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Optical Fiber in Translucent Concrete {Lightcrete}

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Abstract: Due to incorporated light optical elements, typically optical fibres, Lightcrete is a concrete-based building material with light-Transmissive qualities. The stone transmits light from one end to the other. The fibres must therefore penetrate the entire thing. Because of its characteristics, transparent concrete is sometimes referred to as translucent concrete and light-transmitting concrete. It could be utilised for internal wall cladding as well as facade material in fine architecture. In order to combine the advantages of concrete with optical fibre, transparent concrete was created in this study by incorporating Plastic Optical Fibres (POF) with high numerical aperture into the mixture. To transmit light, either natural or artificial, into all places surrounding the resulting translucent panels, thousands of optical fibre strands are cast into concrete. By adding 4 to 5 percent (by volume) optical fibres to the concrete mix, it is possible to create concrete that transmits light. The fibres, which are implanted in the concrete piece, travel parallel to one another and transmit light between its two surfaces. When compared to a sample with no fibres, LightCrete's compressive strength revealed a nearly 30% increase in strength. The major goal is to employ solar energy as a light source to reduce the amount of electricity needed for illumination, to detect structural stress with an optical fibre, and to use concrete as an architectural element for a pleasing aesthetic view of the building. There is a need for smart construction techniques like green building and indoor thermal systems because of globalisation and the construction of high-rise structures, which reduces the space between buildings and increases the usage of non-renewable energy sources. Translucent concrete, often known as transparent concrete, is a novel method. Compared to regular concrete, translucent concrete allows for more light and less weight. Translucent concrete's primary function is to use sunshine as a source of light rather than electrical energy, which reduces the demand on non-renewable resources and results in energy savings. Reduce the usage of artificial light by replacing the standard concrete with translucent concrete, which has natural illumination and artistic design, since optical fibres are a sensing or transmission element.

Introduction

Due to the 1960s' fast urbanisation, concrete used to be frequently misunderstood, despised, and captured by its image stuck. However, since that time, concrete has advanced significantly in both technical and aesthetic dimensions. It is no longer the bulky, drab, and dreary material of the past; instead, it is now lovely and vibrant. Newly developed concrete that is more resilient, lighter, white or coloured, etc. has been produced through research and innovation. The idea of transparent concrete was first proposed by Hungarian architect Aron Losonzi, and the first transparent concrete block, known as LiTraCon, was successfully created in 2003 by adding a significant amount of glass fibre to concrete. Joel S. and Sergio O.G. created a translucent concrete substance that weighs only 30% as much as regular concrete but can transmit 80% of light.

The translucent concrete primarily emphasises transparency, with a green technology and artistic finish as its application goals. "Optical fibres and fine concrete" is what it is. At the moment, energy conservation with indoor thermal systems is a major focus of green buildings. In order to satisfy the structure in terms of safety monitoring (such as damage detection, fire warning), environmental protection, energy saving, and creative modelling, it is important to design a new functional material.

There is a need for smart construction techniques like green building and indoor thermal systems because of globalisation and the construction of high-rise structures, which reduces the space between buildings and increases the usage of non-renewable energy sources. Translucent concrete, often known as transparent concrete, is a novel method. Compared to regular concrete, translucent concrete allows for more light and less weight. Translucent concrete's primary function is to use sunshine as a source of light rather than electrical energy, which reduces the demand on non-renewable resources and results in energy savings. Reduce the usage of artificial light by replacing the standard concrete with translucent concrete, which has natural illumination and artistic design, since optical fibres are a sensing or transmission element. Thousands of optical fibre filaments or acrylic glass strips are arranged on opposite side of the device's faces, allowing light to pass from one side to the other. These filaments combine with the concrete because of their thin thickness. A more attractive and healthy environment is also produced for building inhabitants when daylight is used indoors as opposed to a conventional electric lighting system. It was made of optical fibres and fine concrete mixed together so that the substance was uniform on the inside and outside. It was mostly used for ornamentation and was produced in blocks.

The LightCrete primarily emphasises transparency, with a green technology and artistic finish as its application goals. it is important to design a new functional material. One new response to architects' calls for more transparent architecture is LightCrete. In this research, crushed glass is utilised to partially replace the sand, and optical fibres are embedded. After 28 days, the light-transmitting capabilities and compressive strength are tested.

Literature review

Karsten Pfeffer and Martina Schnellenbach-Held Concrete that is transparent allows for complete interior reflection.In this process, a slight loss of energy can be seen. Translucent concrete's fundamental design relies entirely on light transmission; it absorbs light from a natural source, such the sun. Correlations exist between the strength outcomes of ornamental and regular cement concrete. The outcomes clearly demonstrate that decorative concrete performs exceptionally well in terms of both strength and performance. Because of this, adding optical fibre will both make concrete more aesthetically pleasing and maybe more structurally sound.

