EVALUATION OF SIDE LIGHTING &TOP LIGHTING DAYLIGHT SCHEMES UNDER INDIAN CLIMATIC CONDITION

A Dissertation submitted in partial fulfillment in the requirements for the degree of

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in
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Submitted by

AVIJIT BID

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Under the Guidance of

Prof. (Dr.) BISWANATH ROY

ELECTRICAL ENGINEERING DEPARTMENT

FACULTY OF ENGINEERING AND TECHNOLOGY

JADAVPUR UNIVERSITY
KOLKATA 700032

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JADAVPUR UNIVERSITY
FACAULTY OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT

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THESIS SUPERVISOR

Prof. (Dr.) BISWANATH ROY

ILLUMINATION ENGINEERING SECTION
ELECTRICAL ENGINEERING DEPARTMENT
JADAVPUR UNIVERSITY

Prof. (Dr.) BISWANATH ROY

HEAD OF THE DEPARTMENT
ELECTRICAL ENGINEERING DEPARTMENT
JADAVPUR UNIVERSITY
KOLKATA

Prof. DIPAK LAHA

DEAN
FACULTY OF ENGINEERING AND TECHNOLOGY
JADAVPUR UNIVERSITY
KOLKATA

JADAVPUR UNIVERSITY

FACAULTY OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT

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NAME: AVIJIT BID

EXAMINATION ROLL NUMBER: M4ILN24015

THESIS TITLE: EVALUATION OF SIDE LIGHTING &TOP LIGHTING DAYLIGHT SCHEMES UNDER INDIAN CLIMATIC CONDITION

SIGNATURE:

DATE:

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ABSTRACT

Daylighting is a crucial component of sustainable building design, especially in a diverse and energy-sensitive environment like India. This study explores the effectiveness of top lighting (e.g., skylights, roof monitors) and side lighting (e.g., windows, clerestories) schemes in optimizing daylight under various Indian climatic conditions. The analysis considers the unique challenges and opportunities presented by India's varied climate zones, from hot and arid regions to humid and temperate areas.

Top lighting schemes are shown to provide more uniform daylight distribution, with significant benefits in reducing artificial lighting needs in large, open spaces. However, they also pose challenges related to heat gain, particularly in hot climates. Side lighting, on the other hand, offers more direct interaction with natural light but often results in uneven light distribution and potential glare, especially in deeper spaces.

The study highlights the potential of integrating advanced glazing technologies, automated shading devices, and hybrid daylighting systems to optimize daylight penetration while mitigating thermal loads. These approaches can be tailored to the specific climatic conditions of different regions in India, promoting energy efficiency and occupant comfort.

Future scope includes the use of smart materials, computational simulations, and AI-driven design tools to further enhance the effectiveness of daylighting strategies. By leveraging these innovations, buildings in India can achieve greater sustainability, reducing reliance on artificial lighting and improving indoor environmental quality. This research underscores the importance of context-specific daylighting solutions in the pursuit of sustainable architecture in India.

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Introduction

Daylighting is crucial to create a comfortable living environment as it uses natural light to provide visual and psychological comfort. Moreover, it presents an opportunity to reduce dependence on non-renewable energy sources, contributing to energy conservation. In India, lighting alone accounts for a considerable proportion of electricity consumption, underscoring the importance of incorporating daylighting strategies to offset electric lighting. By effectively implementing daylighting techniques, the presence of natural light can be enhanced, resulting in energy savings. The distribution and effects of daylight within internal spaces are significantly influenced by the design of building envelopes. Variations in the amount of daylight are caused by climate, earth rotation, cloud cover, time of day, and season. Energy efficiency can increase by incorporating daylighting techniques with energy-efficient lighting systems and suitable reflective materials on walls, ceilings, floors, furniture, and other intelligent lighting systems. In residential buildings, window design and glazing significantly improve visual comfort and energy efficiency. Several studies have been carried out to evaluate the performance of windows, considering different parameters, including size, type, material, and orientation to achieve the best visual and thermal comfort

Daylighting strategies include side lighting and top lighting. Side lighting uses windows, light shelves, and shading devices to bring natural light through vertical surfaces, while top lighting employs skylights, clerestory windows, and light tubes to introduce light from above. Effective daylighting design considers building orientation, window-to-wall ratio, glazing types, and shading systems to optimize light distribution and control glare and heat gain.

In India, diverse climatic conditions ranging from hot and dry to warm and humid necessitate tailored daylighting solutions. For example, thick walls and small windows minimize heat gain in hot, dry climates, while large windows with overhangs maximize ventilation and light in warm, humid regions.

Innovations like smart glass, daylight harvesting systems, and reflective materials further enhance daylighting effectiveness. By integrating these strategies, architects can create energy-efficient, comfortable, and sustainable buildings that harness the benefits of natural light.

LITERATURE REVIEW

Daylighting is a vital component of sustainable building design, particularly in India, where diverse climatic conditions demand tailored approaches to minimize energy consumption and enhance occupant comfort. The two primary strategies for daylighting are top lighting and side lighting, each with its own set of advantages and challenges when applied across India's various climatic zones.

Top lighting and **side lighting** are two prevalent approaches. Top lighting, which includes skylights and clerestories, is effective in providing uniform illumination, especially in deep-plan buildings. However, it poses challenges like glare and excessive heat gain, particularly in India's hot-dry and warm-humid climates. Proper shading and reflective materials can mitigate these issues, making top lighting more effective in these regions.

Side lighting, typically through windows and glazed façades, offers better visual connections to the outdoors and easier glare control. However, it can lead to uneven light distribution and significant heat gain, particularly in large glazed areas. High-performance glazing and external shading are critical for managing these challenges in hot climates.

There are 16 no of classroom design alternative north large window, south large window, east large window, west large window, south medium window, south small window, south large window with overhang, south large window with light-shelf, bilateral large window, skylights, north roof monitor, south roof monitor with baffles, north large window with skylights, south large window with skylights, north small window with skylights, south large window with skylights. Among these 16 classroom design we choose 3 classroom design e.g. classroom with roof window with external louvers (for top lighting scheme) class room with large south facing window (for side lighting scheme), class room with small south facing window and roof light.

OBJECTIVE

The primary objective of this study and analyze percentage of coverage of a standard classroom under daylight in different day, time in different Indian climatic condition.

Here are the main objectives for doing this simulation: -

1. Determine the percentage of coverage and daylight distribution pattern of a standard classroom under top lighting scheme (roof window with blinds) for tropical wet and dry climate(Kolkata) in different day and time under clear, average and over cast sky

2. Determine the percentage of coverage and daylight distribution pattern of a standard classroom under top lighting scheme (roof window with blinds) for temperate climate(Delhi) in different day and time under clear, average and over cast sky.

.3. Determine the percentage of coverage and daylight distribution pattern of a standard classroom under side lighting scheme (large south facing window with blinds) in for tropical wet and dry climate(Kolkata) in different day and time under clear, average and over cast sky.

4. Determine the percentage of coverage and daylight distribution pattern of a standard classroom under side lighting scheme (large south facing window with blinds) for temperate climate (Delhi) in different day and time under clear, average and over cast sky.

5. Determine the percentage of coverage and daylight distribution pattern of a standard classroom with small south facing window with blinds and roof window with blinds for tropical wet and dry climate(Kolkata) in Kolkata location in different day and time under clear, average and over cast sky.

6. Determine the percentage of coverage and daylight distribution pattern of a standard classroom with small south facing window with blinds and roof window with blinds for temperate climate in different day and time under clear, average and over cast sky.

Chapter 1

Day lighting – an overview

Daylighting is the strategic use of natural light to illuminate indoor spaces, enhancing energy efficiency, visual comfort, and occupant well-being. It reduces reliance on artificial lighting, leading to significant energy savings and lower carbon footprints. Proper daylighting design can improve mood, productivity, and overall health, making it essential for sustainable architecture.

1.1 Definition and importance

The sun is the biggest source of light and energy on earth and the light we received today comes from the sun in two ways: either directly as sunlight, or modified and redistributed by the atmosphere as diffuse skylight. The light from the sun not only enables us to see, but provides energy and power to the whole ecosystem on earth.

The combination of the direct sunlight and the diffuse skylight can be defined as daylight. The quality and intensity of daylight vary according to geographical latitude, season in a year, time of day, local weather, sky conditions, and building geometry.

In the India, the availability of daylight is crucial as we can use direct sunlight for lighting the interiors of buildings but we have to use it by proper implementation. Despite artificial lighting has long being used to supplement lighting in the interiors of buildings, reports suggest negative effect of artificial lighting on health.

Using natural light, it can help to maintain a good health, cure some of the medical ailments, and reduce psychological sadness related to the Seasonal Affective Disorder. Compared to artificial light, daylight offers better conditions for seeing as it contains consistent alterations of intensity, direction and spectral composition; thus, it brings positive implication biologically and physiologically to all living things on earth, such as, as natural means for human body to produce vitamin D and hormone.

Daylighting is the controlled allowance of natural light through windows and other design elements. This practice, if done right, can result in energy savings through a reduction. When done right, proper daylighting can reduce over one-third of a building's energy costs while simultaneously creating a visually stimulating environment for occupants. Daylighting now utilizes daylight-responsive control systems, which adjust indoor and outdoor lighting based on ambient light levels, significantly reducing energy usage.

Daylighting design enhances both aesthetic and architectural value by creating visually pleasing, well-lit spaces that emphasize natural light, highlight architectural features, and improve occupant comfort and well-being.

1.2 Components of Daylight

1. Direct Sunlight

Direct sunlight is the portion of daylight that comes straight from the sun without being scattered or reflected. It travels in a straight line and is the most intense form of natural light. Average illuminance value is 120000 lux

Characteristics:

Intensity: High intensity and strong luminance.
Shadow Formation: Creates well-defined shadows due to its directness.
Glare Potential: Can cause significant glare and discomfort if not managed properly.

Design Implications:

Glare Control: Utilize shading devices like overhangs, blinds, or louvers to mitigate glare.
Window Placement: Strategically position windows and skylights to optimize sunlight while reducing glare.
Heat Gain: Consider the impact of direct sunlight on cooling loads and thermal comfort.

2. Diffuse Skylight

Diffuse skylight is sunlight that has been scattered by particles in the atmosphere, resulting in a more uniform and diffuse light source. It is the primary source of natural light on overcast days.

Characteristics:

Even Distribution: Provides a softer, more uniform illumination with reduced contrasts.
Reduced Glare: Minimizes glare compared to direct sunlight.
Consistency: More stable light levels throughout the day.

Design Implications:

Even Illumination: Ideal for spaces where uniform light distribution is important, such as offices and classrooms.
Daylight Harvesting: Design windows and skylights to capture as much diffuse skylight as possible.
Light Shelves: Use light shelves to reflect and diffuse skylight deeper into interior spaces.

3. Reflected Light

Reflected light is daylight that bounces off external surfaces like the ground, nearby buildings, or landscape features before entering the building. It helps in enhancing light levels in areas not directly exposed to sunlight.

Characteristics:

Enhanced Illumination: Increases the effective light levels in shaded areas.
Variability: The quality and amount of reflected light vary with the type and colour of reflecting surfaces.

Design Implications:

Reflective Surfaces: Use light-coloured or reflective exterior surfaces to enhance reflected light.

Building Design: Position buildings and windows to maximize the benefits of reflected light from adjacent surfaces.
Interior Design: Incorporate reflective materials and finishes to improve light distribution.

4. Ambient Light

Ambient light refers to the general, diffuse light present in a space, resulting from a combination of all sources of natural and artificial light. It is the baseline level of illumination in an indoor environment.

Characteristics:

Base Illumination: Ensures that spaces receive a minimum level of light.
Blend with Task Lighting: Often used in conjunction with task and accent lighting to achieve desired light levels.

Design Implications:

Balancing Light Levels: Combine ambient light with task and accent lighting to ensure adequate illumination for various activities.
Lighting Control: Use dimmable artificial lighting systems to adjust ambient light levels as needed.
Daylighting Integration: Ensure that natural ambient light complements artificial lighting to enhance energy efficiency.

5. Daylight Penetration

Daylight penetration refers to the depth and extent to which natural light reaches into the interior spaces of a building from apertures such as windows and skylights.

Characteristics:

Depth of Light: Influences how far daylight extends into the building.
Distribution: Affects how uniformly light is distributed within the space.

Design Implications:

Window Design: Optimize window size and placement to maximize daylight penetration.
Light Shelves and Reflectors: Use light shelves and reflective materials to extend daylight deeper into the interior.
Building Layout: Design open floor plans and strategic openings to enhance daylight penetration.

6. Solar Gain

Solar gain refers to the increase in temperature due to solar radiation entering through windows or other openings. It results from the absorption of sunlight by building materials and surfaces.

Characteristics:

Heat Contribution: Can increase indoor temperatures and contribute to heating loads.
Thermal Comfort: Affects the overall comfort and energy requirements of the building.

Design Implications:

Glazing Choices: Use low-emissivity (low-e) glass to reduce heat transfer while maintaining light levels.
Shading Strategies: Implement shading devices to control solar gain and prevent overheating.
Thermal Mass: Incorporate thermal mass materials to absorb and store heat, helping to stabilize indoor temperatures.

1.3 Colour of Daylight

Except on an overcast day, the colour of the sky is far from homogeneous. However, the light striking a window originating from several parts of sky faults, is likely to be less varied in colour. Fortunately, it has been found in practice that the spectral power distribution of daylight depends almost entirely on its correlated colour temperature or chromaticity, so the CIE has been, able to specify (CIE 1986) the spectra of a series of so called D illuminants, notably D50, D55, D65, and D75. These correspond to different phases of daylight, with correlated colour temperatures of approximately 50000, 55000, 65000, and 75000 K respectively. D65 is taken to represent average daylight. Shown in fig.1

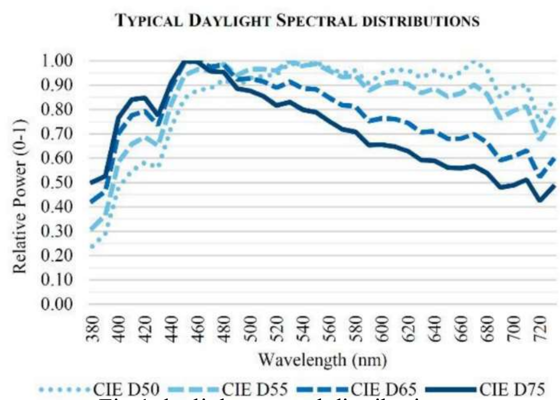


Fig.1 daylight spectral distribution

1.4Matrices and Standards

Metrics in Daylighting

1.Daylight Factor (DF)

Definition: The ratio of the amount of daylight inside a building to the amount of daylight available outside, expressed as a percentage.
Calculation: DF = (Indoor Illuminance / Outdoor Illuminance) × 100%
Use: Evaluates how effectively daylight is distributed within a space. Higher values indicate better daylighting performance.

2.Illuminance

Definition: The amount of light falling on a given surface area, measured in lux (lx) or foot-candles (fc).
Use: Assesses the intensity of daylight within a space. Different tasks andactivities require different levels of illuminance.

3.Daylight Autonomy (DA)

Definition: The percentage of occupied hours in a year when daylight levels meet or exceed a specified illuminance threshold without additional artificial lighting.
Use: Measures the effectiveness of daylight in reducing reliance on artificial lighting.

4.Useful Daylight Illuminance (UDI)

Definition: The amount of daylight that falls within a useful range of illuminance, typically between 100 and 2,000 lux.
Use: Assesses the quality and quantity of daylight that contributes to visual comfort and functionality.

5.Annual Sunlight Exposure (ASE)

Definition: The percentage of occupied hours in a year during which daylight levels exceed a specified illuminance threshold (often 1,000 lux).
Use: Evaluates the risk of glare and potential overheating due to excessive direct sunlight.

6.Daylight Glare Index (DGI)

Definition: A numerical scale used to quantify the discomfort caused by glare from daylight.
Calculation: Based on the luminance of light sources and their contrast with the background.

Use: Helps in designing spaces to minimize glare and improve visual comfort.

7. Daylight Simulations

Definition: Computer-based tools and software used to model and predict daylighting performance in buildings.
Use: Assists in visualizing how daylight will interact with architectural elements and how it will affect indoor light levels throughout the year.

1.5 Indian climatic condition

When considering daylighting in Indian climatic conditions, it is important to account for the diverse climate zones across the country, ranging from tropical in the south, arid in the west, temperate in the north, to humid in the coastal regions.

1. Tropical Wet and Dry Climate (e.g., Mumbai, Kolkata)

Characteristics: High temperatures year-round, significant monsoon season with high humidity.

Daylighting Strategies:

Shading Devices: Use overhangs, fins, and louvers to control direct sunlight and reduce glare.
Light Shelves: Employ light shelves to reflect daylight deeper into the interior while shading lower parts of windows.
High-Performance Glazing: Utilize glazing with low solar heat gain coefficient (SHGC) to reduce heat gain while allowing natural light.
Ventilation: Integrate cross-ventilation to dissipate heat and humidity.

2. Arid and Semi-Arid Climate (e.g., Rajasthan, Gujarat)

Characteristics: Very high temperatures during the day, significant temperature drop at night, low humidity.

Daylighting Strategies:

Small Openings: Minimize window sizes to reduce heat gain while optimizing their placement for maximum daylight penetration.
Thick Walls and Insulation: Use thick walls with good insulation properties to reduce heat transfer.
Courtyards and Atriums: Design courtyards and atriums to bring in natural light while shading from direct sun.
Reflective Surfaces: Use light-colored, reflective surfaces for interior finishes to maximize light distribution.

3. Temperate Climate (e.g., Delhi, Chandigarh)

Characteristics: Seasonal variations with hot summers, cold winters, and moderate rainfall.

Daylighting Strategies:

Seasonal Shading: Employ adjustable shading devices to manage seasonal variations in sunlight.
Insulated Glazing: Use double or triple glazing with low-emissivity (low-e) coatings to manage heat gain and loss.
Skylights and Clerestory Windows: Incorporate skylights and clerestory windows for even light distribution, especially in winter.
Thermal Mass: Utilize thermal mass to store heat during the day and release it during cooler nights.

4. Tropical Wet Climate (e.g., Kerala, Coastal Karnataka)

Characteristics: High temperatures and humidity throughout the year, heavy rainfall.

