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Study on performance of light transmittance geopolymer composite

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Abstract

The demand for sustainable construction materials has prompted the advancement of geopolymer concrete (GPC), offering a low-carbon substitute for conventional ordinary portland cement (OPC) concrete. GPC incorporates fly ash (FA) and ground granulated blast furnace slag (GGBFS) as cement alternatives, significantly diminishing carbon emissions. Light-transmittance concrete (LTC) and light transmittance geopolymer composite (LTGC) amalgamate the ecological benefits of GPC with the energy-efficient characteristics of LTC. The research comprised the development of GPC mixtures integrating FA and GGBFS as substitutes for cement, with differing levels of plastic optical fibers (POF). The research entailed the formulation of GPC mixtures with differing amounts of POF. Standardized tests were performed to evaluate both the mechanical and light transmittance characteristics of the LTGC samples. This study evaluated various significant mechanical and light transmittance properties. The research findings demonstrate that the LTGC can attain a light transmission of up to 15.8% when 6% of its volume is replaced with POF. This study demonstrates that using POF at a replacement level of up to 6% in concrete mixtures produces favorable results in terms of both quality and strength. It highlights the viability of LTGC as a sustainable construction material, offering benefits such as increased transparency, reduced cement usage, and improved mechanical properties. Therefore, LTGC presents a viable alternative to traditional concrete for the construction of sustainable structures.

Keywords

Light transmittance concrete, Plastic optical fibers, Light transmittance geopolymer composite, Fly ash, Ground granulated blast furnace slag.

1.Introduction

Concrete is a vital construction material globally, recognized for its strength, durability, and versatility. Nonetheless, conventional concrete, produced with ordinary portland cement (OPC), substantially contributes to global carbon dioxide (CO_2) emissions. The cement production process contributes around 7% of worldwide CO_2 emissions, rendering it a significant environmental issue [1].

Geopolymer concrete (GPC) is a cement-free concrete that utilizes industrial by-products such fly ash (FA) and ground granulated blast furnace slag (GGBFS) as substitutes for cement, thereby diminishing the carbon footprint and enhancing durability [2]. Besides sustainability, the contemporary construction sector is focused on creating innovative materials that help diminish energy use. Light-transmittance concrete (LTC) is a material that permits the passage of natural or artificial light through concrete. Embedding plastic optical fibers (POFs) in the concrete mix enables LTC to transfer light through walls, floors, and other structural components, thereby diminishing reliance

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on artificial lighting and enhancing energy efficiency in buildings [3, 4]. This research integrates the environmentally sustainable advantages of GPC with the light-transmitting characteristics of LTC to create light transmittance geopolymer composite (LTGC).

In spite of the potential advantages of incorporating POF into GPC, there exists a substantial deficiency in thorough research regarding this amalgamation and its prospective benefits related to mechanical properties, light transmission efficiency, and environmental effects [5]. The growing population has led to the construction of large concrete buildings in densely populated areas, increasing the demand for efficient indoor lighting systems. Achieving energy efficiency in these structures requires innovative materials and sustainable building approaches [6].

LTC effectively facilitates the ingress of natural light into structures, hence diminishing dependence on artificial illumination. This functionality improves the indoor environment, facilitates energy conservation, reduces carbon emissions linked to energy generation, and enhances visual comfort for inhabitants. However, ensuring the durability of integrated POFs within the concrete matrix remains a challenge [7].

A comprehensive comparison analysis is crucial to assess the performance of LTC using POFs in combination with GPC, emphasizing their mechanical qualities, light transmission efficiency, environmental impact, and economic feasibility. Although LTC and GPC present unique benefits, comprehending their synergistic performance is essential for the progression of construction technologies. The combination of POFs with GPC offers a novel strategy to improve the functionality and sustainability of LTC. Nevertheless, there is a lack of comprehensive evaluations of the structural, optical, and environmental properties of this composite material. The fundamental purpose of this work is to thoroughly investigate the mechanical qualities, light transmission efficiency, and environmental impacts of LTGC reinforced with POFs.

This study seeks to assess the viability of LTGC as a sustainable and technologically sophisticated construction material that improves energy efficiency and aesthetic value in architectural projects. The analysis of LTC, which integrates POF and GPC, demonstrates significant potential in advancing construction materials. By incorporating POF into concrete, engineers can design structures that effectively utilize natural light for illumination, thereby reducing reliance on artificial lighting and enhancing energy efficiency [8]. Additionally, the use of GPC, known for its environmentally friendly properties and durability, further supports sustainable construction practices. This research not only advances the field of materials science but also addresses critical issues such as energy conservation and environmental impact, offering more sustainable and resilient infrastructure solutions for the future.

The development of LTGC requires the integration of POF into GPC formulations. This study aims to assess the mechanical properties of LTGC and verify that incorporating POF does not significantly compromise its structural integrity. The light-transmitting properties of LTGC are evaluated by analyzing the effects of parameters such as the concentration and diameter of POF on light transmittance. This research explores the viability of LTGC as a sustainable building material for both structural and architectural applications.

