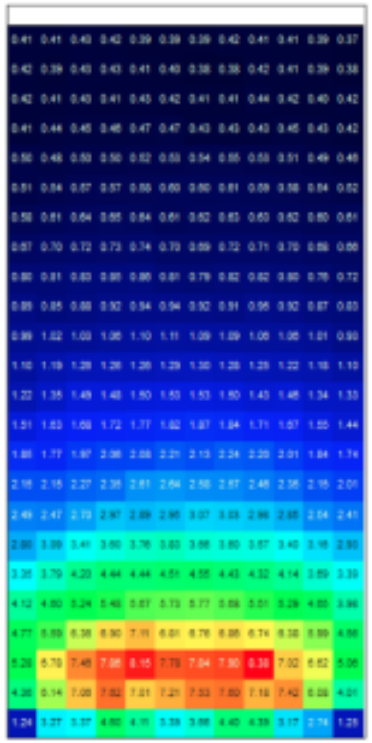
Sun penetration map at 09:00, 13:00 and 17:00 on 21 March

Results: Variable 1, V3

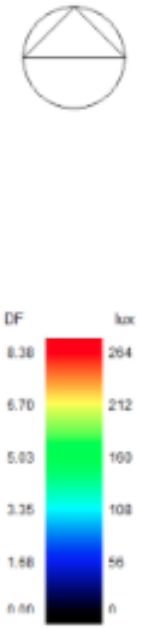
- Kept rectangular window at top
- Raised height of ALL windows
- 6m2 area

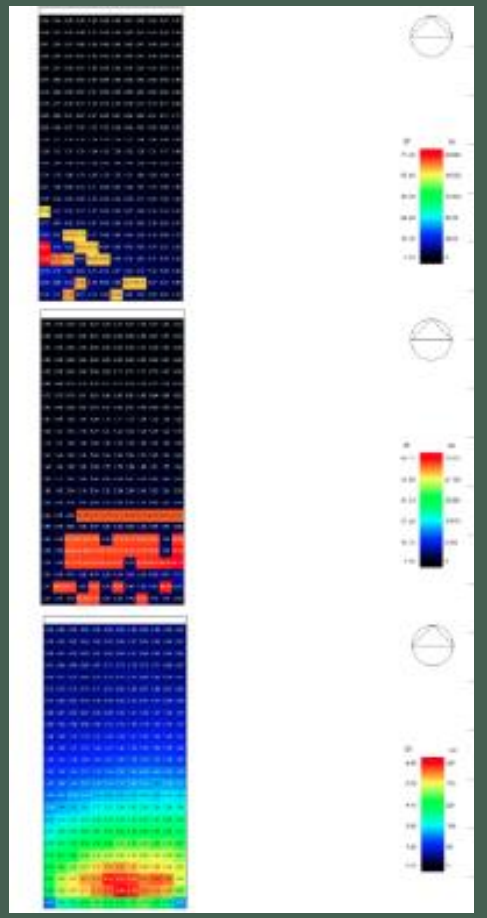


	V3
Av DF	2.261
Min DF	0.369
Min/Av DF	0.163



Daylight Factor Map





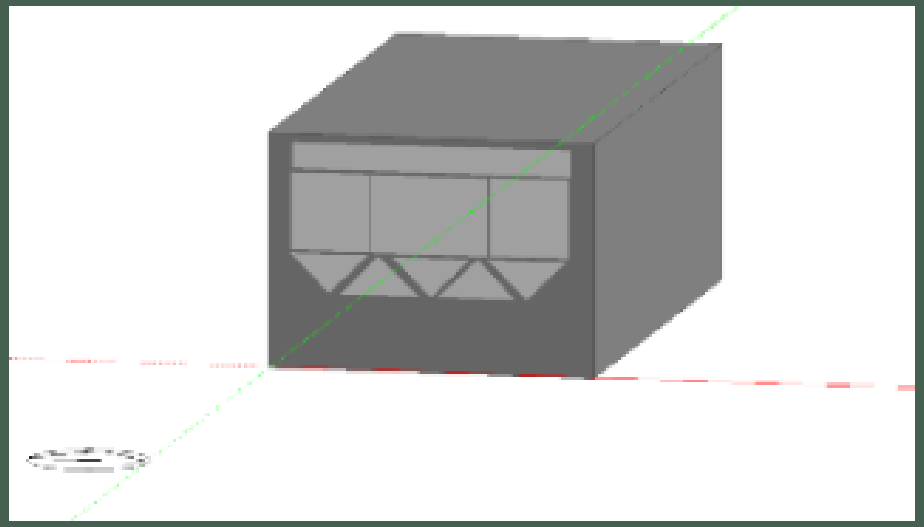
Sun penetration map at 09:00, 13:00 and 17:00 on 21 March

Results: Variable 1, Compared

	V1	V2	V3	Base Case	Required
Av DF	2.146	2.077	2.261	1.944	5
Min DF	0.326	0.284	0.369	0.246	2.5
Min/Av DF	0.152	0.136	0.163	0.127	0.7

For this variable, **V3** was the best performing model for the priority requirements.

