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Experimental Study on Light Transmitting Concrete by Using Optical Fibres

G. Ramanjineyulu[1], A. Akhila[2], A. Saikrishna[3], B. Vanitha[4], P. Soni[5], D. Chakradhar Reddy[6].

[1]Assistant Professor, Sanskrithi School of Engineering, Puttaparthi.
[2,3,4,5,6]Studying Final Year in Sanskrithi School of Engineering, Puttaparthi.

ABSTRACT :

Concrete, a revolutionary material in construction, remains essential for its durability and resistance to mechanical loads and fire. In today's construction landscape, Light-Transmitting Concrete (LTC) offers sustainability benefits. Plastic optical fibres (POF), produced from various plastic materials, replace coarse aggregates in LTC production. Using crafted precision moulds from wood to incorporate POF into the mix, aiming to compare their light transmission with conventional cubes. Our project focuses on utilizing LTC to reduce artificial lighting needs, enhancing environmental consciousness. We gathered materials for conventional cubes and replaced coarse aggregate with POF to produce cubes for analysis. Analyzing the compressive strength of LTC for M25 grade using POF for 0.2% and 0.4% replacement with coarse aggregate, tests conducted at intervals of 3, 7, 14, and 28 days. The major purpose of this research study was to observe the compressive strength of LTC with its properties. Through testing, we assess LTC's potential in reducing energy consumption by utilizing sunlight. LTC can transmit sunlight effectively, reducing reliance on artificial lighting and promoting green architecture.

Keywords: Light transmitting concrete, Plastic optical fibres, Litracon, Cement, Fine aggregate, Compressive strength

1. Introduction

Light Transmitting Concrete (LTC) represents a revolutionary advancement in construction materials, blending aesthetics, functionality, and sustainability by transmitting light through traditionally opaque concrete structures. LTC integrates translucent materials like glass aggregates, polymer resin, and optical fibers into concrete matrices, aiming to enhance interior illumination while reducing reliance on artificial lighting sources for energy conservation.

A. History of Litracon:

he history of Light Transmitting Concrete (LTC) traces back to the early 20th century, with significant advancements in polymer-based optical fibers leading to the development of Litracon in the early 1990s. Hungarian architect Aron Losonzi introduced the concept of transparent concrete in 2001, laying the groundwork for further innovation. Since then, LTC has gained traction worldwide, with notable installations like Europe Gate in 2004 showcasing its innovative qualities.

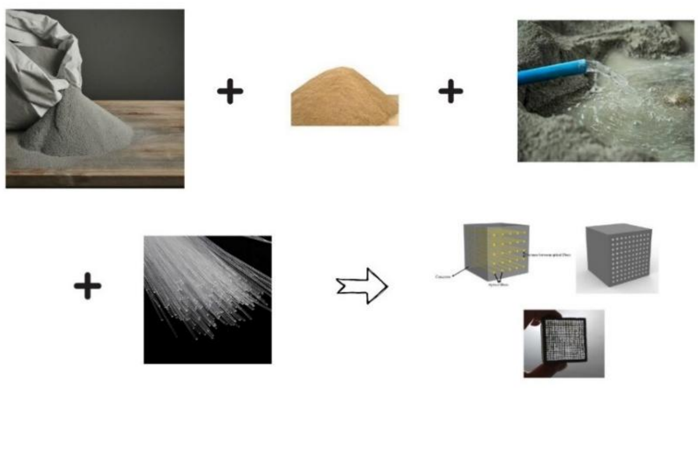

Fig:1 Steps included for Light Transmitting Concrete

Fig:2 Europe Gate, a 4-meter-high sculpture composed of LitraCon blocks

B. Need of Light Transmitting Concrete:

Light Transmitting Concrete addresses the need for sustainable development and green building practices by allowing more efficient use of natural light without compromising strength. It meets optical activity requirements in high-rise buildings, reducing dependence on artificial energy sources and minimizing environmental impact. By allowing natural sunlight to pass through, LTC enhances people's optical activity and reduces the need for artificial lighting, contributing to energy conservation efforts.

C. Working Principle of Light Transmitting Concrete:

Light-transmitting concrete incorporates optical fibers strategically embedded within the concrete mix to transmit natural light deeper into buildings. These fibers act as tiny light highways, utilizing the principle of total internal reflection to guide light from one end to the other. Plastic Optical Fibers (POFs) play a pivotal role in LTC, offering versatility in enhancing concrete translucency while maintaining durability and temperature resistance.