This article is structured to facilitate a thorough understanding of LTGC. Section 2 reviews the existing literature on GPC, LTC, and the integration of POF into concrete. Section 3 describes the experimental methodology, including the materials used and the testing procedures for evaluating both mechanical properties and light transmittance. Section 4 presents the experimental results, analyzing the impact of fiber concentration and placement on light transmission and mechanical strength. Finally, Section 5 concludes the paper by suggesting future research directions and exploring the potential applications of LTGC in sustainable construction.

2.Literature review

The manufacture of OPC, the primary binder in conventional concrete, significantly contributes to CO_2 emissions. The cement industry accounts for approximately 5-8% of worldwide CO_2 emissions, predominantly resulting from the calcination of limestone and the elevated temperatures necessary for manufacture. With the growth of the global population and the expansion of metropolitan areas, the need for concrete rises, intensifying environmental issues. GPC contains no cement and substitutes it with industrial by-products such as FA and ground granulated blast furnace slag (GGBS), both of which are abundant in alumina and silica. These materials endure a polymerization reaction in the presence of an alkaline solution, which is typically a combination of sodium hydroxide and sodium silicate. This reaction results in the formation of a durable aluminosilicate gel binder [9–12].

Over the last quarter-century, GPC technology has advanced significantly, making it a viable alternative to OPC. Geopolymer materials are more durable and have a lesser environmental impact than standard OPC concrete, albeit at a higher cost. transparent geopolymer concrete (TGPC) has been obtainable as an environmentally sustainable alternative to conventional OPC-based concrete. However, using artificial illumination in concrete might increase energy usage and raise environmental issues [13]. The incorporation of POF into GPC is a substantial advancement in the field of light-transmitting concrete. POFs are an optimal solution for incorporating transparency into concrete structures, as they are durable, flexible, and efficient in transmitting light. POFs are particularly well-suited for applications in energy-efficient building designs due to their ability to transmit light over long distances with minimal energy loss. These fibers reduce dependence on artificial illumination sources by transmitting both natural and artificial light when embedded in GPC [14]. The mechanical properties of LTC reinforced with POF are a critical factor in its adoption for structural applications. Although the compressive strength (CS) of the concrete matrix may be marginally diminished by high percentages of POFs, research shows that the CS of LTC remains acceptable for structural applications. Additionally, the reinforcing properties of POFs often enhance LTC's flexural strength. Consequently, LTC is applicable for both aesthetic and load-bearing applications [15,16].

The development of innovative, sustainable construction materials is becoming increasingly popular due to the fact that high-rise buildings necessitate substantial illumination, even during daylight hours. LTC technology efficiently utilizes the sun's abundant energy, thereby decreasing the necessity for electrical illumination. This technology has the potential to transform the perception of concrete from a rigid, opaque, and gray material to a more versatile and aesthetically appealing option [17]. LTC employs a variety of materials, including optical fibers, glass, and plastics, to transmit light in a variety of methods [18].

The primary characteristic of LTC is its capacity to transmit light. The concentration, diameter, and arrangement of the POFs within the concrete matrix determine the transmittance. Optimal fiber placement has been demonstrated to result in light transmittance rates of 2-4% in numerous studies [19] Furthermore, the transmission of light can be improved by minimising scattering by refining the surface of LTC or applying transparent coatings [20, 21] similarly, various research studies on LTC demonstrate that while these materials' ability to transmit light can greatly improve energy economy, the mechanical properties must not be compromised. Tahwia et.al. [22] discovered that the CS of LTC is not substantially diminished by the inclusion of POFs, as long as the fiber concentrations remain within a specific threshold. Chiew et al. [23] also demonstrated that LTC is appropriate for structural applications due to its mechanical properties, which are comparable to those of traditional concrete.

Prior research [24–28] has yielded analogous findings indicating that increased volumetric ratios of optical fiber correlate with diminished compressive and flexural strengths (FS) of the light transmitting cement-based material (LTCM). The gaps in the fiber-matrix interface, resulting from the excessive smoothness of the optical fiber surface, were deemed responsible for weakening the link between them, as evidenced by the scanning electron microscopic (SEM) analysis [29, 30]. Furthermore, Salih et al. [31] observed a comparable outcome indicating that, although the compressive and FS diminished with an increase in combined POF content, these strengths improved with age. They also claimed that lightweight boards might be manufactured due to the reduction in the density of their translucent concrete by augmenting POF sizes and proportions. The literature shows a solid foundation for incorporating GPC with FA and GGBFS as sustainable OPC alternatives. Nevertheless, the incorporation of light-transmitting capabilities into GPC has not been thoroughly investigated. This study thereby closes the gap, advancing sustainable construction with LTGC.

3.Materials and methods

3.1Methodology of work

Figure 1 illustrates the sequential methodology of the proposed work. This investigation began by procuring raw materials, specifically FA and GGBFS as sustainable substitutes for traditional cement, in addition to POF to develop light-transmitting characteristics. The ingredients were combined to create several GPC combinations with varying ratios of FA, GGBFS, and POF, assuring a uniform mixture prior to the addition of an alkaline activator. Following to the mixing operation, the freshly mixed

GPC is put into designated molds and permitted to undergo ambient curing. Subsequently, the cured samples undergo different tests, including assessments of mechanical and light transmittance properties. The results are eventually analysed, and conclusive findings are presented.

