A Comprehensive Experimental Investigation into the Structural and Optical Properties [Transparent Concrete]

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***Abstract*—The project on Experimental Analysis of Transparent Concrete aims to investigate the properties, behavior, and practical applications of transparent or translucent concrete, a relatively new material that integrates optical fibers or other light-transmitting components with traditional concrete. Transparent concrete is characterized by its ability to allow light to pass through, giving it unique aesthetic and functional advantages for modern architectural and civil engineering applications.**

This study explores the development and performance of transparent concrete, a novel construction material designed to transmit light. Transparent concrete is achieved by embedding optical fibers within fine concrete to allow light to pass through, enhancing aesthetics and energy efficiency in structures. The experimental work involved casting 150×150×150 mm cubes using fine concrete without coarse aggregate, embedded with 0.625 mm plastic optical fibers at 2.5 cm spacing. The cubes were cured in water and tested for light transmission and compressive strength. The results demonstrate a balance between structural integrity and light-transmitting capability, indicating potential for innovative architectural applications.

***Keywords*— Transparent Concrete, Optical Fibers, Light Transmission, Fine Concrete, Sustainable Construction**

I. LITERATURE REVIEW

Poornima D et al. (2019) The compressive strength of LITRACON improved by 17.13% and 22.76%, respectively, when 10% and 15% of the cement was replaced with silica fume and there was a rise in split tensile strength of 13.61% and 8.26%, respectively, when compared with the conventional concrete. It is considered as a developing trend in concrete technology since it reduces energy consumption for lighting purposes.

Bharti Sharma and Amarnath Gupta (2018) In this work, the development of an entirely new kind of concrete called translucent or light-transmitting concrete is investigated. It highlights the advantages and disadvantages of translucent concrete compared to regular concrete and provides instances of its use in construction. It implies that transparent concrete is a great architectural material that might improve the aesthetics and energy efficiency of buildings.

Awetehagn Tuaum et al. (2018) This study explains the performance of translucent concrete in transmitting light relies on the volume percentage, spacing, and quantity of optical fibers. According to experimental findings, transparent concrete made with plastic optical fibers and a 6% volume ratio performs up to 22% of light transmittance, making it ideal for pre-cast facades or panels.

Omkar Kadam (2017) In this experimental study the author developed translucent concrete by utilizing plastic optical fiber and fiber Bragg grating, to enhance its mechanical capabilities, self-sensing capabilities, and light transmission. With optical fiber specimens and glass rod specimens, it was discovered to have a compressive strength of 20–23 N/mm2 and 24-26 N/mm2, respectively. The compressive strength decreased as the plastic optical fibers increases. Epoxy resin was utilized to seal the border between plastic optic fibers and concrete in order to increase the anti- permeability of the concrete.

Nikhil K et al. (2016) In this work, testing on transparent concrete revealed that its compressive strength was almost identical to that of conventional concrete, but that it would decline as the proportion of plastic optical fiber rose. The light transmittance test reveal that it increases with closer spacing between optical fibers, and vice-versa and the flexural test done on the translucent concrete revealed a marginally greater flexural value than conventional concrete.

1.1. What is the Significance?

- Natural Lighting: Transparent concrete can reduce the need for artificial lighting during the day by allowing natural sunlight to penetrate deeper into buildings, which can lower energy consumption and decrease electricity costs.

- Reduced Carbon Footprint: The energy saved from reduced lighting demands can contribute to the overall reduction of a building's carbon footprint. Furthermore, transparent concrete, when combined with other eco-friendly building materials, could help in the quest for green building certifications such as LEED (Leadership in Energy and Environmental Design).

- Sustainable Manufacturing: The production of transparent concrete may potentially be more energy-efficient than the production of traditional concrete, especially if optical fibers or additives are sourced from sustainable materials or recycled waste products.

Fig 1. Light Transmission

Fig 2. Low Carbon Footprint

1.2. What is the Light Transmission Process?

- Light (natural sunlight or artificial light) hits the input surface of the concrete.
- The light enters the exposed ends of the optical fibers on that surface.
- The fibers transmit the light through the concrete using total internal reflection.
- The light exits the opposite side of the block, creating a glowing or illuminated effect.

