Investigation on Strength and Light Transmittance of Translucent concrete with and without Foundry Sand

Nandita Mohan[1], Aravind P V[2]

[1] *Civil engineering department, SCMS School of Engineering & Technology, Ernakulam, Kerala.*
[2]*Automobile Engineering Department, SCMS School of Engineering & Technology, Ernakulam, Kerala*

Abstract - *The Translucent concrete (TC) or light transmitting concrete which has light transmittance property due to the optic fibres embedded in it and the fine aggregate being replaced with Foundry sand, which is cheap and being produced largely around the world. In this article, first the optimum percentage of Foundry Sand was found by varying it by 20%, 30%, 40% and 50%. This was subjected to Compressive Test and found 30% to be an optimum value. Then a combination of Optical Fiber (4% of total volume of cube), Optical fiber with 30% Foundry Sand and Treated Optical Fiber with Foundry Sand was subjected to Compressive Strength and Light transmittance test. Here treated Optical Fiber was to produce 29.6 N/mm2 Compressive Strength and no much change in the Light Transmittance.*

Key Words: Optical fiber 1, Light transmittance 2, Mortar 3, Foundry sand 4, Translucent concrete 5.

1.INTRODUCTION

Translucent concrete (TC) or light transmitting concrete which has light transmissivity property due to the optic fibers embedded in it, make the concrete lively and permit a better interaction between the construction and its environment, thereby creating ambiences that are better and more naturally lit. India has the second largest foundries next to China falling under small scale industries. Here the fibers are treated with silane coupling agent and translucent concrete is casted to study the effect in strength along with addition of foundry sand.

1.1 Literature Review 1

Several authors conducted various tests on TC mixture. Testing on a prefabricated transparent concrete panel (TCP) with embedded optical fibres (OFs) was performed by **K.M.Mosalam et al (2018)** with a sheet fitted with compound parabolic concentrators (CPCs). Properties like density, spacing, thickness of optic fibers were under consideration. It was concluded from the analysis that OFs with small diameters performed better during noon time than did OFs with larger diameters apart from OF density in the row. But the percentage of the optical fiber used was not mention that greatly affect the transmissibility of this. **Muhammad Saleem et al (2017)** investigated the application of a new lane separator based on transparent concrete that is capable of transmitting coloured light by embedding plastic optical fibres into the self-compacting concrete. Here they strength of the concrete is decreased due to the lack of bond between the fiber and the concrete which is to be considered. **Aashish Ahujaa, *et al* (2017)** conducted test on translucent panels for a office room and obtained results such as for a volumetric fiber ratio of 6% used in the TC panel leads to savings in lighting energy by around 50, showing the heating property. The TC panels can cut down energy expenditure by 18% for a fiber volumetric ratio of 5.6% which renders the fabrication process to be practical. The compressive strength parameter is not considered. From **Thiago dos S. Henriques et al (2017)** investigated the mechanical activity of POF (polymeric optical fibre) reinforced LTCM (light-transmitting cement-based material) with three fibre contents (2 percent, 3.5 percent and 5 percent) organised in an orderly manner and compared it with the fibre-free reference sample (0 percent). The findings showed that the mechanical properties of the composites decreased and the fibre / matrix 's low grip can be attributed to the fibres' parallel arrangement and the extremely smooth surface of the POF, and the SEM analysis revealed several gaps in this transition region, rendering it a porous and brittle material. With the fibre content that up to 5 percent POF, the light transmittance increased. This result can also be analyzed in a way of decreased compressive strength due to the porosity of the transition zone. **Abdelmajeed Altlomate *et al* (2016)** investigated the performance of concrete which incorporating different dosages and spacing of plastic optical fiber (POF). By adding the POF the compressive strength was found to increase 1.5 mm diameter spaced 10 mm apart for a percentage of 1.43% of fibers, and the maximum amount of light passing through the cubes was 75.53 LUX which is not technically explained. Aashish Ahuja et al (2015) performed a computational modelling of translucent concrete panels and developed a geometric ray-tracing algorithm to simulate the proposed translucent concrete panel's light transmission properties. It was concluded that of all the tilt angles considered, a tilt angle of 30^0 for the panel transmits the maximum amount of light. The sunlight radiation absorbed by the panel was measured and only a preliminary analysis was carried out to measure the panel's solar heat gain coefficient for potential use in the building industry instead of a glazing material that was to be developed as a practical application. **Manoj kumar *et al* (2016)** conducted a review on physical and chemical properties of foundry sand in concrete. It was noticed that slump of Waste Foundry Sand

(WFS) concrete decreases as the replacement ratio increases. This may be most likely because of the presence of clayey type fine substances in the WFS, which are compelling in diminishing fresh concrete fluidity. The studies concluded that the optimum of 10% of replacement of fine aggregate resulted in maximum compressive strength. **Y.Li *et al* (2015)** did the SEM analysis of translucent concrete showing tiny gaps on the interfaces between optical fibers and cement matrix which affected the strength of concrete. By introducing Coupling agents referring to a class of additives helping to improve the property of the interface between polymer materials and fillers. But this was not considered only to the translucent concrete.

