THE UNIVERSITY OF
ALABAMA

CE 491/591 Final Project Report

Introduction to Architectural Engineering

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ABSTRACT

This report covers the steps and tests done to examine the daylight of our building model. We broke the process into five steps: constructing the model, daylight factor measurements, glare analysis, model improvement, and model simulations. Through these tasks, we were able to establish an understanding of daylight design as well as improve the base model layout that was originally provided.

The model improvement and research provided us with a greater understanding of the positive effects of daylight as well as the importance of energy efficiency and sustainability. These insights gave our model importance by comparing it to real-world applications.

1 INTRODUCTION

Daylighting is a fundamental aspect of building design that utilizes natural light to enhance interior spaces' functionality, energy efficiency, and aesthetics. It typically introduces daylight into a building in a controlled manner through the strategic placement and design of windows, skylights, and reflective surfaces. Incorporating daylighting into a building reduces reliance on artificial lighting and positively impacts occupants' physical and mental health and productivity.

Good daylighting is characterized by an even distribution of light throughout the space, adequate illumination for a variety of tasks, and a reduction in glare, which is critical to maintaining visual comfort. In addition, the interaction between natural light and interior surfaces helps to create vibrant and attractive environments that have a positive impact on occupants' physical and mental health and productivity. The quality of light in a building depends on several key factors. The design and placement of openings such as windows, skylights and bay windows are fundamental to bringing light into a building. The interaction between these openings and reflective surfaces, including walls, ceilings and floors, ensures that light is spread evenly throughout the interior. To further refine this process, shading devices such as blinds and shades are used to control the quantity and quality of light entering the space, reducing excessive brightness contrasts that can cause discomfort.

Architectural daylighting serves a variety of purposes in different types of buildings. In residential buildings, daylighting creates a comfortable living environment while reducing energy costs. In commercial and educational environments, daylighting has been shown to improve productivity, concentration and overall user satisfaction. These benefits highlight the importance of daylighting as a sustainable design strategy that integrates environmental goals with user needs. The orientation and geometry of the building determines the amount and quality of light that can be captured. Carefully proportioned and positioned windows allow light to penetrate deep into a space, while highly reflective materials expand the distribution of light.

This project investigates the application of daylighting principles to a scaled-down architectural model, providing a practical exploration of theoretical concepts. A small building model will be fabricated using cardboard to examine daylight factor distribution and perform glare analysis under various scenarios using different testing approaches to identify strategies for optimizing daylighting performance. In addition, we will address challenges such as excessive luminance contrast or under-illumination by further improving the model. The insights gained from this project will contribute to a deeper understanding of daylighting as an important aspect of architectural engineering and its role in the environment.

1.1 Building Model

Prior to construction, the model was simulated in Revit, in which we established a 3D view of the given dimensions. This gave us a better understanding of what the completed building model should look like. The scaled-down building model was constructed using readily available materials, the item lists including cardboard for the structural framework, pens or pencils for sketching, double-sided tape and duct tape (black) to hold the model together and prevent some light leaks, which could compromise the accuracy of daylight and glare measurements. The dimensions of the model were shown below:

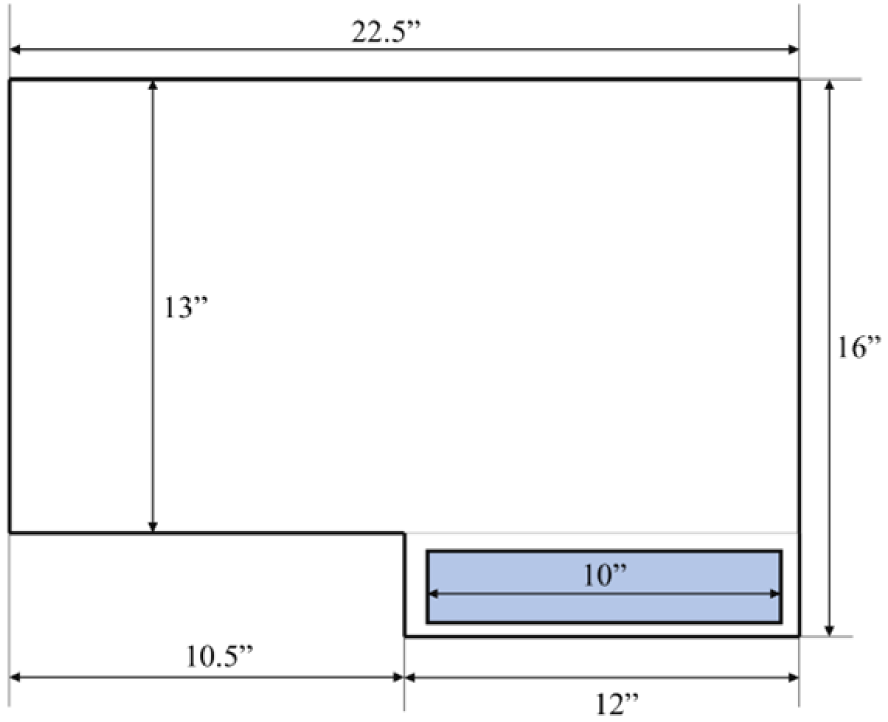


Figure 1.1: Floor Plan

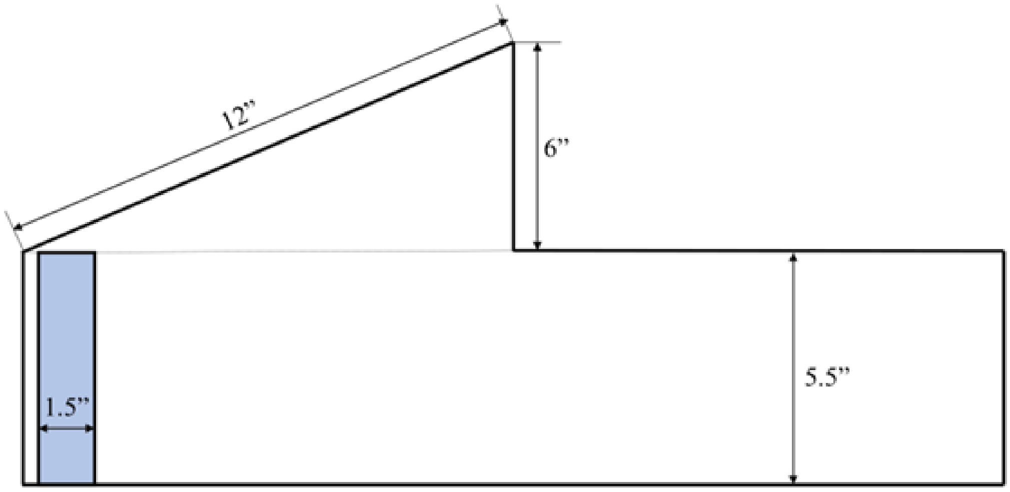


Figure 1.2: Front View

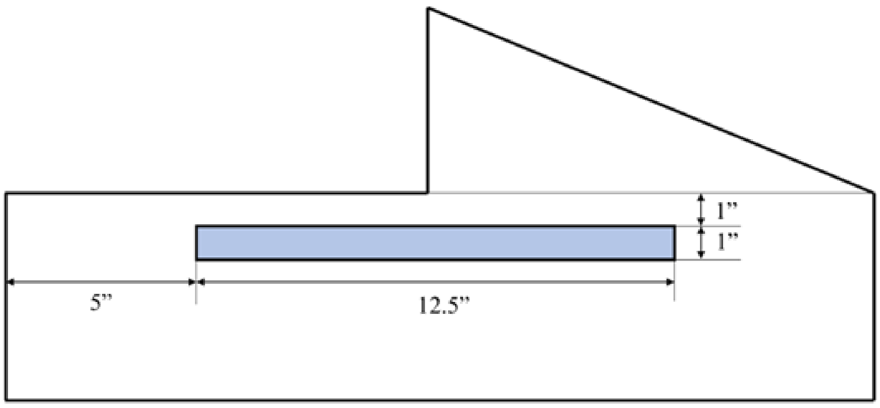


Figure 1.3: Back View

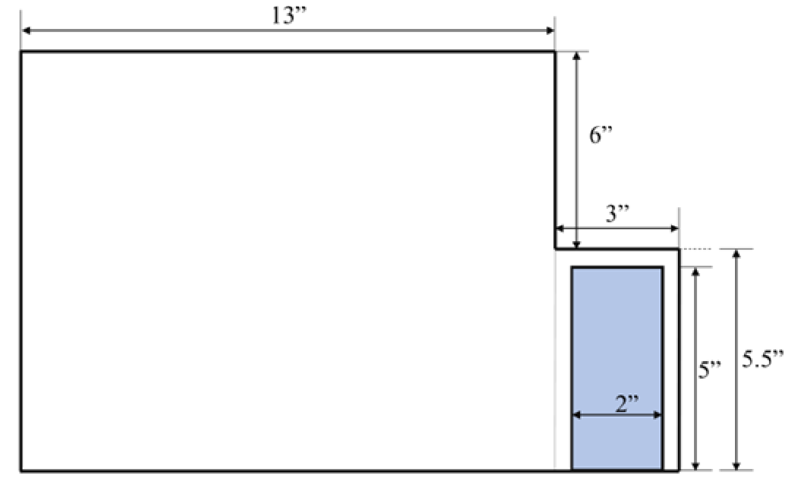


Figure 1.4: Top Floor Plan

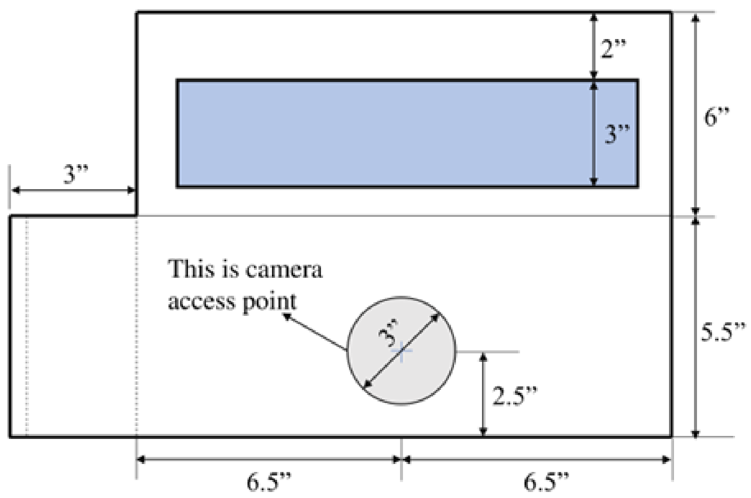


Figure 1.5: Right Wall

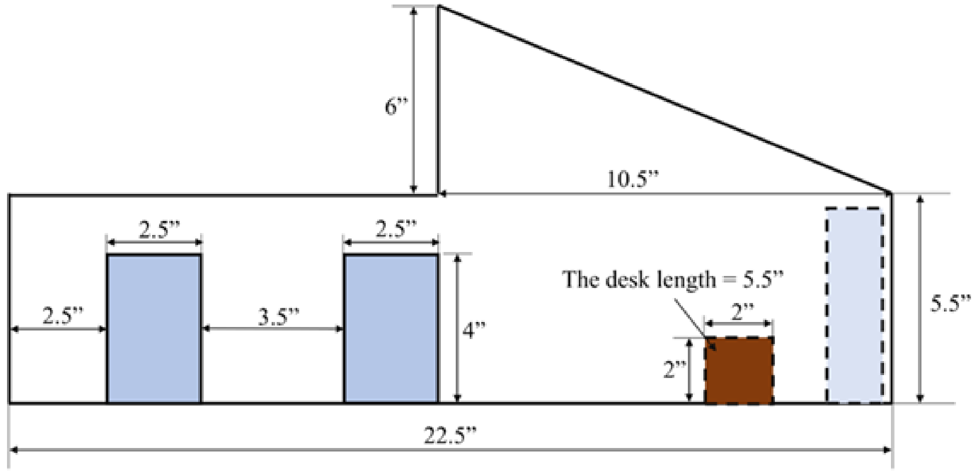


Figure 1.6: Front 1 View

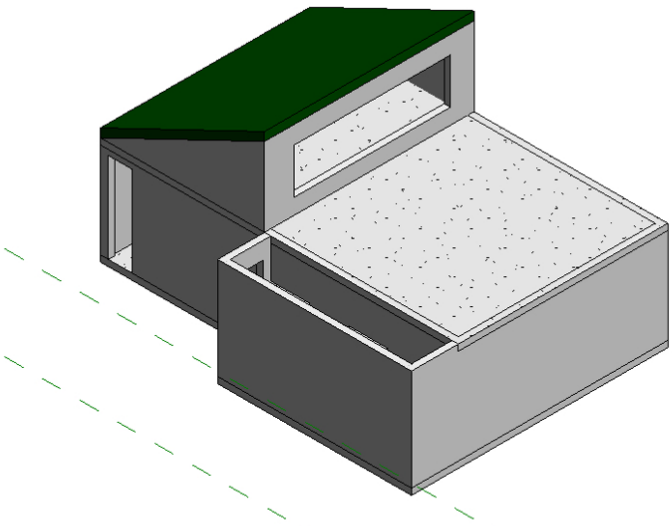


Figure 1.7: 3D Front View of the Building

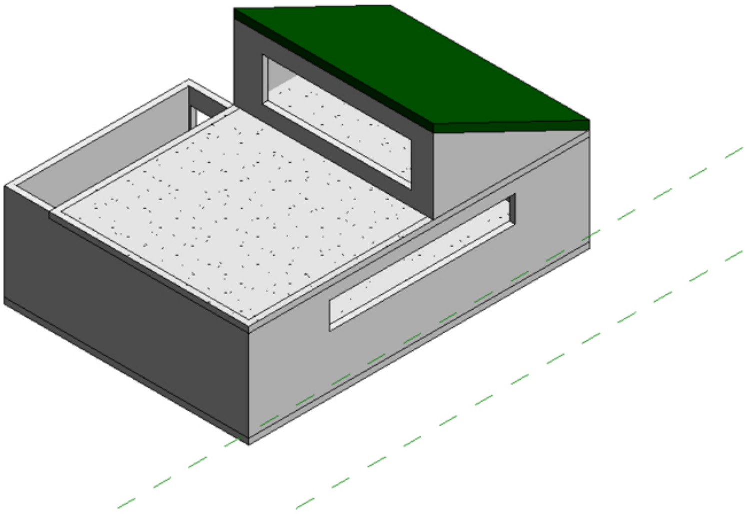


Figure 1.8: 3D Back View of the Building

The overall structure measured the length is 22.5”, width is 16” in total, height is 5.5” for the first floor and 6” with the roof structure and clerestory window, with window and skylight dimensions tailored to the project. Special attention was given that we will set up a camera access point at the back of the building model to measure all the daylighting factors.

The model was constructed using a systematic approach to ensure structural stability and measurement accuracy:

1. The overall dimensions of the model were finalized and recorded to ensure consistency and accurate scaling.

2. The walls, roof, and base were cut from cardboard and assembled using duct tape and double-sided tape for reinforcement.

3. The windows and skylight were positioned based on the required scenarios, including side windows, clerestory windows, and high-level openings. Each window retained its empty space according to the architectural model, with no special material modifications.

4. The complete building model is shown as depicted in Fig. 1.7

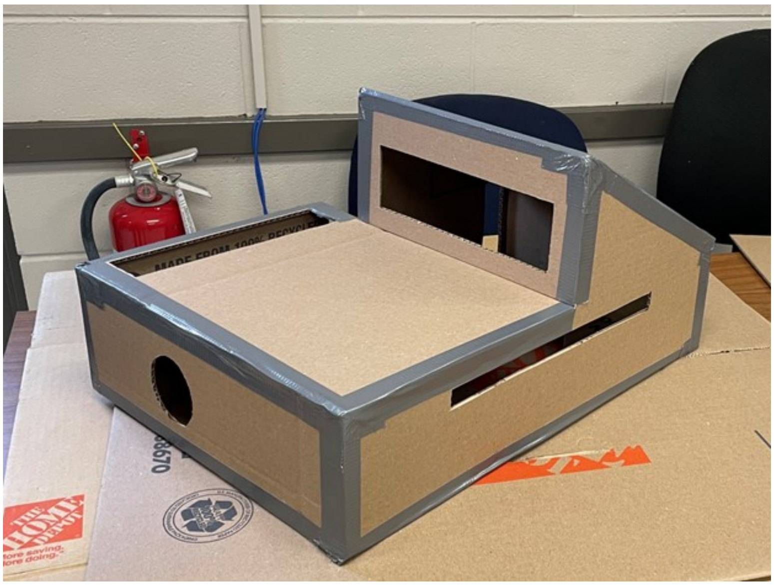


Figure 1.9: Scaled Down Model of the Building

While the scaled model replicates the key architectural features, cardboard may not fully reflect the optical properties of real-world building materials.

2 Daylight Factor Measurement

Daylight factor (DF) measurement is a critical aspect of daylighting analysis, providing a quantifiable metric to evaluate the amount of daylight entering a building. The daylight factor is defined as the ratio of indoor illuminance to outdoor illuminance at a specific point under overcast conditions, expressed as a percentage. We will introduce the methodology of measurement, and results of daylight coefficient measurements using this scaled-down building model.

5 locations along the central line of the building for each scenario will be tested.

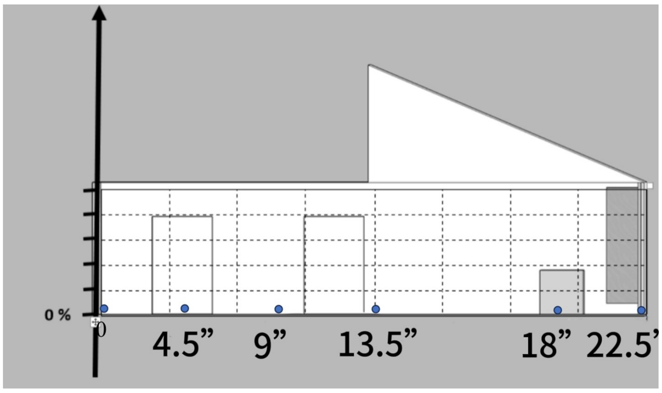


Figure 2.1: Different Locations

We have selected 4.5“, 9”, 13.5”, 18”, and 22.5”, spanning from one end of the structure to the other. These points were chosen to capture variations in daylight distribution in interior spaces. Each option was tested by varying the configuration of openings such as windows, skylights, and bay windows. Measurements were taken using a lux meter and results were recorded for analysis. The entire measurement was performed on **Overcast Sky Condition**.

$$\text{Daylight Factor} = \left(\frac{\text{Indoor Illuminance}}{\text{Outdoor Illuminance}}\right) \cdot 100\%$$

We had different scenarios for the experiment:

2.1 Scenario 1: Only Side Window

On the first scenario, the side window was kept open and the front door was kept open.

Figure 2.2: Scenario 1

Outside Illumination: 8,277 Lux

Measurement Point (inches)	Illumination (Lux)	Daylight Factor (DF)
4.5	12.1	0.14
9	1.8	0.02
13.5	9.7	0.11
18	1.4	0.02
22.5	4.2	0.05

Table 2.1: Measured illumination and daylight factors for Scenario 1.

