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Design and Fabrication of Rectangular Pavement Blocks with Embedded Light-Transmitting Optical Fiber Strands

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ABSTRACT: This study determines the structural and optical performance of rectangular pavement blocks integrated with light-transmitting optical fibers. The objective is to create innovative pavement blocks and identify their best applications based on their properties. The experimental research evaluates two configurations: 1.0 mm diameter fibers at 0.1% volume and 2.0 mm diameter fibers at 0.4% volume. The pavement blocks were tested for mechanical and physical properties—including compressive strength, flexural strength, and water absorption—after a 28-day curing period, as well as light transmittance for sunlight and LED light. Structural testing revealed that smaller fiber diameters yield superior mechanical properties, with the 1.0 mm specimens achieving a compressive strength of 119.991 N/mm² and a flexural strength of 3.467 N/mm², showing significant potential as construction materials for the industry. The optical performance of the 2.0 mm fibers demonstrated maximum efficiency, achieving a peak transmission of 0.072% at midday, which doubles the output of the 1.0 mm variety. Under artificial LED lighting, low-light environments enhanced visual utility by increasing luminance contrast. The 1.0 mm block is commercially viable for residential driveways and walkways due to its selling price and high strength. The 2.0 mm block serves as a high-value solution for specialized architectural installations, interactive displays, and museums, where superior light transmittance and durability are required.

Keywords: Light-transmitting, Optical Fibers, Luminance Contrast, Sun orientation, Pavement blocks

CHAPTER I
INTRODUCTION

In the modern era of urban development, construction materials have evolved from purely structural components into multifunctional, "smart" infrastructure. Traditional concrete paving units have long been the standard for pedestrian walkways and urban landscapes due to their durability, ease of maintenance, and cost-effectiveness. However, as cities grow more complex, there is an increasing demand for infrastructure that enhances energy efficiency and aesthetics. This shift necessitates a departure from standard, one-dimensional materials toward advanced cementitious composites capable of interacting with the urban environment to provide more than just a walking surface.

While walkways commonly consist of plain concrete and standard pavement blocks, material innovation now extends beyond structural performance to include aesthetic appeal. However, most existing studies focus exclusively on vertical applications. Light-transmitting concrete incorporates optical fibers that allow light to pass through the structure while maintaining its structural integrity. The use of optical fibers is highly effective for transmitting light; however, this transmission is linear, requiring a dedicated light source to be positioned directly behind or beneath the blocks, which has primarily proven effective in vertical installations.

This study aims to explore the integration of embedded optical fibers into pavement blocks to create innovative paving units. Specifically, it seeks to fabricate and evaluate rectangular pavement blocks embedded with light-transmitting optical fibers, determining both their light transmission capabilities and structural strength for horizontal pavement applications.

OBJECTIVES

General Objective

The main objective of this study is to design, fabricate, and evaluate light-transmitting rectangular pavement blocks embedded with optical fiber, with the goal of determining the illumination, aesthetics, and structural strength in pavement applications. Furthermore, this research aims to ensure that the produced paving blocks comply with the quality and performance requirements set by Philippine standards for pavement blocks.

Specific Objective

1.) To determine the effect of embedding 1.0 mm (0.1% volume) and 2.0 mm (0.4% volume) optical fibers on the compressive strength, flexural strength, and water absorption of rectangular pavement blocks after a 28-day curing period.

2.) To measure the hourly light-transmission (Lux) of 1.0 mm and 2.0 mm diameter fibers from 6:00 AM.

3.) To determine the ideal installation pattern for the luminous flux of the pavement blocks, including the performance of visibility during partial shadowing.

4.) To determine the difference in cost relative to strength between the produced pavement blocks and conventional pavement blocks available on the market.

METHODOLOGY

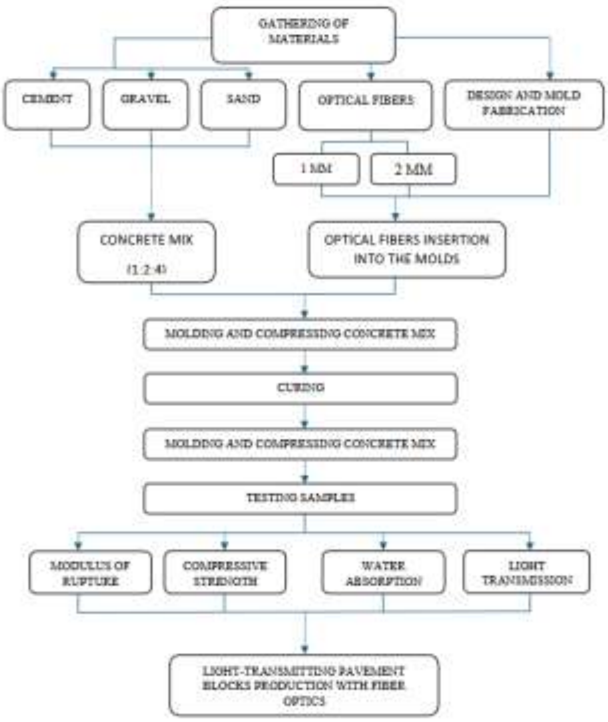

Figure 1. Conceptual Framework

This conceptual framework illustrates the systematic development of light-transmitting pavement blocks through a four-stage process: material preparation, fabrication, testing, and final production. The methodology begins with the procurement of concrete constituents and 1 mm/2 mm fiber optics, alongside the design of specialized molds. The core fabrication involves a 1:2:4 concrete mix ratio for pedestrian integration with optical fibers through a molding and compression sequence. Following a standard curing period, the samples undergo rigorous validation via light transmission, water absorption, flexural, and compressive strength tests. This structured approach ensures that the final output achieves the necessary synergy between aesthetic optical functionality and structural pavement requirements.

Significance of the Study

To the Engineering Field

The study contributes new knowledge to the emerging area of smart construction materials. By exploring the practical application of optical fiber in pavement systems, it provides insights that may guide future research, design innovations, and engineering practices aimed at improving its functionality. The findings may serve as a reference for engineers, architects, and researchers interested in advanced material integration of pavement technologies.

To the Architectural Field

This research offers architects a versatile and innovative material that merges structural form with integrated lighting functionality. By demonstrating how light-transmitting concrete blocks can be fabricated with specific fiber orientations, the study provides a design tool for creating aesthetically pleasing and interactive urban spaces. These findings help professionals move beyond traditional, bulky lighting fixtures toward seamless, minimalist surfaces that enhance the visual character of modern landscapes while maintaining the structural integrity of the built environment.

To the Public

This study contributes to the creation of more engaging and modern communal spaces by introducing an innovative material for interactive urban environments. The integration of light-transmitting technology into common walkways enhances the visual appeal and modern character of public paths, offering a unique sensory experience for pedestrians. Ultimately, this research promotes the development of high-quality, user-centered infrastructure that transforms ordinary surfaces into functional design elements, enriching the overall atmosphere of the built environment.

Scope and Limitations of the Study

The scope of this study is focused on evaluating the mechanical and optical performance of concrete pavement blocks integrated with Optical fiber. Utilizing a standard concrete mix, the research investigates the relationship between various fiber diameters and volume densities on the performance of the blocks. The investigation includes a comprehensive assessment of structural integrity through standardized testing for compressive strength, flexural strength, and water absorption. Concurrently, the study quantifies the optical functionality of the blocks by measuring light-transmission efficiency across multiple axes under varying lighting conditions, providing a technical baseline for integrating passive illumination into pedestrian-grade urban surfaces.

Limitations

The study is constrained by factors that may influence the breadth and generalizability of its findings. The structural evaluation is restricted to core mechanical properties and does not include secondary characteristics such as abrasion or slip resistance. The assessment of illumination is confined to selected light sources and does not encompass all possible environmental lighting conditions or long-term optical degradation. Additionally, environmental performance factors—including prolonged exposure to UV radiation, moisture, and extreme temperature variations—are not fully simulated, as the research focuses on short-term laboratory observations. Finally, the use of specific fiber types and a single conventional concrete mix design may limit the direct applicability of these results to other material combinations.

Delimitations

Several boundaries have been intentionally established to maintain the clarity and manageability of this investigation. This study is delimited to the testing of standard-sized pavement blocks compatible with existing laboratory equipment. The application is strictly limited to pedestrian-oriented pavements and excludes surfaces subjected to heavy vehicular loads. Furthermore, the research focuses on achieving necessary performance criteria rather than maximizing strength beyond conventional requirements. The study also excludes large-scale field installations and long-term performance monitoring. Additionally, the investigation does not account for the impact of surface dirt, debris, or environmental staining on light transmission efficiency, focusing instead on the performance of the blocks in a clean, controlled state. This structured approach ensures that the final output achieves the necessary synergy between aesthetic optical functionality and structural pavement requirements.

Definition of Terms

1:2:4 Concrete Mix. The specific design proportion of one part Portland cement, two parts fine aggregate, and four parts coarse aggregate by volume. In this study, this ratio serves as the constant control matrix into which optical fibers are integrated.

