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BIM-Based Assessment of Light-Transmitting (Translucent) Concrete: Methods, Calibration, and Design Applications

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Abstract

Mainstream BIM lighting engines cannot model micro-scale light piping inside plastic optical fibers (POFs), which makes literal fiber geometry visually convincing but metrically unreliable. We propose a pragmatic dual-model workflow that separates appearance from analysis: (1) a detailed fiber-optic wall family for architectural visualization, and (2) a homogenized composite material whose visible transmittance (VT) is set directly from laboratory lux-based transmittance tests. We document a reproducible calibration recipe—project location and weather (GHI/DNI/DHI), validated sky model, realistic glazing VT and surface reflectances, analysis-plane height, grid density, and reporting thresholds—and show how to map measured to BIM VT. A building-scale case study (Baghdad, Perez all-weather sky) demonstrates that the calibrated model reveals under-lit cores and over-bright perimeters, guiding strategic placement of LTC/POF elements to improve illuminance uniformity while reducing reliance on large vision glazing. We discuss limitations (directionality, thickness effects, solver simplifications) and outline research needs, including BIM–optical co-simulation and a standardized “calibration dossier.” The contribution is a clear, repeatable pathway from laboratory transmittance to decision-grade BIM predictions for LTC in real projects.

Keywords: *Fiber Optic (FO), Light Translucent Or Transparent Concrete (TC), Smart Materials, Nano-Optic, Green Building, Energy-Saving.*

Introduction

Nomenclature & Symbols	
TC	Transparent Concrete
GOF	Glass Optical Fibers
POF	Plastic Optical Fibers
LiTraCon	Light Transparent Concrete
HP	High-Performance
LVDT	linear variable differential transducer
VT	visible transmittance
BIM	Building Information Modelling

Building Information Modeling (BIM) has become a central decision-support environment for daylighting, energy, and visual-comfort assessments long before materials reach the site. For “light-transmitting” or “smart transparent” cementitious composites (LTC/STCC) that embed plastic optical fibers, BIM matters even more: designers need a practical way to predict how much light actually reaches the interior, not just how the surface looks in a render. Yet mainstream BIM lighting engines (e.g., Revit’s Insight Lighting/Light Analysis) do not explicitly simulate micro-scale light piping or total internal reflection inside small-diameter fibers, which means a purely geometric “fiber family” will appear correctly but contribute little or nothing to computed illuminance.

Recent work has therefore adopted a dual-model strategy that separates visualization from analysis. First, a wall-based fiber-optic family is built to capture the characteristic glow and appearance

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in renders—useful for architectural intent and stakeholder communication. Second, for quantitative daylight studies, the wall is assigned a calibrated "composite material" whose visible transmittance (VT) is set from laboratory measurements (e.g., a 10% transparency derived from light-transmittance tests). This homogenized material enables the solver to register transmitted light and predict interior illuminance with realistic magnitudes, effectively linking experimental data to model outputs.

Calibrating the daylight simulation still requires careful environmental setup. Using a validated sky model (e.g., Perez All-Weather), correct site coordinates and weather ensures that the solar geometry and irradiance (GHI/DNI/DHI) reflect local conditions. A representative example is Baghdad (33.27°N, 44.36°E) in mid-August, where measured Global Horizontal Irradiance values around ~837 and ~809 W/m^2 at peak hours can be used to anchor the study; when direct sun is negligible at the test wall, the analysis focuses on diffuse components. These inputs are critical when evaluating a 10%-VT composite in BIM so that predicted illuminance corresponds to measured transmittance.

Beyond climate and sky, material and measurement settings must be realistic: set glazing VT and surface reflectances from credible sources, define the analysis plane near workplane height, and choose a grid spacing fine enough to capture spatial gradients without excessive runtime; ensure rooms are fully enclosed and relevant elements are visible in the analysis view; and declare lower/upper illuminance thresholds to interpret results. Following these best practice steps makes BIM illuminance simulations meaningful for design iteration.

Equally important is choosing realistic transmittance targets for LTC/STCC. Empirical ranges indicate that ~4–5% fiber volume (1–2 mm PMMA on ~15–20 mm grids) in ~100 mm walls can yield ~5–7% VT in practice; thinner panels or optimal lab fixtures may reach double-digit percentages, while very thick or field-installed sections trend lower. Using these ranges to calibrate the composite material in BIM aligns predictions with what is achievable on site.

This review article synthesizes BIM workflows for LTC/STCC with three aims: (1) to compare geometry-based and homogenized material representations and clarify when to use each; (2) to outline a reproducible calibration procedure (location/weather, sky model, materials, analysis plane and grid, thresholds) that ties lab transmittance to indoor illuminance; and (3) to highlight design implications through case-type analyses, illustrating how calibrated BIM studies identify under-lit zones and over-exposed areas in real buildings. The overarching contribution is a repeatable, dual-model BIM workflow—visual family for appearance, calibrated composite for metrics—that bridges experimental research and practical design decisions for translucent concrete.

How LTC is Represented Inside BIM Tools

BIM platforms (e.g., Revit) do not natively simulate micro-scale light piping or total internal reflection inside small-diameter fibers, so a literal, geometry-heavy model of the fibers will look right but won't add measurable illuminance in the solver. This gap forces a pragmatic representation strategy for light-transmitting concrete (LTC).

Explicit "fiber-optic family" (geometry for visuals)

A wall-based Revit family can be built to match the lab geometry (fiber diameters, spacing, embedment) and material assignments. It renders convincingly—showing the characteristic glow and architectural effect—so it's excellent for communication and aesthetic evaluation. However, in lighting analysis runs, this detailed family contributes essentially no extra light because the analysis engine treats it as ordinary geometry rather than a wave-guiding medium.

Use it for: design intent, renders, stakeholder reviews. Avoid relying on it for: quantitative daylight/illuminance metrics.

Homogenized "composite material" (calibrated for analysis)

To obtain realistic illuminance predictions, replace the explicit fibers (for the analysis view) with a single wall material whose visible transmittance matches experiment. In the thesis workflow, a 10% transparency value—derived from lab light-transmittance tests—was assigned to the LTC wall. With this homogenized material, the analysis registered measurable transmitted light and produced magnitudes consistent with experiments, turning the BIM model into a predictive tool for design decisions.

How to choose VT: empirical evidence indicates fiber-optic LTC typically achieves ~2–12% transmittance for 5–15 cm panels; around 4–5% fiber volume (1–2 mm PMMA on ~15–20 mm grid) in a ~100 mm wall yields ~5–7% in practice—values you can map directly to the composite material.

Dual-Model Workflow (keep both in one project)

- In practice, keep both representations and toggle them per view/purpose:
- Fiber family is used for high-quality renders and visual intent.
- Calibrated composite is used for daylight/illuminance studies and reporting.
- This integrated strategy bridges experimental measurements and BIM predictions, enabling both believable visuals and defensible metrics within one model.

Parameter Mapping & Analysis-View Tips

When running lighting studies, to ensure analysis-relevant materials and scene parameters are realistic and documented (e.g., glazing VT, surface reflectances). The used the composite material in the analysis view, with rooms enclosed and the LTC wall visible to the solver; reserve the fiber family for rendering views.

Materials and Methods — Lux (Illuminance/Transmittance) Test

Materials (specimens for the lux test)

Cementitious matrices: white-cement (WCC) with 9 samples and gray/ordinary Portland cement (GCC) mixes with 9 samples to make a total of 18 samples in this experiment, each with 4% superplasticizer and 5% GGBFS, were cast with embedded plastic optical fibers (POFs) of 1, 2, or 3 mm diameter.

Mixture six (WCC-4% SP-5% GGBFS): Mixing ratio 1:0.25:4%, cement: sand: water: superplasticizer - 5% Ground Granulated Blast Furnace Slag.

Mix Seven (STGCC-4%SP-5%GGBFS-25%POF): Mixing ratio 1:0.25:4%, cement: sand: water: superplasticizer - 5% Ground Granulated Blast Furnace Slag-25% Plastic Optical Fibers

Mix Eight Mix Seven (STGCC-4%SP-5%GGBFS-50%POF): Mixing ratio 1:0.25:4%, cement: sand: water: superplasticizer - 5% Ground Granulated Blast Furnace Slag-50% Plastic Optical Fibers

Mix Ninth (STGCC-4%SP-5%GGBFS-75%POF): Mixing ratio 1:0.25:4%, cement: sand: water: superplasticizer - 5% Ground Granulated Blast Furnace Slag.-75% Plastic Optical Fibers

Mix Ten (STWCC-4%SP-5%GGBFS-25%POF): Mixing ratio 1:0.25:4%, cement: sand: water: superplasticizer - 5% Ground Granulated Blast Furnace Slag-25% Plastic Optical Fibers

Mix Eleven (STWCC-4%SP-5%GGBFS-50%POF): Mixing ratio 1:0.25:4%, cement: sand: water: superplasticizer - 5% Ground Granulated Blast Furnace Slag-50% Plastic Optical Fibers

Mix twelve (STWCC-4%SP-5%GGBFS-75%POF): Mixing ratio 1:0.25:4%, cement: sand: water: superplasticizer - 5% Ground Granulated Blast Furnace Slag-75% Plastic Optical Fibers

The mix module is as shown in **Figure 1**:

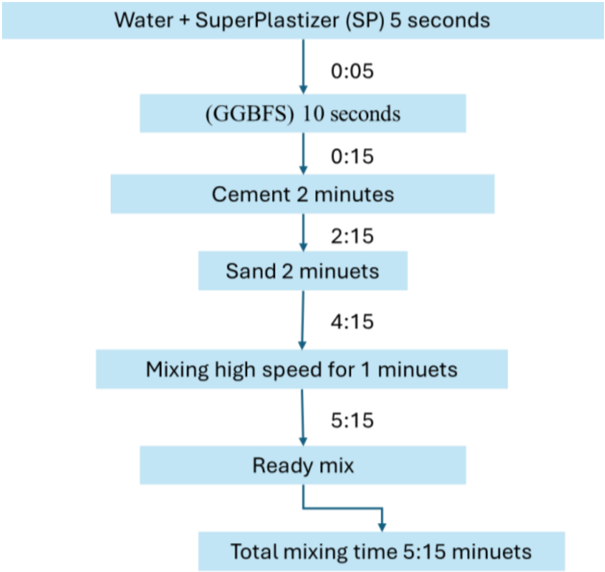


Figure 1 Flow Chart of Mixing

Specimen geometry and fiber layouts: 100 × 100 × 100 mm cubes were used; fiber layouts were controlled by pre-drilled plastic alignment sheets sized to deliver target cross-sectional area fractions of 0.25%, 0.50%, or 0.75% POF per cube face. Fiber ends were trimmed flush, and surfaces polished for optical testing.

