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EXPERIMENTAL STUDIES ON MECHANICAL PROPERTIES & LIGHT TRANSMITTANCE-BASED TRANSLUCENT CONCRETE

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ABSTRACT

Performance Translucent Concrete (P.T.C) is an emerging energy-cutting building unit, as it has good quality light transmitting attributes and superior mechanical properties. This research paper investigates the output of translucent concrete engulfed with plastic optical fibres (P.O.F), its mechanical properties & light-transmittance efficiency. The test data presented in this paper cite specimen of 10 concrete mixes. Besides freshly mixed concrete tests, bulk density, 7,28& 56-days of compression strength test, flexural strength test & light-transmittance test & to build up the relationship b/w mechanical strength & light-transmittance tests were scrutinized. Although, the %age of optical fibre increases in the mix concrete, the compressive strength gradually decreases & light-transmittance capacity increases with the rising volume ratio. The P.O.F carryout up to 10.83% light-transmittance of the specimen with a ranging of 3.5% volume ratio & diameter of 3mm as compared to 1.5% volume ratio with a dia. of 3 mm, as well as vulnerable properties of compression strength of 32.15 N/mm^2 with 2mm P.O.F dia. and 2.5 % volume ratio concrete mix.

Keywords: *Performance Translucent Concrete (PTC), Plastic Optical Fibre (P.O.F), Mechanical Properties.*

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INTRODUCTION:

Advancements in the concrete industry have shepherded the innovation of discrete forms of concrete, such as the performance concrete, light emitting concrete etc. Some designate it as usually "hard concrete" it has been designed using codal calculations, mixed it well, thoroughly compacted & cured so as to accomplish the best mechanical properties & better durability. The Translucent concrete is the emerging type of concrete which the light passes through concrete block with the intrusion of plastic optical fibre (P.O.F) & affect the costs as well as aesthetics in construction field, interior decoration part & architectural part. In today's world where whole investigation in pin pointed towards non utilization of natural resources and to cut down its utilization with minimum time. LiTraCon is the lightweight concrete, building material consists of fine-grained concrete mixed with 5-6% by actual weight of concrete mix design, and were casted in to concrete cube so as white-light may pass from outside in wall to inside out of the wall. Although optical fibre concrete is much better than other light-transmitting matter, the P.O.F is much better than glass optical fibre for casting translucent concrete. Moreover, P.O.F is more flexible in nature, ready to install it & resists more stresses. The core of the P.O.F is much cheaper & light-weight. The majority of vertical buildings are constructed very close to each other all in similar patterns as sky-concrete forests. They've become an apparent issue in deriving natural light in buildings due hindrance of nearby buildings. Where buildings are stacks very closely to each other, there is less possibility of passing of white-light through it.

By research & development, emerging concrete has been recreated which has versatile properties like wearing resistance, light-weight and light transmitting. The first transparent concrete was developed by putting large numbers of optical fibres in freshly mixed concrete in 2003, after named as LitraCon. Figure 1 shows the picture of LitraCon transmitting concrete.

MATERIALS REQUIRED

1. **Cement:** A Portland cement as per Indian Codal specification was used as a binder material in all the concrete mixes.
2. **Fine Aggregates:** It is non-reactive clean and dry sand mostly passes through 4.75 mm IS sieve and fineness modulus of about 3.2 was used. It acts as a filler in concrete mix. The tests are being conducted as per IS 650-1996 for Specific gravity and IS 2386-1968 for Fineness Modulus test.
3. **Coarse Aggregates:** Crushed hard rock aggregate readily available in domestic sources has been used. The max. size of coarse aggregate(c/a) was taken 10 mm & has a specific gravity of 2.6. The fineness modulus (F/M) of coarse aggregates 5.60 was utilized. The water absorption of coarse aggregates was taken 0.4%
4. **Optical Fibre:** The manufacturer-tested P.O.F was obtained in the datasheets. The P.O.F was used with various dia's of 0.75 mm, 2 mm & 3 mm. The P.O.F is not a good conductor of heat and electricity & ultraviolent radiations at the point of glitters.
5. **Mix Design Proportion:** In the present research 1:1:2 mix proportion was designed as per IS 10262-2019 for the mix design M25 concrete.