28-Day Curing Period. The standardized duration for the hydration process of cementitious specimens. This timeframe is the benchmark for measuring the ultimate compressive and flexural strength of the pavement blocks, representing their peak structural maturity.

Compressive Strength. The maximum resistance of the pavement block to axial crushing loads, measured in Megapascals (MPa). This is determined by applying a steady vertical force until the specimen undergoes structural failure.

Flexural Strength (Modulus of Rupture). The ability of the block to resist failure under bending stress. This parameter is critical for pavement blocks, as it simulates the tension experienced by the material when subjected to point loads over potentially uneven subgrades.

Light-Transmission Efficiency. The quantitative measure of luminous flux that successfully passes through the integrated fibers from a light source to the opposite face of the block. This is operationally measured in Lux using a digital light meter.

Longitudinal and Transverse Axes. The directional orientations for light measurement. The longitudinal axis refers to the path parallel to the fiber’s length (straight through), while the transverse axis refers to the perpendicular spread or "glow" across the block’s surface.

Luminous Effect. The visual quality and intensity of light emitted from the surface of the block. This encompasses both the measurable brightness (Lux) and the aesthetic "glow" produced by the fiber ends.

Lux. The SI unit of illuminance and luminous emittance, measuring luminous flux per unit area. It is used in this study to provide a standardized numerical value for the light output of each specimen.

Partial Shadowing. A specific testing condition where exactly one-half of the block’s surface is obstructed (simulating a human shadow or debris). This is used to evaluate how much more visible the light-emitting fibers become in the shadowed portion compared to the unshadowed portion.

Pavement Blocks. The pre-cast concrete units used in this study are rectangular in shape, designed for pedestrian-grade walkways and urban landscaping.

Optical fiber. A light-conducting material characterized by a core and cladding structure. In this study, it serves as the medium for passive light harvesting, selected for its mechanical flexibility and compatibility with concrete.

Volume Density (Fiber Loading). The ratio of the total volume of optical fibers to the total volume of the concrete block. This is the primary independent variable used to determine the balance between light output and structural strength.

Water Absorption. The measure of the concrete specimen's ability to take in water through its pore structure, calculated as the percentage increase in mass after 24 hours of immersion. to 6:00 PM under both natural sunlight and artificial LED lighting.

CHAPTER II
METHODS AND PROCEDURE

This chapter presents a detailed description of the research methodology employed to gather the necessary data and information for the study. It outlines the data collection procedures and the instruments utilized to ensure accuracy and reliability. Furthermore, this chapter discusses the research design and method adopted, the location where the study was conducted, and the step-by-step process followed throughout the project’s implementation.

Research Design

The study employed an experimental research design to systematically investigate the fabrication process and performance characteristics of light-transmitting rectangular pavement blocks embedded with optical fiber. Through this design, the researcher was able to isolate the variable of fiber optic inclusion and assess its effects under standardized testing conditions.

By utilizing controlled fabrication methods and applying standardized performance tests—including compressive strength, water absorption, flexural strength, and light transmission under various illumination conditions—the experimental design provided comprehensive data on the benefits and limitations of the optical fiber integrated blocks. This design further facilitated the validation of hypotheses concerning the functional improvements and practical applications of the new pavement block technology, ensuring the reliability and replicability of the results.

Locale of the study

The researchers conducted the primary fabrication of the specimens at the Sta. Maria Residence in Papua St., Langla, Jaen, Nueva Ecija. This location was selected for its suitability for the specialized molding process, the precise integration of plastic optical fibers into the pavement blocks, and the initial water absorption tests. Furthermore, the site provided a controlled environment conducive to the 28-day curing process required before the samples underwent structural testing.

The mechanical evaluations were conducted within Cabanatuan City to utilize specialized laboratory facilities. Specifically, the compressive strength and flexural strength tests were performed at the Nueva Ecija University of Science and Technology (NEUST), ensuring that the data were gathered using industry-standard calibrated equipment.

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Research Instrument

This study consists of structured documentation and measurement tools designed to systematically collect data relevant to the design and fabrication of light-transmitting rectangular pavement blocks using optical fiber. It includes detailed recording sheets for the fabrication process, noting materials used, preparation methods, and any deviations during production. Mechanical performance tests—such as compressive strength, flexural strength, water absorption—are carried out using standard procedures, and results are recorded with reference to testing dates and sample identifiers to ensure reliability and reproducibility.

Visual observations are noted to complement quantitative data, capturing the effectiveness of the fiber optic integration in different environments. This instrument allows consistent data collection across all phases of the study, ensuring that both the structural and functional aspects of the pavement blocks are thoroughly evaluated.

Data Gathering

The data for this study will be collected through a combination of laboratory experiments and secondary data analysis from previous research. The procedure is outlined as follows:

1. Mold Design Preparation

The desired mold for the light-transmitting rectangular pavement blocks was designed through AutoCAD.

2. Specimen Preparation

The concrete mix was proportioned, mixed, and cast into rectangular block molds. Optical fibers were embedded in the experimental group using alignment frames to ensure consistent placement. All samples underwent controlled curing periods prior to testing.

3. Mechanical Performance Testing

After the designated curing periods, mechanical tests were conducted following the respective ASTM standards. Values for compressive strength, flexural strength, water absorption, and light transmission test were recorded.

4. Optical Performance Measurement

Light transmission was tested using both natural light and controlled LED illumination. A digital lux meter measured incident and transmitted light values to quantify the illumination capacity of the fiber-embedded blocks.

5. Data Recording and Verification

All test results were logged in laboratory data sheets, checked for completeness, and cross-verified to ensure accuracy. Any anomalies were retested to avoid inconsistencies.

Actual Procedure of the Study

1. Preparation of Materials

1.1. Purchasing phenolic board for rectangular pavement block molds.

Figure II. 3. Phenolic board

1.2. The optical fibers used in this study are commercially available through various online stores.

Figure II. 3. 1 mm and 2 mm diameter of optical fiber

2. Creating Mold

2.1. The phenolic board was sectioned using a circular saw equipped with a fine-tooth blade to ensure dimensional precision. This method was selected to achieve a smooth, uniform edge and to prevent unwanted surface texturing or splintering, which could compromise the finish of the concrete pavement blocks. Six (6) pieces of 240 mm by 75 mm, 120 mm by 75 mm and three (3) pieces of 210 mm by 120 mm phenolic board were cut.

Figure II-4 Cutting of phenolic board

2.2. Two sets of sixteen holes were drilled on the base of the formworks with diameters of 1 mm and 2mm on the first and second set, respectively. The large hole was designated for the 2 mm diameter optical fiber, while the smaller hole was designated for the 1 mm diameter optical fiber.

Figure II.-5. Drilling of holes in the base of the formworks

2.3. Each formwork was fastened on every side by 1 mm diameter nails to keep the formworks intact and to prevent the formworks from cracking.

Figure II.-6. Assembling all the parts of the formworks

Table 1– 1. Shows the Physical and Technical Specifications of Samples

Property	**Description**
Block Dimensions	210mm x 120 mm x 60 mm (For Pedestrian)
Fiber Types	Plastic Optical Fiber (POF)
Fiber Diameters	1.0mm (Fiber volume ratio is 0.1%)
	2.0 mm (Fiber volume ratio is 0.4%)
Fiber Quantity	14 Individual Fiber Pieces
Total Luminous Points	28 points
Total Length of Optical fiber for 1 mm and 2 mm diameters	2000 mm

3. Optical Fiber Alignment

The optical fiber was carefully inserted through the pre-drilled holes in the formworks. Each fiber optic follows a curved path passing through two holes on both ends. It consists of 14 at starts and 14 at ends. A 5 mm concrete cover was used to prevent the lowest part of the optical fiber from being exposed at the base of the sample.

Figure II-7. Alignment of the optical fiber into the mold

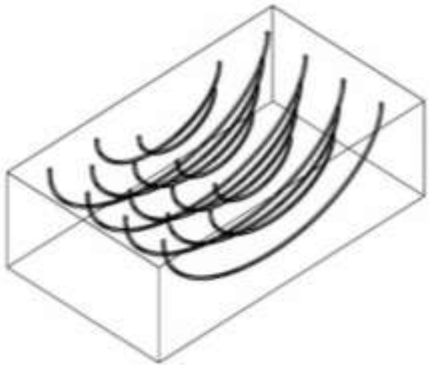

Figure II-8. Illustration of an optical fiber embedded in concrete pavement blocks

Figure II-8 illustrates the insertion of 14 strands of optical fiber. The lengths of the fibers consist of four strands at 230 mm, three strands at 190 mm, four strands at 150 mm, and three strands at 110 mm, with a total allowance of 3 mm for trimming (1.5 mm on each end). The strands are arranged with a 24 mm point-to-point spacing on the surface. To ensure structural integrity, a minimum clearance of 2.5 mm is maintained from the bottom of the mold to the optical fiber. The fiber insertion follows a staggered pattern: the mold contains four holes in the first row, three in the second, three in the third, and four in the final row.

