Experimental Studies on POF and Epoxy-Resin Based Translucent Concrete

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Abstract: **- Translucent concrete is an integral part of transparent architecture and is an active research area in these days. The light transmitting media used are plastic or glass optical fibres, or epoxy resin. This media must run through the thickness of the wall so that as light strikes outer face of wall, inner face gets illuminated. This paper shows the construction of light transmitting concrete using plastic optical fibre (POF) and epoxy resin, and compares the parameters of light transmitting concrete with that of conventional concrete. Average 28 day compressive strength of conventional concrete block is found to be 24.22 kN/mm^2. When using 1 to 4% of plastic optical fibre, the compressive strengths are found to be varying from 25.26 kN/mm^2 to 22.82kN/mm^2 with light transmitting ability varying from 40 lux to 122 lux. In case of epoxy resin block, translucency test was conducted both under laboratory and on field. For 0.5% and 1.8% epoxy used, light transmissivity under laboratory condition are found to be 320 lux and 880 lux respectively. On the other hand, light transmissivity in the field, under sun, for 0.5% and 1.8% epoxy used, are found to be 880 lux and 1396 lux respectively. The paper shows that the light transparent ability of these blocks can be utilized in the green building concept, where aim is to reduce negative environmental impact. Also, the substantial increase in the illuminance of translucent concrete, when using epoxy resin, is a promising result towards its use in interior design with demand for good visual acuity**.

Keywords: **Translucent concrete; POF; epoxy resin; light transmissivity; compressive strength**

I. INTRODUCTION

Concrete is an indispensable part of construction works where it is used for a variety of purposes such as filling of cracks, joining, shotcreting, nuclear proofing, heat-resistance etc. Since conventional concrete lacks aesthetic beauty due to its dull, grey color appearance, material coating such as paint, primer and Plaster of Paris (POP) is commonly followed. However, these materials contain volatile organic compounds (VOC's), which affect the health of inhabitants in long terms. Translucent concrete which is also energy efficient offers a pragmatic solution to this problem. It reduces the dependency of building on grid up to a certain extent by allowing the sunlight to pass through it. This sunlight illuminates the building and can be stored as solar energy. This paper investigate the experimental properties, specifically, the compressive strength and light transmissivity, of POF and epoxy resin based translucent concrete and compares its performance with the conventional concrete.

The paper is organized into the following manner. Next section shows the background of this research that covers the implementation and practical utility of translucent concrete. After that, the experimental procedure for casting the POF and epoxy based translucent concrete blocks is discussed followed by the results and discussion of the experiments. Last section presents conclusion drawn from the experiment and its comparison with conventional concrete.

II. BACKGROUND

Aron Losonzi, a Hungarian Architect first presented the idea of passing light through concrete (Bailey, 2003). The concrete block was made using 96% concrete and only 4% glass optical fibre. The product was named as LitraCon and patented in 2003. Shen and Zhou (2013) worked together to make an entirely new concrete, which can pass light through it as well as sense the stress in the building using smart sensors. It reduces the power consumption of structure by using sunlight instead. It has architectural significance and renders the aesthetic beauty of the structure. One downside of this type of concrete is it requires skilled supervision.

Experiments of translucent concrete having optical fibres are many. Luhar and Khandelwal (2015) use plastic optical fibres (POF) of 1mm in the conventional concrete and reported that the resultant concrete can pass light without significant dissipation of energy. Bhushan et al. (2013) used POF instead of glass optical fibre to make translucent concrete. Apart from that it provides aesthetic beauty to building, it has various advantages which can be attributed to the plastic optical fibre. POF don't produce radiations. It remains unaffected by radio magnetic interference and radio frequency. In comparison to glass optical fibre, it is much stronger and provides more privacy (Kalimnios, 2005). Jiménez-Muñoz and Fernández-Martínez (2014) researched with glass, optical fibre and glass fibre to make translucent concrete. Main aim of their study was to decrease the energy expenditure and increase the life of the building. Momin et al. Used optical fibre cable of 200 micron diameter and showed that Showed that light transparent concrete is possible without any lose in its compressive strength. Varshararaina (2013) studied translucent concrete with optical fibre as an aesthetic material in building architecture. Zhou et al made light transmitting concrete with POF and Fibre Bragg Grating (FBG) and reported that POF could provide a steady light transmitting ratio and the FBG can be used as a sensing element for strain and temperature. Salih et al (2014) showed that translucent concrete made with self-compact mortar and POF have compressive strength of 31.1 to 40.4 MPa and flexural strength of 5.89 to 8.12 MPa.