Preparation of Mould:

A wooden prototype has been prepared with size of 100x100x100 mm and size of beam was 150x150x70 mm. In this Mould, perforated acrylic sheets were used for making perforation and to give a smooth surface to the cube moulds & the holes were drilled with the help of a drilling machine on the side plates as per varying percentage of optical fibres.

Casting of concrete:

The design procedure of concrete mixture is more often based on the performance criteria as suggested in Indian Codal guidelines for the design of a particular concrete mix. The optical fibres are inserted in perforated side plates in the mould with varying %age of volume of concrete and concrete mix is poured in the perforated cube mould in 3 different layers and well compacted with the external plate type vibrator with the combination of diameters of optical fibres. There were 10 sample mixes casted with variations of optical fibres. The plywood formwork & perforated partition wooden sheets were utilized in translucent concrete specimen for the preparation. The plywood formwork was also used in preparing the cubes and beams specimen for compression & flexural tests respectively. While translucent concrete, the bulk density of the cube specimen was recorded at 28 days of curing according to Indian codal provisions.

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Curing:

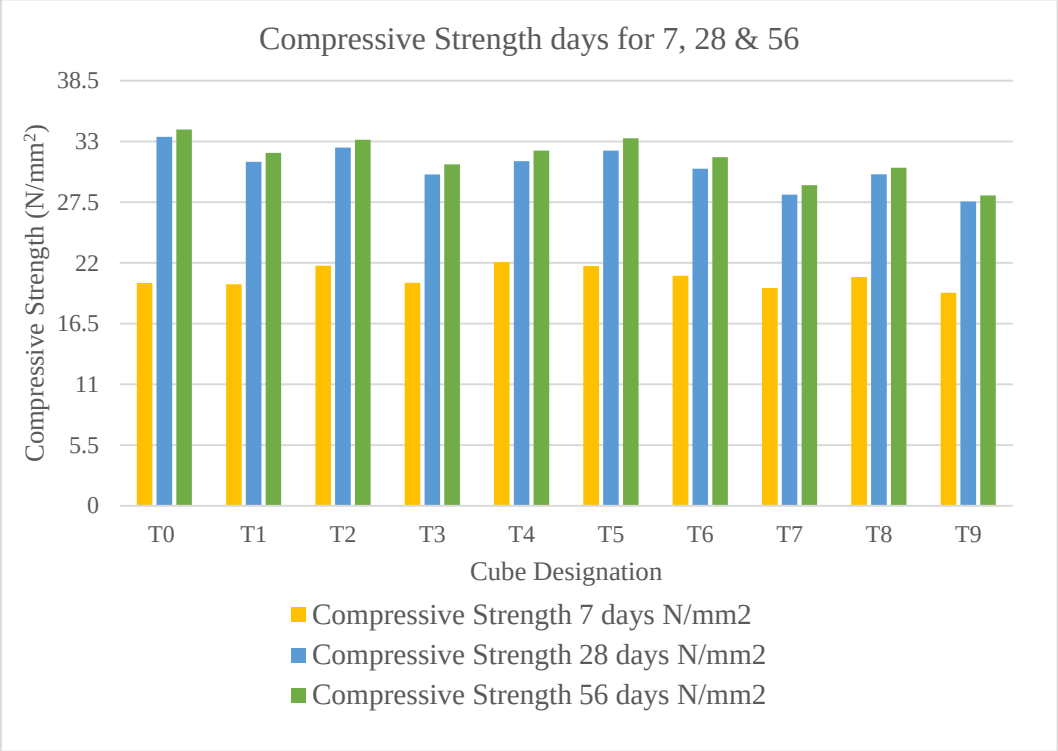
When the concrete is hardened after 10 hrs of casting, the concrete cube is demoulded and are kept in curing tank for 7, 28 & 56 days as per IS codal provisions.

