A Comparative Study on the Light Transmission Properties of Translucent Roofing Panels

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Abstract

This study investigates the comparison of light transmission performance between two types of translucent roofing panels clear corrugated polycarbonate panels and translucent fiberglass panels. The experiment was designed to simulate lighting conditions during morning, midday and evening periods under varying light intensities. The distances between the light source and the light sensor were set at 50, 100, and 150 centimeters as experimental variables. The experiment was conducted in a small-scale test chamber measuring 1.0 × 1.0 × 1.0 meters, with a single circular opening at the top 40 centimeters in diameter, to allow light entry. A data logger was used to record illuminance values over an area of 1 square meter. When the spotlight was positioned at distances of 50, 100, and 150 centimeters from the roofing panels, the clear polycarbonate panels consistently exhibited higher illuminance levels. The light tended to concentrate in small clusters with limited wide-area distribution. In contrast, the translucent fiberglass panels produced lower illuminance values but demonstrated broader light distribution across the area compared to the polycarbonate panels at the respective distances. The results indicate that for usable spaces beneath roofing that require natural lighting through translucent panels, the selection of roofing material should be based on the intended application. If wider light distribution per unit area is desired, translucent fiberglass panels are recommended. However, if higher brightness is required despite more limited light dispersion, clear polycarbonate panels are more suitable. Notably, as illuminance decreases, polycarbonate panels maintain higher brightness levels than fiberglass panels.

Keywords: Daylighting performance , light transmission characteristics, Polycarbonate , fiberglass , Translucent Roofing Panel

Introduction

Human vision is considered the most important human sense, and without light, humans are unable to see. The primary function of a lighting system is to enable visual perception. In general, inadequate lighting is believed to reduce the efficiency of the human visual system. Providing appropriate illumination throughout the day can enhance human performance. Proper lighting is crucial in work environments, and light intensity is a fundamental concept in lighting engineering, serving as the basis for measuring illuminance on surfaces in various locations and for establishing lighting standards.Wright et al. [1]

Daylight illumination is the preferred method of getting light into buildings. This is usually accomplished by the use of windows placed in the façade walls. However, getting daylight into the centre of a deep plan space is di_cult due to the distance from the building façade to the deep space to be lit. This is the case in both open plan layouts in large span buildings (such as o_ces,hospitals, retail centres) and in cellular, short-span buildings with separated enclosed spaces as is the case in housing. Magda et al. [2]

Lighting is the most common and naturally the most constant form of load. It represents a significant portion of the total electricity consumption all building types, and it is more prominent in commercial buildings. For example, according the US Department of Energy, lighting load represents 14% energy consumption in commercial buildings on average. DHW Li *et al.* [3]

Other studies show that average lighting load can be significantly higher in some cases A Pandharipande *et al.* [4]. A European study shows that in case of medium and large buildings, about 40% of the total electricity is used for interior lighting S Abolarin *et al.* [5]

Transparent systems are very important elements in buildings, for windows, façades, shed and skylighting roofs, and in external areas for arcades. The thermal and solar transmittance, transparency, the size and the orientation of transparent elements deeply influence energy use in buildings Oral et al. [6]

This study aims to investigate the distribution of light at varying illuminance levels through two types of commercially available translucent roofing materials: (1) clear polycarbonate roofing panels and (2) fiberglass roofing panels. The objective is to determine which material provides better light transmission and more effective light distribution. Al et al.[7]

This study investigates the light distribution through two types of roofing materials: (1) clear polycarbonate roofing panels and (2) translucent fiberglass roofing panels. Each sample has an area of 1 square meter and includes a light opening with a diameter of 40 centimeters (Figure 1).

This study provides comparative data on the light transmission efficiency and light distribution performance of different types of translucent roofing panels,

The current research aims at evaluating acrylic panels as a light transmitting medium and studying their possible applications to bring natural light to inner spaces due to the lack of researches on acrylic sheets. AlQudah et al.[8] which can serve as a guideline for selecting appropriate roofing materials according to specific spatial and functional requirements, enhance the effective use of daylight within buildings, reduce reliance on artificial lighting, support energy-efficient and environmentally sustainable building design, and serve as a reference for researchers, architects, and engineers in the development of future lighting systems.

