EXPERIMENTAL STUDY ON LIGHT TRANSMITTING CONCRETE

A Major Project

submitted in the partial fulfillment of requirement

for the award of the degree of

Master of Technology

in

Structural Engineering

by

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in this report titled **"EXPERIMENTAL STUDY ON LIGHT TRANSMITTING CONCRETE"** towards the partial fulfillment for the award of degree of **Master of Technology** in **Civil Engineering** with specialization in **Structural Engineering** of Delhi Technological University, New Delhi, is an authentic record of my own work**.**

The data collected herein is original and has not been submitted earlier for award of any other degree or diploma of any University.

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Place: New Delhi

CERTIFICATION

This is to certify that the above statement made by the student is correct to the best of my knowledge and belief.

Dr. Awadhesh Kumar

Associate Professor

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I must like to thank my parents and other family members, for their support for choices in all my life and their love, which has been a constant source of strength for everything I do.

(RAHUL AHLAWAT)

Place: New Delhi

Dated:

ABSTRACT

Due to recent economic and infrastructure development in the developing countries like India, China etc., the dependence on artificial sources of energy has increased drastically. Thus Light transmitting concrete is need of the hour. Light transmitting concrete allows natural sunlight or any light to pass through it. It reduces electricity consumption in the buildings and makes it easier for buildings to achieve higher LEED (Leadership in Energy and Environmental Design) rating. It has all the properties what a eco-friendly technique should have to keep up the green building concept into consideration as it increases the use of natural resource i.e. sunlight which is natural light and it reduces the use of electricity, thus, saving power consumption. Light transmitting concrete also gives aesthetically beautiful surface. It is made up of cement, sand, fine aggregates and thousands of plastic optical fiber strands placed in alternate layers. But, no construction material is can be used until it satisfies all the constructional requirements. For this purpose, experimental study on light transmitting concrete has been carried out to determine it's the light transmittance characteristics with the help of Photometer, device which is used to find the intensity of light in terms of lumens. The Compressive strength of light transmitting Concrete is also found out by testing its cubes with the help of compression testing machine as per the relevant IS code for testing i.e. IS 516:1959. The yielded results shows that light transmittance ratio up to 5.5% can be achieved by using 4% plastic optical fibers in light transmitting concrete. Experimentally found compressive strength results show that there is very little or almost no loss in strength of light transmitting concrete as compared to the traditional concrete. Light transmitting concrete has a very bright future in civil engineering constructions owing to its unique characteristics of transmitting light. Keeping in mind all the advantages of this concrete it is right to say that "Light transmitting concrete is definitely the present as well as future of Civil engineering" as it also encourages the green building concept by reducing the dependence on artificial light sources during the day time. It is also very tremendous innovation in terms of aesthetics and architectural aspect also it gives very pleasing appearance and it can be used for decorative purposes very effectively.

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CHAPTER-1

INTRODUCTION

1.1 General

Concrete is very important construction material composed of cement (commonly Portland cement) as well as other cementitious materials such as lime, fly ash and slag, aggregate(generally a coarse aggregate such as gravel limestone or granite, and a fine aggregate such as sand), water, and chemical admixtures. The word concrete comes from the Latin word "concretus", which means "hardened" or "hard". Concrete solidifies and hardens after mixing with water due to a chemical process known as hydration. The water reacts with the cement, which bonds the other components together, eventually creating a stone-like material. Pavements, architectural structures and motor ways, bridges, parking structures, brick walls, footing, fences and poles are made of concrete. Concrete is used more than any other man-made material in the world.

Thomas Edison patented the Portland cement in 1907. Since then it is being used for a variety of different uses. Sidewalks, buildings, sinks, and furniture are but a few of the products made from cement in the form of concrete. Cement is the dry powder when mixed with other additives and water makes concrete. Over the past decade, new types of concrete and cement have been formulated that do everything from bend, to grow plants, and let light through. Some of the new types of concrete that have evolved with the passage of time, have unique advantages are presented below.

1.1.1 Self healing bacterial concrete

Microbiologists at Delft University of Technology in Netherlands embedded calcite-precipitating bacteria into a concrete mixture to give it self-healing properties under the right conditions. This new type of concrete has the ability to repair itself in order to prevent cracks and pot holes from forming as illustrated in Figure 1.1. The self-repairing bio concrete uses a "healing agent" that becomes active when water gets into cracks on its surface. Also figure1.1 demonstrates a reaction between the bacillus bacteria and the water causes limestone to form and close up the cracks. In theory, using this type of bacteria within commercial concrete mixtures would lead to more durable concrete structures as the crack would be self healed by the concrete itself. Self healing concrete would be ideal for constructing containers for storing hazardous waste as it is difficult to carry out human repairs in such containers. The current cost of constructing this concrete is very high making other potential applications, such as constructing residential buildings, offices, etc. are not yet commercially viable.

Figure 1.1 Self Healing Bacterial concrete

1.1.2 Bendable concrete

Bendable concrete was developed in 2005 by the researchers at the University of Michigan USA. This new type of concrete is 500 times more resistant to cracking and 40 percent lighter in weight in comparison to the traditional concrete. The materials in this concrete are itself designed for maximum flexibility see Figure1.2. Traditional concrete presents many problems: failure under severe loading, lack of durability and sustainability, and the resulting expenses of repair. The bendable or ductile, concrete is made mainly of the same ingredients as in regular concrete with no coarse aggregate relatively costlier. It looks exactly like regular concrete, but under excessive strain, the Engineered cement composites (ECC) concrete having network of fibers veining the cement is allowed to slide within the cement, thus avoiding the inflexibility that causes brittleness and breakage. The Engineered Cement Composites technology i.e. the bendable concrete has been already used on projects in many countries like Japan, America and Korea.

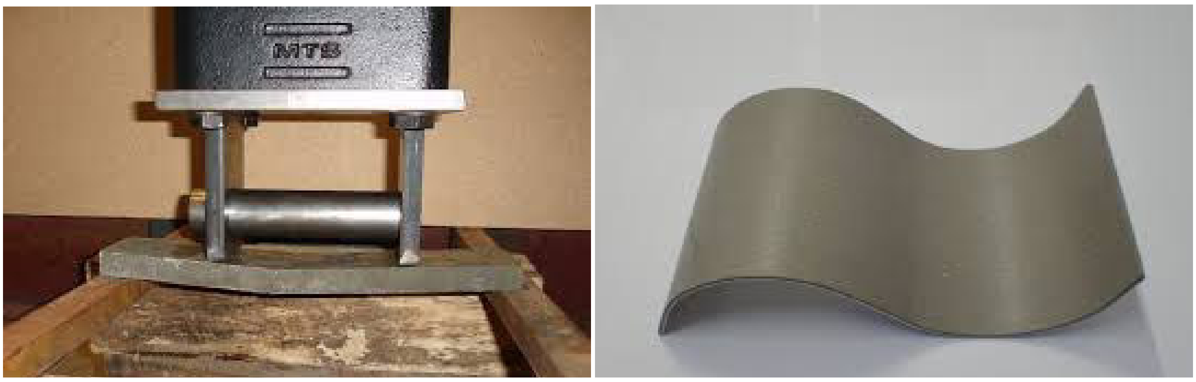

Figure 1.2 Bendable concrete

1.1.3 Pervious concrete

Pervious concrete is some time determined by designers and architects when porosity is obliged to permit some air development or to facilitate the waste and stream of water through structures. Pervious concrete is alluded to as "no fines" concrete on the grounds that it is fabricated by forgetting the sand or "fine total". As Figure 1.3 indicates a pervious solid blend contains almost no sand (fines), making a generous void substance. Utilizing adequate glue to coat and tie the total particles together makes an arrangement of very porous, interconnected voids that depletes rapidly. Ordinarily, somewhere around 15% and 25% voids are accomplished in the solidified cement, and stream rates for water through pervious solid are normally around 480 in./hr (0.34 cm/s, which is 5 gal/ft^2/ min or 200 L/m^2/min), despite the fact that they can be much higher.


Figure 1.3 Pervious or Permeable concrete

1.1.4 Betao organico concrete

Betao organico concrete was created in 2005 by "Lisbon-based architects and designers e-studio”. This organic concrete blends organic and inorganic materials together to create a living surface on which growth of plants and grass is possible. Water is retained by the concrete; as such the concrete is used as a "battery" to provide water during dry periods for the plant life growing on it. Rather than having grass growing between concrete slabs, it is now possible to have the grass grow on the concrete slabs see Figure 1.4. These slabs could be added to walls outside to create living siding on outer side and provide plants to soak up carbon dioxide, this way it is eco friendly.

Figure 1.4 Betao Organico concrete

1.1.5 Light transmitting concrete

The modern construction material is light transmitting concrete. It is also known as translucent concrete. In 2001 Aron Losonczi, a Hungarian Architect developed a special concrete that allowed light to pass through it by using 4to 5% optical fibers. As illustrated in Figure1.5 light transmitting concrete is a special type of concrete that allows light to pass through it. Strength of this concrete is almost same as regular concrete. It can continue to transmit light through walls up to twenty meters thick, as the fiber works without any loss in light up to twenty meters. It is popularly used in green buildings to save electricity.

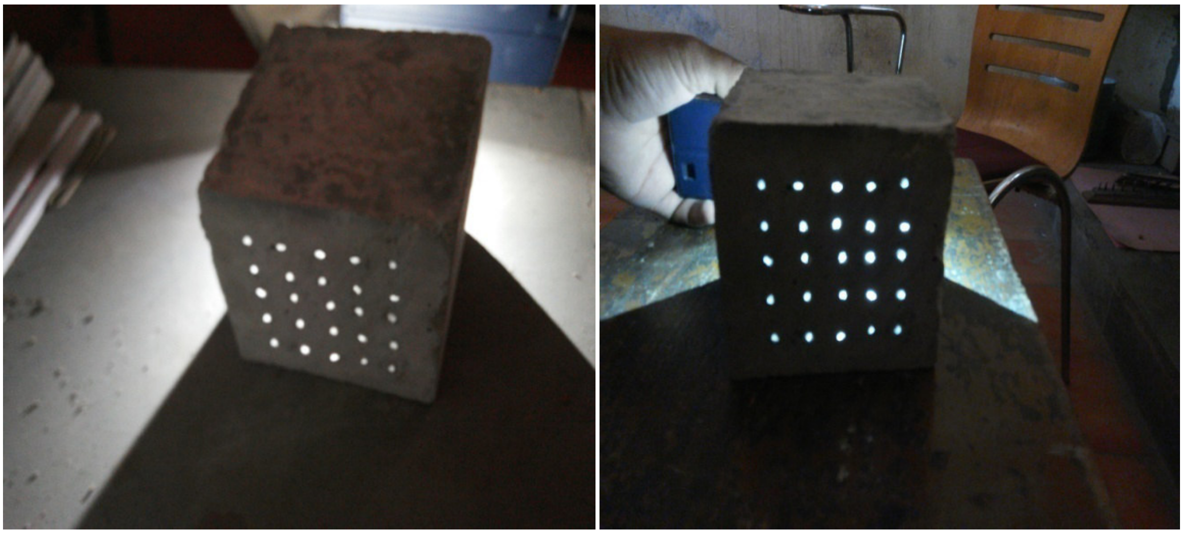

Figure 1.5 Light transmitting concrete

1.2 Need for Light Transmitting Concrete

This concrete is very important from sustainable development and green building point of view as it allows use of natural light more efficiently without compromising much on strength parameter. For green buildings, according to IGBC (Indian Green Building Council), 50% of day light is mandatory which accounts for 3 credits in the green buildings. Light transmitting concrete allows sufficient light inside the building, thereby making it easier to achieve higher ratings for buildings.