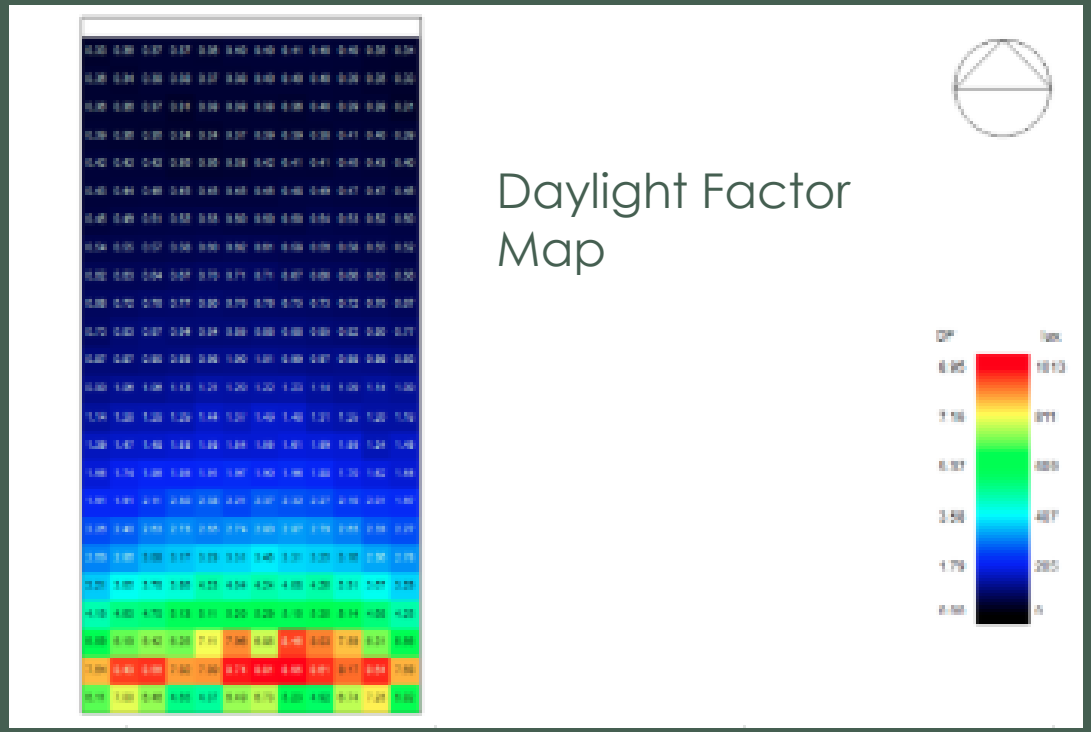
However, it still falls short of the required DF levels and uniformity level.



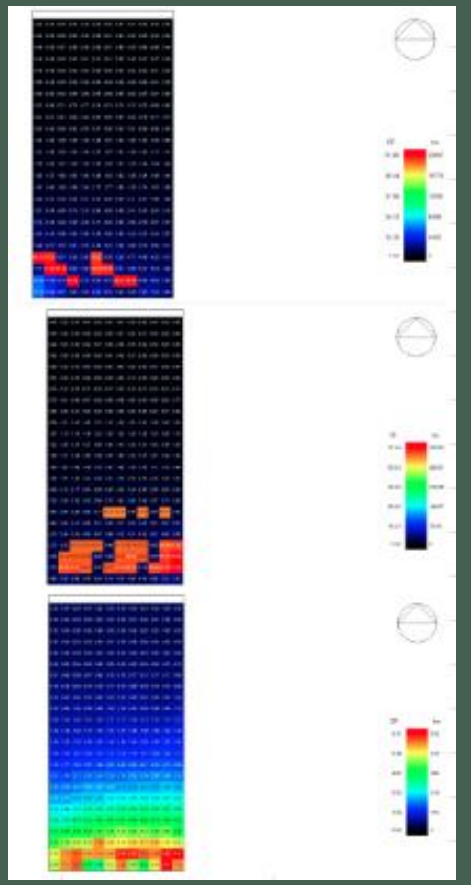
Results: Variable 2, V4

- **Interior Surface: Ceramic Porcelain Tiles**
- **Reflectance: 0.6**

Surface Properties	
Thermal absorptance (emis...	0.9000000
Solar absorptance	0.400
Visible absorptance	0.400
Roughness	3-Rough
Colour	
Texture	Brushed flat c
Radiance Daylighting	
Specularity	0.000
Material class	1-Plastic