Tests and Discussion of Results:

The translucent concrete was obligatory to acquire the desired properties of concrete produced in hardened state. The test was conducted with the help of compression testing machine (CTM) confirming IS:516-2021 (Part I). The test results of compressive strength of concrete in varied %age of optical fibre are shown in Table 1 and Chart 1 for 7-28 & 56 days of age.

Table 1: Test Data for Compressive Strength concrete cube

Cube Designation	%age P.O.F dia 0.75mm	%age P.O.F dia 2mm	%age P.O.F dia 3 mm	Compressive Strength at 7 days (N/mm²)	Compressive Strength at 28 days (N/mm²)	Compressive Strength at 56 days (N/mm²)
T0	0			20.18	33.42	34.08
T1	1.5			20.06	31.16	31.96
T2	2.5			21.74	32.45	33.15
T3	3.5			20.19	30.01	30.92
T4		1.5		22.07	31.21	32.17
T5		2.5		21.72	32.17	33.29
T6		3.5		20.83	30.53	31.58
T7			1.5	19.73	28.18	29.04
T8			2.5	20.72	30.02	30.62
T9			3.5	19.29	27.56	28.11

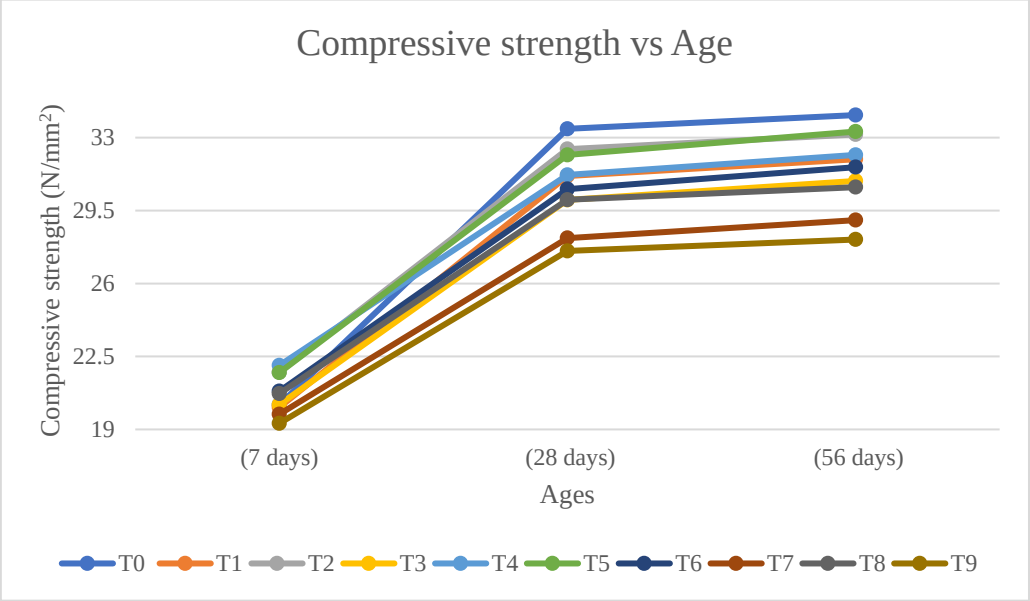


Graph 1: Compressive Strength Comparison of Translucent Concrete w.r.t Conventional Concrete

The study effect of P.O.F ratio volume & diameter with their design mix are stipulated in Table1 & Graph1. It has been observed that with the increase of the Percentage of fibre optical in the concrete, the values of compressive strength of translucent concrete firstly increase with 2.5% as partial replacement of volume of concrete then slashes down with 3.5% partial replacement of volume of concrete after 28 days of curing.