Concrete's translucent strength in compression (2015) Salmanbanu Luhar and others To determine the possibility for employing transparent concrete for the construction of green buildings,By incorporating plastic optical fibres into concrete, translucent concrete has been created.

Translucent glass concrete research (2016) Sisira Sugunan and others In order to examine the potential for recycling discarded glass as fine aggregate for concrete, experimental tests were carried out for this research. The goal of this study is to replace fine aggregate with crushed glass trash to create a solid construction block and to provide translucency for aesthetic purposes.

The Modeling of Translucent Concrete Blocks using Optical Fibers (2013) Padma Bhushan, M. N. V., and others Due to the use of light-optical components like optical fibres, translucent concrete is a concrete-based material with light-transmissive qualities. The stone transmits light from one end to the other. Depending on the fibre structure, this causes a specific light pattern to appear on the opposite surface.

Luminous Concrete (2013) Soumyajit Paul and others Translucent concrete will enable a greater connection between the structure and its surroundings, resulting in richer and more naturally illuminated ambiances. Along with the translucent qualities, the paper restricts its focus to how this form of concrete is reinforced so that it can be used in real-world applications as a load-bearing structure.

A building block with light-transmitting fibres embedded in a cast material is what LightCrete is all about, as well as a process for making such a block. A building component, like a wall, floor, or ceiling surface, is frequently lighted by one or more distinct light sources for both functional and aesthetic purposes. However, such techniques are impractical, time-consuming, and expensive. An item like the LightCrete Block was

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created to get rid of the problems with the state of the art. It's a light-transmitting prefabricated building block. It is possible to construct a brand-new, unheard-of type of architecture by combining two typically incompatible qualities—heaviness and transparency—in one single building material.

Fig 2.1 Translucent concrete wall

It is designed to provide prefabricated, load-bearing building components made of conventional, basic materials, like concrete, while also, to a certain extent, allowing light to pass through the majority of two of its opposite surfaces. This allows for an easy and cost-effective manufacturing process. This was accomplished by incorporating optical fibres or other light-transmitting fibres within the cast material. In addition, a number of fibres are dispersed uniformly throughout nearly the whole lateral surface. The equally spaced fibre ends can emit light in locations throughout nearly the whole lateral surface. Depending on the architectural project's structural requirements and aesthetic requirements, translucent concrete blocks are made. Pre-cast concrete is essentially available in all shapes and sizes, from tiny bricks to acceptable paving stones or façade panels. Translucent concrete blocks have the same technical specifications as the concrete used to make them since optical fibre makes up only 4 to 5 percent of their composition.

The key concept behind smart transparent concrete is the direct arrangement of optical fibres with large numerical aperture into the concrete, which serves as both a sensor and a transmission medium for light. Because optical fibres can transmit light, many shapes of smart transparent concretes can be created, and a specific number of optical fibres are uniformly placed throughout the concrete. Plastic optical fibre has been widely employed in facility or architectural appearance lighting because it is a great medium for transmitting light at precise wavelengths. The fabrication procedure of a typical transparent concrete block using concrete and POFs can be summarised as follows in this study. The plastic sheet is first punctured with holes with orthogonal arrays in accordance with the volume ratio of the concrete and POF. Two plastic sheets with holes that are glued to the slots of wood formwork are used as POFs. The last step involves pouring a specific type of concrete into the formwork and shaking it vigorously. the transparent concrete creation from the transparent demonstration experiment, which has good light transmission.

The idea of transparent concrete was first suggested in 2001 by Hungarian architect Aron Losonzi, and the first transparent concrete block, known as LiTraCon, was successfully created in 2003 by adding a lot of glass fibre to concrete. Joel and Sergio created a translucent concrete substance that weighs only 30% as much as regular concrete but can transmit 80% of light. Scherafe's (1988) research focused on how applications surpass fabric structure. A type of translucent concrete created by combining glass and concrete in 2010 is displayed in the Italian Pavilion at the Shanghai World Expo. While the application of transparent concrete is mostly transparent and relates to green technology and artistic finish. Due to the 1960s' fast urbanisation, concrete used to be frequently misunderstood, despised, and captured by its image stuck. However, since that time, concrete has advanced significantly in both technical and aesthetic dimensions. It is no longer the bulky, drab, and dreary material of the past; instead, it is now lovely and vibrant. Newly developed concrete that is

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more resilient, lighter, white or coloured, etc. has been produced through research and innovation. One new response to architects' calls for more transparent architecture is LightCrete. A recent innovation in the building sector is transparent concrete. Strong substance concrete is a subject of increasing research on a daily basis. It is a reliable and crucial binding element for building any buildings made of reinforced cement concrete. Thus, it is crucial for everyone to understand the significance of concrete. Different varieties of concrete are now accessible on the market, and academics are conducting more research on this subject every day. Concrete that transmits light is also referred to as transparent concrete.

