Light Weight Translucent Concrete Blocks for Load Bearing Components

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Abstract - *With innovation in the field of material sciences and by combining fibre optics with concrete technology, led to the development of translucent concrete, which contribute to more cozy, artistic, safe and energy efficient structures. It serves as an innovative building envelope that allows day light permeability through the opaque parts of exterior facades and roofs. This project incorporates the use of optical fibre for the light guiding properties, glass fibres to improve the mechanical performance and expanded clay aggregate for easy handling and development of slender and highly reinforced structural members. The project exploits the use of self-compacting concrete which is a highly flowable and stable concrete without any segregation or consolidation and resolves any delays and additional cost of projects. Samples of desired proportions are cast and tested for optimum dosages and its performance on compression is tested translucent concrete masonry blocks. These masonry blocks would act more beneficial on commercial buildings which make a significant use of artificial day lighting sources and where safety is prime concern. The project provides a new alternative to entrench the concept of sustainability and translucent concrete can regarded as a green energy saving construction materials.*

Key Words: **translucent concrete, self-compacting concrete, optical fibre, glass fibre, expanded clay aggregates.**

1. INTRODUCTION

Transparent concrete also called as translucent concrete or light transmitting concrete is achieved by replacing aggregates with transparent alternate materials. The bonding material in transparent concrete may be able to transmit light by using clear resins in the concrete mix. Optical fibres and concrete also used for making transparent concrete.

According to studies, strength of building blocks can be improved by incorporating polypropylene fibres or steel fibres in different amounts varying from 0% to 2%.When fibres are used in concrete it enhances both compressive and split tensile strength of concrete.

While Ordinary concrete imparts difficulty in compaction because of the presence of optical fibres. Replacing it with self-compacting concrete (SCC) thus removes difficulty in compaction.
Light weight concrete is a great insulating material that protects against outdoor extreme temperatures while also letting in daylight through the optic fibers .This makes it an excellent compromise for buildings in harsh climates, where it can shut out heat or cold without shutting the building off from daylight.
It is sure to be employed in a variety of interesting ways that will change the opacity of architecture as we know it.

2. LITERATURE REVIEW

From researches it was observed that the best diameter of optical fibers to obtain a uniform light transmittance lies between 0.5mm – 3mm. Optical fibers with smaller diameter worked better (Basma .F. Bashbash 2013). Studies also showed the wide reach and its exploitation in various architectural and structural phases. The use of high strength concrete can help improve the structural performance of the blocks (Abdelmajeed Altlomate 2016). Self-compacting concrete which is a highly flowable and stable concrete mix enables lesser mechanical work, reduced project cost and delays, no segregation and bleeding. Being highly flowable, it can reach the remote densely reinforced sections without any mechanical compaction methods (Vilas .V. Karjinni 2017). Supplementary advantages of using SCC are observed to be faster pace of construction, reduced noise level, faster placement, lesser labour force, superior surface finishes, higher durability, slender sections, secure working domain, etc. Glass fibers incorporated in the mix aids in building load bearing structures whereby glass fibers enhance the tensile strength of concrete with improvement in the impact resistance (B.T. Purandhar Reddy 2014). Added benefits include reduced self-weight and deprivation of rusting or corroding. Lightweight self-consolidating concrete combines the properties of both lightweight concrete and self-compacting concrete. Apart from the reduced weight it brings along benefits of improved fire resistance owing to the refractory properties of expanded clay aggregates and insulation to external heat due the cellular structure of the aggregates (Niki Cauberg 2015). Salmabanu Luhar 2017 stated implications of varying OF ratio, spacing and angle of incidence of source light.

