A study on Performance of Luminance and strength characteristics of High Strength Translucent concrete

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***Abstract*— In recent years, it has become vita to construct energy-efficient buildings. Maintaining a good quality of life while simultaneously lowering the building's energy requirements has been and will continue to be one of the most difficult challenges. Due to its large population, India's business and residential sectors account for around 30% of the country's overall power usage. Thus, the goal is to develop a plan to cut down on greenhouse gas emissions and energy consumption in buildings. An emerging innovation in the building industry is translucent concrete. It's a plan to switch commercial buildings over to using green energy. Light-Transmitting Concrete (LTC) has the potential to transform the inside of a concrete structure from darkish, boring, and greyish to bright, open, and expansive by letting natural light in through the building's outside walls. Using it may deplete energy usage in buildings by a significant amount, which is great for the environment and the economy. In this experimental study, LTC is developed by inducing 4% or 5% of optical fibre by volume in concrete mix and also to investigate the mechanical and optical properties of translucent concrete by the inclusion of 0.75mm diameter plastic optical fibre with three different densities in a cement mortar cube and incorporating Alccofine for cement replacement. The perpendicularly drilled holes on the two opposing faces of the moulding were used to weave the optical fibre. As a light-transmitting component in the current work, a plastic optical fibre with a 0.75mm diameter and three distinct densities—5x5, 6x6, and 7x7—is used. According to this study, the compression resistance is influenced by the amount of plastic optical fibre utilised. Between 7x7 and 6x6 (number of fibre strand in a surface area of 351896 mm^2), the ideal density for 0.75mm diameter fibre to be employed in translucent mortar sample, was discovered. The 5x5 fibre density specimen, which at 28 days of age was approximately 59.93% more dense than the 5x5 density specimen, provides the strength. Above this fibre density, the additional fibre content resulted in a loss of strength and may have increased the amount of voids or gaps within the concrete sample. Despite its humble beginnings, long-term care has recently garnered widespread support among academics, and researchers have also tried to provide answers to long-term care-related concerns through scientific research.**

Keywords— Translucent concrete, optical Fibre, luminance, compressive strength

I. INTRODUCTION

Constructing a building that is energy efficient has become increasingly important in recent years. Ensuring a high quality of life while at same time reducing the energy demand of the building has always remained a key challenge. India being highly populated country, about 30% of country's total electricity consumption takes place in residential and commercial buildings. This demand in energy consumption is likely to increase, as India urbanises. Rising energy consumption will lead to higher power generation affecting both capital and natural resources of the country. At present, India generates 80% of total electricity from fossil fuels. Major contribution of electricity production comes from coal, used as a fuel in thermal power plant. The greenhouse gas carbon dioxide is produced by coal. subsequently having a direct impact on our climate, health, and environment. In order to reduce energy consumption in buildings and the release of greenhouse gases into the atmosphere, a strategy must be developed. The development of light-transmitting concrete is one of the most recent innovations in the construction sector. This project aims to use renewable energy sources in construction. Light-transmitting concrete has the ability to transform the inside of a structure made of concrete from dark, drab and gloomy to fresh, open and airy by allowing natural lighting to enter the building through its outside walls. It can reduce building energy use in a significant way, improving sustainability and lowering energy costs. Aron Losonczi, a Hungarian architect, pioneered the concept of light-transmitting concrete and created the first successful light-transmitting concrete block in 2003. Combining his creative creativity with technological ingenuity, he called his creation LiTraCon. After a modest beginning, the LTC has already gained widespread recognition among researchers. Several research on the subject of LTC have occasionally been conducted.

