"Translucent Concrete: Illuminating the Future of India"

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ABSTRACT

This research delves into the potential of Translucent Concrete, a revolutionary building material that combines the strength of traditional concrete with the ability to transmit light. The study examines the material's composition, manufacturing processes, and properties, focusing on the influence of optical fiber type, density, and arrangement on light transmission and mechanical strength. Findings reveal that while higher optical fiber content enhances light transmission, it can negatively impact compressive and flexural strength. The research identifies an optimal fiber content range: below 5% for improved mechanical performance and around 6% for maximizing energy savings. The study explores the architectural applications of Translucent Concrete, highlighting its potential for visually striking designs and energy efficient buildings. Despite its advantages, challenges remain, including the high cost of production and the need for further research to improve durability and address potential issues related to heat gain and glare control. This research provides valuable insights and recommendations to guide the development and wider adoption of Translucent Concrete in sustainable construction practices, paving the way for a future where buildings are both energyefficient and aesthetically pleasing.

INTRODUCTION

Translucent Concrete, also known as light-transmitting concrete, is a revolutionary building material that breaks the mould of traditional concrete. It offers the strength and durability of concrete with the added benefit of allowing light to pass through. This innovative material is composed of a fine-grained concrete mix (approximately 95%) infused with light-conducting elements, typically optical fibres (around 5%). These fibres act like tiny channels, guiding light from one end of the concrete to the other. The specific type, density, and arrangement of these fibres significantly impact the level of light transmission achieved.

The defining property of Translucent Concrete is its ability to transmit light, offering a range of benefits. It allows natural light to penetrate deeper into buildings, potentially reducing dependence on artificial lighting and creating brighter, more energy-efficient spaces. Studies by the Li Tra Con company, a leading producer of Translucent Concrete, suggest a light transmission rate of up to 14%. Additionally, the ability to transmit light opens doors for architects and designers. Imagine illuminated walls, decorative elements with embedded lighting effects, or even furniture crafted from Translucent Concrete.

One of the most common applications of Translucent Concrete is in building facades. Translucent Concrete panels can be used to create a more open and inviting feel for interior spaces while maintaining structural integrity. A recent project by the Dutch firm Studio Rosengard incorporated Translucent Concrete panels in a public restroom, creating a unique and visually striking space. Beyond structural applications, designers are experimenting with Translucent Concrete for artistic installations and decorative features.

While the materials used in Translucent Concrete are generally considered safe, ongoing research is evaluating any potential health impacts. The long-term durability of Translucent Concrete panels is also being explored. Initial studies suggest comparable durability to traditional concrete when properly manufactured and installed. Translucent Concrete panels can be produced in various sizes, offering flexibility for design applications. However, size limitations are influenced by factors like the thickness of the panel, fibre density, and desired

light transmission level. Additionally, the cost of Translucent Concrete is currently higher than traditional concrete due to the specialized materials and production process.

Research is ongoing to improve the light transmission efficiency of Translucent Concrete, potentially by using more advanced optical fibres or exploring alternative light-conducting materials. Additionally, efforts are underway to bring down the production costs to make this innovative material more accessible for wider adoption in the construction industry. Translucent Concrete presents a revolutionary approach to building materials, offering the potential for more energy-efficient, aesthetically pleasing, and lightfilled structures.

Objectives:

1. To compare Translucent Concrete with conventional concrete to determine its effectiveness as a carbon-neutral material.
2. To assess the environmental impact of Translucent Concrete.
3. To investigate how Translucent Concrete can contribute to sustainable construction practices.
4. To understand the compressive strength and flexural strength of Translucent Concrete.
5. To understand its light transmission properties.
6. To understand how these properties differ from those of regular concrete.

1.3 Scope of the Research

- How effectively does Translucent Concrete transmit natural light? This would involve understanding the impact of factors like fibre type, density, and panel thickness on light transmission levels.

- How can Translucent Concrete be integrated into building design to maximize natural light utilization? This could involve studying the placement of translucent panels, their effect on daylight distribution within a building, and potential adjustments to artificial lighting systems.
- Based on light transmission efficiency and design considerations, what are the estimated reductions in power consumption for illumination achievable with Translucent Concrete? This might involve simulations or case studies comparing buildings with and without Translucent Concrete.
- While the focus is on benefits, it's important to acknowledge limitations. This could include factors like cost-effectiveness compared to traditional materials, potential drawbacks related to heat gain or glare control, and any maintenance considerations specific to Translucent Concrete.
- Briefly discuss potential areas for future research and development in Translucent Concrete technology. This could touch upon advancements in fibre optics, improvements in light transmission efficiency, or broader applications beyond illumination (e.g., self-illuminating elements).

