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Mechanical Properties of Concrete Using Optical and Glass Fibre

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Abstract: *Concrete has been used since Roman times for the development of infrastructure and housing, but its basic components have remained the same. Three ingredients make up the dry mix: coarse aggregate, consisting of larger pieces of material like stones or gravel; fine aggregate, made up of smaller particles such as sand; and cement, a very fine powdered material that binds the mix together when water is added. As is it is well known, traditional or conventional concrete which is greyish in colour, but its high density prevents the passage of light through it, which means that it's also impossible to distinguish colour, shapes and bodies through it. But with the addition of optical fibre to the concrete, light can be passed through the concrete from one end to another end which will very much improve the aesthetical and architectural properties of the concrete. Furthermore, addition of glass fibre can enhance the strength and stability parameter of the concrete. In this paper, main concentration is given to create a special type of concrete using different percentages of optical and glass fibre as additive, which will reduce the power consumption problem of the building, improves aesthetic appearance of it and practically implemented as a load bearing component.*

Keywords: *Architectural, Concrete, Glass Fibre, Light transmitting, Optical Fibre, Reinforcement.*

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I. Introduction

The bright idea of light transmitting concrete was first enlightened by Hungarian architect AronLosonzi in 2001 at Budapest University and first transparent concrete block turned into efficaciously produced by introducing large quantity of glass fibre in the concrete at year 2003. Light transmitting concrete consists of 96% concrete and only 4% optical glass fibres. Despite the seemingly low content of glass fibres in the final pre-fabricated concrete block, light is lead between the two sides of a given block. Due to the parallel position of the glass fibres, light on the brighter side of the wall appears unchanged on the darker side. The most interesting form of this phenomenon is probably the visible display of shadows on the other side of the wall, meanwhile the colour of the light remains the same. These elements can be used indoors and outdoors as decorative building elements such as walls, partition walls, pavements, floors, bar-top covers and possibilities are endless. At present, green structures recognized greatly on saving energy with indoor thermal structures. Consequently it is imperative to develop a new functional material to satisfy the structure in terms of safety monitoring (such as damage detection, fire caution), environmental protection and energy saving and artistic modelling.

II. Objectives

To cast and learn the mechanical properties of optical and glass fibre reinforced concrete which gives advancement in both strength and aesthetic appearance.

III. Materials And It's Properties

1. Cement: The type of cement used for this project work is OPC-43 grade. The specific gravity of the cement used is 3 and its fineness modulus is 0.8% which is lesser than the permissible limit of 7%. Standard consistency is achieved as 35%.

2. Fine aggregate: Fine aggregate selected for this project is river sand, which has a specific gravity of 2.57 and the zone of aggregate is determined by sieve analysis, which is obtained as zone-II as per IS-383:1970. Water absorption is found to be 1.2%.

3. Coarse Aggregate: Coarse aggregate selected for this work is 16 mm downsize, which has a specific gravity of 2.69 and water absorption as 0.35%.

4. Optical Fibre: There are three basic types of optical fibre wire present which can be used in making light transmitting concrete:-

a) Single-mode step index fibre

b) Multi-mode step index fibre
c) Multi-mode graded index fibre
For this particular project work, multi-mode graded index fibre is selected, duplex zipcord cable (GJFJV) of 1 mm thickness whose optical characteristics is as shown in TABLE 1.

Table 1: Optical Fibre Characteristics

Optical Characteristics				
Fibre sort	Multimode	G.651	62.5/125	Graded index fibre

5. Glass Fibre: Glass-reinforced plastic (GRP) is a composite material or fibre-reinforced plastic made of a plastic reinforced by fine glass fibres. The glass can be in the form of a chopped strand mat (CSM) or a woven fabric. For the project work, M133 chopped strand mat is selected and its characteristics are as shown in TABLE 2.

Table 2: Glass Fibre Characteristics

Glass Fibre roll characteristics				
Standard weight (g/m^2)	Standard width (cm)	Diameter (cm)	Length (cm)	Weight (Kg)
450	125	39	150	88

IV. Mix Design And Proportioning

Mix designing is done according to IS: 10262-2009 for M_{25} grade and the mix ratio is achieved as 1:1.6:2.15 with a water to cement ratio of 0.48. In this project, we have chosen combination of seven different ratios of optical and glass fibres as additive to the concrete by the weight of cement and named as NC, $OGRC_1$, $OGRC_2$, $OGRC_3$, $OGRC_4$, $OGRC_5$, $OGRC_6$. The ratios are as shown in TABLE 3.