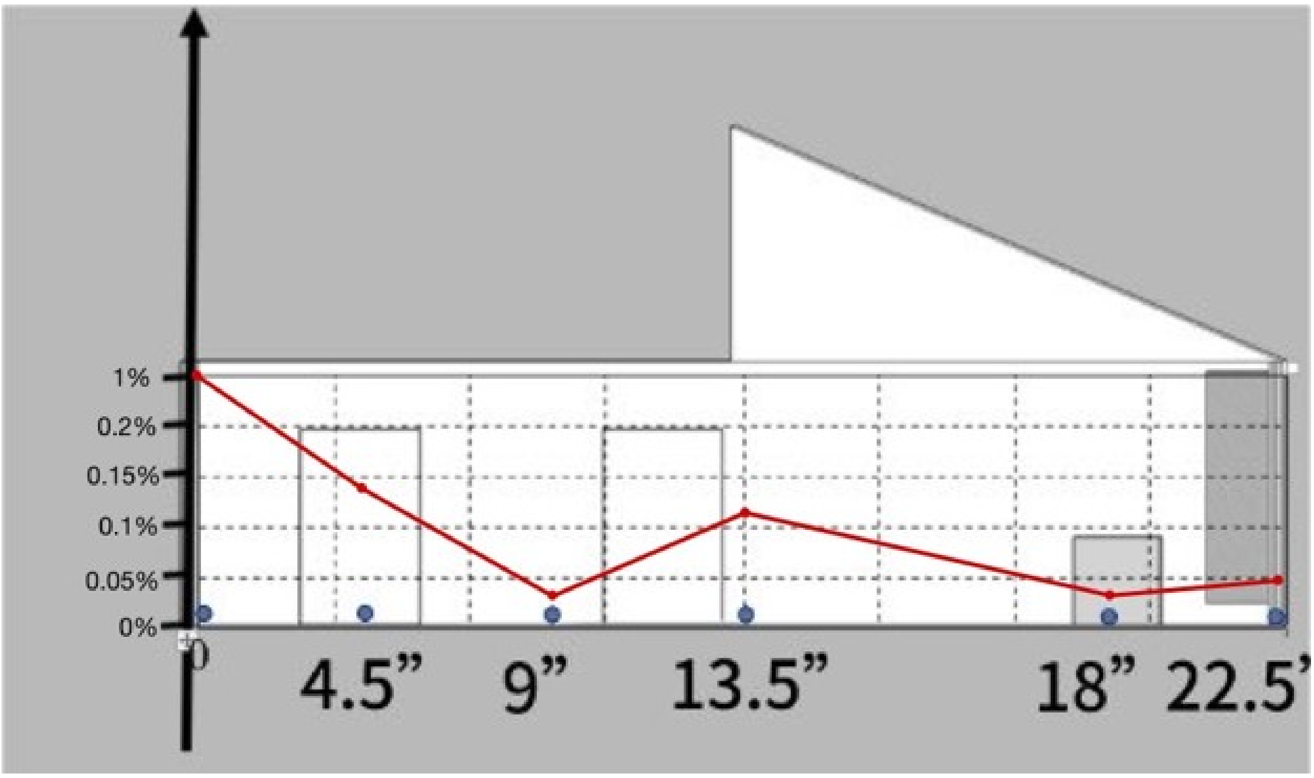


Figure 2.3: Daylight Factor Curve for Scenario 1

This scenario featured a single side window as the sole aperture. The daylight distribution was uneven, with higher illuminance values near the window and rapid attenuation further into the room. This resulted in low DF values at most points, except near the window, highlighting limited penetration depth.

2.2 Scenario 2: Only Clerestory Window

On the second scenario, the clerestory Window was kept open and the front door was kept open.

Figure 2.4: Scenario 2

Outside Illumination: 8,277 Lux

Measurement Point (inches)	Illumination (Lux)	Daylight Factor (DF)
4.5	3.2	0.04
9	5.2	0.06
13.5	308.4	3.73
18	77.1	0.93
22.5	8.0	0.10

Table 2.2: Measured illumination and daylight factors for Scenario 2

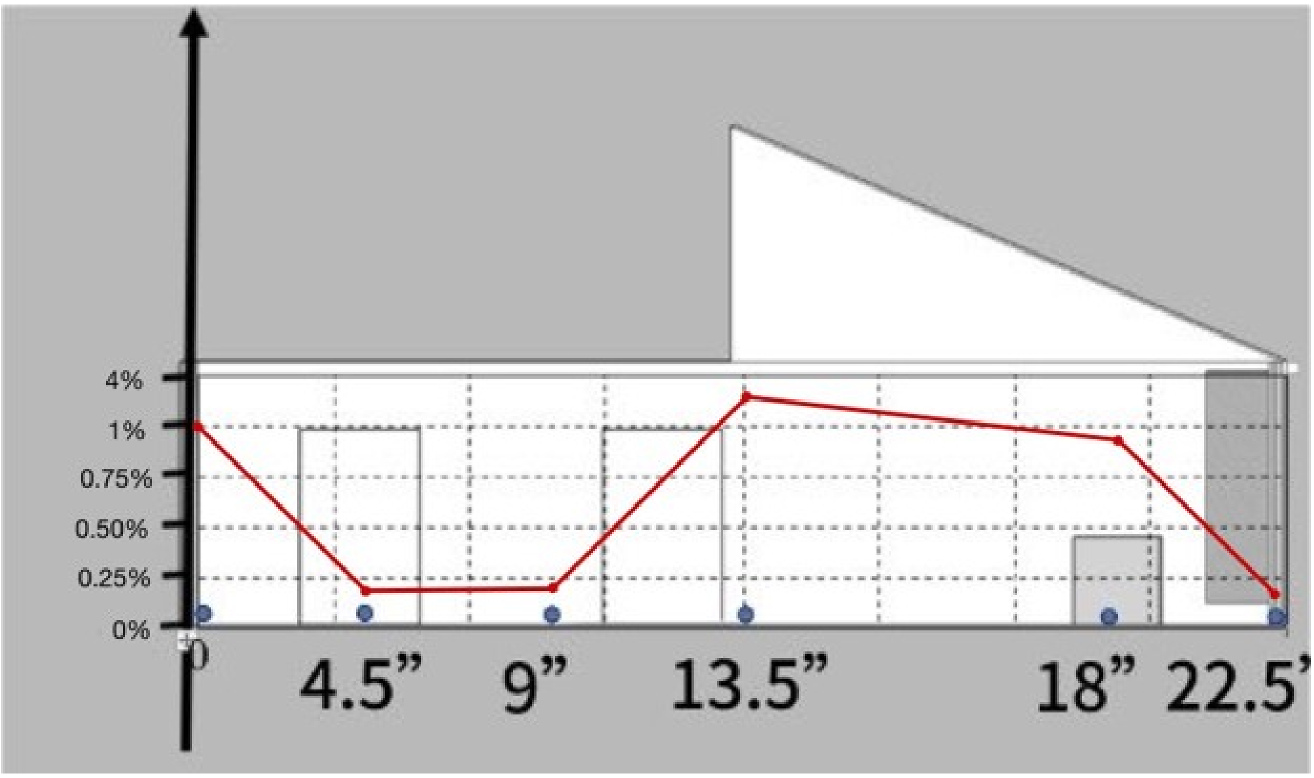


Figure 2.5: Daylight Factor Curve for Scenario 2

The horizontal window located near the roofline provided daylighting. The clerestory window allowed more light penetration to central points in the model. The midpoint section may have significant variance in DF values, indicating potential glare concerns.

2.3 Scenario 3: High Level Window

On the third scenario, the high level window was kept open and the front door was kept open.

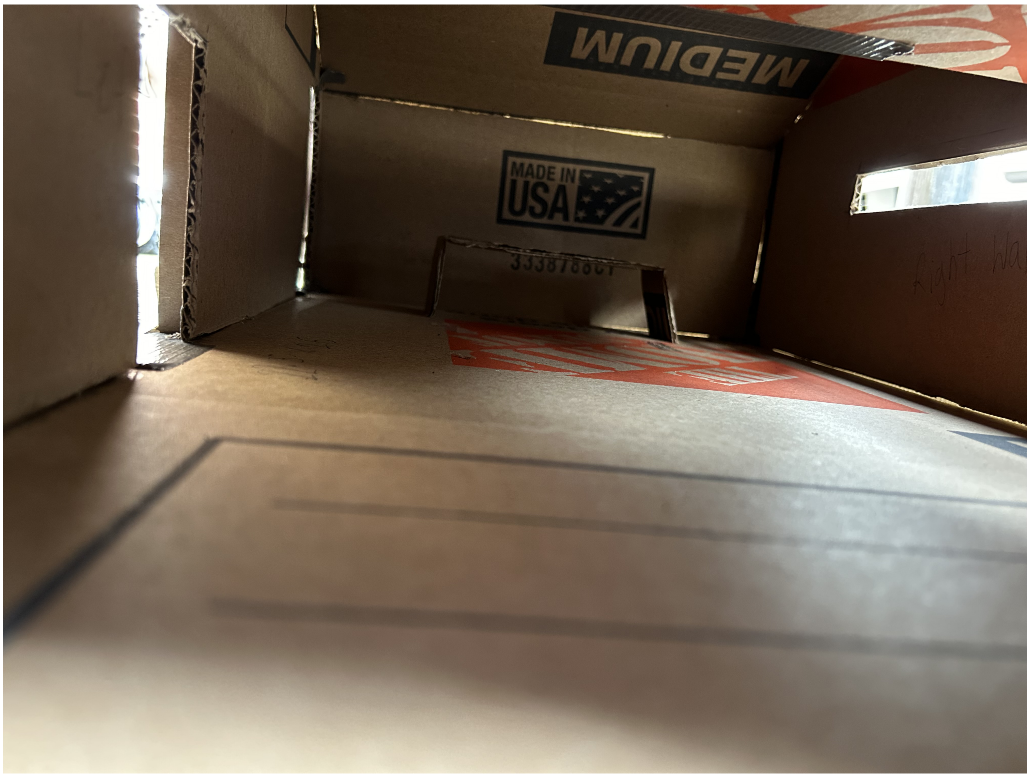


Figure 2.6: Scenario 3

Outside Illumination: 8,277 Lux

Measurement Point (inches)	Illumination (Lux)	Daylight Factor (DF)
4.5	2.5	0.03
9	3.2	0.04
13.5	2.1	0.03
18	1.6	0.02
22.5	2.9	0.04

Table 2.3: Measured illumination and daylight factors for Scenario 3.

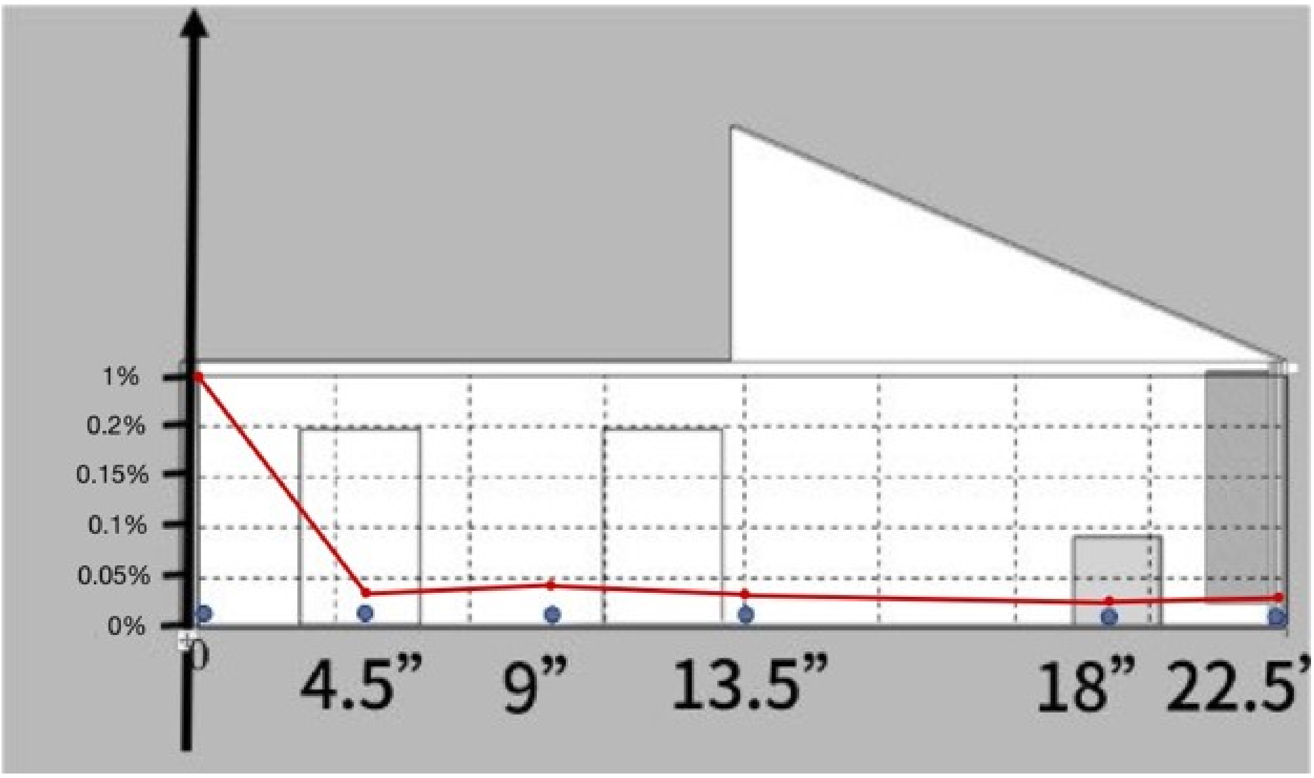


Figure 2.7: Daylight Factor Curve for Scenario 3

This scenario had a window positioned above eye level on the side wall. The measured DF values were consistently low across all points, indicating poor light distribution and insufficient daylighting for most interior areas.

2.4 Scenario 4 (Only with Side Skylight)

On the scenario, the side skylight was kept open and the front door was kept open.

Figure 2.8: Scenario 4

Outside Illumination: 8,277 Lux

Measurement Point (inches)	Illumination (Lux)	Daylight Factor (DF)
4.5	12.3	0.15
9	2.2	0.03
13.5	1.9	0.02
18	0.9	0.01
22.5	0.1	0.00

Table 2.4: Measured illumination and daylight factors for Scenario 4.

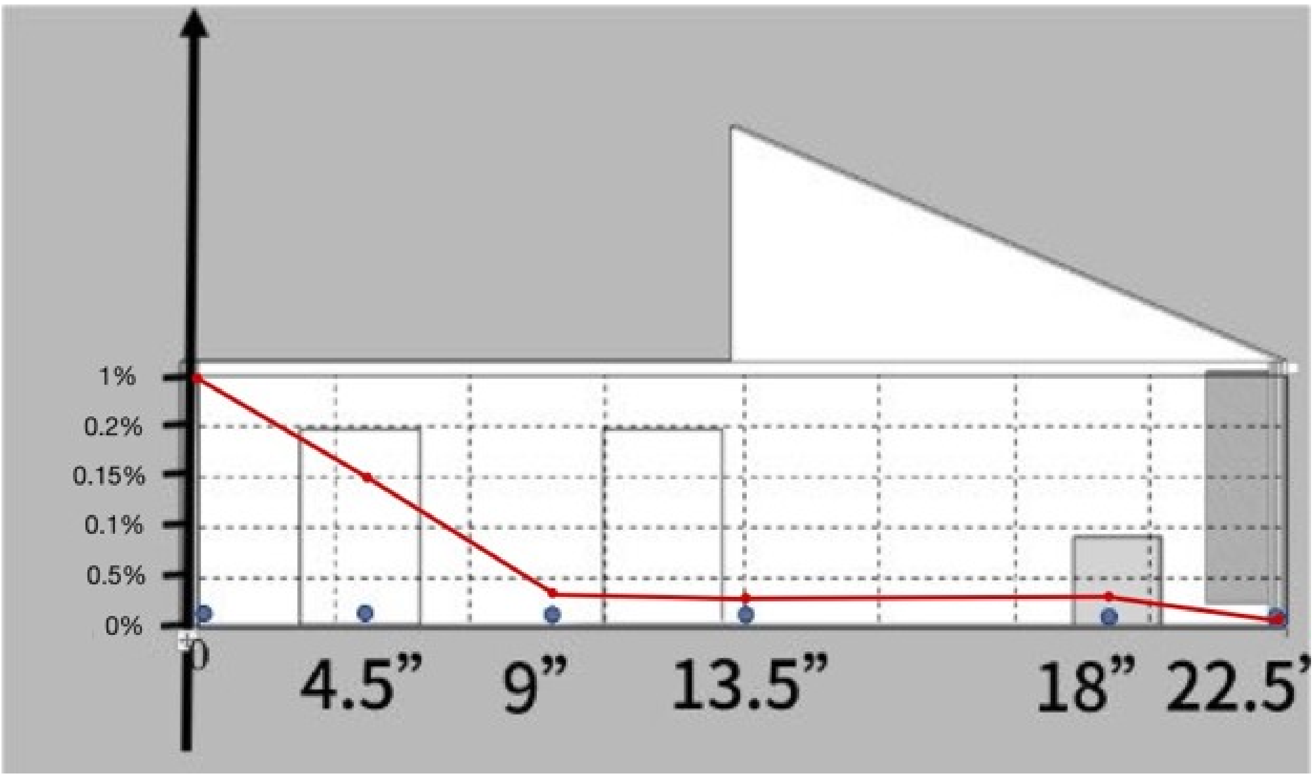


Figure 2.9: Daylight Factor Curve for Scenario 4

A side skylight introduced natural light from the roofline. The measurements showed high illumination levels near the skylight but poor distribution across the rest of the interior. This highlights the need for diffusion mechanisms to ensure balanced light levels.

2.5 Scenario 5 (All Openings)

On the scenario, everything is open.

Figure 2.10: Scenario 5

Outside Illumination: 8,277 Lux

Measurement Point (inches)	Illumination (Lux)	Daylight Factor (DF)
4.5	23.2	0.28
9	29.2	0.36
13.5	528.6	6.39
18	595.4	7.19
22.5	146.5	1.77

Table 2.5: Measured illumination and daylight factors for Scenario 5

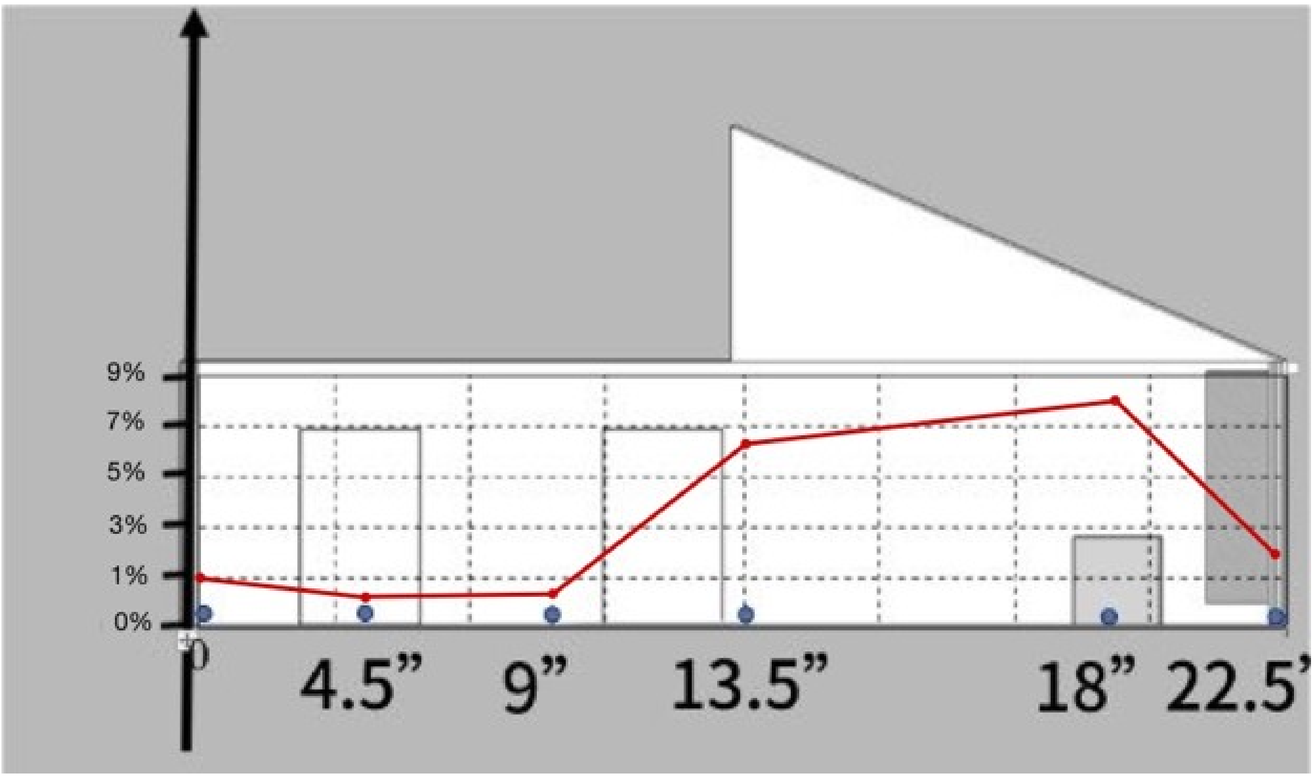


Figure 2.11: Daylight Factor Curve for Scenario 5

In this scenario, all apertures (windows, clerestory, and skylights) were left open. This configuration produced the highest DF values at most points. However, uneven distribution and excessive illuminance in specific locations raised concerns about glare and visual discomfort.