These above mentioned investigations have dealt with the Translucent concrete, its transmittance, compressive strength, light absorption capacity, foundry sand etc. But have not considered a combination of the Foundry sand in translucent concrete which is being done in this paper.

2. MATERIALS AND METHODS 2

2.1 Materials

2.1.1 Pozzolanic Portland cement (OPC)

Cement is a powder converted to solid mass in combination with water by means of its intrinsic setting or hardening properties. It will help to fill the voids and gives density to the concrete.

For the project Portland Pozzolanic cement which has 33% fly ash per bag is used as per the IS 1489 (Part 1):2015 Portland Pozzolana Cement — Specification Part 1 code. Laboratory tests were conducted on PPC as per IS 1489 PART 1 to determine specific gravity and consistency. The results are shown in Table 2.1.

Table -2.1: Properties of Cement

Sl No	Properties	Result
1	Grade	53
2	Specific gravity	2.98
3	Consistency	35%

2.1.2 Fine Aggregate

The effect of fine aggregates on the concrete 's fresh properties is considerably greater than that of coarse aggregate. Aggregate passing through an IS sieve of 4.75 mm and retained on an IS sieve of 150 µm is known as fine. The fine aggregates are divided into four zones on the basis of particle size distribution; the grading zone from grading zone I to grading zone IV is increasingly finer (IS: 383). Manufactured sand (M sand) was used as a fine aggregate for the study. Sieve analysis was performed and the fine aggregate particle distribution and the grading curve were drawn. The sieve analysis details are given in Table 2.2

Table -2.2: Sieve Analysis of Fine Aggregate

SIEVE SIZE (mm)	WEIGHT RETAINED(Kg)	CUMILATIVE % RETAINED	CUMILATIVE % FINER
4.75	0	0	100
2.36	0.128	12.8	87.2
1.18	0.307	43.5	56.5
600 micron	0.148	58.3	41.7
300 micron	0.241	82.4	17.6
150 micron	0.141	96.5	3.5
Pan	0.035	100	0

Fineness modulus is, obtained by adding the cumulative percentage of aggregate retained on each sieve and dividing the sum by 100. The fineness modulus for the fine aggregate ranges between 2.0 and 3.5. Different physical properties of fine aggregate were found out such as specific gravity using Pycnometer, based on IS 383:1970 and is listed in Table 2.3.

Table 2.3 Properties of Fine Aggregate Used

Sl No	Properties	Result
1	Specific gravity	2.77
2	Fineness modulus	2.93
3	Grade Zone	II

2.1.3 Foundry Sand

Foundry sand, favored by the method of sand casting. Sand of uniform scale, clean, high silica sand is used in this method. Sand is recycled and reused many times during the casting process of the foundries but is discarded from the foundries known as waste foundry sand after some time. The application of sand from waste smelting to different engineering sectors will solve the problems of its disposal and negative environmental effects.

Foundry sand is uniformly sized, clean, high-quality silica sand bound to form moulds for metals that are both ferrous (iron and steel) and non-ferrous (copper, aluminum, brass). The type of foundry sand in foundries relies on the casting process. In general, foundry sand is of two kinds: green sand, chemically bounded sand. In this study chemically bounded foundry sand is used. The specific gravity of foundry sand used is 2.74 which was determined by conducting Pycnometer test.

2.1.4 Optical fibers

An optical fibre is a flexible, transparent fibre created to a diameter slightly thicker than that of a human hair by drawing glass (silica) or plastic. Optical fibres are most commonly used as a way of transmitting light between the two fibre ends and for fiber-optic communications, allowing long distance transmission over a greater bandwidth than wire cables. Here there won't be any lose any amount of energy that has been applied to one of its ends. The Fibers are immune to electromagnetic interference, a problem from which metal wires suffer excessively. Generally, strands of 2 μ to 2 mm in diameter are used to build transparent concrete. As, an optical fibre has a central core in which the light is directed, embedded in a slightly lower refractive index outer cladding. Light rays' incident on the core-cladding boundary at angles greater than the critical angle undergo total internal reflection and are guided through the core without refraction. For the project the Plastic Optical Fibers used is PMMA (Poly Methyl Methacrylate) fibers of 2 mm.