Nagdive and Bhole (2013) prepared concrete with optical fibre content and studied the light transmitting ability using sunlight as a light source. Shanmugavadivu et al. used 0.2% optical fibre by weight of cement to prepare concrete and reported the 28 day compressive strength of the product as $24N/mm^2$ and flexural strength as $4N/mm^2$. He et al. (2011) showed that the amount of POF has seriously influenced the compressive strength of the corresponding concrete. Tiwari and Saharan (2016) reported that compressive strength of translucent concrete having optical fibre content can be increased by adding steel fibres and rice husks. Kavya et al.(2016), when performed ANSYS analysis for deflection in concrete structures, observed less deflection in concrete having optical fibre content when compared to the conventional concrete .Nikhil et al.(2016) Reported an increased flexural strength for concrete with glass optical fibres when compared to conventional concrete.

In the present study, apart from plastic optical fibre, epoxy resin is also used. Epoxy resin, which is mainly used for filling structural cracks, can also be used as a medium to transmit light. The comparison between strength and illuminance of epoxy concrete block with that of plastic optical fibre concrete block is made. Result of both types i.e. Plastic optical fibre concrete block and epoxy resin concrete block with conventional concrete.

III. EXPERIMENTAL PROCEDURE

A. *Material Specifications*

Depending on type of block to be casted, the following materials are used for the construction of translucent concrete.

1) *Cement:* Ordinary Portland cement of grade 43 conforming to IS: 8112-1989 was used. Cement was tested according to IS: 4031-1988. The cement was of uniform grey colour. The properties of cement used are given in Table I.

TABLE I
PROPERTIES OF CEMENT

Physical Properties	Experimental results
Consistency of cement	28.80%
Specific gravity	3.08
Initial setting time	30min.
Final setting time	600min.

2) *Aggregates:* Fine aggregates passing through 1.18mm sieve and retained on 0.6mm sieve are taken. Coarse aggregate passing through 10mm sieve and retained on 4.75mm sieve are taken.

3) *Plastic Optical Fibre:* Plastic optic fibre (POF) is used for propagation of light. It is made up of acrylic. It works on the principle of total internal reflection and acceptance cone.

4) *Epoxy:* Epoxy of grade E65B with hardener of grade H-4160 was used. Hardener is mixed in epoxy by 10:1 ratio by weight, where 10 parts of epoxy and one part of hardener are mixed.

Preparation of two different test samples, namely, optical fibre and epoxy resin translucent concrete blocks are summarized below.

B. *Optical fibre translucent concrete block*

1) *Preparation of Mould:* In this study, metal GI sheet of size 10x10cm were cut and drilled such that centers of holes coincide. It was done by placing metal sheets one over another and drilling them. Holes were drilled at varying spacing in both rows and columns. Then a wooden boundary frame of 10cm in length is taken and sheets are nailed to wooden frame, for preparing cube of varying percentage of plastic optical fibres.

2) *Preparation of test specimen:* Concrete is mixed in proportion i.e. 1:1.5:3 (cement: sand: aggregates) with water cement ratio 0.5. It is then poured into the mould into layers, each layer is mechanically vibrated using vibrator so as to remove voids, which could have formed cracks and compromised with strength of concrete. Concrete blocks with varying percentage of plastic optical fibres such as 1%, 2%, 3%, 4% are casted.

