

Experimental Analysis of Light Transmitting Concrete

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Article Info

Volume 82

Page Number: 16674 - 16682

Publication Issue:

January - February 2020

Abstract

The sense of breaching the opaqueness of objects is quite astonishing. That is why the names like light transmitting concrete, translucent or transparent concrete seems captivating. The approach was to maximise the use of natural light in building structures, also the concrete is a technically sound material but can be considered dull in terms of architectural considerations cause of which various artistic methods like wall paints & wallpapers were adopted. However, the light transmitting concrete helped achieving an aesthetic approach of designer and decorators towards the concrete previously considered as ordinary. In this era with technical advancements, the path towards achieving translucent concrete has progressed as well. In this article the purpose and mechanism of optical fibres running within the concrete blocks in order to transmit light have been discussed. However, studying the effect of optical fibre threads on the concrete strength was the sole aim. In order to achieve this, three blocks of concrete with standard dimensions were casted. Optical fibre strands were placed in two of them whereas one was kept as a standard concrete block. the study of strength of materials deals with controlling and varying different parameters with simultaneous observations, in here the percentage used for optical fibre strands was varied to study the effect of percentage of the optical fibre used over the strength of concrete block, strands were placed at a spacing of 1cm in one block and 1.5cm in the other to achieve the same. Further compressive strength analysis was carried for the prepared specimens in order to achieve a basic comparison between them. Various advantages and disadvantages were also studied to get a clear structural, economical and environmental compatibility of this innovation.

Article History

Article Received: 18 May 2019

Revised: 14 July 2019

Accepted: 22 December 2019

Publication: 29 February 2020

Keywords; *Translucent Concrete, plastic optical fibres, green technology, new age concrete, light transmitting concrete*

I. INTRODUCTION

The mixture of fine aggregates & course aggregates with a binding agent was seen solidifying and attaining a certain level of strength, this composite material came to be known as concrete. The origin of concrete is dated back from 6500BC, since then the evolution and modifications in this composite material was initiated and is still ongoing. The major concrete modifications were aimed for improving its strength and structural performance. However, the concrete on one side was able to stand as the 2nd most consumed material worldwide but failed to

support itself on the artistic front. The idea of playing with the luminance of concrete was an attempt of modifying its previous image and transferring that from being dull and unappealing to lively and exciting. Initially the approach started by linking up the coarse flat glass/waste glass in the concrete matrix, running from one face to another. This somehow helped the concrete to possess the light transmitting character of glass as well. Simonetta L. Pagliolico [1] studied the effect of inclusion of coarse glass waste in cement matrix to obtain translucent concrete panels for architectural purposes. The light transmittance of the concrete

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panels with glass inclusions was simultaneously studied with the reduction of energy demand in a particular sample room using the same concept. It was observed that with the use of this technique a good amount of energy reduction could be achieved cause of natural illumination. The concept of linking opaque and transparent material didn't pause here. Various other methods found their way in between until Aron Losonzi came up with the idea of adding optical fibers with in concrete. Initially the concrete with such properties was first casted in 2003. Afterwards number of researches took place in order to accurately understand the behavior of optical fibers with concrete mix, its effects over the strength and bonding of fibers with concrete mix. Salmabanu Luhar [7] studied cubes with standard dimension of 7cm x 7cm x 7cm by adding optical fibers 1mm in diameter and at 8mm spacing. They were tested against compression in order to achieve a comparative strength analysis with conventional concrete block. They concluded by underlining the importance of light transmitting concrete in energy reductions and cutting down of electrical usage and bills. Bhavin K. Kashiyan [9] shed light upon the importance of energy savings by the means of natural lighting for households using the concept of light transmitting concrete. Even The usefulness of such a great innovation within the sectors with inadequate electrical sources was emphasized by the authors. They concluded with their study that the light transmitting concrete possess equal strength with additional artistic abilities and energy efficiency than the conventional concrete. Yue Li [2] prepared Light transmitting cement-based material using polymethyl methacrylate (PMMA) fiber. They worked on the compressive and the flexural strength of the prepared specimen after 28days. The number of optical fiber strands was varied in order to fathom the influence of fibers over the compressive properties of the concrete block. They observed a decrease in flexural strength with the increase in fraction volume of fibers The optical power of the specimen was analysed under various factors like light source distance, diameter of optical

fibers, fraction volume of fibers and diversified light sources.