2.6 Conclusion

Scenario (1) demonstrated limited light penetration, and its inability to achieve consistent day-lighting; the clerestory window (scenario 2) provided a better light penetration but also introduced glare at specific points; the high-level side window (scenario 3) was the least effective, with minimal DF values across all points; the side skylight (scenario 4) highlighted the importance of diffusion techniques for roof line apertures, and the all-openings (scenario 5) emphasized the need for balance between maximizing daylight entry and managing glare. All the results mentioned the importance of aperture design and placement in achieving optimal daylight distribution and visual comfort.

3 Glare Analysis

Glare analysis is a crucial aspect of lighting design that assesses the impact of excessive brightness or light contrasts within a space. The goal of glare analysis is to optimize lighting conditions to ensure that they are comfortable, functional, and safe for occupants, whether in residential, commercial, or industrial settings. Glare occurs when there is a stark contrast between bright and dark areas in the visual field, causing discomfort or reducing visibility. Proper analysis helps mitigate these effects, creating environments that are visually pleasant and supportive of human activity.

Designers use a variety of tools to perform glare analysis, including lighting simulation software such as HDRscope or Radiance. These tools enable designers to model a space and identify potential problem areas where glare might occur, whether from natural or artificial light sources. Advanced simulations can also account for factors such as daylight variation, window positioning, and surface reflectivity, which all contribute to glare levels. In some cases, preventive measures such as adjusting window orientations, using blinds or shades, and incorporating diffused lighting fixtures can effectively reduce glare and create balanced lighting.

Ultimately, the purpose of glare analysis is not just to meet lighting standards but also to enhance the well-being of individuals using the space. A well-designed lighting system minimizes glare, providing a comfortable visual environment that reduces eye strain, improves safety, and contributes to overall quality of life. By carefully considering glare from the design phase and incorporating solutions to mitigate its effects, architects, engineers, and lighting professionals can ensure that their projects achieve both aesthetic and functional goals while promoting occupant comfort.

3.1 Two-comparison under different opening conditions

3.1.1 Scenario 2 -Baseline

Figure 3.1: Exposure compensation: 0.0

Figure 3.2: Exposure compensation: -1.0

Figure 3.3: Exposure compensation: 1.0

3.1.2 Calibration

Figure 3.4: Calibration

Point O

Measured illuminance = 56.3 cd/m^3

3.1.3 False Color Analysis

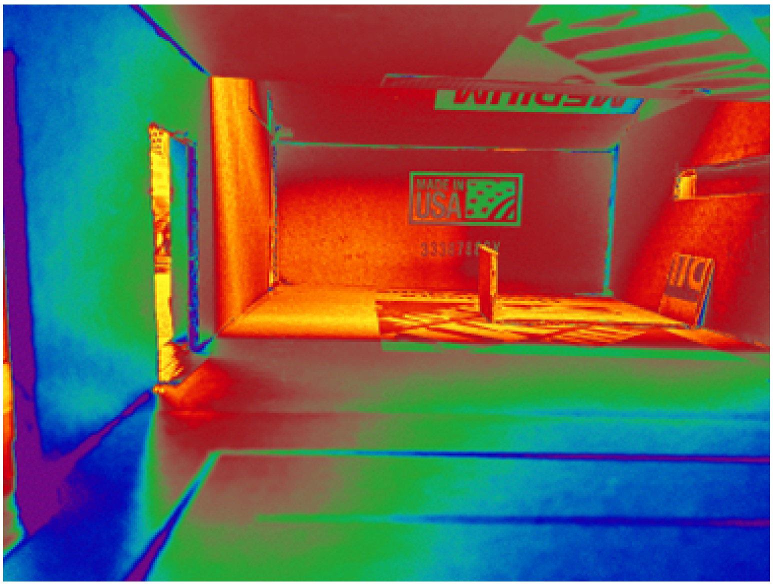


Figure 3.5: False Color

Luminance Ratios Calculations

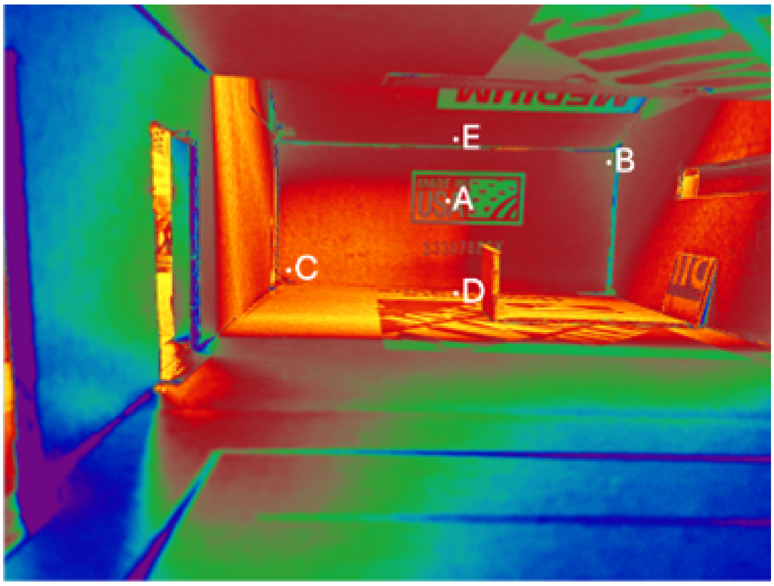


Figure 3.6: Different Point for Luminance Ratio Calculations-Scenario 2

- A: $73.8/179 = 0.412$
- B: $16.8/179 = 0.093$
- C: $101.4/179 = 0.566$

- D: $65.3/179 = 0.365$
- E: $4.6/179 = 0.025$

3.1.4 View Types

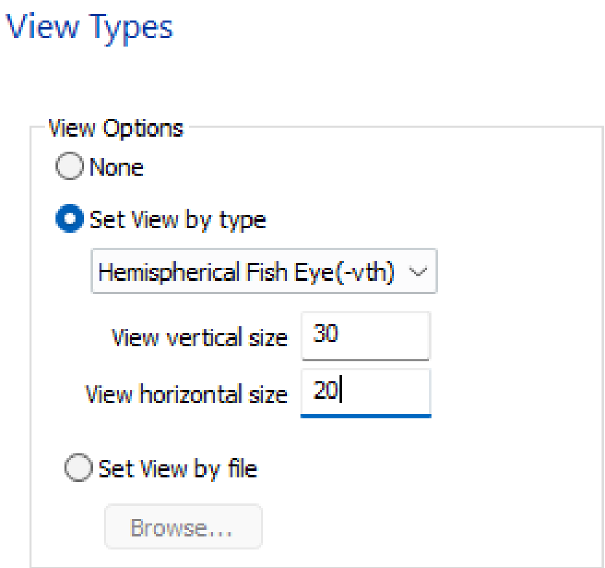


Figure 3.7: All the view by type are using the same size

(All the view by type are using the same size)

- **Notice:** Vertical illuminance is below 100 lux!!
- **Notice:** Low brightness scene. dgp below 0.2! dgp might underestimate glare sources.
- **Notice:** Low brightness scene. Vertical illuminance less than 380 lux! dgp might underestimate glare sources.

Glare Analysis Metrics:

dgp : 0.003214

dgi : 0.000000

ugr : 0.000000

vcp : 100.000000

cgi : 0.000000

Lveil : 0.000000

TABLE 6.5 Recommended Maximum Luminance Ratios[a]

Note: To achieve a comfortable brightness balance, limit luminance ratios between areas *of appreciable size* as seen from normal viewing positions as follows:	
1 to one-third	Between task and adjacent surroundings
1 to one-tenth	Between task and more remote darker surfaces
1 to 10	Between task and more remote lighter surfaces
20 to 1	Between luminaires (or fenestration) and surfaces adjacent to them
40 to 1	Anywhere within the normal field of view

[a]These ratios are recommended as maximums; lesser ratios are generally beneficial.

Figure 3.8: Recommended Maximum Luminance Ratios

DGP (0.003214): Indicates that glare sources are virtually non-existent in this scene. However, the low brightness might underestimate potential glare.

The values for DGI, UGR, and CGI are all recorded as 0.000000, signifying the absence of any measurable glare in the environment. These metrics confirm that the lighting distribution is even, with no excessive luminance contrasts.

The VCP (100) indicates that the scene offers an exceptionally high level of visual comfort, with virtually all occupants likely to find the lighting conditions satisfactory. A VCP of 100 represents the ideal condition where glare is imperceptible or non-existent, making the environment highly conducive for occupant comfort.

The vertical illuminance in the scene was reported to be less than 380 lux, indicative of a low-brightness setting. While glare is effectively controlled in such conditions, the overall brightness may be insufficient for certain visual tasks, potentially necessitating adjustments to improve functional lighting.

Table 1: Glare Indices

Degree of glare sensation	BGI	VCP	CGI	DGI	UGR
Intolerable	31	12	34	30	34
Just intolerable	28	20	31	28	31
Uncomfortable	25	28	28	26	28
Just uncomfortable	22	36	25	24	25
Unacceptable	19	43	22	22	22
Just acceptable	16	50	19	20	19
Perceptible	13	59	16	18	16
Just perceptible	10	67	13	16	13
Imperceptible	7	75	10	14	10
Intolerable	< 40	> 28	> 31	> 28	> 0.45
Disturbing	40 - 60	22 - 28	24 - 31	22 - 28	0.35 - 0.4
Perceptible	60 - 80	13 - 22	18 - 24	13 - 22	0.3 - 0.35
Imperceptible	> 80	< 13	< 18	< 13	< 0.3

[6]

Figure 3.9: Glare Indices

3.1.5 Scenario 5 (baseline)

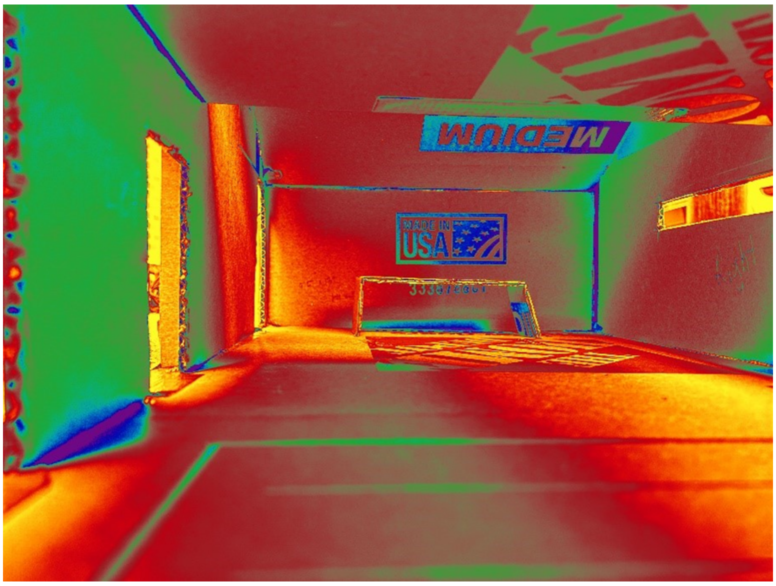


Figure 3.10: False Color

Luminance Ratios Calculations

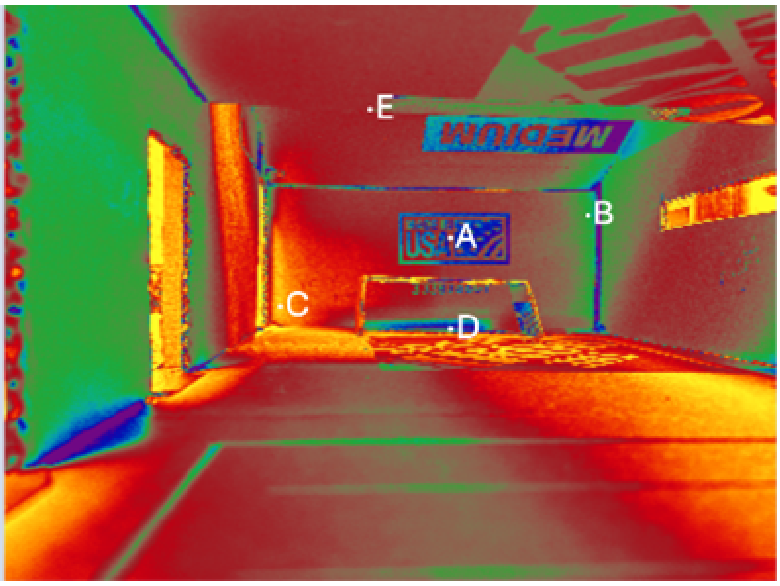


Figure 3.11: Different Point for Luminance Ratio Calculations-Scenario 5

- A: $25.2/178.444 = 0.141$
- B: $6.4/178.444 = 0.035$
- C: $141.8/178.444 = 0.79$
- D: $2.3/178.444 = 0.012$
- E: $32.4/178.444 = 0.181$

- **Notice:** Vertical illuminance is below 100 lux!!
- **Notice:** Low brightness scene. dgp below 0.2! dgp might underestimate glare sources.
- **Notice:** Low brightness scene. Vertical illuminance less than 380 lux! dgp might underestimate glare sources.

Glare Analysis Metrics

dgp : 0.003355

dgi : 0.000000

ugr : 0.000000

vcp : 100.000000

cgi : 0.000000

Lveil : 0.000000

3.2 Two-comparison under different solar conditions

3.2.1 Scenario 3 at sunny conditions

Figure 3.12: Exposure compensation: 0.0

Figure 3.13: Exposure compensation: -1.0

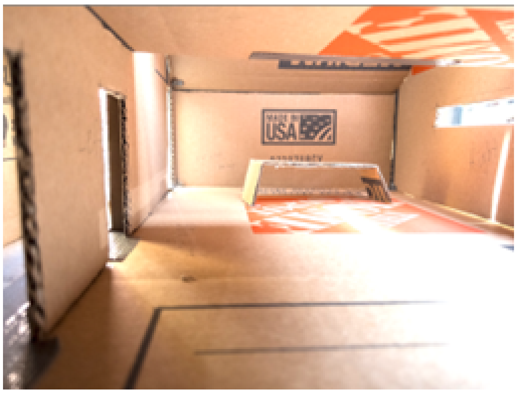


Figure 3.14: Exposure compensation: 1.0

3.2.2 Calibration

Figure 3.15: Calibration

Point O

Measured illuminance = 59.2 cd/m^3

Figure 3.16: False Color

Luminance Ratios Calculations

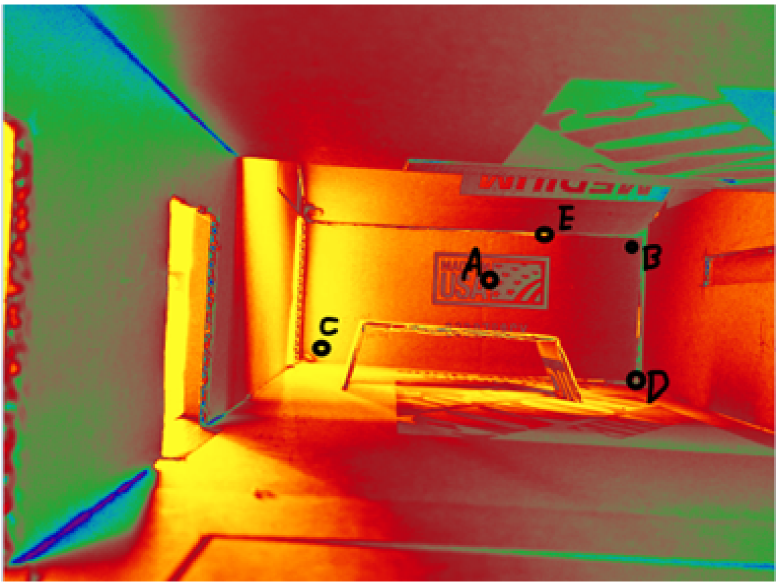


Figure 3.17: Different Point for Luminance Ratio Calculations-Scenario 3

- A: $78.2/179 = 0.469$
- B: $24.9/179 = 0.139$
- C: $162/179 = 0.905$
- D: $43.5/179 = 0.243$
- E: $160.4/179 = 0.896$

- **Notice:** Vertical illuminance is below 100 lux!!
- **Notice:** Low brightness scene. dgp below 0.2! dgp might underestimate glare sources.
- **Notice:** Low brightness scene. Vertical illuminance less than 380 lux! dgp might underestimate glare sources.

Glare Analysis Metrics

- dgp: 0.004146
- dgi: 0.000000
- ugr: 0.000000
- vcp: 100.000000
- cgi: 0.000000
- Lveil: 0.000000

3.2.3 Scenario 5 at 11 am

Figure 3.18: Exposure compensation: 0.0

Figure 3.19: Exposure compensation: -1.0

Figure 3.20: Exposure compensation: 1.0

3.2.4 Calibration

Figure 3.21: Calibration

Point O

Measured illuminance = 56.3 cd/m^3

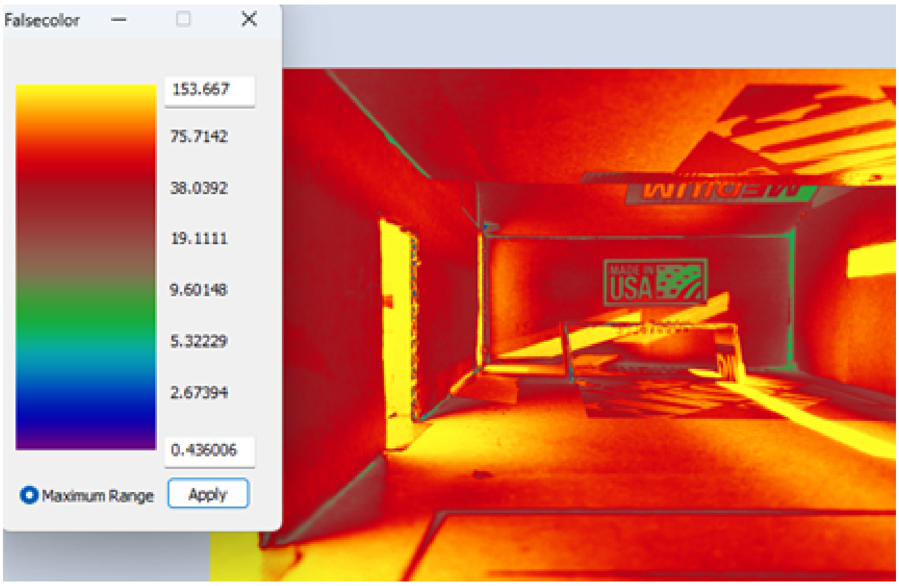


Figure 3.22: False Color

Luminance Ratios Calculations

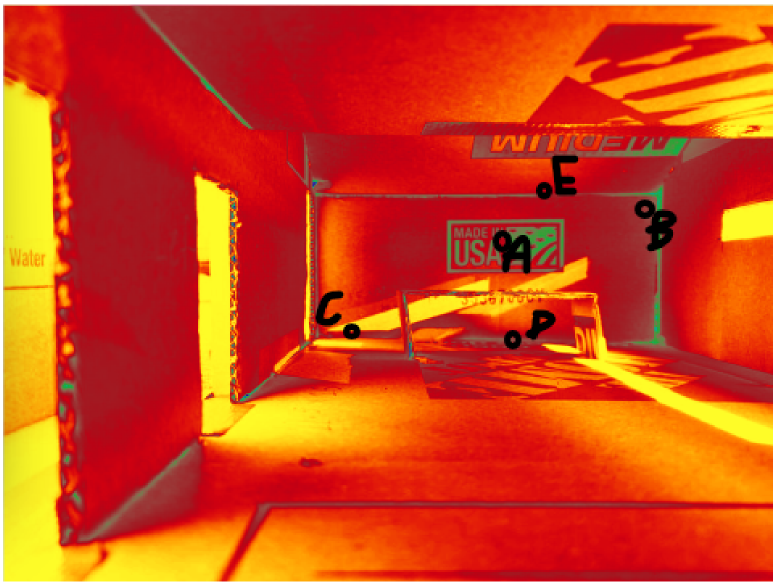


Figure 3.23: Different Point for Luminance Ratio Calculations-Scenario 5

- A: $47.7/153.667 = 0.310$
- B: $18.9/153.667 = 0.123$
- C: $131.7/153.667 = 0.857$
- D: $17.6/153.667 = 0.114$
- E: $21.7/153.667 = 0.141$

Notices

- **Notice:** Vertical illuminance is below 100 lux!!
- **Notice:** Low brightness scene. dgp below 0.2! dgp might underestimate glare sources.
- **Notice:** Low brightness scene. Vertical illuminance less than 380 lux! dgp might underestimate glare sources.