	V4
Av DF	2.089
Min DF	0.310
Min/Av DF	0.149



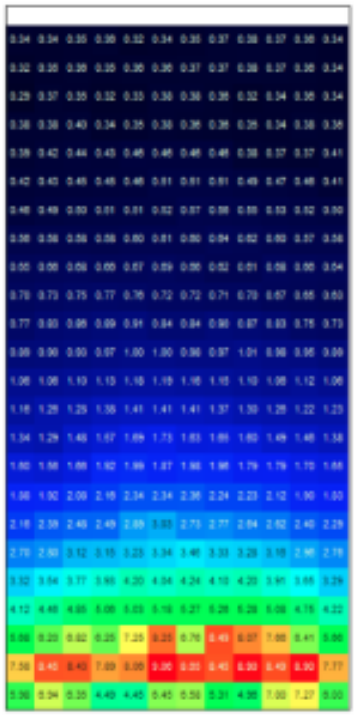
Sun penetration map at 09:00, 13:00 and 17:00 on 21 March

Results: Variable 2, V5

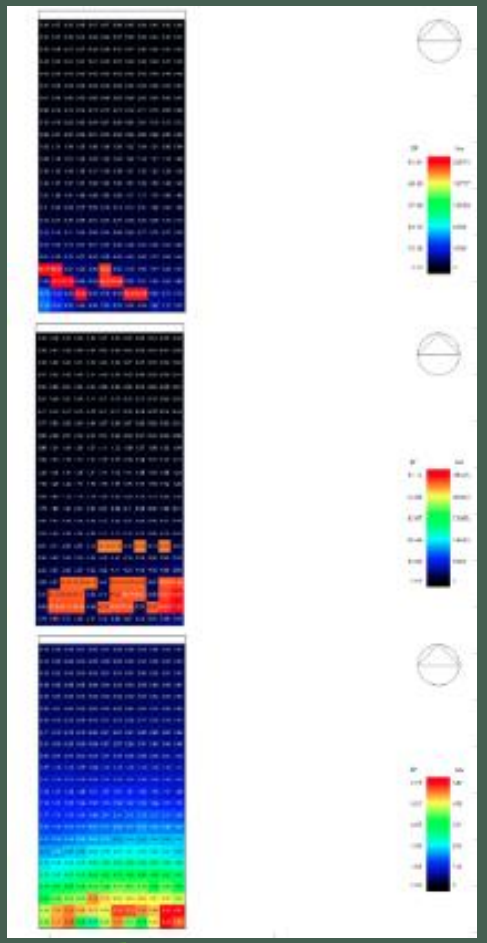
- **Interior Surface: Glass Mosaic**
- **Reflectance: 0.6**

Surface Properties	
Thermal absorptance (emis...	0.9000000
Solar absorptance	0.400
Visible absorptance	0.400
Roughness	3-Rough
Colour	
Texture	White
Radiance Daylighting	
Specularity	0.000
Material class	1-Plastic

	V5
Av DF	2.090
Min DF	0.294
Min/Av DF	0.140



Daylight Factor Map



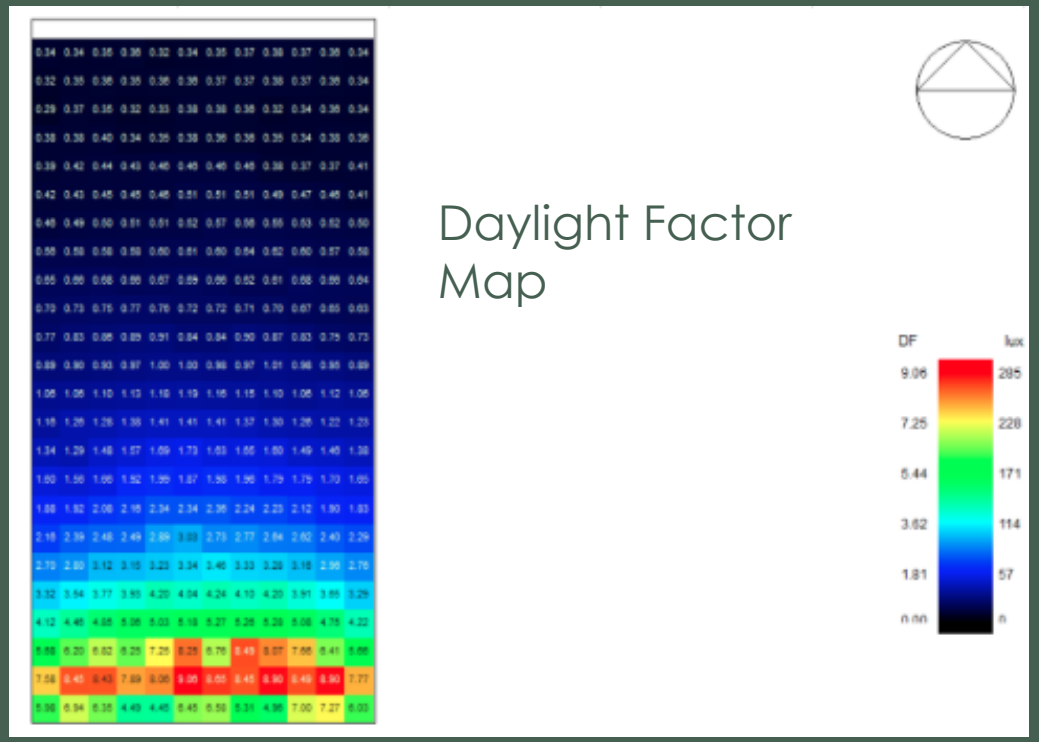
Sun penetration map at 09:00, 13:00 and 17:00 on 21 March