2.1.5 Water

Water is the main element that forms a paste that holds the aggregate together when combined with the cement. The mixing and curing of all the specimens was carried out using potable water available in the laboratory.

2.1.6 Silane coupling agent

SilBond-69 is a bifunctional sulfer-containing organosilane hence has a yellow colour. It has a Sulphur content of about 22%± 1%. Its chemical name is Bis[3-(triethoxysilyl)] propyltetrasulfide. The chemical formula is ($C_2H_5O)_3Si(CH_2)_3$-S_4-$(CH_2)_3Si(O_2CH_5)_3$.

2.1.7 Chemical Admixture

High range water reducing admixture, one of the generations of Polycarboxylic ether-based superplasticizer, designed for the production of self-compacting cement is used. Adhere mix 500 is the name of the admixture used which is a liquid admixture added during the mixing of the materials. It has a Ph of 6-8 and specific gravity of 1.1 at 27^{0}C.

2.2 Methods

2.2.1 Trial Mix

Specimens of size 7.05x7.05x7.05cm was casted for M25 grade mortar and was tested for 7-day characteristic strength, 66% f_{ck} = 16.5 N/mm^2

Three specimens were as shown in Fig 3.8 casted for the mix of 1:2.5 at water to cement ratio of 0.4 and cured for 7 days. The characteristic compressive strength obtained by conducting test is shown in Table 2.4. In this mix, admixture of about 0.8% of cement is added. From the result it is concluded that the mix is appropriate to conduct the test.

Table -2.4: 7 Day Compression Test Result of Trial 2 mix

Trail for specimen 7.05x7.05x7.05cm	Load at failure (kN)	Compressive force (N/mm^2)
1	102	20.4
2	104	21
3	120	24

2.3 Testing and Characteristics

The standard concrete specimen is cast and its compressive strength is measured at 7 days and 28 days. Mortar specimens with different percentages of foundry sand ranging from 20% to 50% of fine aggregate content is casted and 7 days and 28 days compressive strength is obtained. From the result optimum percentage of foundry sand is obtained. Using the optimum content of foundry sand, translucent concrete specimen is casted(TCF). To study the effect of coupling agent on TC, silane treated optical fibers are used to cast the translucent concrete specimens with optimum content of foundry sand as fine aggregate(TCFS). For both 7 days and 28 days of compressive strength test, three each of TC, TCF, TCFS are cast for compressive strength test. Under standard laboratory climatic conditions, the TC, TCF, and TCFS specimens are cured for 24 hours and then placed in tap water for 28 days.

2.3.1 Compression Test

Compressive strength Test is the most common test conducted on hardened concrete because it is the most desirable properties of concrete are comparatively related to its compressive strength. The test was done as per IS: 516-1959. Compressive strength of all specimens will be tested using Compression Testing Machine of capacity 2000kN, by casting cubes of standard dimensions of 100mm x 100mm x 100mm. The concrete cubes casted will be cured in water under normal temperature. The compressive strength at 7days and 28 days will be estimated. The maximum load taken by the specimen was noted and compressive strength was found out using the equation,

$$\text{Compressive Strength} = \frac{\text{Maximum Load}}{\text{Total Bearing Area}}$$

Area of bearing surface, A = 100×100 = 10000 mm^2

Determination of Optimum Foundry Sand Content

Total of 30 specimens of size 10x10x10 cm were casted. At first normal concrete specimen (NC) were casted as control specimen for both 7 days and 28 days compressive strength determination with three each using a wooden mould of 10x10x10 cm is made. Normal concrete with 20%, 30%, 40%, 50% foundry sand content was replaced by fine aggregate were also casted to determine the optimum percentage of foundry sand to provide high compressive strength. The normal concrete specimen with 20%, 30%, 40%, 50% foundry sand replaced may be designated as NCF-20%, NCF-30%, NCF-40%, NCF-50% respectively. Three specimens each for both 7 days and 28 days compressive strength determination were casted for each percentage replacement of foundry sand and its compressive strength was determined using universal compression testing machine(UCT).

