Experimental Study on Light Transmission Concrete by Using Plastic Optical Fibre

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Abstract: *Light transmission concrete (LiTraCon) is used in fine architecture as a facade material and for cladding of interior walls etc. It uses sunlight as a light source to reduce the power consumption of illumination. It is used for architectural purpose for aesthetical view of the building. The main purpose of this project is to make a light transmission concrete by using plastic optical fiber. In this project the optical fiber size is 2mm. The cast specimens contain 95% of concrete and 5% of plastic optical fibers. The concrete considered is cement mortar which contain fine aggregate and cement. The fibers are disturbed in shortest direction to increase the transparency of concrete. The average weight of conventional concrete is 1.5% more than light transmission concrete. The average compressive strength of light transmission concrete is 44.62% less than conventional concrete.*

Key words: Transparent concrete, plastic optical fibre.

1. INTRODUCTION

Concrete is a necessary construction material in a building. To prepare concrete thewidely used composite materials are naturalsand, coarse aggregate, binding materialsuchas cement and water.

Translucent Concrete is also known as transparent concrete because it has light-transmitting properties due to the presence of optical fibres. Fibres act as aggregates and carry light through them, flexible transparent fibres are made of glass or plastic. These concrete works on “nano-optics”, the fibre is placed directly on top of each other. Transparent concrete or Lit racon (light transmitting concrete) can be produced as prefabricated building blocks, the trick is done with embedding parallel fibres of glass or plastic in an exclusive concrete mixture. By arranging the high numerical aperture Plastic Optical Fibbers (POF) or big diameter glass optical fibre into concrete, Optical fibres transmit light so effectively that there is virtually no loss of light conducted through the fibres Optical fibre have very good light guiding and sensing capability. The light is because of its properties.

Objectives:

- To find the compressive strength of ordinary concrete.
- To find the compressive strength of Transparent concrete.
- To compare compressive strength of ordinary concrete with transparent concrete.

Construction of optical fiber:

An optical fiber typically consists of three parts, namely core, cladding, and outer jacket. The material used to make the core and cladding of an optical fiber is generally silica, plastic, or glass. The outer jacket of the fiber is made up of PVC. The size of the core typically varies between 50 µm to 500 µm. The size of the cladding varies as per the requirement. To achieve total internal reflection, the refractive index of the material should always be slightly higher than the refractive index of the material or the air present around it. This is the reason why the refractive index of the core is always maintained higher than the refractive index of the cladding. The cladding prohibits the data from being lost or distorted. The purpose of the

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cladding is not only to support the total internal reflection phenomenon but also to provide a protective coating to the fiber. The main purpose of a jacket layer wrapped around the fiber is to provide protection against the rough and uneven surface. It shields the core of the fiber from getting damaged and from suffering deformations at a micro-level. The optical fiber cables that are laid under the seas and oceans are more prone to suffer data losses, hence they contain more protective coatings around the core than the cables that are present simply beneath the ground.

Types of optical fiber:

On the basis of the refractive index, type of construction material used, and the mode of propagation of light, there exist a number of optical fibers in the market. Broadly the optical fiber can be classified into three categories, given below:

On the basis of Refractive index:

Step index optical fiber:

The refractive index of the core and cladding of a step-index optical fiber is uniform throughout the length. If you cut a step-index optical fiber and notice its cross-sectional view, you can easily observe the step change in the refractive index of the core and the cladding.

Graded index optical fiber:

The refractive index of the core and cladding of a graded-index optical fiber is not uniform throughout the length. If you cut a graded-index optical fiber and notice its cross-sectional view, you can easily observe that the change in the refractive index of the core and the cladding decreases as the radial distance increases. The refractive index profile of the core and cladding of a graded-index optical fiber plotted on graph paper gives a parabolic shape.

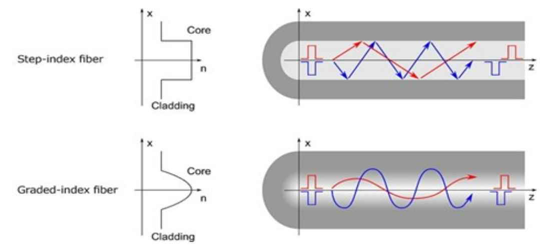

Fig.1 Graded index optical fibre

On the basis of material used:

Plastic optical fibre: As the name itself suggests, plastic optical fibre is made up of plastic. The core element of such fibres is typically constructed with the help of chemical substances such as polymethylmethacrylate.