LITERATURE REVIEW

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According to Anurag Wahane & Shankar Reddy [January 2022]. Light-transmitting concrete, known also as Translucent Concrete, is literally the brightest concrete development in recent years. Strands of optical fibers are cast by the thousands into concrete to transmit light, either natural or artificial, into all spaces surrounding the resulting translucent panels.

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transparent ones, or embedding fiber optics, Translucent Concrete has become a reality. Light Transmitting concrete, also known as Translucent Concrete.

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MATERIALS AND METHODOLOGY

3.1 Materials used for the Manufacturing of Translucent Concrete

A thin, flexible, transparent fiber known as an optic fiber serves as a waveguide or “light pipe” to carry light between its two ends. The optics can range in size from 200µm to 1 mm.

The speed of light inside a certain material is indicated by the term “refractive index,” which is a crucial parameter in optics.

The ratio of the speed of light in a vacuum to that in a second medium with a higher density is used to calculate the refractive index (also known as the index of refraction). An optical medium’s refractive index, which is a dimensionless number in optics, indicates how well the medium bends light. When light enters a material, this determines how much of the light's path is bent or refract

The properties of optical fiber are listed below.

- Coaxial shielding material with a higher refractive index surrounds the core of an optical fiber before a buffer-protective coating is applied to the outside. Within this coaxial core tube, the transmitted light moves through internal reflection.
- Light-emitting in varying colours
- Brittle, which is why such fibers are encased in steel wire
- Washable

Plexiglass Material

High levels of transparency and the capacity to transmit light and color in both straight and curved lines without compromising transparency are both provided by plexiglass materials. Additionally, it is a suitable material for manufacturing Translucent Concrete due to its low cost and availability.

Other Possible Materials

A new kind of Translucent Concrete was created in 2010 by mixing glass with concrete in varying amounts to focus more on transparency so that it may be utilized in green buildings and some properties of glass in structure have been studied.

According to the study, a remedy for these flaws was the addition of transparent plastic bars with a diameter of 5mm and 10mm along with polyvinyl alcohol. This helped to allow light to pass through the concrete and prevented the bonding between concrete and plastic bars, arrested cracking, and increased ductility. The findings demonstrated that the plastic bars' insertion decreased the concrete matrix-fiber transmission ability.

Additional fiber types that are employed include multimode, single-mode, multimode step- index, multimode graded-index, and others. Light-transmitting concrete (LTC) can be made using Waste Tempered Glass (WTG) as the aggregate.

Manufacturing process of Translucent Concrete

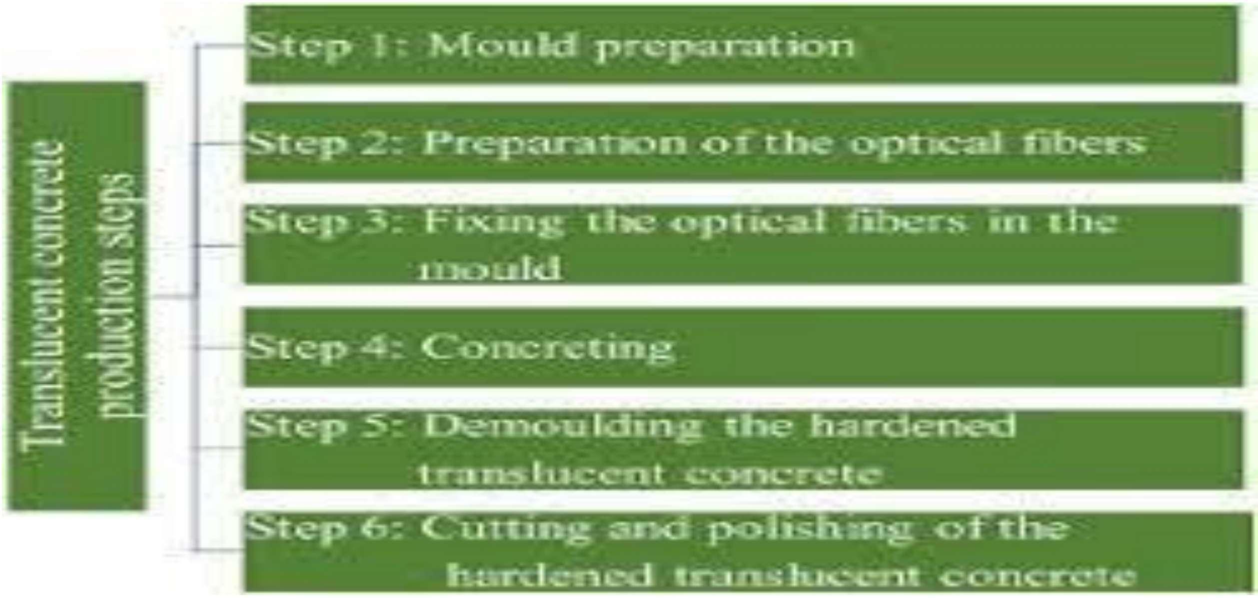
Due to optical elements—typically optical fibers—incorporated in the concrete, Translucent Concrete can transmit light. The stone allows light to pass through it from end to end. As a result, the fibers penetrate the entire object. Depending on the fiber structure, this causes a specific light pattern to appear on the adjacent surface. Through the material, silhouettes of shadows cast onto one side can be seen.