Globalization, economic and infrastructure development in the developing countries like India, China, etc. has resulted in increased usable space requirement, due to which, high rise buildings and skyscrapers are increasingly built. In these structures, people's optical activity requirements are met with the help of artificial sources of energy only. Complete dependence on artificial sources has adverse impact on our environment and health of people living in these buildings. Production of these artificial sources of energy pollutes our environment by releasing harmful by products into the environment.

Light transmitting concrete or translucent concrete (Figure 1.5) is a special type of concrete that allows light to pass through it. It is made up of cement, sand, fine aggregates and optical fibers, placed in alternate layers. Light transmitting concrete allows natural sunlight or any visible light to pass through it, thus, increasing the natural light content in the building to enhance people's optical activity. It is based on the principle of total internal reflection of light in the core of the plastic optical fiber. When light falls on one end of the optical fiber, it gets totally internally reflected in the fiber and gets transmitted on other end of the fiber.

Very limited research has been done on various properties of light transmitting concrete regarding its suitability as construction material. The main objective of this experimental program is to study its light transmitting and strength characteristics by varying plastic optical fiber percentage and concrete grade which may produce different effects on performance.

1.3. Functional Principle of Light Transmitting Concrete

Diffused natural light and sun light provide the full spectrum of colors shining through the concrete panels. Sunlight is the most inexpensive light source. If the panel is mounted free standing or in front of a window, one will not need any artificial light source. Transparent concrete or translucent concrete is due to work based on “Nano-Optics”. Figure 1.6 shows optical fibers pass as much light when tiny slits are placed directly on top of each other when they are staggered. Optical fibers in the concrete act like the slits and carry the light across the concrete.

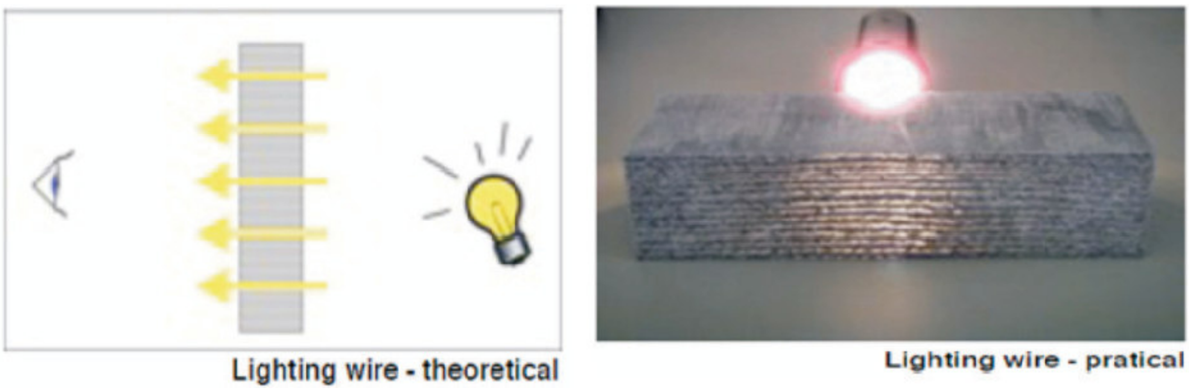

Fig 1.6: Functional principle of light transmitting concrete

1.3.1 Total internal reflection

When light traveling in an optically dense medium hits a boundary at a steep angle (larger than the critical angle for the boundary), the light is completely reflected. This is called total internal reflection. This effect is used in optical fibers to confine light in the core. Figure 1.7 demonstrates that light travels through the fiber core, bouncing back and forth off the boundary between the core and cladding. Because the light must strike the boundary with an angle greater than the critical angle, only light that enters the fiber within a certain range of angles can travel down the fiber without leaking out. This range of angles is called the acceptance cone of the fiber. The size of this acceptance cone is a function of the refractive index difference between the fiber's core and cladding.

In simpler terms, there is a maximum angle from the fiber axis at which light may enter the fiber so that it will propagate, or travel, in the core of the fiber. The sine of this maximum angle is the numerical aperture (NA) of the fiber. Fiber with a larger NA requires less precision to splice and work with than fiber with a smaller NA. Single-mode fiber has a small NA. Refer to Fig. 1.7 which shows propagation of light in a multi mode optical fiber.

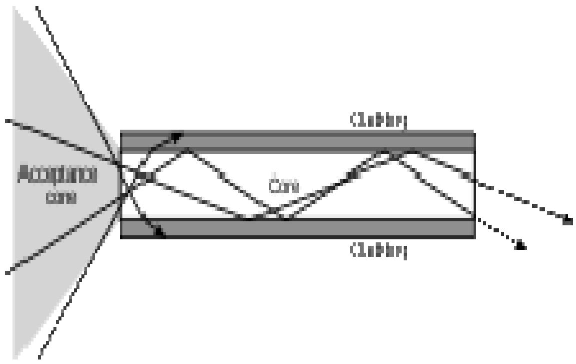

Fig 1.7: Propagation of light in a multi mode optical fiber

1.4 Usage of Light Transmitting Concrete Blocks

- Translucent concrete blocks inserted on front doors or walls next to it allow the residents to see when there is a person standing outside. Translucent concrete walls on restaurants, clubs, and other social establishments help see how many people are actually inside it.
- Sidewalks with translucent concrete fitted with a single light source beneath would add a lot to the scenic beauty as well as safety and also encourage walking or foot travel during night times.
- Ceilings of large corporate buildings with translucent concrete would help reduce a great deal of lighting costs during day time. Transmittance % is very low because it depends on size and percentage of POFs (Plastic Optical Fibers).
- Translucent concrete blocks can be made in desired shapes and used as decorative materials like bookshelves and sunshades, tables and statues.
- Lamps using translucent concrete blocks with a light source would add a great deal of aesthetic look.

- Speed bumps in parking lots and highways can use translucent concrete blocks with a light source beneath or reflecting from other vehicles/sources help in navigation very effectively. Even lane markers in highways can use this material to light up the roads. It may not be effective because natural light will allow the material to be bright and clean while artificial light (depending on its wattage, lumens and colour) can reflect its blue, yellow or pink variance to create light play of colour and shadow.
- They can also be placed as random designs on security walls which also enhance security giving the residents a hazy view of the perimeter.

1.5 Demerits of Light Transmitting Concrete

It has following demerits:

- It requires skilled labor for its manufacture as fibers need to be placed properly and quality control needs to be maintained throughout its manufacture process.
- Cost of construction is very high as plastic optical fiber is used. Due to optical fiber its cost is increased.

1.6 Examples

Translucent concrete is a pretty rare sight. Not many people have a particular idea about this nor its applications and advantages. The largest project exhibiting this technology is an artistic installation, called the ’European Gate´ (2004) at Komarom in Hungary as depicted in Figure 1.8 which was designed to mark the celebration of Hungary joining the European Union (EU). Located at the public entrance of Fortress Monostor in the Hungarian town of Komarom, this is one of the most impressive pieces of art conjugating visual lighting display as well as artistic using translucent concrete.

Fig.1.8: European Gate at Komarom in Hungary

Refer to Figure 1.9 shows light transmittance of entrance gate of Luccon Company in Austria. Most of the uses or applications include partitions or partition walls in office cabins or in houses, and attractive furniture, and intelligent light fixtures, lighting in dark subway stations.

Figure.1.9: Entrance gate of Luccon, company in Austria

1.7 Scope of Research Work

To investigate various experimental properties of the light transmitting concrete is the main aim of this study. Plastic optical fibers are added to concrete, to allow light pass through it. Effects of plastic optical fiber on various properties of concrete such as light transmittance and compressive strength have been studied experimentally. The results obtained in this research work pertain to this special type of material i.e. light transmitting concrete.

1.8 Objective of the Study

In the present study, the effect of varying the plastic optical fiber percentage (volume fraction) on various properties of the concrete is investigated. The precise objectives of the study are as follows:-

- To prepare light transmitting concrete with the help of plastic optical fiber in the laboratory, in order to conduct an experimental study on the light transmitting concrete to study its various properties.
- To prepare a special type of construction material "Light transmitting concrete".
- To study experimentally light transmittance intensity of light transmitting concrete using incandescent and halogen source of light of known intensity with respect to varying percentages of plastic optical fiber in the light transmitting concrete.

- To study the compressive strength as per "IS 516:1959 methods of test for compressive strength of concrete" of light transmitting concrete by varying the percentage of plastic optical fiber, and also varying the grade of concrete.

1.9 Organization of Report

The work carried out in this study is presented in five chapters. A brief idea about the organization of report and its included chapters is as follows:

Chapter 1 introduces the subject matters of the research. It also introduces new trends in the field of concrete and various type of new concrete, the light transmitting concrete. Need of light transmitting concrete, its various uses, various advantages and disadvantages along with application of light transmitting concrete.

Chapter 2 includes the review of the research work done by various researchers on the properties of low grades light transmitting concrete i.e. M10 and M15, such as, light transmittance using devices i.e. light dependence resistor (LDR), voltage regulator, resistance box, new port 835 optical meter and optical power meter, and compressive strength with different mix proportions.

Chapter 3 describes the details of materials used and preparation of specimens. It also includes the overview of properties of the materials and their test procedures.

In chapter 4 results obtained from the experimental work have been discussed in this chapter. It also includes results, tables and graphs along with the conclusion drawn. Scope for future study has also been included in this chapter.