Daylighting Strategies:

Wide Eaves and Overhangs: Use wide eaves and overhangs to protect from rain and direct sunlight.
Ventilated Roofs: Design ventilated roof structures to reduce heat build-up and improve natural ventilation.
High Windows: Place windows high on walls to allow for natural light penetration while avoiding direct glare.
Diffuse Daylighting: Use translucent materials or light-diffusing glazing to soften direct sunlight.

5. Mountain and Sub-Humid Climate (e.g., Himachal Pradesh, Uttarakhand)

Characteristics: Cool to cold temperatures, varying humidity, significant daylight hours.

Daylighting Strategies:

Large South-Facing Windows: Maximize south-facing windows to capture low-angle winter sun.
Thermal Insulation: Ensure good thermal insulation in windows and walls to reduce heat loss.
Reflective Surfaces: Use reflective surfaces to enhance natural light distribution within interiors.
Heat Retention: Incorporate thermal mass elements to retain and release heat during colder periods.

CHAPTER 2

Top lighting Scheme

Top lighting Scheme

Top-lighting systems represent an optimum source of natural light for building interiors. These systems provide abundant illuminance levels from small openings, thus reducing artificial lighting and minimising glazing areas. However, based on a geographic location, these systems transfer high sunlight levels, which directly affect the performance of indoor environment.

2.1 Top-lighting Types

Windows are apertures in a building envelop that allow light and air into indoor spaces; these indoor spaces can be divided into two major categories: first, the openings located in the sidewalls of a building and second, the apertures from the roof commonly known as roof-lights. Top-lighting can give the designer the opportunity to have a better choice of source placement to provide more uniform illumination from the sky and to improve privacy and security. The main limitations for these systems are the structural design, electrical system, mechanical system, fire safety equipment, as well as their implantation in tall buildings due to their ability to illuminate only the upper floors. Shed roof, monitor, and saw-tooth are the most common top-lighting systems. Top-lighting systems can also have horizontal, vertical, tilted, or domed glazing Top-lighting systems are classified as:

1.Skylights

Definition

They comprise a light-transmitting fenestration placed horizontally on flat or sloped roofs, forming all or a part of the roof structure with the potential to deliver a uniform level of illumination over an interior space. It is an effective approach for illuminating one-storey buildings. However, its performance varies under overcast and clear skies, especially under the concern of thermal impact in hot regions. shown in fig.2

Types:

Flat Skylights: Horizontal or gently sloped glazing. They are suitable for low-pitched roofs and are often used in commercial buildings.

Pyramid Skylights: Sloped glazing forming a pyramid shape, ideal for adding architectural interest and directing light inward.

Dome Skylights: Curved glazing units, often made from acrylic or polycarbonate, that help distribute light evenly and are less prone to rain accumulation.

Fig.2 skylights

Design Considerations:

Glazing Material: Use materials with high light transmittance and low heat gain. Options include low-emissivity (low-e) glass or polycarbonate.
Frame and Installation: Proper framing and installation are crucial to prevent leaks and ensure structural integrity.

2.Roof Windows

Definition: Windows installed within the roof plane to provide natural light and ventilation. shown in fig3

Types:

Roof Lanterns: Raised structures with multiple panes of glass, often used in atriums or larger spaces for dramatic lighting.
Roof Hoppers: Small, typically operable windows projecting out from the roof, useful for localized daylight and ventilation.

Design Considerations:

Ventilation: Many roof windows are operable to facilitate natural ventilation and improve indoor air quality.
Insulation: Ensure that roof windows are well insulated minimize heat loss.

Fig.3 Roof window

3.Light Tubes (Solar Tubes)

Definition: Tubular daylighting devices that capture sunlight through a roof-mounted collector and channel it through reflective tubes to interior spaces.

They are considered mechanically complex daylighting devices. They were invented by Solar Tube International in 1993. Their mechanism depends on sunlight to collect light through mirrors controlled by a tracking device, concentrated by means of lenses or mirrors, and then directed inside the building through acrylic rods or fibre-optic cables for light tubes or shafts and light ducts. The tube itself is a passive element that comprises either a light-directing fibre-optic bundle or a simple reflective interior coating. In fact, their potential depends on direct sunlight. They are considered cost-effective only in regions where clean air and blue skies can be assured throughout the year. shown in fig.4

Benefits:

Energy Efficiency: Reduces heat gain compared to traditional skylights and provides daylight to spaces that are otherwise difficult to illuminate.
Design Flexibility: Can be installed in spaces where conventional skylights are not feasible.

Design Considerations:

Reflective Tubes: Ensure tubes are highly reflective to maximize daylight transfer.
Integration: Careful placement to avoid unnecessary bends, which can reduce light output.

Fig.4 Light tubes

4.Clerestory Windows

Definition: High windows located above the main roofline, often used to admit daylight while maintaining privacy and wall space. shown in fig. 5

They are raised or elevated roof planes. Their glazing may be vertical or sloped. They illuminate task areas under each monitor bay. However, their utilisation requires specific orientation as monitors should face east and west directions. South-facing monitors perform differently from north-facing monitors. They are commonly found in tall buildings and usually associated with other types of aperture at low levels to offer the main daylight.

Benefits:

Even Light Distribution: Helps to light deep spaces and reduce the need for additional artificial lighting.
Ventilation: Can be operable to provide natural ventilation.

Design Considerations:

Angle and Orientation: Position clerestory windows to optimize daylight throughout the day and across seasons.

fig.5 Clerestory Windows

5.Saw-tooths

They are openings with an angled slope of 45° or vertical glazing fitted on a sloped roof plane. They are effective when installed in series of three to avoid the equator direction and thus capture more diffused light. The opaque portion of angled glass should preferably be covered with a well-insulated cool roof and radiant barrier. Shown in fig.6

6.Courtyard and light-wells

Courtyards are external spaces open to the sky in the ceiling that permit daylight penetration to the floor and are moderately or completely bounded by the building. The potential of courtyards increases in the northern orientation to decrease glare and minimise the need for sun control. Treatment of building fabric and floor finishing to reflect sunlight and daylight without increasing the level of glare for occupants must be considered. Meanwhile, light-wells are functional shafts for daylight that provide ventilation. They comprise an unoccupied space but function.

7.Atria

It covers a large portion and is normally central to a building design. A modern atrium can be glazed to provide a proper indoor environment whilst allowing for ventilation and reducing the need for air conditioning. Short and wide atria create better conditions than tall and narrow atria. The performance of daylight in an atrium design is complex. It relies on the aspect ratio, orientation, geometry, feature of the floor and wall surfaces, and nature of the glazing roof materials.

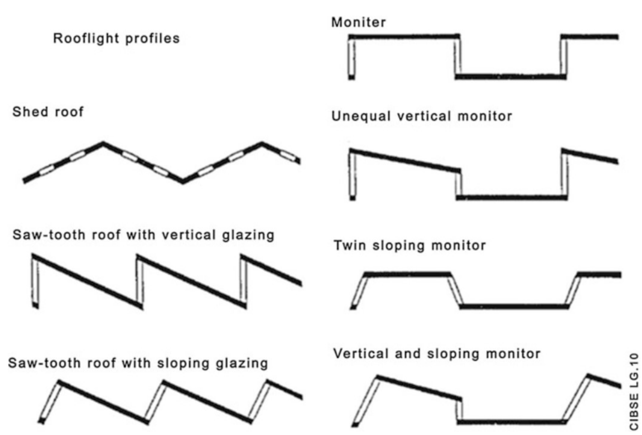


Fig.6 saw-tooth

2.2. Design Considerations

1.Orientation and Angle

Orientation: The orientation of top lighting elements should be designed to capture optimal daylight while avoiding excessive glare and heat gain. For example:

North-Facing Skylights: Provide consistent daylight with minimal glare.
South-Facing Skylights: Capture more sunlight but may require shading to control heat gain.

Angle: The angle of skylights and roof windows should be designed to balance daylight intake and prevent overheating.

2.Glazing

Type: Select glazing materials based on light transmittance and solar heat gain properties. Considerations include:

Low-E Coatings: Reduce heat transfer while allowing high daylight transmittance.
Tinted Glass: Helps control glare and solar heat gain.

Insulation: Ensure that the glazing system has good insulation properties to prevent heat loss and improve energy efficiency.

3.Shading and Controls

Shading Devices: Incorporate devices such as blinds, shades, or louvers to control the amount of daylight and reduce glare. Options include:

Internal Blinds: Adjustable to control light levels and privacy.
External Shading: Louvers or overhangs that block direct sunlight while allowing diffuse daylight.

Automated Controls: Use sensors and automated systems to adjust shading based on sunlight intensity and indoor conditions, improving comfort and energy efficiency.

4.Ventilation

Operable Systems: Incorporate operable top lighting elements to facilitate natural ventilation, which can reduce reliance on mechanical systems.
Airflow Design: Ensure that the ventilation strategy complements the daylighting design to enhance air circulation and indoor air quality.

2.3. Benefits of Top Lighting

1.Enhanced Natural Light

Deep Penetration: Top lighting can penetrate deeper into the building compared to side lighting, making it suitable for large or centrally located spaces.

Uniform Distribution: Reduces harsh shadows and provides a more even distribution of light, contributing to a pleasant indoor environment.

2.Energy Efficiency

Reduced Artificial Lighting: By maximizing daylight, top lighting reduces the need for artificial lighting, leading to lower energy consumption and cost savings.

Thermal Management: When designed properly, top lighting can contribute to thermal comfort by minimizing heat gain and loss.

3.Aesthetic and Comfort

Architectural Appeal: Adds aesthetic value and can create visually interesting spaces.

Occupant Well-being: Improves visual comfort and can enhance productivity and well-being by providing a connection to the outside environment.

2.4. Challenges and Solutions

1.Heat Gain and Loss

Challenge: Skylights and roof windows can lead to significant heat gain in hot climates and heat loss in cold climates.

Solution: Use high-performance glazing with low SHGC, integrate shading devices, and ensure proper insulation.

2.Glare

Challenge: Direct sunlight through top lighting elements can cause glare.

Solution: Implement diffusing glazing, use adjustable shading systems, and design skylight angles to minimize direct light.

3.Maintenance

Challenge: Skylights and roof windows may require regular cleaning and maintenance to ensure their effectiveness and longevity.

Solution: Design for easy access to cleaning and consider self-cleaning or low-maintenance materials.

CHAPTER 3

Side lighting scheme

Side lighting scheme

Side lighting is a fundamental daylighting strategy where natural light enters a building through windows, doors, or other openings in the walls. This approach is often used in combination with other daylighting strategies, such as top lighting, to create a well-lit and energy-efficient interior environment.

3.1 Types of Side Lighting

1.Windows

Windows are the primary elements in side lighting schemes, allowing daylight to enter indoor spaces through the building's facade.

Types of Windows:

Casement Windows: These windows are hinged at the sides and open outwards or inwards like a door. They provide ample daylight and ventilation, making them ideal for areas where fresh air and maximum light are needed.

Sliding Windows: These windows slide horizontally and are often used in spaces where an outward-opening window would be obstructive. They offer a moderate amount of daylight and are easy to operate.

Fixed Windows: These windows do not open and are purely used for daylighting and views. They are commonly used in areas where ventilation is not a priority, such as stairwells or high walls.

Bay and Bow Windows: Protruding from the wall, these windows capture light from multiple directions, making them excellent for enhancing natural light and providing panoramic views.

Clerestory Windows: Positioned high on a wall, often above eye level, clerestory windows allow daylight to penetrate deep into the interior without compromising privacy.

Design Considerations:

Window Placement: Strategic placement of windows is crucial. For example, north-facing windows provide consistent, diffuse daylight with minimal glare, while south-facing windows capture direct sunlight, which can be beneficial in winter but may require shading in summer.

Size and Proportion: Larger windows increase daylight penetration but must be balanced with the potential for heat gain or loss. The size should be proportional to the room size to avoid glare and uneven lighting.

2.Glass Doors

Glass doors, such as French doors and sliding glass doors, serve a dual purpose of providing access and daylight.

Types of Glass Doors:

French Doors: These are double doors with large glass panels, often used to connect indoor spaces with patios or gardens. They provide ample daylight and create a seamless transition between indoors and outdoors.

Sliding Glass Doors: These doors consist of large glass panels that slide horizontally, allowing for easy access and maximizing daylight entry, often used in tight spaces where swinging doors are impractical.

Design Considerations:

Thermal Performance: Glass doors should be energy-efficient, with proper insulation to prevent heat loss in winter and heat gain in summer. Double glazing or low-E coatings can enhance thermal performance.

Security and Privacy: Consider laminated or tempered glass for enhanced security. For privacy, frosted or tinted glass can be used without sacrificing daylight.

3.Transom Windows

Transom windows are horizontal windows placed above doors or other windows. They are often used to bring additional light into a room, especially in spaces where wall space is limited.

Design Considerations:

Ventilation: Some transom windows are operable, providing an opportunity for natural ventilation, which can improve indoor air quality and comfort.

Aesthetic Integration: Transom windows can be designed to complement the overall architectural style, enhancing both daylighting and aesthetic appeal.

4.Light Shelves

Light shelves are horizontal surfaces, typically installed above windows, that reflect sunlight deeper into a room.

Design Considerations:

Material and Reflectivity: Light shelves should be made from highly reflective materials, such as polished metal or white surfaces, to effectively bounce light into the room.

Positioning: Light shelves should be positioned to intercept direct sunlight and redirect it upwards towards the ceiling. This reduces glare and spreads light more evenly.

5.Solar Shading Devices

These devices, such as overhangs, louvers, and brise-soleil are designed to control the amount of sunlight entering through windows.

Design Considerations:

Fixed Shading: Fixed overhangs or louvers are designed based on the sun's path, blocking high summer sun while allowing lower winter sun to enter.

Adjustable Shading: Adjustable shading devices, like operable louvers or blinds, offer flexibility to control daylight throughout the day and seasons.

3.2. Design Considerations for Side Lighting

1.Orientation and Climate

The orientation of the building and its windows relative to the sun's path significantly impacts the effectiveness of side lighting.

North-Facing Windows: These provide diffuse, consistent daylight without direct sun exposure, making them ideal for reducing glare and heat gain.

South-Facing Windows: These capture direct sunlight, especially in winter. They are beneficial for passive solar heating but may require shading to prevent overheating in summer.

East-Facing Windows: These windows receive early morning sunlight, which can be intense but short-lived. They are suitable for spaces like kitchens or breakfast areas.

West-Facing Windows: These capture the late afternoon sun, which can cause glare and overheating. Careful shading or tinting is often necessary.

2.Glazing Options

The choice of glazing affects both the quality of daylight and the energy efficiency of the building.

Low-E (Low Emissivity) Glass: Coated with a thin metallic layer, low-E glass reduces heat transfer while allowing ample daylight. It’s particularly effective in controlling solar heat gain in hot climates.

Double or Triple Glazing: These options provide better insulation, reducing heat loss in winter and gain in summer. They also help in noise reduction, making the indoor environment more comfortable.

Tinted and Reflective Glass: Tinted glass reduces glare and solar heat gain, while reflective glass can bounce back a significant portion of solar radiation, keeping interiors cooler.

3.Shading Devices

Shading devices are crucial for controlling glare, reducing heat gain, and enhancing visual comfort.

External Shading: Devices like awnings, overhangs, and brise-soleil are placed outside the building to block direct sunlight before it enters the window. They are particularly effective in reducing cooling loads.

Internal Shading: Blinds, curtains, and shades inside the building allow occupants to adjust light levels and privacy. Automated systems can enhance convenience and energy efficiency.

Light Shelves: As mentioned earlier, light shelves help redirect sunlight deeper into the space, reducing the contrast between bright and shaded areas.

4.Reflective Surfaces

Using light-coloured or reflective materials on walls, ceilings, and floors can enhance daylight distribution.

Ceilings: White or light-coloured ceilings reflect more light, helping to spread daylight evenly throughout the room.

Walls: Light-coloured walls enhance the reflectance of daylight, reducing the need for artificial lighting.

Floors: Reflective or light-coloured flooring materials can bounce light back into the room, further improving daylight penetration.

3.3. Benefits of Side Lighting

1.Natural Illumination

Side lighting provides a natural source of light that enhances visibility and reduces the need for artificial lighting, leading to energy savings.

Improved Visual Comfort: Daylight offers a more natural and comfortable light spectrum compared to artificial lighting, reducing eye strain and enhancing occupant comfort.

Enhanced Productivity and Well-being: Studies have shown that access to natural light can improve mood, productivity, and overall well-being.

2.Energy Efficiency

Effective side lighting can significantly reduce energy consumption.

Reduced Artificial Lighting Demand: By maximizing daylight, side lighting reduces the need for electric lighting during the day, leading to energy savings.

Passive Solar Heating: In colder climates, south-facing windows can contribute to passive solar heating, reducing the need for space heating.

3.Aesthetic and Architectural Value

Side lighting can enhance the aesthetic appeal of a building.

Architectural Features: Large windows, glass doors, and light shelves can be used as design elements that add visual interest and connect the indoors with the outdoors.

Daylight as a Design Tool: Architects can use daylight to highlight textures, colours, and architectural details, creating dynamic and visually stimulating spaces.

3.4. Challenges and Solutions

1.Glare

Glare is a common issue with side lighting, particularly in spaces with large windows.

Solution: Use shading devices, such as blinds or external louvers, to control the amount of direct sunlight entering the space. Light shelves can also help by diffusing sunlight and reducing glare.

2. Heat Gain and Loss

Windows can be sources of unwanted heat gain in summer and heat loss in winter.

Solution: Use high-performance glazing, such as low-E or double glazing, to improve thermal performance. External shading devices and insulated window frames can also help mitigate these issues.

3.Privacy Concerns

Large windows can compromise privacy, especially in urban settings.

Solution: Use frosted or tinted glass, external screens, or strategic landscaping to enhance privacy without sacrificing daylight.

4.Uneven Light Distribution

Side lighting can result in uneven light distribution, with bright spots near windows and darker areas deeper in the space.

- **Solution**: Use light shelves, reflective surfaces, and strategic interior layouts to ensure more uniform light distribution throughout the space.

Chapter 4

Case Studies on top lighting and side lighting in Indian Climatic Condition

4.1 Introduction

Daylighting is an essential component of sustainable building design, offering numerous benefits that range from reducing energy consumption to enhancing occupant comfort and well-being. In the context of Indian climatic conditions, where the diversity in weather patterns presents unique challenges, the strategic implementation of daylighting through top lighting and side lighting schemes becomes crucial. These strategies not only optimize the use of natural light but also contribute to the thermal comfort and energy efficiency of buildings.