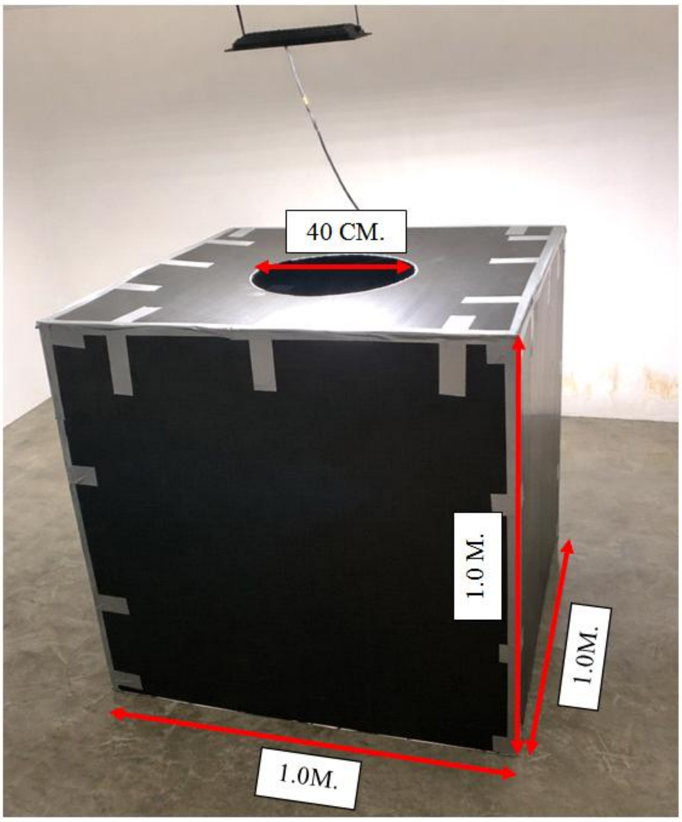

Figure 1. A small-scale test chamber measuring 1.0 × 1.0 × 1.0 meters, with a single circular light entry opening at the top, 40 centimeters in diameter.

Research Methodology

Light Transmission

Light is a fundamental aspect of human experience. We can grow food and perceive our surroundings because of sunlight. When we observe objects, we are detecting specific wavelengths of light reflected from the object into our eyes. The color of an object depends on the light that interacts with it.

How does light travel, and how does it interact with materials it encounters? Light consists of small units called photons, which exhibit both particle and wave characteristics. For example, when light strikes a glass surface, it is reflected similarly to how a ball bounces. When light passes through a small opening, it diffuses throughout a room rather than remaining concentrated, similar to sound waves passing through a small aperture. This illustrates the dual wave-particle nature of light.

The visible spectrum for humans lies in the middle of this range, from red at one end to violet at the other, with other colors in between.

Light Measurement (Illuminometer)

A light meter or illuminometer measures the intensity of incident light. The measurement process involves:

1. Light from the environment strikes the sensor
2. Light-sensitive sensor detects illumination
    - Photodiode / Phototransistor / LDR
3. Conversion of light into electrical signal
    - Current, voltage, or resistance proportional to light intensity
4. Signal processing inside the device
    - Amplification, computation of illuminance (lux) or exposure
5. Display of results
    - Analog dial
    - Digital screen
    - Computer interface for data logging
6. Applications
    - Photography / cinematography: exposure control
    - Architecture: evaluating lighting levels
    - Agriculture: measuring light for plant growt

Operation of a Lux Meter

1. Photodiode Sensor: Converts light energy into electrical current, with the current directly proportional to the incident light intensity.

2. Optical Filter: Adjusts the sensor response to match the human eye's sensitivity across different wavelengths (photopic response).
3. Amplifier: Amplifies the small electrical signal from the photodiode to improve measurement accuracy and processing capability.
4. Analog-to-Digital Converter (ADC): Converts the amplified analog signal into digital data for processing.
5. Microcontroller / Processor: Processes digital data and calculates illuminance in lux based on programmed algorithms.
6. Display Unit: Shows the calculated illuminance value to the user.
7. Power Source: Supplies energy to the system, typically from batteries or rechargeable sources.

Polycarbonate (PC)

Polycarbonate is a thermoplastic polymer characterized by carbonate groups (-O-(C=O)-O-) linked to aromatic rings, giving it the following properties:

1. Mechanical Strength
    - PC has a strong and flexible molecular structure, providing high impact resistance.
    - Principle: Molecules disperse applied forces, reducing the risk of breakage.
2. Optical Transparency
    - Transparent like glass, allowing high light transmission (~88–90%).
    - Principle: Aromatic carbonate structure does not absorb visible spectrum light.
3. Thermal Resistance & Thermoplasticity
    - Can be formed under heat due to its thermoplastic nature.
    - Principle: Above the glass transition temperature (~147°C), molecular mobility allows molding.
4. Chemical & UV Resistance
    - UV coating enhances resistance to ultraviolet radiation.
    - Principle: Aromatic structure prevents UV degradation.
5. Lightweight & Durability
    - About half the weight of glass, yet stronger.
    - Principle: Dense yet strong molecular arrangement creates a lightweight, durable material.