Further seen of 3% reduction of results in compressive strength of concrete cube using 0.75mm diameter of optical fibres with partial replacement of 2.5% volume of concrete as compared with conventional concrete. Secondly, there is a 3.88% decrease in compressive strength of the concrete cube sample using 2 mm dia optical fibre with partial replacement of 2.5% volume of concrete. Lastly, 11.32% deduces compressive strength of translucent concrete using 3 mm dia optical fibre with percentage of 2.5% volume of concrete. This is all due to cement hydration in the transition zone not occurring with age and the contact area between P.O.F concrete & mixture increases, strong adhesion occurs between P.O.F and the mixture which leads to toughness against fracture.

For clarification, the 7-days, 28days & 56 days compressive strength decreases with the increase in %age P.O.F of any diameter. The effect of various ages of different samples of concrete with compressive strength is shown in Graph 2.



Graph 2: Effect of ages on P.O.F concrete

Data for Flexural Strength test:

The flexural test specimen was determined on 150x150x70 mm prisms. The specimen are simply supported on the two ends with a clear span & subjected to two point loads. The clear distance in between the two point loads was 150 mm. while performing the test it was clear cut that good improvement in flexural test occurred with increased P.O.F volume ratios & the diameter used. The result of flexural test of conventional concrete and translucent concrete with 3.5% of optical fibre 0.75mm dia is 2.7% higher than conventional concrete. are discussed in table and chart below. There is 10.83% higher result in flexural strength with 3.5% volume ratio of optical fibre 2.5mm dia while there is 38% hike in test results with 3.5% volume ratio of optical fibre of 3.5 mm dia. The correlation between flexural and compressive strength results for 28 days of curing of concrete sample are determined with the help of a computer application and are shown in Graph 3.

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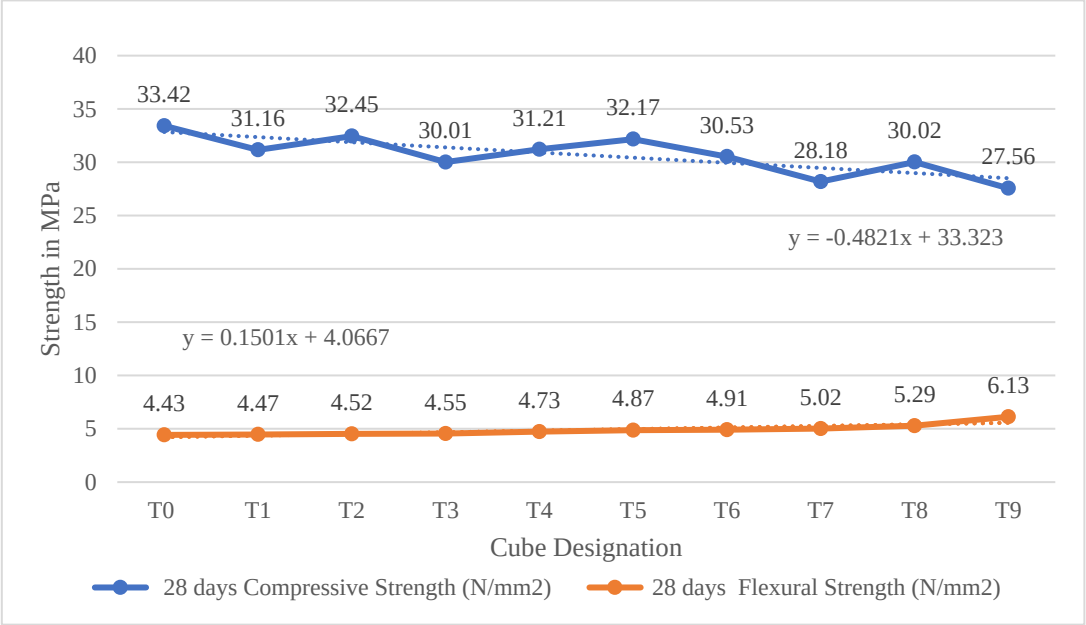

Graph 3: Correlation b/w P.O.F volume ratio and flexural strength vs compressive strength.