4. Concrete Pouring

Figure II-9. Cement was prepared for concrete pouring

5. Disassemblage

After the concrete had hardened, the formworks were dismantled, and the light-transmitting rectangular pavement blocks using optic fibers were then separated from the formworks. The extra optical fiber on the surface of the pavement bricks was cut to create a smooth finished surface.

Figure II-10. Dismantling of the formworks

6. Curing

The samples were submerged in the water to cure. The samples were cured for twenty-eight (28) days.

Figure II-11. Curing the samples

9. Testing

9.1 Water Absorption Test. In the saturation process, test specimens were fully immersed in water at room temperature for a duration of 24 ± 2 hours. After immersion, the specimens were removed and allowed to drain for 1 minute. Visible surface water was carefully removed using a damp cloth. Immediately thereafter, each specimen was weighed, and the saturated mass was recorded in kilograms (kg). After the process of saturation, the specimens were sun dried for a minimum of 24 hours. Drying was continued until two consecutive measurements, taken at 2-hour intervals, showed a mass loss not exceeding 0.1% of the previous mass. The sun-dry mass of each specimen was then recorded in kilograms (kg). Based on the standards set by the Department of Public Works and Highways (DPWH), the water absorption for an individual unit must not exceed 7%, while the average absorption across all units must not exceed 5%.

The water absorption of each specimen was determined using the following equation:

$$\text{Water Absorption (\%)} = \frac{\text{Ms} - \text{Md}}{\text{Md}} \times 100$$

Ms = Saturated weight of the specimen
Md = Dried mass of the specimen

Figure II-12. Testing the samples

9.2 Compressive Strength Test. Before testing, the specimens were immersed in water for 28 days at a controlled temperature of 20°C. Before testing, the bearing surfaces of the compression testing machine were cleaned to ensure proper contact. Each specimen was then carefully positioned and aligned centrally between the bearing plates to achieve uniform load distribution. The load was applied gradually and without shock and increased continuously at a rate of 15 MPa per minute. The loading was continued until the specimen failed, indicated by the inability to sustain additional load or the occurrence of visible cracking or delamination. The maximum load sustained by each specimen at failure was recorded in Newtons (N). The compressive strength of each specimen was calculated using the following equation:

$$\vartheta = \frac{P}{A}$$

ϑ = compressive strength (MPa)
P = maximum load at failure (N)

A= area of the specimen (mm^2)

The structural performance of concrete pavement blocks is governed by the Department of Public Works and Highways (DPWH) standards, which establish specific mechanical benchmarks for various applications. For pedestrian areas, current specifications necessitate a heightened durability threshold to ensure long-term serviceability. According to these guidelines, the minimum allowable compressive strength for any individual paving unit is 24 MPa, while the calculated average of three (3) representative samples must reach at least 28 MPa.

Figure II- 13. Testing the samples

9.3 Modulus of Rupture Test. The test specimens were subjected to a simple beam loading using a three-point loading configuration, in which the load was applied at the midpoint through a loading roller positioned equidistant between two supporting rollers. Before loading, the specimen was correctly aligned on the supporting rollers to maintain stability and avoid eccentric loading. The load was then applied vertically from the top surface without shock. Loading was continued until the specimen failure occurred. For reinforced concrete, the NSCP 2015 (Section 419.2.3) defines the modulus of rupture—the theoretical maximum tensile stress a concrete beam can resist in a flexural test as:

$$f_r = 0.62\gamma\sqrt{f'c}$$

where, f_r = Modulus of Rupture (Flexural Strength) in MPa.
γ = Modification factor for lightweight concrete (1.0).
f'c= Specified compressive strength of concrete in MPa that is based on the minimum compressive strength test according to DPWH.

Figure II-14. Testing the samples

The samples were tested by its flexural strength test using the Universal Testing Machine (UTM).

9.4 Light Transmittance Test. The light transmittance test was conducted to evaluate the ability of fiber optic pavement blocks to transmit light under both natural daylight and artificial LED illumination. For the daylight test, the incident illuminance on the block surface was measured in lux using a calibrated lux meter, and the transmitted illuminance on the opposite side of the block was similarly recorded. The test was performed for blocks containing 1 mm and 2 mm diameter optical fiber, and measurements were taken at hourly intervals to capture variations in sunlight intensity throughout the day. The researchers utilized a Dark Box and a Partial Shadowing technique to evaluate the luminous efficiency of the pavement blocks under different environmental conditions. The Light Transmission Efficiency Formula was applied to calculate the percentage of light transmitted:

$$\text{Transmission Efficiency (\%)} = \frac{\text{Etransmitted}}{\text{Eincident or Eambient}} \text{x}100$$

where $E_{transmitted}$ is the illuminance measured on the block's opposite side, and $E_{incident\ or}$ the $E_{ambient}$ is the illuminance incident on the surface.

The light-transmitting capacity of the concrete pavement blocks was measured using a digital lux meter with an operational range of 0 to 20,000 lux. It is important to note that a reading of 0 lux on the device does not signify an absolute absence of light (absolute darkness).

Figure II-15. Light transmission testing of pavement blocks using artificial and natural light sources in a controlled dark box.

CHAPTER III

Presentation, Analysis, and Interpretation of Data

This chapter presents, analyzes, and interprets the data collected. To ensure clarity, the data is organized using tables, charts, and graphs. Both statistical and qualitative methods are employed to identify patterns and relationships, and the results are interpreted in the context of the research objectives.

Modulus of Rupture Test

Table III – 1.1 Shows the Average Modulus of Rupture Test for Block A

Sample variation (Diameter of	Test specimen (mm)	Area (mm^2)	Load (N)	Modulus of Rupture (N/mm^2)

Optical fiber)					
1 mm	Span Thickness Width	120 60 120	3600	14750	3.5
2 mm	Span Thickness Width	120 60 120	3600	14450	3.4

Table III – 1.2 Shows the Average Modulus of Rupture Test for Block B

Sample variation (Diameter of Optical fiber)	Test specimen (mm)		Area (mm^2)	Load (N)	Modulus of Rupture (N/mm^2)
1 mm	Span Thickness Width	120 60 120	3600	12450	3.5
2 mm	Span Thickness Width	120 60 120	3600	11150	3.3

Table III – 1.3 Shows the Average Modulus of Rupture Test for Block C

Sample variation (Diameter of Optical fiber)	Test specimen (mm)		Area (mm^2)	Load (N)	Modulus of Rupture (N/mm^2)
1 mm	Span Thickness Width	120 60 120	3600	12300	3.4
2 mm	Span Thickness Width	120 60 120	3600	11850	3.5

Table III – 1.4 Shows the Average Modulus of Rupture Test

Sample variation (Diameter of Optical fiber)	Test specimen (mm)		Area (mm^2)	Load (N)	Modulus of Rupture (N/mm^2)
1 mm	Span Thickness Width	120 60 120	3600	13166.557	3.467
2 mm	Span Thickness Width	120 60 120	3600	12483.333	3.4

The Modulus of Rupture (MOR) test results indicate that for the 1:2:4 mix ratio (cement:sand:aggregate), the specimen with 1 mm diameter optical fiber at 0.1% content achieved the highest flexural strength of 3.467 N/mm². In comparison, the specimen with 2 mm diameter optical fiber at 0.4% content showed a slightly reduced flexural strength of 3.4 N/mm². These results suggest that while both configurations are effective, increasing the fiber diameter and volume can lead to a minor decrease in the flexural strength of the pavement blocks. This indicates that the 1 mm fibers provide a more efficient distribution within the pavement blocks, leading to superior resistance against bending forces. The slight reduction seen with the 2 mm fibers suggests that as the fiber diameter increases, the bond area or the "grip" between the fiber and the blocks changes, which slightly affects how the pavement blocks redistribute internal stress under a load.

Sample variation (Diameter of Optical fiber)	Test specimen (mm)		Area (mm^2)	Load (N)	Compressive Strength (N/mm^2)
1 mm	Length Thickness Width	210 60 120	3600	428366.667	118.991
2 mm	Length Thickness Width	210 60 120	3600	327030	90.842

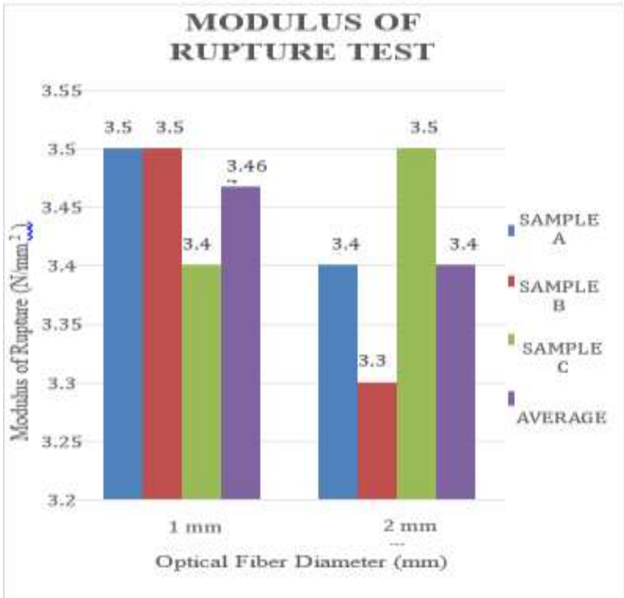

Figure III – 1. Shows the Individual and Average test results of Modulus Rupture, with 1 mm and 2 mm Diameter Optical fiber.