C. *Epoxy resin translucent concrete block*

1) *Preparation of mould*: A wooden open cubical box of dimension 10x10x10cm was prepared using carpentry. Thickness of box has provision for thermocol fitting.

2) *Preparation of epoxy rods:* Epoxy resin is liquid in state. It is used along hardener to cast into desired shape and size. Hardener to cast into desired shape and size. Hardener used in this study is 10% by weight of epoxy. Straws are used to give cylindrical shape to epoxy. One end of straw was plugged with clay as a sealant. Mixture of epoxy and hardener was then injected into these straws using a syringe. After this, other end of straw is plugged with clay and the whole arrangement of epoxy and straw is kept to dry. After hardening of epoxy the epoxy rods were obtained by stripping the straws using blade (Fig. 1).

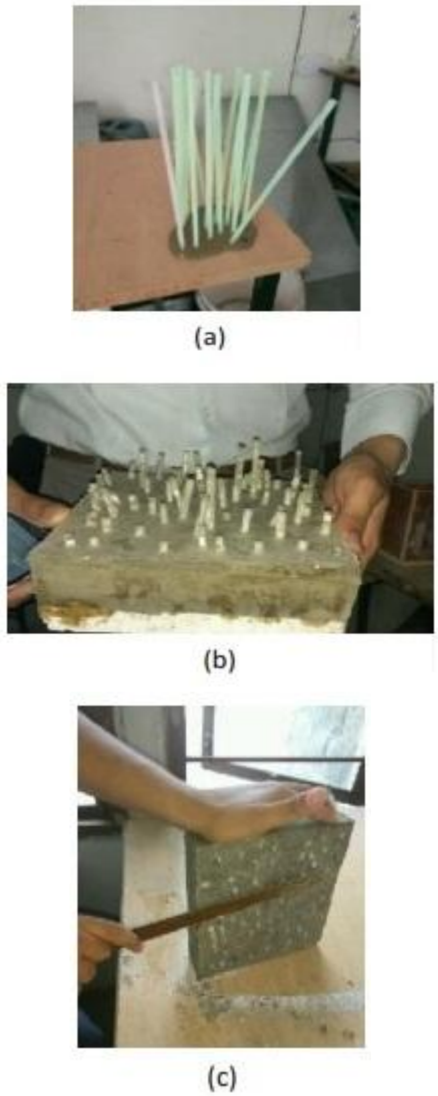

Fig. 1 (a) Epoxy rods to be casted (b) Translucent concrete block with epoxy rods embedded in it (c) Epoxy head being cut

Proportion of optical fibre used	Illuminance (lux)
0%	0
1%	40
2%	75
3%	110
4%	122

3) Preparation of test sample: First of all a layer of thermocol is laid at the bottom of the mould. Inner edges of mould are then lubricated. Epoxy rods are fixed into the thermocol base and concrete is poured into mould in layers. Each layer is mechanically vibrated using vibrator. Varying percentages of epoxy such as 0.5%, 1.8% are used to cast several concrete blocks.

IV. RESULTS AND DISCUSSIONS

A. Compressive strength of translucent concrete

Average 28 day compressive strength of light transmitting concrete of mix 1:1.5:3 (cement: sand: aggregates) with water cement ratio 0.5 for different proportions of POF and epoxy resin is measured using Compression Testing Machine (CTM). A sample concrete block with CTM set up is shown in Fig. 2. The results of test are shown Table II and III.