Glare Analysis Metrics

- dgp: 0.004027

- dgi: 0.000000
- ugr: 0.000000
- vcp: 100.000000
- cgi: 0.000000
- Lveil: 0.000000

4 Model Improvement

To improve the model and reduce glare issues, various strategies can be implemented in the building design. The results of the baseline model and the improved model are then compared to evaluate the impact of these modifications. It is essential to ensure that the minimum daylight factor of a room exceeds 5%, as this threshold provides a sense of adequate illumination; otherwise, the room is perceived as insufficiently lit.

The Goal of our Improvement is to:

- Ensure the average daylight factor (in the central line of the room) is at least 5%.
- Avoid any glare problems:
  - Between task zone and immediate surroundings < 3
  - Between task zone and general surroundings < 5
  - Between task zone and remote dark/bright surface < 10
  - Between windows and adjacent wall surface < 20
  - Between anywhere in the normal field of view < 40

4.1 Baseline Model

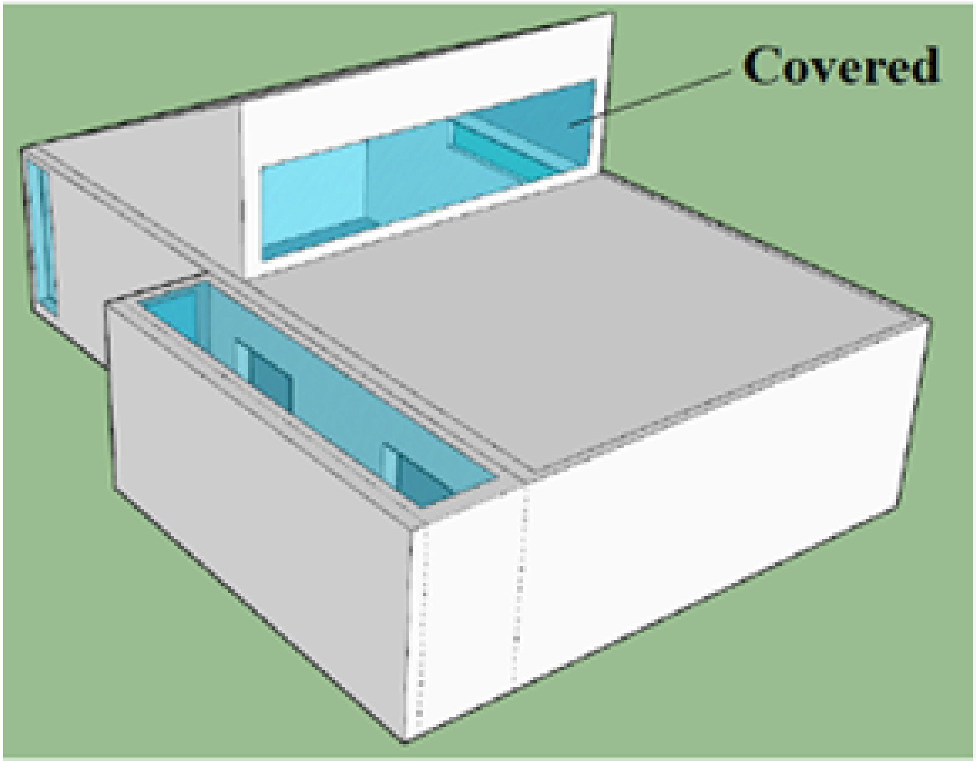


Figure 4.1: Baseline Model

Figure 4.2: Baseline Model Setup

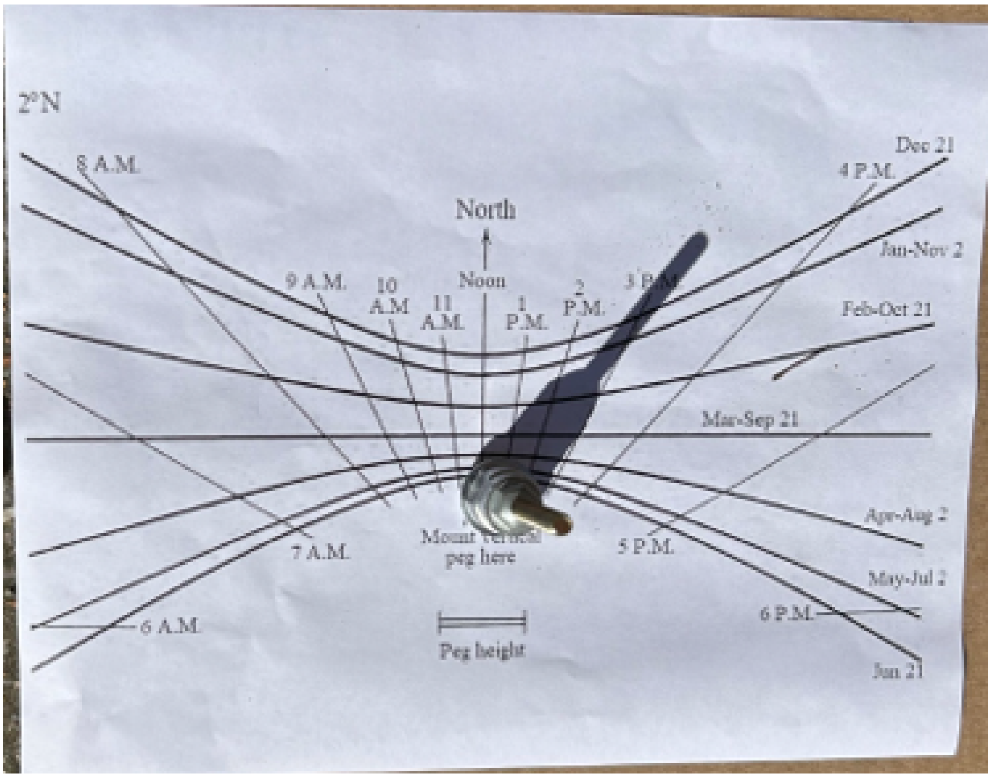


Figure 4.3: Sunpeg Chart

The baseline model featured covered clerestory windows and no additional shading or reflective elements.

We are using a Sunpeg Chart to ensure the **Solar position** on December 21 @ 3 pm.

The **average daylight factor** along the central line was **Indoor Illuminance / Outdoor Illuminance (8700 lux / 57000 lux = 0.152 = 15.2%)**. Daylight Factor : 15.2%$>$ 5%

4.1.1 Results

Figure 4.4: HDR image of Baseline Model

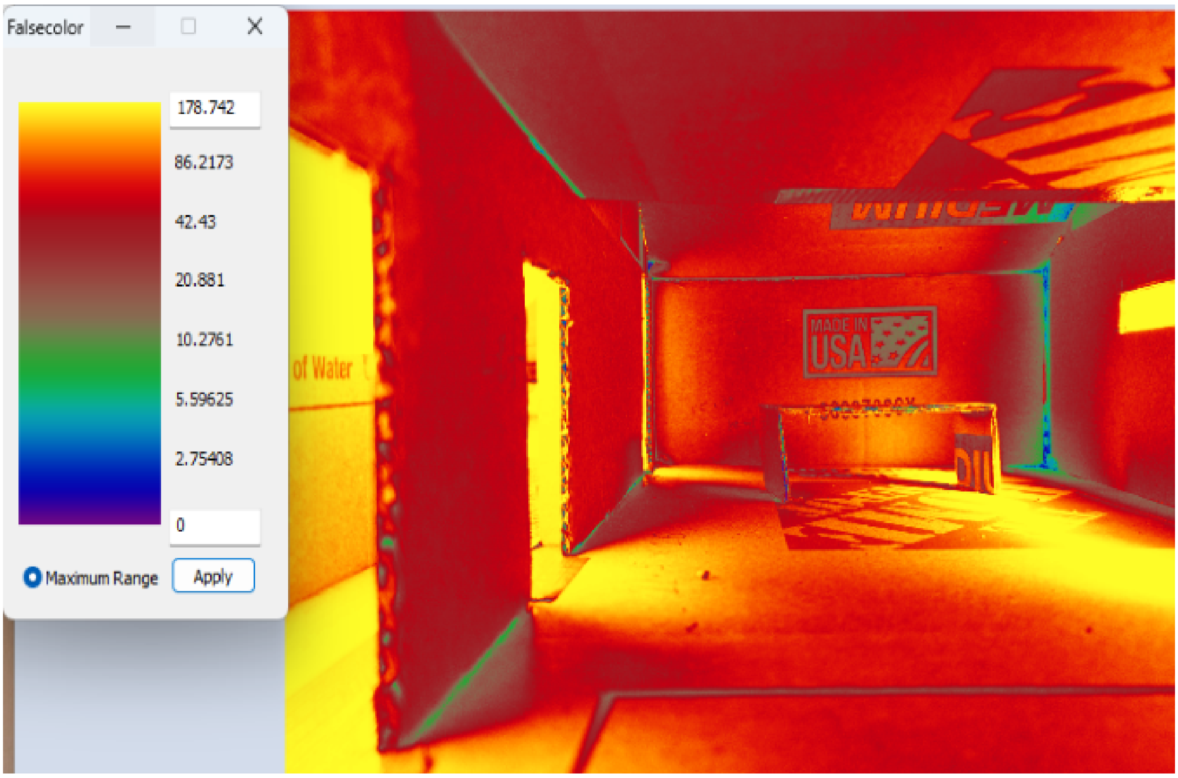


Figure 4.5: False Color of Baseline Model

4.1.2 Luminance Ratio

- Between task and adjacent surroundings $63.8/43.9 = 1.45 < 3$
- Between task and more remote darker surface $63.8/58 = 1.1 < 10$
- Between task and more remote lighter surface $63.8/179.7 = 0.36 > 0.10$
- Between luminaries and surfaces adjacent to them $63.4/20.9 = 3.03 < 20$
- Anywhere within the normal field of view $178.7/2.8 = 63.8 > 40$

4.2 Model Improvement 1

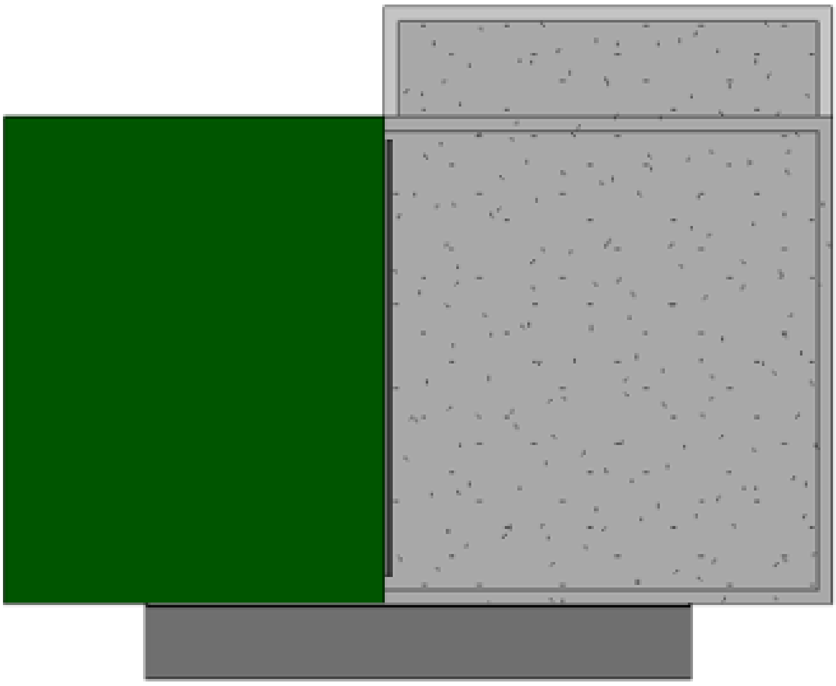


Figure 4.6: Improved Model 1

Figure 4.7: Improved Model 1-Setup

Solar position: December 21 @ 3 pm
Clerestory: is covered
Strategies for reducing glare: use cardboard as a canopy to block direct sunlight (overhang). **Daylight Factor**: 6.31%$> 5\%$

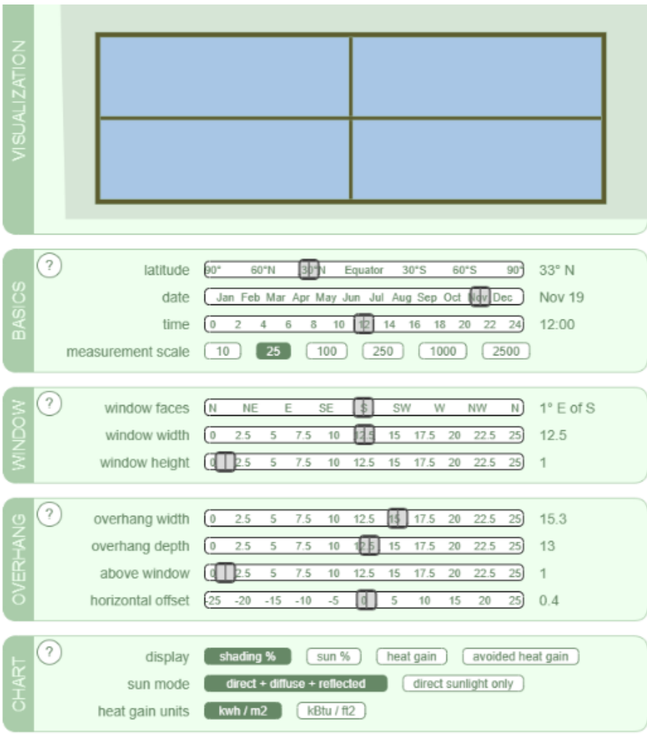
A cardboard canopy was installed above the side window to block direct sunlight and diffuse light entering the space. This modification aimed to reduce high-intensity glare while maintaining sufficient daylight penetration.

The **average daylight factor** along the central line was **Indoor illuminance / Outdoor Illuminance (3600 lux / 57000 lux = 0.0631 = 6.31%**). The daylight factor decreased from 15.2 % to 6.31%, maintaining the minimum threshold of 5%.

4.2.1 Rationale for Modification

The incorporation of an overhang on the window is a vital modification aimed at improving the overall performance of the building model. This change addresses two critical aspects: controlling excessive glare and enhancing the daylight factor. Glare, caused by direct sunlight entering through the windows, can create significant visual discomfort for occupants, making interior spaces less functional. An overhang serves as an effective shading device by reducing the amount of direct sunlight entering the building, particularly during peak daylight hours, while still allowing diffuse natural light to penetrate.

Canopy Design



	MORNING									AFTERNOON									
	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	MONTHLY	
Jan				3%	60%	83%	89%	89%	89%	89%	86%	77%	53%	3%				Jan	66%
Feb				9%	70%	84%	87%	87%	87%	87%	85%	78%	64%	8%				Feb	68%
Mar				42%	69%	80%	82%	82%	82%	82%	81%	74%	63%	35%				Mar	70%
Apr			22%	18%	43%	62%	69%	71%	72%	71%	67%	56%	34%	17%	22%			Apr	48%
May			19%	16%	15%	30%	45%	52%	54%	51%	42%	24%	15%	16%	19%			May	31%
Jun		24%	19%	16%	15%	16%	28%	37%	40%	36%	25%	14%	14%	16%	19%	24%		Jun	23%
Jul			19%	17%	15%	20%	35%	43%	45%	42%	32%	16%	15%	16%	19%			Jul	26%
Aug			21%	17%	26%	48%	59%	63%	64%	62%	56%	42%	20%	17%	21%			Aug	40%
Sep			24%	36%	62%	74%	77%	78%	78%	78%	76%	69%	55%	29%	24%			Sep	58%
Oct				28%	71%	83%	85%	85%	85%	85%	83%	77%	64%	22%				Oct	70%
Nov				3%	65%	84%	89%	88%	88%	88%	86%	77%	58%	3%				Nov	66%
Dec					55%	83%	90%	90%	90%	90%	86%	76%	48%					Dec	79%
	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	ANNUAL	
	MORNING									AFTERNOON								54%	

Figure 4.8: Overhang Design (Gronbeck, 2009)

4.2.2 Results

Figure 4.9: HDR image of the first improvement

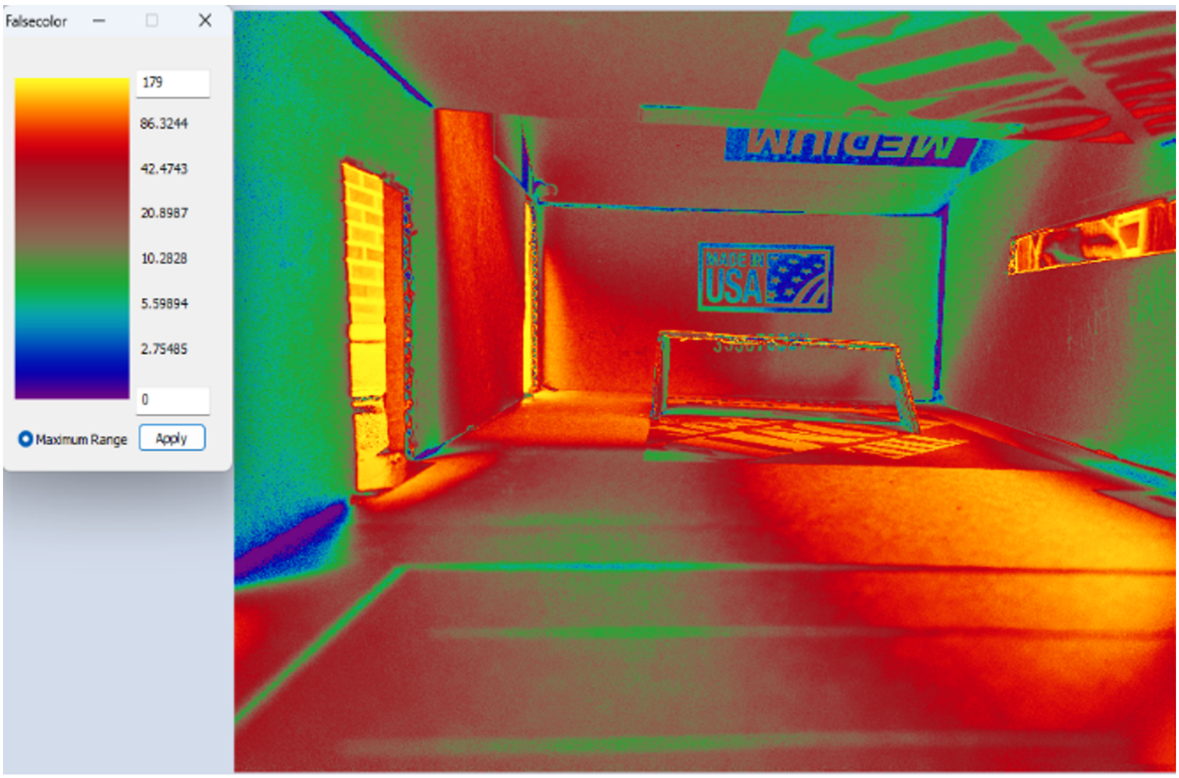


Figure 4.10: False Color of the first improvement

4.2.3 Luminance Ratio

- Between task and adjacent surroundings $42.5/71.7 = 0.59 < 3$
- Between task and more remote darker surface $42.5/30.5 = 1.39 < 10$
- Between task and more remote lighter surface $42.5/124.1 = 0.34 > 0.10$
- Between luminaries and surfaces adjacent to them $20.8/10.2 = 2.03 < 20$
- Anywhere within the normal field of view $179/2.6 = 68.8 > 40$