POF counts per test series (per cube face) were as follows, matching the article's illuminance table:

- 1 mm diameter: 32 / 64 / 96 fibers for 0.25 / 0.50 / 0.75% area.
- 2 mm diameter: 8 / 16 / 24 fibers for 0.25 / 0.50 / 0.75% area.
- 3 mm diameter: 4 / 8 / 11 fibers for 0.25 / 0.50 / 0.75% area.

Each set was produced in both WCC and GCC matrices as shown in **Figure 2**.

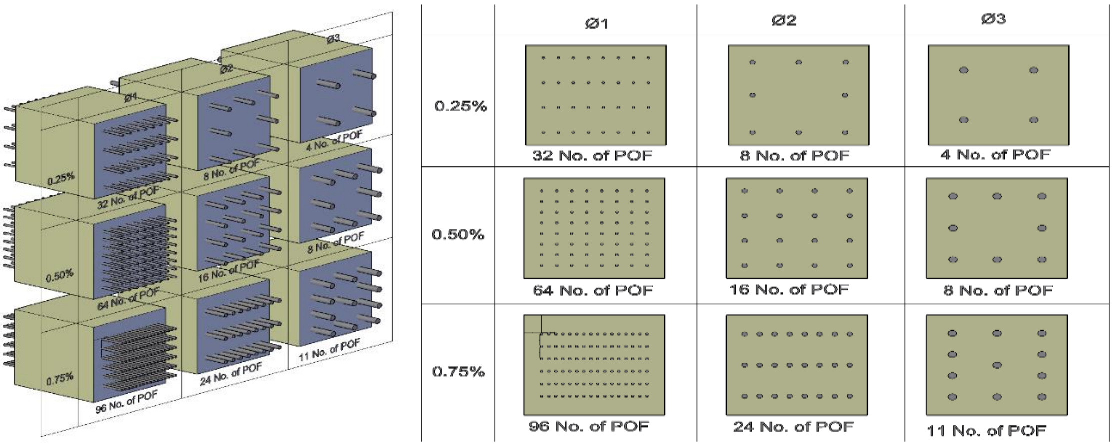


Figure 2 3D and 2D modules of each specimen showing the distribution of POF

Methods (lux/transmittance measurement)

Definition and metric: Plate translucency (light transmittance, ρ) was defined as the ratio of transmitted to incident illuminance, expressed as a percentage:

$$\rho = \frac{J_1}{J_0} \times 100\%$$

where (J_0) is incident illuminance (lux) and (J_1) is illuminance measured after the LTC specimen. The measured ρ values are later used as the BIM material's visible transmittance (VT).

Apparatus: A dark-box fixture was built to provide a “100% dim” environment. The box was blacked out; a dedicated port was cut for the lux meter; specimens were placed in the same opening and measured under identical conditions to ensure like-for-like comparisons across diameters and POF area fractions.

Procedure:

1. Establish baseline incident illuminance (J_0) using the reference configuration (no specimen); in the article’s data table, the baseline is reported as 90.00 lx.
2. Insert the LTC specimen in the box opening and record transmitted illuminance (J_1).
3. Repeat measurements and average per specimen, compute:

$$\rho = \frac{J_1}{J_0} \times 100\%$$

4. Report “Average lux” (transmitted (J_1)) alongside % transparency for each mix/geometry.

Quality & preparation: Specimen faces were kept flat with fiber ends cut flush and polished to avoid parasitic scattering at exits; all readings were taken under consistent laboratory conditions.

Data structure used in the article: Results are presented for WCC and GCC across 1, 2, and 3 mm POF diameters and 0.25/0.50/0.75% area fractions, listing Average lux (J_1) and the derived % transparency ρ. Examples include WCC-1 mm at 0.25/0.50/0.75% giving 2.40/5.63/9.34 lx and 2.67/6.26/10.38 % transparency, respectively; analogous series are reported for 2 mm and 3 mm and for GCC.

Lumania Test

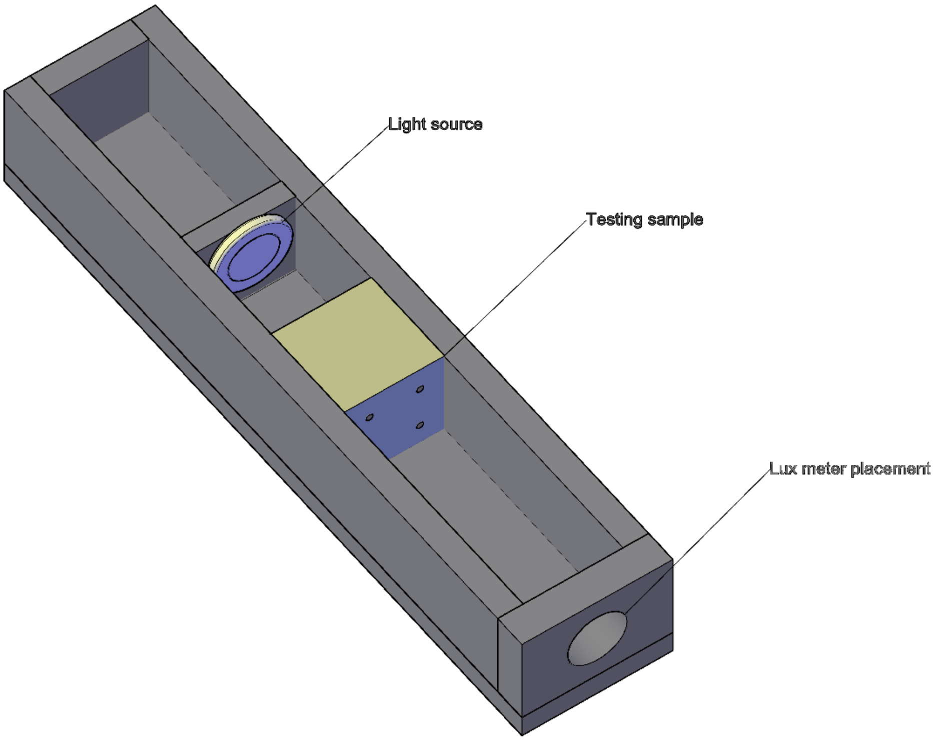


Figure 3 A rectangular box (internal dimensions **40 × 15 × 15 cm**) was built with circular apertures at both ends. The **light source** (LED or halogen, fixed and specified in the Methods) is mounted at the upstream aperture; the **lux-meter sensor** is positioned at the downstream aperture. The **test specimen** is held mid-span in a sealed holder to prevent light leakage. All interior surfaces were lined with matte black cloth along the **perimeter** to suppress reflections; the measured background illuminance inside the sealed box was **< 0.1 lx**, i.e., effectively dark. This arrangement provides a controlled path for comparing transmitted illuminance through samples with different **POF diameters** and **area fractions**,

with **incident** J_0 recorded at the sensor position (aperture open) and **transmitted** J_1 recorded with the specimen in place.

Instrument — Split-Type Lux Meter (Benetech GM1030) Was used to measure illuminance with a GM1030, a split-probe digital lux meter that uses a silicon photodiode sensor and a remote (cabled) probe—useful for placing the detector flush with the dark-box aperture while keeping the display outside. The meter covers **0–200,000 lx** (also 0–20,000 fc) across **four ranges (×1/×10/×100/×1000)** with minimum resolutions of **0.1/1/10/100 lx** respectively; stated accuracy is **±3 % rdg + 5 dgt** on ×1, **±3 % rdg + 10 dgt** on ×10, and **±4 % rdg + 10 dgt** on ×100/×1000, with **±2 % repeatability** and a **2 Hz** sampling/refresh rate. The unit supports **manual (≈60 groups) and automatic (≈2000 groups) data storage** and can export via **USB**; power is from three AAA cells. These manufacturer specifications frame the instrument uncertainty reported for (J_0) and (J_1) in our transmittance calculations.