CHAPTER - 2

LITERATURE REVIEW

2.1 Introduction

Light transmitting concrete or translucent concrete is a special type of concrete that allows the light to pass through it and it is made of cement, sand, fine aggregates and optical fibers. In 2001 Aron Losonczi, a Hungarian Architect developed a special concrete that allowed light to pass through it by using 4 % to 5% optical fibers. Due to the ongoing development around the globe, urbanization is resulting in dependence on artificial energy sources for people's optical activities. Thereby, depleting our environment, as production of these artificial energy sources causes pollution. Light transmitting concrete allows natural sunlight or any form of light to pass through it thus, when it is used in construction, it reduces the dependence on artificial energy by maintaining sufficient natural light to enable people's optical activities to some extent.

Translucent Concrete or Light Transmitting Concrete is based on the principle of total internal reflection in the plastic optical fiber's core, so that when light enters from one end, it is totally internally reflected to the other end without any loss. Either glass optical fibers or plastic optical fibers can be used with concrete in alternate layers to form light transmitting concrete. By increasing the percentage of plastic optical fiber, the light transmitted through the concrete is increased and optimum amount of strength and transmitted light can be achieved at 4 to 5% fibers in the concrete.

According to IGBC (Indian Green Building Council), for building to be green building, 50% of day lighting is mandatory which accounts for 3 credits. Till now very limited research on mechanisms, long term durability and other aspects of translucent concrete have been done. Translucent concrete, allows sufficient natural light, makes it easier to achieve green building ratings in construction.

Kashiyani Bhavin K.et.al (2013) studied light transmitting concrete, its various ingredients, manufacturing process, construction, applications, advantages, disadvantages, etc. Light transmitting concrete was made by blending together the concrete and 4% to 5%

optical fibers. The thickness of optical fibers being 2micrometre to 2mm. Alternate layers of POF and concrete are placed to form light transmitting concrete. This concrete is based on the principle of total internal reflection of optical fibers, as light passes through the optical fibers.

Bhushan Padma, and Johnsan D. (2013) constructed translucent concrete blocks using concrete and plastic optical fibers. They discussed about the usage of these concrete blocks such as in the walls, ceilings to make it architecturally pleasing, illuminating speed bumps, use on sidewalks, on various interior and exterior surfaces of the buildings to make it aesthetically beautiful. Plastic optical fibers have various advantages such as they do not produce radiation, also not affected by radio magnetic interference, radio frequency and noise. Plastic optical fiber is by far the best replacement for glass, as it is much stronger and gives more privacy.

Shen Juan and Zhou zhi (2013) discusses the development of smart transparent concrete based on its excellent properties of smart sensing and transparent. By dealing with its usage and also the advantages it brings in the field of smart construction, it reduces the power consumption of illumination and uses the optical fiber to sense the stress of structures. And this concrete is also used for an architectural purpose for good aesthetical view of the building. Authors conclude that the transparent concrete does not lose the strength parameter when compared to regular concrete and it has very vital property from aesthetical point of view. It can be used for the best architectural appearance of the building. It can also be used where the light cannot reach with appropriate intensity. It has some disadvantages such as, it requires skilled supervision and also it's very costly due to the optical fibers used in it.

Kamdi B Akshaya (2013) found that light transmitting concrete can be used almost anywhere where glass or traditional concrete can be used. Translucent concrete has dual advantage, one of strength and other property of glass to transmit light. It also retains privacy and can be used as structural support. The possibilities for usage of translucent concrete are innumerable, the more it is used, the more new uses will be discovered. As with any new material, it is expensive and has this disadvantage as well. With the further development of this product, its usage is definitely going to increase.

Nagdive Neha R. and Bhole D. Shekhar (2013) manufactured translucent concrete by using optical fiber. For preparing mould, first polymer craft clay is spread into a flat circle, then a ring of spray paint was used to fix over clay for using it as a mould. Then, optical fibers were placed individually in the mould and then slowly the concrete was poured. After 24hours, polymer clay was pulled and the plastic ring was removed. The concrete was allowed to dry and extra fibers were cut. Sand paper was used to polish; it was observed that the concrete prepared this way, was able to pass light through it.

2.2 Experimental Properties Reviewed

2.2.1. Light transmittance property

The main purpose of using light transmitting concrete is to enable light to pass through it. The light transmittance property can be found out with the help of any intensity of light measuring instrument such as photometer, Newport 835 Optical Power meter, etc.

Zhi Zhou et al. (2009) studied the light transmittance characteristics of light transmitting concrete by making four mortar specimens of 100x100x100mm with sand/cement/water ratio of 1:2:0.44. and plastic optical fiber ratio of 3.14%, 3.80%, 4.52% and 5.3%. New port 835 optical meter was used to study the light transmittance; see Figure 2.1, it was observed that light transmittance was between 1% to 2.25% of the incident light for fiber ratio between 3.14% to 5.3%.

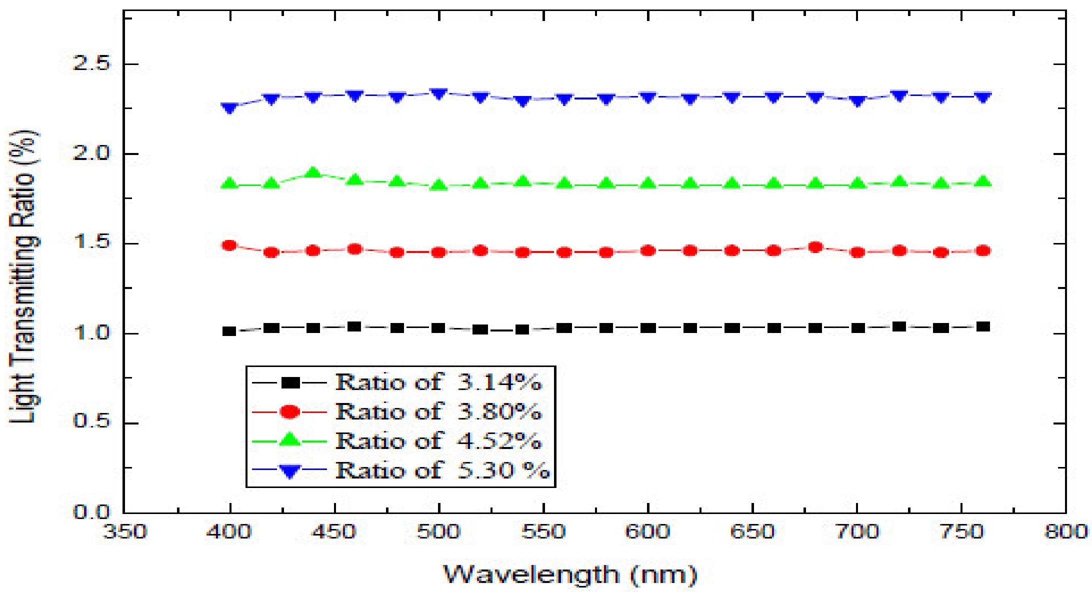

Figure 2.1: Light transmittance characteristics

Momin et al. (2014) made light transmitting concrete samples with the help of Glass rods and optical fiber. The specimens with glass rods were fabricated as 150x150x150mm size cube with cement/sand/aggregates ratio of 1.0:1.5:3.0 and w/c ratio of 0.5. The spacing of glass rods in the specimens was kept as 1.5cm, 3.0cm, and 4.5cm. The optical fiber specimens were made 150x100x100mm cuboids and cement/sand/water ratio was kept as 1.0:2.0:0.45. The spacing of optical fibers in cuboids was kept as 0.5cm, 1.0cm, and 2.0cm. The light transmittance in the specimens was observed by voltage regulator, resistance box, Light dependence resistor (LDR) panel and a plywood box. Light transmittance was found to be 7.0 to 10.0% for optical fiber specimens and 0.2 to 1.5% in case of glass rods specimens.

Soumyajit and Avik (2013) used six specimens of translucent concrete with varying P.O.F ratio as 1%, 2%, 3%, 4%, 5%, and 6% with the diameters of P.O.F as 1mm. Optical Power meter with wavelength range of 400-1100nm. Incandescent lamp of 200W and Halogen lamp of 500W were taken to provide incident light. It was observed that for halogen lamp, transmittance varied as 0.29%, 0.59%, 0.98%, 1.41%, 1.83% and 2.36%; For incandescent lamp transmittance was observed to be 0.41%, 0.82%, 1.22%, 1.72%, 2.15%, 2.59%. This difference was observed because light scattering angle of the chosen lamp was different.

Figure 2.2(a) shows the variation of light transmittance percentage of incident light with respect to varying percentage of plastic optical fiber and Figure 2.2(b) shows varying wavelength of incident light. The light transmittance was observed to increase with increase in percentage of plastic optical fiber; the affect of changing wavelength was not much.

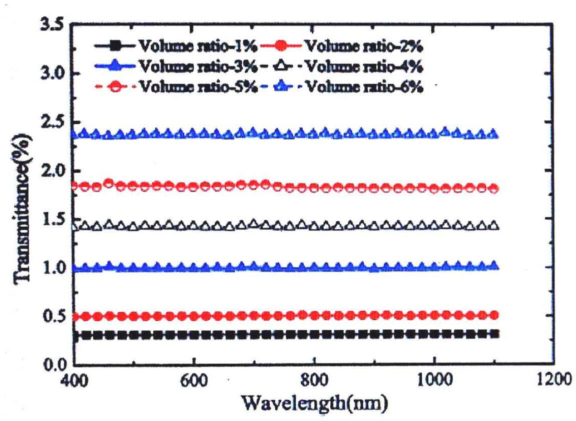

Fig 2.2(a): Transmittance (%) vs wavelength (nm)

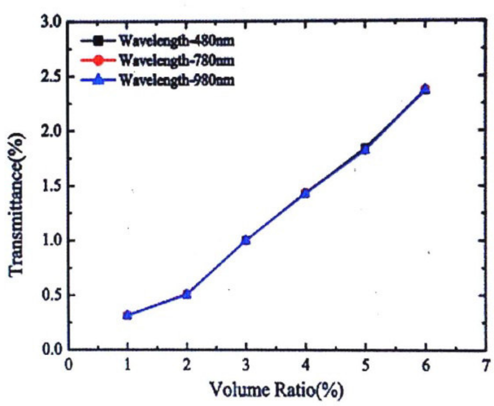

Fig 2.2(b): Relationship b/w POF volume and transmittance (%)

Figure 2.2: Light guiding test by Halogen Lamp

Figure 2.3(a) shows transmittance due to the incandescent lamp and Figure 2.3 (b) shows Light transmittance relationship with different POF volume i.e. at 1%, 2%, 3%, 4%, 5%, 6%. The discrepancy in different light sources is because the light scattering angle is different of the chosen lamp and POFs absorption of light is more in case of incandescent lamp than by halogen lamp.