Fig. 2 CTM Setup

TABLE II

28 DAY COMPRESSIVE STRENGTH OF LIGHT TRANSMITTING CONCRETE WITH OPTICAL FIBRE

Proportion of optical fibre used	Average 28 day compressive strength (kN/mm^2)
0%	24.22
1%	25.26
2%	23.48
3%	23.18
4%	22.82

TABLE III

28 DAY COMPRESSIVE STRENGTH OF LIGHT TRANSMITTING CONCRETE WITH EPOXY RESIN

Proportion of epoxy resin used	Average 28 day compressive strength (kN/mm^2)
0%	24.48
0.5%	24.96
1.8%	23.48

Addition of POF or epoxy resin t causes a slight increase in the compressive strength initially (1% POF or 0.5% epoxy resin) and then the strength gradually decreases. This may be due to the extra binding effect caused due to the additives.

B. Illuminance test of translucent concrete

Translucent Concrete blocks with varying Optical fibre/epoxy resin percentages are tested for illuminance using Lux Meter (Figure 3 and Figure 4).

It is found that translucent concrete have illuminance capacity of 122 lux at its 4% optical fibre content. For concrete with epoxy resin content, the illuminance capacity is found to be 880 lux under laboratory condition (dark room set up, not shown in figure) whereas it increases up to 1396 lux when tested on field under sunlight.

Figure 3: Lux meter testing setup

(a)

(b)

Fig. 4 (a) Lux meter test performed on Epoxy resin block

(b) Lux meter test performed on optical fibre block

The substantial increase in the illuminance of translucent concrete, when using epoxy resin, is a promising result towards its use in interiors with demand for good visual acuity. Table IV and V shows the illuminance result of optical fibre and epoxy resin concrete blocks respectively.

TABLE IV

ILLUMINANCE RESULTS ON OPTICAL FIBRE BLOCK

Proportion of optical fibre used	**Illuminance (lux)**
0%	0
1%	40
2%	75
3%	110
4%	122

TABLE V

ILLUMINANCE RESULTS ON EPOXY RESIN BLOCK

Proportion of Epoxy resin used	**Illuminance (lux) (In Lab)**	**Illuminance (lux) (under sunlight)**
0%	0	0
0.5%	320	880
1.8%	880	1396

V. CONCLUSION

In this study two types of concrete blocks, namely, made of POF and made of epoxy resin, are casted and tested against conventional concrete in terms of strength and translucency. Concrete blocks with varying percentages of fibre and epoxy resins in concrete are tested. Average compressive strength of concrete with 0% POF for 28 days is found to be 24.22 kN/mm^2 and that with 1%, 2%, 3% and 4% are found to be 25.26kN/mm^2, 23.48 kN/mm^2, 23.18 kN/mm^2 & 22.82 kN/mm^2 respectively. Next, average compressive strength of concrete with 0% epoxy resin for 28 days is found to be 24.48 kN/mm^2 and that with 0.5% and 1.8% are found to be 24.96 kN/mm^2 and 23.48 kN/mm^2. Compressive strength for both plastic optical fibre and epoxy resin concrete blocks has been measured by performing CTM and is found on par with that of conventional concrete. Slight addition of POF or epoxy resin caused a slight increase in the compressive strength. However, successive addition of POF or epoxy resin caused gradual decrease in compressive strength. Translucency was measured in form of light intensity by Lux meter. As conventional concrete doesn't pass light, its unit is found to be zero lux. In case of Plastic fibre block, for 1%, 2%, 3% and 4% fibre used, light transmissivity are found to be 40 lux, 75 lux, 110 lux & 122 lux respectively. In case of Epoxy resin block translucency test was conducted both under laboratory and on field. For 0.5% and 1.8% epoxy used light transmissivity under laboratory condition are found to be 320 lux and 880 lux. On the other hand, light transmissivity in the field under sun for 0.5% and 1.8% epoxy used light transmissivity under laboratory condition are found to be 880 lux and 1396 lux respectively. The paper shows that the light transparent ability of these blocks can be utilized in the Green building concept, where aim is to reduce environmental impact. Substantial results obtained from experiments prove that translucent concrete is a viable & efficient material for buildings & environment. Furthermore, Addition of optical fibres and epoxy, which act as a reinforcement, allows translucent concrete block to withstand low tensile forces.