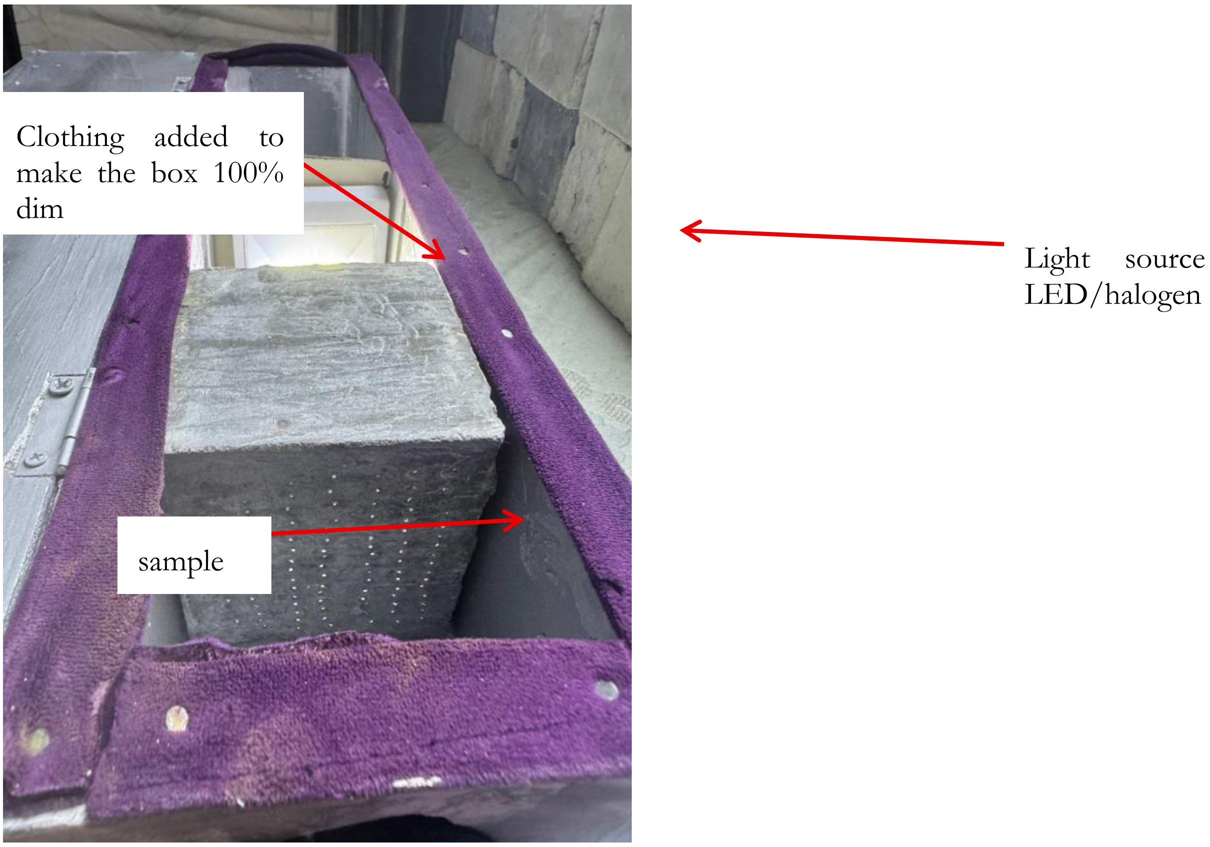


Figure 4 Dark Box Components

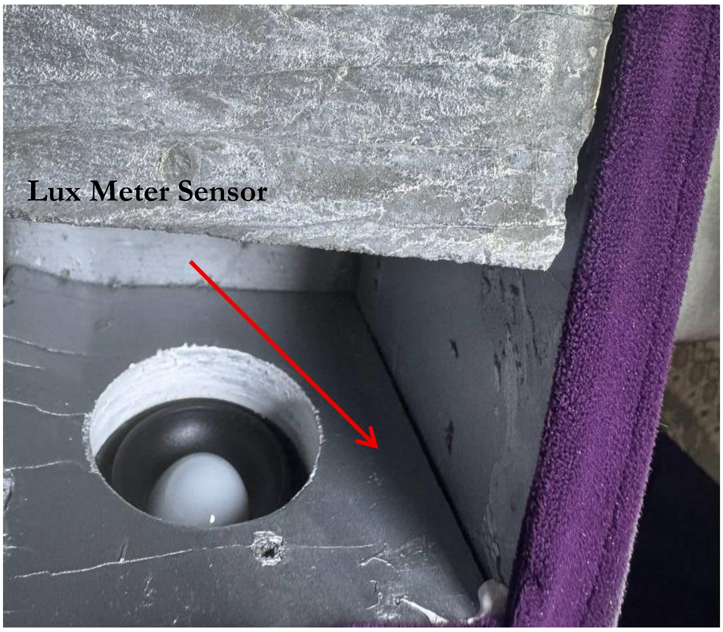
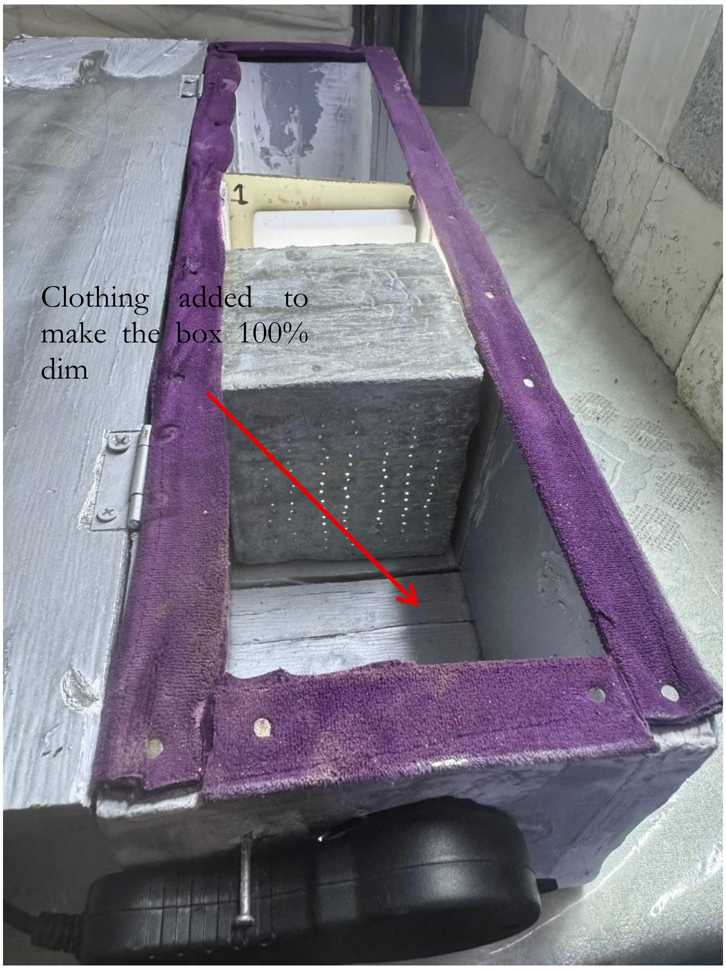


Figure 5 Shows Senser Placement

Figure 6 Light Source on and Off



Clothing added to make the box 100% dim

Figure 7 Light switched off

Figure 8 Light switched on

Illuminance Test Results

Optical transparency in light-transmitting concrete influences daylight admission, visual effects, and the potential to offset electric lighting—thus it is a primary functional outcome for POF-reinforced mixes. The results are summarized in **Error! Reference source not found.** and illustrated in Figures (5-1)-(5-6). This subsection follows the Chapter Five style and terminology used in the thesis.

In the present study, % of transparency was the primary metric and Average lux provided a corroborating auxiliary measure. Factors identifiable from the labels and columns were the matrix (WCC-4% SP-5% GGBFS, GCC-4%SP-5%GGBFS), POF diameter (1, 2, 3 mm), and Cross section area (%) (0.25, 0.50, 0.75). Within WCC, sweeping diameter at fixed area showed monotonic declines with increasing diameter: at 0.25% area, transparency was (2.67, 1.72, 0.42) % for 1, 2 and 3 mm, respectively; at 0.50%: (6.26, 3.59, 2.44) %; at 0.75%: (10.38, 5.07, 3.83) %. The reciprocal sweep (fixed diameter, varying area) showed clear gains with area: at 1 mm, (2.67, 6.26, 10.38) % for 0.25, 0.50 and 0.75% area, respectively; at 2 mm, (1.72, 3.59, 5.07) %; at 3 mm, (0.42, 2.44, 3.83) %. The GCC matrix followed the same patterns but at lower magnitudes: by diameter at fixed area 0.25% it was (1.61, 1.39, 0.26) %; at 0.50%: (5.22, 2.67, 2.00) %; at 0.75%: (9.37, 3.83, 3.49) %. By area at fixed diameter, 1 mm gave (1.61, 5.22, 9.37) %, 2 mm gave (1.39, 2.67, 3.83) %, and 3 mm gave (0.26, 2.00, 3.49) % for 0.25, 0.50 and 0.75%, respectively. Across all conditions, the global maximum occurred for (WCC)-POF-1 mm at 0.75% area with 10.38% (Average lux 9.34), while the global minimum was (GCC)-POF-3 mm at 0.25% area with 0.26% (Average lux 0.23). Between matrices at matched diameter–area, WCC consistently exceeded GCC; the relative gap ranged from ≈66.0% (1 mm, 0.25% area) to ≈9.7–22.0% at 0.75% area across diameters, indicating that matrix choice had its largest proportional effect under low-area, larger-diameter layouts. The auxiliary Average lux mirrored these trends (for example, WCC–1 mm rose (2.40, 5.63, 9.34) lx as area increased 0.25 → 0.75%), supporting the internal consistency of the optical measurements.

The behaviors were consistent with expected mechanisms. Increasing Cross section area (%) raised the effective light-channel fraction, yielding higher transmittance; conversely, increasing POF diameter at fixed area reduced channel count and likely elevated path spacing, both of which can increase scattering losses within the matrix. On the other hand, increasing the number of POF improved transparency by providing a denser distribution of light channels. This suggests that not only the total area fraction but also the spatial distribution of POFs influences light transmission, with more uniform and closely spaced fibers minimizing gaps and reducing internal scattering. The matrix effect (WCC showed higher values than GCC) was consistent with lower intrinsic absorption/opacity in the white-cement matrix, reducing bulk attenuation; differences in the POF–matrix interface may also have contributed to losses. These interpretations remain cautious given that microstructural detail and exact surface finishes were not interrogated here.