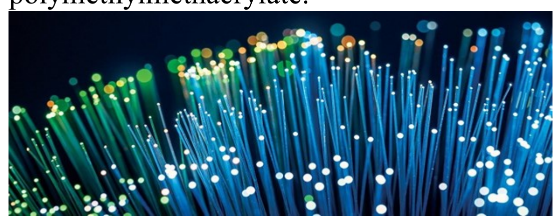

Fig 2 Plastic optical fibre

Glass optical fibre:

The strands of glass optical fibres are made up of fine glass**.**

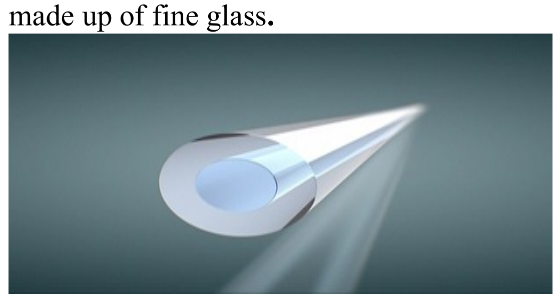

Fig.3 Glass fibre

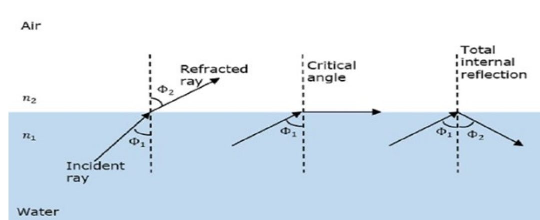

Fig.1.4 Working process of light in optical fibre

To communicate a piece of information between the transmitter and the receiver via optical means, a network of optical fibre cables is laid beneath the surface of the earth. The data that is required to be communicated is first translated into binary format. This binary coded data is then transmitted by the transmitter to the cellular base station in the form of electromagnetic radiations. The 'ones' contained by the data are represented by a high-frequency signal; whereas, the 'zeroes' are represented with the help of a comparatively low-frequency signal. The cell tower picks up the electromagnetic radiations transmitted by a cellular device or a transmitter. When a high-frequency signal is traced, a light pulse gets generated. Similarly, when a low-frequency signal is detected, a light pulse is not generated. The light pulses are transmitted to the receiver through the optical fibre cables. The light used in optical fibre communication is highly directional in nature. When such a ray of light is made to strike the inside of the fibre at an angle that is greater than the critical angle, then the light tends to undergo multiple reflections along the surface of the fibre. This allows the signal to propagate from one end of the fibre to the other end, thereby communicating information between the transmitter and the receiver end. The phenomenon of total internal reflection does not lead to degradation of the light quality; hence the signal can travel long distances without losing the data or the information. Also, the twisted shape of the cable has no effect on the quality of data contained by the ray of light that travels through it. The signal travelling through the fibre tends to undergo various losses and a certain amount of attenuation due to absorption and scattering of light radiation. The reconstruction of the lost signal is performed by adding amplifiers to the circuit.

LITERATURE REVIEW

Visakh. V. A **[1]**2015Experimental Study on Transparent Concrete by using Plastic Optical Fiber Transparent concrete can be developed by adding optical fiber or large diameter glass fiber in the concrete mixture. The transparent concrete has good light guiding property and the ratio of optical fiber volume to concrete is proportion to transmission

A. Magesh Abishek.P, Arunachalam.M, Karthikraj.N, Madhan kumar. B **[2]**2017performance evaluation of light transmitting in m20 grade concrete. The compressive strength of Light Transmitting cement mortar block was found to be as same as the normal concrete strength due to vibration of each layer for a certain period. The compressive strength of Light transmitting concrete was found to be as same as the normal strength requirement for M20 grade concrete. Light transmittance for the samples was found to 5 to 10% in cement mortar blocks and 3 to 6% in concrete blocks.

S. Loganayagan, A. Mohan raj, V. Hariharan. Praveen**[3]**2022Experimental Study on Light Transmitting Concrete Using Plastic Optical FiberThis study investigates the compressive behavior of light transmitting concrete. The properties of Plastic Optical Fiber (POF) used are investigated. This paper contributes to new alternatives of concrete for property constructio

Gurpreet Singh, DhandeUttam, Adurkar Ajith, Prof. Mrs G.A. Sayyed **[4]**June 6 2016experimental investigation of litracon by using plastic optical fiber the transmission of light through Lit racon cube is depends upon percentage of optical fiber used of that surface area. The transmission of light increases with increase in percentage of optical fiber.