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REFERENCES

[1] He, J., Zhou, Z., Ou, J., Huang, M. (2011). "Study on Smart Transparent Concrete Product and Its Performances", The 6th International Workshop on Advanced smart materials and Smart Structures Technology, ANCRiSST2011, July21-26, 2011, Dalian, China.

[2] Kalymnios, D. (2005). Plastic Optical Fibres (POF) in sensing – current status and prospects. 17th International Conference on Optical Fibre Sensors SPIE, 5855,

[3] Victoria Bailey (2003). Translucent Concrete, MEEN 3344-001.

[4] Jiménez-Muñoz E., Fernández-Martínez F. (2014) Translucent Concrete. Research with Glass, Optical Fibre and Glass Fibre. In: Llinares-Millán C. et al. (eds.) Construction and Building Research. Springer, Dordrecht (https://link.springer.com/chapter/10.1007/978-94-007-7790-3_15).

[5] Bhushan Padma. M.N.V, D.Johnson, Md. Afzal Basheer Pasha, Ms. K. Prasanthi, (2013). Optical fibres in the modelling of Translucent Concrete Blocks. International Journal of Engineering Research and Applications, 3 (3), pp.013-017.

[6] Shen, J, Zhou, Z, (2013). Some progress on smart transparent concrete, Pacific Science review, 15 (1), pp. 51-55.

[7] Momin, A., Kadiranaikar, R., Jagirdar, V., Inamdar, A. (2014). Study of Light Transmittance of Concrete Using Optical Fibers and Glass Rods, International Conference of Advances in Engineering and Technology, Nagapattinam, Chennai, May 2014.

[8] Luhar, S, Khandelwal, U. (2015). Compressive strength of translucent concrete. International Journal of Engineering Sciences and Emerging Technologies, 8(2), pp- 52-54.

[9] Zhou, Zhi, (2009). Research and development of plastic optical fiber based smart transparent concrete, Proceedings of SPIE (The International Society of Optical Engineering), 7293, pp. 72930F-2-72930F-6.

[10] Varsharaina (2013). A Study on Transparent Concrete: A Novel Architectural Material to Explore Construction Sector, International Journal of Engineering and Innovative Technology, 2(8), pp. 83-87.

[11] Salih, S.A, Joni, H., H., Mohamed S., A. (2014). Effect of plastic optical fibre on some properties of translucent concrete. Engg. And Tech Journal, 32A, 12, pp. 2846-2861.

[12] Nagdive, N., R. Bhole, S., D. (2013). To evaluate properties of translucent concrete/mortar and their panels. International Journal of Research in Engineering and Technology, 1(7), pp 23-30.

[13] Tiwari, A., Saharan, P. (2016). Study of behavior of translucent concrete using rice husks and steel fibre. SSRG International Journal of Civil Engineering, 3(7), pp. 130-135.

[14] Kavya S., Karthik, D., Sivaraja, M. (2016). An experimental study on Light emitting concrete. International Journal of Advance Research in Engineering and Technology, 3(2), pp 188-192.

[15] Nikhil, K., Ummer, F., NK. Ahmed S., Juraige, MK., Saleem R., Omar, S. (2016). Experimental analysis of translucent concrete by using optical fibres. SSRG International journal of Civil Engineering, 3(3), pp 76-81.

[16] Shanmugavadivu, P., M., Scinduja, V., Sarathivelan, T., Shudhesamithron, C., V. (2014). An experimental study of light transmitting concrete. International Journal of Research in Engineering and Technology, 3(11), pp. 160-163.

[17] Simmons (mouldings) Ltd. Material Properties. Station Street West Business Park, Coventry, CV6, 5BP, UK. (http://www.epoxyworktops.com/epoxy-resin/mech-properties.html).