II. Review of literatures

In 2015, Patil et al. proposed concrete that transmits light - a novel, aesthetically attractive invention called smart transparent concrete. Instead than only being a building material, translucent concrete made from Plastic Optical Fibre (POF) might be used in galleries and specific displays. Despite compromising construction simplicity, the material is certain to be widely embraced because of its benefits. Utilising the natural resource becomes critically necessary as the idea of green technology gains traction and electricity supply starts to be augmented by natural sources. Although Litracon has not yet been made commercially available, it is currently being hypothesised that structures made of the material could reduce the amount of electricity needed for daytime illumination. When light transmitting properties were examined, the test results have revealed that the produced concrete can be cut into different shapes without losing its transparent property and it can be used as architectural concrete on roofs of special buildings. Moreover, this light transmitting concrete can be utilized in the production of special types of home furniture.

Shwan et al,(2020) studied about State-of-the-art developments in light transmitting concrete. He investigated the important parameters, influencing the LiTraCon mix design, which are demonstrated and presented through latest research. Also, the impact of optical fiber content and diameter on the mechanical properties, durability and light transmittance ability of LiTraCon were discussed. In order to support the needs for sustainable construction and green building, the research effort in this area is ongoing. As a result, the strength, cohesion, and fracture propagation at the fiber/matrix interface are improved when highly small-grained binders are used as a substitute for cement in LiTraCon. As the POF content increased, LiTraCon's mechanical qualities degraded. Additionally, the mechanical attributes of LiTraCon are better affected by regular alignment of POF than by random alignment of POF. Additionally, the relationship between the direction of load and POF orientation inside samples and the degree of compressive strength drop in LiTraCon are important. By adding more optical fibre, LiTraCon is able to transfer light more effectively. The performance of LiTraCon's ability to transmit light, however, hasn't been significantly impacted by the alignment condition of the POF. Additionally, due to the challenges of gently filling the spaces between the fibres, LiTraCon's transmittance ability has decreased with fibre loading higher than 5-6%. LiTraCon's capacity to generate optical power is enhanced by larger optical fibre diameter. Additionally, the optimal diameter for producing LiTraCon with improved mechanical properties is 2 mm for POF. Shing et al. (2020) gave a general overview of the advancement of Light-Transmitting Concrete (LTC) and discovered that adding optical fibres to the concrete improved its transparency. They also discovered that using LTC in buildings allows light transmission, which lowers light energy consumption and carbon footprint and creates a more sustainable living environment. The outcome demonstrated that LTC can lower lighting expenditures and carbon footprint production, which supports the development of green buildings, particularly in metropolitan areas. A few nations have LTC installed in their structures, which encourages a beautiful outlook and subsequently fuels the expansion of tourism. Since LTC is a recent addition to the construction industry, there isn't much scientific research on it. The majority of LTC research has been done on its application in buildings and architecture, as opposed to infrastructure.Transparent concrete's strength qualities were assessed by Dileep et al. in 2019. In this examination, an effort has been made to examine mechanical characteristics, such as compressive strength, concrete cubes, and wall panels with optical fibres, and to compare the outcomes with normal concrete. By contrasting optical fibre application efficiency with that of standard M20 grade concrete, researchers were able to demonstrate that optical fibre application efficiency is superior in all respects. The experimental examination on the compressive force of mortar utilising sandstone dust as a partial replacement with river sand was presented by Kaushik et al. (2018). The ratios of 1:3 and 1:6 (cement:sand) that are commonly used in various construction operations for cement mortar. All mixtures had the same water-to-cement and sand-to-cement ratios. Before casting the cubes, the basic material was tested. Sand Stone Dust (SSD) of 0% to 50% by weight of sand was used in its place. A mortar's compressive strength was tested after 3, 7, and 28 days. The outcome demonstrated that SSD can be replaced with Sand up to 50% of the time and still produce reliable compressive strength results.

III. Material Study

- *Optical Fiber*

A flexible, transparent fibre known as an optical fibre is created by pulling glasses (silica) or polymer to a diameter just a hair's width thicker. Most frequently, optical fibres are employed to transmit light between the fiber's two ends.Depending on the necessity, the optical fiber's thickness should range from 2 microns to 5 mm. By volume, optical fibre is added to concrete mixtures at a rate of 4% or 5% to generate concrete. Glass fibre and plastic fibre (poly methyl methacrylate fibre) are the most prevalent optical fibres used in the production of LTC.

