EXPERIMENTAL WORK ON LIGHT TRANSMITTING CONCRETE BY USING OPTICAL FIBER

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ABSTRACT

Small buildings are replaced by high rise buildings and sky scrapers. This arises one of the problem in deriving natural light in building, due to obstruction of nearby structures. Due to this problem use of artificial sources for illumination of building is increased by great amount. So it is very essential to reduce the artificial light consumption in structure. It is considered to be one of the best sensor materials available and has been used widely since 1990. Hungarian architect, Aron Losonczi, first introduced the idea of light transmitting concrete in 2001 and then successfully produced the first transparent concrete block in 2003, named LiTraCon. Since concrete is strong in compression and weak in tension and flexure.

Keywords - Optical Fibers, Litcon

I. INTRODUCTION

1.1 General

Concrete as constructional material being extensively used all over the world where the climatic, environmental and sub soil condition vary. Concrete has a key role in development of infrastructure and housing. Due to great economic growth, population growth and space utilization worldwide, there is drastic change in construction technology. Small buildings are replaced by high rise buildings and sky scrapers. This arises one of the problem in deriving natural light in building, due to obstruction of nearby structures. Due to this problem use of artificial sources for illumination of building is increased by great amount. So it is very essential to reduce the artificial light consumption in structure. It is considered to be one of the best sensor materials available and has been used widely since 1990. Hungarian architect, Aron Losonczi, first introduced the idea of light transmitting concrete in 2001 and then successfully produced the first transparent concrete block in 2003, named LiTraCon. Since concrete is strong in compression and weak in tension and flexure.

1.2 Power Consumption

In total domestic usage of electricity 30% of electricity is used for lightening purpose only, so it is necessary to utilize natural light for illuminating interior of building following Fig. 1 shows detailed electricity consumption for various daily.

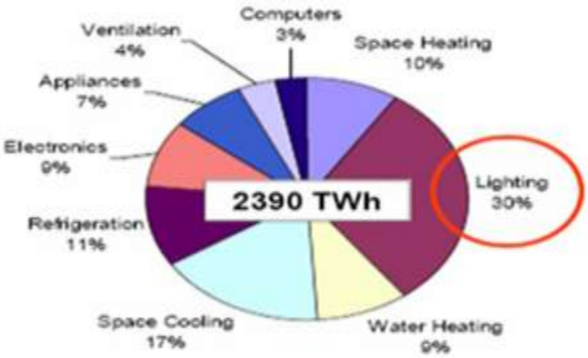


Fig. 1: Domestic Electricity Consumption

1.3 Optical Fiber

The idea of using light to send messages has been developed since the eighth century B.C., when the Greeks used fire signals for sending alarms or calls for help. It was only in the mid 1960s did Charles K. Kao determined that glass had a loss of 20db/km, which spurred researchers into exploring methods for making glass more pure. This discovery sparked a revolution in the telecommunication industry as a new industry of processing optical fibers becomes commercially important. These optical fibers have great light transmission capability. The typical fibers today are made out of glass or plastic since it is possible to make them thin and long. Also both glass and plastic are transparent at particular Wavelengths, which allow the fiber to guide light efficiently. The fiber is constructed with a core with high index surrounded by a layer of cladding at lower index. The core and cladding can be made out of both plastic and glass. For plastics, the core can be polystyrene or polymethylmethacrylate and the cladding is generally silicone or Teflon for glasses both the cladding and the core are made out of Silica with small amounts of dopants such as Boron, Germanium to change its Index.

Major differences exist between the two materials when it comes to making the optical fiber. In plastic core fibers they are more flexible and inexpensive compared to glass fibers. They are easier to install and can withstand greater stresses and weigh 60% less than glass fibre. But losses, giving them very limited use in communication applications. Such plastic fibers are practical for short run such as within buildings. Therefore, due to their restrictive nature glass core fibers are much more widely used because they are capable of transmitting light effectively over large distances.

II. LIGHT THEORY

When light is directed into an optical fiber the effectiveness of the wire depends on its ability to guide the light ray far distances with little scattering or absorption of the light as possible. So it means that the optical fiber must exhibit total internal reflection within the wire, thus when considering the propagation of light for an optical fiber the refractive index of the dielectric medium needs to be accounted. As light rays become incident on an interface between two dielectrics with different index of refractions, refraction occurs between the two mediums. This can be best described by using Snell's Law of Refraction which states

$$N_1 \sin\O_1 = N_2 \sin\O_2$$

This equation shows that at certain angles partial internal reflection will arise, as well at other angles total internal reflection will occur as shown in following figures.