4.3 Model Improvement 2

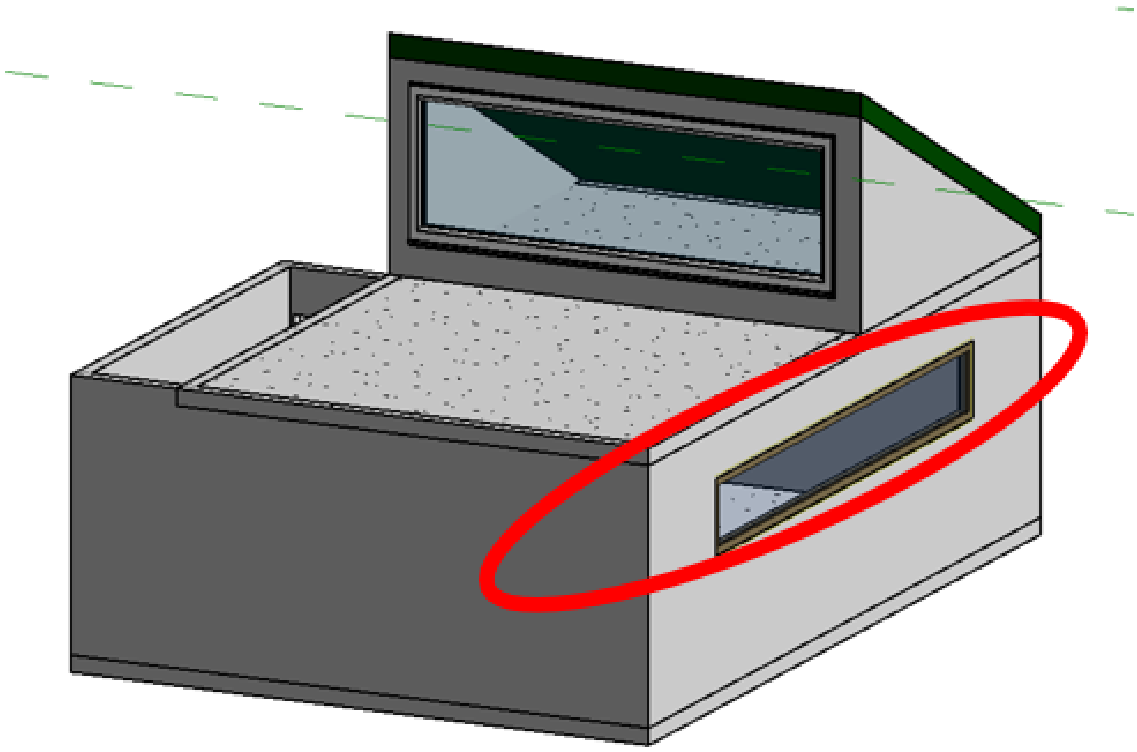


Figure 4.11: Model Improvement 2

Solar position: December 21 @ 3 pm
Clerestory: is covered
Strategies for reducing glare: add plastic pieces to reflect some light through windows
Daylight Factor: 7.0%> 5%

Plastic sheets with reflective properties were added to the windows to redirect and soften incoming light. This adjustment was complemented by covering the clerestory window to further control light entry.

The **average daylight factor** along the central line was **Indoor illuminance / Outdoor Illuminance (4000 lux / 57000 lux = 0.070 = 7.0%)**. The daylight factor decreased from 15.2 % to 7.0%, maintaining the minimum threshold of 5%.

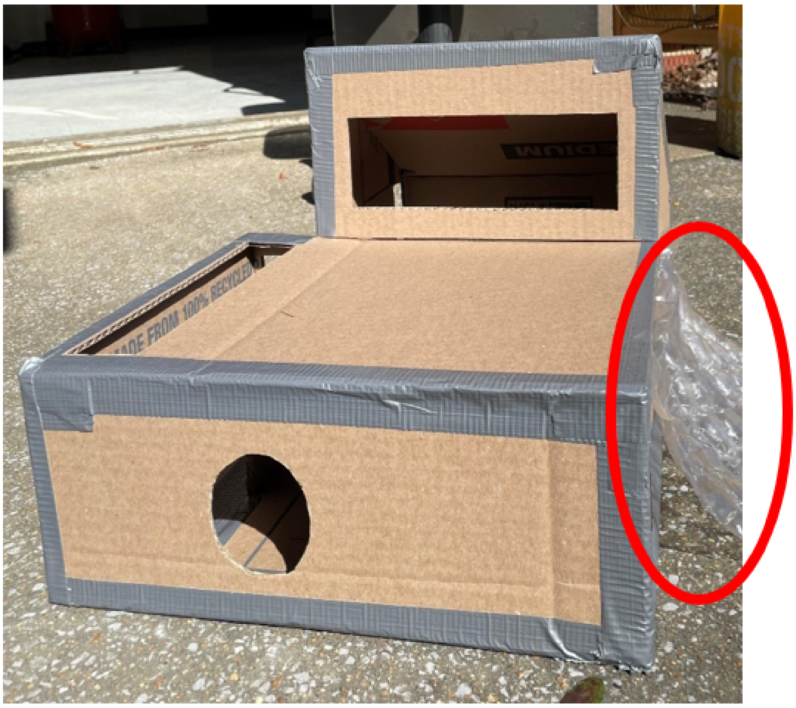


Figure 4.12: Model Improvement 2-Setup

4.3.1 Rationale for Modification

The addition of translucent windows at a high-level side window is another key modification aimed at enhancing the performance of the building model. This design choice allows a controlled portion of natural light to enter the room, contributing to improved day-lighting while minimizing the risk of glare and uneven light distribution. Translucent windows on the high-level side window are strategically positioned to capture diffuse natural light from higher angles, which is less direct and more evenly distributed compared to lower-level windows. This reduces visual discomfort caused by harsh light and glare while ensuring that the interior is adequately lit. The translucency of the material further aids in diffusing incoming light, softening its intensity, and creating a more uniform lighting environment. This not only improves visual comfort, but also contributes to energy efficiency by reducing the reliance on artificial lighting during the day.

4.3.2 Results

Figure 4.13: HDR image of the second improvement

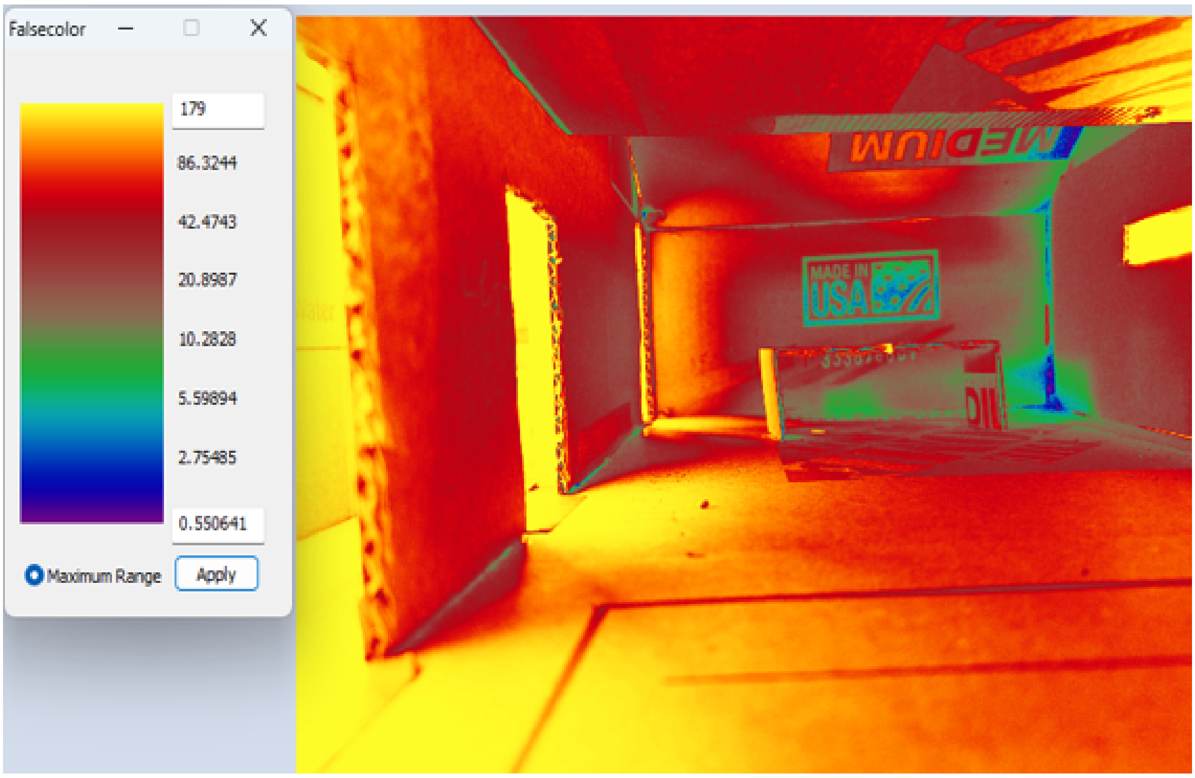


Figure 4.14: False Color of the second improvement

4.3.3 Luminance Ratio

- Between task and adjacent surroundings $64.8/73.6 = 0.88 < 3$
- Between task and more remote darker surface $64.8/172.4 = 0.38 < 10$
- Between task and more remote lighter surface $64.8/81.2 = 0.79 > 0.10$
- Between luminaries and surfaces adjacent to them $20.8/10.2 = 2.03 < 20$
- Anywhere within the normal field of view $179/2.8 = 63.9 > 40$

Metric	**Baseline Model**	**Improved Model 1** (Canopy)	**Improved Model 2** (Window Adjustment)
Average Daylight Factor (%)	15.2%	6.31%	7.0%
Luminance Ratio (Task Zone/Adjacent)	>3	<3	<3
Luminance Ratio (Task Zone/Darker Surface)	<10	<10	<10
Luminance Ratio (Task Zone/Lighter Surface)	>0.10	>0.10	>0.10
Luminaries and Surfaces Adjacent	<20	<20	<20
Luminance Ratio (Field of View)	>40	<40	<40
Glare Reduction	None	Significant	Moderate
Light Distribution	Uneven	Improved	Uniform

Table 4.1: Comparison of Baseline and Improved Models for Daylight Performance

5 Model Simulation

Day lighting simulations are conducted to assess the illumination levels of the room under different weather conditions. These simulations are crucial due to the limitations of the physical scaled-down model, which requires extended periods for testing across various weather patterns. By using daylighting simulations, improvements can be implemented and analyzed efficiently for different environmental conditions, allowing for a comprehensive evaluation of lighting performance in diverse scenarios.

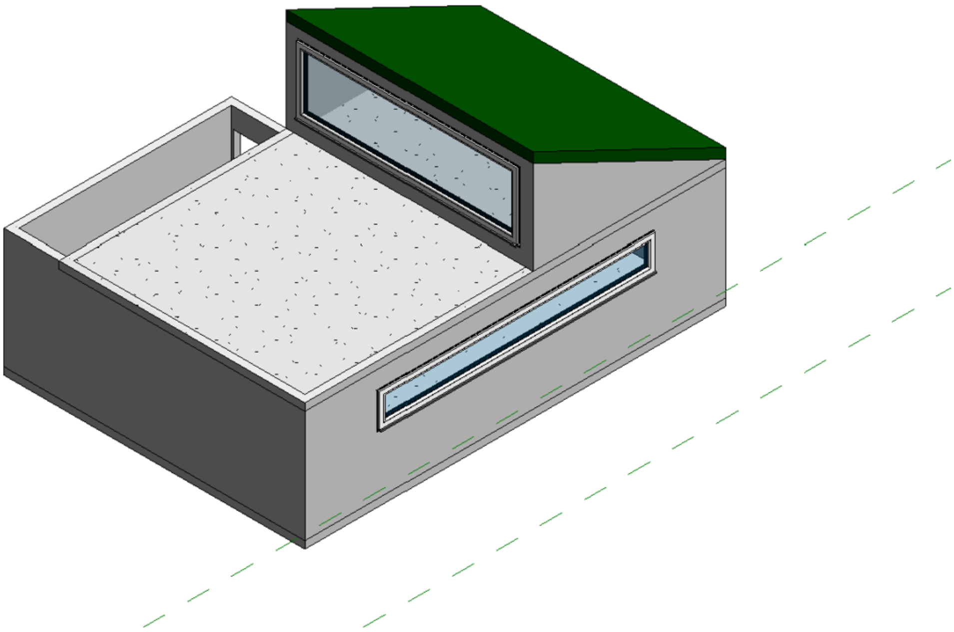


Figure 5.1: Baseline Model on Revit

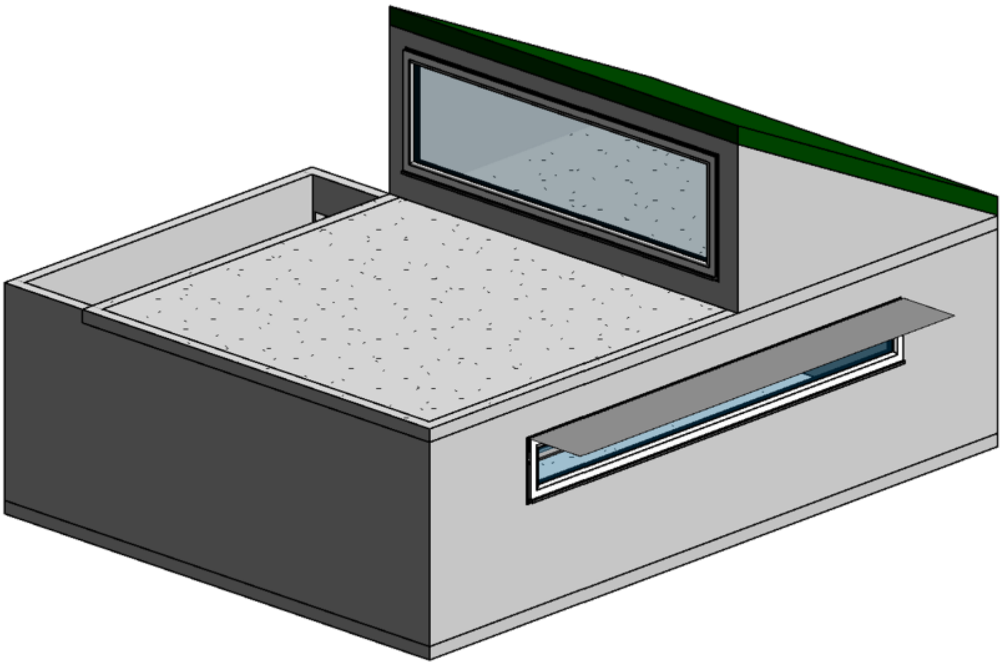


Figure 5.2: Model Improvement on Revit

5.1 Setup

Element	Material Properties
Wall	Stone
Floor	Wood
Roof	Stone (Reflectance: 0.617, Roughness: 0.040)
Windows	Glass (70% Transmittance)

Table 5.1: Material Properties

Parameter	Details
Location	Birmingham, Alabama
Latitude	33.51
Longitude	86.81
Orientation	180 Degree

Table 5.2: Location and Weather Details

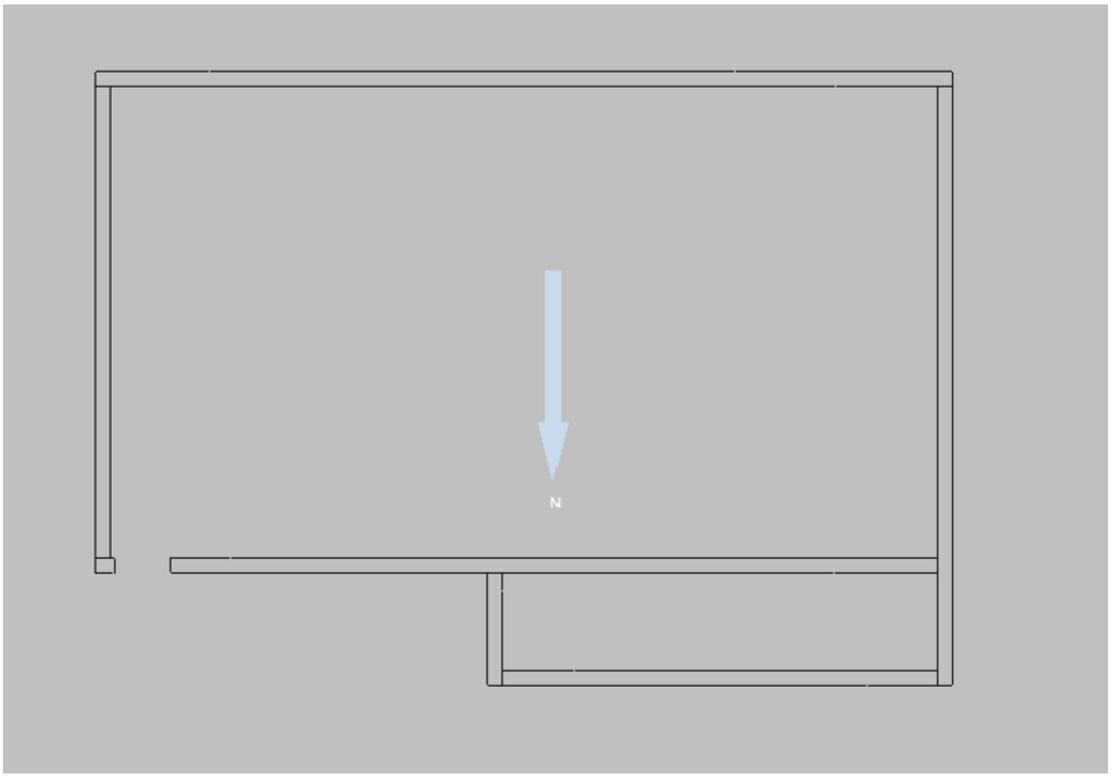


Figure 5.3: Building Orientation

Parameter	**Details**
Time of Year	November 21
Time of Day	12:00
Sky Condition	Overcast
Exterior Illumination	12,571.6 lux