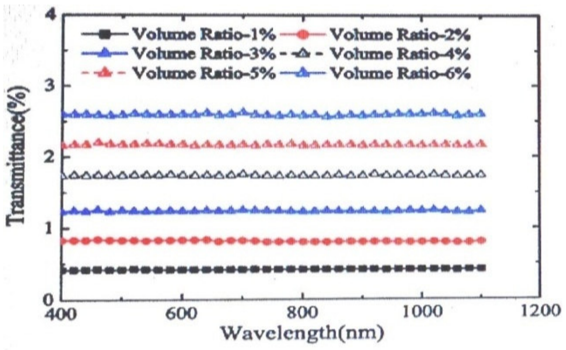

Fig 2.3(a): Transmittance (%) vs wavelength (nm)

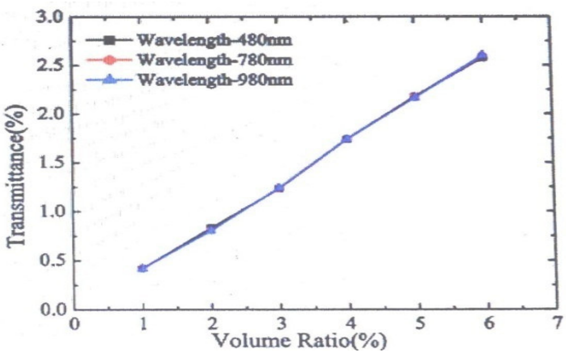

Fig 2.3(b): Relationship b/w POF volume and transmittance (%)

Figure 2.3: Light guiding test by Incandescent lamp

Ahuja, Mosalam.M. et al (2014) investigated translucent concrete. They used fibers to channel solar radiation into the building to reduce the dependence on artificial lighting requirement during the day. They presented a geometrical ray-tracing algorithm to simulate light transmission properties of a panel of translucent concrete. Refer to Figure 2.4, it was concluded from the investigation that a tilt angle of 30 degree for the panel transmitted the maximum amount of light among all the tilt angles considered and it is natural because fibers absorb radiation of sunlight. Using this tilt angle, they calculated rate at which sunlight radiation is absorbed by the translucent concrete panel and conducted a preliminary study to estimate the solar heat gain coefficient of the panel for possibility of using it instead of glazing material by the construction industry.

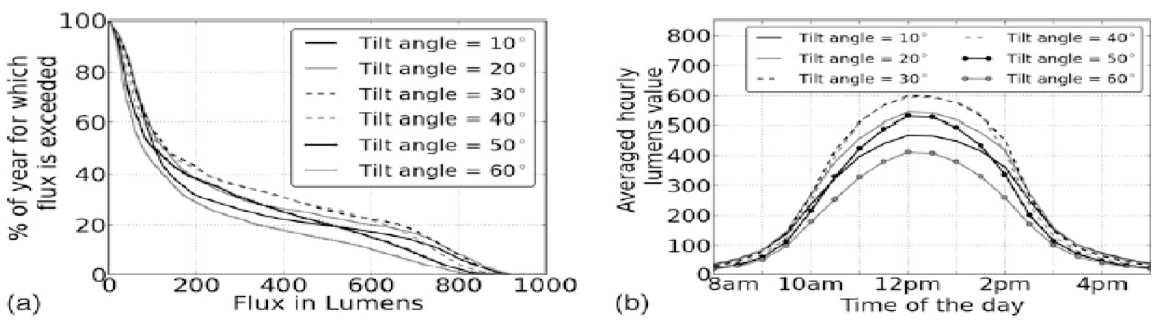

Figure 2.4: Calculations of lumens flux for a fiber volume ratio of 10.56% based on day time

Fig 2.4: Calculations of lumens flux for a fiber volume ratio of 10.56% based on daytime (8 a.m. to 5 p.m.): (a) luminous flux availabilities as a percentage of a non-leap year such that a flux value is exceeded; (b) average luminous flux calculated for each hour of the whole year.

2.2.2 Compressive strength of light transmitting concrete

Compressive strength is most important property for any material that is intended to be used for construction. Any material cannot be used for construction until it satisfies the requirements about sufficient strength to withstand all the loads that will be acting on it after construction during its useful life.

Various studies have been carried out to investigate the compressive strength of light transmitting concrete. It depends upon the grade of concrete used, percentage of fiber, spacing of fiber. It is observed that strength is not affected much and it is acceptable, as the fiber in light transmitting concrete acts as reinforcement and thereby, not reducing the strength much.

Momin (2014) used glass rod cubes of sizes 150mmx150mmx150mm with spacing 1.5cm,3.0cm,4.5cm, 1:1.5:3.0 cement/sand/aggregates w/c 0.50, and for plastic optical fiber 100mmx100mmx100mm cubes with fiber spacing 0.5cm, 1cm,2cm, grade 1:2.0 cement/sand and w/c 0.45. It was observed that for concrete with glass rods, compressive strength was 24.57,25.1,25.27N/mm^2 for 1.5cm, 3cm, 4.5cm rod spacing and for optical fiber, 22.2, 21.3, 20.7N/mm^2 with 0.5cm, 1cm, 2cm spacing.

Siddartha Reddy et al. (2013) made 8cmx8cmx8cm mortar cube with cement/sand/water 1.0:2.0:0.45, plastic optical fiber 5%. They observed that 7-day and 28 day compressive strength was 29.68N/mm^2 and 37.03N/mm^2. Hence, it could be concluded that strength do not reduce much as compared to conventional concrete and it can be used in green buildings to get accreditation under daylight saving with this.

Zhi Zhou et al. (2009) used 100mmx100mmx100mm cubes with cement/sand/water 1:2.0:0.44. and POF ratios 0.0%, 3.14%, 3.80%4.52% and 5.3%. They found that the test loads at failure are 201.8, 201, 195.7, 182.2kN for P.O.F ratios 0.0%, 3.14%, 3.80%, 4.52% respectively. From Table 2.1, they observed that P.O.F proportion less than 5% affects the compressive strength by about 10%.

Table 2.1: Data of the compression performance of the transparent concrete block.

Failure load (kN)	**Fiber Volume Fraction**			
	0.0%	3.14%	3.80%	4.52%
Test data (kN)	190.5	190.0	219.0	180.5
Test data (kN)	220.0	228.0	194.0	182.0
Test data (kN)	195.0	185.0	174.0	184.0
Average	201.8	201.0	195.7	182.2

Shanmugavadivu et al (2014) used 150mmx150mmx150mm cubes, Figure 2.5 compares the strength of the specimens with the M20 concrete and test results proved that the efficiency is more in all the aspects.

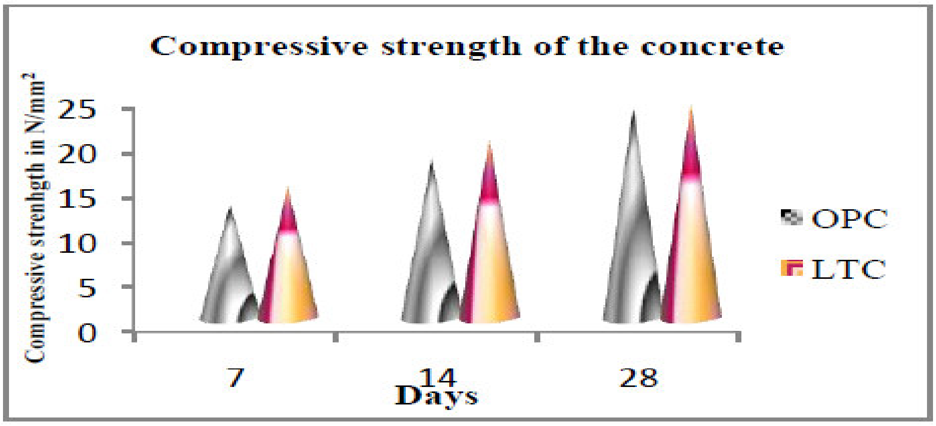

Fig 2.5: Compressive strength of the concrete. *OPC- ordinary Portland cement concrete. *LTC- light transmitting concrete

E.jimenez (2014) used different percentage of glass fibers 0%, 5%, 10%, 15% and 30%, and observed that 28day compressive strength varied as 34.2, 29.5, 34, 30.3, 26.9N/mm² as given in Table 2.2.

Table 2.2: Compressive strength with different addition of glass fibers.

	Glass 0%	Glass 5%	Glass 10%[a]	Glass 15%	Glass 30%
Strength 7 days	33.6	28.9	33.6	29.9	25.7
Strength 28 days	34.2	29.5	34	30.3	26.9

Bashbash et al (2013) used 5cmx5cmx5cm cubes with plastic optical fiber 4% with diameters of fiber as 1.5cm, 2.0cm, 2.5cm, and 3.0cm. Refer to Fig. 2.6 they observed that for the same percentage of fiber, the larger diameter fiber concrete has higher strength.

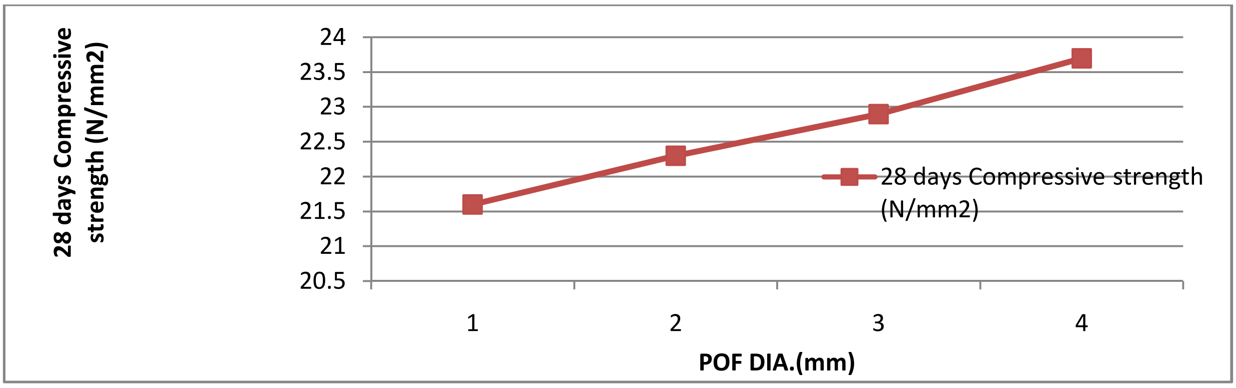

Fig 2.6: 28 day Compressive strength results v/s fiber diameter at fiber content of 4%.