Compressive Strength Test

Table III – 2.1 Shows the Compressive Strength Test for Block A

Sample variation (Diameter of Optical fiber)	Test specimen (mm)		Area (mm^2)	Load (N)	Modulus of Rupture (N/mm^2)
1 mm	Length Thickness Width	210 60 120	3600	486150	135.042
2 mm	Length Thickness Width	210 60 120	3600	368640	102.4

Table III – 2.3 Shows the Compressive Strength Test for Block C

Sample variation (Diameter of Optical fiber)	Test specimen (mm)		Area (mm^2)	Load (N)	Modulus of Rupture (N/mm^2)
1 mm	Length Thickness Width	210 60 120	3600	384550	106.820
2 mm	Length Thickness Width	210 60 120	3600	322300	89.528

Table III – 2.4 Shows the Average Compressive Strength Test

Sample variation (Diameter of Optical fiber)	Test specime (mm)		Area (mm^2)	Load (N)	Compressive Strength (N/mm^2)
1 mm	Length Thickness Width	210 60 120	3600	414400	115.111
2 mm	Length Thickness Width	210 60 120	3600	290150	80.597

Table III–2.4 presents the compressive strength values of the pavement blocks incorporating optical fiber with diameters of 1.0 mm and 2.0 mm after 28 days of curing. The specimens utilizing 1.0 mm diameter optical fiber at 0.1% by volume achieved a compressive strength of 119.991 N/mm². In contrast, the pavement blocks with 2.0 mm diameter optical fiber at a 0.4% content exhibited a lower compressive strength of 90.842 N/mm². These results indicate an inverse relationship between fiber diameter and structural performance, suggesting that a decrease in fiber optic diameter—and a lower overall fiber volume—results in higher compressive strength.

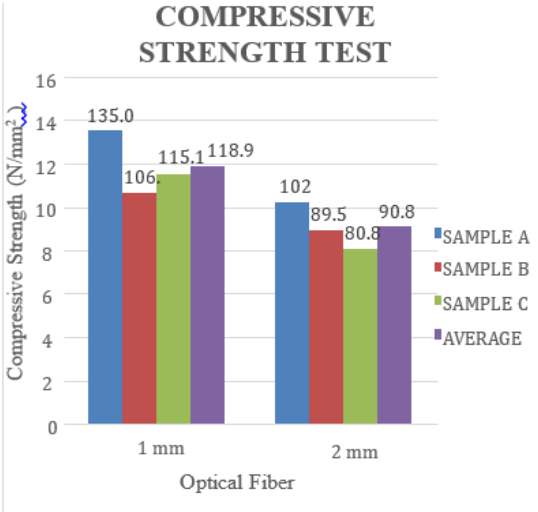

Figure III – 2. Shows the Individual and Average test results of the Compressive Strength Test, with 1 mm and 2 mm Diameter Optical fiber.

Water Absorption Test

Table III – 3.1 Shows the Water Absorption Test for Block A

Sample variation (Diameter of Optical fiber)	Sample Dry Mass (kg)	Sample Saturated Mass (kg)	Water Absorption (%)
1 mm	3.250	3.350	3.077
2 mm	3.200	3.300	3.125

Table III – 3.2 Shows the Water Absorption Test for Block B

Sample variation (Diameter of Optical fiber)	Sample Dry Mass (kg)	Sample Saturated Mass (kg)	Water Absorption (%)
1 mm	3.100	3.200	3.226
2 mm	3.150	3.250	3.175

Table III – 3.3 Shows the Water Absorption Test for Block C

Sample variation (Diameter of Optical fiber)	Sample Dry Mass (kg)	Sample Saturated Mass (kg)	Water Absorption (%)
1 mm	3.250	3.350	3.077
2 mm	3.250	3.350	3.077

Table III – 3.4 Shows the Average Water Absorption Test

Sample variation (Diameter of Optical fiber)	Sample Dry Mass (kg)	Sample Saturated Mass (kg)	Water Absorption (%)
1 mm	3.2	3.3	3.125
2 mm	3.2	3.3	3.125

The water absorption results indicate that both the 1 mm and 2 mm fiber optic pavement blocks attained an average absorption of 3.125%, which is well below the maximum allowable average of 5.0% specified in ASTM C936. This confirms that the specimens exhibit low permeability and dense pavement blocks, reflecting adequate compaction and proper hydration. The similar results for both fiber diameters indicate that the incorporation of optical fiber does not significantly affect the water absorption characteristics of the pavement blocks. Moreover, the low absorption value suggests that the presence of the optical fibers does not adversely influence the integrity of the pavement blocks, thereby maintaining the overall durability of the material. Specifically, the data reveal that adding or increasing the diameter from 1 mm to 2 mm does not affect how much water the units soak up. The performance remains the same, proving that the larger fiber size does not create additional holes or pathways for water to get inside.

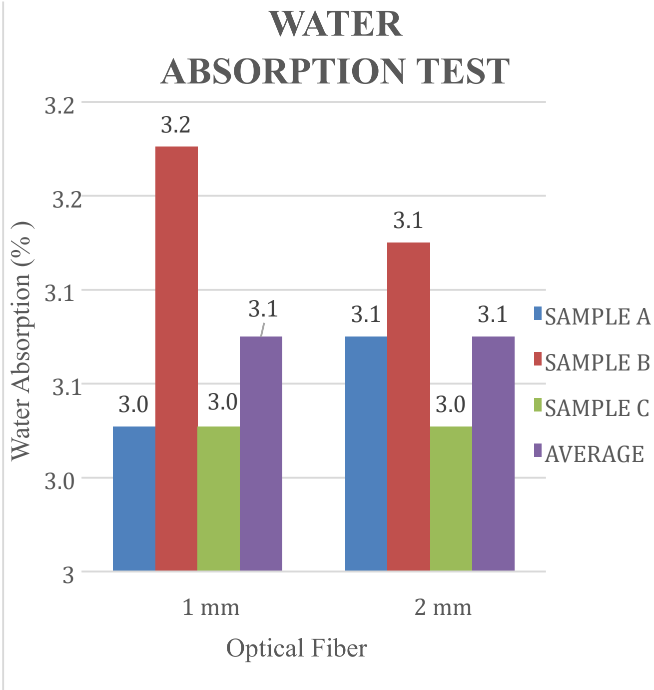

Figure III – 3. Shows the Individual and Average test results of the Water Absorption Test, with 1 mm and 2 mm Diameter Optical fiber.

Table III.4 Testing Results for Physical and Mechanical Properties

1 mm Optical fiber

Testing Methods	Results	Standard for Pavement Blocks (For Pedestrians)	Remarks
Modulus of Rupture Test	3.467	Individual: S ≥ 3.04 MPa Average: S ≥ 3.28 MPa	Passed
Compressive Strength Test	118.89 1	Individual: > 24 MPa Average: S > 28 MPa	Passed
Water Absorption Test	3.125	Individual: S < 7% Average: S< 5%	Passed

2 mm Optical fiber

Testing Methods	Results	Standard for Pavement Blocks *(For Pedestrians)*	Remarks
Modulus of Rupture Test	3.4	Individual: S ≥ 3.04 MPa Average: S ≥ 3.28 MPa	Passed
Compressive Strength Test	90.842	Individual: > 24 MPa Average: S > 28 MPa	Passed

The testing results for both the 1 mm and 2 mm fiber optic variations confirm their suitability for pedestrian pavement, as both types met or exceeded all required standards. Notably, the Compressive Strength for both diameters, reaching up to 118.891 MPa, outperformed the minimum requirement of 28

MPa, ensuring exceptional durability. Additionally, the Modulus of Rupture results of 3.467 MPa and 3.4 MPa surpassed the average flexural standard, while the Water Absorption rate of 3.125% remained within the individual passing threshold of 7%. Overall, the data indicate that embedding optical fiber does not compromise the concrete's structural integrity, making it a viable material for high-performance architectural applications.

East-to-West Transverse Axis Position

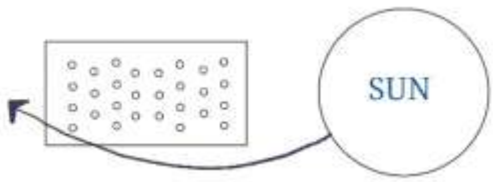

Figure III – 4. Position of pavement blocks along the east-west transverse axis relative to sun orientation.