Table 5.3: Environment Details

5.2 Results

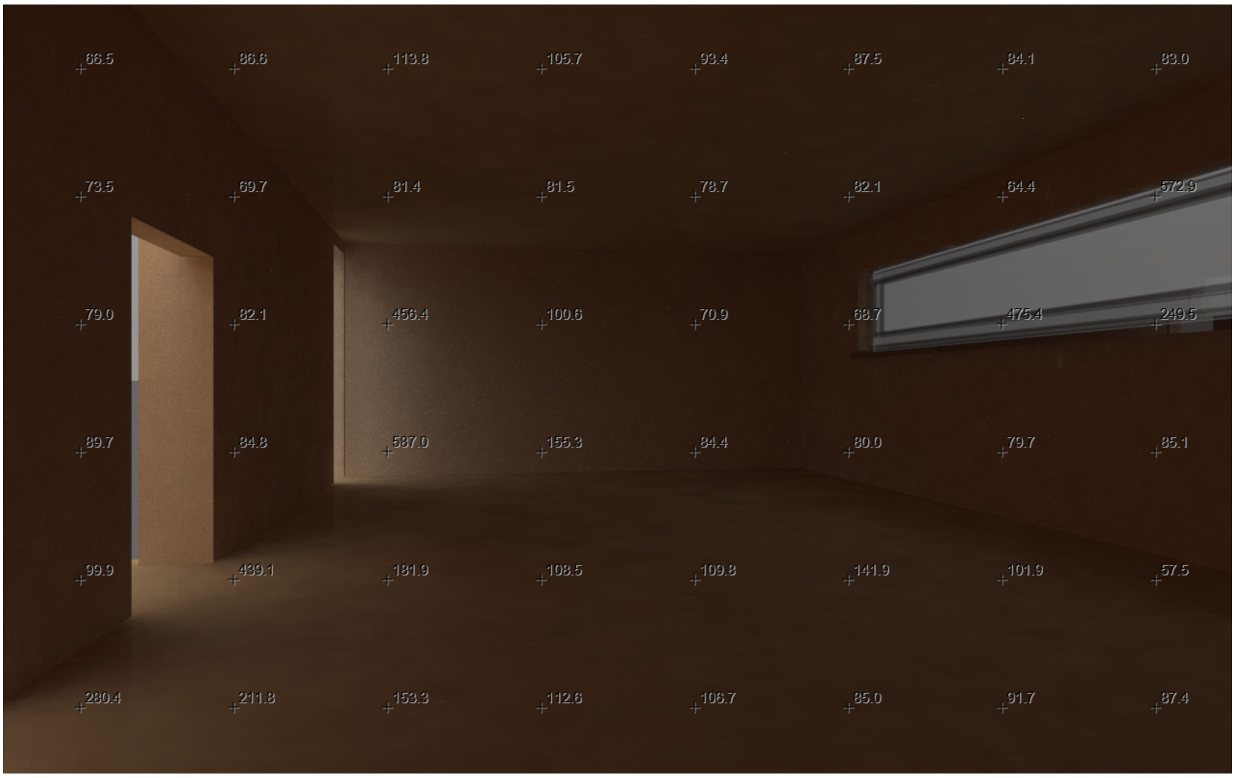


Figure 5.4: Luminance Grid Values on Baseline Model

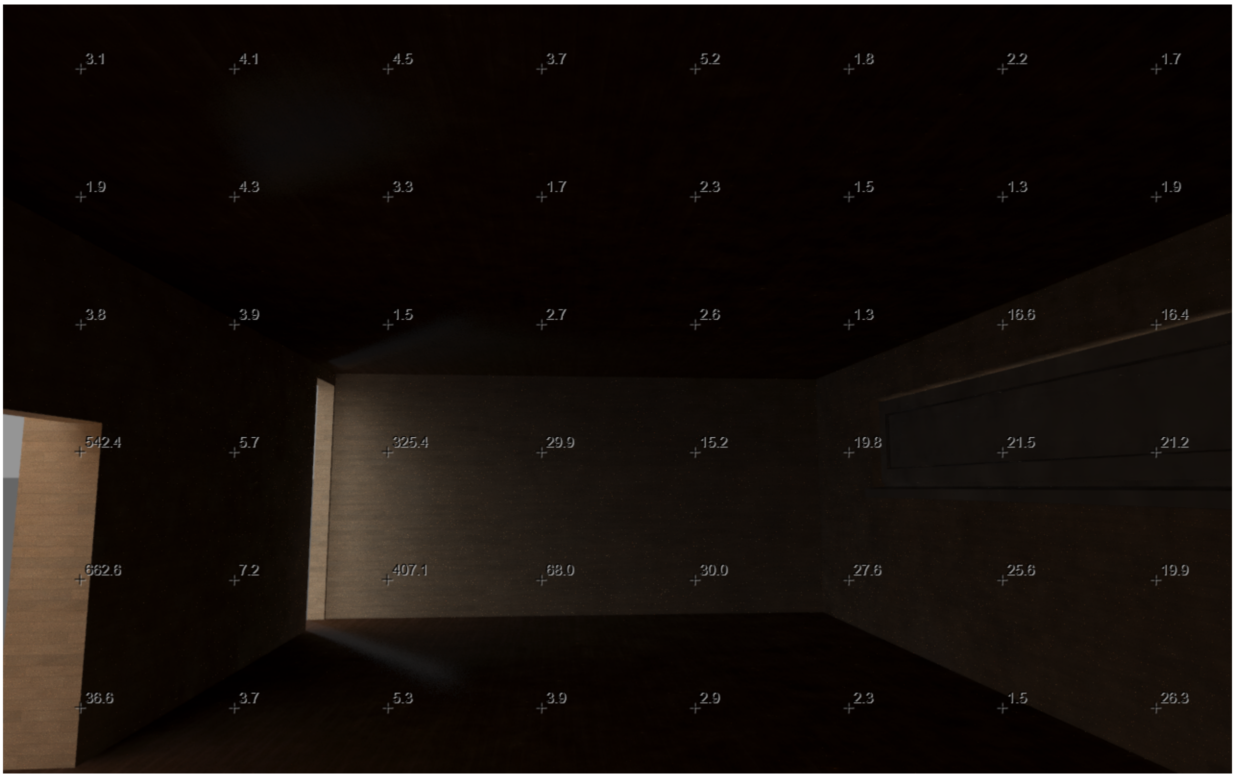


Figure 5.5: Luminance Grid Values on Improved Model

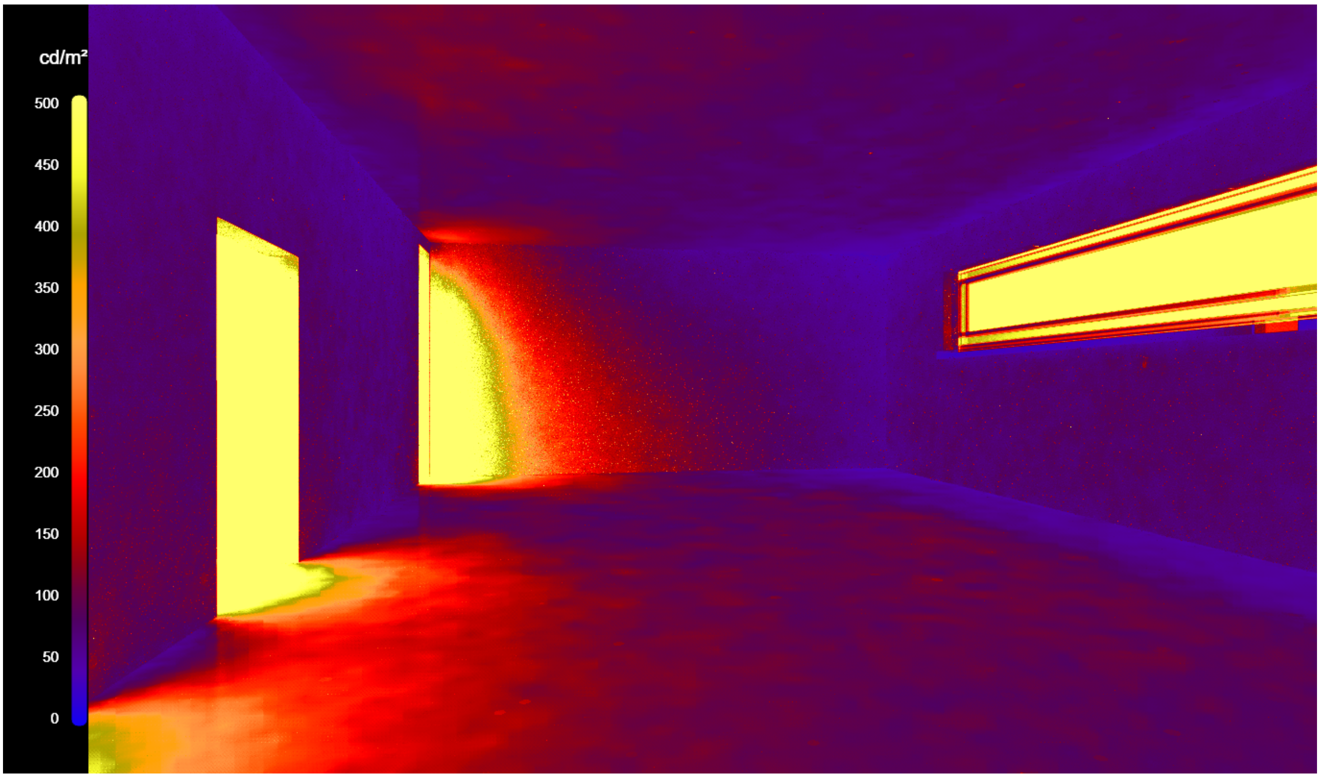


Figure 5.6: Luminance False Color on Baseline Model

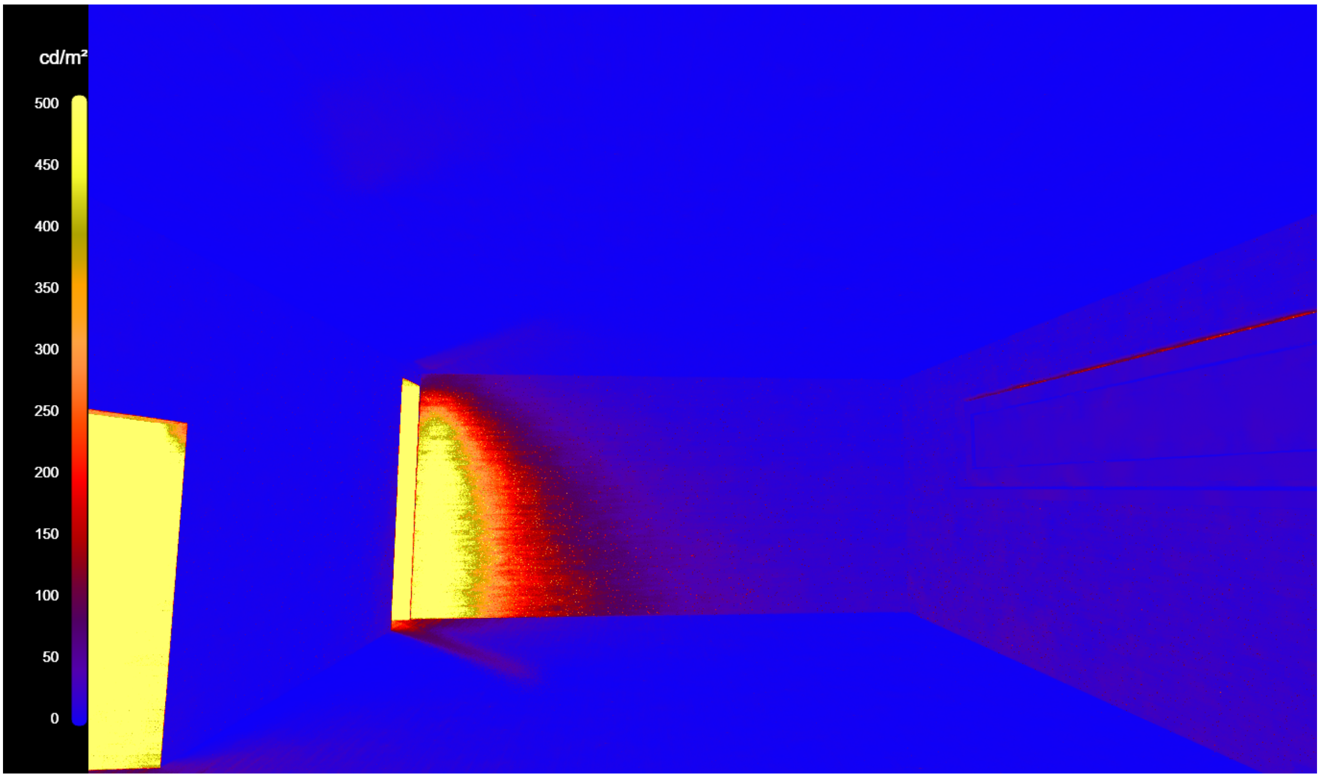


Figure 5.7: Luminance False Color on Improved Model

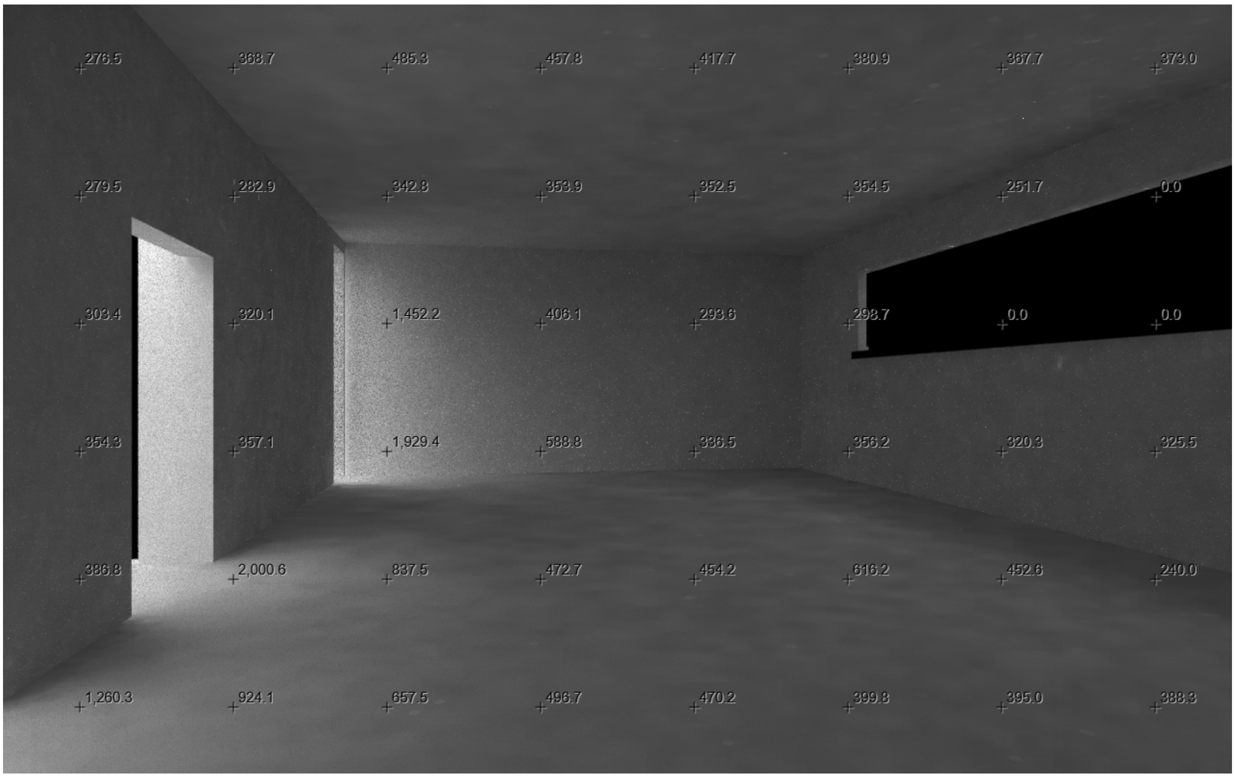


Figure 5.8: Illuminance Grid Values on Baseline Model

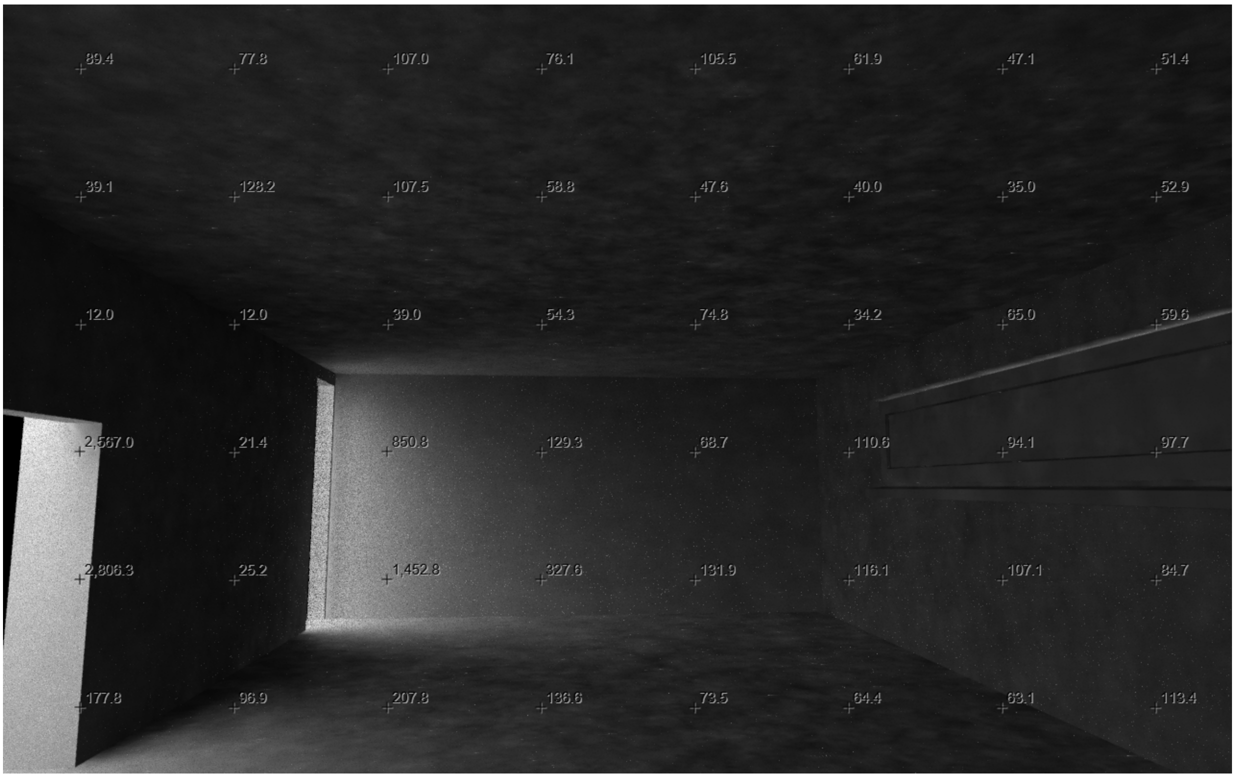