II. METHODOLOGY OF TRANSPARENT CONCRETE

The experimental methodology for the development and analysis of transparent concrete involves a systematic procedure including material selection, specimen preparation, and performance testing. The following steps outline the process:

2.2 Material Selection:

- Cement: Ordinary Portland Cement (OPC) 43 Grade was used as the primary binding material.
- Fine Aggregate: Clean, sieved river sand passing through a 4.75 mm sieve, conforming to IS 383:1970 standards.

- Water: Potable tap water, free from impurities, was used for mixing and curing.

- Optical Fibers: Plastic Optical Fibers (POFs) of 0.625 mm diameter were selected for light transmission. The fibers were flexible, light-weight, and suitable for embedding into the concrete.

- Mold: A wooden mold of dimensions 150 mm × 150 mm × 150 mm was used to cast the test specimens.

2.2 Mix Proportions:

A concrete mix of M40 grade was designed with a cement-to-sand ratio of 1:1.83 and a water-cement ratio of 0.41. Coarse aggregates were intentionally excluded to ensure effective light transmission and proper alignment of optical fibers within the matrix.

III.EXPERIMENTAL PROCEDURE

- Wooden Mold Construction: Prepare a mold of dimensions 150 mm x 150 mm x 150 mm using quality wood. Ensure the interior surfaces are smooth and watertight. Apply a release agent (oil or grease) to the inner walls of the mold to facilitate easy demolding after setting.

- Material Preparation: Gather all required materials: OPC 53 grade cement, clean river sand (fine aggregates), potable water, and plastic optical fibers (diameter 0.625 mm). Clean the optical fibers to ensure they are free from dust and oil, which may affect bonding.

- Concrete Mix Preparation:

Use the predetermined mix design as per IS 10262:2009:

- Cement
- Fine Aggregate
- Water

Mix cement and sand in a dry state thoroughly to achieve uniformity. Gradually add water while continuously mixing until a homogenous and workable mix is obtained.

- Placement of Plastic Optical Fibers: Cut the plastic optical fibers to appropriate lengths (slightly longer than 150 mm to ensure full embedment and extra projection). Mark and fix guiding templates or support inside the mold to maintain a 2.5 cm spacing between fibers in both vertical and horizontal directions. Insert fibers in layers or grids, depending on the required alignment.

- Pouring and Layered Compaction: Pour the concrete in layers (approx. 50 mm each). After placing each layer, insert fibers and compact using a vibrating table or hand compactor. Take care not to disturb or bend the fibers during pouring and compaction.

- Final Surface Finishing: After filling the mold, level the top surface and smooth it using a trowel. Check that all fibers are straight, evenly spaced, and extend to the outer surfaces for effective light transmission.

- Initial Setting and Demolding: Leave the concrete in the mold at room temperature for 24 hours to allow initial setting. Cover the molds with a plastic sheet or damp cloth to avoid moisture loss.

- Curing: After 24 hours, carefully demold the concrete cubes without disturbing the embedded fibers. Place the cubes in a curing tank filled with clean water. Cure samples for 7 days and 28 days to compare compressive strength.

- Testing: Compressive Strength Test: Conducted using a Universal Testing Machine (UTM) as per IS 516:1959. Record load at failure and calculate compressive strength.

- Light Transmission Test: Place the cubes in front of a light source (sunlight or LED torch) in a dark environment. Observe and photograph the transmission of light from one face to the other.

- Documentation: Record all experimental data, observations, and visual results. Photograph the cube at different stages: fiber insertion, casting, curing, and testing. Tabulate compressive strength values and light transmission observations for analysis.