Bulk Modulus or Bulk density:

The table2 shows the results of P.O.F hardened concrete at the age of 28 days. These data showed slightly less in density with an increase in %age of P.O.F volume ratio & dia. Despite the fact the apparent decrease in bulk density is very minute, it is all because of part replacement of concrete volume with P.O.F while is quite lighter in weight. The increased %age of P.O.F in this study the bulk modulus are within in the permissible limits of conventional concrete which lies in the between 2300-2400 kg/m^3 which are quite close to the end condition as per Indian Standard Code.

Table 2: Test data for Bulk Modulus/Bulk Density

Cube Designation	%age P.O.F. dia 0.75mm	%age P.O.F. dia 2mm	%age P.O.F. dia 3 mm	Bulk Density at 28 days (Kg/m^3)
T0	0			2390
T1	1.5			2366
T2	2.5			2361
T3	3.5			2353
T4		1.5		2340
T5		2.5		2337
T6		3.5		2319
T7			1.5	2317
T8			2.5	2309
T9			3.5	2303

Luminous Transmissivity Results:

Even though the performance yardstick of concrete depends upon its properties (freshly & hardened) but the presentation benchmark of translucent-concrete depends predominantly on its transmittance output in addition to other practical outputs. The light-transmittance is the efficient light transmitted from surface of concrete cubes i.e. the transmittance of natural white light generally increases when the sky has sunny weather and less grey, the pragmatic flow area under the curves increases when the rise in the volume ratio of P.O.F. incorporated in the concrete specimen. The results show the max. light intensity through the concrete cube specimen was peak at 12:30 pm and the minimum light transmittance was achieved at 6:30 pm. Lastly, the light-transmittance output is outstandingly hanger-on P.O.F. volume ratios & is not dependable upon the dia. incorporated in concrete mix specimen. It was unavoidable to highlight the interrelationship between 28days compressive strength with all different P.O.F dia concrete specimen. Moreover, the light transmittance data readings at 12:30 pm were taken

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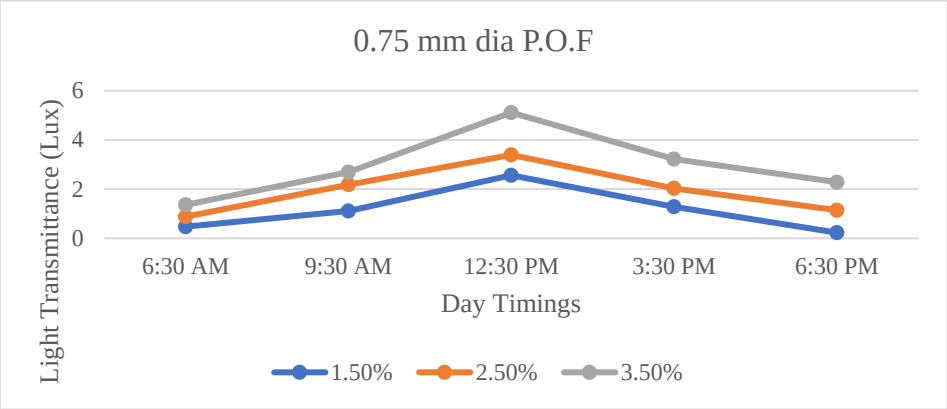
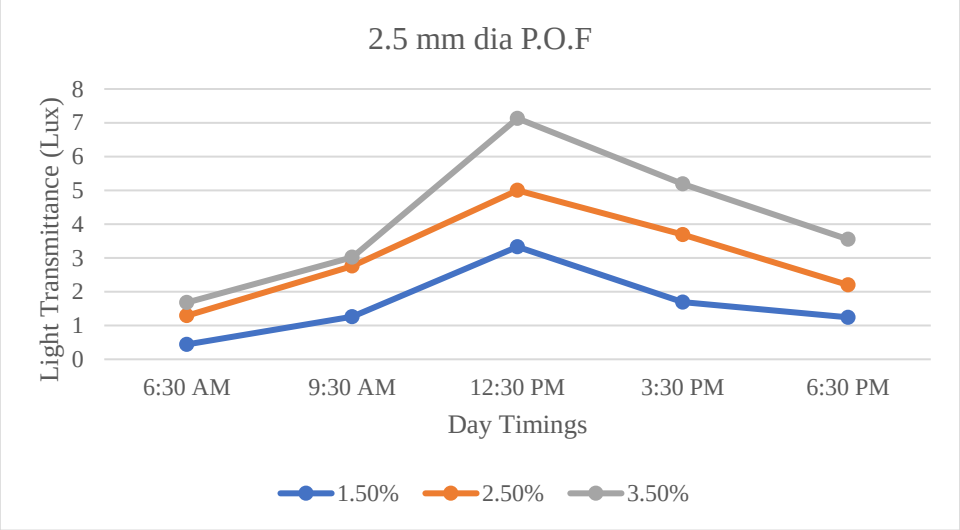
to communicate to P.O.F volume ratio & dia were controlled. The relationship shown in the graphs were not intersecting any points together, so there is no such relationship between expressing that proportional to each other.