2.2.3. Permeability properties

Paul Soumyajit, Dutta avik et al (2013) [14] used the chloride diffusion coefficient method (or electric flux method) to test the impermeability property of translucent concrete, which can rapidly evaluate the permeability of concrete by measuring the electric energy through concrete. Concrete cylinders of 100mm diameter and 50 mm height, with 0%, 3% and 6% POF volume ratio were chosen for the test. The electric energy is recorded by the electric flux detector. Moreover, in order to evaluate the effect of interface bonding on the impermeability property, each model of specimen has been divided in two types viz. one covered with epoxy resin at the border of POF. It was observed that total electric current without covering with epoxy resin was 1897.8C, 3152.6C and 3602.2C for 0%, 3% and 6% respectively as illustrated in Figure 2.7 and comparison of total electrical energy traversing the block in Figure2.8. For 3% and 6% covered by epoxy resin it reduced to 2147C and 3357.8C.

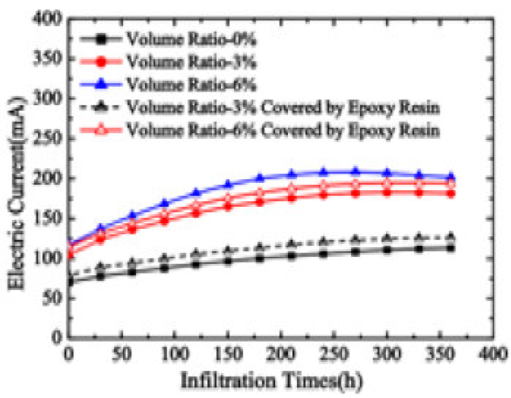

Fig 2.7: Relationship of strength versus time.

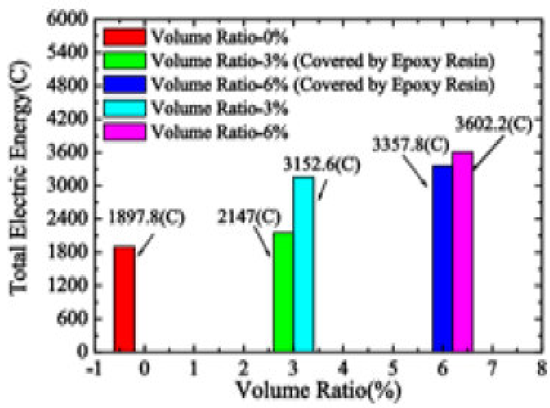

Fig 2.8: Comparison of total electrical energy traversing the block

2.3 Gaps in Litreature

From the above literature, it is evident that very limited research has been done on the light transmitting concrete. Various properties of light transmitting concrete have not been explored sufficiently. Their is need for furthur research work on light transmitting concrete. It is an ecofriendly product that reduces the dependence on artificial source of energy for optical activities. The strength parameters, light transmittance characteristics, Air and water permeability, durability aspects and other experimental properties of light transmitting concrete have not been determined sufficiently. Thus, need arises to study the experimental properties of light transmitting concrete, such as light transmittance properties and compressive strength parameters because it has not been done on M20 and M25 LTC (light transmitting concrete) using photometer device.

Thus, the present study is carried out to study the experimental properties of light transmitting property.

CHAPTER - 3

EXPERIMENTAL PROGRAM

3.1 General

To achieve the objectives of the experimental study, an extensive experimental program was planned, which included studying the light transmittance characteristics, evaluation of compressive strength of the light transmitting concrete for various plastic optical fiber ratio.

This chapter outlines the experimental program planned in detail. The properties of the materials used for the preparation of light transmitting concrete, concrete mix details, casting, curing, details of tests performed on the specimens of light transmitting concrete are presented in this chapter.

3.2 Test Program

The following test program was planned to investigate the light transmittance, and compressive strength of the light transmitting concrete.

To obtain the physical properties of the constituents of light transmitting concrete i.e. ordinary Portland cement (PC), sand, coarse aggregate, plastic optical fiber and water, tests were carried out as per relevant Indian Standard Codes of Practice.

1. Obtaining mix proportions for concrete.
2. Casting and curing of specimens as per the requirement of the test.
3. Testing of specimens for light transmittance characteristics, and compressive strength.
4. Analyzing the observations to obtain various properties of the light transmitting concrete.

3.3. Materials used

The properties of materials used in light transmitting concrete are determined in laboratory as per relevant code of practice. Different materials used in this experimental study were cement, sand, coarse aggregates (passing 10mm IS sieve), plastic optical fiber and water. Results of the tests conducted to determine physical properties of materials are reported and discussed in this section. The materials in general conformed to the specifications laid down in the relevant Indian Standard Codes.

3.3.1 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 color i.e. grey with light greenish shade. 43 grade of cement is popular cement with low heat of hydration and long life of concrete structures. Now a days OPC (Ordinary Portland Cement) grade 43 is being used widely for general construction work.

3.3.2 Fine aggregate

The aggregate most of which passes 4.75mm IS sieve is called as fine aggregates. River sand has been sieved from IS 1.18mm sieve (Table 3.2). It did not contain any impurities such as vegetable matters, organic matter, lumps, etc. The various properties conform to IS: 383-1970 as given in Table 3.1 & Table 3.2.

Weight of sample taken = 1kg.

Sand corresponds to grading zone II of IS 383-1970 (Table 4, clause 4.3). According IS 383-1970, % passing of fine aggregates (shown in Table 3.2) satisfies grading zone II sand.

Table 3.1: Sieve analysis of fine aggregate.

Sieve size (mm)	Retained weight (g)	% weight Retained	Cumulative % weight Retained	% Passing
10	0	0	0	100
4.75	0	0	0	100
2.36	0	0	0	100
1.18	0	0	0	100
600µ	624	62.4	62.4	37.6
300 µ	192	19.1	81.5	18.5
150 µ	155	15.5	96.5	3.5
Total			240.4	

Fineness modulus of fine aggregate = 240.4/100 = 2.404.

Table 3.2: Physical properties of fine aggregate.

Physical tests	Values
Specific gravity	2.63
Fineness modulus	2.404
Bulk density(compacted) (kg/m^3)	1982
Bulk density (loose) (kg/m^3)	1668

3.3.3 Coarse aggregate

The material which is retained on 4.75 mm sieve is known as coarse aggregate. Coarse aggregate passing 10 mm IS sieve was used in this work conforming to IS: 383-1970, with properties as given in Table 3.3 & Table 3.4 respectively. Maximum size of aggregate was limited to 10mm as higher size of aggregate hindered the placement of POF (plastic optical fiber).

Weight taken = 2 kg.

Table 3.3 Sieve analysis of 10mm down coarse aggregate

Sieve size (mm)	Retained weight (g)	% weight Retained	Cumulative %weight Retained	% Passing
20	0	0	0	100
16	0	0	0	100
12.5	20	1	1	99
10	236	11.8	12.8	87.2
4.75	1456	72.8	85.6	14.4
2.36	269	13.45	99.05	0.95
Pan	19			_
Total	**2000**		**198.45**	_

The aggregate is single sized aggregate as per IS 383-1970.

Fineness modulus of coarse aggregate = (198.45+400)/100 = 5.94. Coarse sieve analysis was done which was upto 2.36 mm sieve and below it, 1.18mm, 600 microns, 300 microns, and 150 microns sieves must have 100% retention (i.e. accounts for 400).

Table 3.4 Physical properties 10mm down of coarse aggregate.

Physical tests	***Values***
Specific gravity	2.5
Fineness modulus	5.94
Bulk density (compacted) (kg/m^3)	1649.7
Bulk density (loose) (kg/m^3)	1452.9

3.3.4 Plastic optical fiber

An optical fiber is a flexible, transparent fiber made of extruded glass (silica) or plastic, slightly thicker than a human hair (Figure 3.1 and Figure 3.2). It can function as a waveguide, or "light pipe", to transmit light between the two ends of the fiber. The field of applied science and engineering concerned with the design and application of optical fibers is known as fiber optics.

Optical fibers (Figure 3.1) are widely used in fiber-optic communications, where they permit transmission over longer distances and at higher bandwidths (data rates) than wire cables. Fibers are used instead of metal wires because signals travel along them with less loss and are also immune to electromagnetic interference. Fibers are also used for illumination, and are wrapped in bundles so that they may be used to carry images, thus allowing viewing in confined spaces. Specially designed fibers are used for a variety of other applications, including sensors and fiber lasers.

Optical fibers typically include a transparent core surrounded by a transparent cladding material with a lower index of refraction. Light is kept in the core by total internal reflection. This causes the fiber to act as a waveguide. Fibers that support many propagation paths or transverse modes are called multi-mode fibers (MMF), while those that only support a single mode are called single-mode fibers (SMF). Multi-mode fibers generally have a wider core diameter, and are used for short-distance communication links and for applications where high power must be transmitted. Single-mode fibers are used for most communication links longer than 1,000 meters (3,300 ft).

Optical fibers have a wide number of applications. They are used as light guides in medical and other applications where bright light needs to be shown on a target without a clear line-of-sight path. In some buildings, optical fibers route sunlight from the roof to other parts of the building (see non imaging optics). Optical fiber lamps are used for illumination in decorative applications, including signs, art, toys and artificial Christmas trees. Swarovski boutiques use optical fibers to illuminate their crystal showcases from many different angles while only employing one light source. Optical fiber is an intrinsic part of the light-transmitting concrete.

An optical fiber (Figure 3.2) is a cylindrical dielectric waveguide (non-conducting waveguide) that transmits light along its axis, by the process of total internal reflection. The fiber consists of a core surrounded by a cladding layer, both of which are made of dielectric materials. To confine the optical signal in the core, the refractive index of the core must be greater than that of the cladding. The boundary between the core and cladding may either be abrupt, in step-index fiber, or gradual, in graded-index fiber.