Fig 3. Optical Fiber (0.625 mm)

Fig 4. Wooden Mold (150X150X150 mm)

Fig 5. Placement of Optical Fibers

Fig 6. Placement of Optical Fibers

Fig 7. Concrete Mix Preparation

Fig 8. Final Surface Finishing

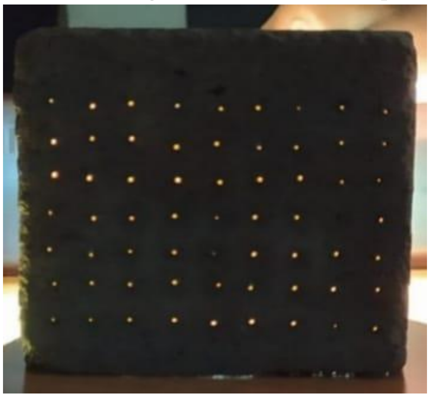


Fig 9. Casted Concrete Cube

Fig 10. Curing of Concrete Cubes

IV.TEST ON CONCRETE CUBES

4.1 Compressive Strength Test: The compressive strength test is conducted to evaluate the strength characteristics of concrete and to determine if it meets the design requirements of M40 grade concrete. This test helps in assessing the structural performance and quality of the mix, especially when modified with plastic optical fibers for transparency.

4.1.1 Apparatus Used:

- Compression Testing Machine (CTM) – 2000 KN capacity
- Vernier caliper or steel scale
- 150 mm × 150 mm × 150 mm concrete cubes
- Water curing tank
- Cleaning brush and damp cloth

4.1.2 Test Specimens:

Concrete cubes of dimensions 150 mm × 150 mm × 150 mm were cast using fine concrete (without coarse aggregates), embedded with plastic optical fibers at 2.5 cm spacing. The cubes were cured in water and tested at 7 and 28 days to evaluate early and full strength development.

4.1.3 Test Procedure:

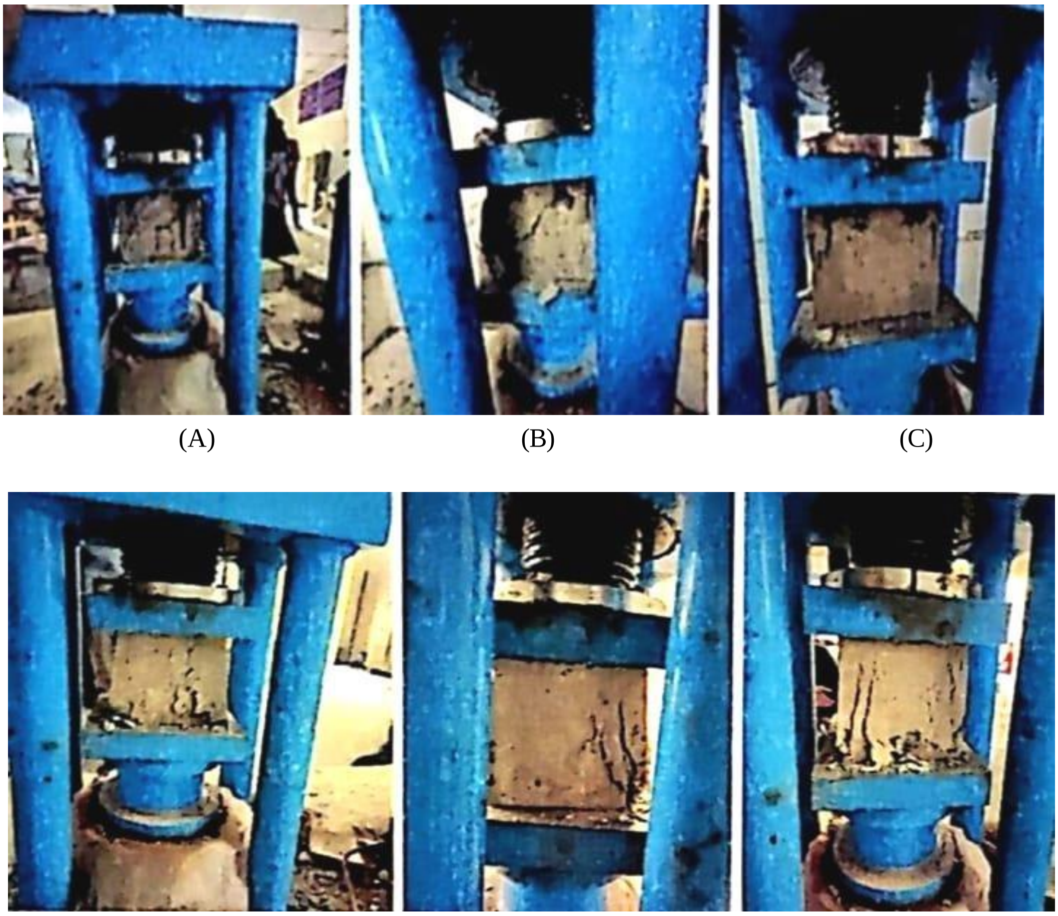
4.1.3.1 Curing and Preparation:
After the respective curing period (7 and 28 days), the cubes were removed from the water tank, and excess water was wiped off with a damp cloth.