Ismail Luhar, SalmabanuLuhar, Pericles Savva, Antreas**[5].** Light Transmitting Concrete the LTC has excessive potential to be employed for buildings and infrastructures; however, the investigations on LTC are still in an initial stage and its industrial applications currently less competitive than other new innovative construction materials.

R. Divahar1 P.S. Aravind Raj **[6]** 24thfeb 2022Strength and light transmitting characteristics of translucent concrete using plastic optic fibers. A novel architectural material called transparent concrete can be developed by adding optical fiber or large diameter glass fiber in the concrete mixture.The transparent concrete has good light guiding property and the ratio of optical fiber volume to concrete is proportional to transmission. The transparent concrete does not lose the strength parameter when compared to regular concrete and also it has very vital property for the aesthetical point of view. It can be used for the best architectural appearance of the building. It can also be used in areas, where the natural light cannot reach with appropriate intensity. This new kind of building material can integrate the concept of green energy saving with the usage self-sensing properties of functional materials

Danial Navabi**[7]** Developing light transmitting concrete for energy saving in buildings. A smart transparent concrete is aesthetically pleasing. POF-based transparent concrete could be regarded as an art which could be used in museums and specific exhibitions rather than just a construction material. Although ease of construction is to be compromised, the material is bound to be accepted universally due to it advantages. With the concept of green technology catching up, electrical supply, being supplemented by natural sources, it becomes absolutely necessary to utilizethe natural resource. Although „Litracon" has yet to be made available for commercial use, it has already been suggested that buildings made with the material could save electricity that would otherwise be required for daytime lighting. When light transmitting properties were examined, the test results have revealed that the produced concrete can be cut into different shapes without losing its transparent property and it can be used as architectural concrete on roofs of special buildings.

Ahmed Tahwia Mansoura University · Structural engineering department **[8]** Mechanical and Light Transmittance Properties of High-Performance Translucent Concrete June 2022 Concrete is one of the most widely used materials in the construction industry. Concrete is homogeneous mixture of cement, sand, coarse aggregate and water. Cement production gives rise to CO2 emissions and being responsible for about 5% of the CO2 emissions in the world. The availability of the natural river sand is decreasing due to the over exploitation of river sand. In order to reduce the usage of cement and river sand, partial replacement can be done and an eco-friendly concrete should be produced. Rice Husk ash and used Foundry sand are used as partial replacement materials. Fiber reinforced concrete is one of the recent trends in construction industry, using of the fibers reduces cracks in the concrete and improves tensile strength. In this study Literatures are reviewed to understand the light transmission concrete.

P. subathra, S.P. Sangeetha **[9]** October 2021 Performance of Pellucid Concrete by using Optical Fibers. Concrete is one of the widely used composite materials. The demand for concrete in the construction field is increasing day by day. Cement is used as a binder material in concrete which is highly energy intensive and emits CO2 to the atmosphere which is responsible for global warming. So, to protect pollution it is necessary to find the alternatives for OPC which is eco-friendly with the environment. Geopolymer is a best solution that utilizes industrial by-products as a binding material and is similar to cement. In this study, fly ash and GGBS is used as a binder material to prepare a geopolymer concrete for replacing cement by 100% to investigate the fresh and hardened properties in addition with different percentages of basalt fibers.

Shing Mei Chiew**[10]** May 2020 Development of light-transmitting concrete. The light-transmitting concrete is good architectural material. It was reported strength of concrete found to be increase till 4% optical fiber and decreased at 5% ophicalcites. As we increased the percent of optical fiber from 2%to 3%, light intensity increased and was high during afternoon. It was reported that, change in surface area of concrete block led to decrease in the light intensity. Light transmitting concrete give's aesthetical view to buildings and is energy efficient. As per discussion, cost of light-transmitting concrete is high but cost is justified because of its advantages

It was observed that the addition of optical fibers had
slightly increased the water absorption characteristics
and it increases with increase in diameter. Water absorp-
tion values for 10 mm spacing are slightly higher than the
fibers placed at 20 mm interval. The increase in the volu-
metric percentage of fibers enhanced the water absorp-
tion of concrete due to the higher PFLTC contents in
the specimens is due to the fiber/matrix in the transition
zone

1. Methodology

2.1 Tests on cement

Fineness of cement

The fineness represents the particle size of cement. It should not be greater than 90-microns when sieved as per IS standard. The fineness of cement is determined by the sieving method. It is measured by the ratio between coarse particles (which retained in 90-micron sieve analysis) to the fineness particles (which passed through the sieve analysis). IS code – The test should be conducted as per IS code 4031 Part 1[8], and the test sample should be collected as per IS code 3535.