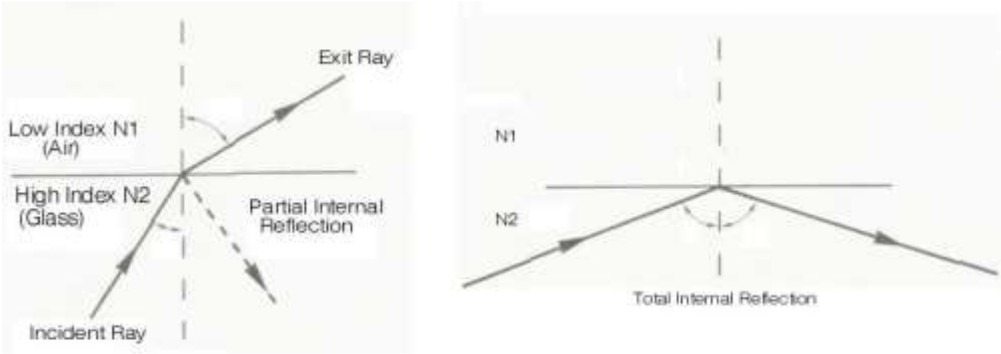


Fig. 2: Light Ray Diagram

This relationship can then be used to find the critical angle $Ø_c$ which serves as the limiting case of refraction and the angle of incidence. By launching the light ray at an angle $Ø > Øc$ within the optical fiber. A typical optical fiber with two to total internal reflection as seen in fig. 2, it is reflected at the same angle to the normal, leading dielectric mediums is shown in fig. 3, with the silica core having the index refraction of n_1 and the silica cladding with a lower index of refraction of n_2. With this setup it is possible to send packets of information through light rays which can propagate through an optical fiber with very little loss or distortion.

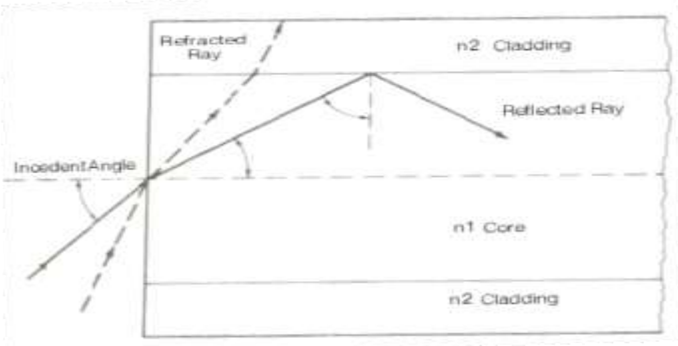


Fig. 3: Total Internal Reflection Between Two Dielectric Mediums

2.1 Optical Fiber Types

There are 3 basic types of optical fibers: multimode graded-index fiber, multimode step-index fiber and single-mode step-index fibers. A multimode fiber can propagate hundreds of light modes at one time while single-mode fibers only propagate one mode as shown in fig. 4

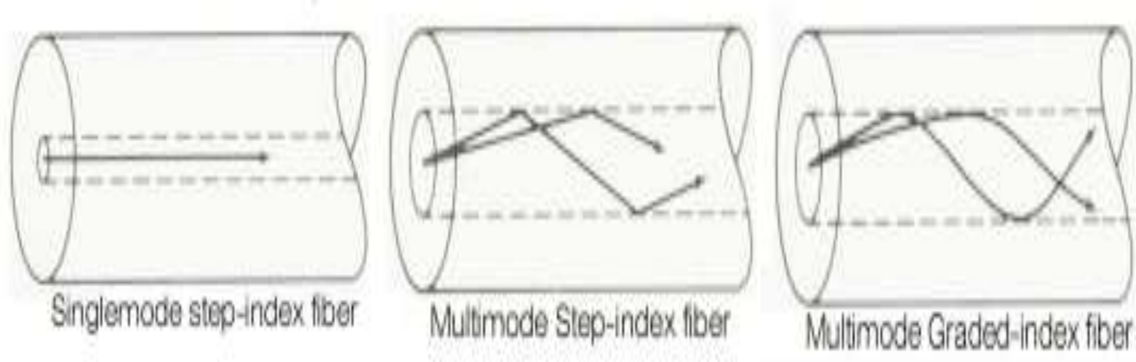


Fig. 4: Optical Fibre

The difference between graded-index and step-index fibers is that in a graded-index fiber it has a core whose refractive index varies with the distance from the fiber axis, while the step-index has core with the same refractive index throughout the fiber. Since the single-mode fibers propagate light in one clearly defined path, intermodal dispersion effects is not present, allowing the fiber to operate at larger bandwidths than multimode fiber. On the other hand, multimode fibers have large intermodal dispersion effects due to the many light modes of propagations it handles at one time. Because of this multimode fibers operate at lower bandwidths, however they are typically used for enterprise systems such as offices, buildings, universities since they are more cost effective than single mode ones. In this experimental work the intensity of light passing through concrete blocks provided with optical fiber is measured in lux unit for measurement of light.