Methodology

LightCrete is a concrete-based building material with light-Transmissive properties because it contains integrated light optical devices, usually optical fibres. Light travels through the stone from one end to the other. Therefore, the entire object must be penetrated by the fibres. Transparent concrete is also known as translucent concrete and light-transmitting concrete due to its properties.

Fig 3.1 Glass

Fig 3.2 Crushed Glass

Optical Fibers

Nowadays, optical fibres are employed in a wide range of industries, from remote sensing to small electrical components in computers. These were initially created in the 1970s with communication in mind (telecommunications industry).In this study, plastic optical fibres were employed. There are various kinds of optical fibres, each with a unique characteristic like being metal-free or having a high fibre count. Compared to other materials like glass, they have a few advantages.

Fig 3.3 End Glowing Optical Fibre

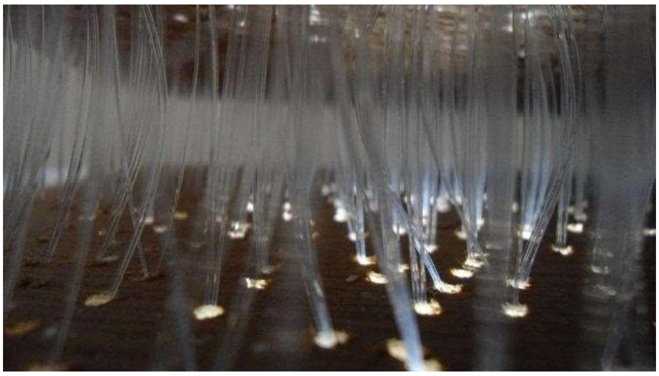

Fig 3.4 Embedded Optical Fibers

Table 3.1 Specifications of Optical Fibers

Fiber Type	Multimode step index
Core size diameter	100 µm +/-3 µm
Cladding Thickness	12 µm +/-5 µm
Buffer Thickness	17 µm +/-3 µm
Buffer Material	Acrylate
Maximum OD Total	0.85mm
Operating Temperature	-65 to 30

Crushing of Glass

The glass is sourced from waste glass recycling facilities and the neighbourhood glass industry. When a large quantity is needed, it is typically crushed in nearby crushers. However, it was smashed in a Los Angeles abrasion testing machine that is available in Transportation labs, where the steel balls shatter the glass within, for small-scale purposes.

With a set of 12 metallic balls within, an electric motor rotates the drum at a speed of 30 to 33 rpm.

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Fig. 3.5 Los Angeles Abrasion Testing Machine

It can also be crushed using an impact testing equipment.

Fig. 3.6 Impact Testing Machine

Material Characterization

With the aid of IS Sieves, crushed glass that is utilised as an aggregate replacement for sand is graded.

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Fig. 3.7 Process of Sieving

Table 3.2 Sieve Analysis

IS Sieve	Weight Retained (gm)	Cumulative Weight Retained (gm)	Percentage Weight Retained	Percentage Finer
2.36 mm	120	120	6%	94%
1.18 mm	500	620	31%	69%
600 µ	640	1260	63%	37%
300 µ	370	1630	81.5%	18.5%
150 µ	210	1840	92%	8%
pan	160	2000	100%	0%

Fig 3.9 Electronic weighing Balance

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Making of Moulds

Various wooden moulds were created by a local carpenter to cast the LightCrete slabs and cubes. For slabs and cubes, various mould sizes were created.

CUBICAL MOULD

Fig. 3.10 Wooden Cubical Mould

L-SHAPED SLAB

Fig. 3.11 L-Shaped Slab

Fabrication

Fibers are added to the experiment in three distinct volumetric proportions: 0.5 percent, 1.2 percent, and 5.0 percent.

As seen in the image, the fibres were manually inserted into the moulds through the mold's pores.