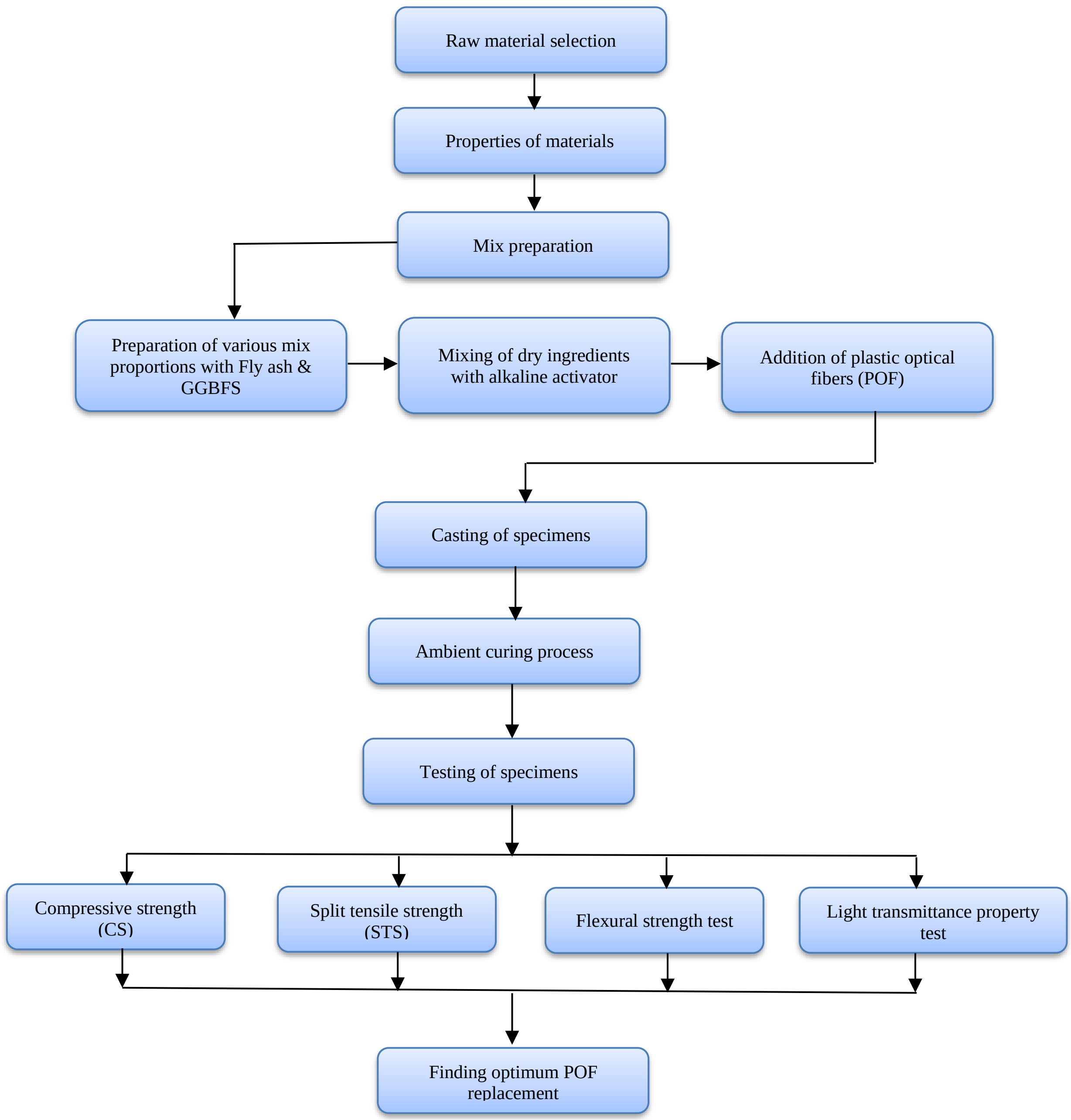

Figure 1 Flowchart of the process for developing and testing composite materials POF reinforcement

3.2Materials

These days, many researchers are interested in FA, the primary by-product of burning coal, because of its potent qualities and potential uses. In order to provide good durability and minimize the size of concrete pores to withstand harsh climatic conditions, FA has been added to cement in a decreased nano size form [32, 33]. Class-F FA was selected due to its widespread availability and its minimal tricalcium aluminate (C3A) content, which is a primary contributor to concrete degradation under sulfate attack. FA was obtained from thermal plant, Mettur, India. The chemical composition of the FA was determined using X-ray fluorescence (XRF) analysis. *Tables 1* and *2* illustrate the fundamental characteristics of FA.