Figure 5.9: Luminance Grid Values on Improved Model

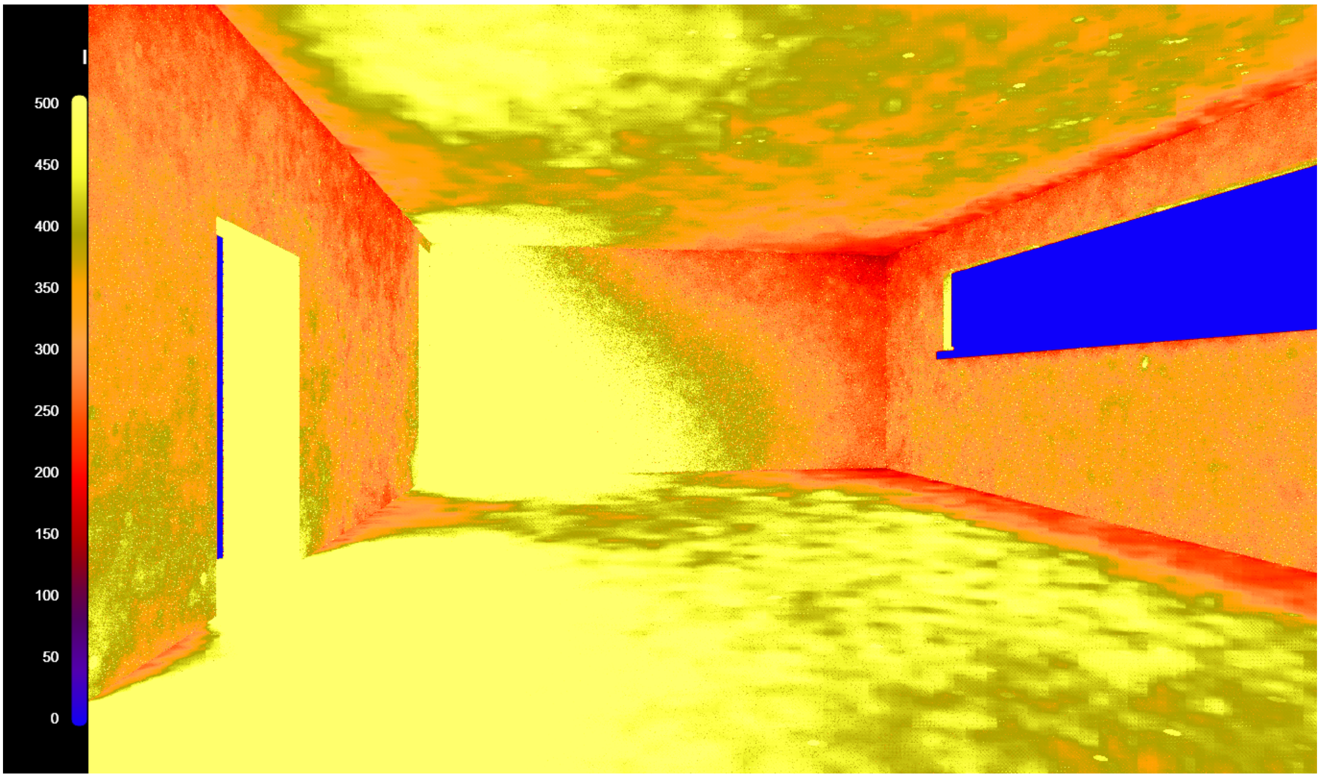


Figure 5.10: Illuminance False Color on Baseline Model

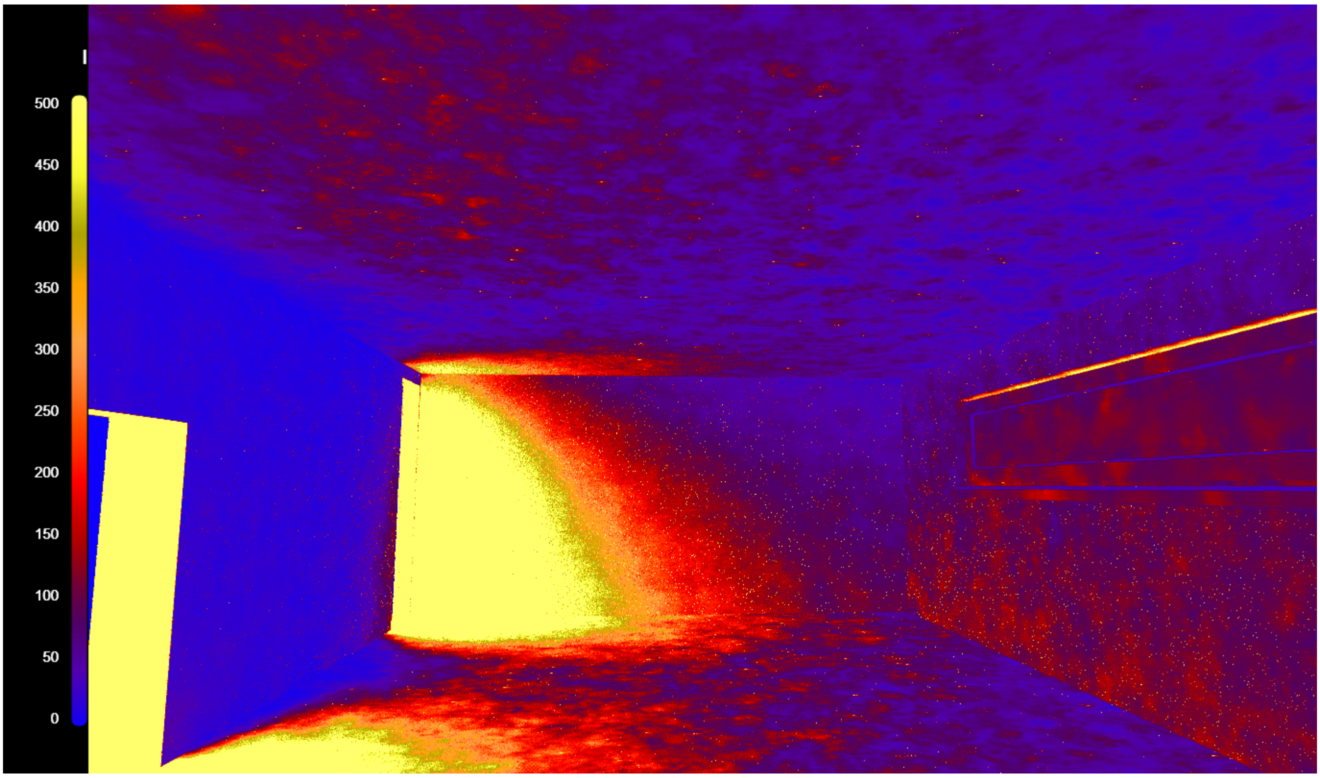


Figure 5.11: Illuminance False Color on Improved Model

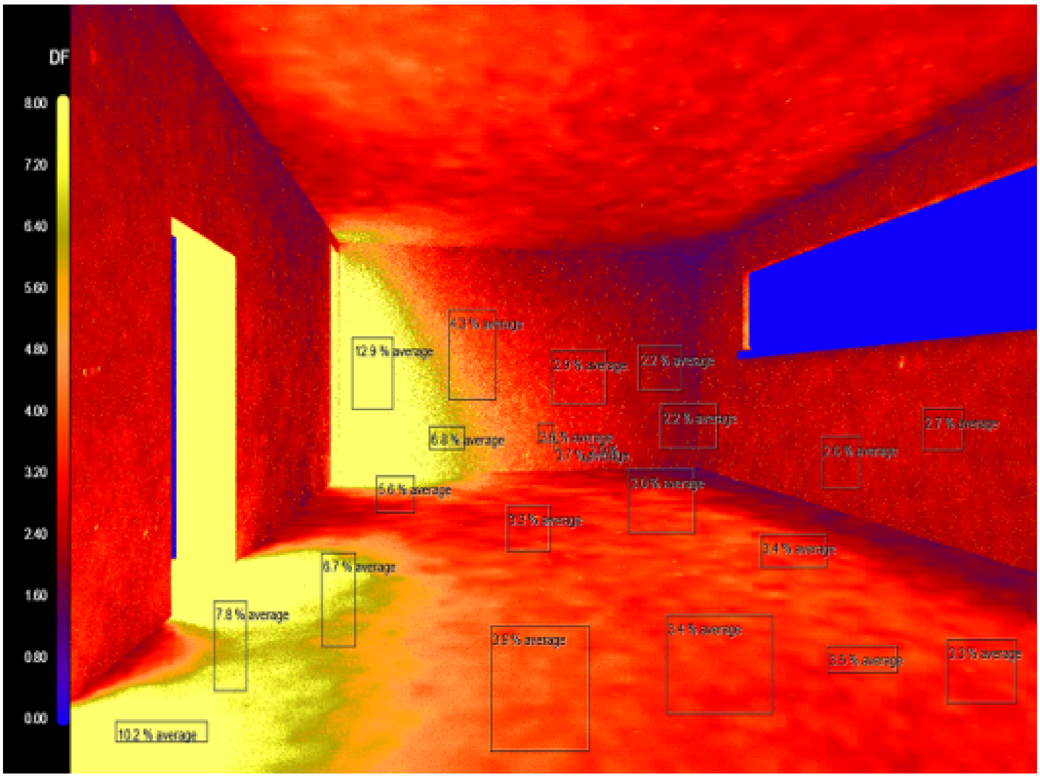


Figure 5.12: Day Light Factor on the Baseline Model

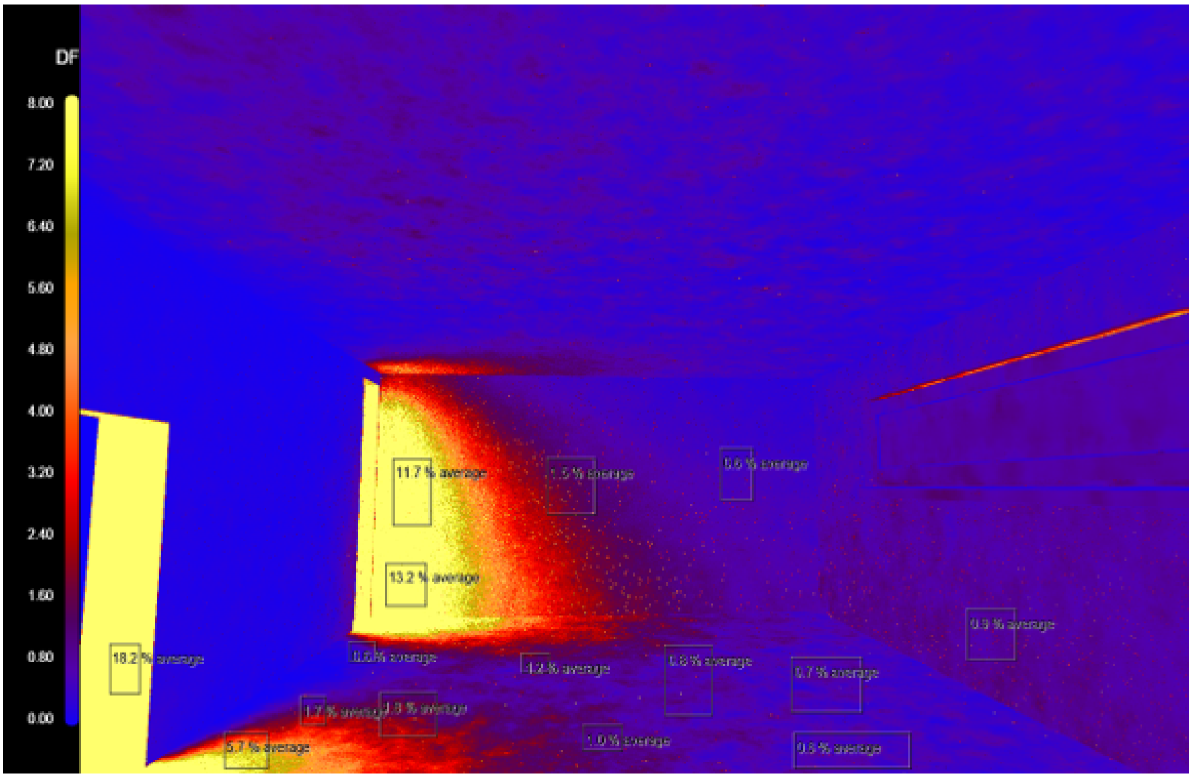


Figure 5.13: Day Light Factor on the Improved Model

5.3 Result on Sunny Condition

Parameter	**Details**
Time of Year	November 21
Time of Day	12:00
Sky Condition	Sunny
Exterior Illumination	56,136.6 lux