India's vast and varied geography includes climatic zones such as hot and dry, warm and humid, composite, temperate, and cold, each with its distinct challenges and opportunities for daylighting. Effective daylighting design must consider these climatic factors, as well as the orientation, building typology, and specific use of spaces, to maximize the benefits while minimizing potential drawbacks like glare, overheating, and energy loss.

Top lighting and side lighting are two primary methods used to introduce natural light into buildings. **Top lighting** involves the use of openings in the roof, such as skylights, atriums, or clerestories, to bring daylight into the deeper parts of a building. This method is particularly effective in spaces where uniform light distribution is needed or where wall space for windows is limited. **Side lighting**, on the other hand, utilizes windows or other vertical openings to bring light into a space from the sides. This method is most effective for providing views and ventilation in addition to daylight.

The purpose of this thesis is to evaluate the effectiveness of top lighting and side lighting schemes in various Indian climatic zones. Through a combination of literature review, case studies, and analysis of classroom, this research aims to identify best practices and innovative solutions that enhance daylighting performance in diverse environmental contexts. By exploring how these strategies are applied in real-world scenarios, the study seeks to contribute valuable insights into the design of energy-efficient, sustainable buildings that are well-suited to India's climatic conditions.

4.2 Design Methodology for Classroom of Daylighting in Indian Climatic Conditions

The design methodology for daylighting in Indian climatic conditions involves a systematic approach that integrates climate-specific considerations with architectural and engineering practices. This methodology aims to find the coverage of natural daylight in standard class room. The following steps outline a comprehensive design methodology for both top lighting and side lighting schemes:

1.Site Analysis and Climate Assessment

Climatic Zone Identification:

Determine the specific climatic zone of the project site (e.g., hot and dry, warm and humid, composite, temperate, or cold).

Understand seasonal variations in solar radiation, temperature, humidity, and daylight availability.

Site and Building Orientation:

Analyse the site's orientation relative to the sun's path, considering factors such as sun angles, prevailing winds, and shading from surrounding structures.

Assess the impact of site topography and vegetation on daylight access and shading.

Classroom Context:

Examine the surrounding environment, including adjacent buildings and natural features, to understand their influence on daylighting and shading.

2. Daylighting Goals and Objectives

Functional Requirements:

Define the lighting needs of different spaces based on their function (e.g., offices, classrooms, laboratories, residential areas).

Determine the desired levels of daylight, glare control, and visual comfort for each space.

Energy Efficiency Targets:

Set goals for reducing artificial lighting use and energy consumption through effective daylighting strategies.

Thermal Comfort Considerations:

Establish objectives for maintaining thermal comfort by balancing daylighting with heat gain and loss.

4.3 Designing Tools

To do any kind of work we need some tools, instruments with the help of which we can complete that work in a faster way and with high efficiency.

To design and implement a day-lighting scheme of a classroom, at first, we design a lighting scheme by following, we calculate the daylight availability of that place, geographic location of that place (latitude, longitude), window and roof window size, placement& orientation, room dimension after that we input those in various lighting software available and do the simulation.

It is very much important to simulate the design and compare the results with the standards, before final installation. Software simulation helps us in minimizing the error at the time of final installation and help us in achieving the desired values during the post installation test.

Some lighting design software presently available are listed below:

1. DIALux 4.13
2. DIALux evo
3. AGi32

This software allows us to create a virtual scene where we can input the measured dimensions and the desired space will be created. We can also input daylight availability of that place, geographic location of that place (latitude, longitude), window and roof window size, placement& orientation, room dimension other data to develop a space in which we want to design a lighting scheme. This software also provides comprehensive photometric analysis and lighting calculations, provides 3D modelling capabilities for visualizing light layout, percentage of coverage, illuminance of working plane and many more. We can also generate exportable report for documentation purpose.

Benefits of using lighting simulation software are:

1. By simulating various lighting designs virtually, it reduces the rework needed to correct the mistakes if any, during the installation of the lighting fixtures.

2. Software enables the creation of detailed 3D models of lighting layout and high-quality rendering capabilities provide realistic representations of lighting effect which in turn helps in easy decision making to choose a particular design.

3. Software generates comprehensive reports and documentation, which includes photometric data, lighting calculations, supporting project documentation and regulatory requirements.

4. Simulation provide accurate and precise values of all the parameters of lighting design which allows the designers to visualize how much light we will achieve after installation and to compare the values with the standards.

Some instruments that we use to measure the actual values of the crucial parameters after final installation of the window and roof monitor are as follows:

Luxmeter : It is an instrument which is used to measure the illuminance level of the working plane. We can measure the illuminance level of both the horizontal and vertical plane with this meter. It uses a photoreceptor cell (white circle like structure as shown in Fig7), which captures all the incoming light and then the meter converts this light into electric current, and after measuring the electric current, the device calculates the illuminance value and display the value on the screen in Lux.

fig.7 . A Luxmeter

4.4 Design procedure in Dialux Evo

There are 16 no of classroom design alternative north large window, south large window, east large window, west large window, south medium window, south small window, south large window with overhang, south large window with light-shelf, bilateral large window, skylights, north roof monitor, south roof monitor with baffles, north large window with skylights, south large window with skylights, north small window with skylights, south large window with skylights. Among these 16 classroom design we choose 3 classroom design e.g. classroom with roof window with external louvers (for top lighting scheme) class room with large south facing window (for side lighting scheme), class room with small south facing window and roof light.

Design procedure

Step1: Firstly, we take standard classroom dimension, having a dimension of length 8 meter, width 6 meter & height 2.8 meter(26ft*20ft*10ft), wall thickness is 0.2 meter.

Step 2: Then go to site icon where we can select the geographic location of the classroom by searching the city after searching the city automatically software gives the latitude and longitude of that place If it is not then we have to put latitude and longitude of that that place manually. For Indian climatic condition we choose Kolkata for Tropical wet and dry climate and Delhi for temperate climate.

Step 3: After that, go to aperture icon where we can choose the door and window and place it according to our requirement.

Step 4: To define north direction go to display icon and on it, north direction in very crucial for daylighting design because it defines sun path.

Step 5: To select the grid point on the work plane we have to go calculation object icon and select calculation grid, the distance between two grid point is 1 meter.

Step 6: After that go to light scene icon where we varying the weather condition like clear sky, average sky and over cast sky. Also choose the date and time according to our requirement. Here we take four different date (21.03.24, 21.06.24, 21.09.24, 21.012.24) and three different time (9am ,12pm, 3pm) .

Step 7: Repeat the procedure for each weather condition with date and time.

Step 8: find out the no of grid point which above the 300 lux value as we know for classroom design 300 lux is standard required illuminance.

Step 9: to find out coverage, $\%coverage = \frac{\text{no. of grid point above 300 lux} \times 100}{\text{no. of grid point}}$

1.Simulation of classroom with large south facing window with blinds (for side lighting scheme)

Room dimension – 8m*6m*2.8m
Work plane height– 0.8m
Window dimension- 2.5m*2.5m
Frame thickness-0 .120m
Door dimension-2m*0.9m
No of window-3
Window orientation- south facing
External ventilation blinds- double glazing
Hare, Date- 21.03.24
Time- 9am
Weather condition – clear sky
Location – Kolkata (22.5744° N, 88.3629° E), shown in fig.8

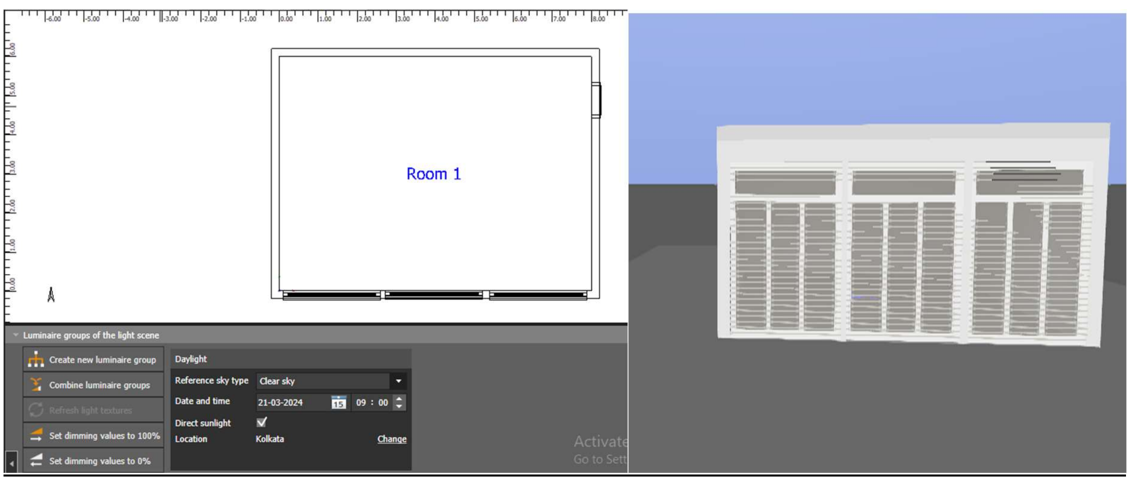


Fig.8 classroom with large south facing window with blinds (for side lighting scheme)

2.Simulation of classroom with roof window with blinds (for Top lighting scheme)

Room dimension – 8m*6m*2.8m
Work plane height– 0.8m
Roof window dimension- 1m*1m
Frame thickness-0 .080m
Mounting height of roof window -2.8m
No of roof window-4
External ventilation blinds- solar triple control glass

Hare, Date- 21.03.24

Time- 9am

Weather condition – clear sky

Location – Kolkata (22.5744° N, 88.3629° E), shown in fig.9

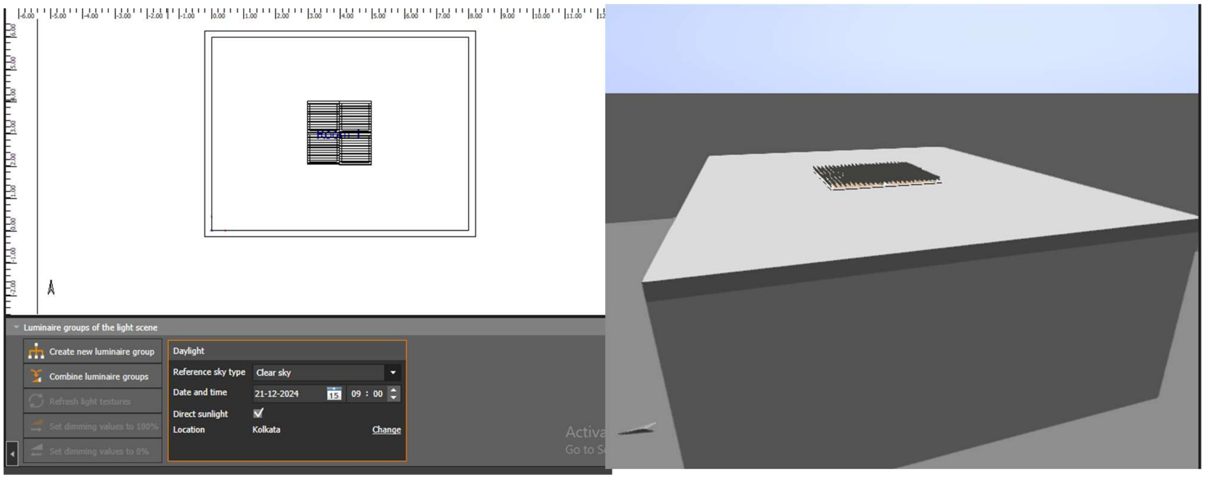


Fig.9 classroom with roof window with blinds (for Top lighting scheme)

3.Simulation of classroom with small south facing window and roof window with blinds

Room dimension – 8m*6m*2.8m

Work plane height– 0.8m

Roof window dimension- 1m*1m

Frame thickness-0 .080m

Mounting height of roof window -2.8m

No of roof window-2

Window dimension- 1.5m*1.5m

Frame thickness-0 .120m

Door dimension-2m*0.9m

No of window-2

External ventilation blinds- solar triple control glass

Hare, Date- 21.06.24

Time- 9am

Weather condition – clear sky

Location – Kolkata (22.5744° N, 88.3629° E) shown in fig.10

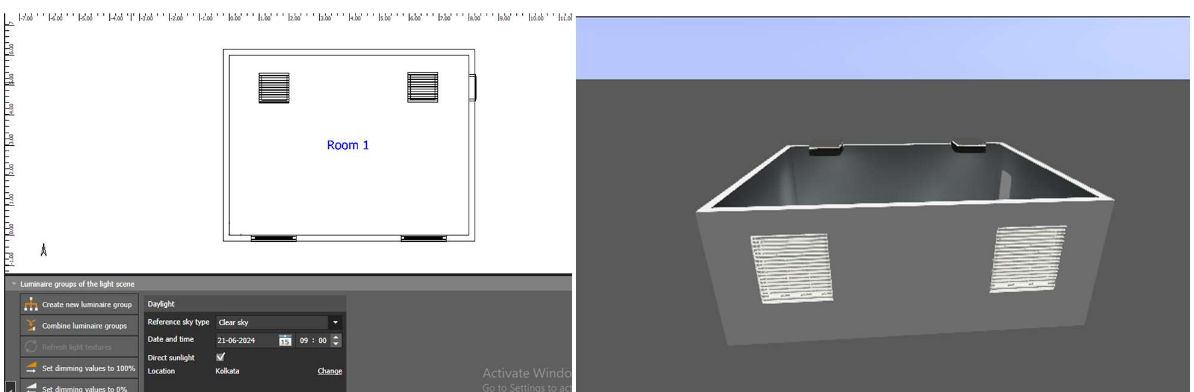


Fig.10classroom with small south facing window and roof window with blinds

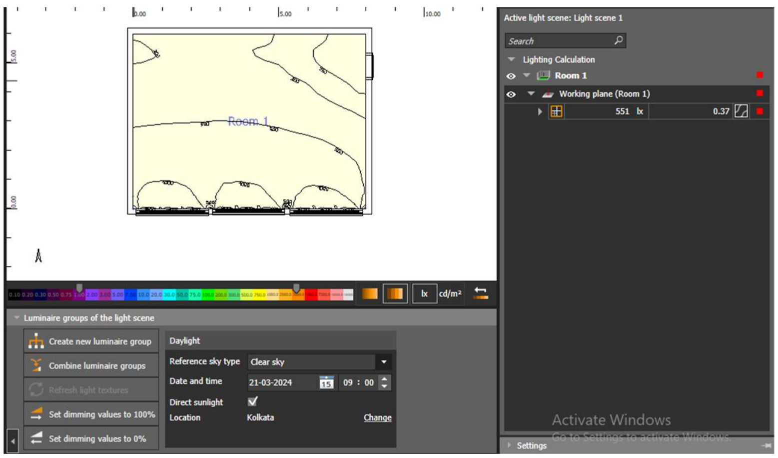
4.5 Results

We have done the simulation for the location Kolkata (22.5744° N, 88.3629° E) for tropical wet and dry climate and Delhi (28.7041° N, 77.1025° E) for temperate climate. For each location we run the simulation and calculation for the date21.03.24, 21.06.24, 21.09.24, & 21.012.24, time 9am,12pm,3pm with three different weather condition i.e. clear sky, average sky, over cast sky.

1.Simulation result of classroom with large south facing window with blinds (for side lighting scheme)

Simulation result for Kolkata, clear sky, 9am,21.03.24 shown in fig11

The average illuminance, no of grid point above the 300 lux ,% of coverage is depicted in table 1 for classroom with large south facing window with blinds (for side lighting scheme), for tropical wet and dry climate(Kolkata).



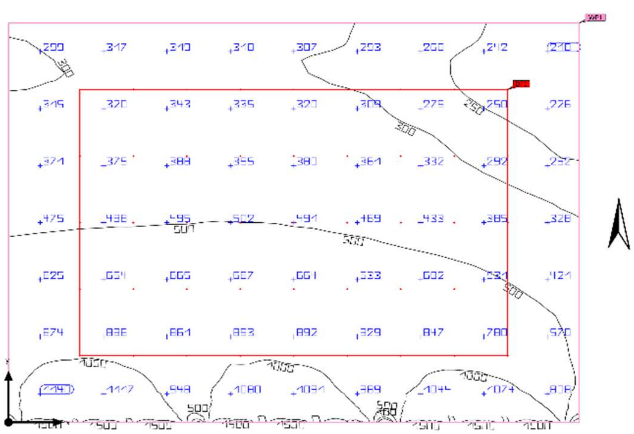


Fig11. Simulation results classroom with large south facing window with blinds (for side lighting scheme)

Classroom with large south facing window with blinds (for side lighting scheme), Kolkata								
Date	Weather condition	Time	E (Avg)Lux	E (Max)lux	E (Min)Lux	No of grid point above 300 Lux	No of grid point below 300 Lux	% of coverage
21.03.2024	Clear Sky	9:00 AM	551	1140	210	53	10	84
		12:00 PM	599	1217	248	59	4	93
		3:00 PM	393	785	157	32	31	50
	Average Sky	9:00 AM				60	3	95
		12:00 PM				61	2	96
		3:00 PM				34	29	53
	Overcast Sky					10	53	15
21.06.2024	Clear Sky	9:00 AM	319	645	150	26	37	41
		12:00 PM	315	643	148	26	37	41
		3:00 PM	294	579	140	25	38	39
	Average Sky	9:00 AM	383	857	135	32	31	50
		12:00 PM	206	459	80	17	46	26
		3:00 PM	393	888	136	32	31	50
	Overcast Sky		204	466	77	17	46	26
21.09.2024	Clear Sky	9:00 AM	556	1136	215	55	8	87
		12:00 PM	589	1203	243	54	7	85
		3:00 PM	361	761	140	32	31	50
	Average Sky	9:00 AM	730	1628	241	60	3	95
		12:00 PM	645	1426	232	56	7	88
		3:00 PM	392	885	133	33	30	52
	Overcast Sky		158	361	60	9	54	14
21.12.2024	Clear Sky	9:00 AM	2954	8961	426	63	0	100
		12:00 PM	1896	4028	557	63	0	100
		3:00 PM	1300	3376	233	55	8	87
	Average Sky	9:00 AM	1916	5261	364	63	0	100
		12:00 PM	999	2206	365	63	0	100
		3:00 PM	229	486	79	17	46	26
	Overcast Sky		995	227	38	0	63	0

Table 1 Classroom with large south facing window with blinds (for side lighting scheme), Kolkata

The average illuminance, no of grid point above the 300 lux ,% of coverage is depicted in table 2 for classroom with large south facing window with blinds (side lighting scheme), Temperate climate(Delhi).