Alccofine

Alccofine-1203 is a highly reactive material comes from GGBS, Alccofine-1203 is a fine flour. In past few decades, the use of these powder has been drastically increasing in the improvement of concrete industry because of its ultra-tight packing density of fine powder and its chemical properties as mentioned in EADX analysis.

- *Objective of Study*

- To study the mechanical and optical properties of translucent concrete by the inclusion of 0.75mm diameter plastic optical fiber with three different densities in a cement mortar cube.
- To make concrete partly transparent by using optical fibers in it to impart good appearance to structure.
- To study energy saving for illumination by using transparent panel for building.

IV. Experimental Work

Prior to the testing of samples, it was necessary to go through the experimental procedure started with the preparation of mould, designing of mortar mix, casting, curing and finally preparation of specimens for testing. In the process of producing light transmitting concrete, the first step involved is preparation of mould. The mould prototype can be made with different materials such as, cast iron or play wood. In the mould preparation, it is very important to fix the basic dimensions of mould. In order to safeguard the alignment and arrangement of optical fiber, specific moulds were designed is shown in Fig.1. The ratios of 1:3 (cement:sand) that are commonly used in this study. The optical fiber was weaved through the holes which were drilled perpendicularly on the two opposite faces of the mould. In the present study plastic optical fiber of 0.75mm diameter with three different densities (5x5, 6x6, 7x7) is used as a light transmitting element is indicated in Table.I.One mould of (5x5) density consists of total 25 holes. Two numbers of POF are made to run in the holes. Similarly, one mould of (6x6) density consists of total 36 holes and one mould of (7x7) density consists of total 49 holes shown in Table 1.

TABLE I. No.of POF with varying Densities

Section size	No of Needle
5x5	25
6x6	36
7x7	49

For manufacturing light transmitting concrete, the standard size of the cement mortar cube according to IS (2250 – 1981), is 70.6 mm x 70.6 mm x 70.6 mm.The selected proportion is 1:3 (1 part of cement to 3 parts of M-sand).Alccofine is replaced from 0 % to 100% by its weight of cement. Optimization of Alccofine results(40% by its weight of cement) is introduced into High-Srength LTC.

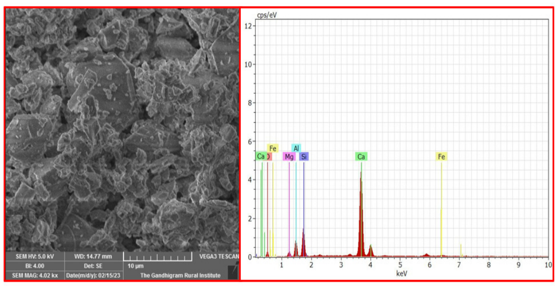

Figure : SEM and EDX analysis of Alccofine.

The optical fiber was weaved through the holes which were drilled perpendicularly on the two opposite faces of the mould is shown in Fig 2. Mould oil was applied from inner surface of mould and cement, M-sand mortar was poured carefully to produce light transmitting mortar cubespecimens.

Fig. 1. Arrangement of holes for (5x5), (6x6), (7x7) densities

Fig. 2. Weaving of optical fibers

For each fiber densities, three cubes were casted. The well mixed mortar is poured into the fiber placed mould in 3 equal layers with the help of spatula and travers. Each layer is compacted with the help of vibrator machine. After pouring of mortar, the top surface should be leveled. De-moulding was done after 24 hours of casting. Totally 18 cubes have been casted with three different densities of plastic optical fibers for taking 7 and 28 days compressive strength as shown in Fig.3.