Test for Light Transmittance Test

Table III – 4.1. Shows the Hourly Daylight Transmission Test for Block A along the East-to-West Transverse Axis.

me	Ambient Light	Transmitted Light (1 mm FO)	Transmission Efficiency	AmbientTransmitteLight tted	Light (2 mm FO)	Transmission Efficiency
	)	(Lux)	%)	ux)	(Lux)	(%)
6:00 AM	083	.000	0.000	2192	0.000	0.000
7:00 AM	9220	.400	005	9650	2.500	0.008
8:00 AM	55660	.000	005	6090	7.400	0.013
9:00 AM	0620	.200	006	3510	42.400	0.051
10:00 AM	7140	).000	023	5510	57.200	0.060
11:00 AM	9500	3.300	032	17100	78.600	0.067
12:00 PM	5700	3.800	035	23700	88.600	0.072
1:00 PM	9900	5.800	033	07200	71.800	0.067
2:00 PM	7890	5.400	027	8880	57.300	0.058
3:00 PM	2030	.900	011	5480	37.200	0.049
4:00 PM	9150	.100	003	0220	6.700	0.017
5:00 PM	5040	.200	001	6670	2.400	0.014
6:00 PM	017	.000	000	1022	0.000	0.000

Table III – 4.2. Shows the Hourly Daylight Transmission Test for Block B along the East-to-West Transverse Axis.

e	Ambient Light	Transmitted Light (1 mm FO)	Transmission Efficiency	Ambient TransmiLight tted Light	(2 mm FO)	Transmission Efficiency
	)	)	(%)	ux)	(Lux)	(%)
6:00 AM	230	000	0.000	122	0.000	0.000
7:00 AM	8980	200	0.004	8910	2.200	0.008
8:00 AM	8140	900	0.005	8140	10.700	0.018
9:00 AM	3450	200	0.010	7430	44.100	0.050
10:00 AM	0180	.900	0.028	5570	59.400	0.062
11:00 AM	9200	.600	0.032	3000	74.800	0.066
12:00 PM	7500	.600	0.033	7300	92.300	0.073
1:00 PM	3600	.500	0.026	4600	75.400	0.066
2:00 PM	9730	.100	0.024	6730	45.600	0.047
3:00 PM	3890	500	0.006	2690	21.600	0.030
4:00 PM	8000	100	0.003	9540	6.500	0.016
5:00 PM	5520	100	0.001	6800	2.800	0.017
6:00 PM	041	000	0.000	118	0.000	0.000

Table III –4.3. Shows the Hourly Daylight Transmission Test for Block C along the East-to-West Transverse Axis.

e	Ambient Light	Transmitted Light (1 mm FO)	Transmission Efficiency	AmbientTransmi Light Light (2	tted mm FO)	Transmission Efficiency
	)	(Lux)		ux)	(Lux)	(%)
6:00 AM	220	0.000	0.000	2354	0.000	0.000

7:00 AM	8860	1.000	0.003	29530	2.400	0.008
8:00 AM	7440	3.100	0.005	58260	7.700	0.013
9:00 AM	4480	4.800	0.006	85610	40.800	0.048
10:00 AM	6320	23.200	0.024	88610	45.300	0.051
11:00 AM	117900	41.300	0.035	117600	84.200	0.072
12:00 PM	125900	42.100	0.033	124300	90.600	0.073
1:00 PM	114300	39.200	0.034	111200	73.800	0.066
2:00 PM	98620	32.500	0.033	97940	60.300	0.062
3:00 PM	73550	9.600	0.013	73210	29.800	0.041
4:00 PM	39730	1.000	0.003	41080	.800	0.017
5:00 PM	15620	0.100	0.001	15690	2.300	0.015
6:00 PM	1032	0.000	0.000	1079	0.000	0.000

Table III – 4.4. Shows the Average Hourly Daylight Transmission Test along the Eastto-West Transverse Axis

Time	bient t	Transmitted Light (1 mm FO)	Transmission Efficiency	Ambient e Light	Transmitted Light (2 mm FO)	Transmission Efficiency
	(Lux)	(Lux)	(%)	(Lux)	(Lux)	(%)
6:00 AM	2177.667	0.000	0.000	2222.667	0.000	0.000
7:00 AM	29020.000	1.200	0.004	29363.333	2.367	0.008
8:00 AM	57080.000	3.000	0.005	57496.667	8.600	0.015
9:00 AM	82850.000	6.067	0.007	85516.667	42.433	0.050
10:00 AM	91213.333	22.700	0.025	93230.000	53.967	0.058
11:00 AM	118866.667	39.067	0.033	115900.000	79.200	0.068
12:00 PM	126366.667	42.833	0.034	125100.000	90.500	0.072
1:00 PM	112600.000	35.167	0.031	111000.000	73.667	0.066
2:00 PM	98746.667	27.667	0.028	97850.000	54.400	0.056
3:00 PM	73156.667	7.333	0.010	73793.333	29.533	0.040
4:00 PM	38960.000	1.067	0.003	40280.000	6.667	0.017
5:00 PM	15393.333	0.133	0.001	16386.667	2.500	0.015
6:00 PM	1030.000	0.000	0.000	1073.000	0.000	0.000

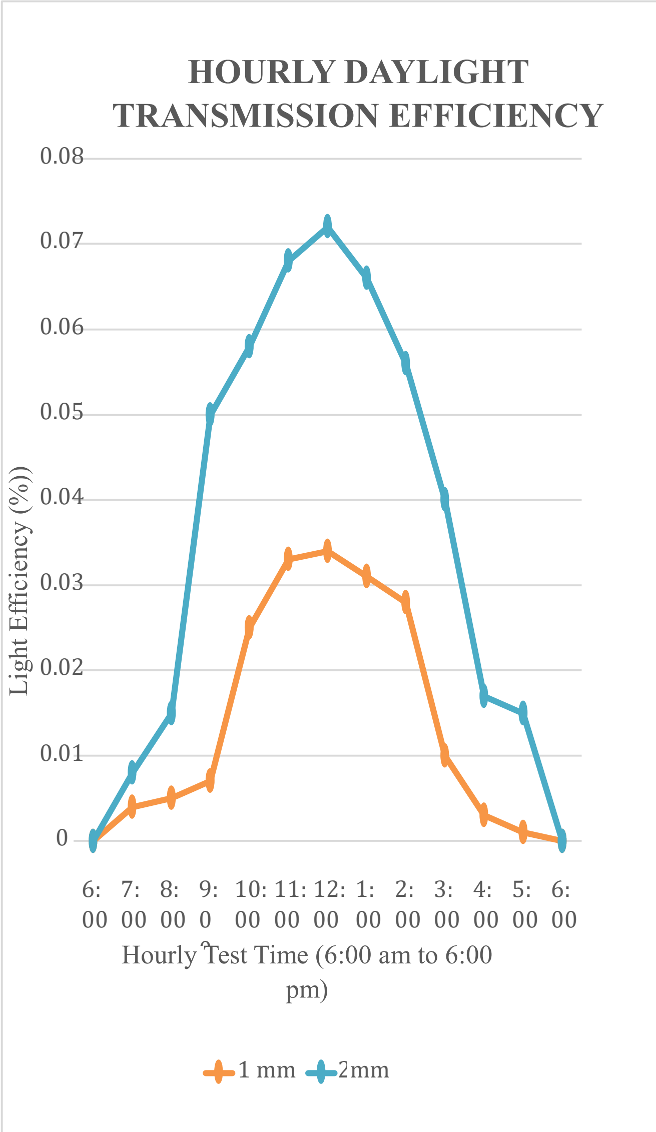

Figure III–5 Average hourly light transmission of fiber optic pavement blocks under natural daylight along the East-to-West

The findings of the Hourly Daylight Transmission Test along the East-West Transverse Axis demonstrate that the fiber diameter is a key predictor of light-harvesting performance. As seen in Figure III-5, the 2mm diameter optical fiber consistently displayed higher transmission during the 12-hour cycle, reaching a peak efficiency of 0.072% at 12:00 noon, whilst the 1mm diameter achieved its maximum at 0.034% at the same time. The statistics indicate that transmission is highly sensitive to source angle, with peak performance occurring within a six-hour window between 9:00 a.m. and 3:00 p.m., followed by a sharp decline as the sun advances past 4:00 p.m. Additionally, the presence of shadows on the receiving surface increases the brightness ratio, making the transmitted light more visible.

South-to-North Transverse Axis

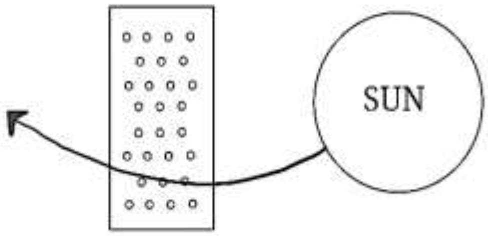

Figure III – 6. Position of pavement blocks along the south-to-north transverse axis relative to sun orientation.

Table III – 5.1. Shows the Hourly Daylight Transmission Test for Block A along the South-to-North Transverse Axis.