Table 1 Chemical characteristics of FA

SiO_2	58.95%
Fe_2O_3	3.72%
CaO	6.92%
Al_2O_3	21.04%
MgO	1.45%
SO_3	1.02%
K_2O	0.95%

Table 2 Physical characteristics of FA

Specific gravity	2.22 Kg/m^3
Colour	Light-grey
Fineness	288 m^2/kg
Bulk density	996 $kg/\boldsymbol{m^2}$

The crushed GGBS contains a high concentration of silicon and aluminum, which undergo a chemical reaction to form a paste that, when mixed with an alkaline solution, binds together the aggregates. It was sourced from Astrra chemicals, Chennai, Tamil Nadu, India. A combination of admixtures and corrugated steel fiber is employed in order to mitigate fatigue and impact [34]. The utilization of GGBS as extra components in cement has been a longstanding practice, and they have also been employed in the development of geopolymerization reactions [35]. The cohesive mix created by GGBS reduces permeability. The substitution of cement with GGBS resulted in a significant enhancement of concrete's resistance to capillary penetration. The presence of GGBS leads to a decrease in the number of micro and macrospores in concrete due to the substantial formation of secondary C-S-H bonds. These bonds are a result of inadequate $Ca(OH)_2$ resulting from the hydration of cement [36]. *Tables 3* and *4* illustrate the key characteristics of GGBFS

Table 3 Chemical characteristics of GGBS

CaO	40.03%
SiO_2	35.06%
Al_2O_3	12.97%
MgO	8.02%

Table 4 Physical characteristics of GGBS

Bulk density	1224 $kg/\boldsymbol{m^2}$
Colour	light grey
Specific gravity	2.89

Alkaline activator solution: Alkaline activators, such as sodium hydroxide and sodium silicate, are commonly employed in geo-polymerization processes and it was purchased from Krisna trading company, Surat, Gujrat, India. The availability of Al and Si ions in the raw materials is significantly affected by the selection of the activator. A weight ratio of 2:1 was observed between the sodium silicate and sodium hydroxide solution [37]. In order to improve its mechanical characteristics compared to OPC concrete, the GPC concrete incorporates sodium hydroxide, leading to increased strength and performance [38]. The ideal molar concentration for the sodium hydroxide solution was recorded as 16 M. The study demonstrated that the alkaline solution-to-FA ratio has a substantial effect on the characteristics of GPC, with an estimated ideal ratio of 0.40 [39]. Numerous variables can impact the efficacy of GPC, including the choice of binder materials, the alkaline solution concentration, the molarity of sodium hydroxide, the sodium silicate to sodium hydroxide ratio, quantities of extra water, mixture proportions, and the curing procedure [40].

Plastic optical fibre: The optical fiber is a type of glass material characterized by its closed fiber structure, which enables it to transmit light transmission across long distances at the velocity of light [41]. POF was sourced from Edmund Optics India Private Limited, Bengaluru, Karnataka, India. Optical fibers made of polymethyl methacrylate (PMMA) with outer diameters measuring 2 - 3 mm were employed. The cladding material employed for the optical fiber was fluororesin. The numerical aperture of the fiber was measured to be 0.5, while its core refractive index was noted to be 1.49%. The effective bending radius of the fiber was found to be ten times greater than its diameter, within the operational temperature range of -40ºC to +70ºC [42]. An optical fiber consists of three essential components: a core, wrapping, and covering [43]. The basic principle behind the way light moves through optical fibers is that they are typically composed of two coaxial layers stacked in a cylindrical configuration. One is a core that sits in the center of the fiber. The other encircles the focal area and covers the full periphery [44]. The producer was unable to offer information regarding the composition of the material. Characterizing the surfaces of the fibers was the first step in creating the translucent composite [45]. The two materials differ significantly in terms of how the optical fiber is created. Compared to plastic core fibers, glass fibers are more costly and less flexible. Glass fibers are more expensive and less flexible than plastic core fibers. They weigh 60% less than glass fiber, are simpler to install, and are more resilient to stress. Essentially, the fine glass or plastic threads that guide light are the optical fibers employed in the formation of this concrete [46].

3.3Testing methods

3.3.1Experiment methods for strength and light transmittance property

A lux meter, commonly referred to as a light transmitting test, was employed to quantify the CS, split tensile strength (STS), and FS of the hardened concrete specimen, together with its light transmittance properties. The optical fibers in a CS test are oriented perpendicular to compression and parallel to the specimen's length. The optical fibers in a FS test are parallel to the load [47]. The universal testing machine (UTM) was utilized in this examination. The light transmittance quality was evaluated by measuring the light intensity in lumens using a lux meter with a range of 0.1 to 1,00,000 lux. The light source used was a 16-W light-emitting diode (LED) fiber mini-optic kit. To mitigate the risk of loss, the concrete cube samples are stored within a wooden box measuring two by two feet. The measurements obtained from the lux meter were recorded. In the concrete specimen, the optical fibers are securely wound around insulating tape at both ends. One end of the fibers is connected to the light source intensity of the LED small kit, while the other end is connected to the Lux meter. To determine the intensity of light, apply this illuminance test. The lighting of the samples was assessed. The samples' brightness was assessed under both natural and artificial lighting conditions. Sealing the horizontal and vertical spaces between the fibers increases illumination.

The controlled temperature and humidity conditions were used to conduct all testing procedures. Throughout the preparation, casting, and curing procedures, the temperature was maintained at 25°C ± 2°C and the relative humidity at 60% ± 5%. The purpose of selecting these conditions was to minimize variations caused by environmental factors and to replicate typical indoor environments. In a humidity-controlled compartment, the concrete mix was cured for 28 days after being cast into moulds. The mix contained POF, FA, sodium silicate, and sodium hydroxide.

