Study of Light Transmittance by using Optical Fibers

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Abstract— Rapid growth in population has led to dense building constructions with cement and concrete with large internal lightening requirement. To achieve energy efficiency, new and innovative materials are required for sustainable construction practices. This remains as a challenging task for engineers and other building professionals to design and promote low energy requirement buildings in a cost effective and environmentally responsive way. In the present work, light transmitting blocks of size 200mmx100mmx100mm were prepared by using plastic optical fibers. In this work, plastic optical fibers of 0.38mm diameter were used. Fibers are inserted in mortar bricks in order to investigate the light transmitting potential and also the strength parameter i.e., Compressive strength. From this, the optimum fiber percentage and optimum fiber number with location is determined and it can be used to observe the flexural crack behaviour pattern in various specimens such as prisms which is of standard size 50cmx10cmx10cm and also in beams of size 130cmx18cmx20cm with mesh, fiber alone and a combination of both mesh and fiber and has been compared with that of conventional concrete.

Key words: Cement, Fine aggregate, Coarse aggregate, Optical fibers, Water, Wire mesh, HYSD Steel, Compressive strength, Flexural behaviour

I. INTRODUCTION

Infrastructure development is always indicative of the development of a country. Rapid urbanization has led to the development of many innovative materials and technology for construction. Today we are living in a world where energy expenditure and environmental problems have escalated to a global scale. The brightness of indoor environment is entirely maintained by artificial lightening, which consumes a large number of resources.

A. Objectives:

The following are the objectives

- To find optimum water cement ratio and also optimum fiber percentage in the manufacture of light transmitting blocks so as to ensure good workability for the mix.
- To improve performance of concrete by using plastic optical fibers as an inhere material for reinforcing.
- To study the strength properties such as compression and flexure of conventional concrete in comparison with that of light transmitting concrete.
- To study the load deflection behaviour (load carrying capacity) in beams with conventional concrete as well as light transmitting concrete.

II. LITERATURE REVIEW

Zhou*et.al.* (2006) carried out experimental studies using plastic optical fiber (POF) in concrete and investigated its light transmitting, mechanical and self-cleansing properties. They concluded that an optical fiber can be easily combined with concrete and that the POF could provide a steady light transmitting ratio. The smart transparent concrete can be regarded as a green energy saving construction material.

Montilla*et.al*, (2015) studied that light incident on concrete undergo any of three optical phenomena viz., reflection, absorption or transmittance. A comparison of the three optical phenomenon's were investigated with respect to different parameters such as type of cement, size of aggregate, and thickness of mortar. From the experimental studies, masonry blocks having low light absorption were considered to be effective.

III. MATERIALS

A. Cement:

In this work, ordinary Portland cement of 43grade is used.

S. No	Property	Results Obtained	Specification as per IS – Code
1	Normal consistency, %	31%	26-33%
2	Initial setting time, min	60min	Should not be less than 30min
3	Final setting time	360min	Should not be more than 600min
4	Specific gravity	3.15	3.15

Table 1: physical properties of cement

B. Fine aggregate:

In this work, the conventional river sand passing 4.75mm IS sieve having a specific gravity of 2.535 with a fineness modulus of 2.6 is used.

S. No	Property	Results Obtained	Specification as per IS – Code
1	Water content corresponding to maximum bulking, %	4	<10%
2	Fineness Modulus of Sand	2.6	2.4-3.1
3	Specific gravity	2.535	2.65-2.7

Table 2: physical properties of River sand

C. Optical fibers

An optical fiber is a flexible, transparent, fiber made of glass (silica), or plastic having a diameter slightly thicker than that of human hair. Optical fibers are used to transmit light between two ends of the fiber and are commercially available of different diameters such as 0.75mm, 1mm, 1.5mm and 2mm. For the present studies, optical fibers viz., plastic optical fiber of 0.38mm diameter is used.

D. Working principle of optical fibers

The optical fibers works on the principle of Total internal reflection (TIR)

1) Total internal reflection:

Total internal reflection is a phenomena which occurs when a ray of light travels from denser to rare medium such that

the angle of incidence is greater than that of critical angle, the ray reflects back into the same medium this can be termed as "total internal reflection".