Fig. 3. Curing of Specimen

After 28 days of curing the specimen is taken out and leave it for complete dry. Before subjecting for tests, the extra portion of optical fibers projecting out of the cubes and cylinders has been cut by using knife or blades and polished for better transmission of light through the optical fibers.

V. TESTING OF SPECIMEN & ITS RESULTS

The method used to investigate the amount of light passing through light transmitting concrete consists of a lightbox was designed and the light source (an incandescent lamp with a filament of tungsten wire inside the bulb and a power of 35W was placed on one side, light transmitting concrete in the middle (in sample window) and Andriod mobile having Light lux meter application on the other side of it. Further to avoid unnecessary entry of light a hollow box was used as shown in Fig.4. On one side of which mortar cube with optical fibers was placed and on other side Andriod mobile having Light lux meter application was placed. Lux meter measures the brightness of light. This application consists of photocell sensor which capture and measures the light. The lux meter was located in the fixed position in the lightbox and the brightness through the sample window without and with LTC sample was measured is mentioned in Fig.5. This would determine how much light had transmitted through the light transmitting concrete. Fig 19 shows the mortar cubes of three different densities of optical fibers (5x5, 6x6, 7x7)) were tested by this method to determine that how much light passed through each sample. A compressive strength test was carried out to investigate the effect of using various densities of optical fibers in light transmitting mortar cubes on the compressive strength of this type. The method of compressive strength testing was determined according to (IS 4031 – Part 6 1988) "Determination of compressive strength of hydraulic cement". According to these standards, light transmitting cement mortar cubes (70.6 x 70.6 x 70.6 mm) dimensions were made to test the compressive strength. The test procedure includes first, the mortar cubes are removed from curing tank and the surface water is wiped off and grit with a damp cloth. Size of the test specimen was determined by averaging perpendicular dimensions at least at two places. The specimen was placed centrally on the compression testing machine and load has been applied continuously and uniformly on the surface perpendicular to the direction of tamping. The load is increased until the specimen fails and the maximum load carried by each specimen during the test was recorded.

Fig. 4. Testing of Specimen

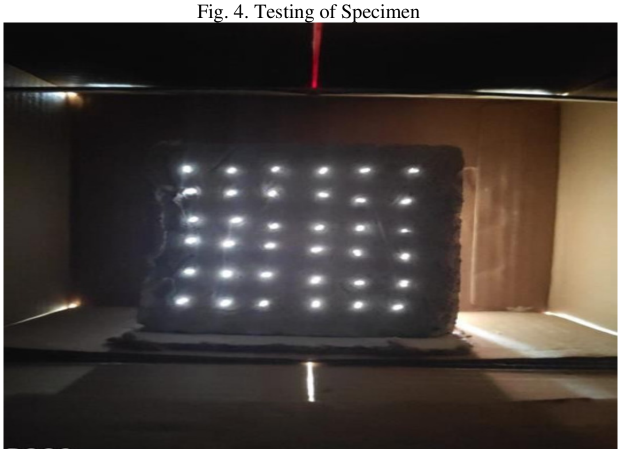

Fig. 5. Sunlight passing through the mortar cubes during daytime.

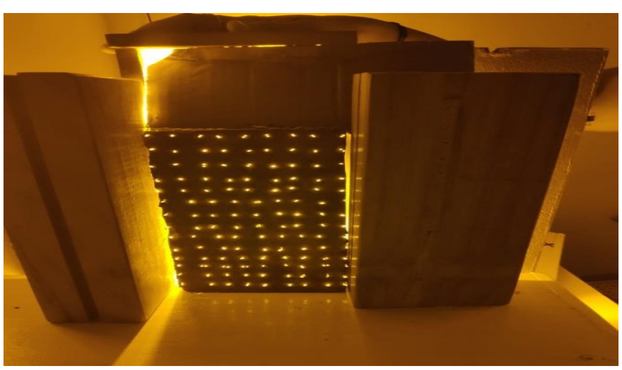

Fig.6.Light transmittance of Translucent panel (20cmx10cmx5cm)