III. TESTING OF SPECIMENS

3.1 Placing Optical Fiber

Optical fibers have very small diameter for placing in concrete block, so that bunches of fiber are made. The numbers of fiber in each bunch contains according to percentage of optical fiber like 150, 200 fibers for 4 % & 5 % respectively. These bunches are passed transversely from the holes made at opposite face of mould, the bundles of optical fibers are laid such that it extends from face for length of at least 1 cm to make it stable and to avoid sagging during concreting and compaction.

3.2 Testing Of Specimen for Light Reflection

Prepare 8 plywood boxes of depth 0.75 m with different surface areas, for checking the reflection of light intensity through the concrete block for different surface areas with constant percentage of fiber.(i.e. for 4% & 5% of fibers)

IV. RESULT ANALYSIS

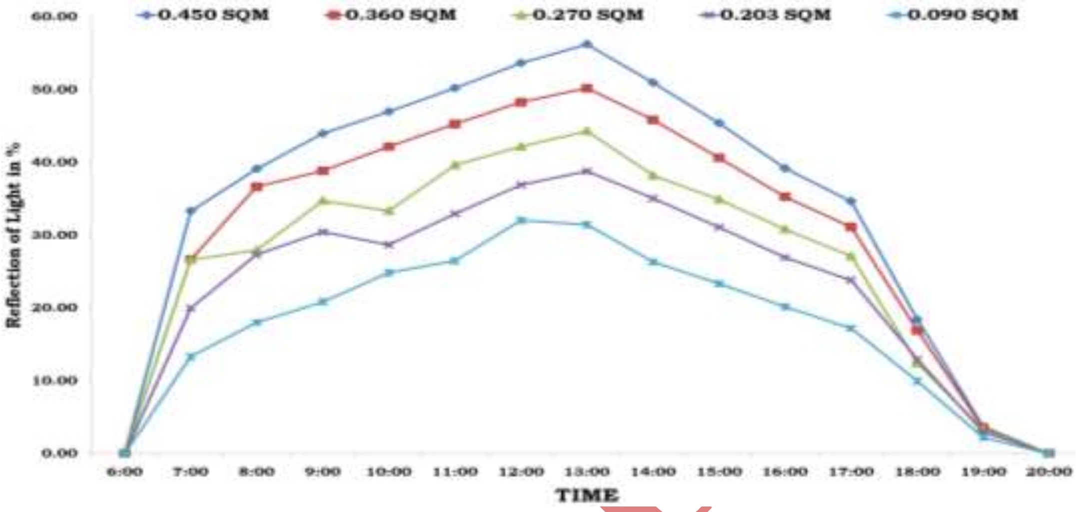
4.1 Reflection Of Light Through Blocks (From Different Block Area)

Then after, reflection of light was checked through the concrete blocks with 4 % and 5 % of optical fibers but for the different surface areas. Results of the same are tabulated in Table 1 & Table 2.

Table 1: Reflection of Light Through Different Surface Areas With 5 % Optical Fibers

Time	External Radiation Intensity In Lux.	Internal Radiation Intensity Near Cube Face In %				
		Near Box Face				
		0.450 Sqm	0.360 Sqm	0.270 Sqm	0.203 Sqm	0.090 Sqm
6:00	0.00	0.00	0.00	0.00	0.00	0.00
7:00	15.00	33.33	26.67	26.67	20.00	13.33
8:00	161.00	39.13	36.65	27.95	27.33	18.01
9:00	489.00	43.97	38.85	34.76	30.47	20.86
10:00	749.00	47.00	42.19	33.38	28.70	24.83
11:00	910.00	50.22	45.27	39.67	32.97	26.48
12:00	1092.00	53.66	48.26	42.22	36.90	32.05
13:00	1193.00	56.24	50.21	44.34	38.81	31.43

14:00	1075.00	50.98	45.86	38.23	35.07	26.33
15:00	861.00	45.41	40.65	34.96	31.13	23.34
16:00	768.00	39.19	35.29	30.86	26.95	20.18
17:00	453.00	34.66	31.13	27.15	23.84	17.22
18:00	201.00	18.41	16.92	12.44	12.94	9.95
19:00	54.00	3.70	3.52	3.33	2.96	2.22
20:00	0.00	0.00	0.00	0.00	0.00	0.00