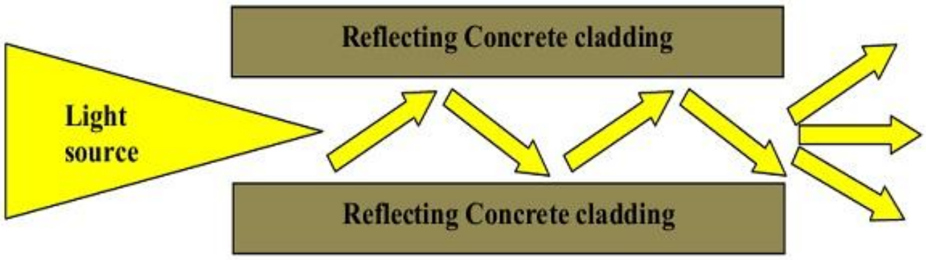

Fig:3 Working principle of light transmitting concrete

D. Plastic Optical Fibres (Pof):

Plastic Optical Fibres (POFs) play a pivotal role in the development of Light Transmitting Concrete (LTC), offering a versatile means of enhancing the translucency of concrete structures. POFs are part of the optical fiber family, distinguished by their core composition made from transparent plastic materials such as polymethylmethacrylate (PMMA). In the context of LTC, POFs guide and transmit light within the concrete matrix, contributing to the overall aesthetic and functional properties of the material. The incorporation of POFs in LTC panels is typically carried out by strategically placing these fibres within the concrete mix during the casting process. The plastic core of the optical fiber facilitates the transmission of light through a principle known as total internal reflection.

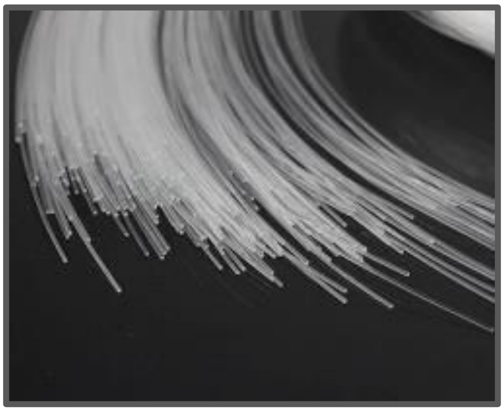

Fig:4 plastic optical fibres

Fig:5 LTC Panel

E. Properties of PMMA POF:

PMMA POFs offer optimal diameter, core material clarity, temperature resistance, long lifespan, UV stability, chemical resistance, flexibility, and ease of handling. These properties make PMMA POFs suitable for various lighting applications, ensuring consistent and maintenance-free operation over extended periods.

F. Production of Litracon:

The production process of translucent concrete involves careful selection of high-quality optical fibers, meticulous concrete mix design, and strict quality control measures. Optical fibers are alternated with small layers of concrete within the mold, ensuring uniform distribution and maximizing light penetration without compromising structural integrity. Pre-cast blocks or panels are produced, undergo a polishing process, and are tested for performance and durability.

G. Advantages of Litracon:

Transparent concrete offers advantages such as light transmission, energy savings, economic benefits, utilization of natural resources, heat transmission, reduced need for artificial lighting, aesthetic appeal, and environmental friendliness. It enhances architectural designs by integrating natural light and reducing energy consumption, contributing to sustainable building practices.

2. Objectives:

- To reduce dependence on artificial lighting during the day, leading to energy savings and a more sustainable built environment.
- To enhance the appearance of building facades, interior partitions, floors, and other architectural elements, contributing to a modern and innovative aesthetic.
- To create unique branding opportunities by integrating logos, images and messages to concrete surfaces
- Enhance daylighting strategies in buildings, which can have positive impacts on occupant well-being, productivity, and comfort.