1.1 Advantages & Disadvantages

The most and the major highlighting advantage of light transmitting concrete is its ability to allow the natural light to pass through it. This helps in branching out other advantages like reduction in energy consumption, cutting off the electricity bills, architectural appearance, interior beautification and illumination of underground and under paths. The usage of light transmitting concrete in regular domestic wall constructions could manage the use of artificial lighting sources during daylight. It provides spacious feeling in the rooms and gives an artistic touch to your image.

If the usage of artificial sources is well managed during the daytime, then it'll simultaneously consume less meter readings/consumed units resulting in lower electricity bills and the lesser the usage of energy goes the more it makes a tech environmental friendly. This innovation can be applied in subways and under paths where the natural light source gets restricted cause of the opaqueness of the material. However, can be easily counteracted by the usage of light transmitting concrete which will allow the natural lights to fall in.

Beside these advantages the light transmitting concrete do come with certain downfalls as well. As the procedure of manufacturing this product is very complex and requires precision which calls for the skilled labor in turn increasing the labor cost. The optical fiber is itself a costly material and with the addition of labor cost the overall manufacturing becomes costlier.

II. MATERIAL PROPERTIES

CEMENT: A standard Portland cement of 43 grades or 53 grades can be used for the casting purposes. There is no need for adding plasticizer. The type of cement used may vary with the requirement of the

manufacturer. Standard properties of the cement can be found from the table.1

FINE AGGREGATES:A standard sample of sand passing IS 2.36mm sieve was used as the fine aggregate materialA 1:4 cement sand ratio was used uniformly for casting all the specimens.

PLASTIC OPTICAL FIBRE The refraction of rays through mediums of varied densities is the basic principle of optical fibers. The optical fiber is the conglomeration of 2 different materials, a core made with polymethyl methacrylate (PMMA) and a fluorinated polymer as the cladding. The diameter of the POF was kept about 1mm. the properties of used POF are listed in table.2

Table 1 General properties of concrete

| Compressive strength, f_{ck} (N/mm ²) | Density (Kg/m ³) | Flexural strength (N/mm ²) | Modulus of elasticity (N/mm ²) | Poisson's ratio |
|--|---------------------------------|---|---|-----------------|
| 20-40 | 2240-2400 | 3-5 | $5000\sqrt{f_{ck}}$ | 0.15-0.2 |

Table 2 General properties of POF

| Fiber diameter (mm) | Attenuation (db/km) | Jacket material | Core material |
|------------------------|------------------------|-----------------|---------------|
| 1.0 | <200 | Black PE | PMMA |

III. METHODOLOGY

The preparation of the specimens was done in a very similar manner with that of conventional cubes. Firstly, the cement and sand mortar was prepared using desired mix ratio, simultaneously on the other hand the plastic optical fibres were cut into pieces with respect to the cube dimensions i.e. 70mm. The 70mm strands of optical fibres of diameter 1 mm were then pinned slightly over flattened clay. The strands were kept at different spaces for two different specimens, one at 1mm apart and other at 1.5mm apart. They were then foam worked and concreted in 3 layers. Similarly, the conventional cube was also prepared using the same mix; foam worked without the strand placements and was concreted in 3 layers. The prepared specimens were then allowed to dry for about 24 hours and were tested after curing for 7days, 14days and 28days

respectively. One block each of 1mm spacing and 1.5mm spacing of light transmitting concrete was kept for light transmission test. They were carefully removed from the foam work and the optical fibre projecting outwards were cut and finished respectively. This whole process is quite complex to fulfil and thus require a great sense of accuracy and perfection.