Casting of translucent concrete specimens

Translucent concrete specimen with 4% of optical fiber content of concrete volume (TC), translucent specimen with 4% optical fiber and 30% foundry sand replaced with fine aggregate (TCF-30%) and translucent concrete specimens with 30% foundry sand replaced with fine aggregate whose optical fibers are silane treated were casted for both 7days and 28 days compressive strength using steel moulds of size 10x10x10 cm is made with holes of 2mm at 10mm spacing at the two opposite sides. The procedure for casting of translucent concrete is as follows:

1. Mould is prepared by tightening and applying grease. The materials for mixing the mortar is taken according to the mix design.

2. The optical fibers were obtained from the shop in rolls. The fibers were cut down to length slightly greater than the mould and were inserted into the holes of the mould. For TCFS specimens the optical fibers are dipped in the silane for 24 hours and after which it is heated in oven for 10 minutes at 110 ^{0}c and inserted into the mould.

3. Mixing of the materials to obtain mortar of the required workability was done and the specimen was casted. shows the casted cubes of translucent concrete (TC) specimens and translucent concrete specimen with foundry sand (TCF-30%).

4.

Unmoulding was done after 24 hours of casting and immersed in water as per the normal mortar specimens, Fig 3.14 shows the specimens after 28 day of curing.

2.3.1 Light Transmitting test

An electrical circuit set up with a light-dependent resistor (LDR) tested the light-transmittance capacity of the specimens. A 40 W lamp was the source of light used; a resistance of 100 Ω was used in the circuit set-up and a uniform DC voltage of 10 V was established between the circuits. The experimental system, including the transparent concrete and the experimental equipment used for microampere measurement, is shown in Figure 2.1. Transmitting range is found out by equation given below in percentage.

$$\text{Light transmittance} = 100 - \frac{(1-A2)}{A1} x100$$

Where A1 is the amount of light transmitted without sample and A2 is the amount of light transmitted with sample.

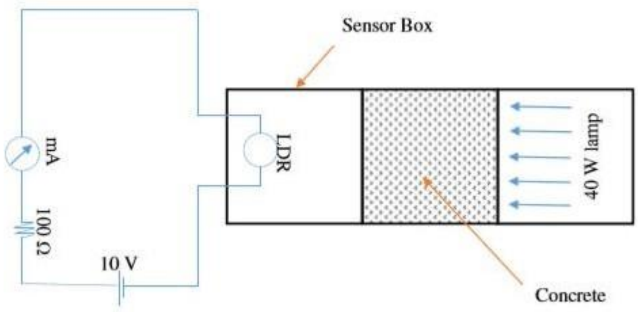


Fig -2.1: Light Transmittance Test Set Up

3. RESULTS AND DISCUSSIONS

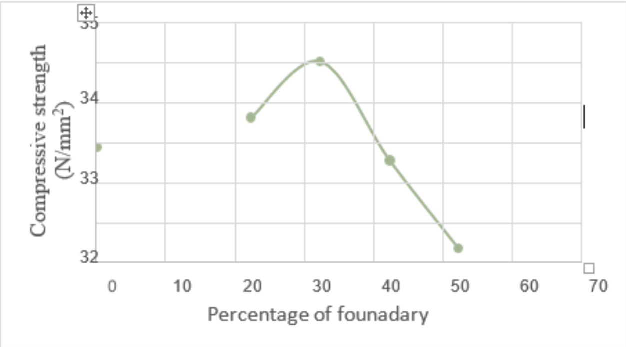
3.1 Compression Test

Optimum foundry content:

Total of 30 cubes were tested. Compressive strength was determined using universal compression testing machine(UCT) as for both 7 and 28 day specimens NCC, NCF-20%, NCF-30%, NCF-40%, NCF-50%. The result obtained are in Table 3.1

Table 3.1 Comparison of compressive strengths

Specimens	**Strength at 7 day (N/mm²)**	**Compressive strength at 28 day (N/mm²)**
NCC	21.92	31.93
NCF-20%	21.4	32.6
NCF-30%	27.8	34
NCF-40%	25.8	31.53
NCF-50%	18	29.33



Graph 3.1 Compressive Strength at 28 Day

The tabulated result is shown as graphical representation in Graph3.1 , showing that the NCF -30% shows higher strength for both 7 day and 28 day compressive strength analysis. Hence 30% foundry sand replacement with fine aggregate is taken for the further study. The size of the foundry sand is found to be very small resulting in a dense mix showing an increase of compressive strength. But there was a drop in strength above 30 percent foundry sand due to some reaction between the foundry sand and the cement.