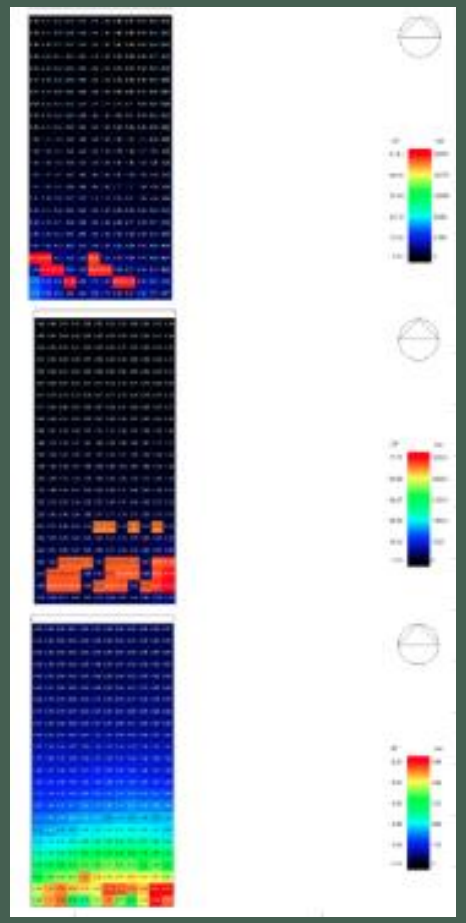
Results: Variable 2, V6

- **Interior Surface: Glass block**
- **Reflectance: 0.6**

Surface Properties	
Thermal absorptance (emis...	0.9000000
Solar absorptance	0.400
Visible absorptance	0.400
Roughness	3-Rough
Colour	
Texture	Light grey
Radiance Daylighting	
Specularity	0.000
Material class	1-Plastic

	V6
Av DF	2.091
Min DF	0.284
Min/Av DF	0.140





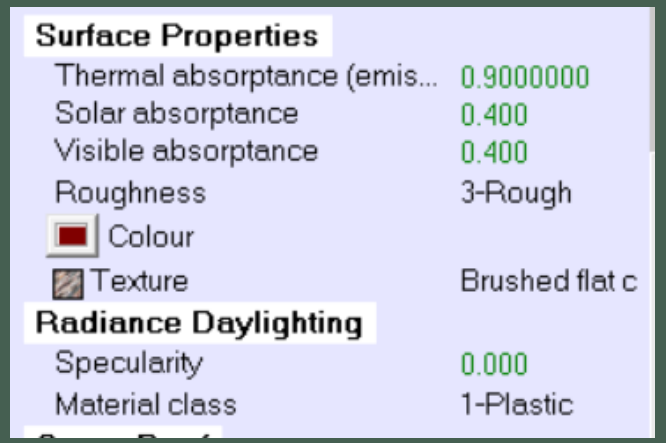
Sun penetration map at 09:00, 13:00 and 17:00 on 21 March

Results: Variable 2, Compared

	V4	V5	V6	Base Case	Required
Av DF	2.089	2.090	2.091	1.944	5
Min DF	0.310	0.294	0.284	0.246	2.5
Min/Av DF	0.149	0.140	0.140	0.127	0.7

For this variable, **V4** (ceramic porcelain tiles) was the best performing model for the priority requirements.

However, it still falls short of the required DF levels and uniformity level.