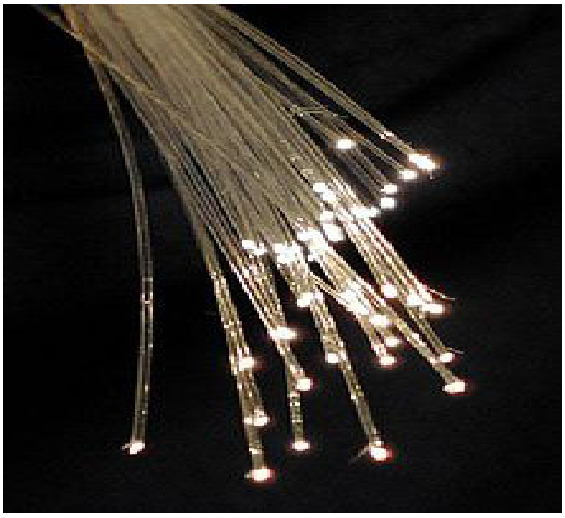

Fig 3.1: Bundle of optical Fiber

These can have diameters up to 2mm. POF allows to transmit sunlight or light from any source to pass through it. When used in concrete, these fibers transmit light that falls on one face of the concrete to the other face. There is little or no signal loss in the POF when light passes through its core. P.O.F (Figure 3.2) of diameter 0.5mm has been used for preparing samples. Refer to Figure 3.2 which shows transmitting of light through plastic optical fibers.

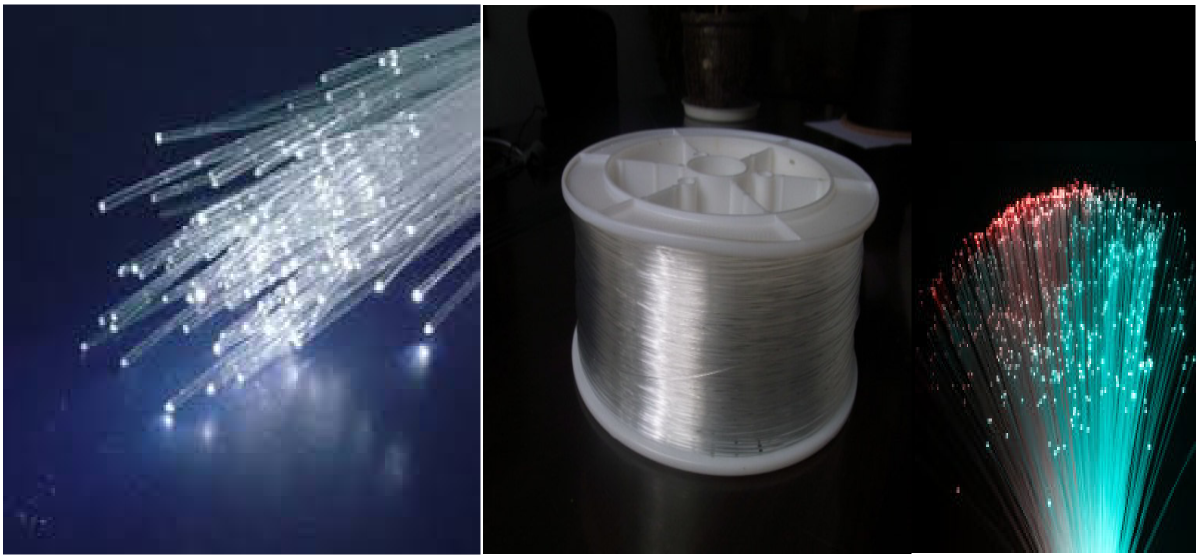

Fig 3.2: Showing plastic optical fiber.

3.3.5 Water

Clean potable water was used from the tap in concrete laboratory. This water was used in making concrete specimens. Water was free from suspended solid and organic materials, which might have affected the properties of fresh and hardened concrete. The pH value of the water was 7.5 (checked form litmus paper strips which is method of testing pH).

3.4 Preparation of Light Transmitting Concrete Specimens

3.4.1. Preparation of specimen for light transmittance and compressive strength test

As per ASTM, cubes for testing compressive strength should be between 5cmx5cmx5cm to 15cmx15cmx15cm. In this study, wooden moulds of size 10cmx10cmx10cm (shown in Figure 3.4) were prepared with the perforated wooden sheets (see Figure 3.3) because size of cube can be of 15cmx15cmx15cm and 10cmx10cmx10cm for the test of compression strength according to IS 516 – 1959 and the largest nominal size of aggregate does not exceed 20mm, so it is better to use 10cmx10cmx10cm cubes. Wooden sheets which are used for electrical switch boards were used. Perforated wooden sheets with varying number of drilled holes (Figure 3.3) were attached in the moulds, for preparing cubes of varying percentage of P.O.F (plastic optical fiber). The diameter and spacing of the holes depended on the percentage of fiber in the cube. Fig 3.3 shows perforated wooden plate through which plastic optical fibers passes and Fig 3.4 shows moulds with fibers placed.

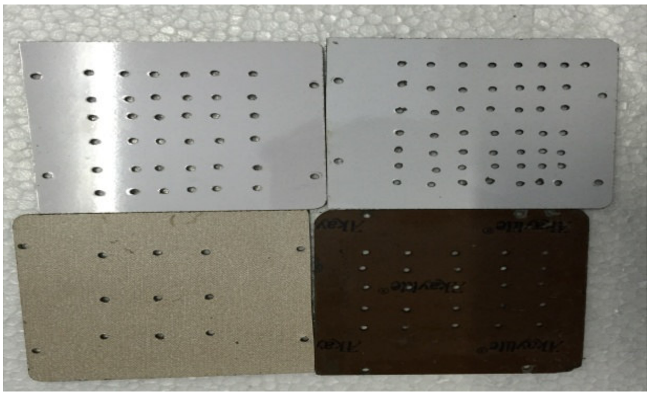

Fig 3.3: Perforated wooden plate

Fig 3.4: Moulds with fibers placed

3.4.2 Preparation of light transmitting concrete specimens

Concrete of two mix proportions i.e. 1:1.5:3 (cement: sand: aggregates) with water cement ratio 0.45 and 1:1:2 with w/c 0.45 (see Figure 3.6) were used for preparing cubes of 10cmx10cmx10cm size (see Figure 3.4). Varying percentage of Plastic Optical Fibers such as 0.25, 0.50, 0.75, 1.0, 1.25, 1.50, 1.75, 2.0, 2.25, 2.50, 2.75, 3.0, 3.25, 3.50, 3.75, 4.0% (as given in Table 3.6) were used to study strength and light transmittance characteristics of POF (plastic optical fiber) because greater than 4% POFs volume will deteriorate the strength and it will be of no use as well.

After placing fibers, plates were fitted to the wooden moulds (Figure 3.4). Concrete was poured in the moulds while placing moulds on the vibrating table (see Figure 3.5). By giving vibrations concrete was completely filled in the moulds with no void left in between the fibers. The cubes were compacted properly on the vibrating table (Figure 3.5). POF of 0.5mm diameter were used in the cubes. After casting (see Figure 3.7), cubes is then immersed in water for 7 days.

Fig 3.5: Vibrating table for compaction

Fig 3.6: Preparation of cubes

Fig 3.7: Cubes after curing for 7 days

Table 3.6 below shows number of 0.5 mm diameter POF (plastic optical fiber) strands (Figure 3.1 and figure 3.2) as per percentage of plastic optical fiber used in the cubes.

The diameter of 1 POF (plastic optical fiber) = 0.5 mm

Area of 1 POF (plastic optical fiber) = 0.197 mm²

Size of cube = 10 cmX10cmX10 cm. Area of cube = 100 cm²

For 1 % POF (plastic optical fiber) = 100 X 1/100 = 1 cm².

Area required for 1 % POF = 1 cm² = 100 mm²

Number of POF used for 1% = (1 X 100 mm²)/0.197 = 500(approx.) as shown in Table 3.5.

Table 3.5: Showing number of plastic optical fiber strands as per percentage of fiber used

Percentage of plastic optical fiber	Number of plastic optical fiber strands used
0.25%	125
0.50%	250
0.75%	375
1.00%	500
1.25%	625
1.50%	750
1.75%	875
2.00%	1000
2.25%	1125
2.50%	1250
2.75%	1375
3.00%	1500
3.25%	1625
3.50%	1750
3.75%	1875
4.00%	2000

3.5 Experimental Properties Studied

3.5.1. Test for light transmittance property

Light transmittance test was performed to study the light transmittance characteristics. It is most important test to be performed, as main purpose of translucent concrete is to transmit light. Transmittance ratio is found by measuring intensity of incident light and transmitted light. Intensity of light is measured with the photometer. Photometer measures intensity of light in terms of lumens.

Experimental setup for light guiding property test

For studying light guiding property of light transmitting concrete, samples of P.O.F volume ratios of 0.25%, 0.5%, 0.75%, 1%, 1.25%, 1.5%, 1.75%, 2%, 2.25%, 2.5%, 2.75%, 3%, 3.25%, 3.5%, 3.75%, and 4% were cast. The transmittance was measured by Photometer (or lux meter) that measures intensity of light in lumens, having range of 0.1 to 1,00,000 lux. The incandescent lamp with 100W (1,500 lumens), 200W (3,000 lumens) and halogen lamp with 500W (11,000) were chosen as light source because the range of photometer is divided in three classes i.e. class A, class B, class C as given in Table 3.6 and Table 3.7 indicates that these three light sources i.e. two incandescent lamp of 100W (1,500 lumens) and 200W (3,000 lumens), and halogen lamp of 500W (11,000 lumens) satisfies light intensity of three classes. So we simply used incandescent light source i.e. 100W and 200W, and halogen lamp of 500W to determine transmittance % of light, it may be of any light intensity. A wooden box with light source (Figure 3.8) fitted on one face, photometer (see Figure 3.8) was attached on other face in the box, such that all light transmitted from the sample falls in the box of photometer. Readings of transmitted light were noted from photometer (Figure 3.8). Precaution was taken to see that the box of photometer was correctly attached and all transmitted light fall in the box.