2) Water:

Water is the key ingredient, which when mixed with cement forms a paste that binds the aggregate together. Potable water available in laboratory is used for casting all the specimens and the quality of water is found to satisfy all the requirements as per IS: 456-2000.

3) Wire mesh:

A square mesh of size 2mmx2mm is used in order to observe its strength property.

4) Coarse aggregate:

The retained material on IS 4.75mm sieve can be termed as coarse aggregate. The properties are tabulated in table 3

S.NO	Property	Result Obtained
1	Specific gravity	2.73
2	Fineness modulus	6.34
3	Water absorption	0.7%

Table 3: physical properties of coarse aggregate

IV. METHODOLOGY

- The manufacturing process of light transmitting concrete is almost same as that of conventional concrete. Only the optical fibers are spread throughout the aggregate and cement mix. There are various methods for the installation of optical fibers into the concrete.
- One method is that small layers of the concrete are poured on top of each layer and is infused with fiber and is then connected. Thousands of strands of optical fibers are casted into concrete in order to transmit light which is either natural or artificial.
- But in this present work, masonry blocks of size 200mmx100mmx100mm were used. For preparing light transmitting blocks, optical fibers were placed in the direction parallel to 200mmx100mm.direction.Here for manufacturing of masonry blocks, a thermocol of size of base plate is taken and plastic optical fibers are placed at uniform spacing and mortar is poured till the top level of the mould and is been compacted and finished. This is shown in figure 1.

Fig. 1: shows the arrangement of fibers

A. Different Configurations

For this work, different configurations were prepared in order to choose the best among the different configurations by conducting preliminary studies. These configurations were shown in figure 2.Preliminary studies or trail and error method includes trying with different water cement ratio such as 0.45, 0.50, 0.55 and different percentages of fibers such as 2%, 4% by volume.

` In general, light transmitting concrete is produced by adding 4% to 5% of optical fibers by volume into the concrete mixture. But in the present project, light transmitting mortar is produced for 2% and 4% by volume for plastic optical fibers and for these two percentages, light transmitting masonry blocks of different configurations were prepared. For instance, 2% of plastic optical fibers corresponds to 36 strands and were embedded in 3 different configurations i.e., a bundle of 6 strands at six different locations, bundle of 9 strands at four different locations and a bundle of 12 strands at 3 different locations provided uniform spacing

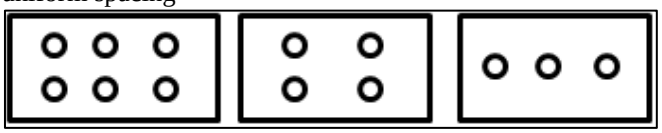

Fig. 2: 2% of plastic optical fibers embedded in 3 different configurations

B. Experimental Program

- For manufacturing light transmitting concrete block, cement mortar cubes of size 200mmx100mmx100mm are used which is same as that of standard brick size.
- The selected proportion is 1:3 (1 part of cement to 3 parts of sand)
- Cement used is 1100gm and 3300gm of fine aggregate respectively per one block of size 200mmx100mmx100mm.
- A thermocol is cut of a size equal to that of base plate and is placed at the bottom.
- Now, the optical fibers are placed or immersed into the thermocol of required or desired shape.
- Now the cement mortar is prepared by using w/c as 0.45, 0.5, 0.55, for choosing the optimum water content and optimum fiber percentage.
- After that, start filling the cement mortar in layers and by giving hand compaction such that the optical fibers placed in the thermocol should not get damaged or cut.
- After completely filling the mould with mortar, the mould should be finally placed on a vibrator for final compaction.
- The vibration is done for 3 to 5 seconds to obtain final compaction and smooth finish.
- The top layer is leveled and finishing is done for aesthetic use.