3. OPTICAL FIBRE

Optical fibre is a wave guide, made of transparent dielectric (glass or plastics) in cylindrical form through which light is transmitted by total internal reflection. It guides light waves to travel over long distances without much loss of energy. Optical fibre consists of an inner cylinder made of glass or plastic called core of very high refractive index. The core is surrounded by a cylindrical shell of glass or plastic of lower refractive index called cladding. The cladding is covered by a jacket which protects the fibre from moisture and abrasion.
Optical fibers are widely used in fiber-optic communications, which permits transmission over longer distances and at higher bandwidths .Fibers are used for illumination, and are wrapped in bundles so that they may be used to carry images, thus allowing viewing in confined spaces

Types of Optical Fibres:

Based on the refractive index profile and the number of modes, optical fibers are divided into three types. They are:
- Step index single mode fibre
- Step index multimode fibre
- Graded index multimode fibre

A step index single mode fibre may have very small core diameter (i.e. 5- 10μm). Due to its small core diameter, only a single mode of light ray transmission is possible. About 80% of the fibres that are manufactured in the world today are of this type.

A step index multimode fibre has a core diameter of 50 to 200μm and an external diameter of cladding 125 to 300μm. Since the core material is of uniform refractive index and the cladding material of lesser refractive index than that of core, there is a sudden increase in the value of refractive index from cladding to core. Since the core has larger diameter, propagation of many modes within the fibre is allowed.

In a graded index multimode fibre, the refractive index of the core is maximum at the axis of the fibre and it gradually decreases towards the cladding. Since there is a gradual decrease in the refractive index of the core the modal dispersion can be minimized.

Total Internal Reflection In A Fibre:

The principle behind the transmission of light waves in an optical fibre is total internal reflection. The total internal reflection in the walls of the fibre can occur only by the following two conditions:

i. The glass around the centre of the fibre (core) should have higher refractive index (n1) than that of the material (cladding) surrounding the fibre (n2).
ii. The light should incident at an angle (between the path of the ray and normal to the fibre wall) greater than the critical angle, θc.

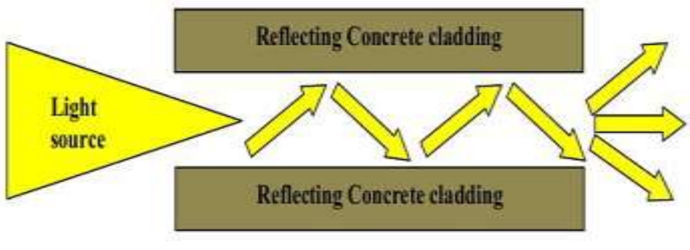

Figure 1: Total internal reflection in fibre

The common ingredients of translucent concrete are cement, fine aggregate, plastic optical fiber and water. Polypropylene fibers are added to increase the strength. The physical and chemical properties of each ingredient has considerable role in the desirable properties of concrete like strength and workability. Here the properties of materials used for mix proportioning are discussed.

4. PROPERTIES OF CONSTITUENT MATERIALS

A. Cement

Selection of cement type depends on the requirement of strength and durability. Cement used is of OPC 53 Grade with specific gravity 3.15 and standard consistency 31%.

B. Fly ash

Fly ash is a by-product from coal combustion which falls to the bottom of the boiler. It is an efficient pozzolanic substance that improves strength, segregation properties and makes it easier to pump thereby, is inevitable in SCC mixes. Fly ash used belongs to Class F category with a specific gravity of 2.14.

C. *Fine aggregate*

Manufactured sand free from deleterious and organic impurities was used. Conforming to IS standards, the fine aggregates must pass 4.75mm sieve and retain on 150 micron sieve. The specific gravity of 2.59 and fineness modulus of 3.47 was used

D. Coarse aggregate

Naturally available coarse aggregates from neighboring quarries of size less than 10mm were used. Substantiating with standards of preparing SCC mixes it specifies that coarse aggregate proportion is lesser than fine aggregates to improve flowability. The maximum size of coarse aggregate is limited to 20mm as per EFNARC standards. The specific gravity of 2.69 and fineness modulus of 2.63 was used. The table given below mentions acquired properties of fine and coarse aggregates.