Recent studies on light-transmitting concrete (LTC) reinforced with plastic optical fibers (POFs) broadly agrees our study's findings regarding fiber diameter, fiber content, and cement matrix effects. A comprehensive 2024 review [1] noted that LTC light transmittance correlates positively with fiber volume fraction and negatively with fiber diameter (and spacing) [2]. In other words, increasing the total cross-sectional area of POF (higher fiber content) generally increases transparency, while using smaller-diameter fibers (more fibers for the same area) enhances light transmission – both in agreement with the trends observed in our study. In the other hand, Henriques et al. (2020) found that raising the POF content from 3.5% to 5% (by volume) doubled the concrete's light transmittance [3], directly supporting that a larger fiber cross-sectional area yields higher illuminance. Similarly, [4], who embedded 5 mm and 10 mm PMMA rods in concrete, reported a "positive correlation between the area of rods and transmittance". This indicates that specimens with a greater total fiber cross-sectional area had higher light output. Several studies also confirm the fiber diameter effect: smaller fiber diameters tend to improve transparency (when total fiber volume is fixed) because more fibers can be packed and light is distributed more uniformly [5]. Tuaum et al. (2019) observed that LTC light transmission decreases as fiber diameter increases [6], which aligns with the present study's finding that using finer fibers (at constant total area) increases illuminance. Some authors explain this by noting that more thin fibers allow denser light channels in the same volume. (It is worth noting that one simulation study [3] found transmittance increasing with fiber radius under certain conditions[7], but this appears to be an outlier or scenario-specific result.)

Findings on the cement matrix type – white vs. gray (ordinary Portland) cement – are somewhat mixed. Intuitively, a white cement matrix might transmit light more efficiently due to its higher reflectance and lower absorption of light within the matrix. In practice, some researchers do choose white Portland cement for making translucent concrete slabs, aiming to maximize brightness and clarity [8]. White cement can have a reflectance up to ~0.6, compared to ~0.2–0.3 for typical gray cement [9]. This difference suggests white cement could reduce light loss in the matrix. Indeed, the present study's observation that white-cement LTC samples outperform gray-cement ones in light transmission is partially supported in the literature. However, at least one recent study indicates that the matrix color's effect on overall transparency is minor. [9] reported that using white vs. ordinary cement had no significant impact on LTC transmittance, reasoning that the fiber channels dominate light conduction while matrix reflectance differences are comparatively small [9]. In summary, nearly all recent works concur that increasing POF volume fraction markedly improves light throughput, and most agree that smaller POF diameters (with a higher fiber count at equal volume) yield higher illuminance, reinforcing the trends found in the present study. On the other hand, while a white cement matrix can theoretically aid light transmission (and is often used for aesthetic reasons), the magnitude of its advantage over gray cement is not uniformly confirmed – some authors note only marginal or negligible gains [9], suggesting that fiber architecture plays a more dominant role than matrix color in LTC transparency.

Table 1 Illuminance Test Results

Mix type	POF Diameter (mm)	Number of POF	(VT) (lux)	% of transparency
Reference	-	-	90.00	-
(STWCC-4%SP-5%GGBFS-25%POF)	1	32	2.40	2.67
(STWCC-4%SP-5%GGBFS-50%POF)	1	64	5.63	6.26
(STWCC-4%SP-5%GGBFS-75%POF)	1	96	9.34	10.38
(STWCC-4%SP-5%GGBFS-25%POF)	2	8	1.55	1.72
(STWCC-4%SP-5%GGBFS-50%POF)	2	16	3.23	3.59
(STWCC-4%SP-5%GGBFS-75%POF)	2	24	4.56	5.07
(STWCC-4%SP-5%GGBFS-25%POF)	3	4	0.38	0.42
(STWCC-4%SP-5%GGBFS-50%POF)	3	8	2.20	2.44
(STWCC-4%SP-5%GGBFS-75%POF)	3	11	3.45	3.83
(STGCC-4%SP-5%GGBFS-25%POF)	1	32	1.45	1.61
(STGCC-4%SP-5%GGBFS-50%POF)	1	64	4.70	5.22
(STGCC-4%SP-5%GGBFS-75%POF)	1	96	8.43	9.37
(STGCC-4%SP-5%GGBFS-25%POF)	2	8	1.25	1.39
(STGCC-4%SP-5%GGBFS-50%POF)	2	16	2.40	2.67
(STGCC-4%SP-5%GGBFS-75%POF)	2	24	3.45	3.83
(STGCC-4%SP-5%GGBFS-25%POF)	3	4	0.23	0.26
(STGCC-4%SP-5%GGBFS-50%POF)	3	8	1.80	2.00
(STGCC-4%SP-5%GGBFS-75%POF)	3	11	3.14	3.49

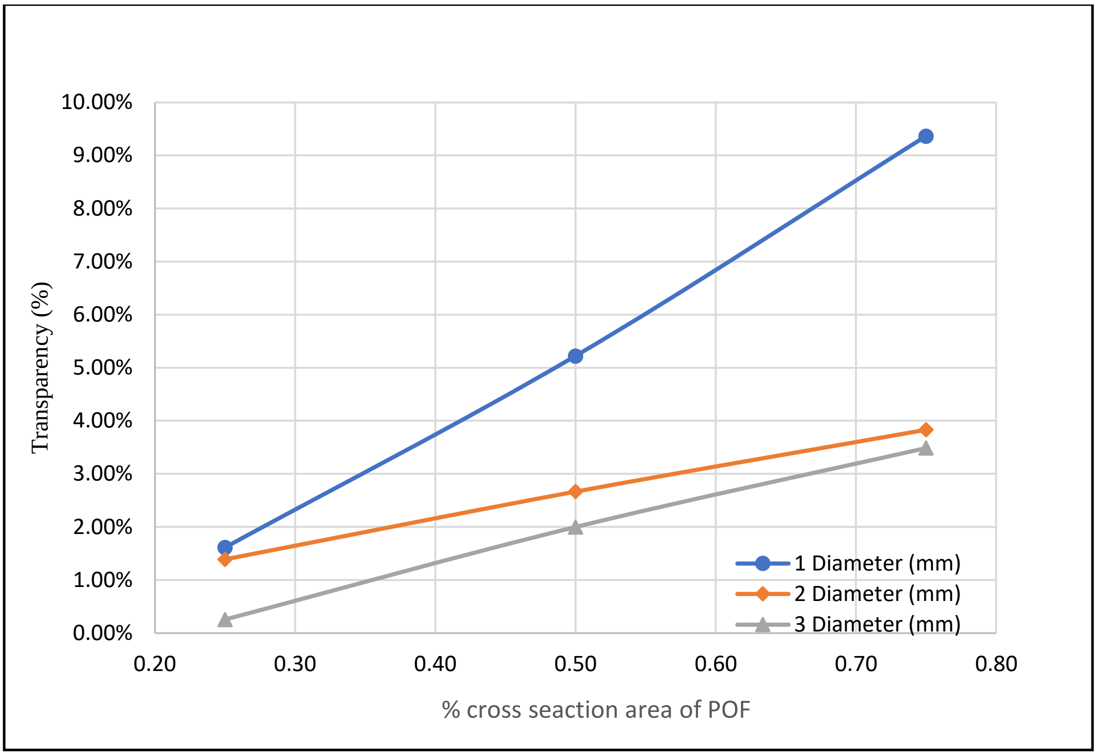


Figure 9 Effect of % cross section area of POF on lux for (GCC)

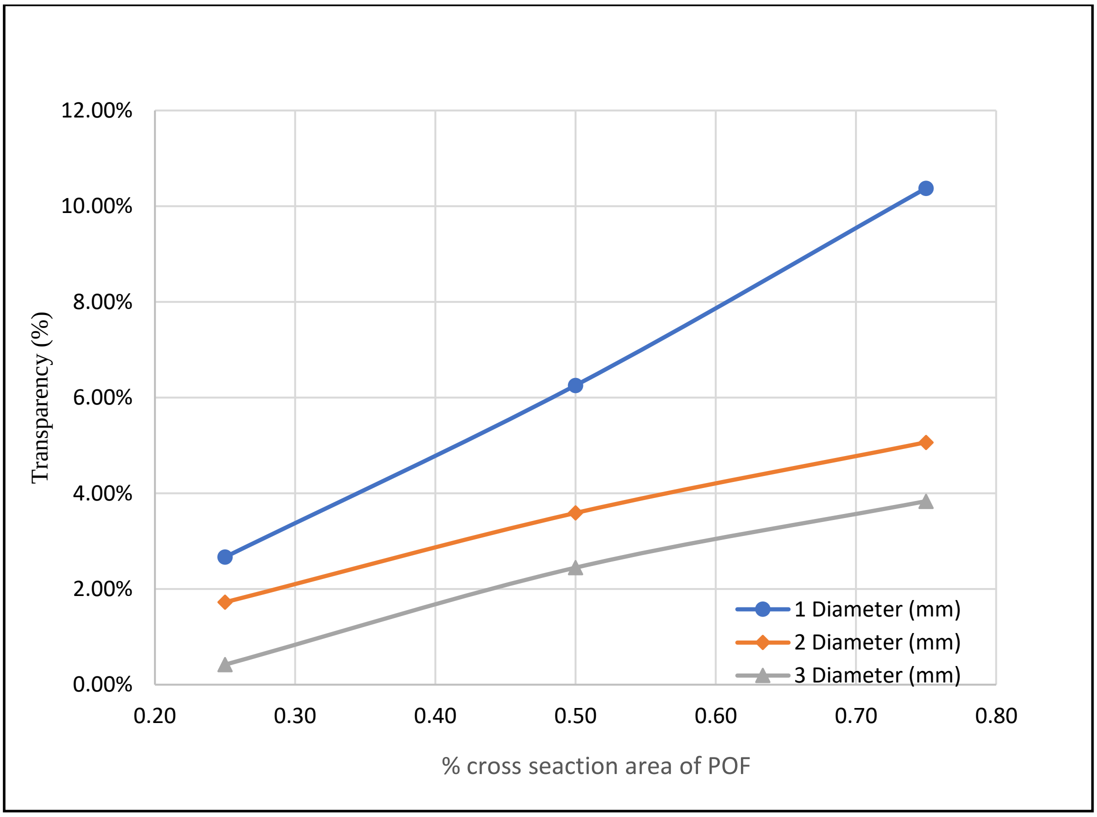


Figure 10 Effect of % cross section area of POF on lux for (WCC)