Similarly, take 4% of fibers which corresponds to 72 strands and were embedded in 3 different configurations i.e., a bundle of 12 strands at six different locations, a bundle of 18 strands at four different locations, a bundle of 24 strands at 3 different locations and the procedure which has been followed above is to be adopted for this, the strength parameters has to be calculated. With this, the optimum water cement ratio and the optimum fiber percentage are determined.

Based on this observation, the same methodology that has been carried out is to prisms which are of standard

size 50cmx10cmx10cm.A wire mesh is taken and is placed in the prism and the strength parameter such as flexure is determined and has been compared with that of nominal mix of M20.

V. TEST RESULTS

A. Compressive strength

The compressive strength test is conducted on a specimen of size 200mmx100mmx100mm mortar cube for 2% , 4% of fibers and the test results can be compared with that of nominal concrete or conventional concrete mortar cube for 7,14 &28 days respectively.

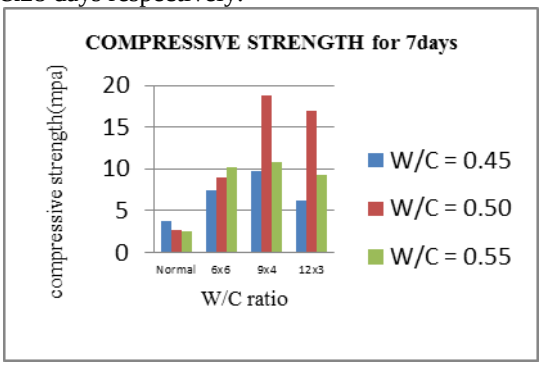

Fig. 3: shows compressive strength for 2% of fibers for 7days

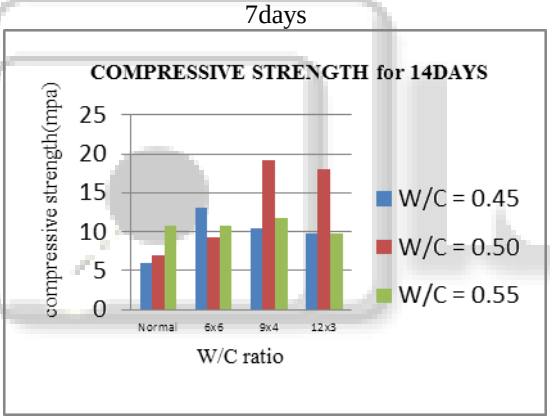

Fig. 4: shows compressive strength for 2% of fibers for 14days

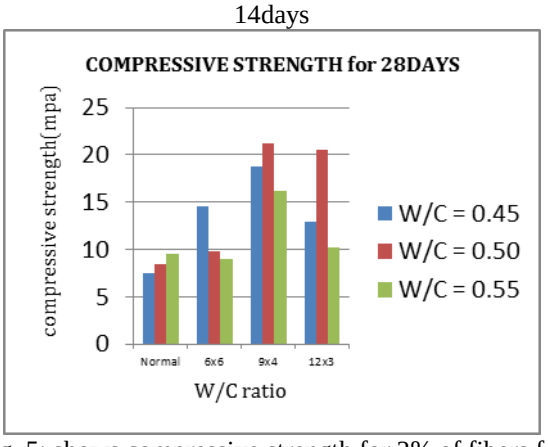

Fig. 5: shows compressive strength for 2% of fibers for 28days

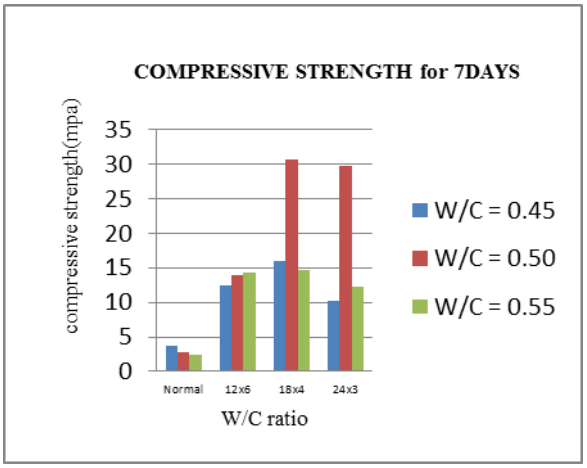

Fig. 6: shows compressive strength for 4% of fibers for 7days

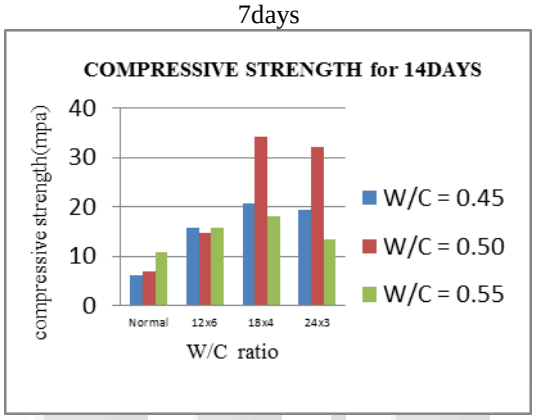

Fig. 7: shows compressive strength for 4%of fibers for 14days

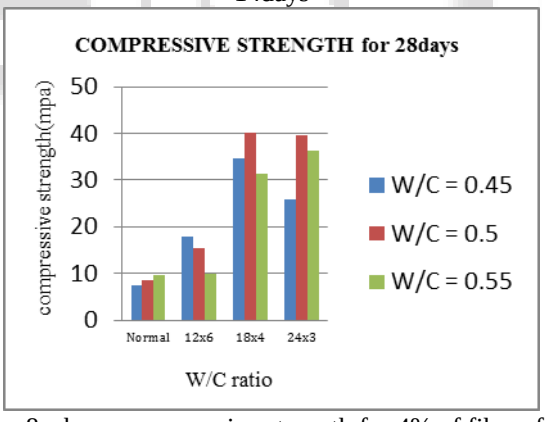

Fig. 8: shows compressive strength for 4% of fibers for 28days