Fig. 3.13 Fabrication of Fibers in mould

Calculation of Fiber Content
Diameter of fiber = 0.85mm Area = 0.56×10^{-6} m²

Table 3.3 Observation

Percentage fiber by volume of the cube	**0.5% fiber Reinforcement**	**1.2%fiber reinforcement**	**5.0% fiber reinforcement**
Diameter of fiber	0.85mm	0.85mm	0.85mm
Aspect ratio (l/d)	82.35	82.35	82.35
Area of section	0.56×10^{-4} m²	0.56×10^{-4} m²	0.56×10^{-4} m²
Volume of cube	3.43×10^{-4} m³	3.43×10^{-4} m³	3.43×10^{-4} m³
Volume of fiber optics	0.01715×10^{-4} m³	0.04116×10^{-4} m³	0.1715×10^{-4} m³
Required Length of Optical fiber	**3.062m**	**7.33m**	**30.62m**

Mixing
Water content is regulated at 0.47 for optimal working conditions, and mixing is done by hand.

The sand and aggregate components of the cement paste will separate if there is too much water present.

Additionally, water that is not used up by the hydration reaction may leak out of the concrete as it solidifies, causing microscopic pores (bleeding), which would lower the concrete's ultimate strength.

A mixture with too much water will shrink more when the extra water evaporates, leading to internal fissures and obvious fractures (especially in the interior corners), which will again lower the ultimate strength.

The cement aggregate ratio should remain at 1:2.5, and 2 percent by volume of mixture is added.

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Fig 3.14 Mixing

Casting

Fresh mortar is filled inside the wooden moulds and the compaction is done with the help of vibratory desk. The inside surface of the mould is painted with turpentine oil to make the surface smooth and for sake of ease while opening the moulds. The casting is done with thirty minutes of mixing the mortar, as soon as the mould is filled, it is cover packed by polythene film to maintain the water content inside the mould.

Curing

Due to the fact that curing regulates the rate and volume of moisture loss from concrete during cement hydration. It must be done carefully. As soon as the moulds are open, the samples are kept under water for 28 days for effective curing.

Polishing and Grinding

A hand handled concrete polisher is a specialist tool needed to polish concrete counter tops. While you can rent this piece of equipment from numerous home improvement stores, you need also budget about $100 for concrete polisher pads to finish this process. After curing for 28 days, samples and cubes' surfaces were dried, polished, and ground at a nearby grinding shop. The optical fibre extensions were ground, and then the polishing machine polished the surface to make it smooth and lustrous.

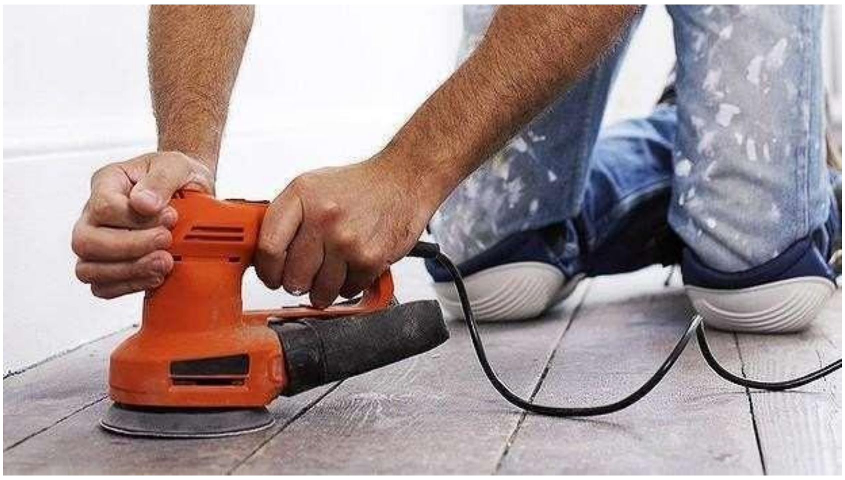

Fig. 3.15 Grinding and polishing machine

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Fig.3.16 LightCrete sample polished with high precision

Results and discussions

The same material is used to manufacture plain cement concrete with 0% of the fibre in order to compare the outcomes produced by adding various amounts of optical fibres. As shown in Table-4.1, the compressive strength results after 7 days and 28 days of curing.