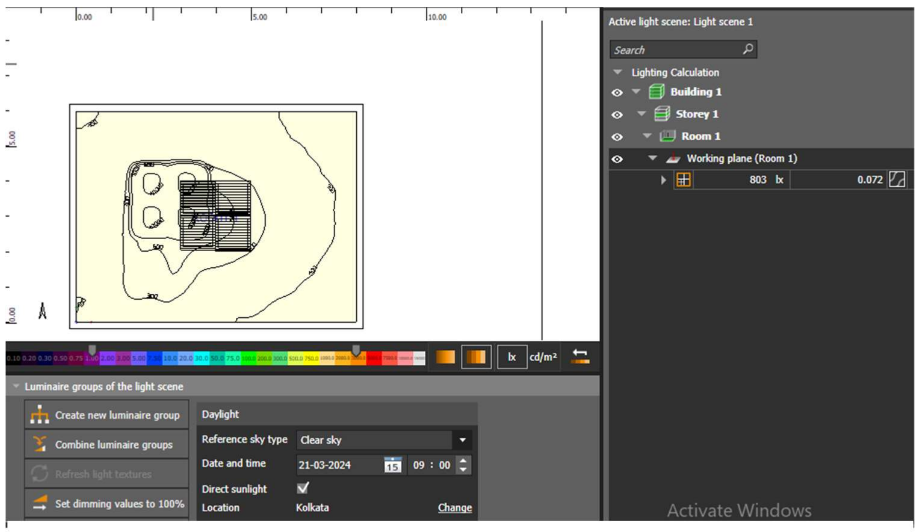
Classroom with large south facing window with blinds (for side lighting scheme), Delhi								
Date	Weather condition	Time	E (Avg)Lux	E (Max)lux	E (Min)Lux	No of grid point above 300 Lux	No of grid point below 300 Lux	% of coverage
21.03.2024	Clear Sky	9:00 AM	582	1290	211	55	8	87
		12:00 PM	819	1456	408	63	0	100
		3:00 PM	574	1256	212	54	9	85
	Average Sky	9:00 AM	707	1603	238	58	5	92
		12:00 PM	703	1602	274	53	4	93
		3:00 PM	634	1370	214	54	9	85
	Overcast Sky		210	478	79	16	47	30
21.06.2024	Clear Sky	9:00 AM	333	686	147	26	37	41
		12:00 PM	340	702	162	27	36	43
		3:00 PM	330	673	148	26	37	41
	Average Sky	9:00 AM	480	1099	468	27	36	42
		12:00 PM	254	572	107	18	45	28
		3:00 PM	482	1099	163	35	28	55
	Overcast Sky		250	571	95	19	44	70
21.09.2024	Clear Sky	9:00 AM	579	1218	212	56	7	88
		12:00 PM	180	1461	397	63	0	100
		3:00 PM	537	1189	202	52	11	82
	Average Sky	9:00 AM	742	1630	247	60	3	95
		12:00 PM	141	1740	342	63	0	100
		3:00 PM	628	1367	213	56	7	88
	Overcast Sky		197	449	75	16	47	25
21.12.2024	Clear Sky	9:00 AM	612	1318	191	54	9	62
		12:00 PM	860	1806	386	63	0	100
		3:00 PM	541	1232	169	50	13	79
	Average Sky	9:00 AM	455	981	155	35	28	55
		12:00 PM	979	2159	391	63	0	100
		3:00 PM	350	751	124	27	63	42
	Overcast Sky		121	276	46	0	63	0

Table 2 Classroom with large south facing window with blinds (for side lighting scheme), Delhi

2.Simulation result of classroom with roof window with blinds (for Top lighting scheme)

Simulation result for Kolkata, clear sky, 9am,2103.24 shown in fig12

The average illuminance, no of grid point above the 300 lux ,% of coverage is depicted in table 3 for classroom with large south facing window with blinds (for side lighting scheme), for tropical wet and dry climate (Kolkata)



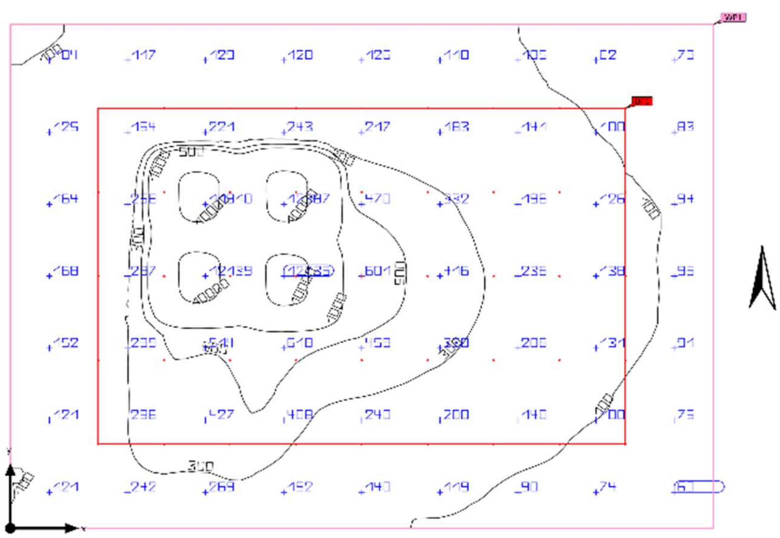


Fig12 simulation result of classroom with roof window with blinds (for Top lighting scheme), Kolkata

Classroom with roof window with blinds (for Top lighting scheme), Kolkata								
Date	Weather condition	Time	E (Avg)Lux	E (Max)lux	E (Min)Lux	No of grid point above 300 Lux	No of grid point below 300 Lux	% of coverage
21.03.2024	Clear Sky	9:00 AM	803	12910	60	14	49	22
		12:00 PM	470	4544	37	16	47	25
		3:00 PM	160	924	28	8	55	12
	Average Sky	9:00 AM	540	7092	45	16	47	25
		12:00 PM	376	3005	32	16	47	25
		3:00 PM	107	490	11	5	58	7
	Overcast Sky		77	424	7.3	4	59	6
21.06.2024	Clear Sky	9:00 AM	399	2669	31	13	50	20
		12:00 PM	206	1297	22	12	51	19
		3:00 PM	537	7147	53	16	47	25
	Average Sky	9:00 AM	364	1870	31	15	48	23
		12:00 PM	268	1906	24	14	49	22
		3:00 PM	374	3719	38	14	49	22
	Overcast Sky		9.4	498	8.6	6	57	9
21.09.2024	Clear Sky	9:00 AM	338	2935	33	14	49	22
		12:00 PM	458	2635	37	16	47	22
		3:00 PM	136	762	25	6	57	9
	Average Sky	9:00 AM	312	2225	32	15	48	23
		12:00 PM	371	2955	32	15	48	23
		3:00 PM	130	432	19	9	54	14
	Overcast Sky		70.5	386	6.7	3	60	4
21.12.2024	Clear Sky	9:00 AM	122	482	16	7	56	11
		12:00 PM	141	589	19	12	51	19
		3:00 PM	43.1	144	6.2	0	63	0
	Average Sky	9:00 AM	145	580	17	10	53	15
		12:00 PM	175	785	19	12	51	19
		3:00 PM	44.9	190	5.6	0	63	0
	Overcast Sky		44.3	243	4.3	0	63	0

Table 3 Classroom with roof window with blinds (for Top lighting scheme), Kolkata

The average illuminance, no of grid point above the 300 lux ,% of coverage is depicted in table 4 Classroom with roof window with blinds (Top lighting scheme), Temperate climate(Delhi).

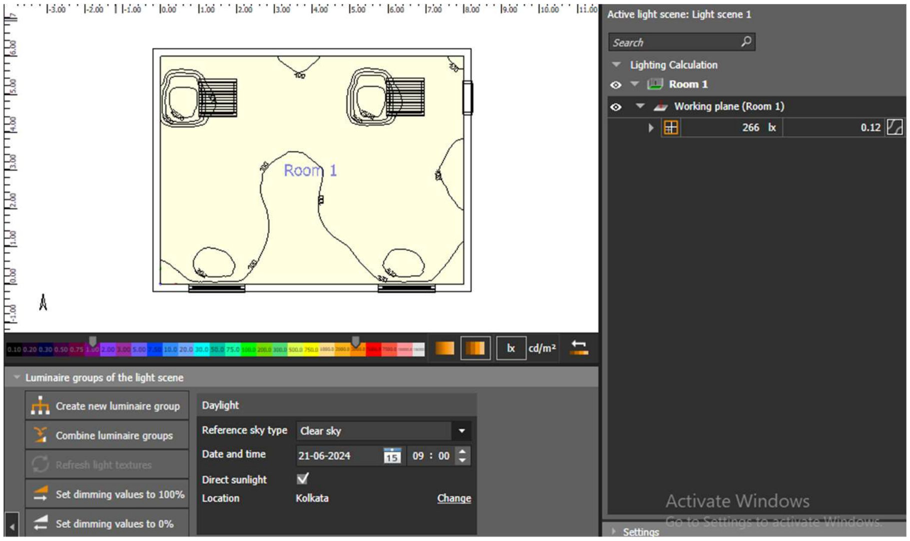
Classroom with roof window with blinds (for Top lighting scheme), Delhi								
Date	Weather condition	Time	E (Avg)Lux	E (Max)lux	E (Min)Lux	No of grid point above 300 Lux	No of grid point below 300 Lux	% of coverage
21.03.2024	Clear Sky	9:00 AM	189	762	26	15	48	23
		12:00 PM	563	3858	45	18	45	28
		3:00 PM	183	998	25	12	51	19
	Average Sky	9:00 AM	200	627	26	15	48	23
		12:00 PM	418	2077	37	18	45	28
		3:00 PM	194	718	23	16	47	25
	Overcast Sky		93.4	511	8.8	6	57	9
21.06.2024	Clear Sky	9:00 AM	604	7059	45	15	48	23
		12:00 PM	1012	10245	62	14	49	22
		3:00 PM	559	7158	45	12	51	19
	Average Sky	9:00 AM	455	4498	38	17	46	26
		12:00 PM	666	3475	44	15	48	23
		3:00 PM	425	4345	36	17	46	26
	Overcast Sky		112	610	11	7	56	11
21.09.2024	Clear Sky	9:00 AM	204	909	27	16	47	25
		12:00 PM	556	2206	43	18	45	28
		3:00 PM	190	1143	35	9	54	14
	Average Sky	9:00 AM	217	809	28	18	45	28
		12:00 PM	415	2065	35	19	44	30
		3:00 PM	188	657	28	17	46	26
	Overcast Sky		877	480	8.3	6	57	9
21.12.2024	Clear Sky	9:00 AM	73.3	223	10	0	63	0
		12:00 PM	137	559	16	11	52	17
		3:00 PM	59.4	189	8.5	0	63	0
	Average Sky	9:00 AM	81.8	327	10	2	61	3
		12:00 PM	159	678	18	11	52	17
		3:00 PM	64.3	264	8	0	63	0
	Overcast Sky		92.4	606	7	9	56	11

Table 4 Classroom with roof window with blinds (for Top lighting scheme), Delhi

1.Simulation result of classroom with small south facing window and roof window with blinds

Simulation result for Kolkata, clear sky, 9am 21.06.24 shown in fig13

The average illuminance, no of grid point above the 300 lux ,% of coverage is depicted in table 5 for classroom with large south facing window with blinds (for side lighting scheme), for tropical wet and dry climate(Kolkata).



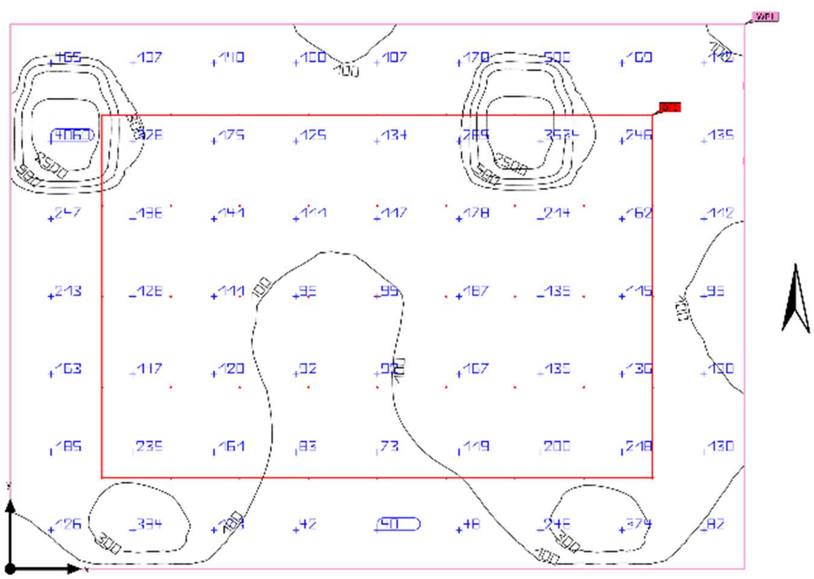


Fig. 13 Simulation results of classroom with small south facing window and roof window with blinds

Classroom with small south facing window and roof window with blinds), Kolkata								
Date	Weather condition	Time	E (Avg)Lux	E (Max)lux	E (Min)Lux	No of grid point above 300 Lux	No of grid point below 300 Lux	% of coverage
21.03.2024	Clear Sky	9:00 AM	493	8455	124	14	49	22
		12:00 PM	357	4977	154	19	44	30
		3:00 PM	155	996	102	4	59	6
	Average Sky	9:00 AM	422	4435	74	25	38	40
		12:00 PM	324	2786	56	19	44	33
		3:00 PM	176	646	33	7	56	11
	Overcast Sky		77.6	256	15	0	63	0
21.06.2024	Clear Sky	9:00 AM	266	4060	40	7	56	11
		12:00 PM	135	413	83	53	58	7
		3:00 PM	108	334	68	2	61	3
	Average Sky	9:00 AM	194	558	70	8	55	12
		12:00 PM	177	1015	53	8	55	12
		3:00 PM	240	694	37	9	54	14
	Overcast Sky		91.1	314	14	2	61	3
21.09.2024	Clear Sky	9:00 AM	282	3433	71	11	52	17
		12:00 PM	349	4814	65	17	46	26
		3:00 PM	109	408	31	2	61	3
	Average Sky	9:00 AM	316	1931	62	22	41	34
		12:00 PM	325	2697	64	21	42	33
		3:00 PM	150	498	27	4	59	6
	Overcast Sky		70.6	223	11	0	63	0
21.12.2024	Clear Sky	9:00 AM	817	9304	150	27	36	42
		12:00 PM	536	4256	183	34	29	53
		3:00 PM	321	4497	76	15	48	23
	Average Sky	9:00 AM	555	5305	117	25	38	39
		12:00 PM	309	1522	186	17	46	26
		3:00 PM	73.9	320	17	1	62	1
	Overcast Sky		44.4	147	67	0	63	0

Table 5Classroom with small south facing window and roof window with blinds), Kolkata

The average illuminance, no of grid point above the 300 lux ,% of coverage is depicted in table 6 Classroom with small south facing window and roof window with blinds), Temperate climate(Delhi). .

Classroom with small south facing window and roof window with blinds),Delhi								
Date	Weather condition	Time	E (Avg.)Lux	E (Max)lux	E (Min)Lux	No of grid point above 300 Lux	No of grid point below 300 Lux	% of coverage
21.03.2024	Clear Sky	9:00 AM	203	652	58	6	57	9
		12:00 PM	440	6253	91	26	37	41
		3:00 PM	201	644	70	8	55	12
	Average Sky	9:00 AM	250	259	52	16	47	25
		12:00 PM	390	3227	72	28	35	44
		3:00 PM	246	938	52	14	49	22
	Overcast Sky		93.6	309	14	2	61	3
21.06.2024	Clear Sky	9:00 AM	347	7494	46	8	55	12
		12:00 PM	580	13720	45	7	56	11
		3:00 PM	324	6685	44	6	57	9
	Average Sky	9:00 AM	318	3986	45	16	47	25
		12:00 PM	166	710	21	9	54	14
		3:00 PM	205	633	33	10	53	15
	Overcast Sky		112	369	17	2	61	3
21.09.2024	Clear Sky	9:00 AM	208	664	57	9	54	14
		12:00 PM	435	6184	88	25	38	39
		3:00 PM	197	1249	53	7	56	11
	Average Sky	9:00 AM	266	1022	55	17	46	26
		12:00 PM	387	3376	71	27	36	42
		3:00 PM	228	847	46	11	52	17
	Overcast Sky		87.9	290	13	0	63	0
21.12.2024	Clear Sky	9:00 AM	169	776	32	8	55	12
		12:00 PM	243	1146	40	13	50	20
		3:00 PM	149	674	30	6	57	9
	Average Sky	9:00 AM	453	4810	81	13	50	9
		12:00 PM	813	5481	103	34	29	53
		3:00 PM	363	2598	64	12	51	19
	Overcast Sky		54	178	8.1	0	63	0

Table 5Classroom with small south facing window and roof window with blinds), Delhi

4.6 Analysis

Iso-lux diagrams for top lighting and side lighting, with more focus on how these techniques are impact daylighting performance, particularly in the context of Indian climatic conditions.

4.6.1 Classroom with Roof Widow with Blinds (Top Lighting)

1. Light Distribution:

Uniformity:

Iso-lux Pattern: The Iso-lux contours for top lighting tend to be distributed across the space. In a typical Iso-lux diagram, we'll see almost circular or oval contours centred around the light source. This indicates a gradual reduction in light intensity from the centre towards the edges of the classroom.

%of coverage: For tropical wet and dry climate average percentage of coverage is 20% in Kolkata, for temperate climate average percentage of coverage is 25% in Delhi.

Centralized Brightness:

Iso-lux Pattern: The highest lux levels are typically directly beneath the skylight or roof window, with decreasing levels radiating outwards.

Benefits: Provides sufficient illumination even in deeper parts of the space, ensuring a comfortable visual environment without harsh shadows.