Table -1: Properties Of Aggregate

Properties	Fine aggregate	Course aggregate
Specific gravity	2.59	2.69
Fineness modulus	3.47	2.63
Bulk modulus(g/cc)	1.46	1.5

E. Light weight aggregates

Light weight aggregates(LWA) used in this study are expanded clay aggregates of size less than 10mm and with a specific gravity of 1.13. They are used as replacements for natural coarse aggregate(NCA) to reduce the dead weight of the member as well as satisfying the strength requirements.

F. Glass fibers

Glass fibers(GF) used are anti crack resistant. They bridge cracks and improve toughness of concrete members. They are lightweight but strong and robust. Glass fibers have a higher coefficient of thermal expansion and a high tensile strength of about 1700MPa. The glass fibers used in this work have a length of 12mm, diameter 14 micron and specific gravity 2.68. Lightweight aggregates and glass fibers used are shown below in Fig 3.

Figure 2: Expanded clay aggregate and glass fibre

G. *Optical fibers*

The optical fibers used are Segolike methyl methacrylate fibers (shown in Fig 4) of diameter 0.75mm and runs along the thickness of the member. There are two optical fibers passing through each hole on the mould. It should run continuous from one end to the other.

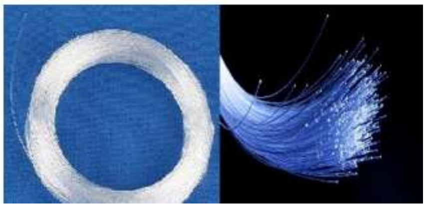

Figure 3: Optical Fibre

H. *Superplasticizer*

High range water reducer, Master glenium sky 8233, which is a light brown liquid of relative density 1.08 is used.

I. *Water*

It is a key component capable of forming a paste when in contact with cement and to bind aggregates with the matrix. The water used should be pure, free from acids, salts and other deleterious substances.

5. EXPERIMENTAL PROGRAM

After arriving at the mix proportions for the M30 SCC mix, given below in table 3, prepared from Modified NanSu method and by varying the dosage of superplasticizer, the work is set about to casting and testing of specimens. The mix proportion satisfying all the EFNARC standards and target strength is selected as the design mix. The entire work is sub divided into tasks which include casting of blocks to obtain optimum optical fiber spacing which allows the maximum light to be transmitted through the block to obtain the optimum dosage of glass fibers that can improve the structural performance of the specimen o to ascertain the optimum dosage of light weight aggregates that satisfies the structural performance as well as reduces the overall dead load o to determine the performance of these optimum quantities on concrete masonry blocks o to test the efficiency of panels cast using all the above mentioned ingredients and check for suitability as structural members Concrete cubes, cylinders and prisms of standard sizes are cast and tested for compressive strength, split tensile and flexural strength respectively. Concrete masonry blocks of standard size as per IS 2185 (part 1) – 2005 are cast and tested for compressive strength. Concrete panels of standard sizes are also tested for compression and tension, whose performance decides its use as interior, exterior or partition walls.

A. *Mix proportions*

Conventional concrete mix was determined by altering the superplasticizer dosage from 0.25-0.6% by weight of binder. The mix satisfying strength and EFNARC standards formed the base mix for obtaining the optimum optical fiber spacing in the mould. Optimum glass fiber content was obtained by altering the addition glass fiber content from 0-0.2% and optimum dosage of light weight aggregates were obtained by altering its replacement ratios from 0-100%. All mix proportions are tabulated below, Table 2.

B. *Casting and testing of specimens*

Concrete masonry block moulds are prepared based on IS 2185(part-1) – 2005 of sizes 300mm x 200mm x 150mm (Fig 5). Optimum fiber spacing was obtained from lux meter tests on masonry blocks. Lux meter is a device which measures illuminances by a light sensor. The intensity of light entering a dark room through the masonry block cast with optical fibers was measured

Figure 4. Mould for masonry block

fiber content was ascertained after tests done on standard moulds; cubes of size 150mm x150mm x 150mm for compressive strength; cylinders of size 300mm x 150mm for split tensile strength; prisms of size 100mm x 100mm x 500mm for flexural strength. Compressive strength was obtained both for 7 days and 28 days. Specimens were cured in water until the day of testing after 24 hours of air drying. Concrete cubes cast with varying replacement percentages of light weight aggregates were tested for compressive strength and unit weights measured. The optimum dosages extorted from the tests are subsumed for casting masonry blocks and panels and their combined performance assessed. The height/thickness ratio was chosen to satisfy the specification mentioned in IS 456. The testing of cubes, cylinders and prisms were done as per IS 516. All specimens were demoulded after 24 hours and cured by immersing in water for the respective number of days.