3. Methodology

Collection of Materials

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Design Mix Ratio for M25 Grade Cubes

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Casting M25 Grade Mortar Cubes

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Cutting Plastic Optical Fibres (POF)

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Design Mix Ratio for POF Cubes

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Casting POF Cubes

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Curing Period

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Comparative Strength Analysis

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Testing Light Transmittance

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Analysing Results

Materials:

The following materials are used in our project:

- Cement
- Fine aggregate

- Water
- Plastic optical fibres
- Wood and thermocol

Cement

Cementitious material used was OPC 53 grade, is the main ingredient used for bonding of concrete. OPC 53 sets quicker than OPC 47 and has a quite initial setting time. It is used in structures where rapid strength gains recurred like large load bearing structures like bridges, huge buildings.

Table 1: Physical properties of cement

NAME OF TESTS	RESULTS
Initial setting time	30 minutes
Final setting time	300 minutes
Fineness	8 %
Consistency	31mm
Specific gravity of cement	3.14

2. Fine aggregate

Fine aggregates used were available on site and are tested, the results are as per indian standards IS 383 1970, Use of fire aggregate improves the compressive strength of concrete. Use of fine aggregates provides better bonding or interlocking.

Table: 2 Physical Properties of Fine aggregates

Name of Tests	Results
Specific gravity	2.6
Water absorption	3.0%
Bulking of sand	29.9%

3. Water

Water is essential in concrete, initiating hydration and binding aggregates; its quality impacts strength and durability. Improper water management in concrete production poses environmental risks like pollution and soil contamination.

4. Plastic optical fibres

Plastic optical fibres (POF) are composed of polymers such as polymethyl methacrylate (PMMA) or polycarbonate. They are engineered to transmit light efficiently through total internal reflection. POF efficiently transmits light through its core, making it suitable for applications requiring optical communication or light transmission. POF is flexible and can be bent without significant loss of light transmission, allowing for versatile installation in various configurations and environments. Unlike glass optical fibres, POF is non-toxic, non-conductive, and does not pose a risk of injury from broken shards or fragments. It experiences signal attenuation or distortion at extreme temperatures, requiring temperature-controlled environments for optimal performance.

Table: 3 Properties of plastic optical fibre

Plastic optical fiber	Properties
Type	PMMA
Diameter	0.75 MM
Length	100 Meters
Lifespan	20 years
Temperature withstand	-58°F to 167°F

5.Wood and Thermocol

Wood is prized for its strength, versatility, and eco-friendliness, serving as a key material in construction, furniture, and artistic expression. Thermocol, noted for its lightweight nature and insulation properties, finds use in mold fabrication, packaging, and creative projects, contributing to cost-effective solutions and sustainability in various industries.

B. Procedure:

1. Mortar cubes made with metal moulds, meticulously prepared and treated with release agent to prevent adhesion of mortar, poured with M25 grade mortar mixture, compacted thoroughly, and cured for 28 days to ensure optimal strength and durability.
2. Molds prepared with thermocol and wood, with specific dimensions to accommodate mortar and POFs, treated with grease or oil to prevent water absorption, maintaining mold stability during casting, ensuring precise shaping of the cubes.

3. Mixture meticulously prepared with precise proportions of cement, sand, aggregate, water, and POFs, hand-mixed until achieving uniform consistency, ensuring thorough incorporation of POFs throughout the mortar matrix, guaranteeing uniform distribution of optical fibers.
4. POFs infused into mortar at specific intervals, maintaining alignment and orientation within the mortar matrix, layers compacted using gentle tamping rod to ensure proper consolidation and removal of air voids, surface finished smoothly to provide uniform appearance, enhancing visual appeal.

5. Labeled molds placed in curing pond for 28 days, allowing mortar cubes to attain optimal strength and durability, after curing, cubes retrieved, allowed to dry, and underwent surface treatment to prepare them for testing, ensuring accurate evaluation of mechanical and optical properties.
6. Cubes retrieved from curing pond, underwent surface drying to remove excess moisture, followed by polishing to enhance visibility and facilitate accurate examination of surface features, ensuring precise evaluation of cube characteristics.
7. Detailed preparation ensures accurate testing of mechanical and optical properties, laying the foundation for reliable assessment of light-transmitting concrete cubes, ensuring consistency and quality in subsequent testing procedures.