Research Methodology

Initial Data for Simulation

1. Physical Room Model:
   - Dimensions: 1.0 × 1.0 × 1.0 m
   - Volume: 1.0 m³

This illuminance level used is measured in lux or lumen per metre square (lumen/m2), which means the amount of luminance (lumen) affected on a 1m x 1m surface area. By referring to this measurement, the study can determine the indoor lighting performance by using comparative analysis between pedentive dome and pyramid roof form Runsheng et al. [9]

2. Light Opening (Skylight):
   - Diameter: 40 cm
   - Quantity: 1 opening
3. LED Spotlight:
   - Power: 100 W
   - Color Temperature: 6500 K (white light)
   - Luminous Flux: 9500 lumen
   - Dimensions: 290 × 205 × 35 mm

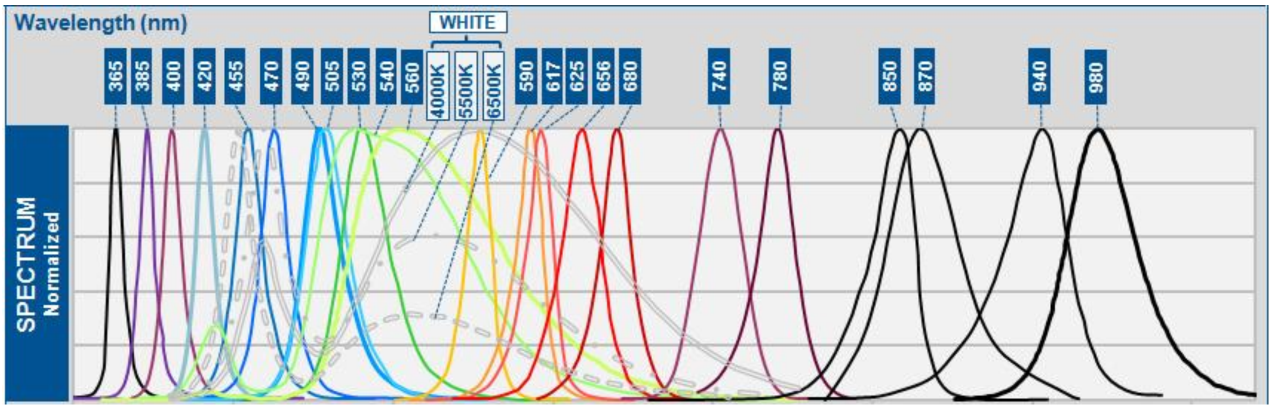

Figure 2. LED wavelengths

4. Measurement of Light Transmission through Clear Corrugated Polycarbonate Roof Sheet
5. Measurement of Light Transmission through Translucent Fiberglass Roof Sheet
6. Measurement Area:
   - Illuminance measured over 1 m² surface

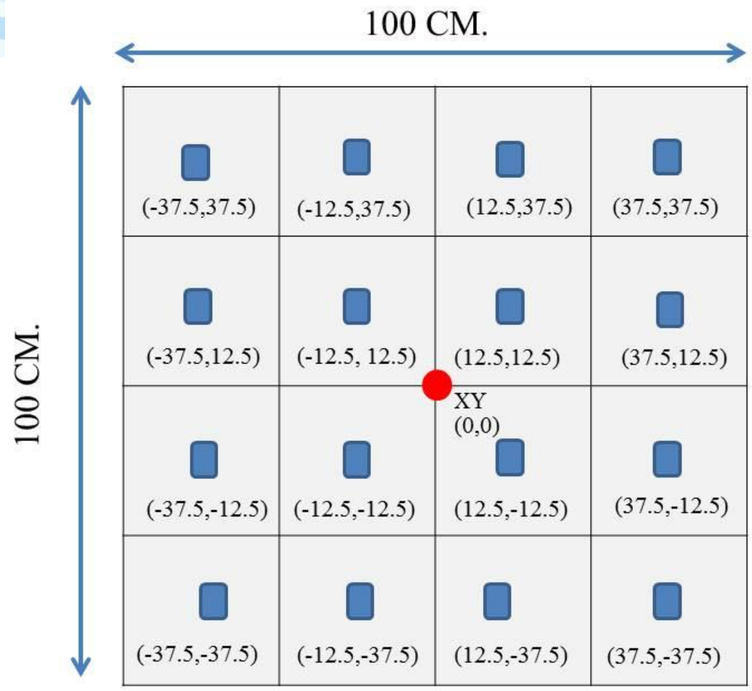

Figure 3. Positioning of light measurement sensors.