2. Thermal Impact:

Top lighting can lead to increased heat gain, which is a crucial consideration in hot climates. Proper shading devices or selective use of top lighting in the design can help control this. Advanced glazing materials or solar control films can also be employed to minimize heat gain while allowing sufficient daylight.

3. Depth of Light Penetration:

Isolux Pattern: The light penetration in top lighting is effective even in the farthest corners of a space. The isolux diagram will show consistent lighting levels throughout the space, which is particularly useful in spaces that require even illumination.

4.6.2 Classroom with large south facing window with blinds (for side lighting scheme)

1. Light Distribution:

Gradient of Illumination:

Iso-lux Pattern: In side lighting, the Isolux diagram shows more elongated and asymmetrical contours. The contours are denser near the window, indicating higher illuminance, and they spread out as the distance from the window increases.

%of coverage: For tropical wet and dry climate average percentage of coverage is 75% in Kolkata, for temperate climate average percentage of coverage is 85% in Delhi.

2. Thermal Impact:

Side lighting, depending on window size and orientation, can lead to heat loss during winters or heat gain during summers. The design of window openings should consider the balance between daylight access and thermal comfort.

3. Depth of Light Penetration:

Iso-lux Pattern: In side lighting, the light tends to fall off rapidly as you move away from the window. The iso-lux diagram will show closely spaced contours near the window, indicating high illumination, and widely spaced contours further away, indicating lower light levels.

4.6.3 Classroom with small south facing window and roof window with blinds

Light Distribution:

Uniformity:

Iso-lux Pattern: The Iso-lux contours tend to be distributed across the space. In a typical Iso-lux diagram, we'll see almost circular or oval contours centred around the light source under roof window and The contours are denser near the window, indicating higher illuminance, and they spread out as the distance from the window increases for small south facing window.

%of coverage: For tropical wet and dry climate average percentage of coverage is 17% in Kolkata, for temperate climate average percentage of coverage is 28% in Delhi.

4.6.4 Specific Iso-lux Diagram Analysis

Typical Iso-lux Diagram for Top Lighting:

- The diagram would show concentric circles or ellipses with the highest lux level at the centre, decreasing gradually as you move outward.
- The uniformity index (ratio of minimum to average illuminance) tends to be higher, indicating more even light distribution.

Typical Iso-lux Diagram for Side Lighting:

- The diagram would show a dense cluster of is-olux lines near the window with a rapid drop-off in illuminance as you move deeper into the room.
- The uniformity index is usually lower compared to top lighting, indicating less uniform distribution.

CHAPTER 5

Conclusion and future scope

5.1 Conclusion

The choice between top lighting and side lighting should be based on the specific requirements of the space, the desired uniformity of daylight, and the climatic conditions. In Indian climates, where both heat gain and daylight access are critical, a hybrid approach often works best. Combining top and side lighting can provide a balanced daylighting solution, minimizing the disadvantages of each technique while maximizing the benefits.

5.2 Future Scope

The future scope of implementing top and side lighting in daylighting under Indian climatic conditions holds significant potential for innovation and energy efficiency. With the growing emphasis on sustainable architecture, several advanced materials and technologies can be leveraged to optimize daylighting.

1. Advanced Glazing Technologies: Smart glazing, including electrochromic and thermos-schromic windows, can dynamically adjust transparency based on external conditions. This would allow for better control of heat gain and daylight, particularly in hot climates, reducing reliance on artificial cooling and lighting.

2. Integrated Daylighting Systems: Combining top and side lighting with automated shading devices, such as motorized blinds or louvers, can enhance daylight penetration while minimizing glare and overheating. These systems can be controlled by sensors that respond to the intensity and angle of sunlight, ensuring optimal indoor lighting conditions throughout the day.

3. Sustainable Building Design: Future building designs in India may incorporate hybrid daylighting systems, using both top and side lighting tailored to specific climatic zones. For instance, in hot and arid regions, top lighting could be paired with reflective materials and light shelves to diffuse light and reduce heat gain, while in cooler regions, large south-facing windows could be used to maximize passive solar heating.

4. Computational Simulation and AI: The use of advanced simulation tools and AI can optimize daylighting designs by predicting the performance of different lighting strategies under varying climatic conditions. These tools can help architects design buildings that maximize natural light while minimizing energy consumption, tailored to the diverse climatic zones across India.

Overall, the future of daylighting in India lies in the integration of smart technologies, sustainable design practices, and advanced computational tools, enabling buildings to harness natural light more effectively and reduce energy use in a climate-responsive manner.

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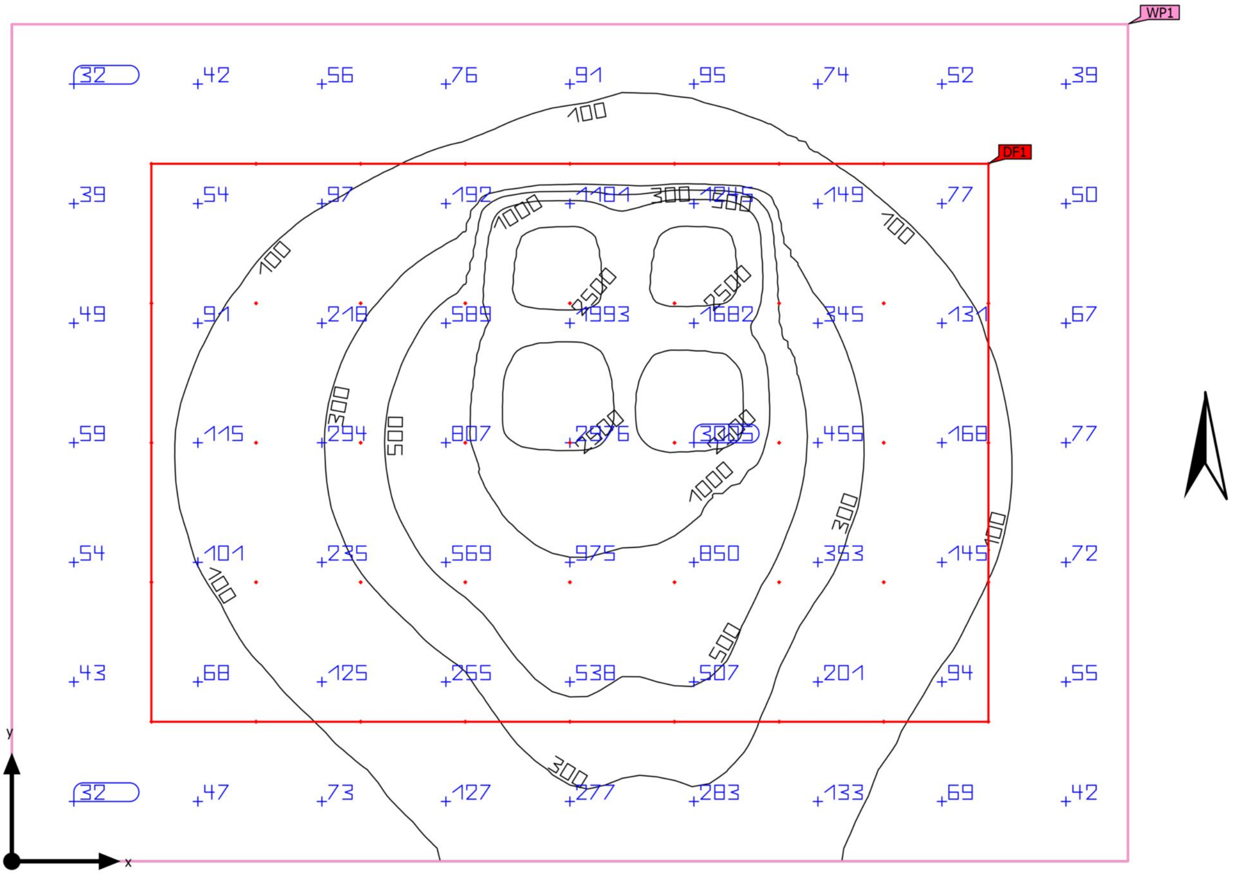
DIALux

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m²
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	0.959 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	376 lx	≥ 500 lx	✗	WP1
	U_o (g_1)	0.078	≥ 0.60	✗	WP1
Energy estimation(2)	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

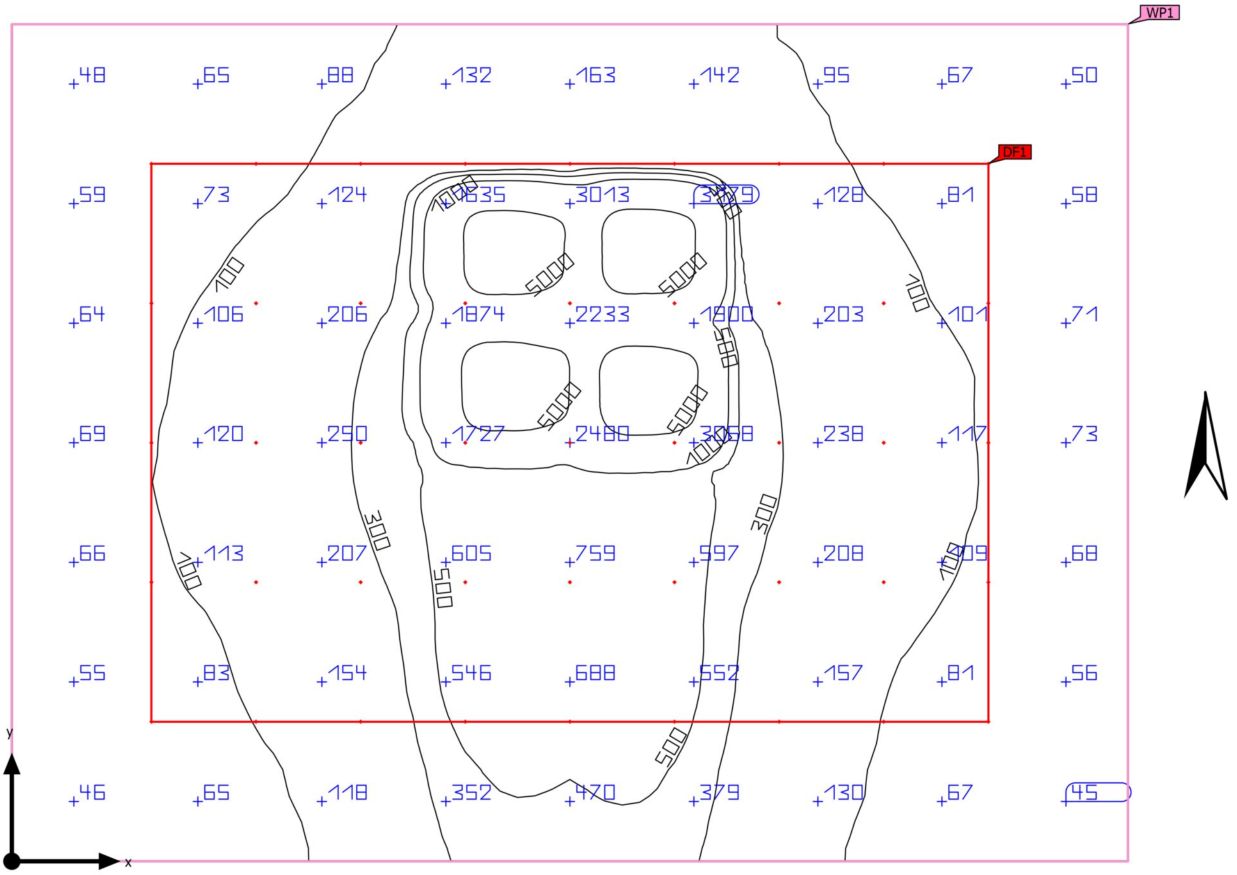
Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Average sky (Direct sunlight) on 21-03-2024 at 12:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

DIALux

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m²
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

DIALux

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	0.959 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	563 lx	≥ 500 lx	✓	WP1
	U_o (g_1)	0.076	≥ 0.60	✗	WP1
Energy estimation[(2)]	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

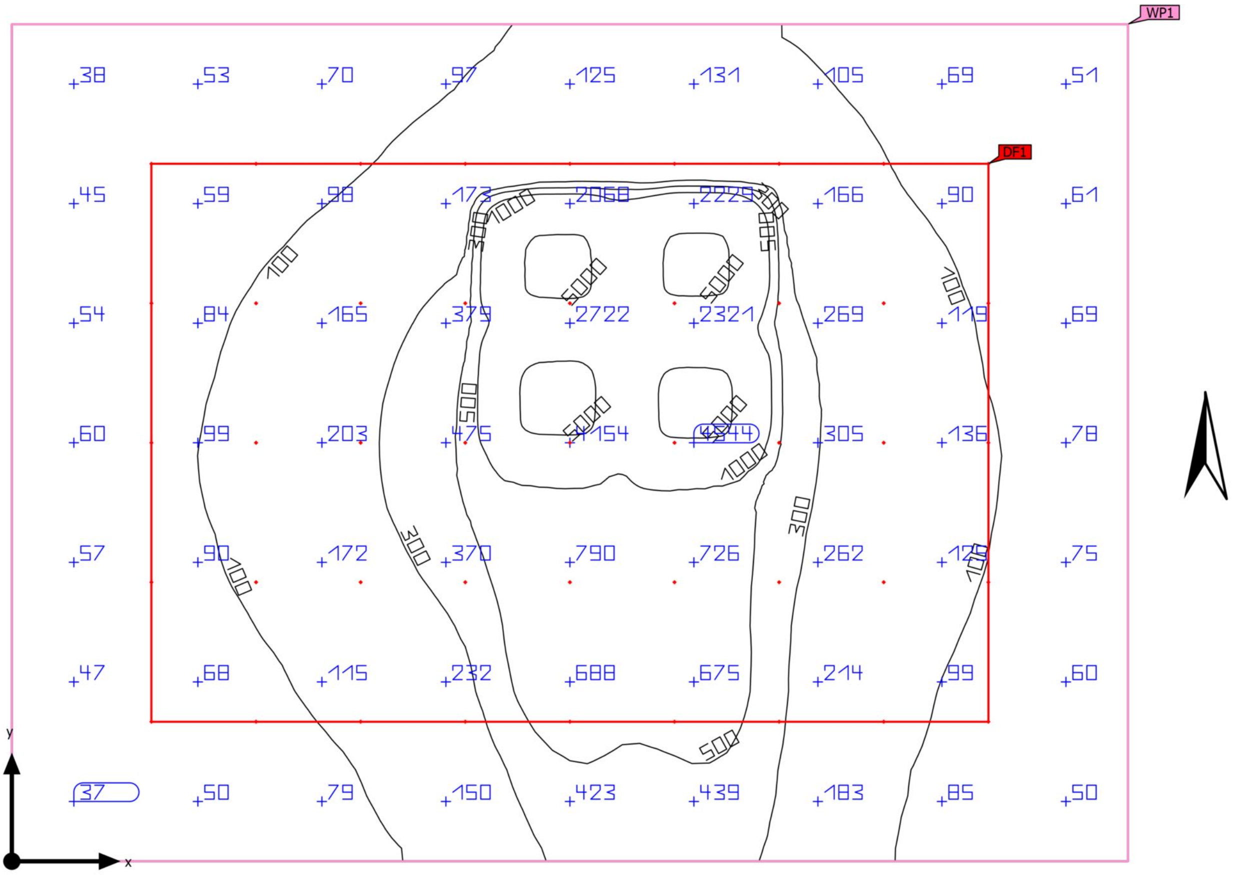
Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Clear sky (Direct sunlight) on 21-03-2024 at 12:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

DIALux

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m^2
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

DIALux

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	0.959 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	470 lx	≥ 500 lx	✗	WP1
	U_o (g_1)	0.073	≥ 0.60	✗	WP1
Energy estimation(2)	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

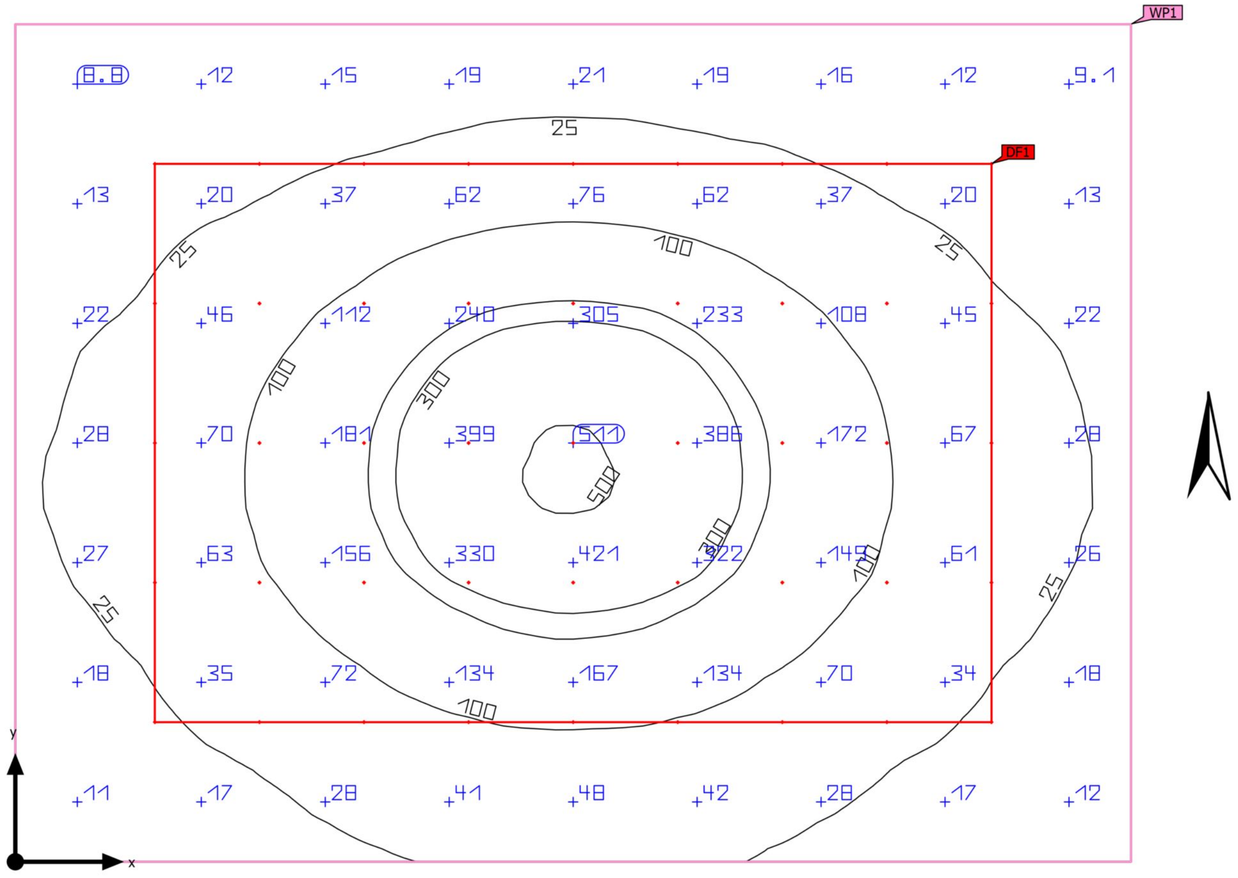
Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Clear sky (Direct sunlight) on 21-03-2024 at 12:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