The method of production of Translucent Concrete is the same as that used to produce traditional concrete and some other varieties. The only difference is the inclusion of optical fibers in the Translucent Concrete placed in the mold, spaced 2 to 5 mm apart and parallel to one another.

The fibers are infused with the concrete as it is poured in thin layers over one another. Smaller layers allow an increased amount of light to pass through concrete. Translucent Concrete, which can transmit both artificial and natural light, is made using thousands of fiber strands. Since coarse aggregate tends to damage fiber strands and reduce the concrete block's ability to transmit light, it is not used in production.

In addition, the procedures for producing Translucent Concrete are briefly described in 6 (six) steps as written in the research, as well as the steps shown in Image 3.3.

The steps for the production of Translucent Concrete outlined in Image 3.3 are explained and demonstrated below.



Procedures for the production of Translucent Concrete Step 1 is the Preparation of the Mould

A wooden or steel mold is produced based on standard dimensions. The clay or mud is placed on the sides where the optical fibers are exposed to the mold for easy demoulding after the concreting.

Step 2 is the Preparation of the Optical Fiber

The optical fibers are cut carefully to the required size of the mold. The commonly available diameters of optical fibers are 0.25 mm, 0.5 mm, 0.75 mm, 1 mm, and 2 mm.

Step 3 is Fixing the Fibers in the Mold

Fibers are placed either in organic distribution or in layered distribution. Holes are driven on the wooden or steel plates through which optical fibers are allowed to pass.

Step 4 is the Concreting

The thoroughly mixed concrete is poured carefully and slowly without causing much disturbance to the previously laid optical fibers. The concrete is filled in smaller or thinner layers and is agitated with the help of vibrating tables to avoid void formation.

Step 5 is De-moulding the Hardened Concrete

After 24 hours, the mold is removed, and the mud is pulled off. The casted mold was kept undisturbed on the levelled platform. Then, it was de-moulded carefully after 24 hours from casting. Immediately after de-moulding, the cube specimens were marked by their respective identification marks/numbers.

Step 6 is Cutting and Polishing

The extra-long fibers are cut the same as the thickness of the panel. The panel surface is polished by using polishing paper or using sandpaper.

Properties of Translucent Concrete

Through a series of experiments, the study attempted to determine the strength and durability properties of Translucent Concrete by using a water permeability test. It was discovered that transparent concrete with 4% optical fiber is more durable than conventional concrete and more durable than transparent concrete with 2.5% plastic optical fiber by 28%.

Mechanical and Physical Properties

The studies reviewed indicate that increasing the percentage or volume fraction of optical fibers (POF) added to concrete results in a decrease in the mechanical properties of Translucent Concrete, particularly the compressive strength (fc) and flexural strength (ff). However, the fc and ff of Translucent Concrete improved with curing time.

Specific findings include:

- Altlomate et al. found the maximum fc was 34.16 MPa at 28 days with 1.5 mm POF diameter at 10 mm spacing.

- Henriques et al. concluded that increasing POF concentration caused fc and ff to decrease, with randomly distributed POF reducing strength more than ordered fibers.

- Silica fume helped prevent microcracks caused by closely spaced POF.