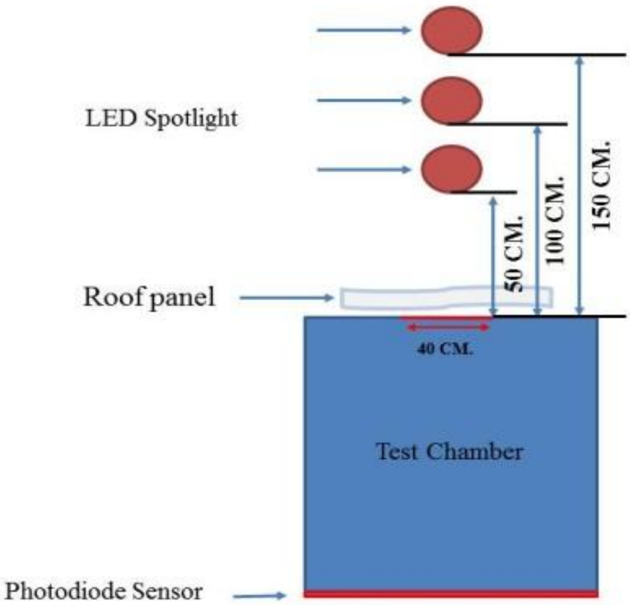

Figure 4. Simulation of LED spotlight positions at 50 cm, 100 cm, and 150 cm above the roof sheet

Figure 5. Experimental chamber equipped with clear corrugated polycarbonate roofing panels.

Figure 6. Experimental chamber equipped with translucent corrugated fiberglass roofing panels.

Result

Analysis of Light Transmission

The light transmission of clear corrugated polycarbonate roof sheets and translucent fiberglass roof sheets was analyzed under the illumination of a spotlight LED at distances of 50 cm, 100 cm, and 150 cm above the roof sheets. The experiments were conducted in a small-scale room with an external temperature of 33°C.

The light transmission values were measured over a 1 m² area. The results are presented graphically to show the light transmission performance of the two roof materials under controlled laboratory conditions.

From Figure 7, the light transmission of the clear corrugated polycarbonate roof sheet at a distance of 50 cm above the sheet over a 1 m² area is shown.

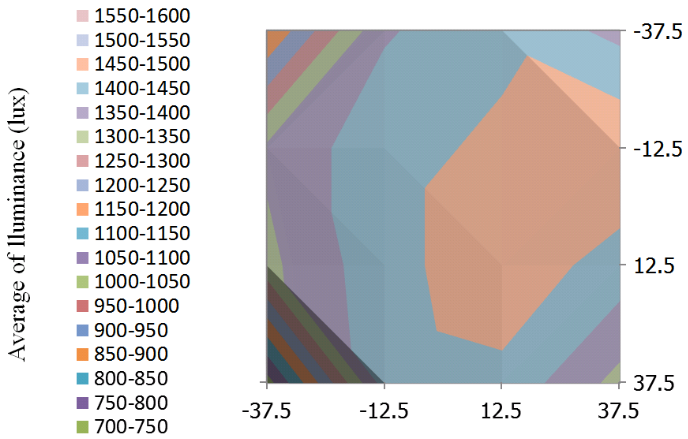

Figure 7. Graph showing the light transmission measurements of the clear corrugated polycarbonate roof sheet at a distance of 50 cm.

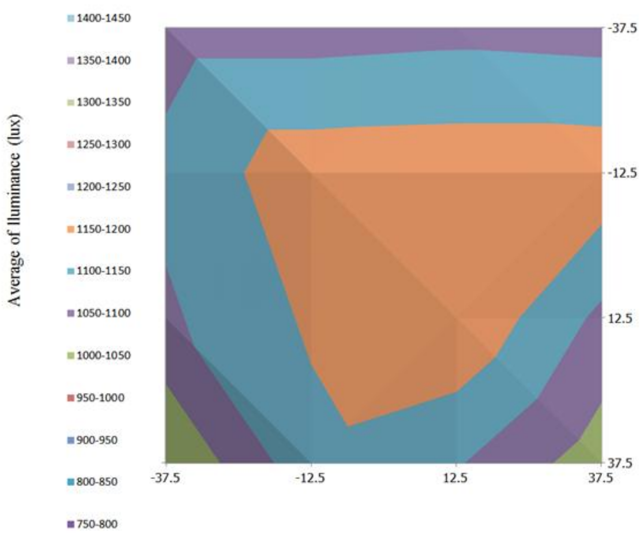

Figure 8. Graph showing the light transmission measurements of the translucent fiberglass roof sheet at a distance of 50 cm.