Apparatus Required

1. Lid
2. Pan
3. Nylon brush
4. 90-micron sieve
5. Weighing balance – nearly weight 10 mg

Test Procedure

A quantity of 100g cement should be taken and weighed as W1.

The sample cement should be free from lumps. Nicely stir the cement with a clean rod to spread the fineness to the whole area.

Now place the cement sample into the 90-micron sieve and close it by the lid.

Then shake the sieve gently for at least 15 minutes. Now note down the weight of retained cement particles in the sieve as W2.

Calculation

Fineness of cement = (W2/W1) x 100. The test has to be done with at least three samples from the same batch. The average value is the fineness of the cement. The ratio between the test samples should not be greater than 0.2% if else then repeat the test. The retaining cement particles in sieve should not be more than 10%.

The fineness ratio of ordinary Portland cement is
Ordinary Portland cement – 10%.

Normal consistency

The standard consistency of cement paste is defined as the percentage of water added to the 300gm weight of cement. which will permit a Vicat plunger having a 50 mm length and 10 mm diameter to penetrate in cement paste to a depth of 33-35 mm from the top of the mould.

Apparatus

- Vicat apparatus
- Balance
- Gauging Trowel,
- Stop Watch

Procedure of Consistency Test of Cement
The procedure of the consistency test of cement is straightforward and can be performed in a laboratory or on the construction site. The following are the steps involved in the test:

1. The standard consistency of any cement is achieved when cement permits the Vicatplunger to penetrate to a point 33 to

35 mm from the bottom of the Vicat mould.

2. First of all, take about 300 gm of cement into a tray and is mixed with a known percentage of water by weight of cement.
Let's start with 26% of water and then it is increased by 2% until the normal consistency is achieved.

3. Prepare cement paste by adding 26% of water to 300 gm of cement and mixing it well taking care that the time of mixing is not less than 3 minutes, nor more than 5 min and the mixing shall be completed before any sign of setting occurs.
The mixing time shall be counted from the time of adding water to the dry cement until commencing to fill the mold.

4. Fill the Vicatmold having 80mm diameter and 50mm height with this paste, mold shall be resting upon a non-porous plate (glass plate). After completely filling the mould with cement paste level the top surface removes any extra cement from the top and makes it smooth. Sometimes, shaking should be done to remove any extra air.

5. Place the cement paste-filled mould together with the non-porous resting plate, under the consistency test plunger in the Vicat apparatus.

6. Now, Lower the plunger such that it touches the top surface of mould filled with paste, and quickly release, allowing it to sink into the paste. This process shall be done quickly after filling the mould.

7. Observe the penetration value on the Vicat apparatus scale. It should be around 33 to 35 mm from the mould filled with cement paste. It is not, then increase the % of water and repeat the above steps.

8. Repeat the whole process with varying % of water to cement, until the penetration value comes to 33 mm to 35 mm from the top of mould toward the bottom of the mould.

Weight of cement = 300 gm,
% of water = 26% to 38 % (normal consistency of OPC range between this)

Take 26% of water for the test, then the amount of water to be added in 300 gm of cement will be
= 300 x 26%
= 300 x (26/100)
= 78 ml
Then add 78 ml of water to 300 gm of cement, prepare well mix and test.
If the test is not successful, increase % of water by 28 %.
Take 28% of water for a test, then the amount of water to be added in 300 gm of cement will be
= 300 x 28%
= 300 x (28/100)
= 84 ml
Then add 78 ml of water of 300 gm of cement prepare a good mix and test.
The result of Normal consistency: The depth of penetration is 6 mm.

3.3.12 Tests on fine Aggregates

3.3.13 Fineness modulus

The fineness modulus of sand is a measure of the average particle size of sand particles. It is calculated by adding the cumulative percentages of sand particles retained on each of a specified series of sieves and dividing the sum by 100. The fineness modulus of sand ranges from 2.2 to 3.2.

To find the fineness modulus of fine aggregate required IS sieve are sizes of 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.3mm, and 0.15mm.

Fineness Modulus of Sand Test Apparatus

- Sieves as per IS standards
- Mechanical sieve shaker(optional)
- Dry oven
- Digital weight scale

Sample Preparation

Sample preparation for fineness modulus of sand is given as under. Take a sample of sand in a pan and placed it in the oven at a temperature of approximately 100-110°C.After drying, take the sample out of the oven and note down its weight using a digital weighing scale.

Sieve Analysis of Fine Aggregate

Following is the test procedure for the fineness modulus of the sand test,

1) Take the sieves and arrange them in descending order with the largest sieve on top.