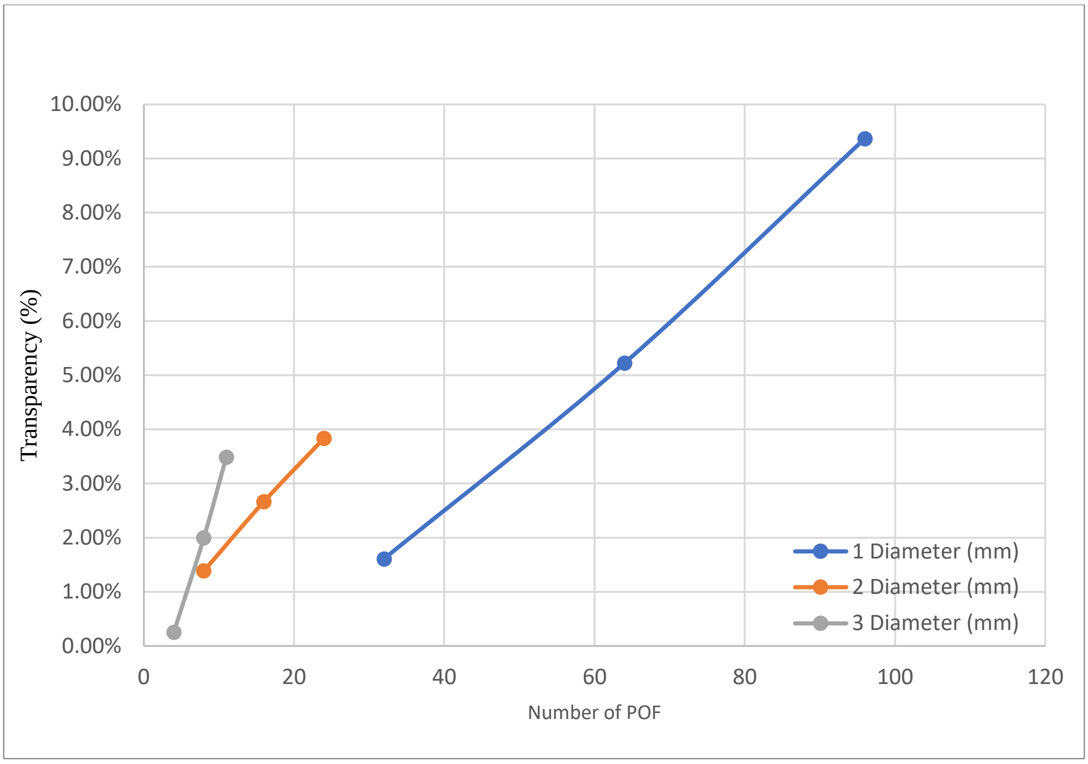


Figure 11 Effect of Number of POF on lux for (GCC)

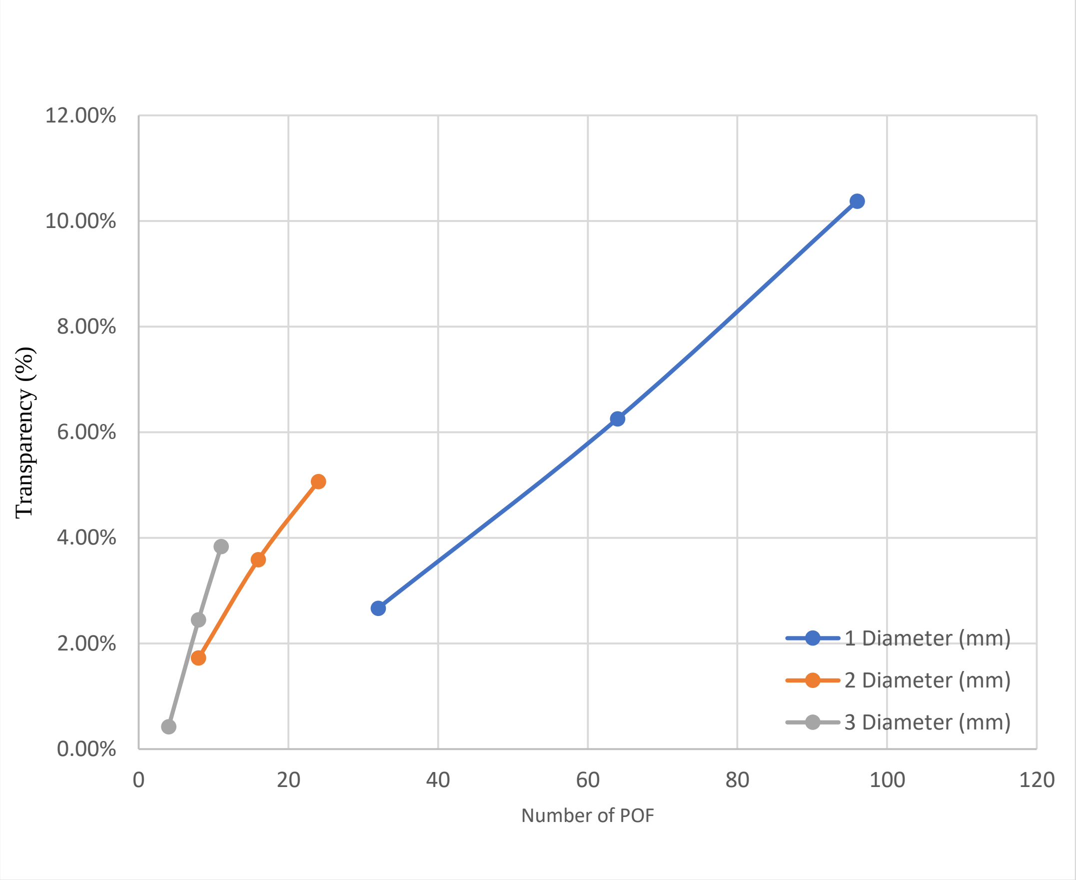


Figure 12 Effect of Number of POF on lux for (WCC)

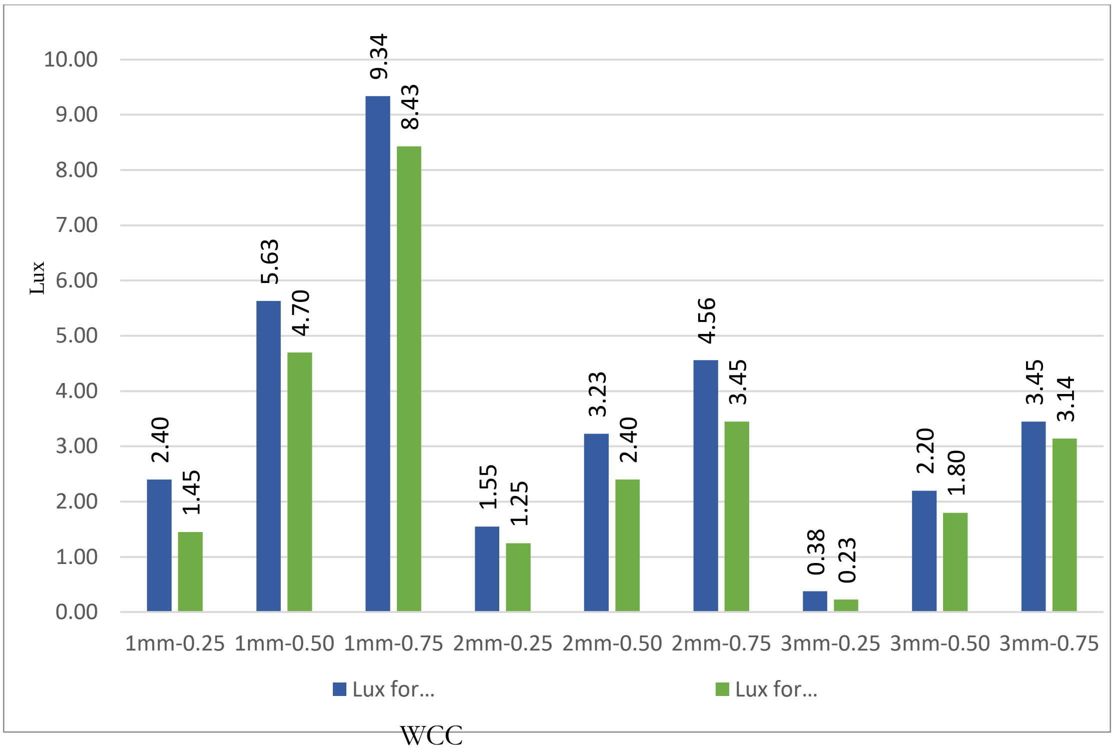


Figure 13 Comparison between Transparency (Lux) For (WCC) and (GCC)