DIALux

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m²
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	0.959 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	93.4 lx	≥ 500 lx	✗	WP1
	U_o (g_1)	0.087	≥ 0.60	✗	WP1
Energy estimation(2)	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

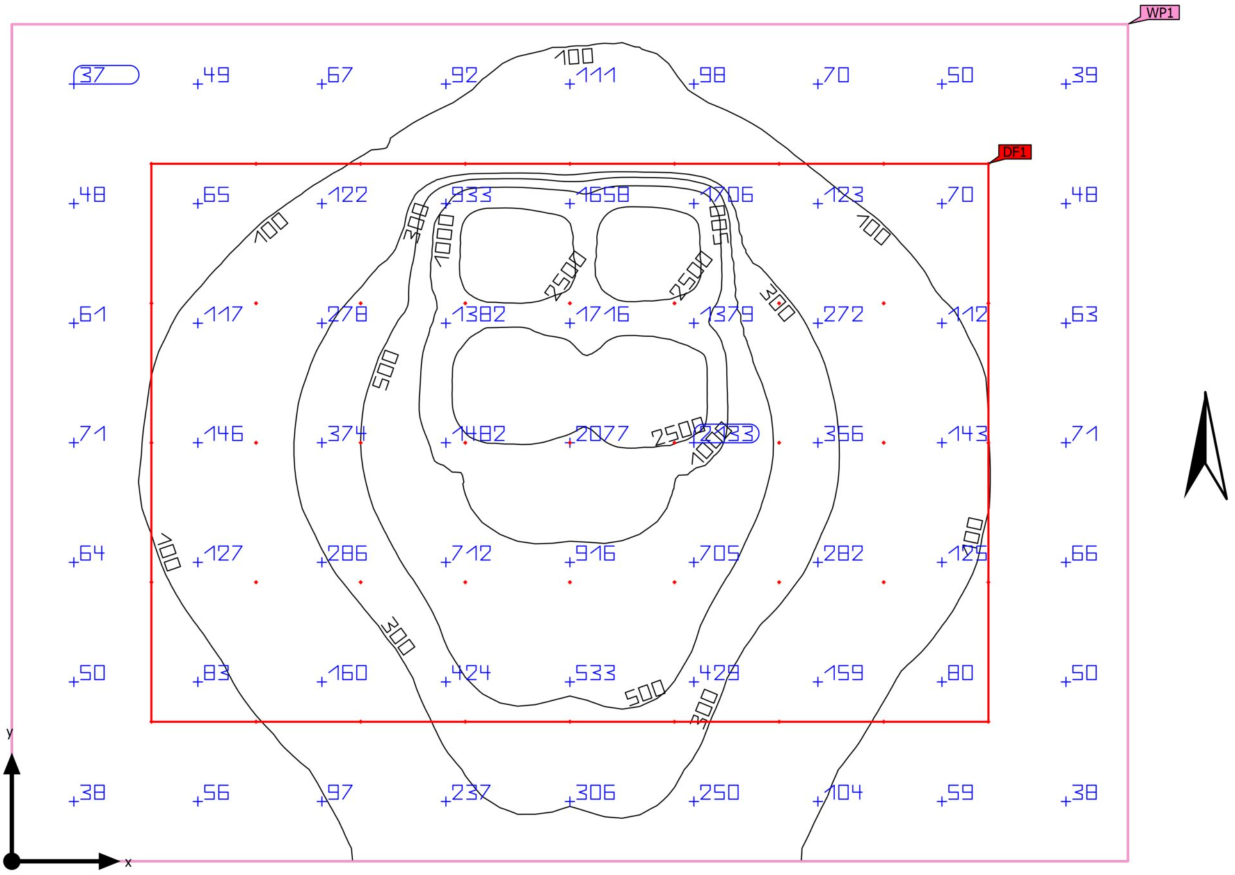
(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Overcast Sky on 21-03-2024 at 15:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m²
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

DIALux

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	0.959 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	418 lx	≥ 500 lx	✗	WP1
	U_o (g_1)	0.084	≥ 0.60	✗	WP1
Energy estimation(2)	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

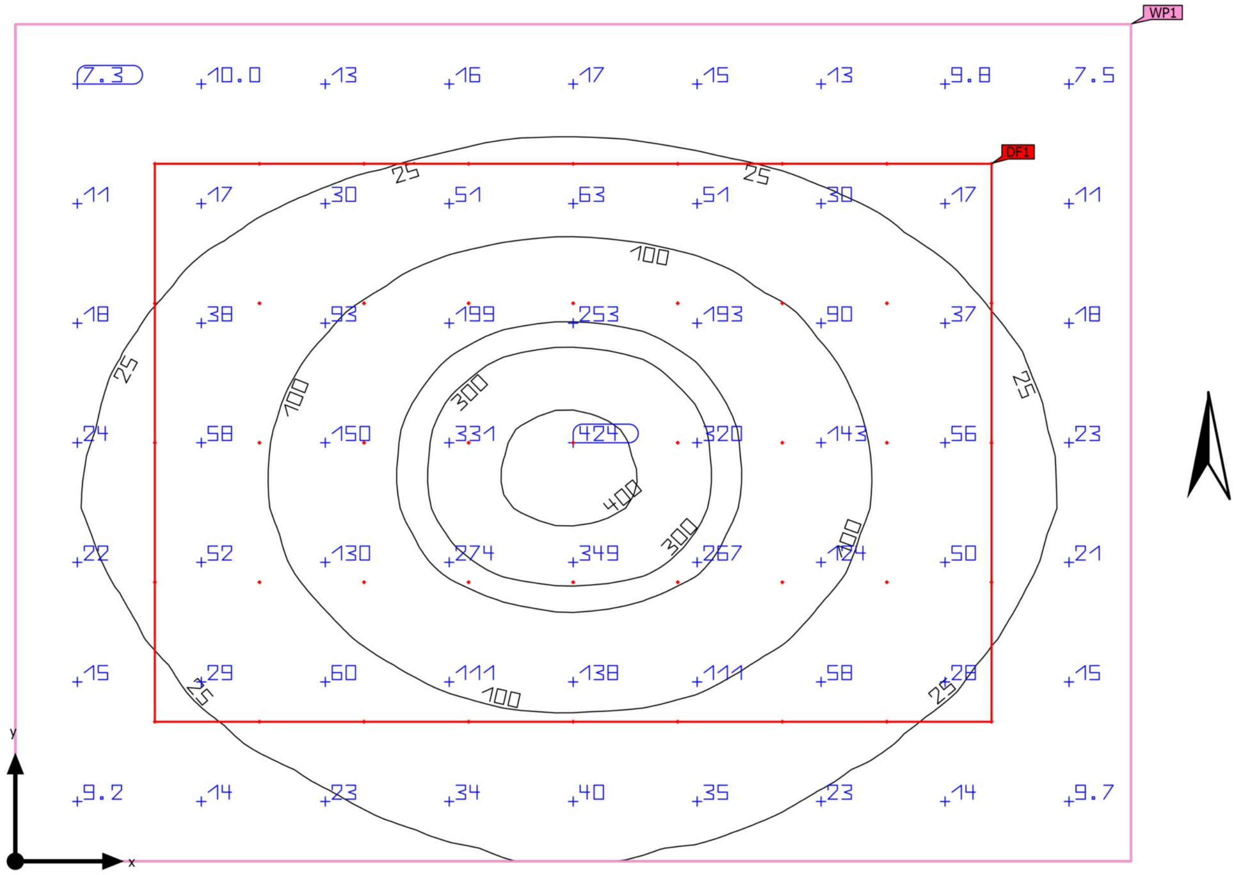
Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Average sky (Direct sunlight) on 21-03-2024 at 12:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

DIALux

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m²
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	0.959 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	77.4 lx	≥ 500 lx	✗	WP1
	U_o (g_1)	0.087	≥ 0.60	✗	WP1
Energy estimation(2)	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

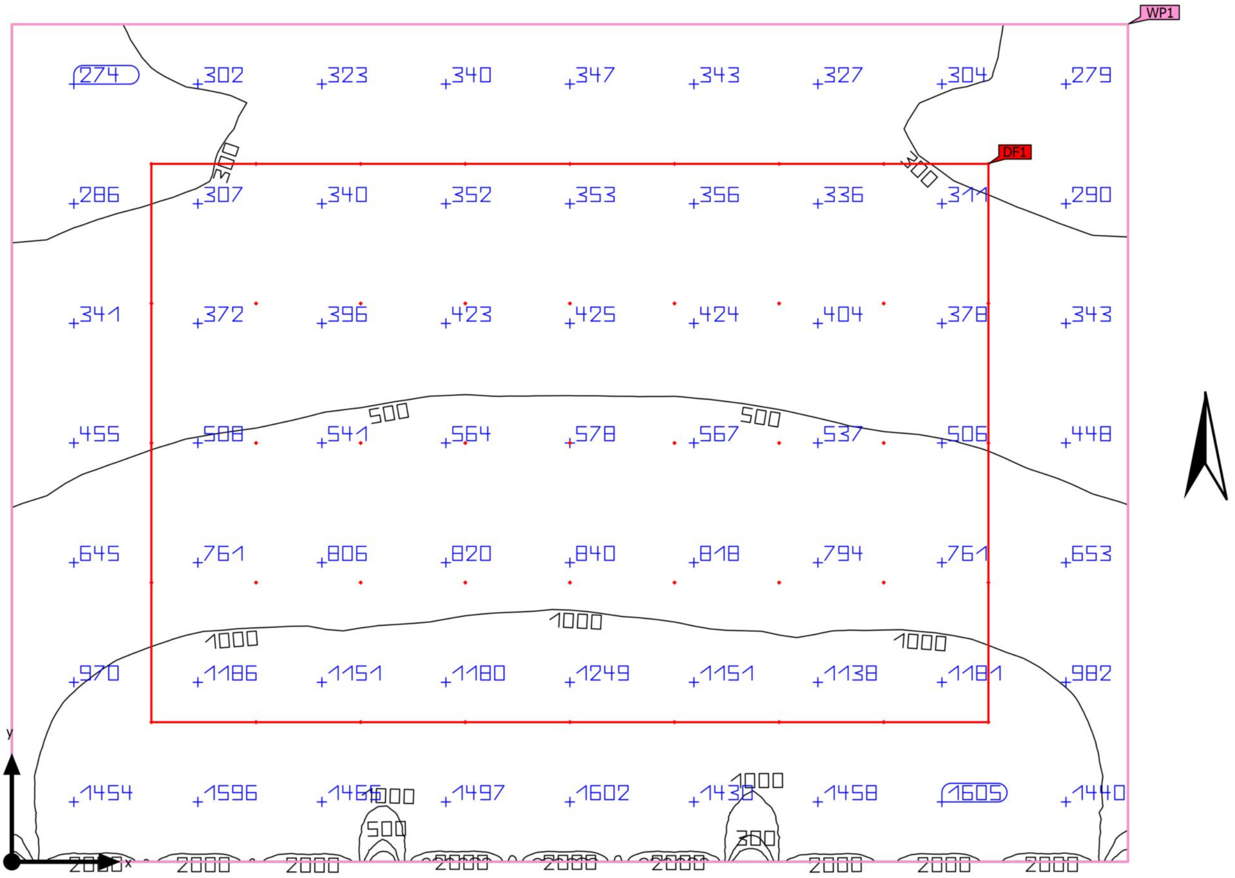
(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Overcast Sky on 21-03-2024 at 15:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m²
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	1.492 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	703 lx	≥ 500 lx	✓	WP1
	U_o (g_1)	0.25	≥ 0.60	✗	WP1
Energy estimation[2]	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

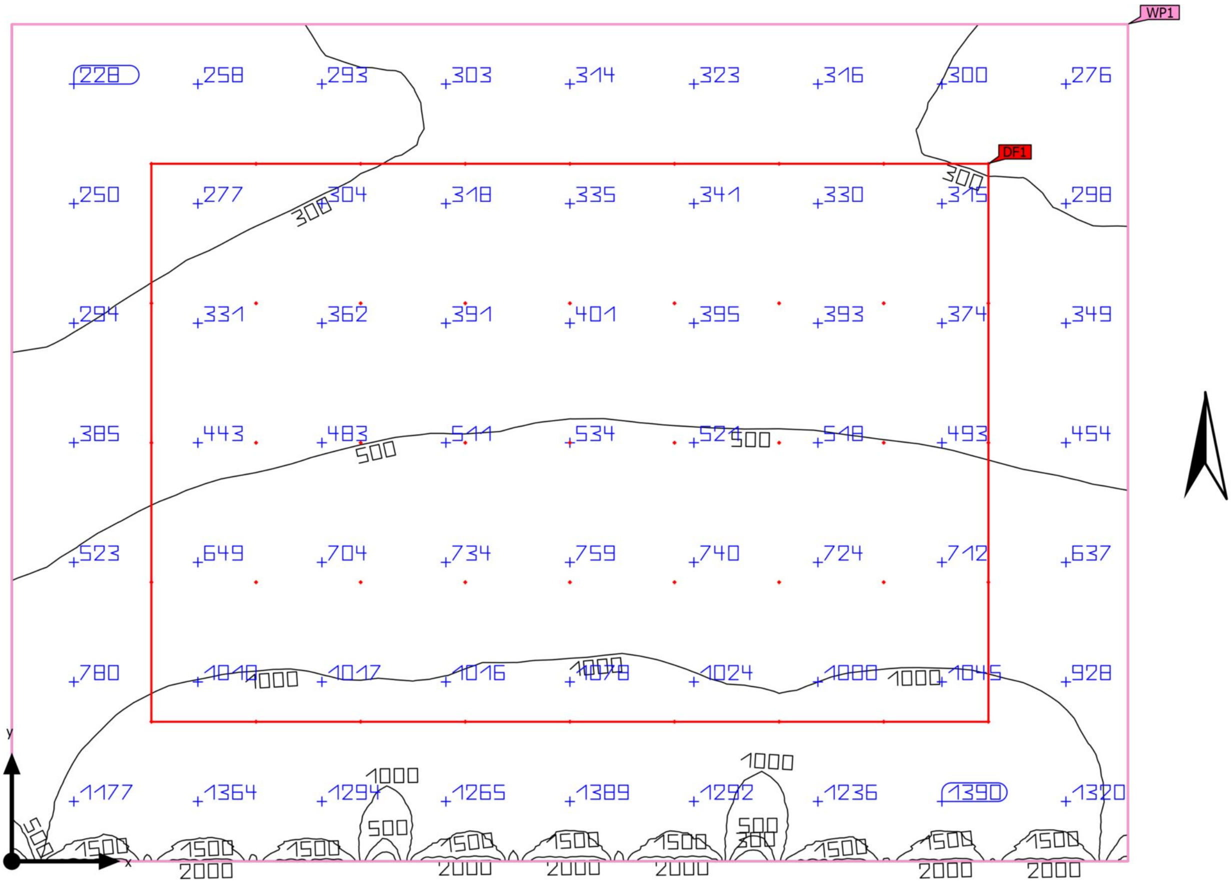
(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Average sky on 21-03-2024 at 12:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m²
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

DIALux

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	1.492 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	628 lx	≥ 500 lx	✓	WP1
	U_o (g_1)	0.34	≥ 0.60	✗	WP1
Energy estimation(2)	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

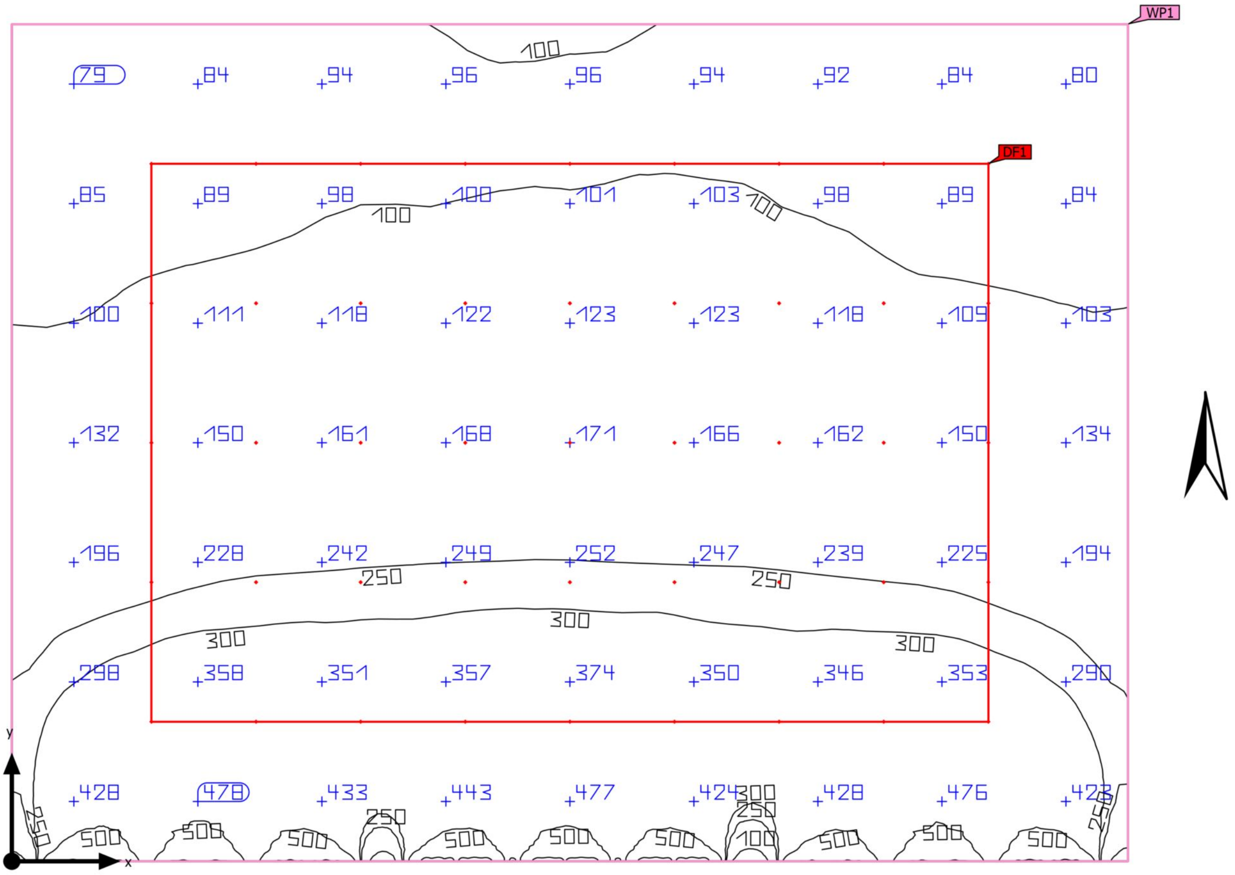
(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Average sky (Direct sunlight) on 21-03-2024 at 12:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m²
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	1.492 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	210 lx	≥ 500 lx	✗	WP1
	U_o (g_1)	0.28	≥ 0.60	✗	WP1
Energy estimation(2)	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