Table 3: Test Results of Light Transmitting Test of translucent concrete

diameter used (mm)	%age P.O.F	6:30 A.M.	9:30 A.M.	12:30 P.M.	3:30 P.M.	6:30 P.M.
0.75	1.50%	0.47	1.11	2.56	1.28	0.23
	2.50%	0.88	2.18	3.39	2.03	1.14
	3.50%	1.36	2.69	5.11	3.22	2.28
2.5	1.50%	0.44	1.26	3.33	1.69	1.24
	2.50%	1.29	2.76	5	3.69	2.2
	3.50%	1.68	3.02	7.13	5.19	3.55
3.5	1.50%	0.75	1.97	3.49	2.16	1.44
	2.50%	1.38	2.84	6.34	3.48	3.18
	3.50%	2.05	5.72	9.23	7.23	4.59



Graph 4: Light Transmittance P.O.F specimen for natural light throughout day for 0.75 mm dia.



Graph 5: Light Transmittance P.O.F specimen for natural light throughout day for 2.5 mm dia.

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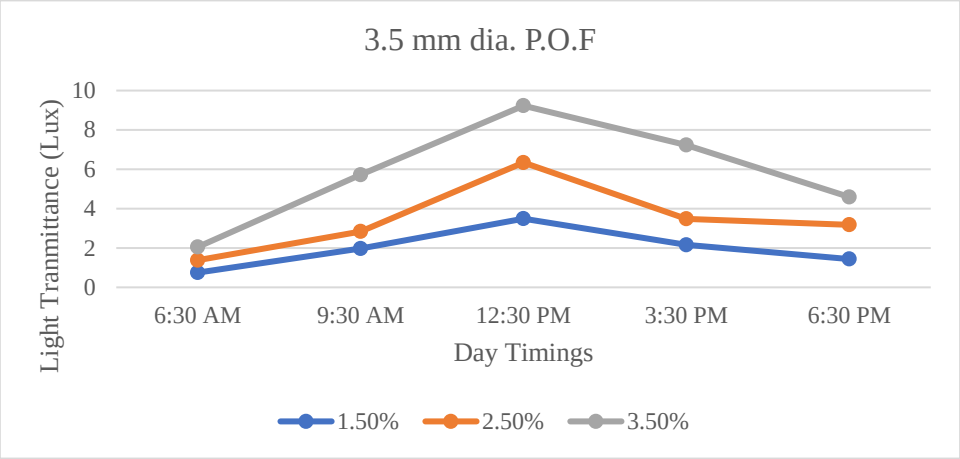
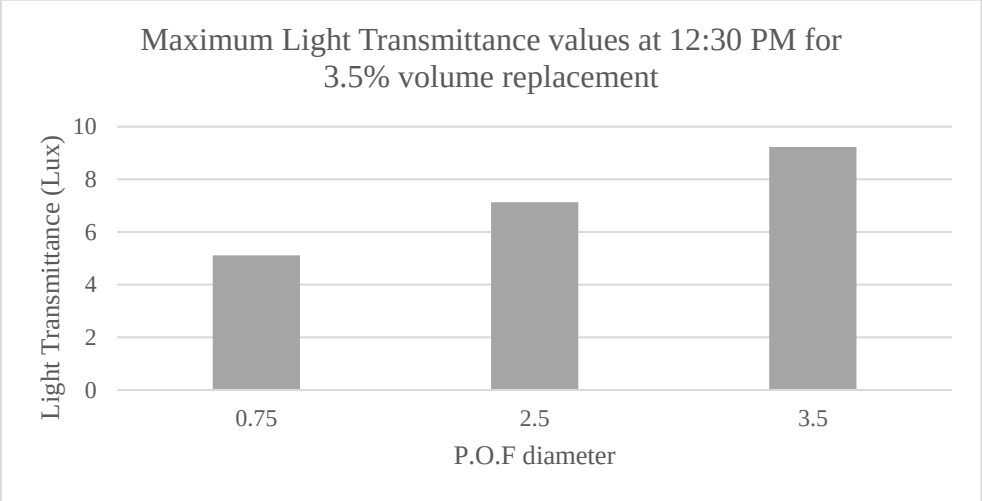
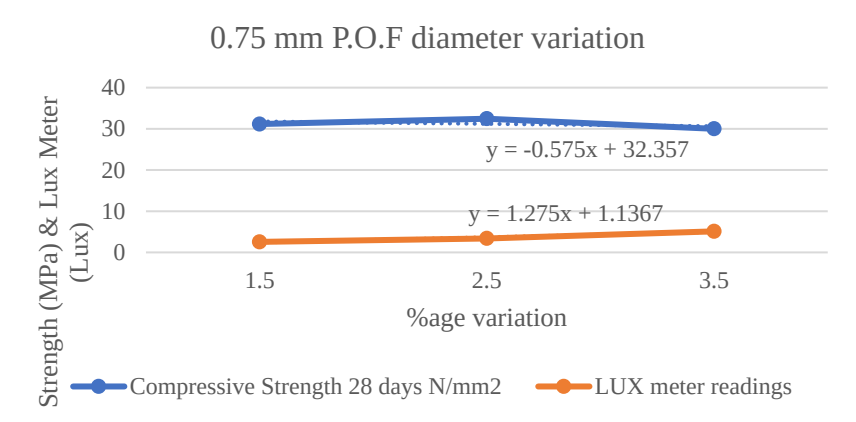


Graph 6: Light Transmittance P.O.F specimen for natural light throughout day for 3.5 mm dia.



Graph 7: Maximum Light Transmittance Tests for various Translucent Concrete mix



Graph 8: Correlation b/w 0.75 mm P.O.F Light Transmittance vs compressive strength.