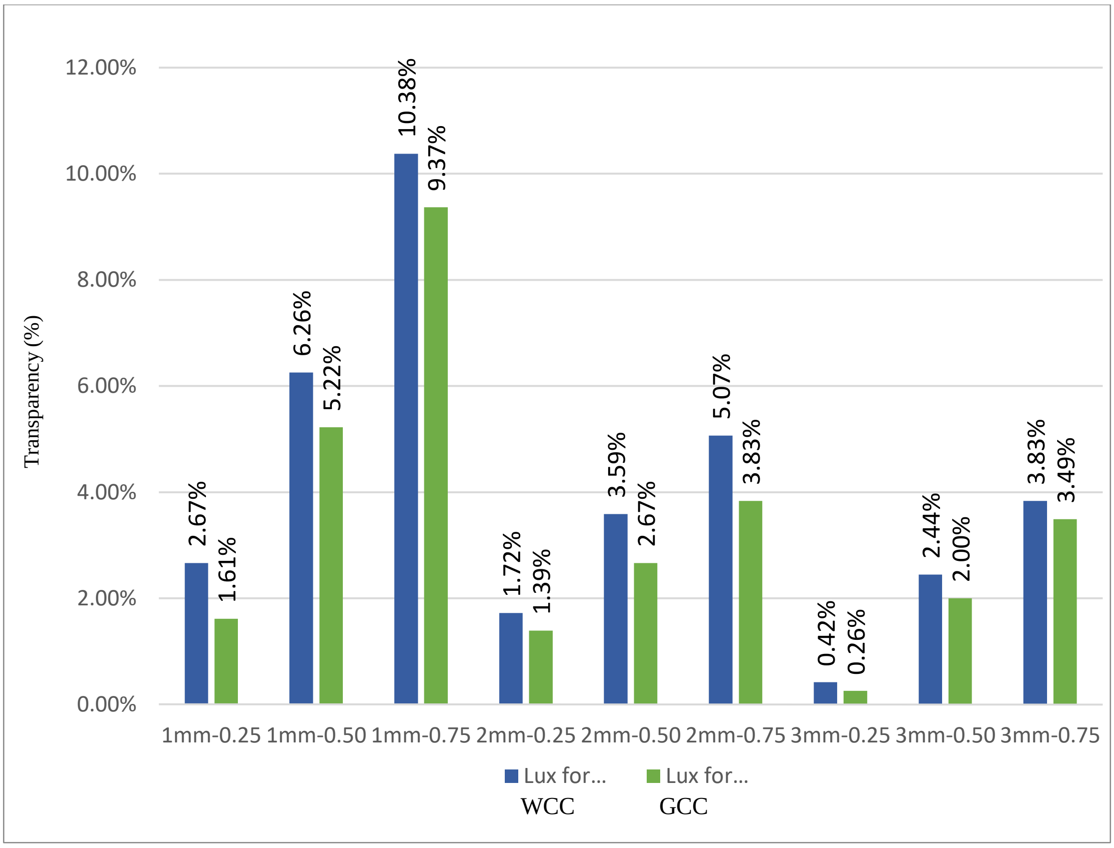


Figure 14 Comparison between Transparency (%) For (WCC) and (GCC)

Daylighting simulation setup & calibration in BIM

A BIM lighting study becomes trustworthy only when the environment, materials, and measurement settings are calibrated to real site conditions and to the actual optical behavior of the LTC wall. The workflow below consolidates the setup used in our study and general best practices for Revit Insight/Light Analysis.

Practical Study

Calibration of Revit Light Study Sitting

Error! Reference source not found. and **Error! Reference source not found.** and shows our BIM daylight simulation, the Perez All-Weather Sky model was selected due to its validated accuracy in representing diffuse sky luminance across various weather conditions (Perez et al., 1993). The simulation was configured using geographic coordinates of 33.27°N, 44.36°E, which correspond to the climatic conditions of Baghdad, Iraq, thereby ensuring that the solar geometry and irradiance levels reflect real local conditions. Two simulation time points, August 10 at 1:00 p.m. and 3:00 p.m., were chosen to capture peak daylight conditions during the summer, when natural illuminance is at its highest. Based on local meteorological data (e.g., ASHRAE TMY data), the Global Horizontal Irradiance (GHI) at these times was approximately 837 W/m² and 809 W/m², respectively. Additionally, due to the orientation of the test wall relative to the sun at these times, the direct sunlight component (Direct Normal Irradiance, DNI) is effectively negligible, meaning that the simulation primarily considers diffuse irradiance. These settings were critical for evaluating the performance of the 10% transparent composite material, ensuring that our simulation accurately links experimental transmittance measurements with predicted interior illuminance levels.

Global Horizontal Irradiance (GHI) is the total amount of solar radiation (shortwave energy) received per unit area on a horizontal surface. It includes both the direct sunlight that reaches the surface without scattering and the diffuse radiation that is scattered by molecules and particles in the atmosphere. GHI is typically measured in watts per square meter (W/m²) and is a key parameter in solar energy studies and daylighting analysis, as it provides a comprehensive measure of the solar resource available at a specific location.

In conducting a reliable light study in Revit (using Insight Lighting / Light Analysis), accurate calibration of settings is essential to ensure results reflect real-world conditions. First, the project location and climate data must be set correctly: latitude/longitude, time zone, and appropriate weather station data so GHI, DNI, DHI match site-specific climate. Autodesk documentation emphasizes that defining the project location via Manage → Location is the step that enables using the correct weather data. [10] Next, selecting an appropriate sky model (e.g., Perez All-Weather, CIE Clear, Overcast, etc.) is crucial, since sky condition heavily affects daylight input. The “Insight Lighting Analysis Help” guides show that many study types (including Illuminance and LEED/Custom studies) allow choosing sky models and weather/sky overrides. [11] Material properties must be properly calibrated: glazing transparency (visible transmittance), and reflectance of walls, ceilings, floors should be realistic rather than generic defaults. The Autodesk “Revit Lighting and Daylighting Performance Analysis” PDF details how opaque surface materials are calibrated via material appearance (RGB reflectance) and glazing properties. [12] The analysis plane height (where illuminance is measured) must correspond with typical working height above the floor (or relevant surface); for example, LEED studies frequently require analysis planes at about 30 inches (≈ 75-80 cm) above finished floor. [11] Also grid resolution (spacing between measurement points) should be fine enough (e.g. 12-inch / ~30 cm grid) to capture variations in light, but balanced to avoid excessive computation time. The “Lighting Analysis Help” guide notes that higher resolution grids (12-inch) give more precise spatial variation but also higher computing/cloud credit cost. [10] It’s also important to ensure rooms or spaces are fully enclosed (geometry correct, no unintended gaps blocking light paths) and that relevant model elements like windows, shading devices, interior surfaces are visible in the analysis view. Tutorials and best-practice guides for Insight remind users that missing elements or open boundary gaps can lead to misleading results. [13] Finally, clear threshold values for acceptable and excessive illuminance (lower and upper limits) should be defined so pass/fail or compliant/non-compliant zones can be visualized. Revit’s Insight Lighting / Light Analysis tools include settings for thresholds/cut-offs in the Illuminance Settings dialog, and these are used in LEED or custom analyses. [11] With all these settings calibrated, the illuminance simulation becomes a meaningful tool to guide architectural design and daylighting improvements, giving both qualitative visual feedback and quantitative metrics for performance.

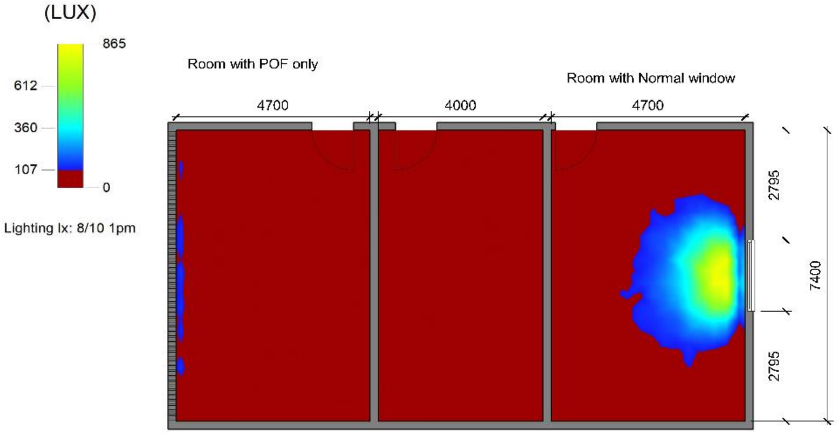


Figure 15 Window and FO only

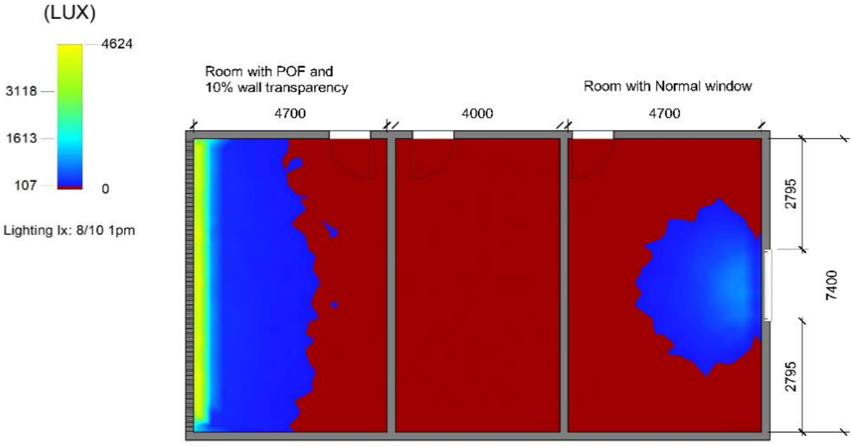


Figure 16 Window and FO and wall Transparency 10%

Case-Study: Lighting Analysis & POF-based Recommendations for Al-Rafidain Bank, Al-Mansour

In our lighting analysis of the Al-Rafidain Bank building in Al-Mansour as shown if **Error! Reference source not found.** and **Error! Reference source not found.**, we used cloud-based illuminance simulation with two environment settings on August 10, first at 11:00 AM and second at 3:00 PM, under the Perez All-Weather Sky model. Actual weather data were used (i.e. global horizontal irradiance [GHI], direct normal irradiance [DNI], diffuse horizontal irradiance [DHI]) for both times to ensure realism. The analysis plane was set 5 inches above the floor, with acceptable illumination levels between 300 lux (lower threshold) and 3000 lux (upper threshold). A 12-inch grid resolution was used in the mapping.