Table 5.4: Environment Details

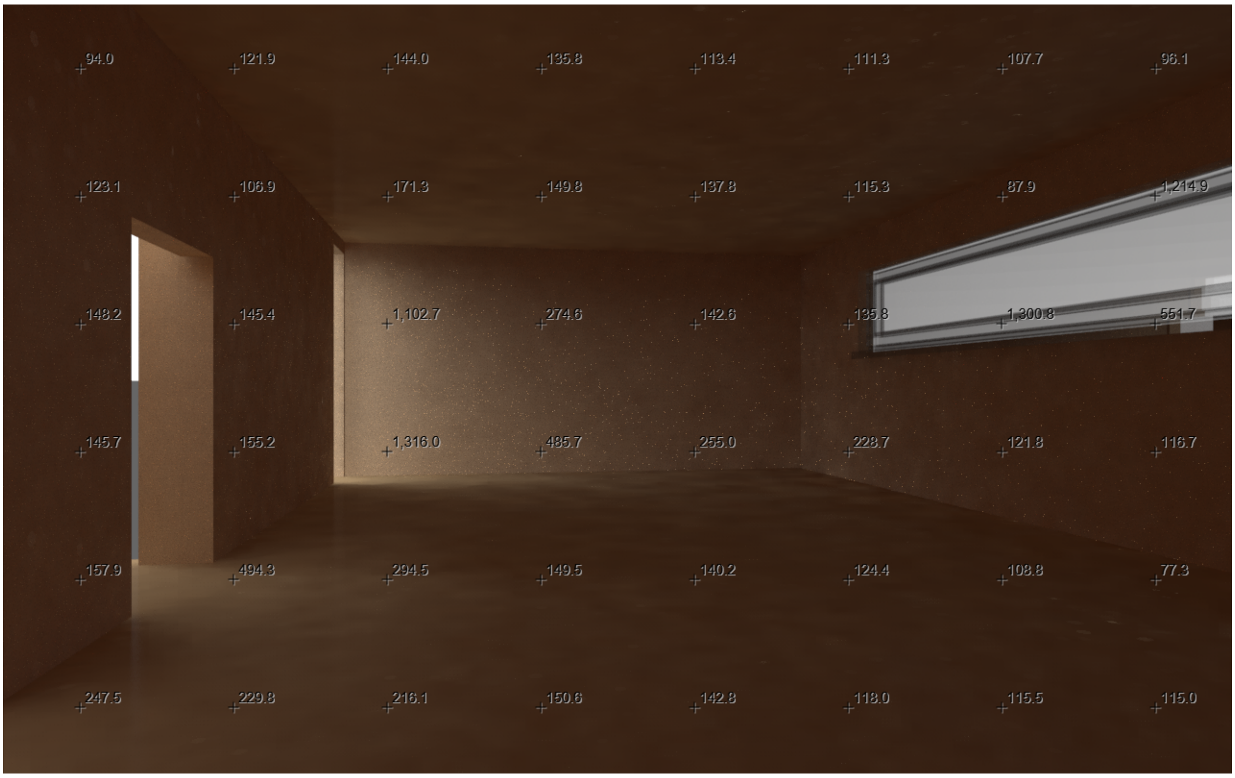


Figure 5.14: Luminance Grid Values on Baseline Model

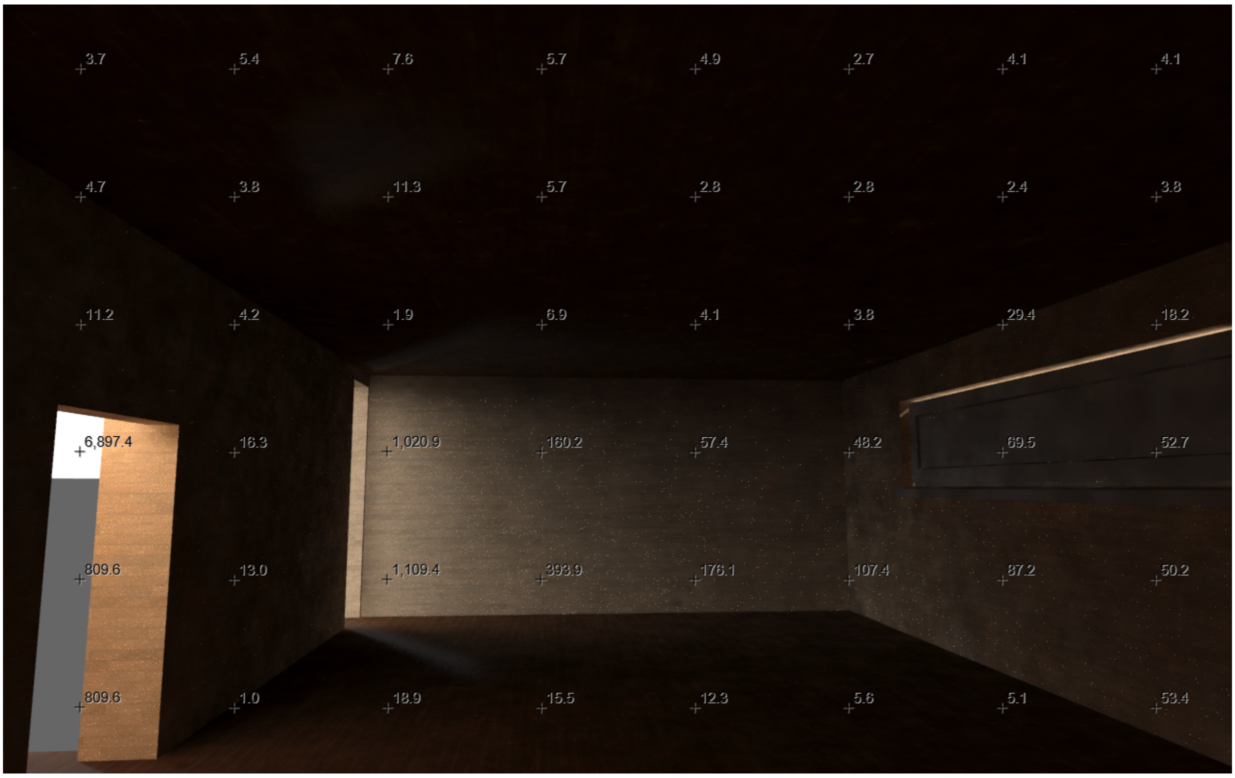


Figure 5.15: Luminance Grid Values on Improved Model

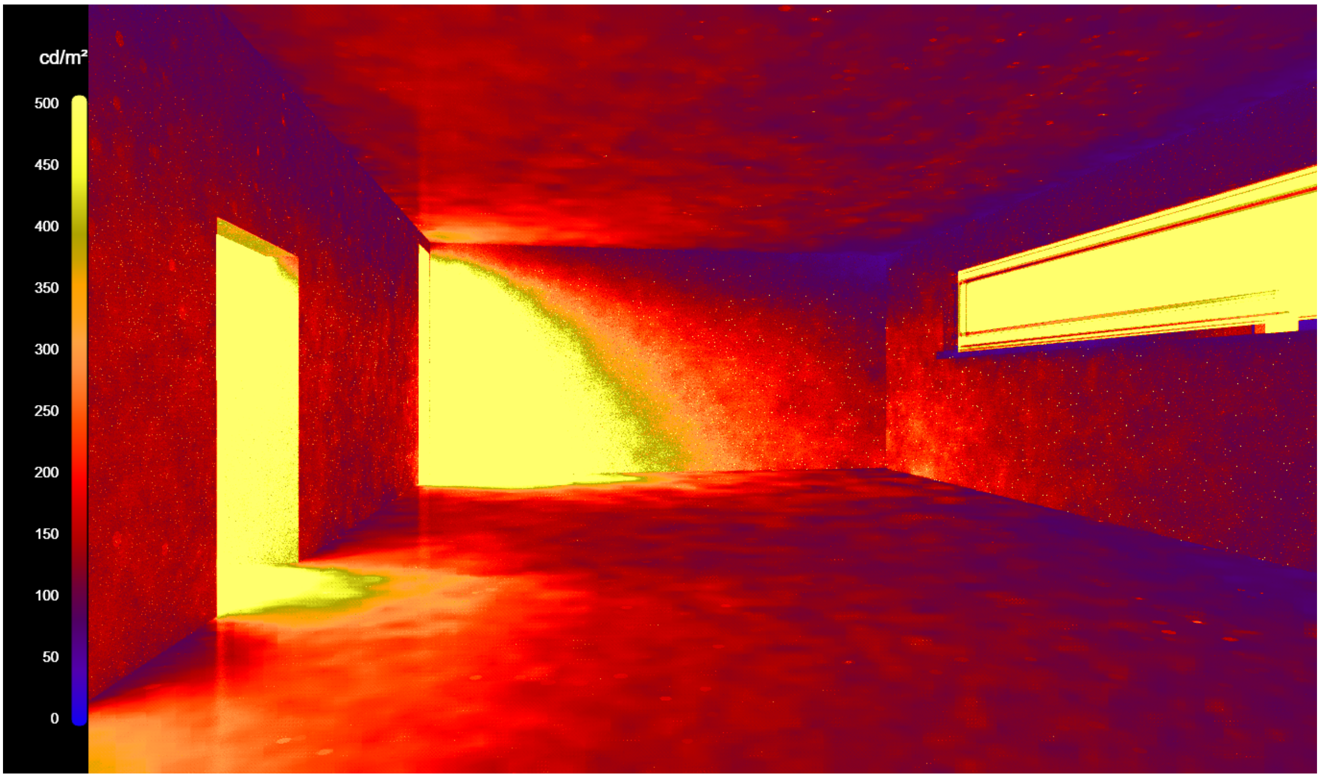


Figure 5.16: Luminance False Color on Baseline Model

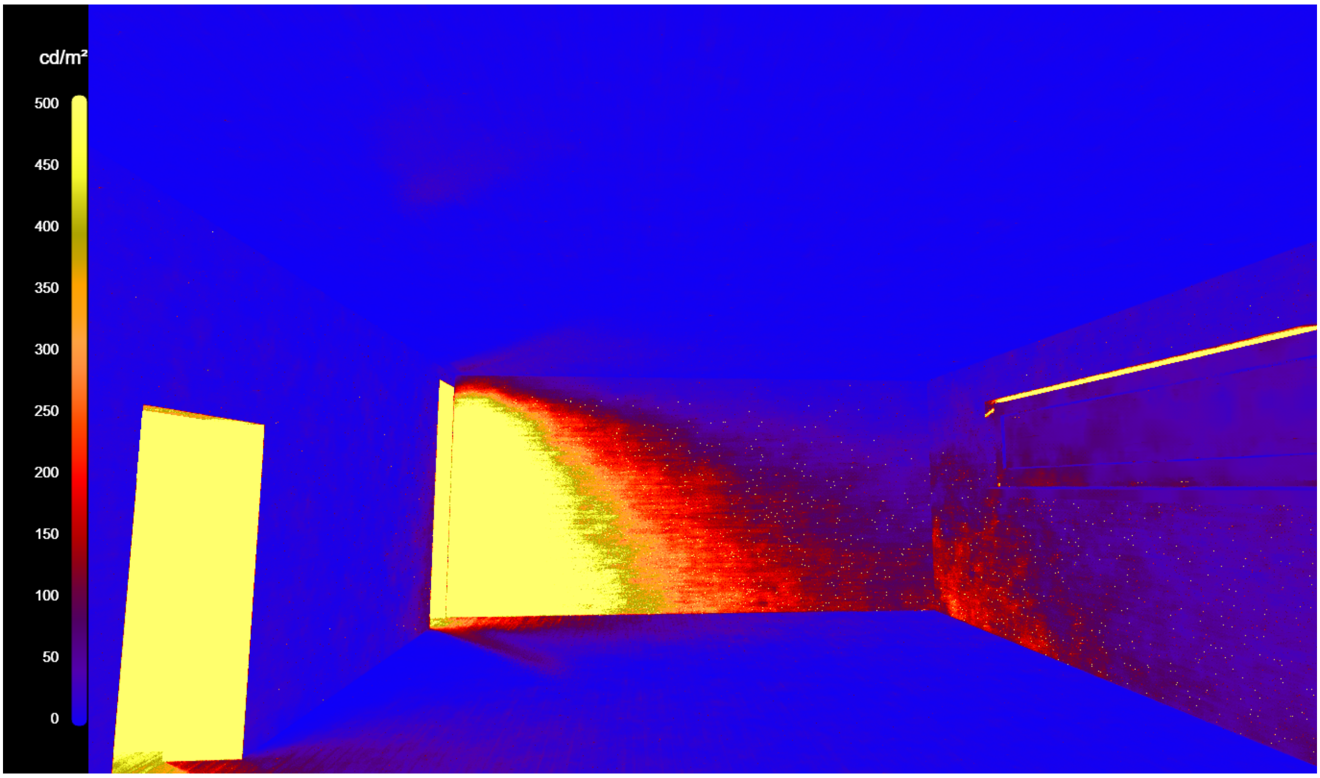


Figure 5.17: Luminance False Color on Improved Model

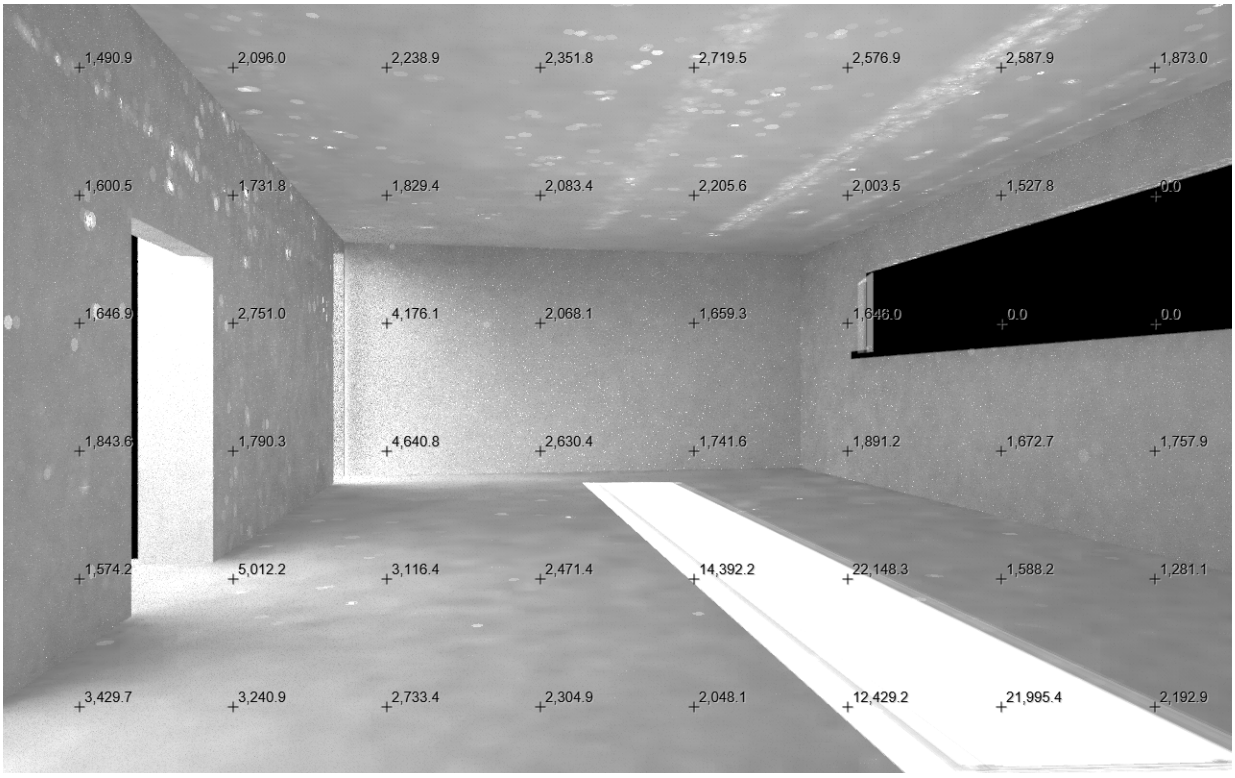


Figure 5.18: Illuminance Grid Values on Baseline Model

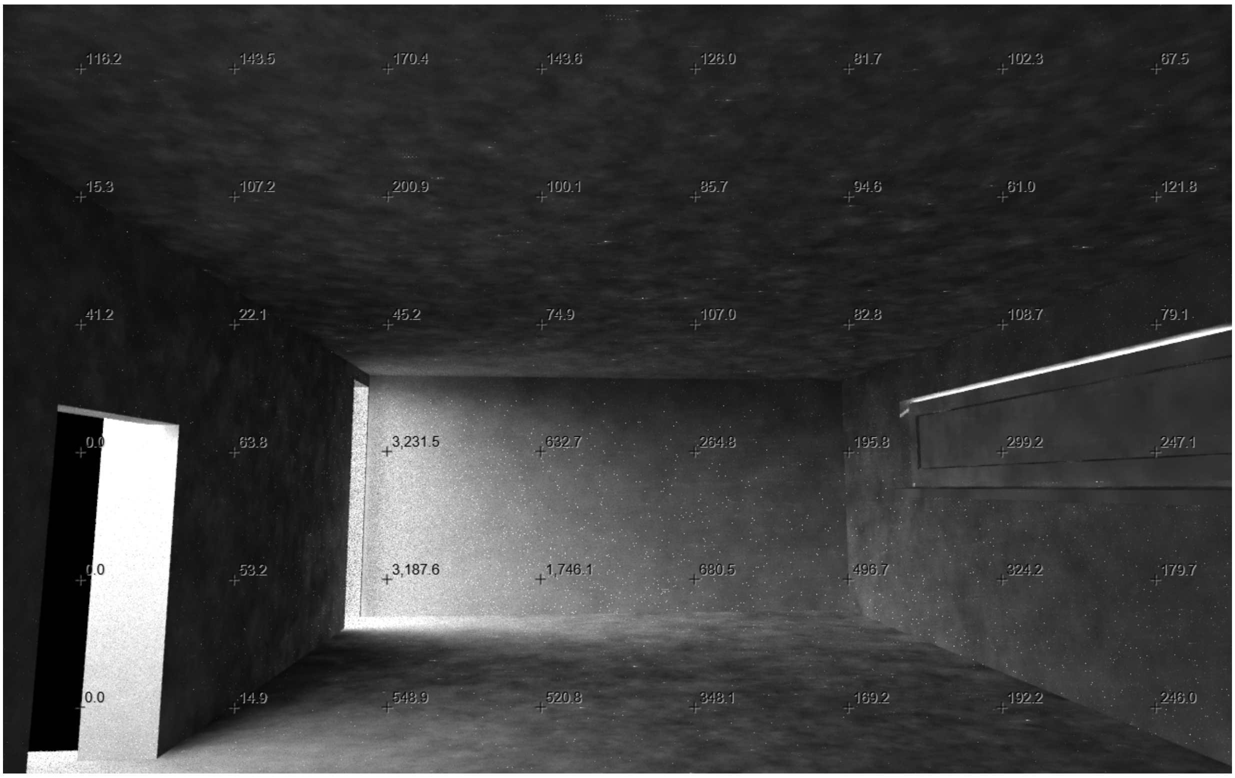


Figure 5.19: Luminance Grid Values on Improved Model

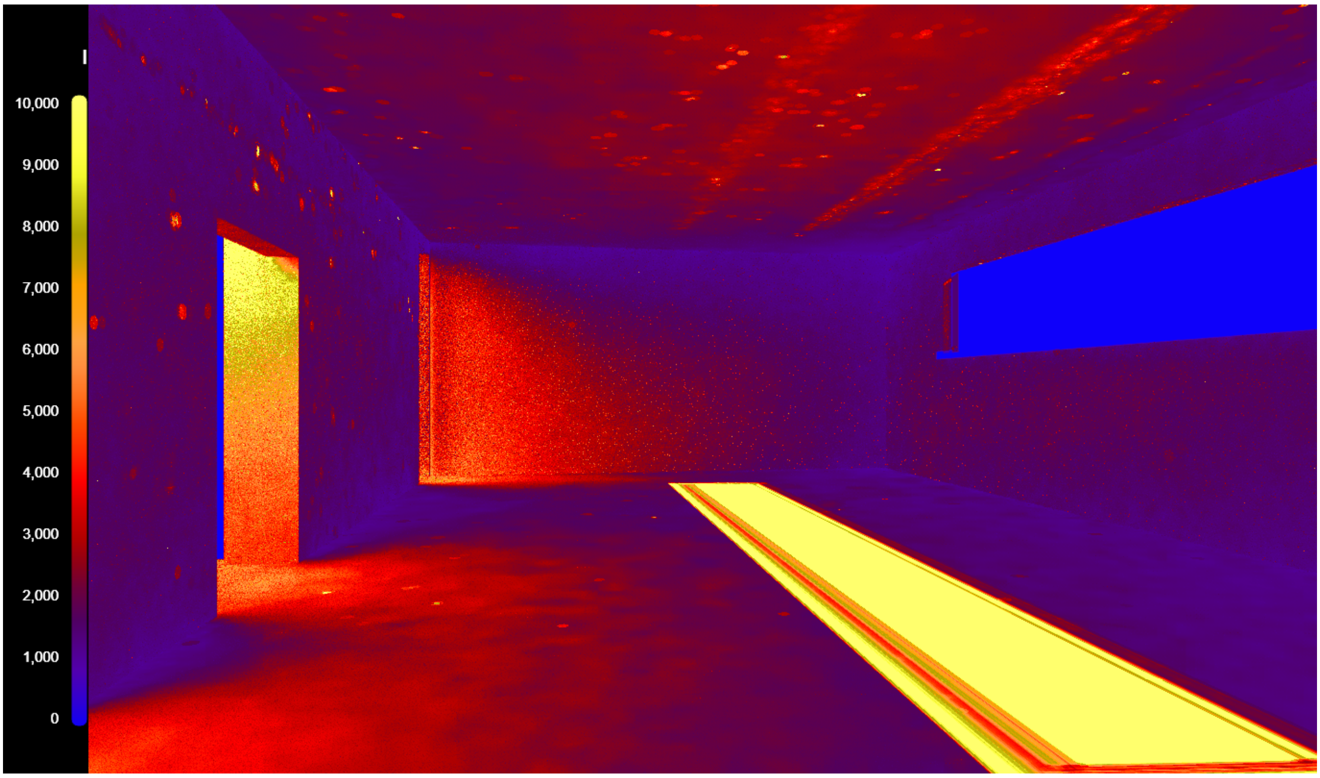


Figure 5.20: Illuminance False Color on Baseline Model

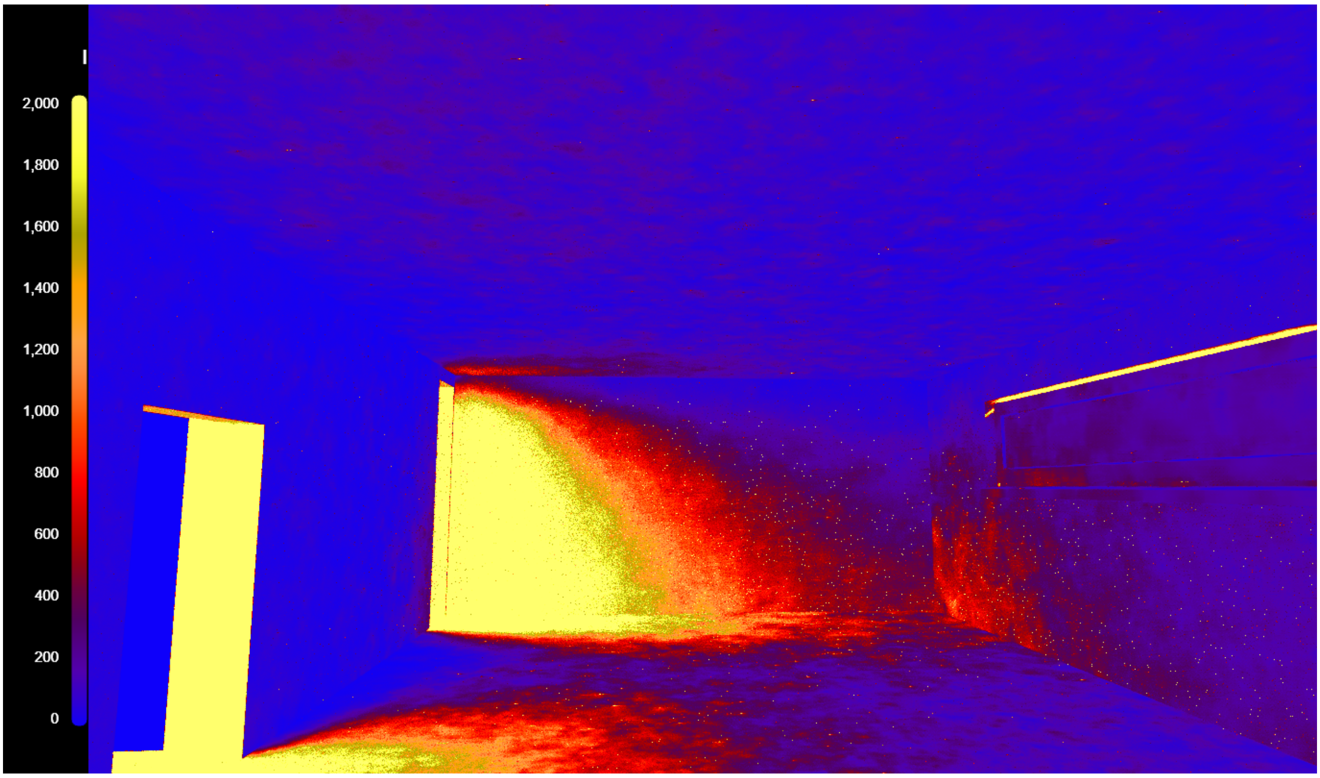


Figure 5.21: Illuminance False Color on Improved Model

5.4 Discussion

From the results obtained through the simulation comparing the baseline and improved models, it was observed that the glare in the improved model was drastically reduced with simple modifications. However, the model could be further enhanced by incorporating additional changes.

In the baseline model, glare issues were prominent at noon due to the high-level window's orientation towards the south, which receives direct sunlight throughout the day. The addition of an overhang effectively reduced the overall glare on the building, although it also led to a slight reduction in the daylight factor.

Further improvements can be achieved by making modifications to the windows on the left, which would address remaining glare issues and enhance the overall performance of the model.

6 Conclusion

Daylighting is essential to sustainable building design that incorporates energy efficiency, functionality, and aesthetics. Introducing daylight into a building can increase lighting for visibility and positively impact inhabitants. According to (Wirz-Justice, Skene, & Münch, 2021), daylight reduces the risk of myopia, improves bone health and immune systems, and also serves as an anti-depressant. We considered all these important details when constructing our cardboard model.

To gain a better understanding of optimal daylighting, we conducted a series of tests: daylight factor measurements and glare analysis. From the data collected, we could make educated and informed decisions on how best to improve our model. These tests were done under a multitude of different conditions in which we compared which window openings would affect the daylighting in the most significant of ways.

Following our tests, we modified the base model of our building to adjust for the best daylighting. We added an awning on the side window, and a piece of clear plastic to reflect the severe light entering the clerestory window. Taking these into account, there was much improvement shown as we discussed with the comparison of the simulated models.

All in all, the model could be improved with better material usage such as utilizing wood and nails as well as better sealants to prevent light leaks around the edges of the walls and ceilings. The instruments used to improve daylighting could also be improved upon. This model construction provides our team with a greater insight into just how much the position of windows and other factors affect the amount of daylight inside a structure, as well as how vital daylighting is to a variety of different applications. We have a greater understanding of the practices used to adjust these factors and what it looks like to have a sufficient amount of daylight in a building.

References

Gronbeck, C. (2009). *Overhang analysis.* Retrieved 2024-11-20, from https://www.susdesign.com/overhang/

Wirz-Justice, A., Skene, D. J., & Münch, M. (2021). The relevance of daylight for humans. *Biochemical pharmacology*, *191*, 114304.