Fig. 3 Wire

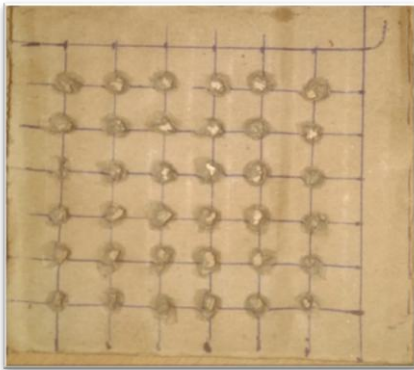


Fig. 4 Wire meshing



Fig.6 casting of cubes



Fig. 5 Placement of wire



Fig.7 Cube after casting

The above shown figures help understanding the pictorial step incrimination of the casting process of light transmitting concrete. The figure 3 depicts the cutting of plastic optical fibres into smaller sizes of about the cube dimensions (here 70mm). The figure 4 shows the grid plotting of optical fibre strands within the cube and The Figure 5 involves the clasping of optical fibre strand on flattened clay. The figures from 6 to 8 showcases the form work collectively with vertically clasped fibre strands, the removed light transmitting concrete block after 24 hours and a properly finished block with detailed fibre distribution respectively. The prepared specimens were tested under compression and a simultaneous comparison between Light transmitting concrete and convention concrete was done. Moreover, the behaviour of concrete with the increased space distribution between the optical fiber strands was also studied.



Fig.8 Final sample for testing

IV.RESULT AND DISCUSSION

The prepared specimens were tested against compression within 7 days, 14days and 28 days of curing. The obtained results are discussed in the table 3. The table clearly shows that the conventional concrete cube possesses slightly higher strength capacity than the light transmitting concrete blocks. The difference between their strength capacities could be seen decreasing with the

increased spacing of optical fiber strands within the concrete block. The tests resulted in developing a direct relation between percentage of optical fiber used and the strength of concrete cube as shown in figure 11. However, the decrease was not alarming but minute and can be ignored. The failure of samples during testing can be seen in the fig. 9 and 10.



Fig. 9 Testing of sample



Fig. 10 Failure of sample

Further, light transmission capacity of both the cubes with 1mm and 1.5mm strand spacing was carried out respectively. The test was done using a light dependent resistor which has an ability to convert the light from the source into electric current. A 100W incandescent bulb was used as a source of light with an applied 100 ohms resistance between the circuits. The obtained results can be seen in the table. Here A defines the situation when no restriction between the light source and the resistor(LDR) was kept and B defines when the light from the source travelled through the prepared blocks of translucent concrete. Simple and obvious result can be drawn from this test. The light transmittance from the blocks with lesser no. of optical fiber strands i.e. with 1.5mm strand spacing was relatively lower than the blocks with greater no. of strands i.e. with 1mm strand spacing. This simply assisted us towards an obvious conclusion that light transmittance of the concrete block could be easily elevated with increased use of optical fibers in it. However, the compressive strength results restrict the use of optical fiber as it can cause a reduction in the load carrying capacities of the concrete blocks. This directs the manufacturer in a direction of achieving an optimum value for the optical fibers within the concrete such that it possesses good amount of artistic image with satisfying load carrying capacities.

Table 3 Compressive strength of cubes

| Compressive Strength(N/mm ²) | | | |
|--|--------|---------|---------|
| | 7 days | 14 days | 28 days |
| Normal Cement concrete cube | 17 | 35 | 45 |
| Translucent concrete (1cm spacing) | 14 | 30 | 40.3 |

| | | | |
|--|-------|----|----|
| Translucent concrete (1.5 cm spacing) | 15.60 | 32 | 43 |
|--|-------|----|----|