Table 3: Designations of materials, optical and glass fibre percentages

Designations / Materials	Optical Fibre (%)	Glass Fibre (%)
NC	0	0
$OGRC_1$	0.75	0.5
$OGRC_2$	0.75	1
$OGRC_3$	1.25	0.5
$OGRC_4$	1.25	1
$OGRC_5$	1.75	0.5
$OGRC_6$	1.75	1

With the above ratios, the concrete is casted and cured by normal curing methods for 28 days. For "NC", total 6 numbers of cubes and 6 numbers of cylinders are casted, where as for remaining ratios, 8 numbers of cubes and 6 numbers of cylinders are prepared.

Table 4: Quantity of materials (Kg/m^3)

Specimen	Cement	Fine aggregate	Coarse aggregate	Water	Optical Fibre	Glass Fibre
	(Kg/m^3)					
NC	449.3	718.38	965.71	218.32	Nil	Nil
$OGRC_1$	449.3	718.38	965.71	218.32	3.37	2.246
$OGRC_2$	449.3	718.38	965.71	218.32	3.37	4.493
$OGRC_3$	449.3	718.38	965.71	218.32	5.62	2.246
$OGRC_4$	449.3	718.38	965.71	218.32	5.62	4.493
$OGRC_5$	449.3	718.38	965.71	218.32	7.86	2.246
$OGRC_6$	449.3	718.38	965.71	218.32	7.86	4.493

V. Mould Preparation, Concreting And Compaction

A mould of rectangular cross section of size 150mm x 150mm x 150mm and cylindrical mould of 110mm diameter with 200mm height is prepared by steel and holes are made to the mould with calculated proper spacing of wires. Afterwards, wires are placed through the holes and tied with bolts and then concrete is poured. The compaction is done by vibration using vibrating table. The de-moulding is done after 24 hours and casted cubes and cylinders are kept for curing.

Figure 1 Preparation of Mould

Figure 2 Vibrating Table for compaction of concrete

Figure 3 Fibre reinforced cylindrical mould on vibrating table

Figure 4 Curing of concrete cubes

Figure 5 Curing of concrete cylinders

Figure 6 Preparing the concrete cubes for compression test

VI. Tests And Results

***1. Compressive Strength*:** Compressive strength of concrete is tested with the help of compression testing machine. The cube with fibre is kept perpendicular to the load in compression testing machine and the testing is carried out. The compressive strength check is done for both 7 and 28 days. The formula for calculating the compressive strength is given below,

Compressive Strength = (Compressive Load / Surface area)

Table 5: 7th and 28th day's compressive strength of concrete

Specimen	Percentage of additives (To the weight of cement)		Compressive Strength (N/mm^2)	
	Glass fibre	Optical fibre	Grade of concrete: M25	
			7 Days	28 Days
NC	0	0	18.53	29.96
$OGRC_1$	0.5	0.75	20.56	31.85
$OGRC_2$	1	0.75	20.53	29.67
$OGRC_3$	0.5	1.25	24.79	32.85
$OGRC_4$	1	1.25	24.64	31.78
$OGRC_5$	0.5	1.75	24.04	34.85
$OGRC_6$	1	1.75	22.75	30.98