3.3.2Specimen preparation

3.3.2.1Preparation of concrete specimen

Concrete cubes, cylinders, and beams contain 3%, 4%, 5%, and 6% plastic fiber, respectively. A 300 mm cylinder was produced with a 150 mm diameter, and 100 mm cubes were made. The measurements of the cast concrete prisms were 100 mm×100 mm×500 mm. The GPC was made with varying amounts of plastic fiber. For every percent, three specimens were cast. POF were used in place of the original material in 3%, 4%, 5%, and 6% of the cases. GGBS and FA were utilized in dry mixing, together with both fine and coarse aggregates. Two 1:1:3 solutions of NaOH and Na_2SiO_3, each with a molarity of 16 M, were added to the alkali activator solution. The material is sorted as coarse aggregate using a 6.3-mm sieve. Using different percentages, the POF are arranged in a suitable configuration. After that, the ready-to-use concrete mixture is poured into the cube. The molds remain undisturbed for the full day. To cure the specimens, they were removed from the mould and heated at 100 degrees for four hours. A 28-day water cure is also necessary for conventional concrete. After the completion of the curing period, the specimens are permitted to undergo further analysis. *Figures 1* and *3* illustrate the experimental configuration employed to measure the CS and STS of specimens incorporating LTGC specimens and *Table 5* represents the identification of specimens.

Table 5 Specimen details

Specimen ID	Description
CC-M30	Conventional concrete of M30 grade (control mix)
Geopolymer (GP)	GPC without any POF additions
LTGC-I	GPC with 3% POF content
LTGC-II	GPC with 4% POF content
LTGC-III	GPC with 5% POF content
LTGC-IV	GPC with 6% POF content

3.3.2.2Quality control

Stringent quality control procedures are necessary in the experimental phase of measuring light transmittance in geopolymer composites containing POF. First and foremost, it is imperative to calibrate the testing equipment in order to guarantee precision and dependability. Furthermore, the utilization of consistent sample preparation processes ensures the preservation of uniformity during trials. In addition, conducting routine assessments of environmental factors such as temperature and humidity guarantees consistent testing settings. Likewise, the implementation of several trials and the subsequent averaging of results serve to reduce the impact of outliers and random fluctuations. Ultimately, the thorough recording of procedures and observations facilitates the ability to replicate and verify the experimental results.

4.Results and discussion

4.1Compressive strength (CS)

Figure 2 illustrates the compression strength test specimen for the LTGC specimen. The performance of hardened concrete was primarily influenced by its CS. The data depicted in *Figure 3* were derived from the mean of the three samples. The CC-M30 demonstrates the lowest CS at 34.3 N/mm², whereas GP showed an enhancement to 38.5 N/mm². The incorporation of POF incrementally improves CS, with LTGC-I (3% POF) at 42.2 N/mm², LTGC-II (4% POF) at 43.7 N/mm², LTGC-III (5% POF) at 44.1 N/mm², and LTGC-IV (6% POF) attaining the maximum strength of 45.8 N/mm². Mineral additives are incorporated into cement to enhance the rate of hydration, improve the penetration and sealing of interstitial spaces between cement particles, and consequently provide the material with significant initial strength as well as increased long-term strength due to the pozzolanic reaction [48].

The primary factor contributing to the increase in CS is the reinforcing effect facilitated by the presence of fibers. Due to its lightweight and resilient properties, facilitates the uniform distribution of applied loads within the concrete matrix resulting in a decrease in the occurrence and spread of micro cracks. Through the implementation of this reinforcement mechanism, the concrete's overall structural integrity and CS are ultimately improved [49].

Figure 2 Compression strength LTGC specimen

4.2Split tensle strength (STS)

Cylindrical specimens, like concrete cylinders, are commonly tested to determine their STS. This involves applying diametrical compression to the specimen until failure occurs along the plane perpendicular to the applied force. This test quantifies the material's tensile strength in the direction perpendicular to the loading direction. *Figure 4* exhibits the split tensile test of the LTGC specimen. A range of 4.57 N/mm^2 to 4.86 N/mm^2 was observed for the STS of LTGC. *Figure 5* depicts the graphical representation of the fluctuation in strength. The addition of POF was demonstrated to enhance the STS. The STS and transmittance of concrete can be enhanced with the application of POF in varying amounts. *Figure 5* illustrates a 3% to 6% increase in POF volumetric replacement. The CC-M30 exhibits the lowest STS at 3.75 N/mm², whereas the mix GP displays an increase to 4.24 N/mm². As the proportion of POF increases, the STS correspondingly enhances, with LTGC-I (3% POF) measuring 4.57 N/mm², LTGC-II (4% POF) at 4.67 N/mm², LTGC-III (5% POF) at 4.81 N/mm², and LTGC-IV (6% POF) attaining the peak value of 4.86 N/mm². This suggests that the addition of POF improves the tensile characteristics of GPC. The cohesive properties of the geopolymer matrix are attributed to the tangling and interlocking of the POF fibers, resulting in enhanced resistance to tensile stresses [50]. Higher fiber volume fractions result in increased STS; there is a positive correlation between POF content and STS [51].