6. TEST RESULT

The test results generated from the comprehensive experimental procedures conducted are shown in tables and graphs in the coming paragraphs. Table 3 shows the results of illuminances obtained from a lux meter. All other test results and associated graphs are presented in the upcoming sections. Three specimens are tested for each test and average of the values obtained are depicted in the coming sections

Table 2: Mix Proportion

Sl.no	Mix designation	Cement (kg/m3)	Flyash (Kg/m3)	fine aggregate (Kg/m3)	Coarse aggreagate (Kg/m3)	Water (Kg/m3)	Superplastizer (% of binder)	Glass fiber(% of vol of mixing)	LWA(% by wght of the CA)
1	CM	375	142.67	824.68	724.086	206.86	0.27	-	-
2	SCC1	375	142.67	824.68	724.086	206.86	0.27	.05	-
3	SCC2	375	142.67	824.68	724.086	206.86	0.27	.10	-
4	SCC3	375	142.67	824.68	724.086	206.86	0.27	.15	-
5	SCC4	375	142.67	824.68	724.086	206.86	0.27	.20	-
6	SCC5	375	142.67	824.68	724.086	206.86	0.27	.10	25
7	SCC6	375	142.67	824.68	724.086	206.86	0.27	.10	50
8	SCC7	375	142.67	824.68	724.086	206.86	0.27	.10	75
9	SCC8	375	142.67	824.68	724.086	206.86	0.27	.10	100

Table 3: Light intensity value obtained from Lux Meter

Spacing	Morning				Afternoon				Evening			
	East	South	West	North	East	South	West	North	East	South	West	North
2cm	78	50	35	22	29	24	17	17	59	34	80	22
1.5cm	80	58	37	25	30	24	19	18	60	35	84	25
1cm	Observed severe honeycombing due to closer spacing											

*All values are entered in Lux

Table 4 : Test results from varying Glass fibre

Glass fiber (% of total volume of mix)	Compressive strength		Split tensile strength (N/mm^2)	lexural strength (N/mm^2)
	7 day (N/mm^2)	28 day (N/mm^2)		
0	26.20	38.20	3.08	2.70
0.05	28.42	40.40	3.18	2.72
0.1	29.80	41.02	3.84	3.16
0.15	28.14	40.14	3.16	2.95
0.2	27.06	39.10	3.12	2.70

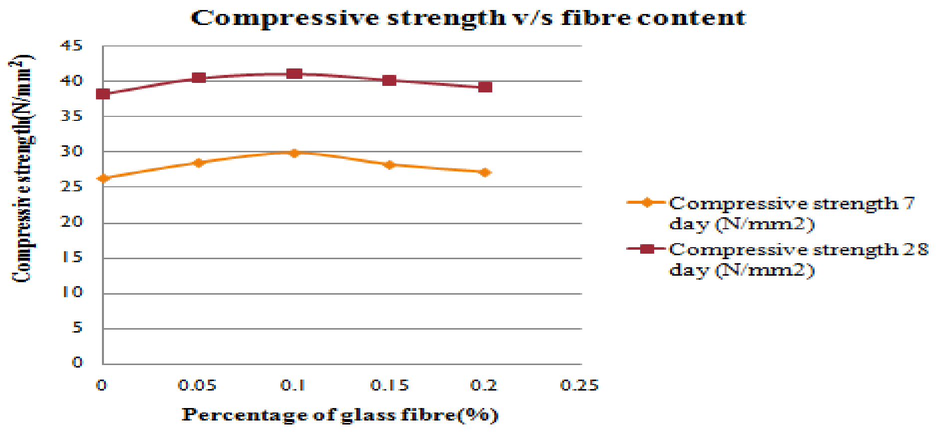

Figure 5: Relation between compressive strength of concrete and glass fiber content