Time	Ambient Light	Transmitted Light (1 mm FO)	Transmission Efficiency	Ambient Light	Transmitted Light (2 mm FO)	Transmission Efficiency
	(Lux)	(Lux)	(%)	(Lux)	(Lux)	(%)
6:00 AM	1941	0.000	0.000	1904	0.000	0.000
7:00 AM	27330	2.800	0.010	27290	7.300	0.027
8:00 AM	59750	6.700	0.011	60050	18.600	0.031
9:00 AM	86340	14.700	0.017	85500	28.200	0.033
10:00 AM	110000	20.100	0.018	114700	52.800	0.046
11:00 AM	115000	34.900	0.030	117600	64.800	0.055
12:00 PM	122900	38.200	0.031	121000	78.900	0.065
1:00 PM	112000	32.700	0.029	115200	71.400	0.062
2:00 PM	101300	12.800	0.013	104100	44.000	0.042
3:00 PM	74330	6.600	0.009	78650	24.300	0.031
4:00 PM	39760	2.100	0.005	42920	9.700	0.023
5:00 PM	17330	0.200	0.001	16730	2.200	0.013
6:00 PM	842.500	0.000	0.000	998.100	0.000	0.000

Table III – 5.2. Shows the Hourly Daylight Transmission Test for Block B along the South-to-North Transvers Axis.

Time	Ambient Light	Transmitted Light (1 mm FO)	Transmission Efficiency	Ambient	Transmitted Light Light (2 mm FO)	Transmission Efficiency
	(Lux)	(Lux)	(%)	(Lux)	(Lux)	(%)
6:00 AM	2099	0.000	0.000	1876	0.000	0.000
7:00 AM	28420	3.000	0.011	27700	8.000	0.029
8:00 AM	59390	6.600	0.011	59350	17.600	0.030
9:00 AM	85500	14.300	0.017	85690	29.000	0.034
10:00 AM	104000	23.500	0.023	115600	46.900	0.041
11:00 AM	113800	32.300	0.028	119700	56.400	0.047
12:00 PM	123700	42.500	0.034	126200	68.400	0.054
1:00 PM	114000	34.400	0.030	116100	61.600	0.053
2:00 PM	100600	16.800	0.017	101000	38.900	0.039
3:00 PM	73510	4.600	0.006	75070	25.800	0.034
4:00 PM	40960	2.400	0.006	37980	9.100	0.024
5:00 PM	17900	0.100	0.001	17980	1.700	0.009
6:00 PM	883.200	0.000	0.000	952.800	0.000	0.000

Table III – 5.3. Shows the Hourly Daylight Transmission Test for Block C along the South-to-North Transverse Axis.

Time	Ambient Light	Transmitted Light (1 mm FO)	Transmission Efficiency	Ambient Transmitted Light Light (2 mm FO)		Transmission Efficiency
	(Lux)	(Lux)	(%)	(Lux)	(Lux)	(%)
6:00 AM	2089	0.000	0.000	1822	0.000	0.000
7:00 AM	28030	2.000	0.007	28090	8.200	0.029
8:00 AM	60720	6.200	0.010	59540	19.200	0.032
9:00 AM	87180	13.700	0.016	86630	30.300	0.035
10:00 AM	100700	22.000	0.022	101300	38.900	0.038
11:00 AM	114900	30.600	0.027	115900	56.300	0.049
12:00 PM	120900	35.400	0.029	125600	75.800	0.060
1:00 PM	112000	28.300	0.025	113400	61.100	0.054
2:00 PM	100800	10.800	0.011	101900	40.600	0.040
3:00 PM	75240	5.600	0.007	72330	20.200	0.028
4:00 PM	39130	1.800	0.005	38990	9.000	0.023
5:00 PM	17810	0.100	0.001	17420	2.600	0.015
6:00 PM	827.800	0.000	0.000	1013	0.000	0.000

Table III – 5.4. Shows the Average Hourly Daylight Transmission Test along the South-to-North Transverse Axis

Time	Ambient Light	Transmitted Light (1 mm FO)	Transmission Efficiency	Ambient Transmitted Light (2 mm FO)	Light	Transmission Efficiency
	(Lux)	(Lux)		(Lux)	(Lux)	(%)
6:00 AM	2043.000	.000	0.000	1867.333	0.000	0.000
7:00 AM	27926.667	.600	0.009	27693.333	7.833	0.028
8:00 AM	59953.333	6.500	0.011	59646.667	18.467	0.031
9:00 AM	86340.000	4.233	0.016	85940.000	29.167	0.034
10:00 AM	104900.000	1.867	0.021	110533.333	46.200	0.042
11:00 AM	114566.667	2.600	0.028	117733.333	59.167	0.050
12:00 PM	122500.000	3.700	0.032	124266.667	74.367	0.060
1:00 PM	112666.667	1.800	0.028	114900.000	64.700	0.056
2:00 PM	100900.000	3.467	0.013	102333.333	41.167	0.040
3:00 PM	74360.000	.600	0.008	75350.000	23.433	0.031
4:00 PM	39950.000	.100	0.005	39963.333	9.267	0.023
5:00 PM	17680.000	0.133	0.001	17376.667	2.167	0.013
6:00 PM	851.167	0.000	0.000	987.967	0.000	0.000

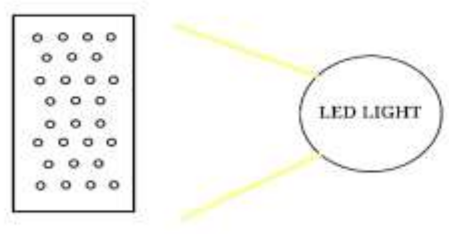

Figure III–7. Average hourly light transmission of fiber optic pavement blocks under natural daylight along the South-to-North Transverse Axis.

The study of South-to-North Transverse Axis data in Table III – 5.4 confirms that the 2mm diameter optical fiber outperforms the 1mm diameter in terms of daylight testing results. During the testing period, the 2mm optical fiber consistently achieved better transmission efficiencies, peaking at 0.060% during solar noon at 12:00 noon, whereas 1mm optical fiber only reached its highest efficiency of 0.032% at that time. Notably, while both designs exhibit a significant link between ambient light intensity and transmitted lux, the 2mm fibers almost doubled the output values of the 1mm fibers during peak hours. These findings imply that increasing fiber diameter greatly improves light-transmitting capability for South-to-North oriented installations, even though total efficiency remains low, indicating that fiber density or incoming light angles remain performance-limiting variables. Moreover, shadows on the receiving surface enhance the brightness ratio, making the transmitted light appear more distinct.

LED Light Transmission at Night Test along the Longitudinal Axis

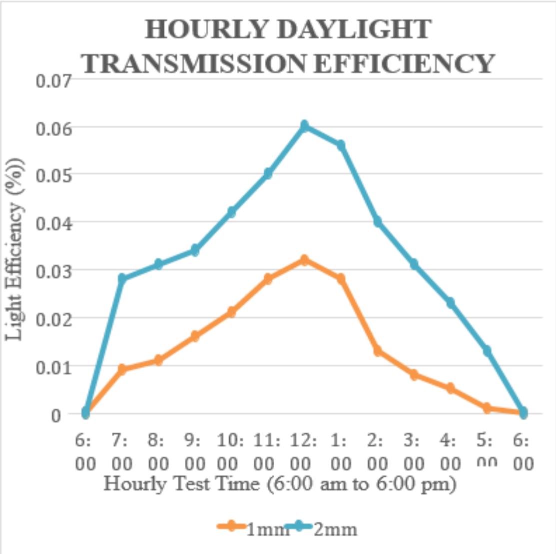

Figure III – 8. Position of pavement blocks along the longitudinal axis relative to the LED light source.

Table III – 6. Shows the calculated Average for the LED Light Transmission at Night Test along the Longitudinal Axis.

LED Watt	Height of Post (m)	Distance (m)	Incident Light (Lux)	Transmitted Light (Lux)	Transmission Efficiency (%)
30	3	0.5	19.1	0	0
30	3	1.0	17.8	0	0
30	3	1.5	14.7	0	0
30	3	2.0	11.6	0	0
30	3	2.5	9.6	0	0
30	3	3.0	6.7	0	0
30	3	3.5	4.7	0	0
30	3	4.0	3.7	0	0
30	3	4.5	1.2	0	0
30	3	5.0	0.5	0	0

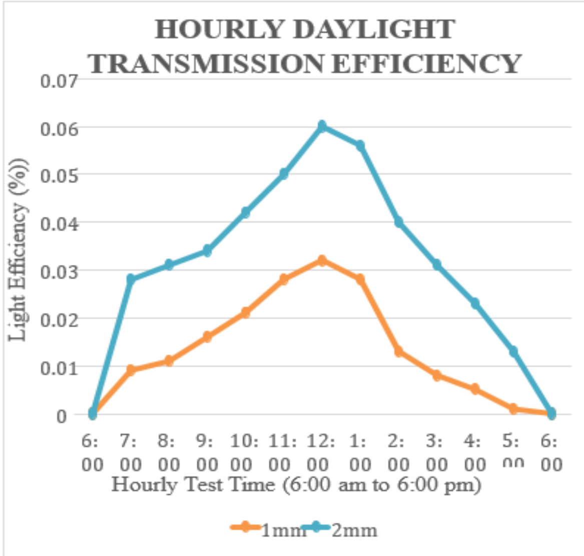

Figure III–9. Average for the LED Light Transmission at Night Test along the Longitudinal Axis.