Table 3.6:- Range of photometer for measuring light intensity divided in three classes

Range of photometer	**Light intensity in lumens**
Class A	1 to 2,000 lumens
Class B	2,000 to 10,000 lumens
Class C	10,000 to 20,000 lumens

Fig 3.8: Experimental setup to find light guiding property of light transmitting concrete

Calibration of photometer was done using incandescent light sources of various intensity viz. 15watts, 40watts, 60watts, 100watts, 200watts. The calibration table for photometer is given below:

Table 3.7: Calibration table for photometer used for measuring intensity of light

Intensity of light used for calibration (watts)	Light intensity recorded by photometer (lumens)
15	225
40	600
60	900
100	1500
200	3000

3.5.2. Compressive strength test on light transmitting concrete

Cubes of size 10cmx10cmx10cm of various plastic optical fiber ratio i.e. 0.25%, 0.5%, 0.75%, 1%, 1.25%, 1.5%, 1.75%, 2%, 2.25%, 2.5%, 2.75%, 3%, 3.25%, 3.5%, 3.75, 4% were prepared. Three specimens of each POF percentage and mix proportion were prepared according to procedure mentioned above. The cube specimens were cast at an average temperature of 24^{0} C and demoulded after 24 hours. After casting cubes, curing was done for 7 days. The cubes were tested for 28 day compressive strength on Compression testing machine (see Figure 3.9) (3000 KN capacity). All the specimens were tested on compression testing machine at constant loading rate as per IS: 516-1959. The cubes failure after compression test as illustrated in Figure 3.10.

Fig3.9: Compressive strength test setup showing light transmitting concrete cube.

Fig3.10: Crushed LTC (Light Transmitting Concrete) cubes after failure

3.6 Summary

The test program as planned to achieve the objectives of the experimental study has been described in this chapter. The physical properties of the various constituents of light transmitting concrete such as cement, fine sand, coarse aggregate, plastic optical fiber and water are presented in this chapter. Preparation of moulds for specimens, and method of casting of specimens for various tests has been reported. The testing procedure for various experimental tests i.e. Light transmittance test, compressive strength test of light transmitting concrete are discussed in detail.

CHAPTER - 4

RESULTS AND DISCUSSION

4.1 General

Experimental investigations were carried out to study the light transmittance characteristics using incandescent light source of 100Watts (1,500 lumens) and 200 Watts (3,000 lumens) and Halogen light source of 500 Watts (11,000 lumens) intensity. Compressive strength characteristics of mix proportion 1:1.5:3 with water cement ratio 0.45 and mix proportion 1:1:2 with w:c ratio 0.45 were determined.

The detailed analysis and discussion of test results as obtained from the test program is presented in the following sections.

4.2 Light Transmittance Characteristics

Table 4.1 shows light transmittance of light transmitting concrete with different POF ratios i.e. 0.25%, 0.5%,0.75%, 1%, 1.25%, 1.5%, 1.75%, 2%, 2.25%, 2.5%, 2.75%, 3%, 3.25%, 3.5%, 3.75% and 4% using incandescent light source of intensity 100Watts (1500lumens) and 200Watts (3000lumens)in terms of lumens. As shown in Table 4.1, it is observed that light transmittance varied from 0.34% to 5.62% for 100W light source, for 200W light source it varied from 0.26 to 5.40%. Refer to Fig. 4.1, shows the relationship between POF (plastic optical fiber) volume and transmittance (%) of two incandescent light sources i.e. 100W and 200W and their comparison.

Table 4.1: Light passing characteristic using incandescent source of light of 100W and 200W

POF volume Ratio	Incandescent light source of 100W (1500 lumens)		Incandescent light source of 200W (3000 lumens)	
	Transmittance (lumens)	Transmittance Ratio %	Transmittance (lumens)	Transmittance Ratio%
0.25%	5.2	0.34%	7.8	0.26%
0.50%	12.8	0.85%	17.6	0.58%
0.75%	16.6	1.10%	28.4	0.94%
1.00%	24.4	1.62%	39.4	1.31%

1.25%	26.8	1.78%	46.8	1.56%
1.50%	31.0	2.06%	55.6	1.85%
1.75%	36.2	2.41%	68.0	2.26%
2.00%	40.4	2.69%	81.8	2.72%
2.25%	43.8	2.92%	92.6	3.08%
2.50%	48.0	3.20%	105.2	3.50%
2.75%	53.6	3.57%	111.8	3.72%
3.00%	59.1	3.94%	121.4	4.04%
3.25%	63.8	4.25%	128.0	4.26%
3.50%	74.2	4.94%	139.6	4.65%
3.75%	77.6	5.17%	150.0	5.00%
4.00%	84.4	5.62%	162.2	5.40%

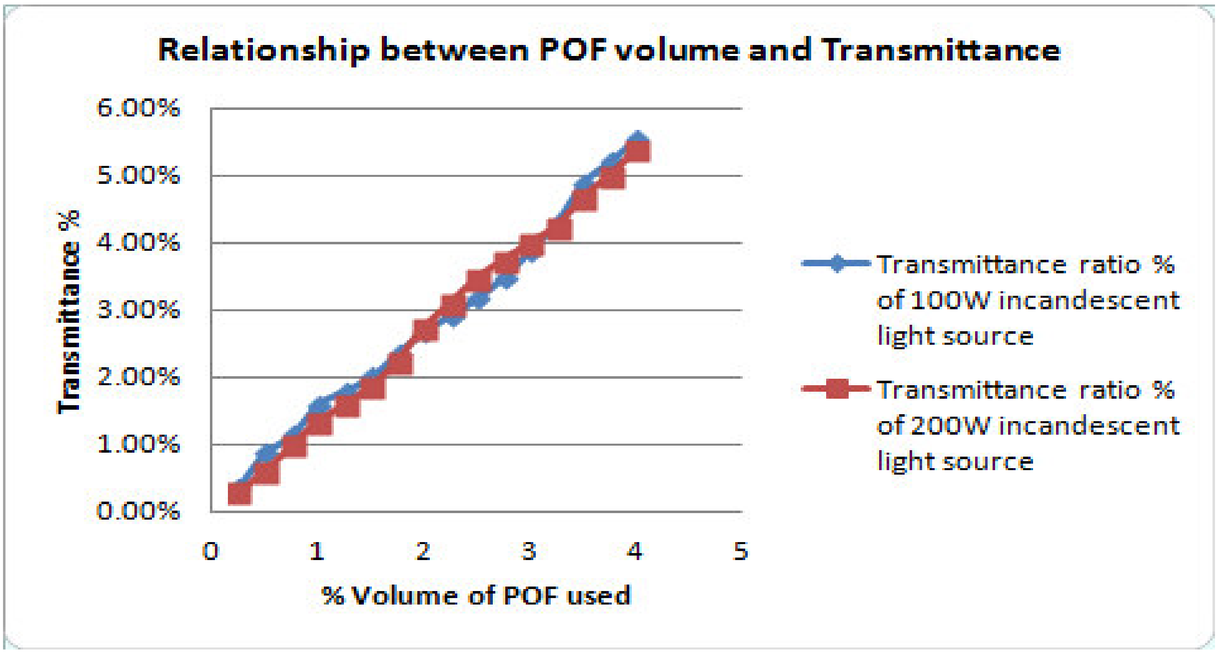

Figure 4.1: Light passing % for various volume fractions of POF used for incandescent light source

Table4.2 below shows light transmittance characteristics of light transmitting concrete when we use Halogen light source of 500Watts (11,000 lumens) for various POF volume ratios 0.25%, 0.5%, 0.75%, up to 4%. As given in Table 4.2, it was observed that light transmittance varied from 0.32% to 4.78% for various POF volume ratios. Refer to Fig. 4.2, shows the relationship between POF (plastic optical fiber) and transmittance (%) of halogen light source i.e. 500W (11000 lumens). The relationship between the POF (plastic optical fiber) volume and transmittance (%) and variation of light intensity through different proportion of POFs (plastic optical fibers) volume using halogen light source as illustrated in Figure 4.2.

Table 4.2: Light passing characteristic using Halogen source of light of 500W (11000 lumens)

POF volume Ratio	Halogen light source of 500W (11000 lumens)	
	Transmittance (lumens)	Transmittance Ratio %
0.25%	35.4	0.32%
0.50%	67.2	0.61%
0.75%	104.0	0.94%
1.00%	137.2	1.24%
1.25%	159.6	1.45%
1.50%	180.4	1.64%
1.75%	196.0	1.78%
2.00%	249.6	2.26%
2.25%	271.2	2.46%
2.50%	313.1	2.84%
2.75%	356.5	3.24%
3.00%	388.8	3.53%
3.25%	435.6	3.96%
3.50%	453.8	4.12%
3.75%	495.6	4.50%
4.00%	526.4	4.78%

As it clear from observations of experimental set up of LTC (light transmitting concrete) that transmittance of light is different in case of different light source so it can be understood by observing the scattering of light source used, when 100W (1500 lumens) incandescent light source was used its percentage of incidence is different as compared to 200W (3000 lumens) incandescent light source and same was the case with 500W (11000 lumens) halogen light source and propagation of light incidence of plastic optical fiber as shown in Figure 1.7. As 100W (1500 lumens) incandescent light source was having more incidence over cube as light source being small but as we move to 200W (3000 lumens) incandescent and 500W (11000 lumens) halogen light source its incidence decreases and at the same time it can be observed as percentage of POF (plastic optical fiber) increases, difference can be seen to seize.

It was observed that for 100W incandescent lamp transmittance % varied from 0.34% to 5.62% (see Table4.1), for 200W incandescent lamp transmittance % varied from 0.26% to 5.40% (see Table 4.1) and for 500W halogen lamp transmittance % varied from 0.32% to 4.78% (see Table 4.2) with same percentage of POF (plastic optical fiber) i.e. from 0.25% to 4%.This discrepancy in different light sources is because the light scattering angle is different of chosen lamp and POFs (plastic optical fibers) absorption of light is more in case of incandescent lamp than be halogen lamp.