2) If a mechanical shaker is used for shaking, then put the sieve set in position on the mechanical shaker and pour the sample in the top sieve & then close it with the sieve plate.

3) Then switch on the machine and shaking of sieves should be done at least for 5 minutes.

Sieve Analysis for Fineness Modulus of Sand

4) If the shaking is done manually (by the hands) then pour the sample in a top sieve and close it then holds the top two sieves and shake it inwards and outwards, vertically and horizontally.

5) After some time shake 3 and 4 and finally last sieves simultaneously.

6) After sieving, record the sample weights retained on each sieve. Then find the cumulative weight retained.

7) Finally, determine the cumulative percentage retained on each sieve.8) Add all cumulative percentage values and divide by 100 then we will get the value of fineness modulus.

Calculation of F.M. of Sand

Let us assume the dry weight of the sample = 1000gm

After sieve analysis, the values that appeared are tabulated below.

Sieve size	Weight retained(g)	Cumulative weight retained (g)	Cumulative percentage weight retained (%)
4.75mm	0	0	0
2.36mm	100	100	10
1.18mm	250	350	35
0.6mm	350	700	70
0.3mm	200	900	90
0.15mm	100	1000	100
Total			**275**

Fineness o

Hence, Fineness modulus of Sand = (Cumulative % retained) / 100

= (275 / 100)

= 2.75

Range of Fineness of Modulus

The following table indicates sand fineness modulus value ranges from 2.6 to 3.2.

Types of Sand	Fineness Modulus (F. M) Value
Fine Sand	2.6 – 2.6
Medium Sand	**2.6 -2.9**
Coarse Sand	2.9 -3.2

Sand F. M. Ranges

Fineness modulus with respect to various zones of sand according to IS 383-1970 are given in the table below.

Sieve size	Zone1	Zone2	Zone3	Zone4
10mm	100	100	100	100
4.75mm	90-100	90-100	90-100	95-100
2.36mm	60-95	75-100	85-100	95-100
1.18mm	30-70	55-90	75-100	90-100
0.6mm	15-34	35-59	60-79	80-100
0.3mm	5-20	8-30	12-40	15-50
0.15mm	0-10	0-10	0-10	0-15
Fineness Modulus	4.0-2.71	3.37-2.1	**2.78-1.71**	2.25-1.35

3.3.14 Specific gravity

The considerable specific gravity is around 2.65 for sand. Which is mainly the ratio of the weight of the given volume of aggregates to the weight of an equal volume of water. But normally in the road construction ranges from about 2.5 to 3.0 with an average of about 2.68. This is mainly composed of quartz have a specific gravity range from 2.65 to 2.67. Inorganic clay generally ranges from 2.70 to 2.80. Soils with large amounts of organic matter or porous particles have specific gravities below 2.60. Some range as low as 2.00. Tropical iron-rich laterite, as well as some lateritic soils, usually have a specific gravity of between 2.75 and 3.0 but could be higher. Water absorption shall not be more than 0.6 per unit by weight.

2. RESULTS AND DISCUSSIONS

Table 1.1 Weight of conventional concrete

concrete	1st sample	2nd sample	3rd sample	Average weight
Weight	8.030 kg	8.100 kg	8.080 kg	8.070 kg

Table 1.2 Weight of LiTraCon

concrete	1st sample	2nd sample	3rd sample	Average C.S.
Compressive strength	29.96 KN	26.98 KN	30.38 KN	29.10 KN

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Table 1.3 Compressive strength of conventional concrete

Table 1.4 Compressive strength of light transmission concrete

concrete	1st sample	2nd sample	3rd sample	Average C.S.
Compressive strength	20.18 KN	20.33 KN	22.13 KN	20.17KN

Table 1.4 Compressive strength of light transmission concrete

DISCUSSIONS

- The average weight of conventional concrete is 8.070 kg.
- The average weight of light transmission concrete is 7.950 kg.
- The average compressive strength of conventional concrete is 29.10 N/mm^2.
- The average compressive strength is 20.17 N/mm^2.
- The average weight of light transmission concrete is less than conventional concrete because in the light transmission concrete there is fully replacement of coarse aggregates. Instead of coarse aggregates we used plastic optical fibre.
- The compressive strength of light transmission concrete is also decreased as compared with conventional concrete.
- It is used building for good lighting and architectural design.

CONCLUSION

- The average weight of conventional concrete is much more than light transmission concrete.
- The average compressive strength of light transmission concrete is less than conventional concrete.
- It is used in the building for good lighting and architectural design.

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