During the night testing, although the total light received is zero because the lux meter cannot detect the values below zero, the absence of light glare and the presence of shadows allow the transmitted light to achieve a much higher luminance contrast against the darkened surface. Consequently, the fibers appear significantly more pronounced and visible in low-light environments, as the reduced competition from external light sources permits the received output to become the dominant visual feature.

LED Light Transmission at Night Test along the Transverse Axis

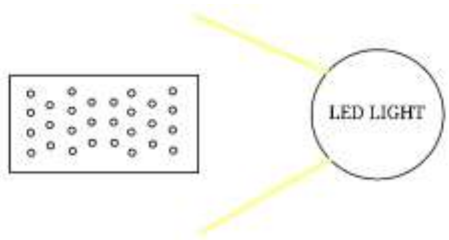

Figure III – 10. Position of pavement blocks along the transverse axis relative to the LED light source.

Table III – 7. Shows the calculated Average for the LED Light Transmission at Night Test along the Transverse Axis.

LED Watt	Height of Post	Distance	Incident Light	Transmitted Light	Transmission Efficiency
		(m)	Lux)	(Lux)	(%)
30	3	0.5	19.1	0	0
30	3	1.0	17.8	0	0
30	3	1.5	14.7	0	0
30	3	2.0	11.6	0	0
30	3	2.5	9.6	0	0
30	3	3.0	6.7	0	0
30	3	3.5	4.7	0	0
30	3	4.0	3.7	0	0
30	3	4.5	1.2	0	0
30	3	5.0	0.5	0	0

The visibility of the light transmitted along the transverse axis remains limited despite the presence of shadows. This occurs because the light source itself will obstruct both ends of the optical fiber by the shadow. This confirms that the angle of the light source and the spatial orientation of the blocks are the most critical factors in maximizing the effect of the optical fiber embedded in the pavement blocks.

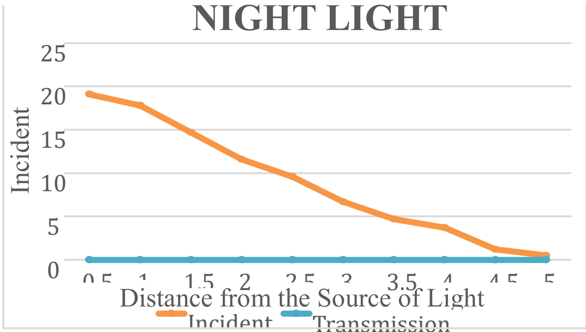

Figure III–11. Average for the LED Light Transmission at Night Test along the Transverse Axis.

Table III-8. Testing Results for Light Transmission

The following are the remarks for the light transmission test:

Opaque – No visible effect.

Trace - Tiny, dim pin-pricks visible only in darkness.

Lightly Visible - Visible but washed out by 30W LED/Sunlight.

Distinctly Visible - Sharp light points are clearly visible under the shadow.

Table III-9. Testing Results for Light Transmission

	1 mm Optical Fiber		2 mm Optical Fiber	
	East to West	South to North	East to West	South to North
Time	Remarks	Remarks	Remarks	Remarks
6:00 AM	Trace	Trace	Trace	Trace
7:00 AM	Trace	Lightly Visible	Lightly Visible	Distinctly Visible
8:00 AM	Trace	Lightly Visible	Lightly Visible	Distinctly Visible
9:00 AM	Lightly Visible	Lightly Visible	Distinctly Visible	Distinctly Visible
10:00 AM	Distinctly Visible	Distinctly Visible	Distinctly Visible	Distinctly Visible
11:00 AM	Distinctly Visible	Distinctly Visible	Distinctly Visible	Distinctly Visible
12:00 PM	Distinctly Visible	Distinctly Visible	Distinctly Visible	Distinctly Visible
1:00 PM	Distinctly Visible	Distinctly Visible	Distinctly Visible	Distinctly Visible
2:00 PM	Lightly Visible	Lightly Visible	Distinctly Visible	Distinctly Visible
3:00 PM	Lightly Visible	Lightly Visible	Distinctly Visible	Distinctly Visible
4:00 PM	Trace	Lightly Visible	Distinctly Visible	Distinctly Visible
5:00 PM	Trace	Trace	Lightly Visible	Lightly Visible
6:00 PM	Trace	Trace	Trace	Trace

The results indicate that 2 mm optical fibers provide significantly better light transmission than 1 mm fibers under both daylight and nighttime conditions. During daylight, the 2 mm fibers sustain "Distinctly Visible" illumination for a longer duration (7:00 AM to 4:00 PM), particularly in a south-to-north orientation, whereas the 1 mm fibers only achieve this level between 10:00 AM and 1:00 PM. In nighttime LED testing, both fiber sizes perform similarly at short distances (0.5–1 m) along the longitudinal axis. However, the 2 mm fibers extend "Distinctly Visible" visibility up to 1.5 m, compared to only 1.0 m for the 1 mm fibers. Visibility along the transverse axis is generally higher when unobstructed, although it may be affected by interference from the light source. As distance increases, visibility declines more rapidly in the 1 mm fibers, which become "Opaque" at 3.5 m, while the 2 mm fibers maintain visibility until approximately 4.5 m. These findings demonstrate that larger fiber diameter enhances both the duration and range of effective light transmission.

Table III-10. Shows the Cost Assessment

Assessment Cost Estimate of Pavement Block					
	Description	**Unit**	**Qty**	**Direct Unit (Php)**	**Amount (Php)**
Material Cost					
Portland Cement	Cost	kg	40	210	2.49
	Unit Cost	kg	0.017	2.49	
Sand	Cost	m^3	1200	530	0.35
	Unit Cost	m^3	0.00067	0.35	
Gravel	Cost	m^3	1400	650	0.86
	Unit Cost	m^3	0.00133	0.86	

Table III-11. Shows the Mark-up for Costs

Product/Item	**Description**	**Unit**	**Production Cost Per Unit (PHP)**	**Selling Price Per Unit (PHP)**	**Mark-up (PHP)**
Pavement Blocks	1 mm Optical Fiber (210mm x 120mm x 60 mm)	pc	23.43	32	8.57
Pavement Blocks	2 mm Optical Fiber (210mm x 120mm x 60 mm)	pc	73.03	85	11.97

The cost assessment for producing 210 mm x 120 mm x 60 mm pavement blocks embedding optical fiber shows a direct material cost of ₱23.43 per piece for 1 mm fibers and ₱73.03 per piece for 2 mm fibers. This includes 0.017 bags of Portland cement at ₱2.49, 0.00067 m^3 of sand at ₱0.35, 0.00133 m^3 of gravel at ₱0.86, and optical fiber costs of ₱6.40 for 1 mm and ₱56.00 for 2 mm. Labor costs consist of ₱5.33 for skilled workers and ₱8.00 for two unskilled workers per block.

The blocks embedding 1 mm optical fiber generate a profit of ₱8.57, resulting in a 36.58% markup. This makes the product's price much higher than that of conventional pavement blocks available in the market at ₱13.00; however, this is reasonable given the inclusion of optical fiber compared to plain pavement blocks. In contrast, embedding 2 mm optical fiber yields a profit of ₱11.97, resulting in a lower markup of 16.39%. While the production cost is higher, the 2 mm product remains a reasonable and justified investment for specialized infrastructure. Although its market price is approximately double that of a premium 6,000 psi (41.369 MPa) block—which typically retails for ₱32.00—it provides more than double the compressive strength and significantly higher light visibility. This extreme durability ensures a longer service life and reduced maintenance costs over time.

In conclusion, the study demonstrates that while the 1 mm optical fiber is commercially viable, the 2 mm diameter is a high-value, long-term solution for architectural projects where maximum structural integrity and superior light transmittance are required.

CHAPTER IV

Summary of Findings, Conclusions, and Recommendations

This chapter presents a summary of the key findings of the study. It explains the main conclusions based on the results and provides recommendations for future improvements. It also suggests how the study can be applied in practice and offers ideas for future research.