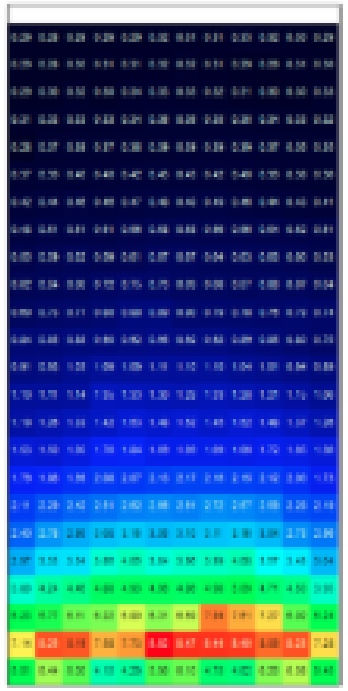


Results: Variable 3, V7

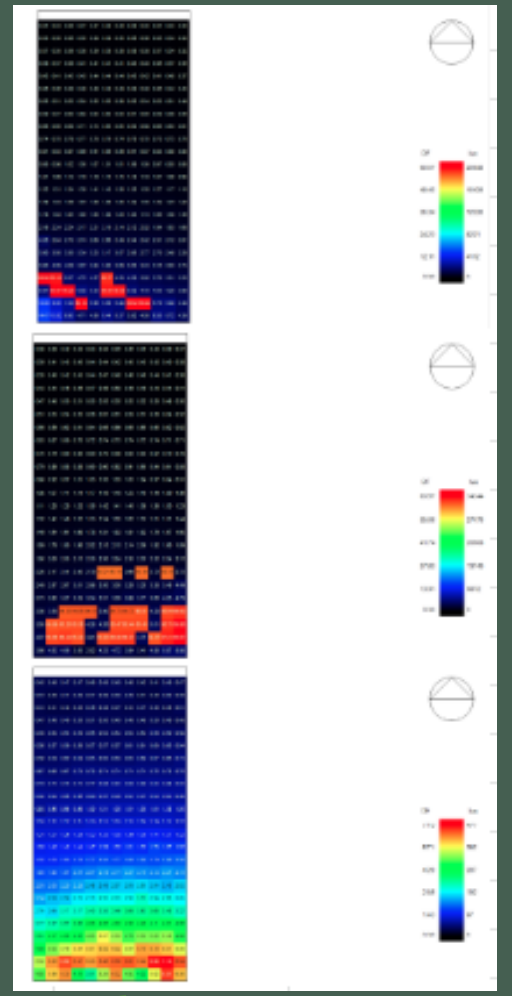
- **Shading device: Blind with high reflectivity slats**

General	
Blind with high reflectivity slats	
Category	Slatted blin
Source	E+
Slat Properties	
Blind-to-glass distance (..	0.0150
Slat orientation	Horizontal
Slat width (m)	0.02500
Slat separation (m)	0.01875
Slat thickness (m)	0.00100
Slat conductivity (W/m-K)	0.900
Slat angle (°)	45.0
Minimum slat angle (°)	0
Maximum slat angle (°)	180

V1



Daylight Factor Map



	V7
Av DF	1.955
Min DF	0.278
Min/Av DF	0.142

Sun penetration map at 09:00, 13:00 and 17:00 on 21 March

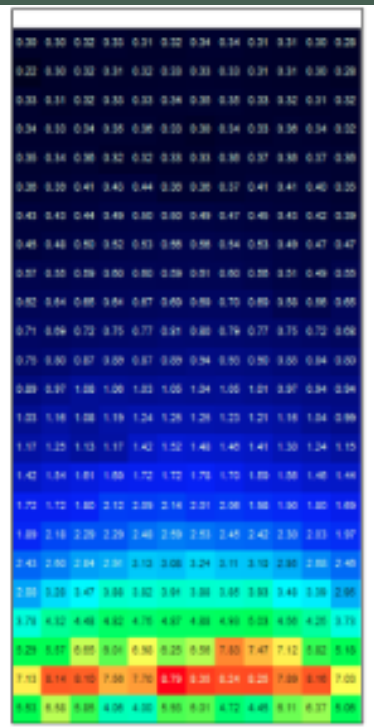
Results: Variable 3, V8

Mid-pane blind with medium refle	
Category	Slatted blin
Source	E+
Slat Properties	
Blind-to-glass distance (..	0.0500
Slat orientation	Horizontal
Slat width (m)	0.02000
Slat separation (m)	0.01875
Slat thickness (m)	0.00100
Slat conductivity (W/m-K)	0.900
Slat angle (°)	45.0
Minimum slat angle (°)	0
Maximum slat angle (°)	180