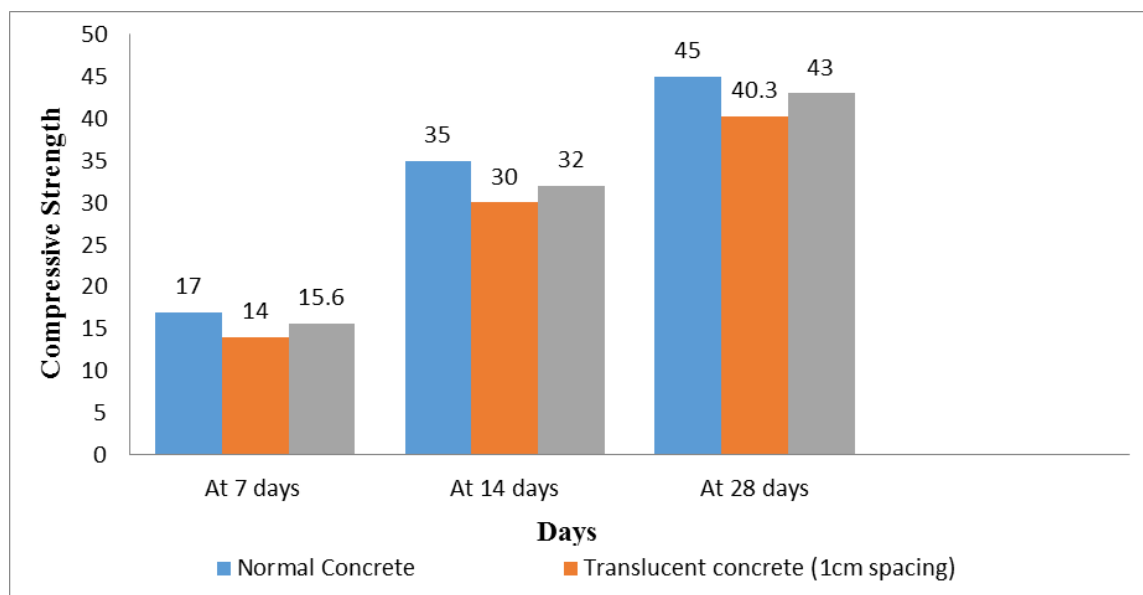


Fig.11 Compressive strength of conventional and translucent concrete

Table.4 Light transmission properties of translucent concrete

| Sample | Optical fiber specimen | | |
|-------------------------|------------------------|-------------|---------------|
| | Spacing | 1cm spacing | 1.5cm spacing |
| Ammeter readings | Without sample (A1) | 15.2 | 15.2 |
| | With sample (A2) | 1.28 | 1.18 |
| Light Transmittance (%) | | 8.42 | 7.76 |

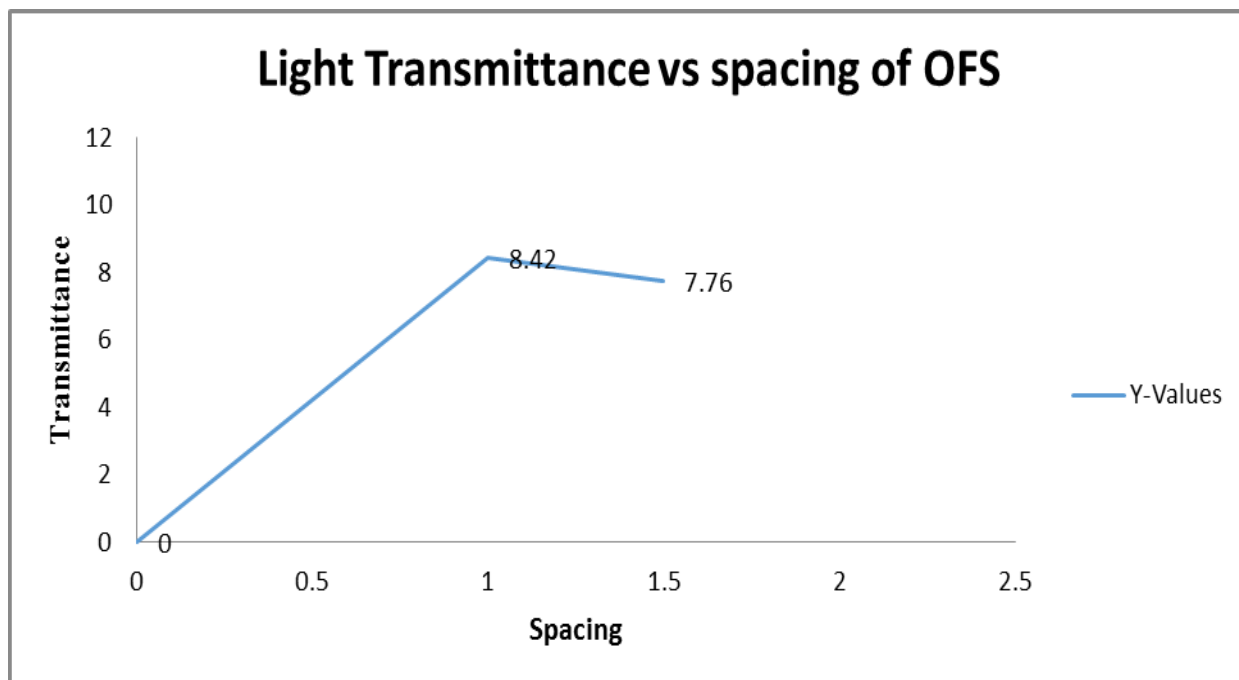


Fig. 12 Light transmittance versus spacing of plastic optical fiber strands(OFS)