- Salih et al. reported fc and ff decreased as POF volume increased, but improved with aging. Higher POF volume enabled lighter weight concrete.

- Tuaum et al. found density, fc, and ff decreased as POF volume ratios of 2%, 4%, 6% increased.

- Bashbash et al. found increasing POF diameter could increase fc using the same 2%, 4%, 6% POF volumes, as larger diameter fibers had higher compressive load resistance.

- Momin et al. found glass optical fibers gave similar fc to conventional concrete, but glass rods performed better due to higher rigidity.

- He, Zhou and Ou concluded endlessly increasing light transmission by raising POF volume ratio is not possible due to detrimental effects on mechanical properties.

- Zhou et al. observed failure load reductions of 0.379%, 3.023%, 9.712% for concrete with 3.14%, 3.8%, 4.52% POF volume respectively compared to normal concrete.

- Tensile strength tests showed Translucent Concrete exhibited more uniform elastic deformation compared to sudden failure in conventional concrete.

In summary, increasing optical fiber content tends to reduce compressive, flexural and tensile strengths of Translucent Concrete, but factors like fiber diameter, distribution, silica fume use and curing time can influence the mechanical performance.

Stress-strain Behaviour for Translucent Concrete

The slope of the stress–strain curve for concrete under uniaxial loading determines the static modulus of elasticity under tension or compression. The elastic property of a material is a gauge of its stiffness, but this curve for concrete is nonlinear. As a result, stronger concrete has a more elastic static modulus. A crucial factor expressing concrete's ability to deform elastically is its modulus of elasticity. The modulus of elasticity is important because, for a given strain, a higher modulus produces a higher tensile stress, which means that stronger concrete exhibits a lower strain. As a result, the length of the member under compression affects the descending branch of the stress-strain relationship.

Light-Transmitting Property

The compressive behavior and light transmission capabilities of transparent concrete were studied. The fc was found to rise by 3% with the addition of fibers to the concrete volume (0.10%–0.20%), and the highest quantity of light that could travel through the cube was 2122 lux.

The effectiveness of Light Transmissive Concrete (LTC) specimens produced utilizing various dosages and spacings of POF was examined by Altlomate et al. The effectiveness of POF was examined and evaluated.

Temperature Effect, Thermal and Energy-saving Properties

By harnessing sunshine and reducing the need for artificial lighting throughout the night, using light-transmitting concrete will provide a decorative aspect. After examination, transparent glazing solutions have demonstrated excellent thermal insulation characteristics. On the other hand, a transparent concrete panel (TCP) achieves the same thermal performance by utilizing concrete components and additives that are energy efficient.

An experimental study on a Translucent Concrete panel investigated the light emissions and thermal properties by modelling the arrangement of the optical fibers into the concrete during exposure to simulated sunlight for 12 months. Results proved the good thermal and mechanical properties of Translucent Concrete.

Computing modelling for a transparent concrete panel with dimensions (0.3 m*0.3 m*0.1 m) was made using a fiber volumetric ratio of 10.56% to investigate the model's light transmission properties under the weather in Berkeley, California. Throughout a year of simulation, an algorithm is utilized to model and compute the transparent concrete panel's solar heat absorption.

The results of this study will create a formula for calculating the amount of sunshine that will enter a building when transparent concrete is employed. This will have an impact on following design decisions made during the heating, ventilation, and air conditioning (HVAC) design process. To provide thermal and lighting evaluations and estimate the ideal optical fiber ratio for transparent concrete panels to conserve the most energy feasible, new research was carried out as a follow-up to the prior work. The investigation will make use of a model room with the dimensions (3 m*3 m*2.895 m), and panels with the same measurements as the computational model from the earlier research will be produced in the lab. The program was developed to simulate and calculate the heating and cooling loads on the HVAC system, as well as other light and thermal assessments, to find the optimal ratio of optical fibers for panels that would achieve the most potential for energy savings. According to this, employing fiber with a volumetric ratio of roughly 6% results in an 18% decrease in energy use.