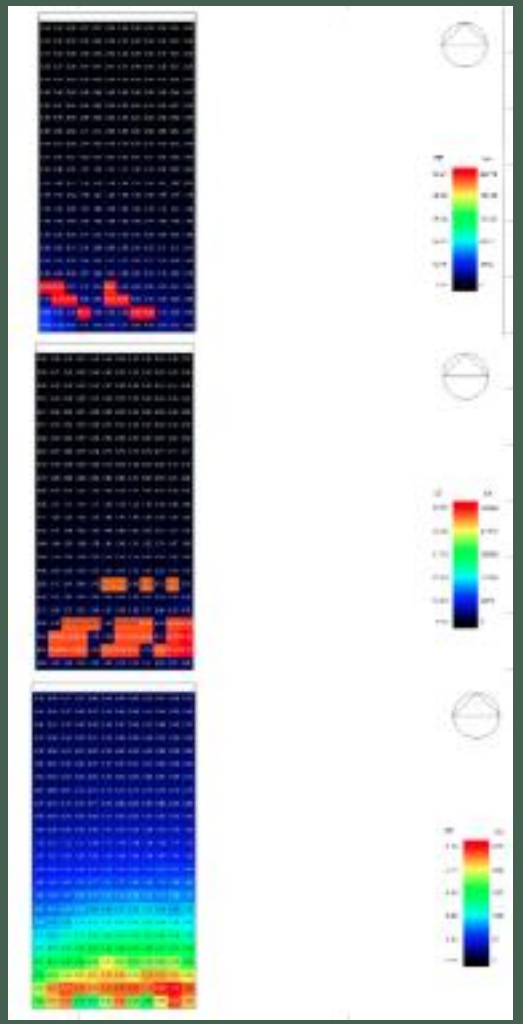
V1

	V8
Av DF	1.907
Min DF	0.224
Min/Av DF	0.118

- **Shading device: mid-plane blind with medium reflectivity slats**



Daylight Factor Map



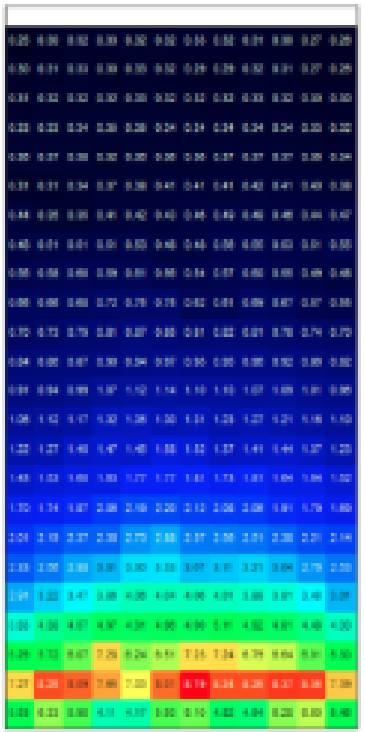
Sun penetration map at 09:00, 13:00 and 17:00 on 21 March

Results: Variable 3, V9

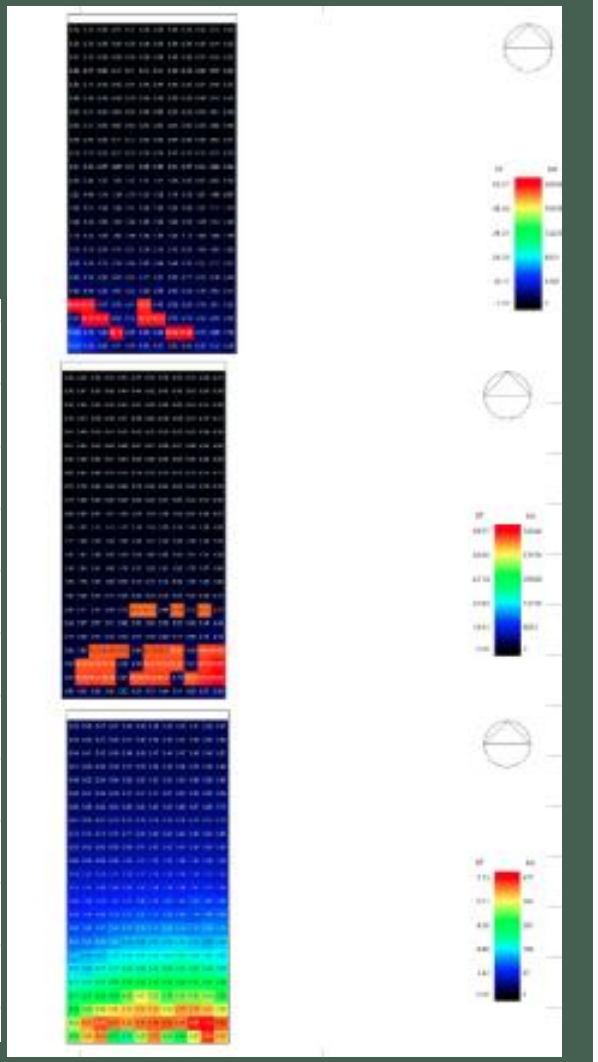
- **Shading device: MicroLouvre**

General	
MicroLouvre	
Category	Slatted blin
Source	SmartLouvr
Slat Properties	
Blind-to-glass distance (..	0.0100
Slat orientation	Horizontal
Slat width (m)	0.00138
Slat separation (m)	0.00149
Slat thickness (m)	0.00032
Slat conductivity (W/m-K)	0.900
Slat angle (°)	73.0
Minimum slat angle (°)	73
Maximum slat angle (°)	73