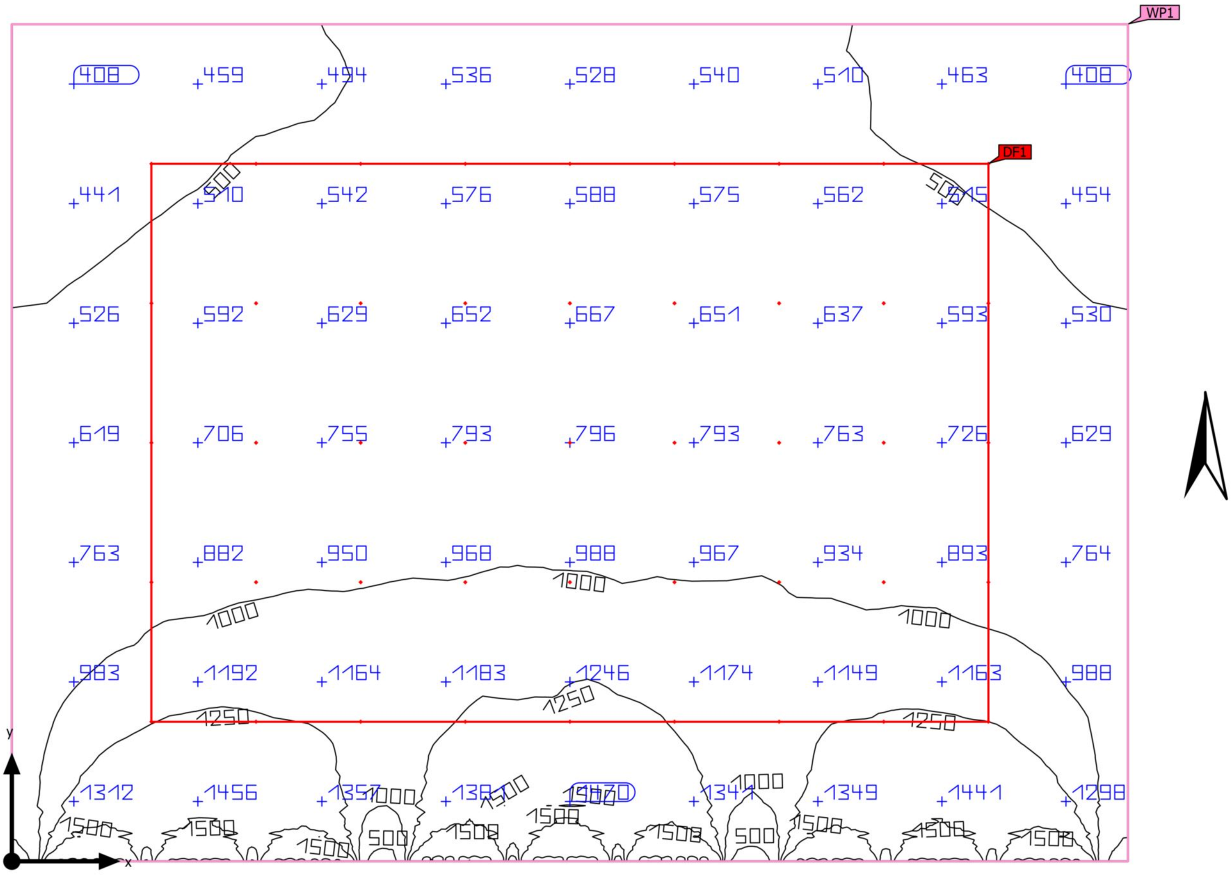
(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Overcast Sky on 21-03-2024 at 15:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m²
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

DIALux

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	1.492 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	819 lx	≥ 500 lx	✓	WP1
	U_o (g_1)	0.44	≥ 0.60	✗	WP1
Energy estimation(2)	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

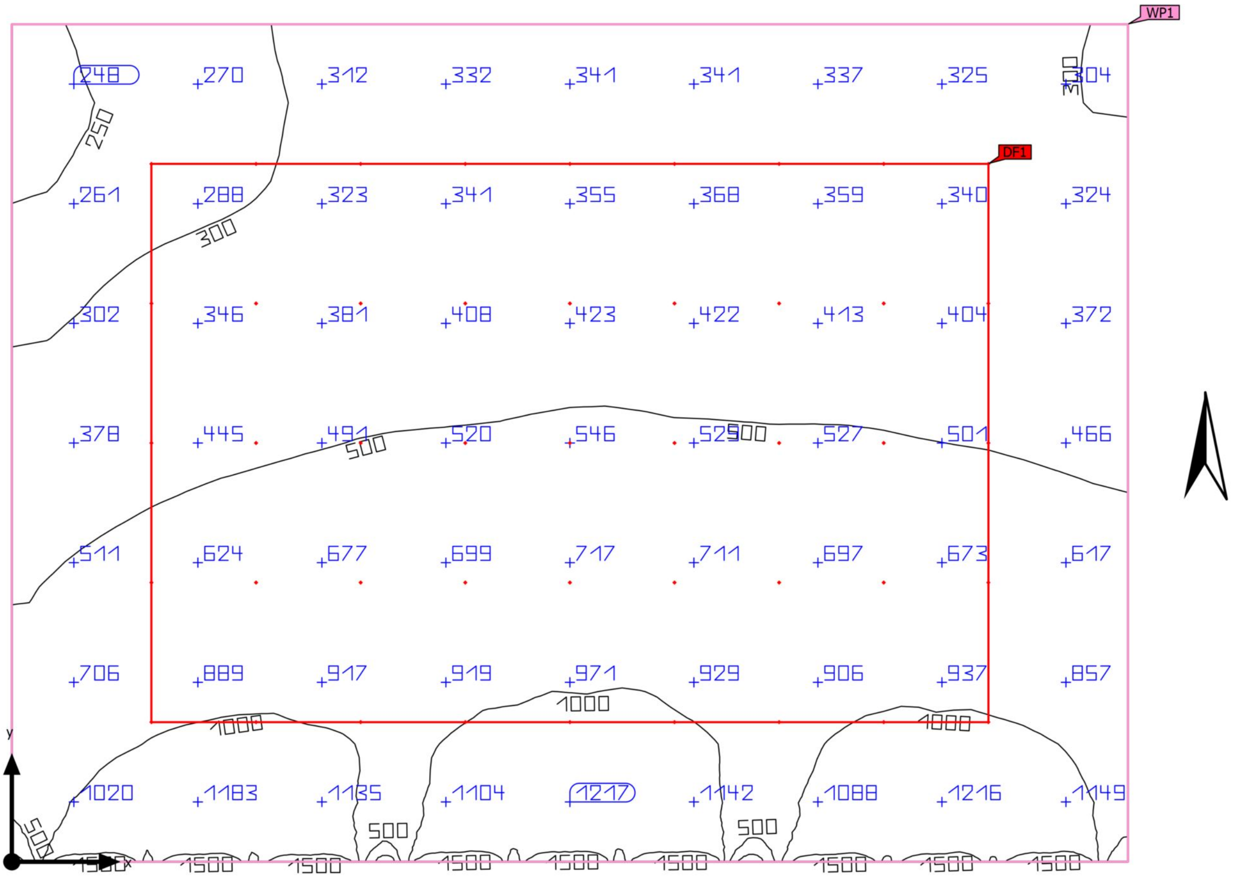
(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Clear sky (Direct sunlight) on 21-03-2024 at 12:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m²
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	1.492 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	599 lx	≥ 500 lx	✓	WP1
	U_o (g_1)	0.40	≥ 0.60	✗	WP1
Energy estimation(2)	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

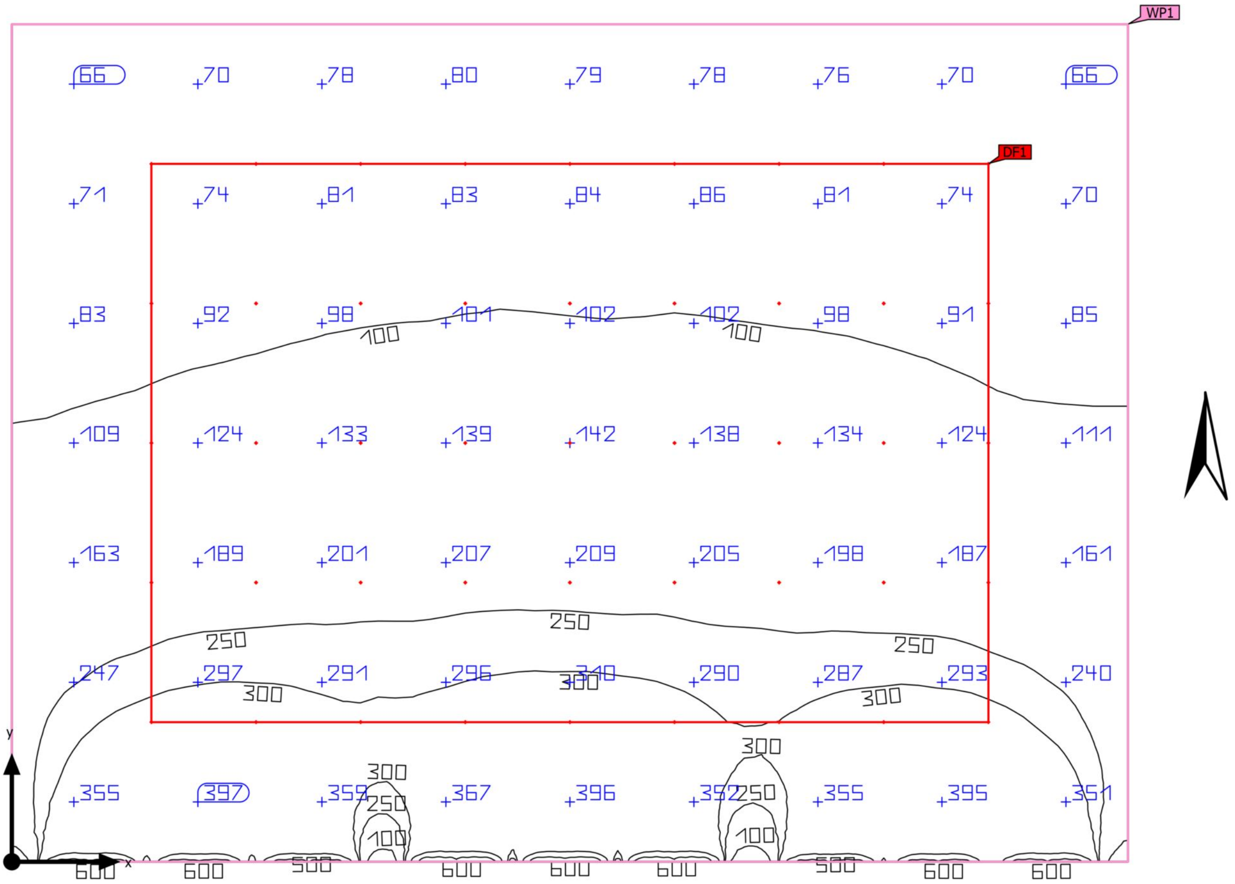
(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Clear sky (Direct sunlight) on 21-03-2024 at 12:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m^2
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	1.492 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	174 lx	≥ 500 lx	✗	WP1
	U_o (g_1)	0.28	≥ 0.60	✗	WP1
Energy estimation(2)	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

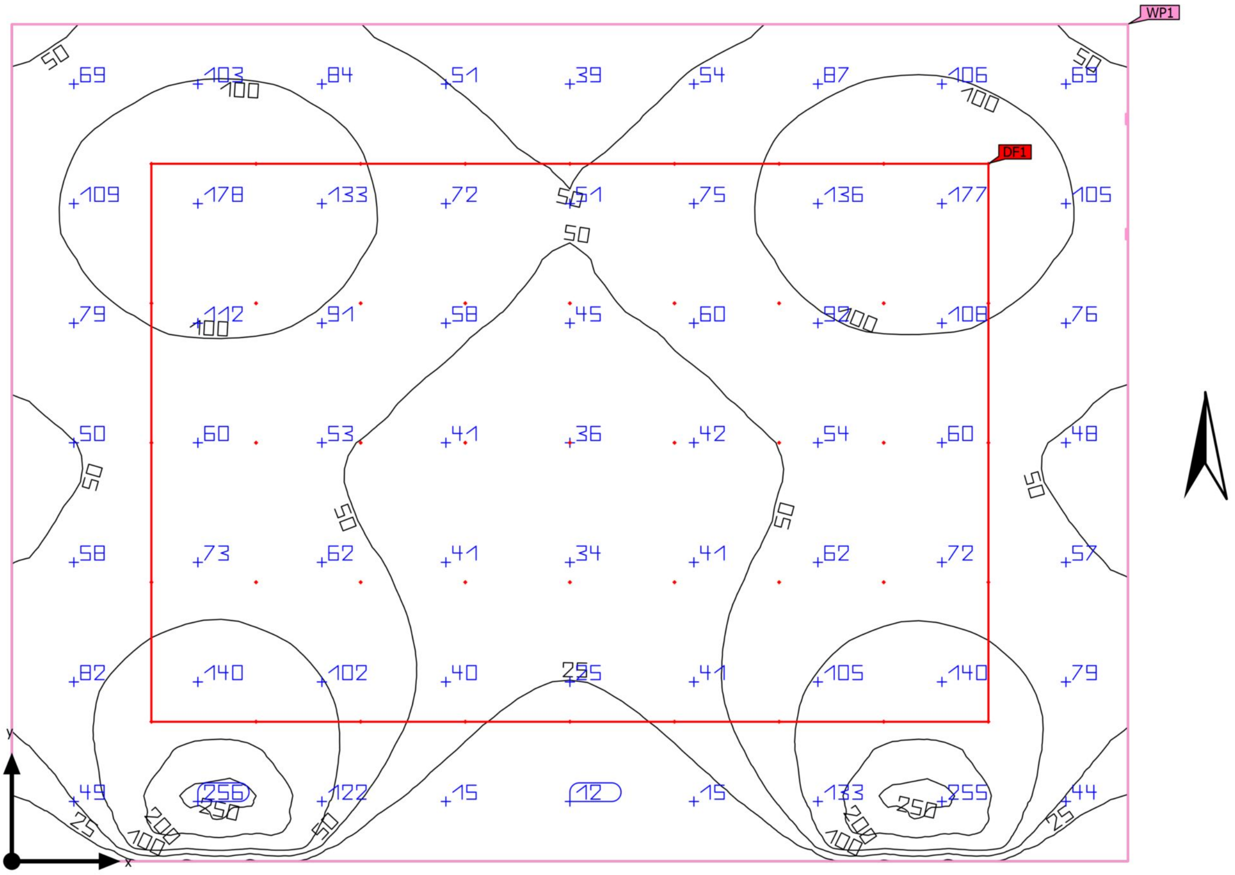
Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Overcast Sky on 21-03-2024 at 15:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

DIALux

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m²
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	0.748 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	77.6 lx	≥ 500 lx	✗	WP1
	U_o (g_1)	0.14	≥ 0.60	✗	WP1
Energy estimation(2)	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