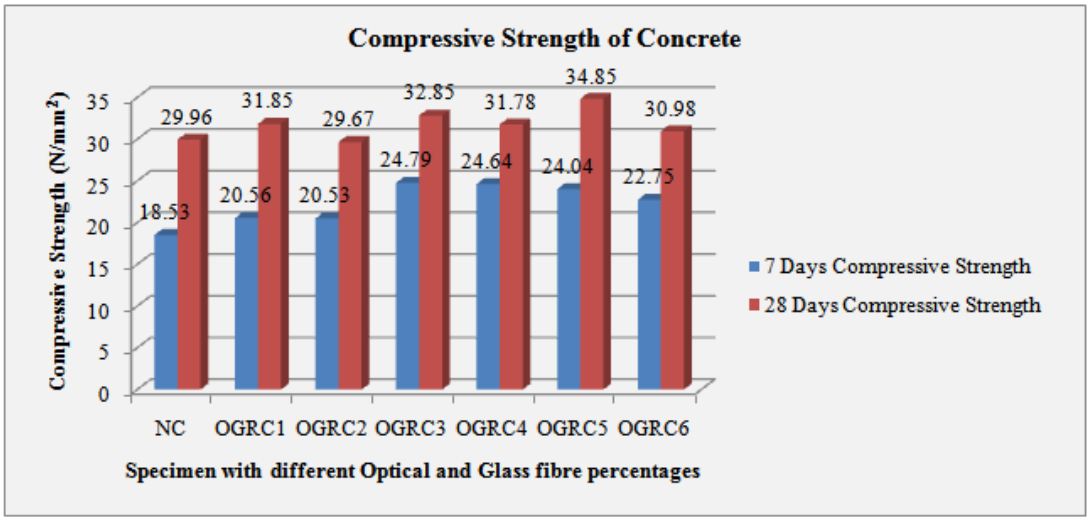

Chart 1 Compressive strength of concrete

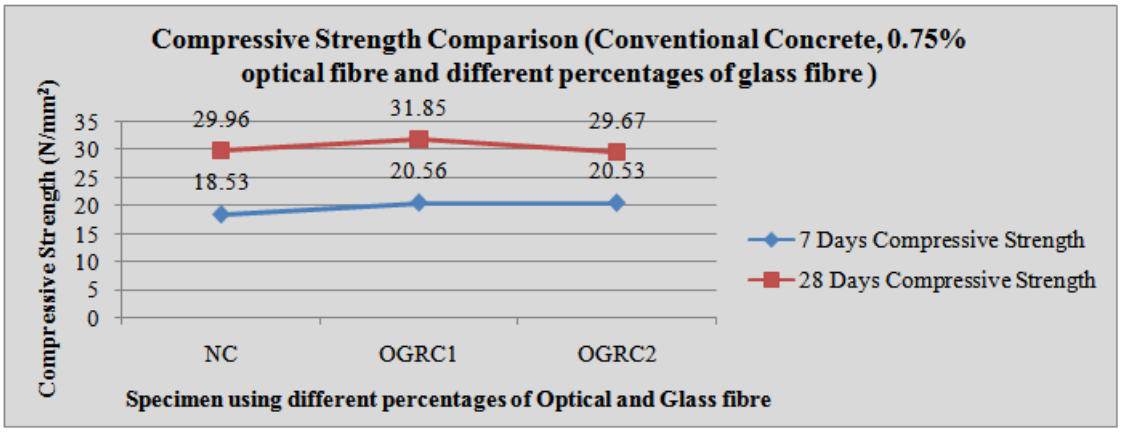

Chart 2 Comparison of compressive strength for 0.75% of optical fibre ratio

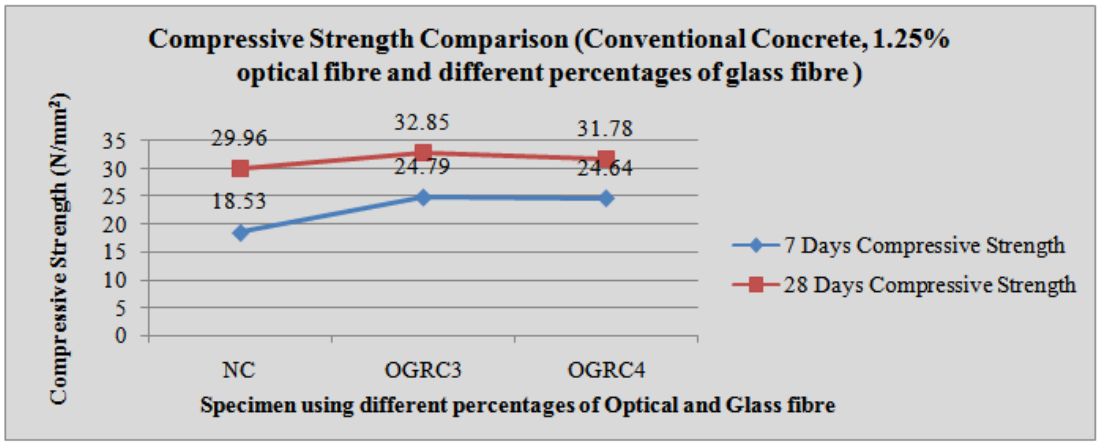

Chart 3 Comparison of compressive strength for 1.25% of optical fibre ratio

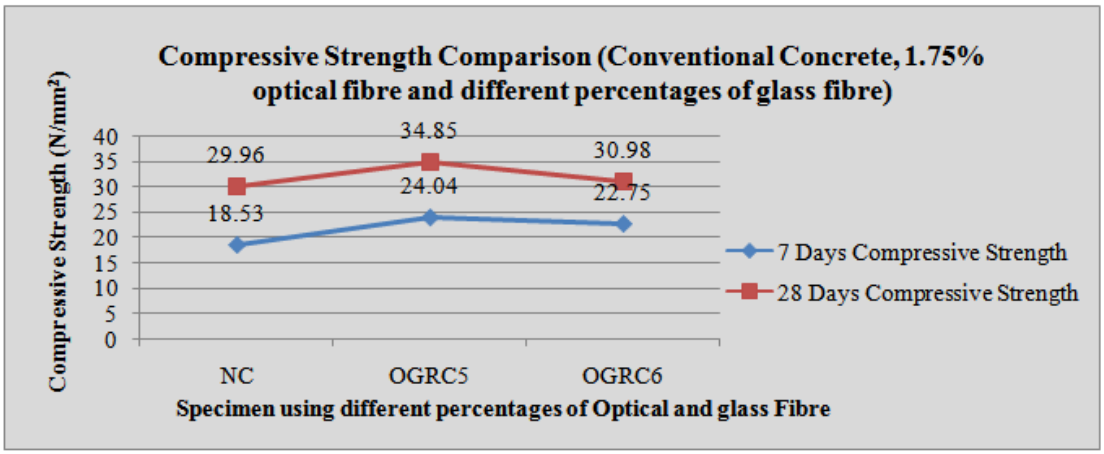

Chart 4 Comparison of compressive strength for 1.75% of optical fibre ratio

2. Split Tensile Strength: As we know, concrete is good in compression and weak in tension. But with the use of new materials and technology in construction field, many different types of innovative concrete is developed which has the capacity of withstanding high tensile strength than normal or conventional concrete. With reinforcing the concrete with optical and glass fibre, the tensile strength of the concrete is studied in this project work. The split tensile strength formula is given below,

Split Tensile Strength = (2 x Tensile Load / Surface area)

Table 6: 7th and 28th day's split tensile strength of concrete

Specimen	Percentage of additives (To the weight of cement)		Split Tensile Strength (N/ mm^2)	
	Glass fiber	Optical fiber	Grade of concrete: M25	
			7 Days	28 Days
NC	0	0	2.16	3.12
$OGRC_1$	0.5	0.75	2.56	3.5
$OGRC_2$	1	0.75	2.58	3.24
$OGRC_3$	0.5	1.25	2.7	3.86
$OGRC_4$	1	1.25	3.06	3.95
$OGRC_5$	0.5	1.75	2.77	4.02
$OGRC_6$	1	1.75	3.44	4.73