TABLE II. COMPRESSIVE STRENGTH OF VARYING FIBRE DENSITY(MPA)

% of Alccofine (by its weight of cement)	Fibre Density		
	5x5	**6x6**	**7x7**
ATC0%	24.89	23.65	21.33
ATC 10%	30.31	29.36	25.34
ATC 20%	40.89	39.77	29.44
ATC 30%	**59.93**	**52.37**	**35.78**
ATC 40%	55.32	45.88	40.92
ATC 50%	54.32	42.88	42.67
ATC 60%	49.78	39.67	39.32
ATC 70%	45.32	35.88	35.89
ATC 80%	42.21	32.21	32.44
ATC 90%	39.88	32.11	27.77
ATC 100%	34.23	29.88	23.66

The cubes shall be tested on their sides without any packing between the cube and the steel plattens of the testing machine. One of the pattens shall be carried on a base and shall be self-adjusting, and the load shall be steadily and uniformly applied, starting from zero at a rate of 35 N/mm^2/min. In this experiment, namely 18 cement mortar cubes having three different densities (5x5), (6x6) and (7x7) of plastic optical fibers has been tested after curing period of 7 and 28 days. From the Fig 4 compression resistance test, the effect of adding Plastic Optical Fiber on Concrete Compressive Strength at 7 and 28 days was studied as shown in Table II. The plotted results showed that the maximum strength of 59.93 N/mm^2 possessed by 5×5 density specimen which was about 11.74% more than the 7 x 7 density specimen at 28 days of age. From the above results it seems that with the increase in fiber density, the compressive strength also increases. This increasing trend of compressive strength with increasing fiber density was not shown by 7×7 fiber specimen has compressive strength value of 19.17N/mm^2. In fact, there was a reduction of 2.55 N/mm^2 compressive strength for 7x7 fiber density specimen when compared with 6x6 fiber specimen.Decrease in strength after a certain rise in fiber content might be due to the reason that with the increase in fiber content more and more voids get introduced thus breaking the continuity of matrix and making the concrete less- denser. Fig 5 indicated that that presence of plastic optical fiber in a concrete material has a significant impact on compressive strength and gives a favourable result for improving the compressive strength of concrete as long as the percentage of fiber does not exceed the optimum limits.

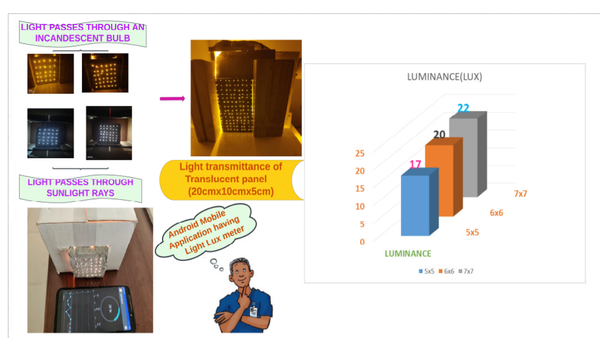

Fig.7.Light transmittance capacity of Translucent panel

V. Conclusion

The amount of light that is transmitted through the light-transmitting concrete has been measured using a source of light as the source of illumination. From Fig. 6, it can be inferred that as optical fibre density rises, so does the amount of light that can pass through light-transmitting concrete. Fig 7 indicated that the Maximum illumination was observed in a cube with an optical fibre density of 7x7, which was 22 lux at the box face, next in a cube with an optical fibre density of 6x6, which was 20 lux, and eventually in a cube with an optical fibre density of 5x5, where 17 lux were detected with a 30% substitution of cement by alccofine. From a 5x5 to a 7x7 fibre density concrete cube, the light intensity of transmission rose by roughly 22.7%. The findings demonstrate that light transmission through concrete is related to the density of optical fibres within the concrete cube, with an increase in light transmission intensity occurring with increasing optical fibre density.

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