Figure 17 Al-Rafidain Bank building in Al-Mansour

The results showed substantial areas as shown in **Error! Reference source not found.**, especially in the inner offices and corridors, which did not meet the 300 lux minimum — these appear in blue in the illuminance map. Near windows and external walls, overly high illuminance levels, sometimes exceeding the upper threshold, were observed. This indicates an uneven distribution of natural light: strong light where windows are, but poor light deeper inside.

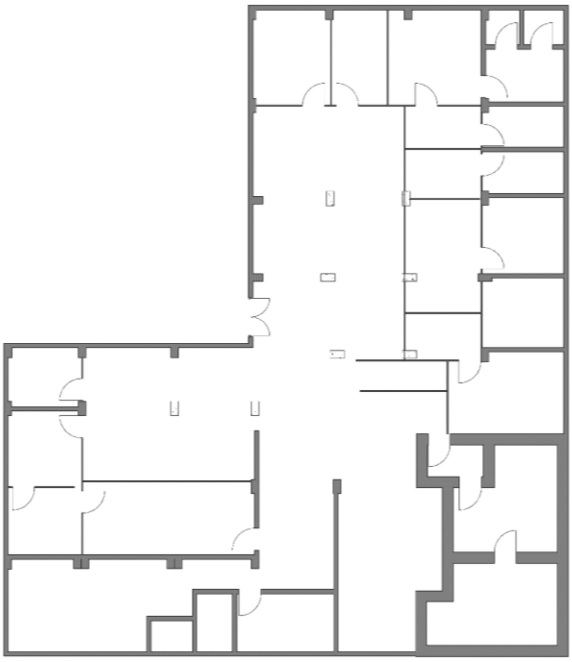


Figure 18 2D plan of Al-Rafidain Bank building in Al-Mansour

Figure 19 Light Analysis Results Study of Al-Rafidain Bank building in Al-Mansour

Given these findings, we recommend implementing a Plastic Optical Fiber (POF) daylighting system as a secure, efficient alternative to large windows. The benefits are:

- Improved security: large windows can be points of vulnerability (in terms of visibility from outside, risk of breakage, intrusion). POF allows transmission of daylight into interior zones without large transparent surfaces, reducing security risks.

- Better light distribution: optical fibers can carry light into inner spaces that currently suffer from low illumination, helping those areas meet the 300-lux minimum and reducing reliance on artificial lighting.

- Reduced thermal load: windows (especially unshaded ones) allow heat through solar gain; POF collectors minimize glazing area, thereby reducing cooling requirements.

- Enhanced architectural form: using POF allows cleaner façades and interior layouts (less need for large windows or glazed surfaces), yielding aesthetic flexibility and possibly better control over daylight glare.

Furthermore, case studies (e.g. “Analysis of plastic optical fiber based daylight system suitable for building applications”) show that POF systems, especially when combined with solar trackers or concentrators, can significantly reduce reliance on electric lighting and achieve payback periods in the order of ~5 years under favorable conditions. (OUCI)

In summary, replacing or reducing large window areas with POF daylighting collectors/distributors (while keeping some windows as needed for views) could improve interior lighting uniformity, enhance security, reduce energy and cooling costs, and yield a better architectural outcome for the bank building.

Location, Climate Data, and Sky Model

The site and weather was Set as the following: Project latitude/longitude was defined, time zone, and link to a weather source so GHI/DNI/DHI reflect the local climate (Manage → Location). This is the prerequisite for realistic solar geometry and irradiance in Insight.

Use a validated sky model: Select Perez All-Weather (or an appropriate CIE model) because sky choice strongly affects diffuse luminance distribution. Perez is widely validated for diffuse conditions and was used in our study.

Study Times and Irradiance Anchors

Representative dates/hours were chosen that capture peak daylight and typical working periods. In our calibration run (Baghdad, 33.27°N, 44.36°E), August 10, 1:00 pm and 3:00 pm yielded GHI ≈ 837 W/m² and 809 W/m². Because of wall orientation, direct sun (DNI) on the test surface was negligible, so the analysis emphasized the diffuse component—ideal for evaluating an LTC wall with homogenized transmittance.

Material Calibration (glazing, reflectances, and LTC)

Glazing VT & opaque reflectance: Replace generic defaults with realistic values. Revit/Insight reads glazing properties and RGB-based reflectances for walls/ceilings/floors; these strongly influence illuminance.

LTC as a composite material: For analysis views, apply a homogenized LTC wall material whose visible transmittance = lab-measured transparency (e.g., 10% from our tests). This enables the solver to “see” transmitted light and align predictions with experiments. Keep the explicit fiber family for renders only.

Measurement Settings: Analysis Plane, Grid, View Integrity

- Analysis plane height: Set at typical workplane level (e.g., ~0.75–0.80 m above finished floor, aligned with common LEED practice).
- Grid resolution: Use a fine grid (e.g., ~30 cm / 12 in) to capture spatial gradients without exploding compute time.
- Enclosed, valid analysis view: Ensure spaces are watertight; windows/shading/interior surfaces are visible to the analysis. Missing elements or tiny gaps can distort results.

Thresholds and Reporting

Define lower/upper illuminance limits so outputs clearly map compliant vs non-compliant zones. In our case study runs, thresholds like 300–3000 lux were used, with a 12-inch grid and the analysis plane 5 in above floor (for that specific model).

What Transmittance Numbers to Use (and why)

What “transmittance” means. In this study, light transmittance (plate translucency, ρ) is defined as the ratio of light measured after the LTC element ($J1$) to the incident light before it (J_0), expressed in percent: ($\rho = \frac{J_1}{J_0} * 100\%$). This is the number you should map to the BIM material’s visible transmittance (VT).

Realistic ranges to expect. A synthesis of reported results shows that fiber-optic LTC typically delivers ~2–12% VT for 5–15 cm panels, with the exact value driven by thickness and fiber content. Small lab specimens—especially thin cubes with high fiber fraction and favorable alignment—can show double-digit VT, whereas thicker or real-world panels trend much lower. Example data points: ~50 mm cube with 4% PMMA fibers → 21.3% (lab best-case); 150 mm cube with 4% POF → 12.5%; 100 mm cube with 5% POF → ~6.4%; 75 mm wall panel at ~1.4% vol. → ~1.6% under sunlight.

Why field numbers are lower. Thicker sections, lower fiber volumes, non-ideal alignment, and real daylight (non-normal incidence, diffuse sky) all reduce effective transparency compared with small, optimally prepared lab samples. Practical fiber content is also constrained—typically ≤ 5% by volume—to avoid workability and strength penalties.

Thickness–fiber recipe you can trust. For design-scale walls, the thesis recommends treating ~4–5% fiber by volume (1–2 mm PMMA on ~15–20 mm grid) in a ~100 mm wall as yielding ~5–7% VT in practice. Use this band as our default BIM input when no project-specific lab data exist. Thinner panels or optimized lab setups may reach 10–20%, while very thick or on-site installations will often be in the low single digits.

Choosing a BIM VT (and documenting it).

- If you have lab tests: set the BIM material VT equal to the measured transmittance (e.g., the thesis used 10% from experimental tests for its homogenized composite).
- If you don't have tests: pick from these grounded defaults:
    - 100 mm wall @ ~4–5% vol. fibers → 5–7% VT (baseline case).
    - Thin panels (≈50–75 mm) with higher fiber ratios → 8–12% VT (use cautiously; lab conditions can overstate field performance).
    - Thick sections (≥150 mm) or low fiber volume → 2–6% VT.

Sensitivity you should run. Because sky condition, incidence angle, fiber diameter, and volumetric fraction all influence throughput (see regression/angle studies cited in the thesis), run ±2–3 % VT sensitivity around our chosen value and report both the assumed VT and source (lab vs literature).

- Default to 5–7% VT for ~100 mm walls with ~4–5% fibers when specific measurements aren't available.
- Prefer measured VT whenever possible and mirror it in the BIM material.
- Document thickness, fiber volume, and the VT source, and include a ±2–3% sensitivity band in our daylight reports.

Validating BIM Predictions with Experiments and Case Work

Validation ties the measured light that LTC actually transmits to the predicted illuminance in a BIM scene. In this project the link is made in two steps: (i) measure panel transmittance in the lab, then (ii) mirror that value as the BIM material's visible transmittance and run a calibrated daylight study for the site and hours of interest.

Map Lab Measurements to BIM Inputs

Lab definition. Transmittance is (\rho=\frac{J_1}{J_0}\times100%), where (J_0) is incident light and (J_1) is transmitted light (lux). Use the measured (\rho) as the BIM material VT.

BIM material. Replace the geometric fiber model (for rendering) with a homogenized composite wall in the analysis view; set VT = our measured value (e.g., 10% in this study). This unlocks realistic illuminance predictions in Insight/Light Analysis.

Experimental Setup (how (\rho) was obtained)

A dark-box arrangement was used to compare illuminance before and after the LTC specimen: the box was blacked out to create a "100% dim" environment, a hole was cut for the lux meter, and panels with different fiber diameters/percentages were tested in like-for-like conditions. This produced the (J_0) and (J_1) readings from which (\rho) was computed.

Chapter Five reports the illuminance/transparency trends across mixes (e.g., higher fiber area → higher (\rho); smaller diameters at fixed area → higher (\rho)), which guided the choice of VT for BIM.