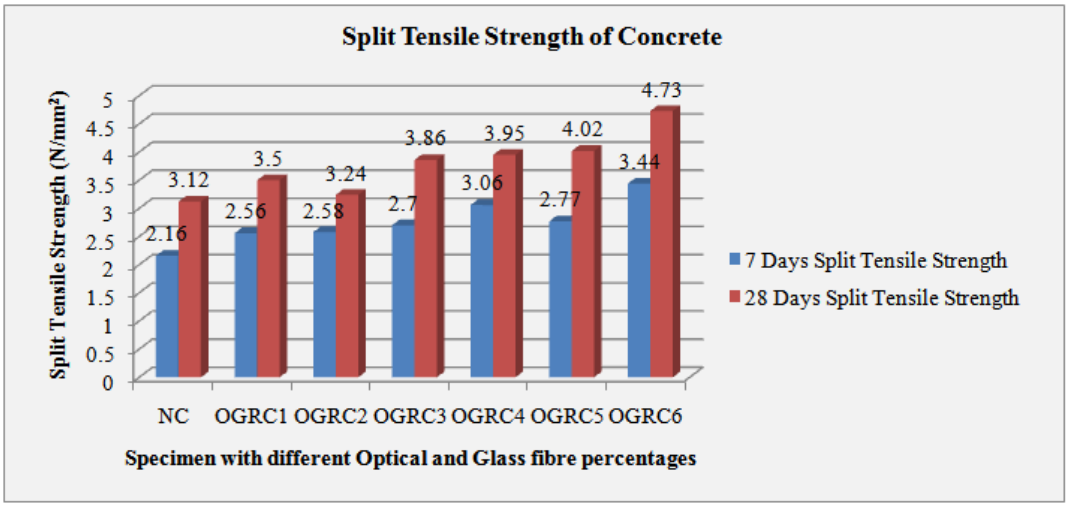

Chart 5 Split tensile strength of concrete

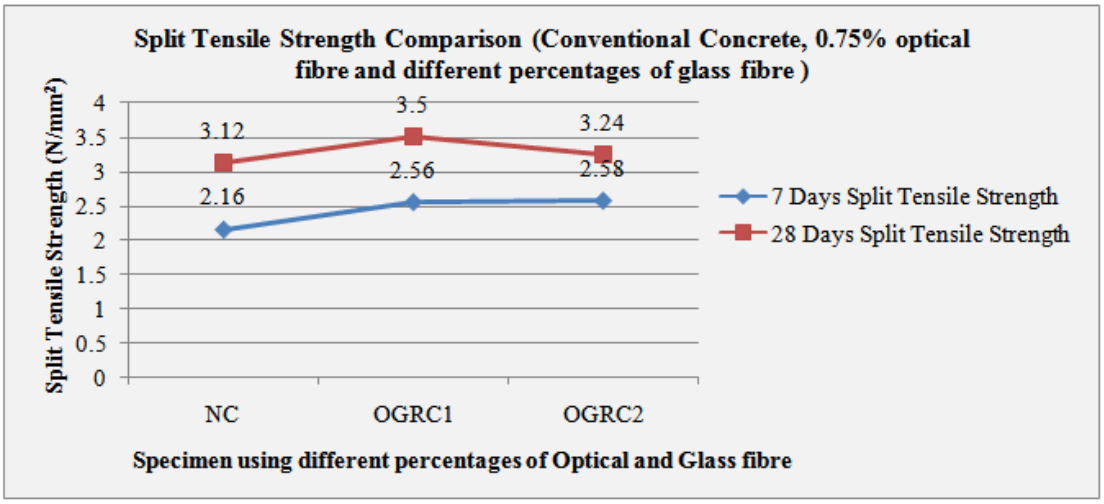

Chart 6 Comparison of split tensile strength for 0.75% of optical fibre ratio

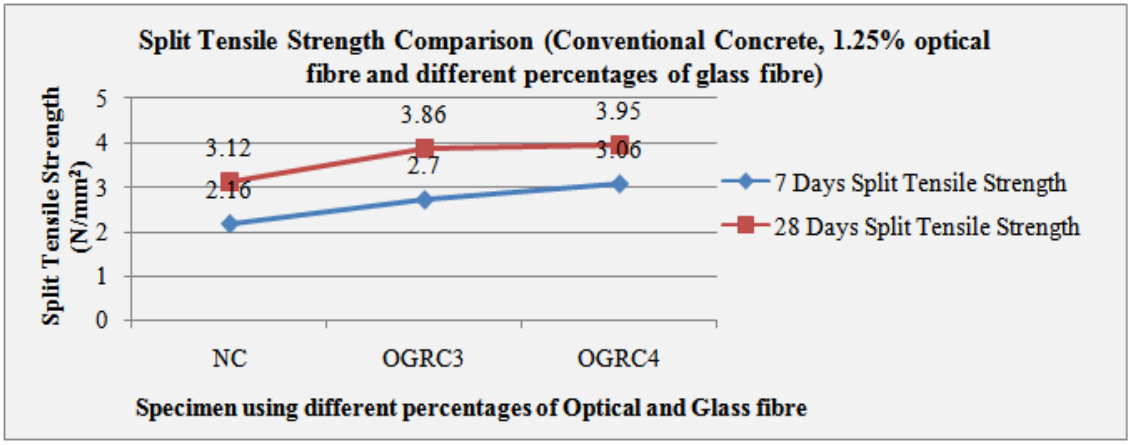

Chart 7 Comparison of split tensile strength for 1.25% of optical fibre ratio

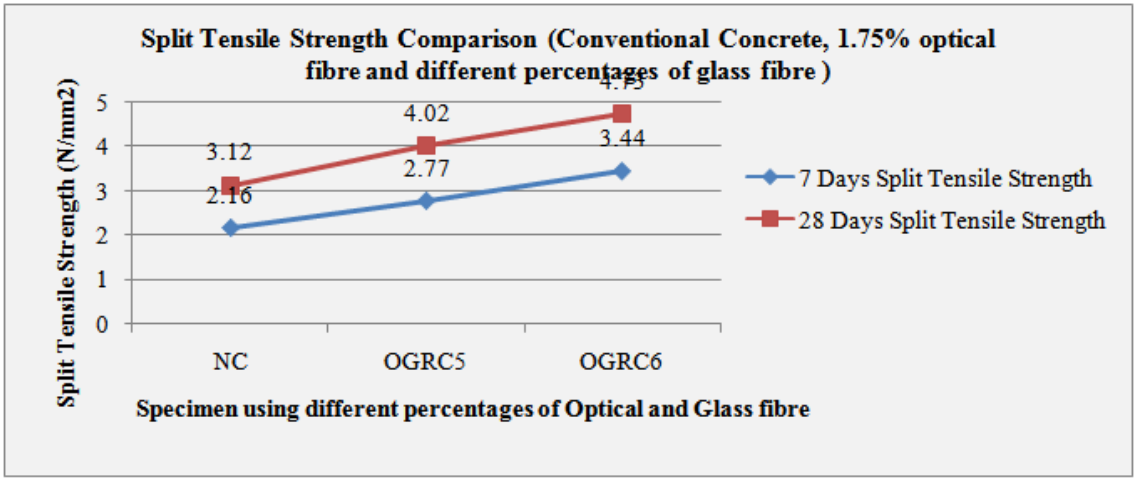

Chart 7 Comparison of split tensile strength for 1.75% of optical fibre ratio

3. Light Transmittance Test: Light transmittance test is carried out in a dark place to check the intensity of light transmitting through optical fibre within the concrete. For this project work, the light transmittance ability is tested by an electrical circuit setup consisting of LED (Light emitting diode) arrangement, LDR (Light detecting diode) arrangement, ARDUNIO UNO board and software. The light transmittance from concrete samples is detected with the help of LDR arrangement which is connected to ARDUNIO UNO board's port and the ARDUNIO