4.3Flexural strength (FS)

The test results about the FS of different prism specimens are depicted in *Figure 6*. The control mix had a FS of 3.83 N/mm^2. The FS of the LTGC specimens varied between 6.45 N/mm^2 and 7.28 N/mm2. The graph illustrates a 3%–6% rise in the volumetric replacement of POF. The mix CC-M30 exhibits the lowest FS at 3.83 N/mm², whereas the GP mix exhibits a FS of 5.65 N/mm². The integration of POF in LTGC mixtures incrementally improves FS, with LTGC-I (3% POF) at 6.45 N/mm², LTGC-II (4% POF) at 6.62 N/mm², LTGC-III (5% POF) at 6.85 N/mm², and LTGC-IV (6% POF) at 7.28 N/mm². This suggests that the incorporation of additional POF into the concrete mixture has the potential to enhance its FS by a maximum of 6%. The increase in the amount of POF is attributed to the FS of the concrete. Concrete that possesses a high percentage of POF exhibits notable FS. The bending strength of the concrete is enhanced by the percentage of POF.

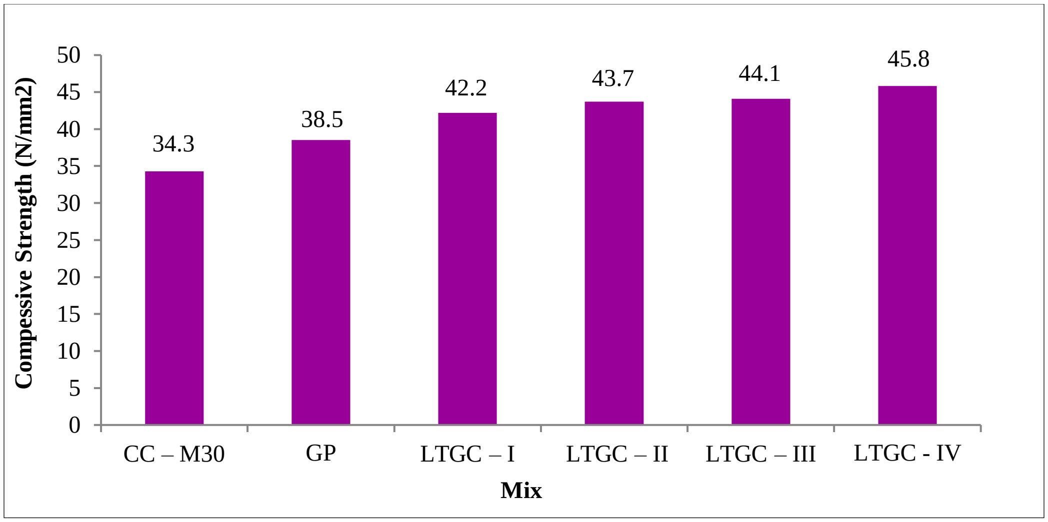

Figure 3 Graphical representation of compression strength test result

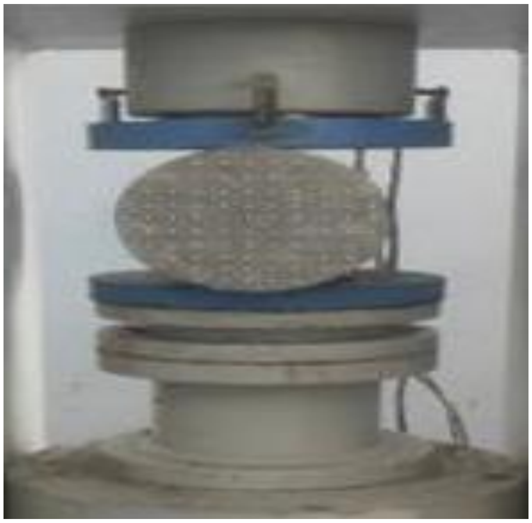

Figure 4 Split tensile test of LTGC specimen

4.4Light Transmittance property

Figure 7 depicts the variation in light transmission properties of POF specimens with varying percentages. The light transmission capacity (%) of several LTGC blends was measured at different times of day. At 9:00 AM, the values varied from 6.5% for LTGC I to 9.7% for LTGC IV. By 11:00 AM, the transmission had risen, with LTGC-I at 8.3% and LTGC-IV at 12.6%. At 1:00 PM, the highest values were recorded, reaching 12.4% for LTGC-I and 15.8% for LTGC-IV. At 3:00 PM, the transmission rate dropped marginally, from 8.2% (LTGC-I) to 12.1% (LTGC-IV). It also indicates that light transmission varies throughout the day, with peak values obtained around midday. The behavior of the transmittance will undergo changes as the quantity of optical fibers present in the concrete sample rises. Previous studies have shown evidence that an augmentation in the volume ratio of the POF results in an enhancement in the transmittance of light [52]. The primary factors influencing the light-transmitting efficiency in this study are the volume ratios of the POF, rather than the diameter of the POF included in the LTGC.