	V9
Av DF	1.941
Min DF	0.252
Min/Av DF	0.130



Daylight Factor Map



Sun penetration map at 09:00, 13:00 and 17:00 on 21 March

Results: Variable 3, Compared

	V7	V8	V9	Base Case	Required
Av DF	1.955	1.907	1.941	1.944	5
Min DF	0.278	0.224	0.252	0.246	2.5
Min/Av DF	0.142	0.118	0.130	0.127	0.7

For this variable, **V7** (blind with high reflectivity slats) was the best performing model for the priority requirements.

However, it still falls short of the required DF levels and uniformity level.

Also note that some variations – notably V8 – performed worse than the base case (in red).

Results: All results

	Av DF	Min DF	Min-Av DF
base case	1.944	0.246	0.127
v1	2.146	0.326	0.152
v2	2.077	0.284	0.136
v3	2.261	0.369	0.163
v4	2.089	0.31	0.149
v5	2.09	0.294	0.14
v6	2.091	0.284	0.14
v7	1.955	0.278	0.142
v8	1.907	0.224	0.118
v9	1.941	0.252	0.13

The most significant improvements come from Variation 1 – adjusting the shape, size and position of the windows.

The least successful results come from Variation 3 – internal shading (with some values – in red – performing worse than the base case.

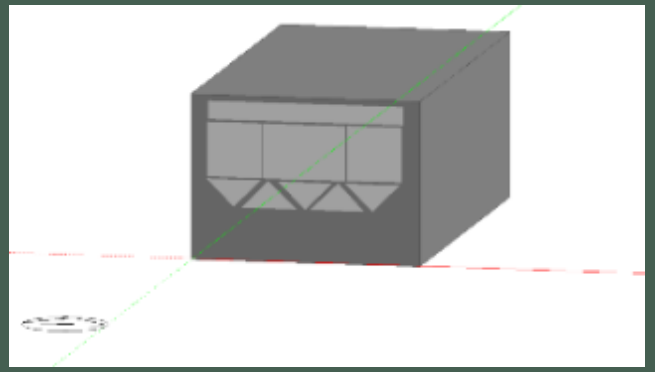
Moving forward, I will take the best performing variation under each variable and combine them to produce my final design (V10).

For Variation 1, that's V3.

For Variation 2, V4

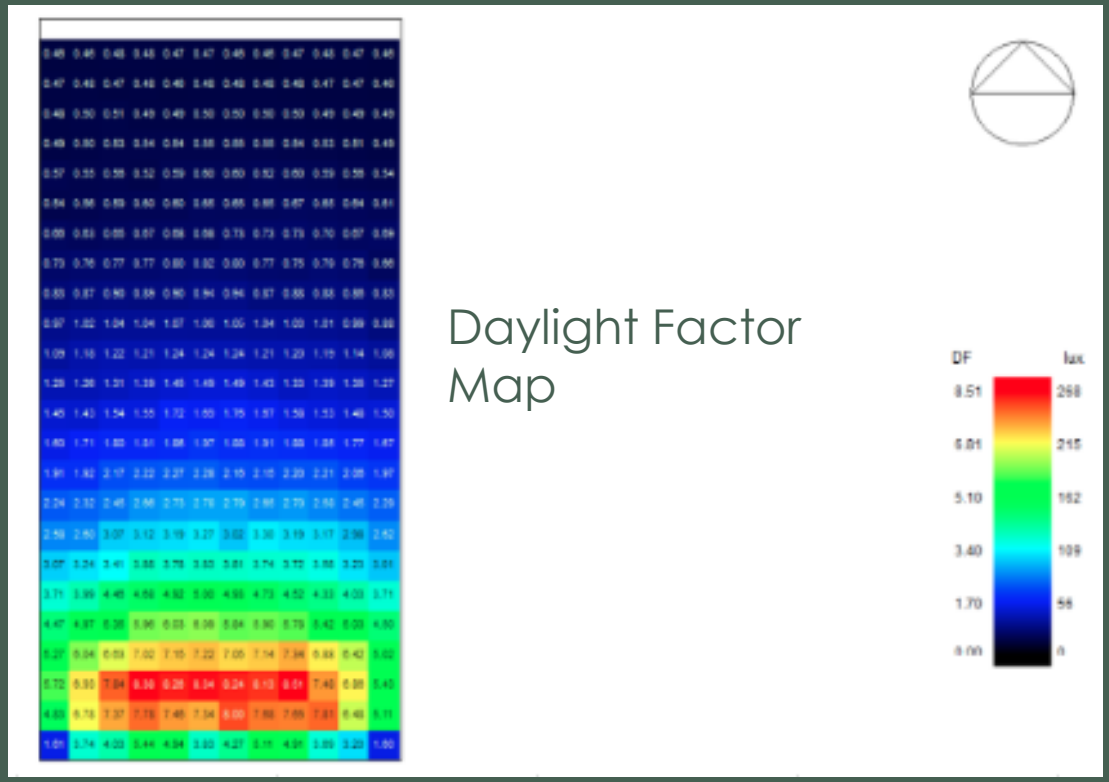
For Variation 3, V7.