Test on Translucent Specimens

Cube specimens of size 100 mm × 100 mm × 100 mm was tested for cube compressive strength of concrete at 7 and 28 days in compression testing machine.

Three samples of each mix were tested average compressive strength was found out. Total of 18 cubes were tested. Compressive strength was determined using universal compression testing machine(UCT) as for both 7 and 28 day specimens NCC, TC, TCF-30%. The result obtained is represented in Table 3.2. The result suggests that the presence of the coupling agent and the foundry sand will not affect the strength parameter much. But the coupling agent greatly contribute to the bonding of fibres and the cement aggregate that can been seen in the result as the compressive strength of TC is greater than TCFS.

Table 3.2 Compression Strength at 7 Day and 28 Day

Specimen	**Strength at 7 day (N/mm²)**	**Compressive strength at 28 day (N/mm²)**
NCC	21.92	31.93
TC	15.6	22.6
TCF-30%	18.84	25.7
TCFS	20.2	29.6

3.2 Light Transmittance Test

An electrical circuit set-up with a light-dependent resistor (LDR) tested the light-transmittance capability of the samples. A 40 W lamp was the source of light used; a resistance of 100ohm was used in the circuit set-up and a uniform DC voltage of 10 V was established between the circuits. Light transmittance of specimens at 28 day were conducted. Three cubes of each translucent concrete specimen(TC) and translucent concrete with optimum content of foundry sand (TCF-30) were considered. The result obtain is tabulated in Table 3.3. The result explains that the light-transmittance ability is not dependent on Coupling agent or foundry sand.

Table 3.3 Light Transmittance Test Result

Sl No	Specimen	Current in micro ampere with specimen	Current in micro ampere without specimen	Transmittance range
1	TC	276	2760	9.66
		274		
		260		
2	TCF-30	274	2760	9.6
		268		
		254		
3	TCFS	264	2760	9.68
		272		
		266		

4.CONCLUSION

From the experimental study it can be observed that the optimum % of foundry sand was found to be 30 % due to the fineness of the sand, causing it to produce a highly dense concrete. With this, the investigation with the optical fiber, Foundry sand and coupling agent was done. The strength of TCF-30% is more than TC but lesser than NC and TCFS. From which it can be concluded that replacement of fine aggregate with foundry sand can modify the strength. Translucent specimen made with silane treated optical fiber also helps in bond strength. Hence we can assume that the gap between thee cement matrix and the fiber may have decreased. From the light transmittance test result we can conclude that addition of foundry sand and silane treatment does not affect the light transmittance capacity of optical fibers.

REFERENCES

[1] Ahuja, A. and Mosalam, K.M., 2017. Evaluating energy consumption saving from translucent concrete building envelope. Energy and Buildings, 153, pp.448-460.Aashish Ahuja, Khalid M. Mosalam(2015) "Computational Modelling of Translucent Concrete Panels" , Journal of Architectural Engineering, © ASCE, ISSN 1076-0431 / B 4014008 (8).

[2] Altlomate, A., Alatshan, F., Mashiri, F. and Jadan, M., 2016. Experimental study of light-transmitting concrete. International Journal of Sustainable Building Technology and Urban Development, 7(3-4), pp.133-139.

[3] Mosalam, K.M. and Casquero-Modrego, N., 2018. Sunlight permeability of translucent concrete panels as a building envelope. Journal of Architectural Engineering, 24(3), p.04018015.

[4] Saleem, M., Elshami, M.M. and Najjar, M., 2017. Development, testing, and implementation strategy of a translucent concrete-based smart lane separator for increased traffic safety. Journal of Construction Engineering and Management, 143(5), p.04016129.

[5] Paul, S. and Dutta, A., 2013. Translucent concrete. International Journal of Scientific and Research Publications, 3(10), pp.1-10.

[6] Li, Y., Li, J., Wan, Y. and Xu, Z., 2015. Experimental study of light transmitting cement-based material (LTCM). Construction and building materials, 96, pp.319-325.

[7] Li, Y., Li, J. and Guo, H., 2015. Preparation and study of light transmitting properties of sulfoaluminate cement-based materials. Materials & Design, 83, pp.185-192.

[8] Xie, Y., Hill, C.A., Xiao, Z., Militz, H. and Mai, C., 2010. Silane coupling agents used for natural fiber/polymer composites: A review. Composites Part A: Applied Science and Manufacturing, 41(7), pp.806-819.