UNO board is connected to a system which has ARDUNIO UNO software from which the readings are taken and converted into current unit (mA). The light source (LED) arrangement needs a uniform 20 Volts power supply, 47 K Ω resistor is used in the LDR circuit arrangement and it is connected in 5 volt port in ARDUNIO UNO board.

The light transmittance is calculated by the following formula

Light Transmittance=

100-((Difference in Current between conventional concrete and fibre reinforced concrete / Current of Conventional concrete) x 100

Table 7: Test results for light transmittance

Specimen		Percentages of Optical Fibre		
		0.75	1.25	1.75
Current readings (mA)	Optical fibre reinforced concrete readings (A_1)	8.52	8.74	8.88
	Conventional Concrete readings (A_2)	0 % Optical Fibre		
		21.92		
Light transmittance = 100-((A_2. A_1) / A_2) x 100		38.87%	39.87%	40.51%

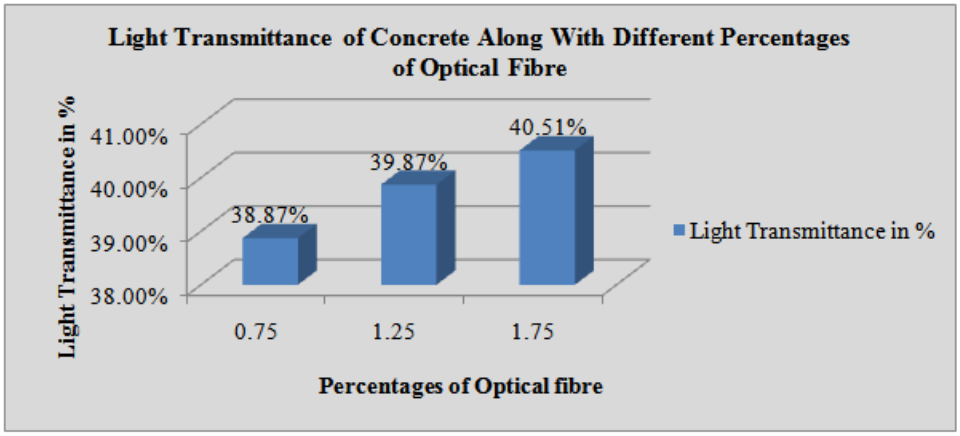

Chart 8 Light transmittance of concrete

Figure 7 Light detecting resistor (LDR)