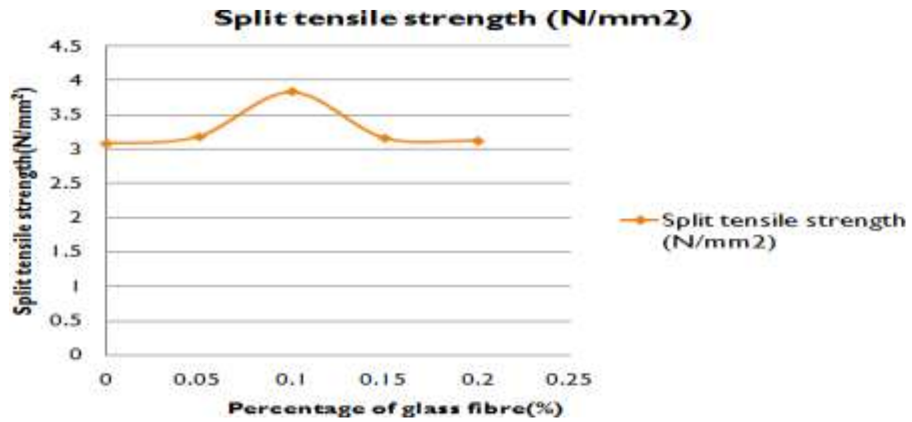

Figure 6: Relation between split tensile strength of concrete and glass fiber content

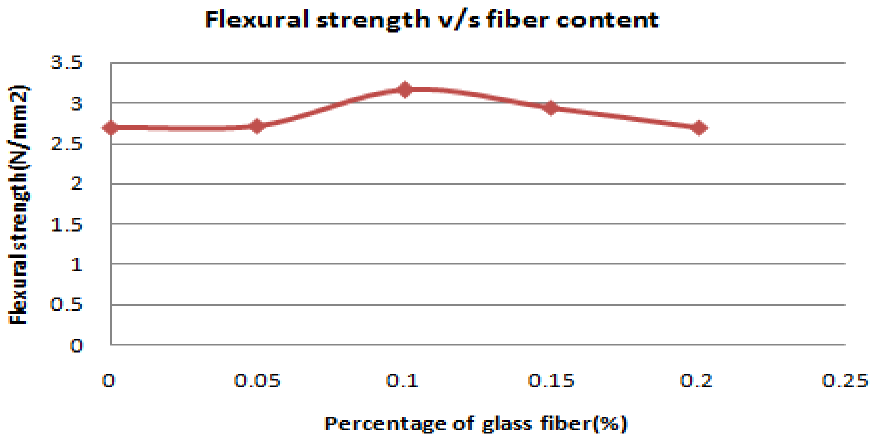

Figure 7: relation between flexural strength of concrete and glass fiber content

7. CONCLUSIONS

Translucent concrete blocks can be used in many ways and implemented into many be highly advantageous. It's a great sign of attraction and artistic evolution. Introducing light weight property to translucent concrete had made it an efficient structural member. The following conclusions were derived with the limited studies conducted on translucent light weight concrete blocks.

- The optimum super plasticizer dosage was obtained to be 0.27% by weight of powder content.

- The addition of glass fibres showed only slight increase in compressive strength of around 10% but there was a significant increase in split tensile strength of 25%. The optimum glass fibre content was obtained as an addition of 0.1% to total volume of mix.

- The addition of light weight aggregate resulted in reduction 4kg compared to normal concrete masonry block.

- Light transmitting concrete can be used in structures to make them aesthetically beautiful with the added advantage of reducing power consumption and protecting privacy.

- Currently, the cost of manufacture of light transmitting concrete is high due to the usage of plastic optical fibers and the effort in laying it ,but this will be offset by the host of advantages it posses.

8. ACKNOWLEDGEMENT

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