Out of these two percentages represented above, 4% of fiber yields the optimum water cement ratio 0.5 and optimum fiber number which is 72(18 strands at four positions).As per the observation, inserting fibers into the concrete yields strength that is compressive and also if the fiber number increases, there will be an increase in the compressive strength correspondingly. In phase 1,The optimum4% of fibers is used to observe the flexural crack behavior pattern in prism of standard size 50cmx10cmx10cm and the prisms are casted with

1) Mesh
2) Fiber
3) A combination of both mesh and fibers.

Later, the test results obtained for prism with mesh, fiber alone and combination of both mesh and fiber is to be compared with that of nominal prism of M20 grade.

B. Flexural strength

The flexural strength is carried out on a standard prism of size 50cmx10cmx10cm and the test results obtained can be compared with that of nominal prism for 7, 28days respectively. For this, M20grade of concrete is used.

Mix proportions is 1:2.48:3.55

Cement = 320kg/m^3

River sand = 794kg/m^3

Water = 176kg/m^3

Coarse aggregate

6mm = 683kg/m^3

12mm = 455kg/m^3

Fig. 9: Finishing Of Prism

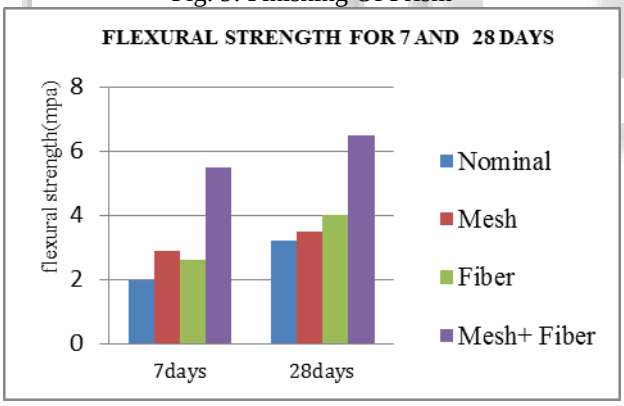

Fig. 10: shows flexural strength for optimum 4% of fibers for 7&28days

Fig. 11: Light transmitting block under natural ventilation

Fig. 12: Light transmitting block when placed in dark room

After observing the performance of fibers in concrete in terms of its flexural strength in phase1, the optimum 4% of fibers is again used in beams of size 130cmx18cmx20cm i.e., phase 2(say)

Provide 2 bars of 8mm diameter at top, 4 bars of 12mm diameter at bottom with 2legged vertical stirrups of 6mm diameter at 150mmc/c.(% tension = 100Ast/bd = 0.12568%; %compression = 100Asc/bd = 0.055%).