The CS of the LTGC specimen with 6% volumetric POF substitution was 45.8 N/mm². Conventional concrete exhibited a CS of 34.3 N/mm², whereas the GPC without POF demonstrated 38.5 N/mm². The maximum STS was attained with a 6% POF substitution. The fibers augmented tensile strength by interlocking within the geopolymer matrix, so boosting its cohesion. A positive connection was discovered between POF content and STS. The FS of LTGC specimens enhanced with the incorporation of POF, varying from 6.45 N/mm² to 7.28 N/mm², in contrast to the control mix's 3.83 N/mm². The FS enhanced by as much as 6% with a 3%–6% substitution of POF. Increased POF content enhanced the structural integrity of the concrete. The elevated POF % improved the concrete's flexural strength. The light transmission characteristics of LTGC improved with higher POF concentrations, achieving a transmittance of 15.8% at 6% POF substitution. Tests performed at various intervals demonstrated a distinct link between POF volume and light transmission. Increased POF volumes enhanced light transmittance, although the diameter of the POF exerted less influence. The research determined that POF volume was the primary factor affecting light transmission efficiency.

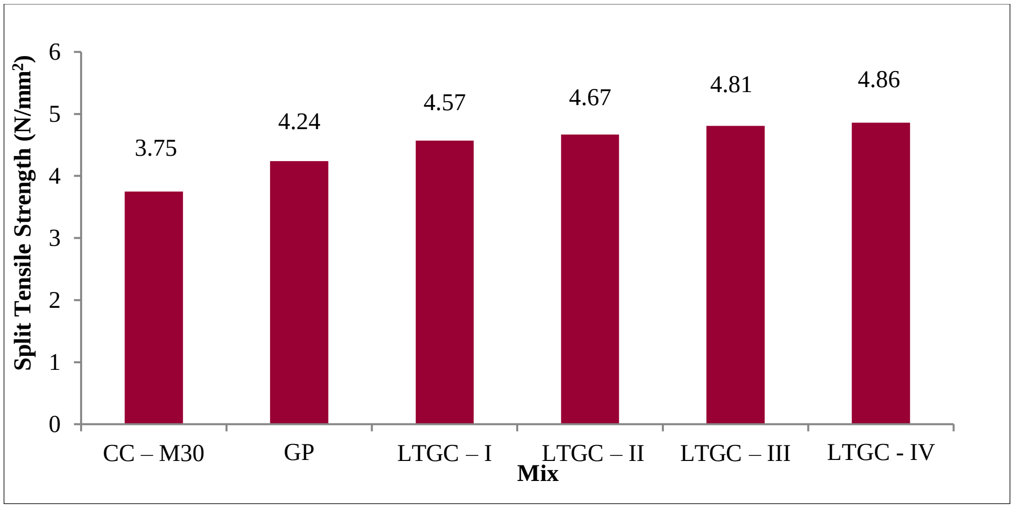

Figure 5 Graphical representation of STS test

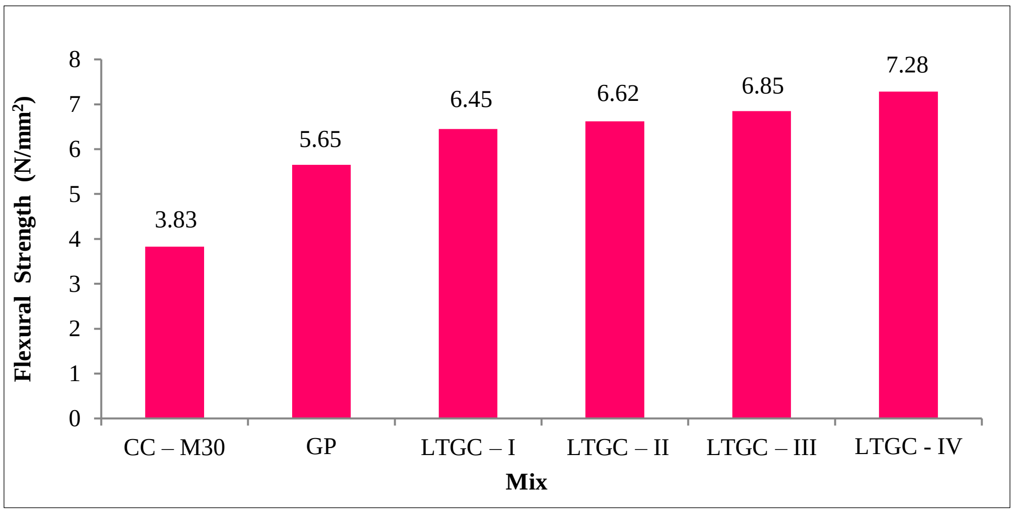

Figure 6 Graphical representation of FS test result

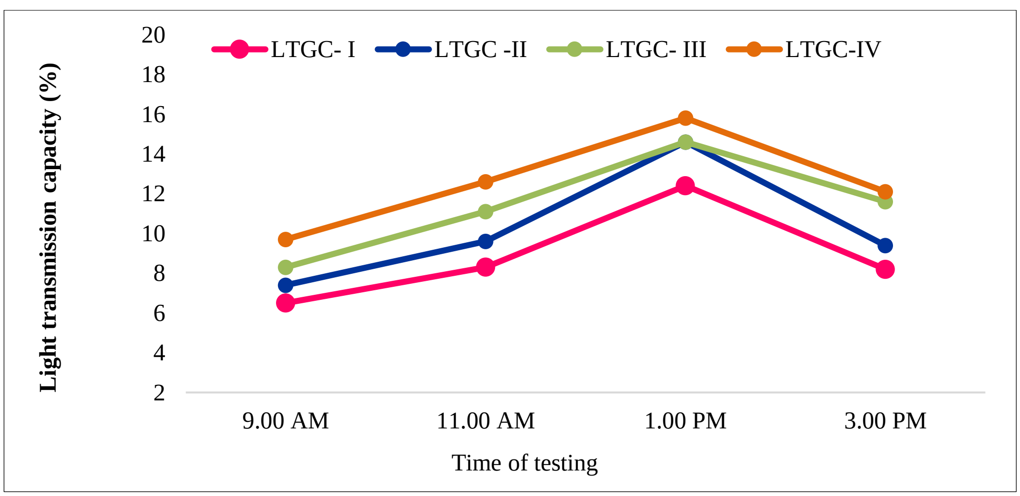

Figure 7 Graphical representation of light transmittance test result

4.5Limitations

The incorporation of FA and GGBFS in POF-GPC presents numerous benefits, including improved sustainability, increased durability, and a diminished carbon footprint in comparison to conventional Portland cement-based concrete. Nevertheless, it is not without its constraints. One significant constraint is to the mechanical properties of the material at an early stage, specifically its initial low tensile and FS. This characteristic may require meticulous handling and curing procedures in the earliest phases of development. Moreover, the expeditious curing period of GPC can provide difficulties in relation to its workability and positioning, necessitating modifications to building methodologies and timetables. In addition, it is imperative to do additional research on the extended-term efficacy of POF and GPC particularly in hostile surroundings or when subjected to prolonged loading circumstances, to ascertain its long-term structural soundness and resilience. The aforementioned constraints emphasize the necessity for continuous research and development endeavors aimed at tackling the obstacles and enhancing the efficacy of POF-GPC across various applications.

A complete list of abbreviations is listed in *Appendix I.*

5.Conclusion and future work