The figure 13 and 14 further shows the finished light transmitting concrete samples. The samples are lightened with the help of a light source at background. The appearance of the light transmitting concrete immediately came out to be mesmerizing as soon as the light hit the optical fibers.

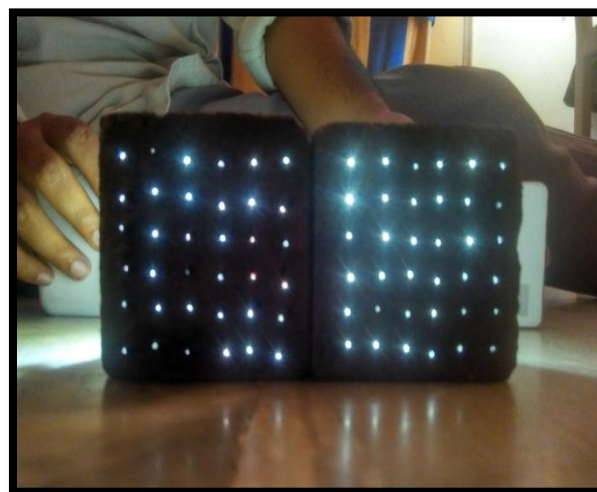
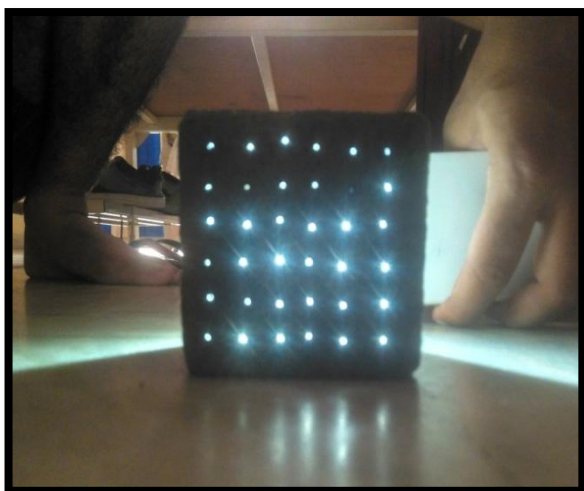


Fig.13 and 14 Finished light transmitting concrete samples



V. SUMARRY

Light transmitting concrete was prepared using 1mm thick plastic optical fiber strands, running parallel throughout the block. The fiber strands were kept at 2 different spaces of about 1mm and 1.5mm in order to vary the percentage of optical fiber and observe its effects on the strength of concrete block. The obtained results showcased a decrease in strength of light transmitting concrete with greater percentage

of optical fiber strands. It was seen that the compressive strength of light transmitting concrete came out to be lower than the conventional concrete and the increased use of optical fiber strands somehow affected the strength negatively. Further a light transmission test was conducted and it was observed that the transmission decreased with the decrease in the volume fraction of optical fibers. The observed decrease in the strength on the light transmitting concrete was minimal and won't affect the practical applications of this technology. However, the manufactures must can use an optimal volume fraction of optical fiber strands to maintain the strength and light transmission of translucent concrete. The concept of transmitting light through opaque concrete walls itself makes this innovation stupefying. The light transmitting concrete totally moved the image of conventional concrete from being dismal to an artistic and inventive composite material. Not only the use of optical fibers improved the performance of the ordinary concrete walls on architectural front but also it maximized the use of natural lighting in residential structures. This helped in reducing the artificial lighting and in turn improved the electrical consumption in the households. The modification of ordinary concrete using plastic optical fibers made it more artistic, energy efficient and environmental friendly at the same time.

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