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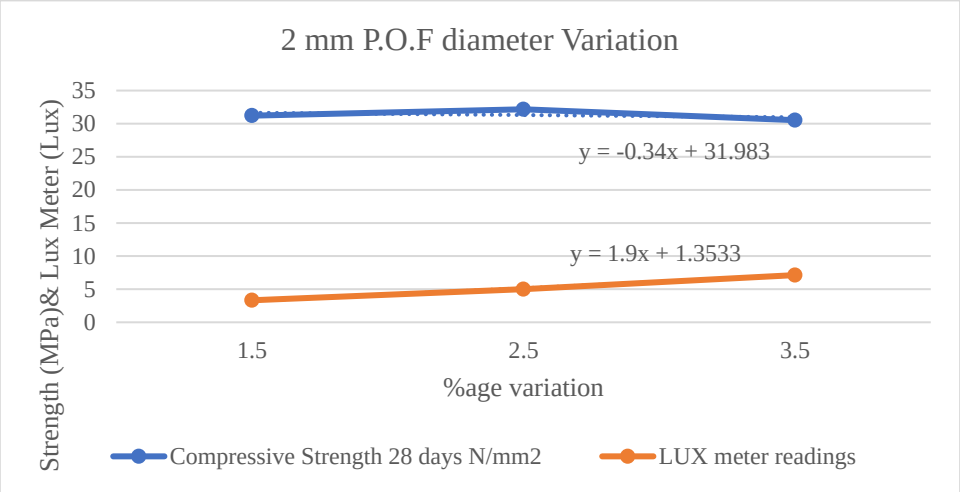
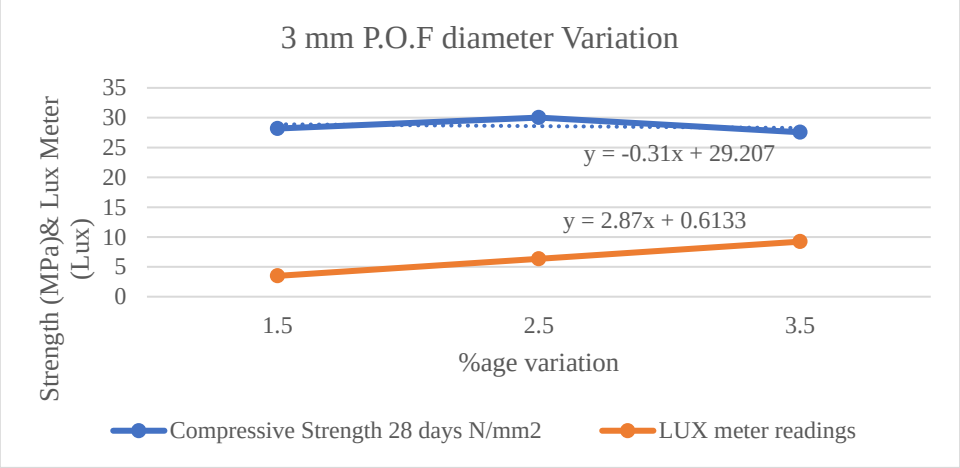


Graph 9: Correlation b/w 2 mm P.O.F Light Transmittance vs compressive strength.



Graph 10: Correlation b/w 3 mm P.O.F Light Transmittance vs compressive strength.

CONCLUSIONS:

From the laboratory analysis and results discussion obtained data the ensuing conclusions are made.

1. The average value of 28 days compressive strength tests shows a 3% reduction of results of translucent concrete using 0.75mm diameter of optical fibre along with the 2.5% partial replacement of the volume of concrete as compared with conventional concrete. For using 2 mm dia optical fibre along with partial replacement of 2.5% volume of concrete there is a 3.88% decrease in compressive strength value of translucent concrete as juxtaposed with nominal concrete mix. Lastly, there is an 11.32% slashed result in the values of compressive strength of translucent concrete using 3 mm dia optical fibre with the partial replacement of 2.5% volume of concrete.
2. The experimental data shows good light transmittance properties. It was recorded 10.83% light-transmittance for the specimen with 3.5% volume ratio with 3mm dia.
3. The correlation between the compression strength test & the light-transmittance test is quite different, there is no such relation in between these two tests. One can't predict the values of another if any one of the values is known.
4. The light transmittance of P.O.F concrete is dramatically hanger-on volume ratio of P.O.F inclusion regardless of P.O.F dia. However, the compressive strength values of P.O.F are directly proportional to the volume ratio of P.O.F & dia. itself.

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