SUMMARY

The study successfully demonstrated the viability of integrating optical fiber into a 1:2:4 concrete mix to create light-transmitting rectangular pavement blocks that meet the structural standards for pedestrian use. The evaluation of two fiber configurations, 1.0 mm diameter at 0.1% volume and 2.0 mm diameter at 0.4% volume, revealed that while the 1.0 mm fibers yielded superior mechanical performance with a compressive strength of 119.991 MPa and a modulus of rupture of 3.467 MPa, the 2.0 mm fibers provided significantly better optical utility. Specifically, the 2.0 mm fibers achieved a peak light transmission efficiency of 0.072%, which doubled the output of the 1.0 mm fibers and maintained "distinct visibility" for nine hours of daylight. Both variations exhibited a low water absorption rate of 3.125%, within the 5% safety limit, indicating that the inclusion of optical fibers does not compromise the density or durability of the concrete. In the night LED light test, the transverse position is much more visible, but visibility decreases as the distance increases from 0.5m to 5m. Overall, the 2.0 mm fiber configuration was identified as the more effective choice as it balances high-strength performance with enhanced passive illumination and aesthetic visibility, particularly in low-light environments where luminance contrast is maximized. The 1 mm fiber blocks offer nearly triple the strength of premium 6,000 psi blocks at a lower cost (₱32.00), making them a highly cost-efficient solution for residential driveways and walkways. Meanwhile, the 2 mm fiber blocks, despite a higher selling price of ₱85.00, provide extreme durability and superior light transmittance, serving as a justified investment for specialized architectural projects like museums and galleries. Overall, both designs provide a high-value, long-term alternative to traditional paving through enhanced longevity and reduced maintenance.

CONCLUSIONS

1. The integration of optical fibers into rectangular pavement blocks successfully maintains structural integrity while introducing light-transmitting capabilities. Regarding physical and mechanical properties, the study concludes that a smaller fiber diameter and lower volume percentage (1.0 mm at 0.1%) yield superior structural performance compared to a larger configuration (2.0 mm at 0.4%). Specifically, the 1.0 mm fibers achieved a higher compressive strength of 119.991 N/mm² and a higher flexural strength of 3.467 N/mm², while the 2.0 mm fibers achieved a compressive strength of 90.842 N/mm² and a flexural strength of 3.4 N/mm². A One-Way Analysis of Variance (ANOVA) was utilized to compare the means of the different groups; the statistical results confirm a significant difference between the fiber-integrated specimens and the conventional control group, leading to the rejection of the null hypothesis (H0). The exceptional strength and durability of these blocks make them ideal for residential driveways and parking areas. These results suggest that smaller optical fibers experience significantly less loss of strength. Despite these variations, all tested groups significantly exceeded the minimum standards for pedestrian pavement blocks, which require a compressive strength of only 28 MPa and a modulus of rupture of 3.28 MPa. Furthermore, the water absorption rate remained consistent at an average of 3.125%, proving that the inclusion of fibers does not create additional voids or compromise the density of the blocks across all groups. For landscaping and patios, their dense composition ensures they remain resistant to moisture and environmental wear over time.
2. In terms of optical performance, the fiber diameter serves as the primary predictor of light efficiency. The 2.0 mm diameter fibers consistently outperformed the 1.0 mm fibers in both daylight and artificial light testing. During the 12-hour natural light cycle, the 2.0 mm fibers achieved a peak transmission efficiency of 0.072%, doubling the 0.034% peak of the 1.0 mm fibers at 12:00 noon daylight. While transmission is highly sensitive to the angle of the light source, with peak performance occurring between 9:00 AM and 3:00 PM, the study found that low-light environments actually enhance the visual utility of the blocks. Under artificial LED lighting at night, the absence of ambient glare and the presence of shadows allowed the transmitted light to achieve a higher luminance contrast, making the fibers appear more pronounced and visible as a dominant decorative feature. The most effective outdoor application for light transmission is in pedestrian walkways and garden paths, where the blocks can be aligned with sunlight patterns. Beyond outdoor utility, these blocks serve as innovative structural flooring for museums, galleries, and clubs, where their light-transmitting properties create unique, interactive installations and functional aesthetic features.
3. The research identifies the 2 mm diameter Plastic Optical Fiber (POF) at 0.4% volume as the configuration for maximum light-transmission efficiency. This diameter consistently outperformed the 1.0 mm variation, achieving a peak transmission efficiency of 0.072% at 12:00 noon. While both the East-to-West and South-to-North axes followed a similar 12-hour cycle, the East-to-West orientation showed slightly higher peak efficiencies. The east-to-west transverse axis yields the highest efficiency because the angle of the optical fibers aligns directly with the sunlight. This direct angle allows the fibers to serve as a primary receiver, resulting in a higher peak transmission efficiency during the sun’s movement throughout the day. However, in the South-to-North orientation, the 2 mm fibers nearly doubled the output of the 1.0 mm fibers during peak hours, confirming that spatial orientation and the light source angle are critical performance variables. For sunlight, the east-to-west transverse axis yields the highest efficiency. Based on experimental observations, the transverse position provides the strongest visibility when using LED light. Regarding partial shading, the south-to-north transverse axis is best for partial shadowing that is not fully covered by the shadow. Similarly, when using LED lighting, a longitudinal position proves most effective for managing partial shadowing and maintaining consistent light distribution. These findings suggest that proper alignment is essential to maximizing both the aesthetic and functional performance of the blocks.
4. The study demonstrates that embedding optical fibers in pavement blocks results in a product that far exceeds the structural standards of the conventional Philippine market. While standard pavement blocks typically offer a compressive strength of 3,000 psi (20.684 MPa), the 1 mm fiber specimens achieved 119.991 N/mm², and the 2 mm specimens achieved 90.842 N/mm².From an economic perspective, the 1 mm optical fiber block is commercially viable, with a production cost of ₱23.43 and a selling price of ₱32.00. This design offers nearly triple the strength of premium 6,000 psi blocks while remaining significantly cheaper than their ₱32.00 market price. Furthermore, although the 2 mm optical fiber block has the highest selling price, it presents a reasonable and justified investment for specialized infrastructure. Although its production cost of ₱73.03 and selling price of ₱85.00 are more than double the price of a 6,000 psi (41.369 MPa) block (₱32.00), it provides more than double the compressive strength and vastly superior light transmittance. This extreme durability ensures a longer service life and reduced maintenance, making the 2 mm diameter a high-value, long-term solution for architectural projects where both visibility and maximum

structural integrity are paramount. Given these properties, the 1.0 mm fiber blocks are best suited for residential driveways, parking areas, and walkways, where high mechanical resistance and cost-efficiency are required. Meanwhile, the 2.0 mm fiber blocks are most effective for specialized architectural installations, landscaping, museums, or cultural galleries, where superior light-transmitting capabilities can be fully utilized alongside extreme structural durability.

RECOMENDATION

Recommendations for Research

These suggestions aim to expand the scientific understanding of light-transmitting concrete and investigate further methods for enhancing the material's utility.

1. Since 1.0 mm fibers at 0.1% volume yielded higher compressive strength (119.991 N/mm²) than 2.0 mm fibers at 0.4% volume (90.842 N/mm²), further research is needed to find the exact tipping point where fiber density maximizes light without compromising the structural integrity.
2. It is recommended that future studies utilize advanced sensors capable of measuring light levels below the current lux meter's detection to quantify the efficiency under low-light artificial LED sources and identify the specific lux below zero.
3. Investigating different concrete mix ratios beyond the 1:2:4 standards could reveal if more specialized aggregates can improve light scattering while maintaining the required pedestrian strength of 28 MPa.

Recommendations for Practitioners

These guidelines assist engineers and architects in the effective implementation of light-transmitting pavement blocks in real-world settings.

1. For projects prioritizing aesthetic impact and visibility, practitioners should specify 2 mm diameter fibers, as they provide significantly more "Distinctly Visible" light points over a longer duration (7:00 AM to 4:00 PM).
2. To maximize the natural light, blocks should be installed along the East-to-west transverse axis, which demonstrated superior peak transmission efficiencies during the 12-hour solar cycle.
3. Designers should intentionally place these blocks in areas with partial shadowing, as the study confirmed that shadows enhance the brightness ratio and make the transmitted light appear sharper and more pronounced.
4. During installation, careful planning must be taken to position artificial light sources so they do not cast shadows over both ends of the optical fiber, which would nullify the light-transmitting effect.

Recommendations for Improving this Study

The following adjustments are suggested to refine the current methodology and provide more resilient design considerations.

1. Future versions should investigate different shape designs, such as hexagonal, interlocking, or circular patterns, and various pavement sizes. Testing different dimensions will help to determine how the length of the fiber path affects light attenuation and how different shapes influence the distribution of transmitted light.
2. The study would benefit from testing a wider range of fiber diameters, such as 0.5 mm or 3.0 mm, to better define the relationship between diameter, light output, and bond strength.
3. To more accurately quantify the "Distinctly Visible" quality, researchers should implement a standardized shadowing metric to measure exactly how much external darkness is required to optimize visual contrast.
4. Future versions should maintain a constant fiber diameter while varying the percentage volume to isolate the effects of fiber density on both water absorption and mechanical rupture.
5. To incorporate darker pigments or carbon black into the concrete mix design to enhance the luminance contrast ratio. By lowering the surface reflectivity of the pavement block, the light emitted by the optical fibers becomes significantly more visible, particularly in high-ambient light environments

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