4. Results and Discussion:

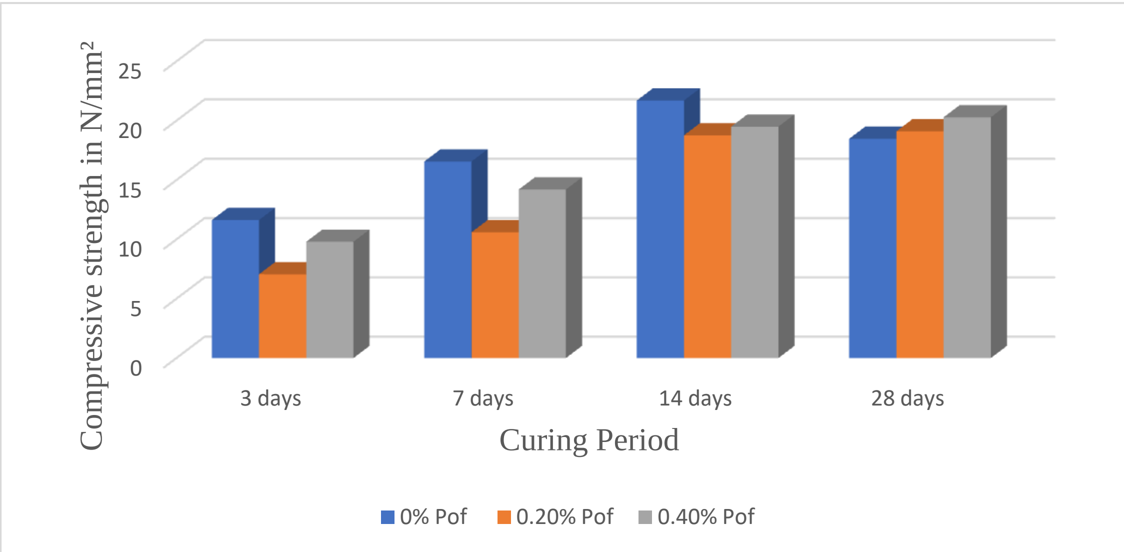
- Compares test results of mortar and POF cubes, focusing on their response to axial loading and compressive behaviour. It particularly examines the load-carrying capacity of mortar cubes with 0.2% and 0.4% POF replacements, providing insights into POF fiber content's impact on compressive strength.

COMPRESSIVE STRENGTH ANALYSIS OF 150MM CUBE SPECIMENS: TABULAR AND GRAPHICAL OBSERVATIONS.

A. Comparison of 3,7,14 and 28 days curing compressive strength:

S. No	% of plastic optical fibre	Compressive strength of cubes for different curing periods			
		3 days	7 days	14 days	28 days
1	0 % pof's	11.63	16.56	21.7	18.48
2	0.2 % pof's	7.06	10.6	18.77	19.11
3	0.4 % pof's	9.8	14.2	19.5	20.29

B. Graph for Compressive strength of cubes



C. Analysis

- Incorporating plastic optical fibers (POFs) into mortar reduces compressive strength over 3 days, with values decreasing from 12 MPa to 9 MPa for 0%, 0.2%, and 0.4% POF content.
- At 7 days, 0.2% POF sample sees a significant 36% strength reduction compared to the control, while 0.4% experiences a moderate 14% decrease, suggesting non-proportional effects of POF fibers.
- By 14 days, strength shows a possible increase, approaching required levels, indicating improving bond between mortar and fibers over time.
- At 28 days, strength further increases, nearing required levels, demonstrating enhanced bond between mortar and fibers with longer curing time.

5. Conclusion

- We are living in a world, where energy consumption and environmental problem have increased to ultimate level. Everybody has to focus on "green technology" and "Sustainability".
- The efficiency of the application of optical fibres is studied by comparing the strength with the normal concrete and the test results proved that the efficiency is more in all aspect.

- As the LTC cubes didn't gain strength at early ages but it diminished and acquired for longer curing periods and met the nearest strength of 28 days.
- When the fibres percentage increased the strength of the cubes also got improved.
- Light-transmitting concrete offers unique design possibilities for architects, fostering innovative facades, partitions, and interior elements. While its strength might not always match standard concrete, its ability to bring natural light into buildings and create a distinctive aesthetic makes it a valuable tool.
- Despite its limitations in structural applications, light-transmitting concrete finds practical uses in non-load-bearing elements like pavements, walkways, staircase, ceilings, floors and decorative features. This emphasizes its role beyond just aesthetics, contributing to a building's functionality and user experience

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