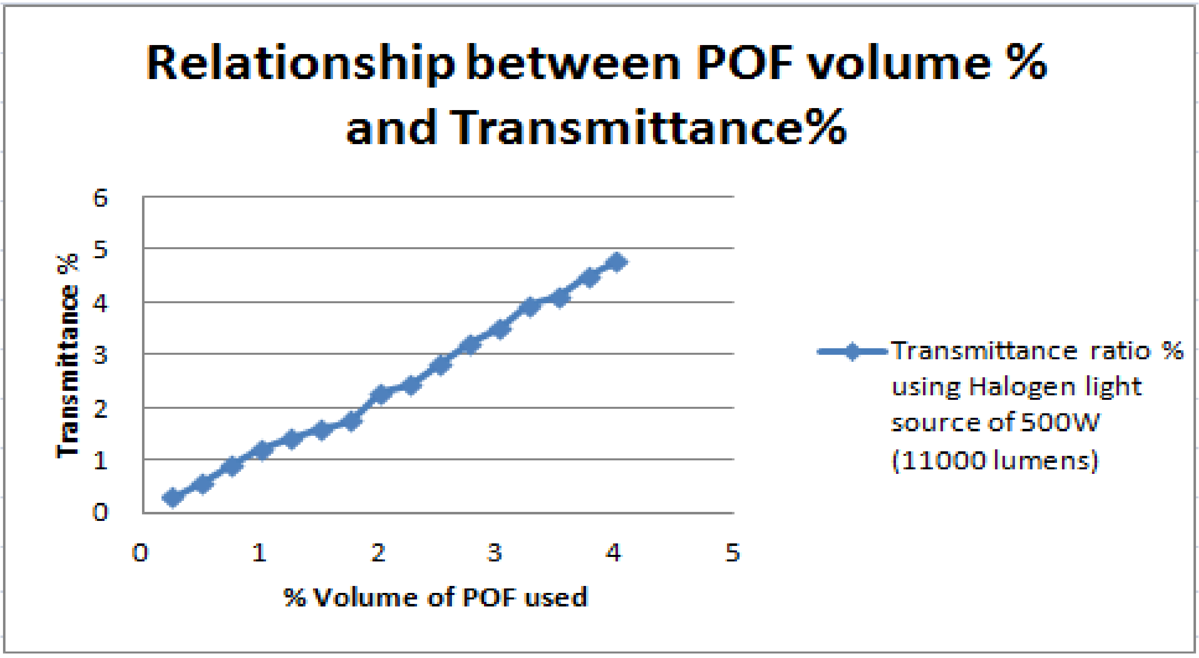

Figure 4.2: Light passing % for various volume fractions of POF used for Halogen light source

4.3. Compressive Strength

28 days compressive strength results of concrete cubes for two mix proportions and volume fraction of POF varying 0.25% to 4% are given in Table 4.3 and Table 4.4. Figure 4.3 shows cube placed in compressive strength test machine and Figure 4.4 shows cubes after failure in compression test, cracks occurred on side of cubes and these are minor cracks (see Figure 3.10 and Figure 4.4) because it may be due to weak bond between plastic optical fibers and concrete on side of cubes.

Fig4.3: Compressive strength test Fig4.4: crushed cubes after failure in compression test

Table 4.3: 28 day compressive strength of M20 light transmitting concrete with water/cement ratio of 0.45.

Proportion of Optical Fiber Used	28 day Compressive Strength of Cube 1 (in N/mm^2)	28 day Compressive Strength of Cube 2 (in N/mm^2)	28 day Compressive Strength of Cube 3 (in N/mm^2)	Average 28 day Compressive strength (in N/mm^2)
0.00%	26.8	26.5	25.8	26.3
0.25%	25.4	25.2	24.8	25.1
0.50%	25.3	25.5	24.9	25.2
0.75%	25.6	25.9	25.0	25.5
1.00%	25.7	25.5	25.6	25.6
1.25%	25.9	25.7	26.0	25.8
1.50%	26.2	26.0	26.3	26.1
1.75%	26.6	26.4	26.8	26.6
2.00%	27.2	26.9	27.0	27.0
2.25%	26.5	26.1	26.3	26.3
2.50%	26.3	26.1	25.8	26.0
2.75%	25.8	25.2	25.7	25.5
3.00%	25.0	24.8	24.6	24.8

3.25%	24.1	23.9	23.7	23.9
3.50%	23.7	23.1	23.0	23.2
3.75%	23.1	22.9	22.7	22.9
4.00%	22.6	22.2	22.1	22.3

Table 4.4: 28 days compressive strength of M25 light transmitting concrete with water/cement ratio of 0.45.

Proportion of Optical Fiber Used	28 day Compressive Strength of Cube 1 (in N/mm^2)	28 day Compressive Strength of Cube 2 (in N/mm^2)	28 day Compressive Strength of Cube 3 (in N/mm^2)	28 day Average Compressive strength (in N/mm^2)
0.00%	31.4	30.9	31.8	31.3
0.25%	30.06	30.4	30.2	30.4
0.50%	30.9	30.1	30.0	30.3
0.75%	31.0	30.7	31.5	31.1
1.00%	31.6	31.3	31.8	31.5
1.25%	32.0	31.7	31.1	31.6
1.50%	31.4	31.9	31.8	31.7
1.75%	32.1	32.2	31.9	32.0
2.00%	32.8	32.2	31.7	32.2
2.25%	32.0	31.6	32.7	32.1
2.50%	31.5	31.9	31.8	31.7
2.75%	31.7	31.4	31.5	31.5
3.00%	31.3	31.8	31.0	31.3
3.25%	30.8	30.6	30.2	30.5
3.50%	30.0	30.6	30.1	30.2
3.75%	29.4	29.6	29.9	29.6
4.00%	29.0	28.9	29.4	29.1

The test results, as graphically indicated in Figure 4.5 and shown difference in compressive strength of M20 and M25 light transmitting concrete. Refer to Figure 4.5; it was observed that compressive strength of M25 light transmitting concrete is more or less constant upto

4% POF (plastic optical fiber) volume, which for M20 grade it is more or less constant upto 3% of POF (plastic optical fiber) and thereafter decreases at slower rate.

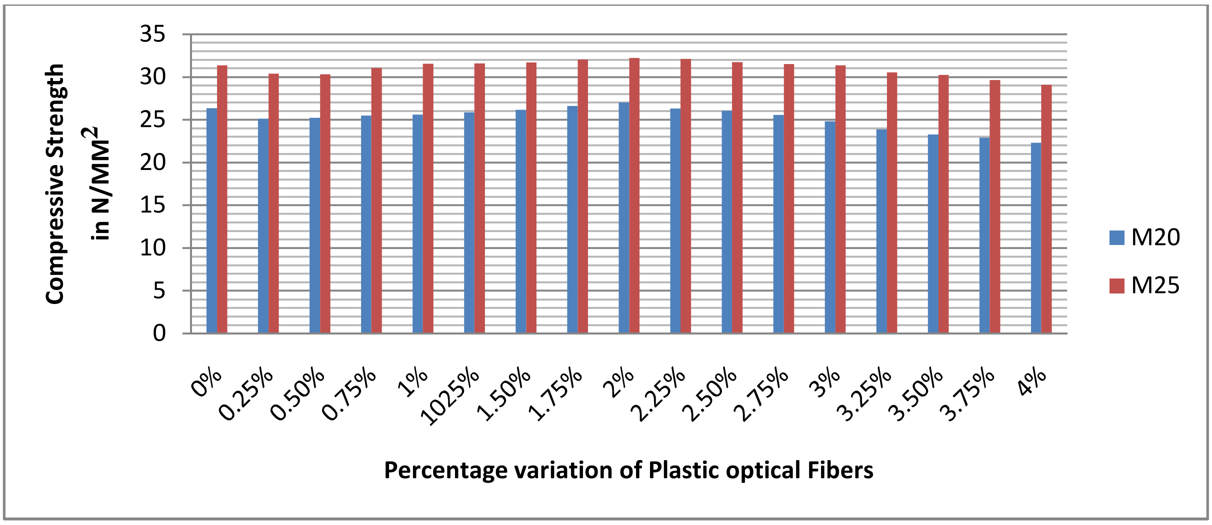

Figure 4.5 shows compressive strength of both M20 and M25 LTC (Light Transmitting Concrete).

4.4. Discussion

Tests were conducted over cube samples having different variations of fibers shows slight variation of strength which is more or less constant in entire range for M25 LTC (light transmitting concrete) and constant upto 3% POFs (plastic optical fibers) volume and then starts to decrease at slower rate. It may be due to large percentage increase in fiber starts to weaken the chemical bond of concrete.

As title suggests, we are interested in intensity of light so that we can deter the dependence on artificial sources of light and depend on natural light source and make our planet green and sustainable for future generations.

CHAPTER - 5

CONCLUSIONS

5.1 Conclusions

Through this experimental study, it is concluded that light transmitting concrete is very advantageous construction material. It can be used in green buildings to increase the energy efficiency of the structure. It is surely the future of civil engineering construction material, and in future it will be highly demanded. The following conclusions can be drawn based on the results of this experimental work.

1. The light transmittance ratio up to 5.62% was achieved by using 4% Plastic Optical Fiber ratio. Thus, it proves that Light transmitting concrete can be very efficiently used in Green buildings. It will ensure natural sunlight inside the buildings throughout the day.
2. From the compressive strength results, it can be seen that strength of light transmitting concrete is not affected much as compared with control concrete. For concrete of M20 concrete, 28 day compressive strength decreased from 26.3 N/mm^2 of control concrete to 22.3 N/mm^2 for concrete with 4% of POF. For concrete of M25 concrete, 28 day compressive strength decreased from 31.3 N/mm^2 to 29.1 N/mm^2 for concrete with 4% of POF. The maximum decrease in compressive strength is 16.1% for M20 and 7.5% for M25.
3. Strength of cubes is good and failure of cubes was due to minor cracks only because it was observed that while conducting compressive strength test over cubes failure was not inside or from centre, it was on side of cubes and it may due to weak bond strength of POFs (plastic optical fibers) and concrete on sides, this shows that Plastic optical Fiber does not affect the strength much. The strength is best at 2% of POF, after that the strength begins to reduce as the POF ratio increases.
4. Light transmitting concrete requires skilled labor for its manufacture, as POF should be properly placed in concrete, and special attention is needed while placing concrete, to ensure proper preparation of light transmitting concrete.

5. Light transmitting concrete can be used in structure to make them architecturally and aesthetically beautiful, as various types of glowing patterns can be made with this concrete.
6. Cost of manufacture of light transmitting concrete is also high due to plastic optical fibers used and care needed during its preparation. But, its cost is fully justified because of its usefulness as eco-friendly, energy efficient, aesthetically beautiful, sustainable, etc.
7. By using this concrete, higher energy efficiency ratings can be ensured as it is a green building construction material.
8. Natural sunlight content for optical activities in the building can be increased in the building by using light transmitting concrete, which is very good for health.

5.2 Scope for Future Study

Very limited research has been done on light transmitting concrete so far, and there is vast scope of future research on its various aspects regarding durability, mechanical property, light guiding characteristics, etc.

The following proposals are made for future study

- This study was carried out to study light transmitting characteristics, and compressive strength of light transmitting concrete. It can be extended for investigating the split tensile strength, flexural strength, ultra sonic pulse velocity, air and water permeability etc.
- Durability aspects such as, alkali resistance, sulphate resistance, effect of sea water test, RCPT (Rapid Chloride Penetration Test), can also be carried out.
- By varying the angle of incident light, its effect can be found on the transmittance characteristics.

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