The aim of this study is to examine the strength properties of GPC, which consists of POF, FA, and GGBS. The conclusion was derived from the experimental results of LTGC with volumetric substitution employing POF at volumes of 3%, 4%, 5%, and 6%. The maximum CS observed was 45.8 N/mm² for the LTGC-IV mix. A significant improvement in CS occurred with a rise in POF to 6%. The application of POF at a volumetric replacement rate of 6% achieved a STS of 4.8 N/mm² and a flexural strength of 7.8 N/mm². The results suggest that the integration of POF is expected to improve these two properties. The LTGC exhibits a 2.01% enhancement in STS and a 1.6% advancement in FS relative to normal concrete. LTGC demonstrates a light transmission of up to 15.8% when 6% of its volume is substituted with POF. This behavior fluctuates with the increasing quantity of optical fiber in the concrete. The aforementioned study unequivocally illustrates that using POF at a substitution rate of up to 6% in concrete mixtures yields favorable results in terms of strength and quality. LTGC is an efficient method widely utilized throughout various applications. The research demonstrates that a rise in POF% led to an enhancement in the mechanical strength of the concrete. Future research could focus on investigating the durability properties of FA, GGBS, and POF-based LTC.

Acknowledgment

None.

Conflicts of interest

The authors have no conflicts of interest to declare.

Data Availability

None.

Author’s contribution statement

Ganeshprabhu Parvathikumar: Concept, methodology, Writing – original draft, Writing – review and editing. **Abarnadevi Baburajendran**: Experimentation, Writing – original draft, Writing – review and editing. **Brintha Sahadevan:** Supervision, Writing – original draft, Writing – review and editing. **Kavitha Eswaramoorthy:** Interpretation of results, Final review and editing.

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Appendix I

S. No.	Abbreviation	Description
1	Al_2O_3	Aluminium Oxide
2	CaO	Calcium Oxide
3	CO_2	Carbon Dioxide
4	CS	Compressive Strength
5	FS	Flexural Strengths
6	FA	Fly Ash
7	GP	Geopolymer
8	GPC	Geopolymer Concrete

9	GPC	Geopolymer Concrete
10	GGBFS	Ground Granulated Blast Furnace Slag
11	LTC	Light -Transmittance Concrete
12	LTCM	Light Transmitting Cement-Based Material
13	LTGC	Light Transmittance Geopolymer Composite
14	LED	Light-Emitting Diode
15	MgO	Magnesium Oxide
16	OPC	Ordinary Portland Cement
17	POF	Plastic Optical Fibers
18	PMMA	Polymethyl Methacrylate
19	KOH	Potassium Hydroxide
20	K_2O	Potassium Oxide
21	SiO_2	Silicon Dioxide
22	NaOH	Sodium Hydroxide
23	Na_2O	Sodium Oxide
24	Na_2SiO_3	Sodium Silicate
25	SEM	Scanning Electron Microscopic
26	STS	Split Tensile Strength
27	SO_3	Sulfur Trioxide
28	TGPC	Transparent Geopolymer Concrete
29	C3A	Tricalcium Aluminate
30	UTM	Universal Testing Machine
31	XRF	X-Ray Fluorescence