Recommendations

It is safe to conclude that researchers will need to discover affordable production methods for transparent concrete before it can be considered a viable substitute. Research into less costly light transmitting materials is strongly advised. It is necessary to improve the strength and durability of Translucent Concrete especially when exposed to harsh environments hence, this study suggests the use of fiberglass mesh as external confinement of the concrete and

Properties and Characteristics of Fiberglass Mesh

i. Corrosion and chemical resistance: Fiberglass, unlike metal, shows excellent resistance to oxidation and corrosion as a result of exposure to a humid microclimate, salts, or chemicals. Due to this, the durability of the concrete floor itself, reinforced with fiberglass mesh, increases.

ii. Strength: During the research, it was determined that the breaking capacity of the composite mesh is 3 times higher and exceeds the metal mesh of a similar diameter in strength. Due to this, while maintaining the strength characteristics, the metal mesh can be replaced with a composite plastic mesh of a smaller diameter.

iii. Low thermal conductivity: The thermal conductivity of composite reinforcement is approximately 100 times less than the thermal conductivity of metal. Thus, the composite mesh can be used to prevent the formation of “cold bridges” inside the structure.

iv. Ease: If metal and composite mesh of the same size are compared, then the composite mesh is 6 times lighter in weight than its metal counterpart, which greatly simplifies construction and installation work.

v. Durability: Masonry mesh is an extremely wear-resistant material that does not lose its properties over time. According to research by British scientists, over 100 years, the strength reduction coefficient of composite reinforcement is 1.25, that is, the strength of the material is maintained at 79.6% of the original level.

vi. Characteristics: Fiberglass masonry mesh is a dielectric, not magnetizedSince glass fiber enables light to travel through it, using fiberglass mesh will not prevent transparent concrete from transmitting light; instead, it will improve the material's mechanical and physical qualities.

Discussion: With the growing need for green buildings and alternative building materials, Translucent Concrete has a bright future. Because sunlight can easily pass through Translucent Concrete to provide visual clarity for the occupants even at night when the moon is out, Translucent Concrete is environmentally friendly, sustainable, and less expensive for the government and individuals to use during the day. Translucent Concrete is a great way to save money and energy.

CASE STUDY

World’s First Light Transmitting Concrete Façade:

The LUCEM light-transmitting concrete panels used in the facade project at RWTH Aachen University showcases innovative features and capabilities. Each panel is accompanied by an LED light panel of the same size, equipped with RGB chips that allow for the control of over 16 million colors. The building owner wanted a facade that could express innovation by displaying various light scenarios on the surface, appearing as a natural stone facade during the day and glowing with plain or moving lights at night.

LUCEM LINE White

As part of its renovation of the bathing hall at Obermain Therme in Bad Staffel stein, Germany, Krieger Architected Ingenuine designed a cave-like space whose form was inspired by salt crystals. Two layers of LUCEM light-emitting concrete panels give the enclosure its colourful glow.

CONCLUSION

Translucent Concrete is an innovative and promising material that offers the potential for energyefficient and aesthetically appealing building designs. By allowing natural light to penetrate through concrete structures, it can significantly reduce the need for artificial lighting during daylight hours, leading to substantial energy savings and contributing to sustainable construction recites. The research has comprehensively explored the materials, manufacturing processes, and properties of Translucent Concrete. Various factors, such as the type of optical fibers, their diameter, density, and arrangement, have been investigated to understand their impact on transmission, mechanical strength, and overall performance. The study has identified the optimal range of optical fiber content in Translucent Concrete to balance light transmission efficiency and structural integrity. While higher fiber content enhances light transmission, it can adversely affect the mechanical properties, such as compressive and flexural strength. The recommended fiber content is below 5% by volume for improved mechanical performance and around 6% for optimal energy savings. Translucent Concrete has demonstrated promising applications in architecture, particularly as a façade material, interior wall cladding, and decorative elements. Its ability to transmit light and create visually striking designs has potential for enhancing the aesthetic appeal of buildings and creating unique architectural experiences.

Despite its advantages, Translucent Concrete faces certain limitations and challenges. The high cost of optical fibers and the labor-intensive manufacturing process currently make it more expensive than conventional concrete. Additionally, there is a need for further research and development to improve the material's durability, investigate its long-term performance, and address potential issues related to heat gain or glare control. The integration of Translucent Concrete in eco-friendly designs is driven by factors such as energy efficiency, architectural appeal, illumination in confined spaces, cost savings, and insulation properties. However, its widespread adoption in the construction industry may require addressing the limitations and exploring cost-effective manufacturing techniques.

Overall, while Translucent Concrete presents a revolutionary approach to building materials with significant potential for energy-efficient and visually appealing structures, further research and development are necessary to overcome the current challenges and pave the way for its broader implementation in sustainable construction practices.

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