3 types of beams were casted with mesh, fiber alone and a combination of both mesh and fibers and the test results obtained can be compared with that of nominal beam of same size. Among these 4 beams, mesh with fibers has the highest load carrying capacity and the load VS deflection curves for beams are represented below.

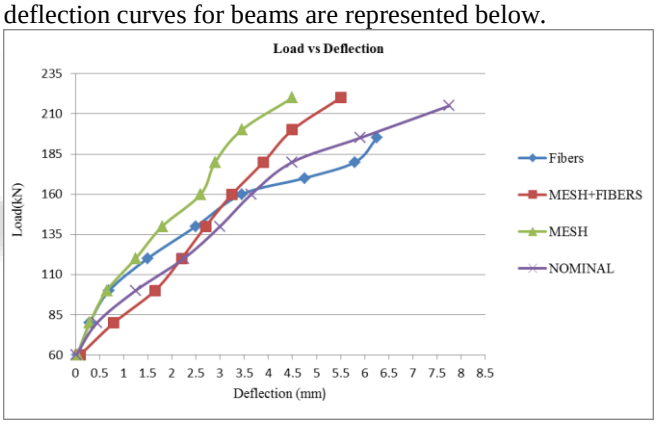

Fig. 13: shows Load VS deflection curve for 28 days

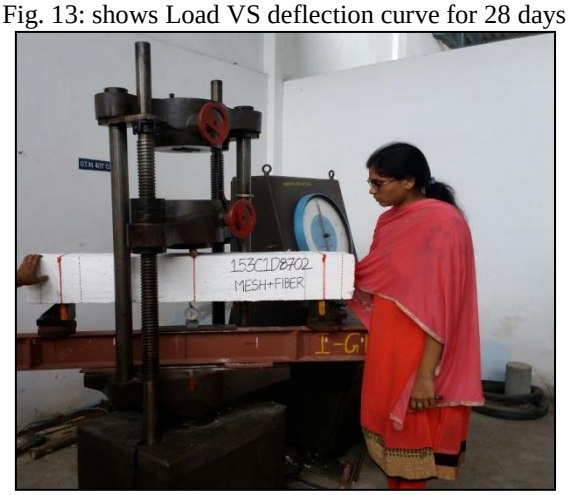

Fig. 14: Testing of beam

Fig. 15: shows crack pattern

VI. CONCLUSION

1) The compressive strength of light transmitting concrete is greater than that of conventional concrete up to some certain limit, beyond that limit the compressive strength goes on decreasing with increase in the volume of optical fiber.
2) The highest compressive strength occurs at optimum 4% of fibers with 18 strands at 4 different positions.
3) The compressive strength of optimum light transmitting mortar cube is increased by 78.8% than that of nominal or conventional concrete.
4) The flexural strength of optimum light transmitting concrete prisms with fiber is increased by 2.485% than that of conventional concrete.
5) Also, the flexural strength of optimum light transmitting concrete prisms with mesh alone is increased by 8.053% that that of conventional concrete prisms.
6) Finally, the flexural strength of optimum light transmitting concrete prisms with a combination of mesh and fiber is increased by 53.03% than that of conventional concrete prisms.
7) Mesh with fiber beams shows better resistance against first cracking load and ultimate load than nominal concrete beam its factor is 1.11 and 1.4.
8) The load deflection characteristics at mid span of mesh with fiber beams shows less deflection than nominal concrete beams with factor is 0.93.
9) All beams were failed in flexure mode by yielding of tensile steel followed by crushing of concrete in compression face.

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