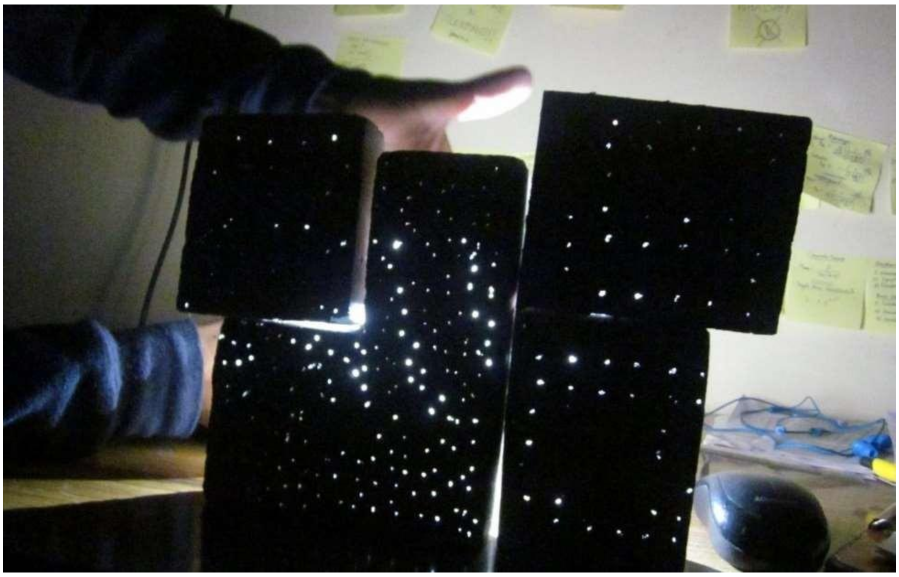

Fig 4.1 Light transmitting concrete

Table 4.1 compressive strength

PERCENTAGE FIBRE USED BY VOLUME OF THE SAMPLE	Compressive Strength after 7 days (N/mm²)	Compressive Strength after 28 days (N/mm²)
0.0%	24.88	38.00
0.5%	24.88	40.15
1.2%	26.22	42.28
5.0%	29.10	49.80

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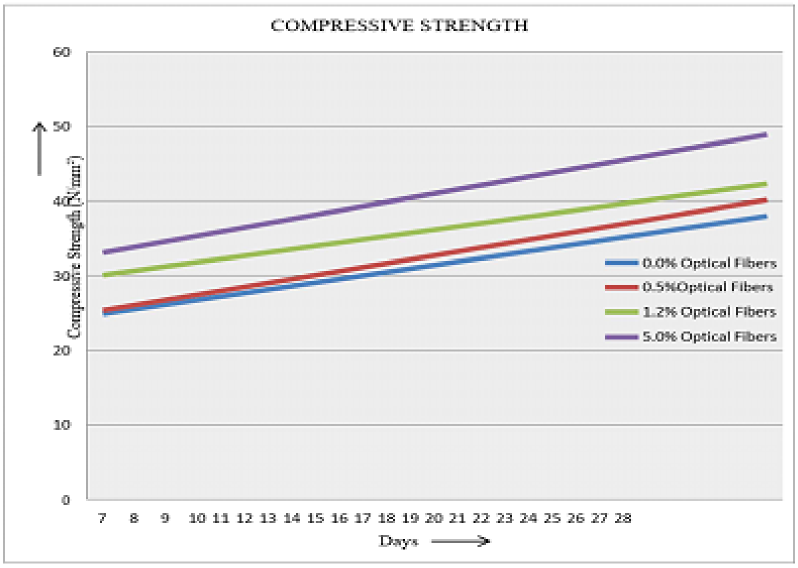

Fig 4.2 compressive strength

According to the findings in table 4.1, concrete's compressive strength significantly changed after 7 and 28 days. This was anticipated because fibres can withstand compressive loads, as is well known.

Conclusions

The current research focuses on using waste products from the glass industry, such as optical fibre and crushed glass aggregate, in concrete. The research is in its early stages, but it shows promise because the initial findings meet the fundamental requirements for concrete that an alternative material should meet. However, as predicted, LightCrete's compressive strength demonstrated a strength improvement of about 30% over the beam with 0% fibres. These behaviours' causes are discussed. Thus, it can be inferred that adding optical fibre and glass to concrete not only enhances its qualities and allows for a slight cost reduction, but also gives the finished product properties that make it light-transmitting.

Recycled glass concrete can be manufactured using traditional concrete manufacturing and building methods by partially substituting cement with milled waste glass with micron-sized particle size. Concrete's resistance to absorbing moisture is increased when milled waste glass is used as a partial replacement for cement, improving the material's durability properties. The use of milled waste glass in concrete is a practical method that would have significant energy, environmental, and financial advantages. It would also significantly reduce the carbon footprint of the building sector. It is finally concluded that:

1. Compared to regular concrete, LightCrete's compressive strength increased by 30%.

2. There is an increase in the sample's ability to transmit light.

Because it meets the strength criteria, LightCrete could be successfully employed for architectural purposes in a compendium. It could also be used as a building material for green structures.

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