4.1.4.2. Dimensional Check:
The sides of the cubes were measured to confirm standard dimensions and ensure accurate cross-sectional area calculations.

4.1.4.3. Placing in CTM:
The cube was placed in the Compression Testing Machine (CTM) with the cast surface positioned perpendicular to the direction of load application.

4.1.4.4. Loading:
Load was applied gradually at a uniform rate of approximately 5.2 kN/sec until the specimen failed. The maximum load at failure was recorded from the CTM.

4.1.4.5. Calculations:
Compressive Strength (MPa) = Maximum Load (N) / Cross-sectional Area (mm²)
Since cube face = 150 mm × 150 mm = 22,500 mm²



(A) (B) (C) (D) (E) (F)

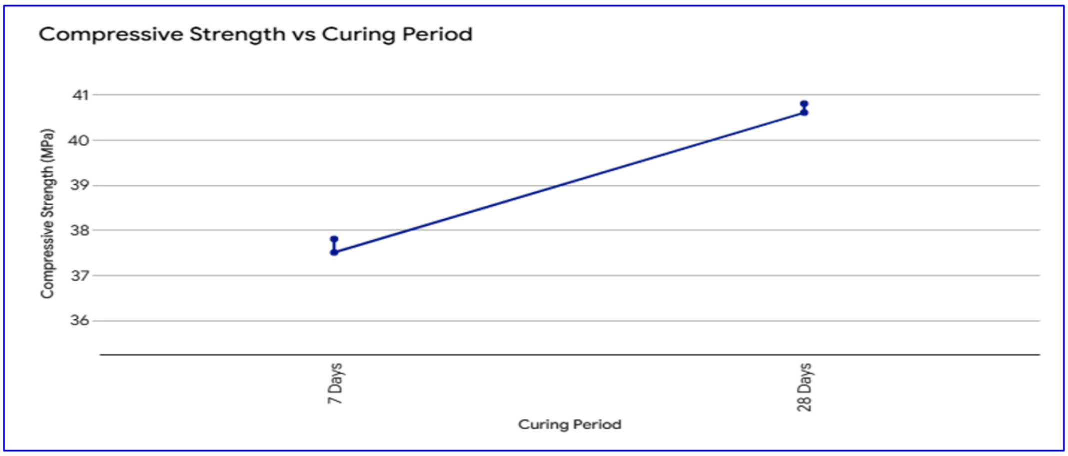
Fig 11. Compressive Strength Test on Concrete Cubes

V.RESULTS AND DISCUSSION

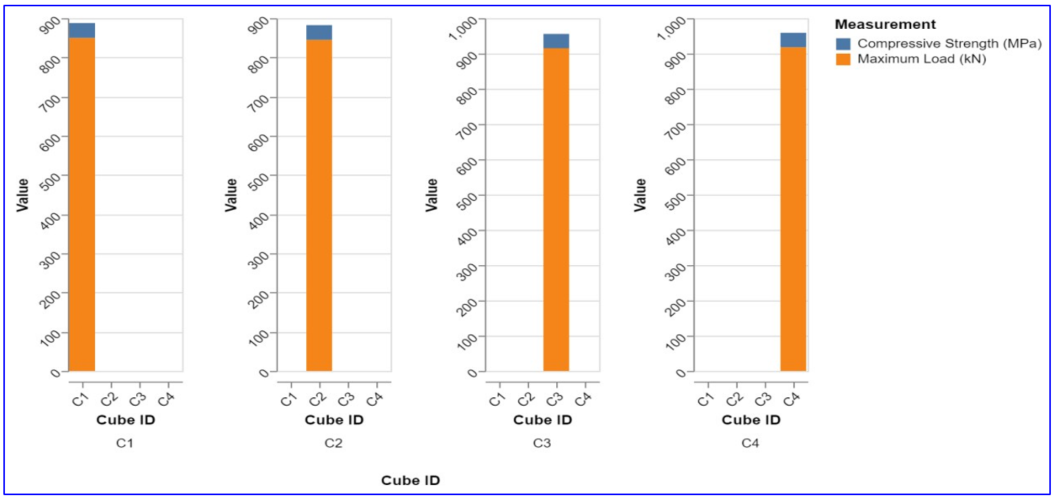
5.1 Test Results Record:

Cube ID	Curing Period	Maximum Load (KN)	Compressive Strength (MPa)
C1	7 Days	850	37.8
C2	7 Days	845	37.5
C3	28 Days	915	40.6
C4	28 Days	918	40.8

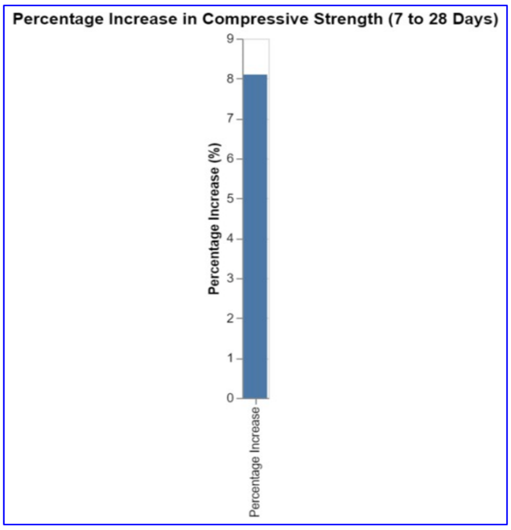
5.2 Compressive Strength VS Curing Period:



5.3 Scatter Plot of Maximum Load VS Compressive Strength



5.4 Percentage Increase in Compressive Strength



VI. CONCLUSIONS

The experimental study on transparent concrete using plastic optical fibers has successfully demonstrated the feasibility and potential of integrating transparency into concrete while maintaining satisfactory mechanical strength. The cubes were cast using fine concrete without coarse aggregate and embedded with 0.625 mm plastic optical fibers at 2.5 cm spacing. The use of M40 grade concrete further ensured that high strength criteria were met, making the material suitable for structural and aesthetic applications.

The compressive strength test results showed a consistent performance with average values of:

- 7-day strength: Approximately 37.8 MPa, indicating early strength development suitable for rapid construction.
- 28-day strength: Approximately 40.8 MPa, confirming that the strength meets the M40 grade requirements even with the inclusion of optical fibers.

From the density calculation, it is evident that the cubes maintained expected weight profiles, confirming good compaction and minimal voids.

The uniform strength across samples suggests that the distribution of optical fibers and the omission of coarse aggregate did not compromise the structural integrity of the material.

The optical properties of the transparent concrete also contribute to sustainable building practices, as it allows for natural light transmission, reducing the need for artificial lighting and enhancing the visual appeal of structures.

6.1 Key Observations:

- The presence of optical fibers does not significantly affect the compressive strength of concrete when properly placed.
- Uniform spacing and correct fiber alignment are crucial for both light transmission and structural stability.
- The project proves that transparent concrete can be both strong and sustainable, opening doors to innovative applications in green buildings, pavements, aesthetic walls, and facades.

6.2 Future Scope for Study:

- Smart Infrastructure Applications: The material holds potential for use in smart cities — for instance, in ambient-lit pavements, energy-efficient road medians, or illuminated pedestrian pathways, reducing dependency on traditional lighting systems.
- Enhanced Light Transmission Studies: Future research can explore the use of alternative optical materials (e.g., fiber Bragg gratings or glass rods) to optimize light transmission and potentially enable data transmission through structural elements.
- Durability Under Aggressive Environments: Long-term studies can be conducted to evaluate how transparent concrete withstands harsh environments — such as coastal regions or freeze-thaw conditions — to determine its viability in extreme climates

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