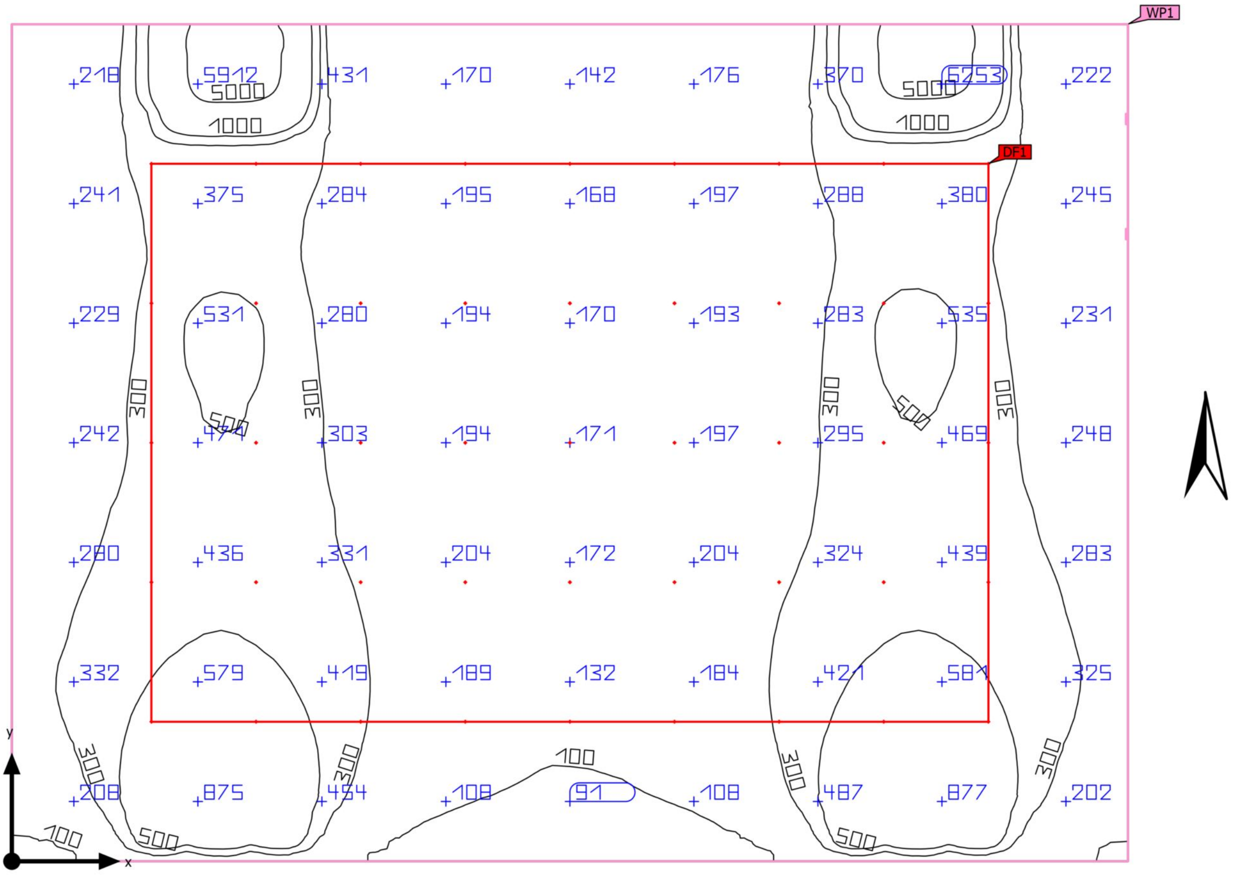
(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Overcast Sky on 21-03-2024 at 15:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m²
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	0.748 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	440 lx	≥ 500 lx	✗	WP1
	U_o (g_1)	0.19	≥ 0.60	✗	WP1
Energy estimation(2)	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

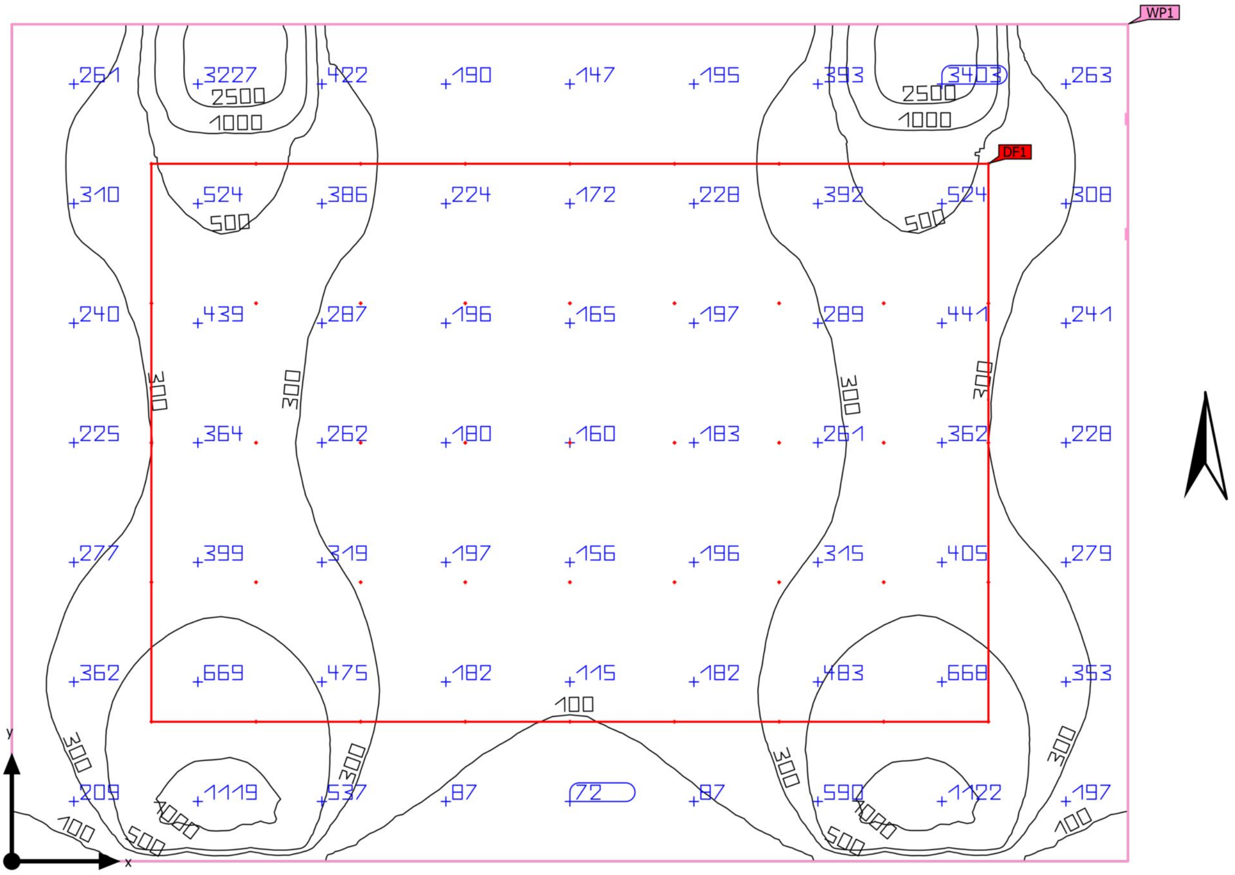
(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Clear sky (Direct sunlight) on 21-03-2024 at 12:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m²
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	0.748 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	390 lx	≥ 500 lx	✗	WP1
	U_o (g_1)	0.17	≥ 0.60	✗	WP1
Energy estimation(2)	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

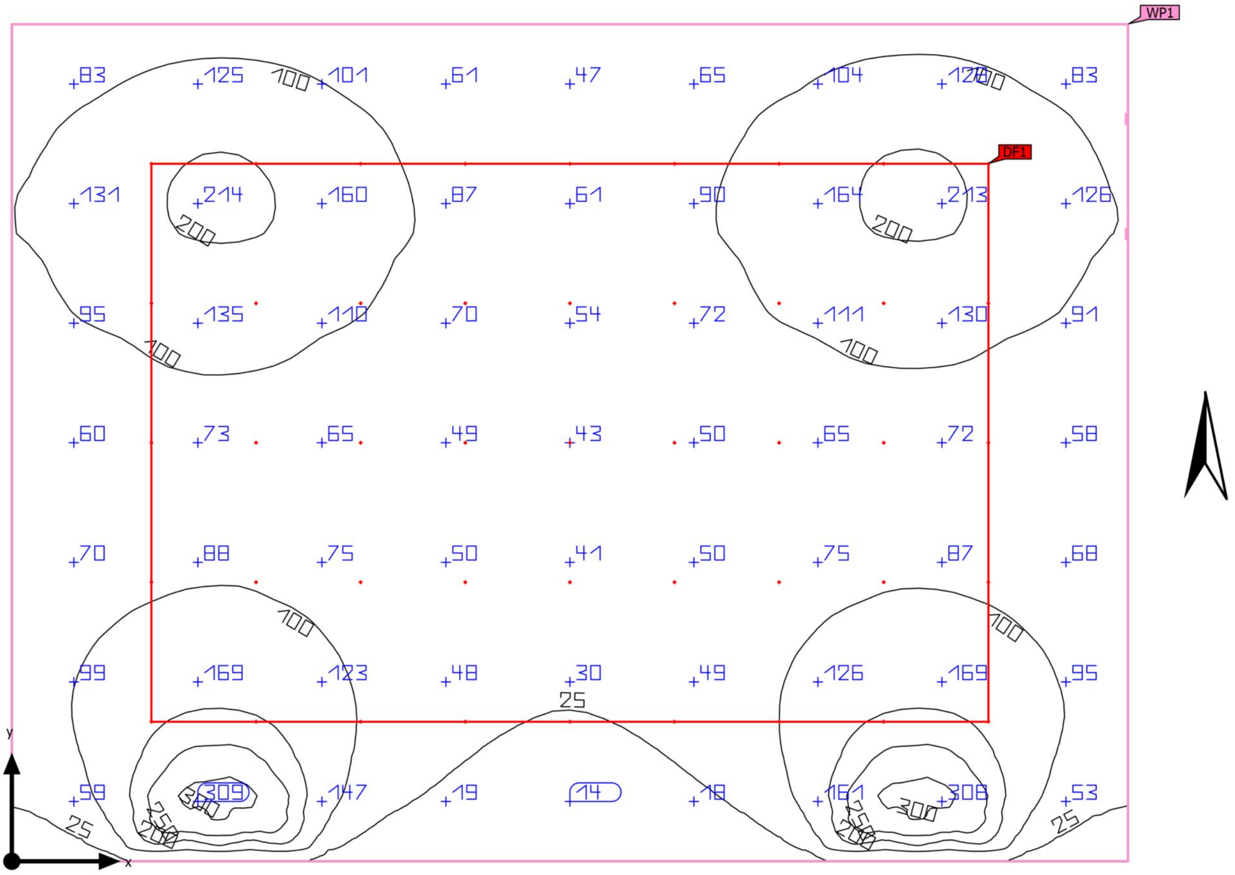
(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Average sky (Direct sunlight) on 21-03-2024 at 12:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m²
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	0.748 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	93.6 lx	≥ 500 lx	✗	WP1
	U_o (g_1)	0.14	≥ 0.60	✗	WP1
Energy estimation(2)	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

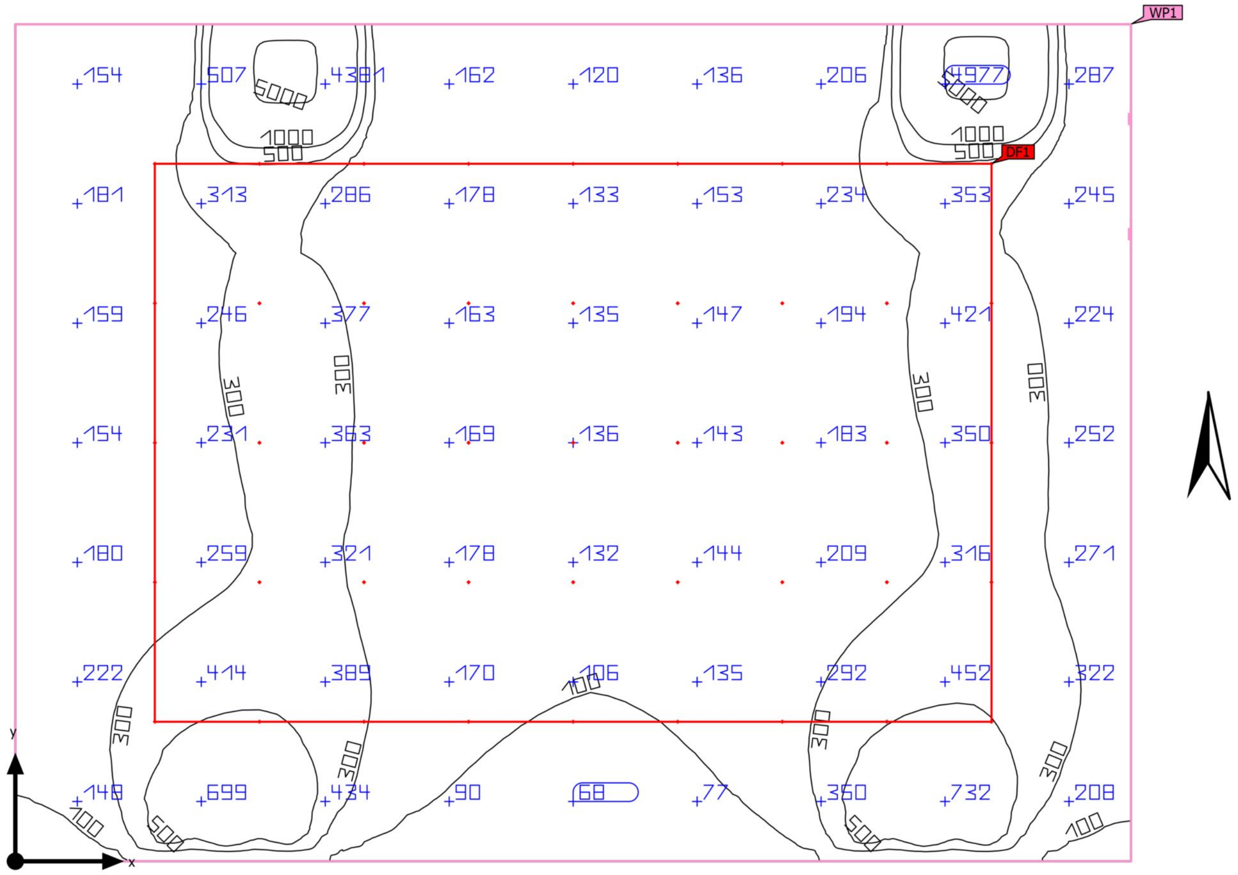
(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Overcast Sky on 21-03-2024 at 15:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m²	Clearance height	2.800 m
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %	Height Working plane	0.800 m
Maintenance factor	0.80 (fixed)	Wall zone Working plane	0.000 m

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	0.748 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	357 lx	≥ 500 lx	✗	WP1
	U_o (g_1)	0.17	≥ 0.60	✗	WP1
Energy estimation(2)	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

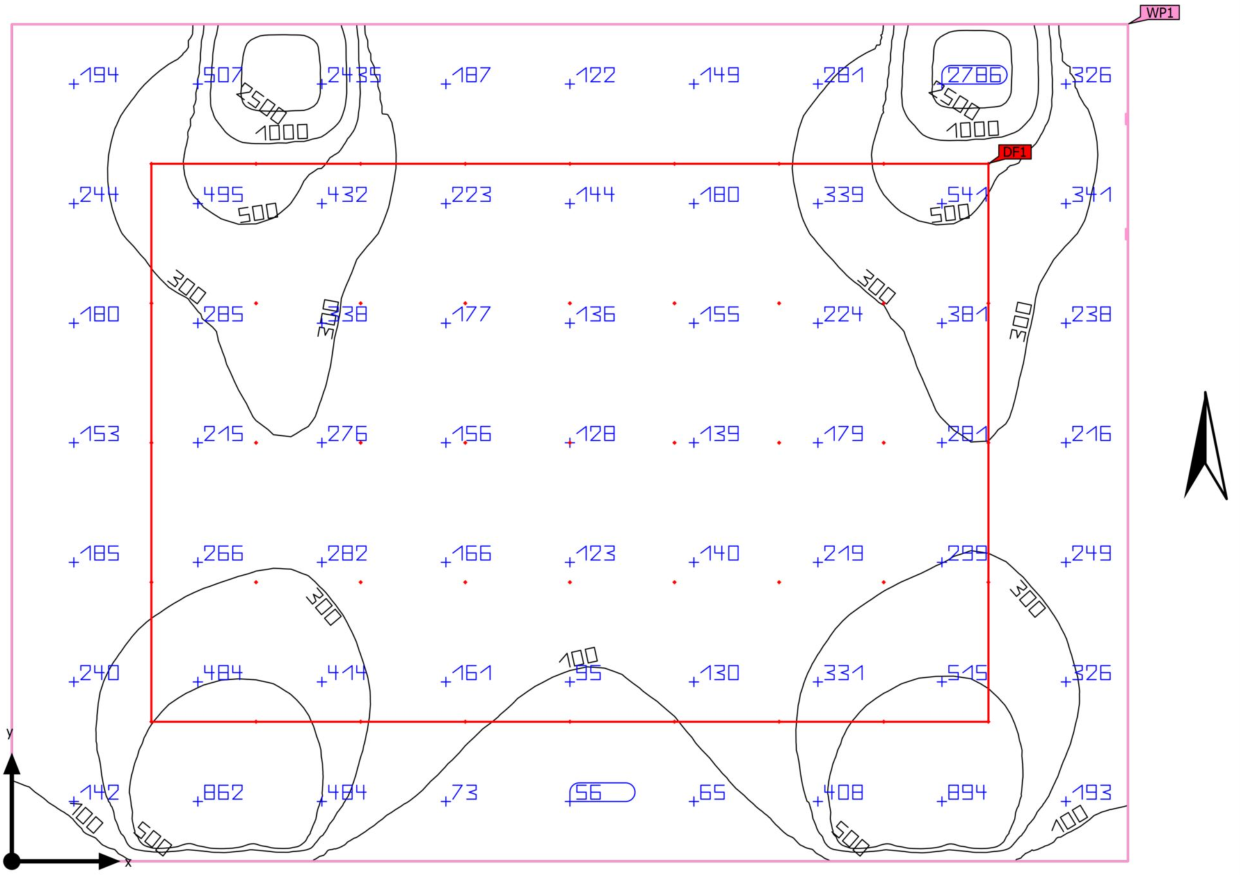
Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Clear sky (Direct sunlight) on 21-03-2024 at 12:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.

DIALux

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary



Ground area	48.00 m^2
Reflection factors	Ceiling: 70.0 %, Walls: 50.0 %, Floor: 20.0 %
Maintenance factor	0.80 (fixed)

Clearance height	2.800 m
Height Working plane	0.800 m
Wall zone Working plane	0.000 m

Building 1 · Storey 1 · Room 1 (Light scene 1)

Summary

Results

	Symbol	Calculated	Target	Check	Index
Daylight	D	0.748 %	–		DF1
Working plane	$\bar{E}_{perpendicular}$	324 lx	≥ 500 lx	✗	WP1
	U_o (g_1)	0.16	≥ 0.60	✗	WP1
Energy estimation(2)	Consumption	0.00 kWh/a	max. 50 kWh/a	✓	
Room	Lighting power density	0.00 W/m²	–		
		0.00 W/m²/100 lx	–		

(1) Based on a rectangular space of 8.000 m x 6.000 m and SHR of 0.25.
(2) Calculated using DIN:18599-4.

Utilisation profile: DIALux presetting (5.26.2 Standard (office))

Notes on planning:
Daylight proportion for Average sky (Direct sunlight) on 21-03-2024 at 12:00 ((UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi). The ambient conditions for "Room 1" are clean.