Figure 8 ARDUNIO UNO board

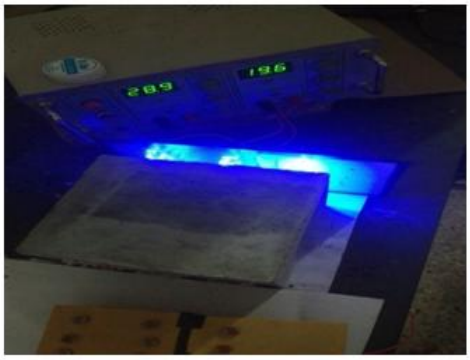

Figure 9 Power source and LED's

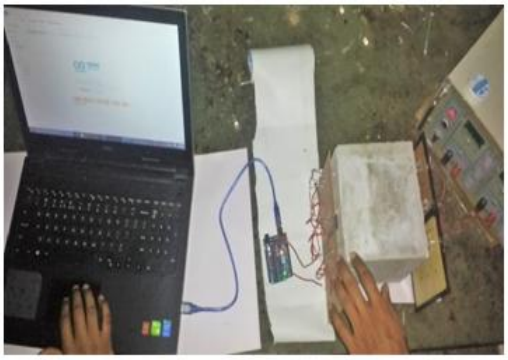

Figure 10 Circuit setup for Light transmittance test

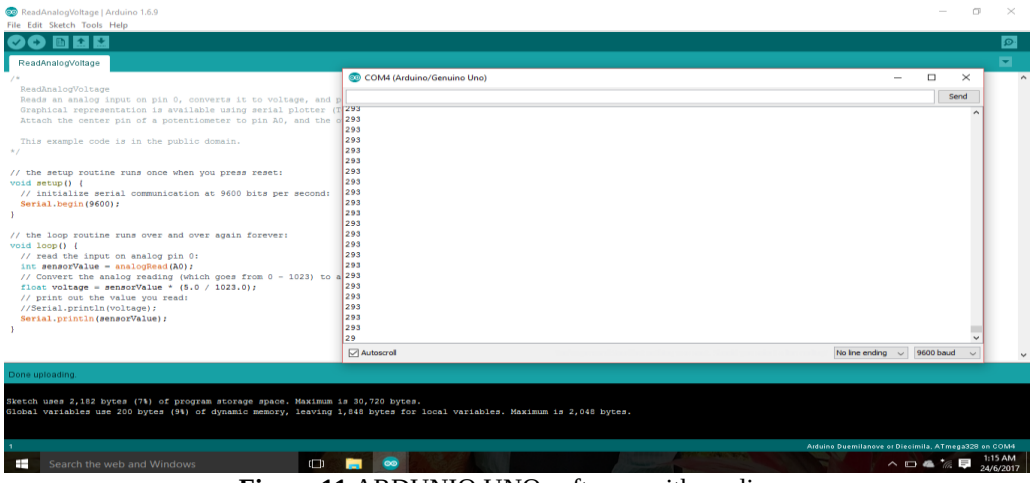

Figure 11 ARDUNIO UNO software with readings

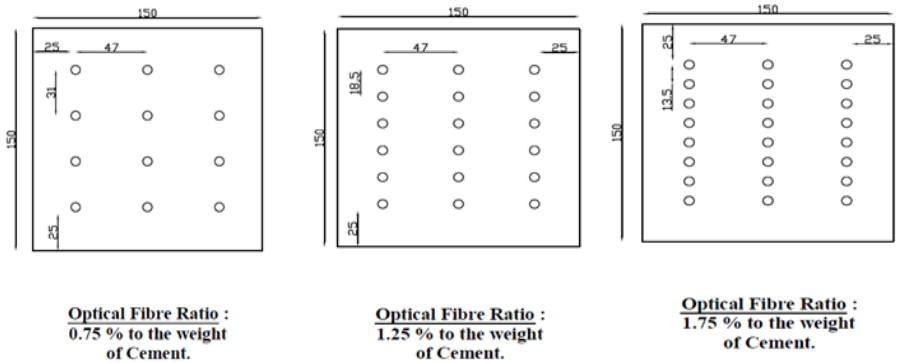

Figure 12 Position and dimension of holes for cube moulds

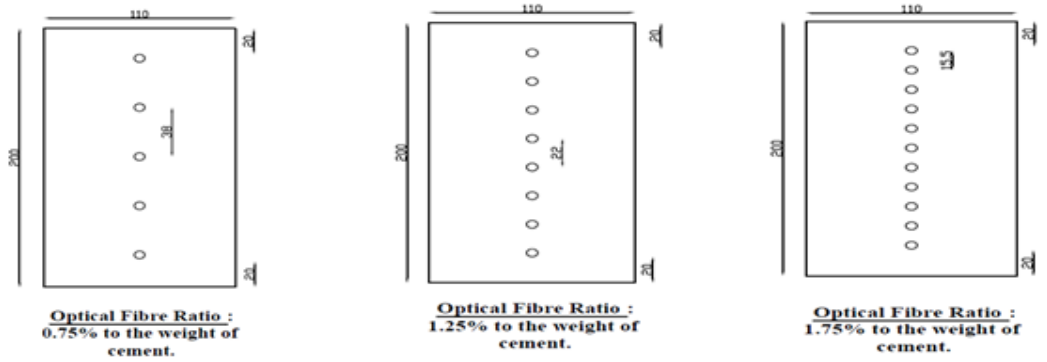

Figure 13 Position and dimension of holes for cylinder moulds

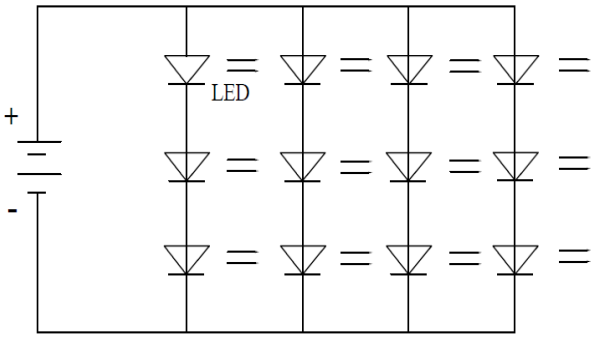

Figure14 Electrical circuits for LED

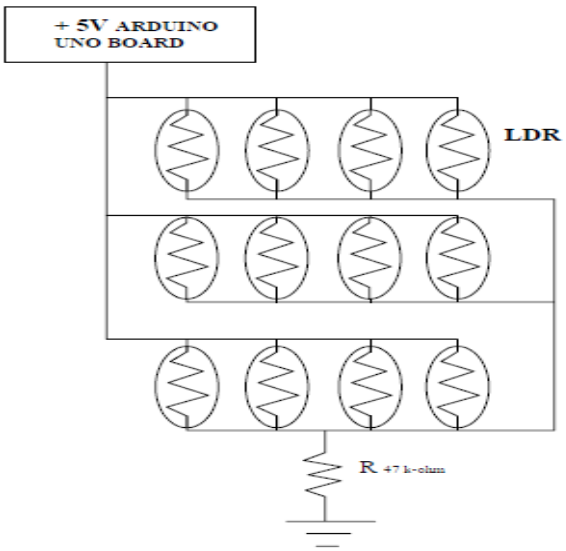

Figure 15 Electrical circuits for LDR

VII. Conclusion

Based on the experimental investigations conducted on optical fibre and glass fibre reinforced (additive) concrete for M_{25} grade, the following conclusions are drawn:-

- Addition of increased percentages of optical fibre from 0.75% to 1.75% and 0.5% of glass fibre increases the compressive strength of the concrete by conventional curing. Furthermore addition of glass fibre (1%) decreases the compressive strength of the concrete.
- Addition of increased percentages of optical fibre from 0.75% to 1.75% and increased percentages glass fibre from 0.5% to 1% increases the split tensile strength of the concrete by conventional curing.
- Addition of optical fibre in concrete increases the light transmittance property of the concrete.
- Addition of higher percentage of optical fibre (0.75% to 1.75%) in concrete increases light transmitting ability, in addition to that, strength parameter of the concrete is also increased.

- As the strength parameter of the concrete is enhanced with the addition of increased percentages of optical fibre (0.75% to 1.75%), the percentage of light transmitting (38.87% to 40.51%) is also increased.

Henceforth, this type of concrete can be used for both aesthetic work and as load bearing structural material.

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