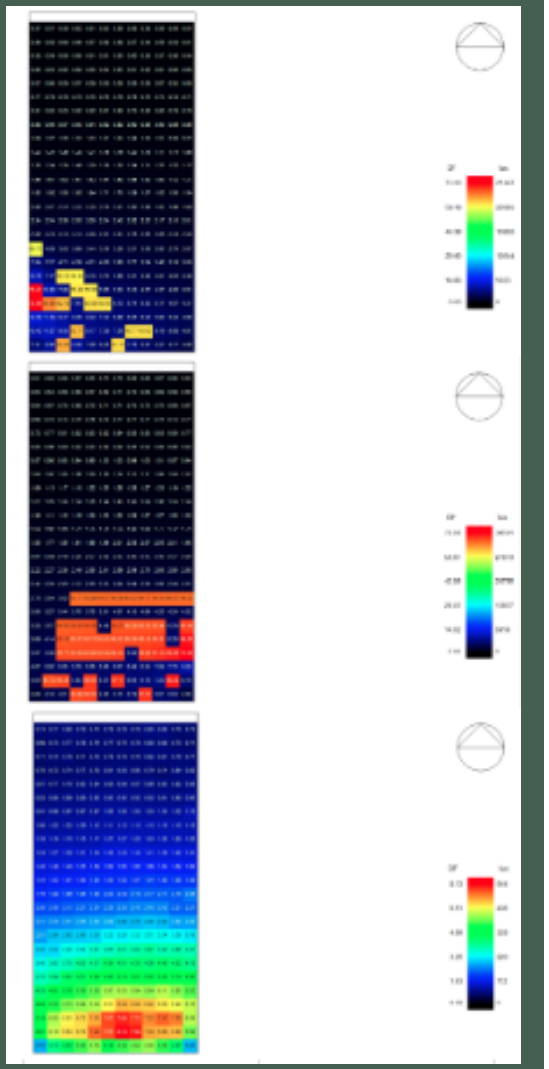
Results: Final Design, V10



- **Interior Surface:** Ceramic Porcelain Tiles
- **Shading device:** Blind with high reflectivity slats

	V10
Av DF	2.438
Min DF	0.456
Min/Av DF	0.187





Sun penetration map at 09:00, 13:00 and 17:00 on 21 March

The Design: Analysis

Requirement (in priority order)	Level required	V10	Base Case	V10 Score	Notes
Quality of light (uniformity)	Minimum 0.7 (min/av DF)	0.187	0.127		Even though V10 is an improvement on the base case, the improvement is very slight (only + 0.06). **Conclusion:** It may not be possible to attain the required level of uniformity in this space without either increasing the number of openings in the space (including roof lighting and side lighting on other walls), or introducing artificial light.
Quality of light (colour)	Natural!*	n/a	n/a		We can assume that the colour of the light has remained consistent as we are only using natural light, and have not used tinted glazes or transparent shading which could alter the colour.

The Design: Analysis... Continued

Requirement (in priority order)	Level required	V10	Base Case	V10 Score	Notes
Quantity of light	Minimum 2.5 DF Av 5 DF	Min 0.456 DF Av 2.438	0.246, 1.944		This is perhaps the measurement that we have seen the most improvement. I have been able to almost double the minimum DF from the base case. However the values are still far too low to meet the requirements of this space.
Quality of light (glare)	Low-medium	?	?		Observations of the sun penetration of each design did not show a notable variation AT ALL in the amount of sun entering into the space. In future I would experiment further with shading devices.
View	Good	Good	Good		The large window surface area and height is adequate to give good views

SUMMARY

1. The final design does not meet the requirements of the space.

2. In addition, the final design was the result of an experiment – as such it may not be a feasible option for users of the space (eg. Ceramic porcelain tiles on all walls may be too expensive and impractical).

3. If only one variable could be chosen, it should be Variable 1 (size / position / shape of the windows), though this may not be the most economical option (that would be Variable 3, shading).

Recommendations for further study

WITHIN the scope of the design brief:

- Interior layout / orientation
- Light shelf / other daylighting features

OUTSIDE of the scope of the design brief:

- Roof / other side lighting
- Orientation of the building/site
- Artificial light

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