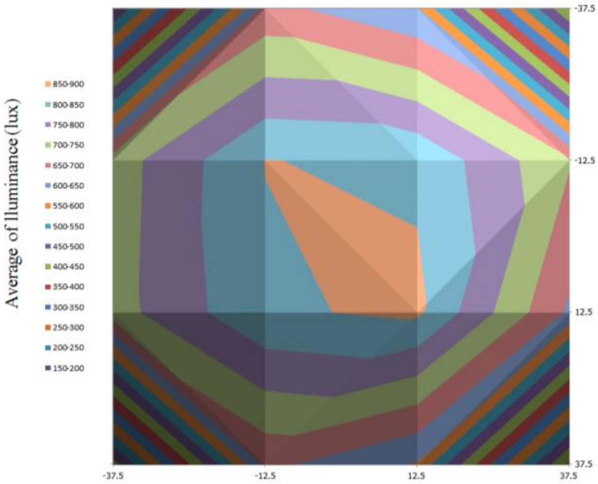

Figure 9. Graph showing the light transmission measurements of the clear corrugated polycarbonate roof sheet at a distance of 100 cm.

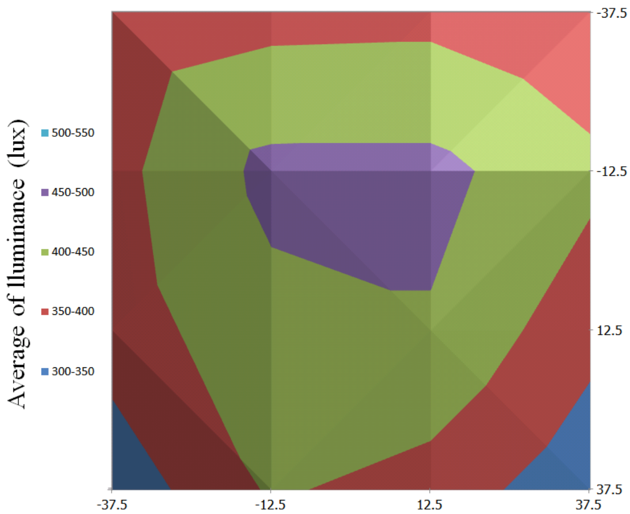

Figure 10. Graph showing the light transmission measurements of the translucent fiberglass roof sheet at a distance of 100 cm.

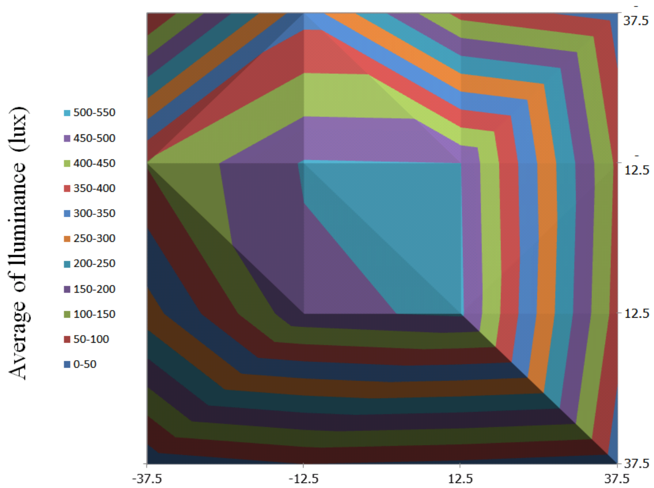

Figure 11. Graph showing the light transmission measurements of the clear corrugated polycarbonate roof sheet at a distance of 150 cm.