Calibration of the Daylight Study (so predictions reflect reality)

The BIM analysis was anchored to Baghdad (33.27°N, 44.36°E) under Perez All-Weather sky, with August 10 runs at 1:00 pm and 3:00 pm using local weather (GHI ≈ 837 and 809 W/m²). Orientation at those times made DNI negligible, so results emphasize diffuse light—appropriate for checking an LTC wall with homogenized VT.

Standard measurement hygiene was followed: realistic glazing VT and surface reflectances; enclosed rooms; analysis plane at workplane height; and declared illuminance thresholds for interpreting pass/fail zones.

Building Case Study (Al-Rafidain Bank, Al-Mansour)

A cloud-based illuminance study was run on August 10 at 11:00 AM and 3:00 PM (Perez sky, real GHI/DNI/DHI). The analysis plane was 5 in above floor, grid 12 in, and thresholds 300–3000 lux. Results showed widespread sub-300 lux zones in inner offices/corridors (blue on the map) and over-threshold zones near windows—i.e., strong light at the perimeter, poor light depth inside.

Based on the pattern, POF-based daylighting was recommended to transport light into under-lit interiors while reducing large window areas (security/thermal benefits) and improving uniformity—consistent with the project's measured transmittance and the calibrated BIM predictions.

Cross-Checks With Broader Literature

The review section compares this BIM-calibrated approach with:

- Radiance-validated optical modeling of translucent panels (Mainini et al.) showing accuracy when internal reflections are handled correctly.
- Scaled-room experiments confirming LTC elements measurably raise interior illuminance versus solid concrete (Štochl et al.).
- Optical/ray-tracing tools (e.g., TracePro) and CPC collectors for fiber daylighting, sometimes coupled to building energy models.
- Empirical transmittance ranges (2–12% for 5–15 cm panels; lab best-cases higher) that align with the VT values used for BIM calibration here.

Applications & Design Implications

Light-transmitting concrete (LTC/STCC) is most compelling where you want daylight depth without the liabilities of large glazing. The thesis evidence and case studies point to four practical application families and the BIM choices they imply.

Where LTC shines (use cases)

Façades that limit glazing area but still "pull" light inside. Real projects—from Expo pavilions to LUCEM façades—use thin translucent panels to add a luminous skin while preserving structural solidity. These demonstrate architectural impact at 15–40 mm thicknesses and building-scale coverage.

Interior partitions and light-sharing walls. LTC partitions can borrow daylight from bright zones to lift illuminance in corridors and deep-plan areas, improving visual connection while avoiding transparency in the conventional glass sense.

Secure or privacy-critical programs (banks, schools, museums, correctional facilities). The bank case study showed under-lit cores and over-bright perimeters; the recommendation was a POF daylighting system to carry light inward while reducing large window area—boosting uniformity and security. Broader program types benefit similarly from visibility control without big vision panels.

Night identity and media façades. Fiber-optic concrete used on projects like the Capital Bank façade transmits interior light outward at night for a distinctive glow (qualitative effect).

Daylight, Energy & HVAC Implications

Uniformity gains with smaller glazing ratios. Replacing part of the window area with collector/distributor POF or LTC sections can smooth the "bright rim / dark core" pattern and push more areas above 300 lux. The Mansour bank analysis used calibrated weather/sky, a 5 in analysis plane, and 300–3000 lux thresholds to illuminate this trade-off.

Cooling-load relief. By cutting glazing, POF/LTC systems reduce solar heat gains compared with large unshaded windows—lowering cooling requirements.

Operational savings potential. Literature summarized in the thesis notes ~5-year paybacks in favorable POF daylighting deployments (with trackers/concentrators). Combined with the thesis abstract's energy-savings argument for STCC, this supports LCC analyses in schematic design.

Thermal, Acoustic & Comfort Side-Benefits

Thermal and sound-insulation tests (ASTM C518, E90/E413) are part of the thesis program; results and the abstract show potential to improve energy efficiency and occupant comfort beyond daylight alone—useful when arguing for multi-benefit façade upgrades.

Structural & Material Trade-Offs That Drive Design

Strength compatibility. The study reports that optimized mixes preserved adequate mechanical strength; epoxy replacement in the matrix improved bonding and strength, while GGBFS aided durability—important when LTC is load-bearing or used as a façade wythe.

Fiber content limits. Reported data compiled in Chapter 4 show that pushing transparency via fiber volume has practical ceilings (workability/strength). Many real panels land in single-digit to low-teens VT for 5–15 cm thickness—set expectations accordingly.

BIM Implications for Placement, Sizing, And Targets

Place LTC where it earns the most lux. Use our calibrated model to test bands/strips of LTC adjacent to collectors or bright façades, targeting the zones that fell below 300 lux in the baseline. Report %-of-floor above threshold to guide area takeoff.

Design for realistic VT. For analysis views, model LTC as a homogenized material set to the measured VT (or a literature-based default within the 2–12% range for 5–15 cm panels) and keep the fiber family for visuals. This prevents over-crediting the daylight contribution.

Glare and façade composition. The bank recommendation highlights another design lever: smaller vision panels + LTC/POF can deliver a cleaner façade with more controllable glare paths, useful for security programs.

Limitations, Pitfalls, and Open Research Needs

Methodological Limitations Inside BIM

No micro-optics in mainstream engines. Revit's lighting solver does not model light piping/total internal reflection in small-diameter fibers—so a literal fiber model looks right in renders but adds essentially no illuminance in analysis.

Homogenized material = useful but simplified. Swapping the fiber geometry for a single wall material with a fixed transparency (e.g., 10%) enables quantitative studies, yet it collapses directionality and angle-of-incidence effects into one scalar VT. The thesis itself positions this as a pragmatic workaround rather than a full optical model.

External literature summarized in the thesis shows transmission depends on incidence angle, fiber area ratio, and surface finish—dependencies a single VT cannot capture.

Data Realism Limits

Thickness and field setup matter. Lab best-cases on thin specimens can overstate performance; thicker sections and real sun/sky reduce effective transparency (e.g., ~1.6% in a 75 mm panel at ~1.4% fibers under sunlight).

Distance/dispersion losses. Experiments reviewed in the thesis note illuminance drop with distance from the source and with thicker specimens (dispersion/attenuation), again not explicitly handled by a constant-VT material.

Setup Pitfalls That Skew Results

Using the render family for analysis. Running Insight on the fiber family (without the calibrated composite) yields little/no transmitted light—misleading underestimation. Use the composite material for analysis views.

Uncalibrated environment. If location, weather (GHI/DNI/DHI), or sky model are not set correctly, solar geometry and diffuse components won't match the site.

Material defaults. Generic glazing/reflectance values, wrong analysis-plane height, or overly coarse grids distort illuminance and uniformity maps.

Leaky spaces & hidden elements. Open boundaries or hidden windows/shading in the analysis view can produce false negatives/positives.

Over-interpreting a single climate/hour. The thesis calibration focuses on Baghdad, Aug-10 at 13:00/15:00 with diffuse-dominant conditions; conclusions at other times/climates need separate runs.

Conclusion

Our study demonstrates a practical, reproducible BIM pathway for evaluating light-transmitting concrete (LTC) that respects current engine limits while still yielding decision-grade daylight predictions. The key contributions and takeaways are:

- **Dual-model workflow that actually works.**

Keep an explicit fiber-optic family for architectural visuals, but switch to a homogenized composite material (VT = measured lab transmittance) in analysis views. This avoids the micro-optics gap in mainstream solvers and turns lab data into realistic illuminance maps the design team can act on.

- **Calibration that anchors predictions to reality.**

When location, sky model, and irradiance (GHI/DNI/DHI) are set from the project climate—and when glazing VT, surface reflectances, analysis-plane height, grid density, and thresholds are documented—BIM outputs align with measured magnitudes. The Baghdad case (Aug-10; Perez sky; diffuse-dominant hours) showed consistent, interpretable maps without over-crediting LTC.

- **Evidence-based VT inputs for design scale.**

Use measured VT whenever available. Absent tests, adopt 5–7% VT for ~100 mm walls at ~4–5% POF by volume (1–2 mm fibers on ~15–20 mm grids) and run ±2–3% sensitivity. Expect thinner, optimized panels to reach low double digits, and thicker or field installations to land in the low single digits. This keeps expectations realistic and comparable across options.

- **Design implications: more light where it counts, with less glass.**

Calibrated BIM studies reveal the typical bright perimeter / dim core pattern. Targeted LTC/POF placement pulls daylight deeper, improves uniformity, and allows smaller vision areas—supporting security, glare control, and cooling-load reduction in programs like banks, schools, and museums.

- **Validated by experiment and case work.**

Lux-box measurements ($\rho = J_1/J_0$) feed directly into the BIM material VT and reproduce observed trends: higher POF area → higher transmittance; smaller diameters at fixed area → higher transmittance; WCC > GCC under matched geometry. The building case confirmed under-lit cores and guided LTC/POF interventions.

- **A minimal “calibration dossier” for reproducibility.**

To make studies portable across teams and climates, each run should list: (a) VT & source (lab/literature) and panel thickness/fiber recipe, (b) site/sky/time and GHI/DNI/DHI, (c) analysis-plane height, grid spacing, thresholds, and (d) glazing/reflectance assumptions. This standard note makes results transparent, auditable, and easy to replicate.

Bottom line: A calibrated composite-VT approach—paired with disciplined environmental setup—bridges the lab and the model, enabling designers to place and size LTC confidently before construction. Accuracy will continue to improve by coupling BIM with physics-based optical engines (e.g., Radiance or ANSYS Optical/ zemax), but the workflow presented here is fit-for-purpose today and immediately applicable to real projects.

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