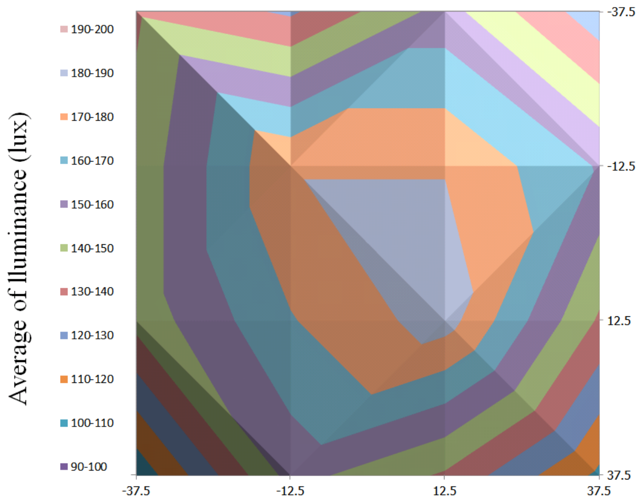

Figure 12. Graph showing the light transmission measurements of the translucent fiberglass roof sheet at a distance of 150 cm.

Discussion and conclusions

Experimental Results

Light transmission measurements were recorded using a data logger over an area of 1 m^2. The experiments were conducted using an LED spotlight placed at three different distances from the roofing sheets: 50 cm, 100 cm, and 150 cm.

At 50 cm.

The clear corrugated polycarbonate roofing sheet showed a maximum light intensity of 1550–1600 lux, with light concentrated in small clusters. The light distribution was mainly concentrated at the central area, while the illuminance at the edges of the test area decreased to 850–1200 lux, as shown in Figure 7.

The translucent fiberglass roofing sheet exhibited a maximum light intensity of 1450–1500 lux, with light distributed across the entire test area, and a gradual decrease in illuminance to approximately 1300 lux, as shown in Figure 8.

At a distance of 50 cm, if a higher light intensity is required within a limited area, the clear corrugated polycarbonate roofing sheet is recommended. However, if better light distribution and sufficient usable illuminance are desired, the translucent fiberglass roofing sheet is more suitable.

At 100 cm.

The polycarbonate roofing sheet recorded a maximum illuminance of 650–900 lux. The light distribution remained concentrated in the central area, while a noticeable reduction in illuminance was observed at the four corners of the test area. As the height of the LED spotlight increased to 100 cm, the edge illuminance decreased to 150–500 lux, as shown in Figure 9.

The fiberglass roofing sheet showed a maximum illuminance of 500–550 lux at the central area of the test region, with relatively good light distribution. The edge illuminance ranged from 300–400 lux, indicating that the corners still maintained relatively uniform light distribution, as shown in Figure 10.

At a distance of 100 cm, when the illuminance level decreases, the fiberglass roofing sheet provides a more uniform light distribution compared to the clear corrugated polycarbonate roofing sheet.

At 150 cm.

The polycarbonate roofing sheet recorded a maximum illuminance of 500–550 lux at the central area of the test space. However, a significant reduction in illuminance was observed at all four corners, where the values ranged from 0–150 lux. When the LED spotlight distance was increased to 150 cm, such low illuminance levels at the edges may negatively affect human visual perception, resulting in insufficient brightness in peripheral or corner areas of the room, as shown in Figure 11.

The fiberglass roofing sheet showed a maximum illuminance of 190–200 lux concentrated at the central area of the test space. At the four corners, the illuminance ranged from 100–150 lux. It can be observed that the fiberglass translucent roofing sheet provides better light distribution and coverage in the corner areas of the test space, as shown in Figure 12.

The results indicate that as light intensity decreases with increasing distance, the polycarbonate sheet still provides higher central illuminance; however, edge illuminance decreases significantly. In contrast, the fiberglass translucent roofing sheet provides lower central illuminance than the polycarbonate sheet but offers better light distribution at the corners of the test area. Therefore, selecting an appropriate translucent roofing sheet is crucial and should depend on the specific application and spatial requirements of each area.

Suggestion

Recommendations for Design and Future Studies

Based on the experimental results and analysis of light transmission through translucent roof sheets, the following recommendations are proposed for design and future research:

1. Vary the angle of the spotlight LED:
    - Conduct experiments with angles of 30° and 45° relative to the roof sheet to simulate the varying angles of sunlight incidence in real conditions.
2. Roof geometry design for light concentration:
    - Design roof shapes that focus or guide light to achieve higher illumination levels within the interior space.
3. Selection of roofing materials with high solar reflectance:
    - Although polycarbonate sheets allow natural light to enter the building effectively, they can lead to significant heat accumulation.
    - Consider using materials or coatings with high solar reflectivity to reduce heat buildup while maintaining sufficient daylight penetration.

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