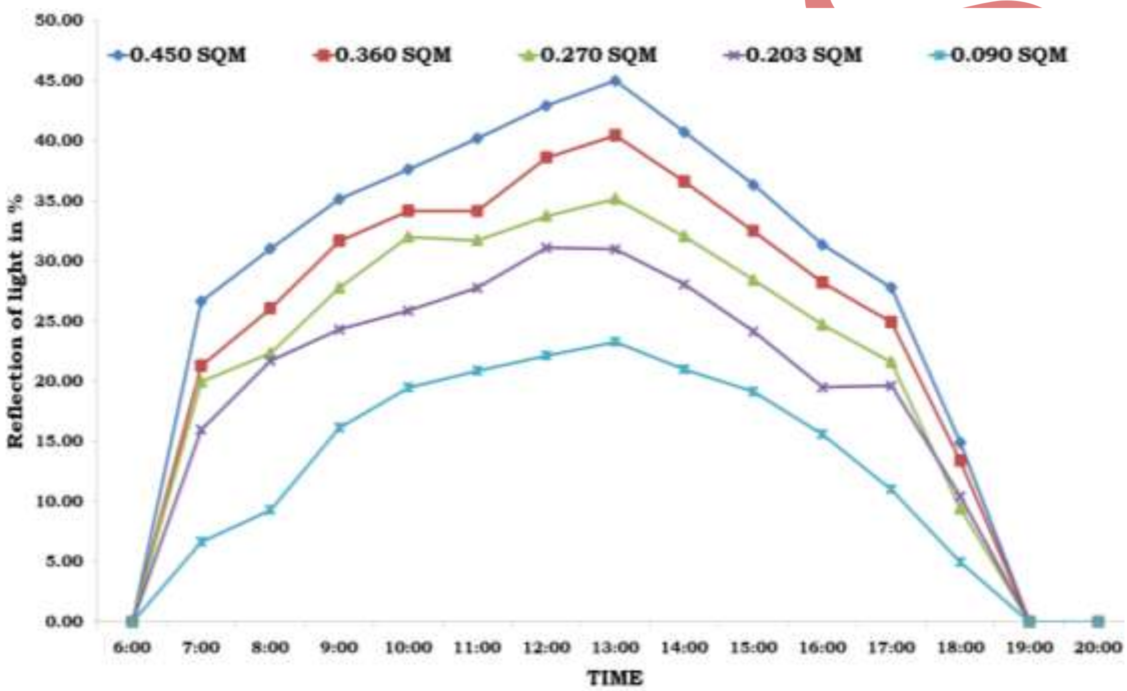


Graph 1: Reflection Of Light Through Different Surface Areas With 5% Optical Fibers

Table 2: Reflection Of Light Through Different Surface Areas With 4 % Optical Fibers

Time	External Radiation Intensity In Lux.	Internal Radiation Intensity Near Cube Face In %				
		NEAR BOX FACE				
		0.450 Sqm	0.360 Sqm	0.270 Sqm	0.203 Sqm	0.090 Sqm
6:00	0.00	0.00	0.00	0.00	0.00	0.00
7:00	15.00	26.67	21.33	20.00	16.00	6.67
8:00	161.00	31.06	26.09	22.36	21.74	9.32
9:00	489.00	35.17	31.70	27.81	24.34	16.16
10:00	749.00	37.65	34.18	32.04	25.90	19.49
11:00	910.00	40.22	34.18	31.76	27.80	20.88
12:00	1092.00	42.95	38.64	33.79	31.14	22.16
13:00	1193.00	45.01	40.49	35.21	31.01	23.30
14:00	1075.00	40.74	36.65	32.09	28.09	21.02
15:00	861.00	36.35	32.52	28.46	24.16	19.16

Time	External Radiation Intensity In Lux.	Internal Radiation Intensity Near Cube Face In %				
		NEAR BOX FACE				
		0.450 Sqm	0.360 Sqm	0.270 Sqm	0.203 Sqm	0.090 Sqm
16:00	768.00	31.38	28.26	24.74	19.53	15.63
17:00	453.00	27.81	24.94	21.63	19.65	11.04
18:00	201.00	14.93	13.43	9.45	10.45	4.98
19:00	54.00	0.00	0.00	0.00	0.00	0.00
20:00	0.00	0.00	0.00	0.00	0.00	0.00



Graph No. 2: Reflection of light through Different Surface areas with 4 % optical fibers

V. COST ANALYSIS

Table 3: Cost Analysis Of M30 Grade Concrete (Conventional And OFRC) For 1 Cum

	Cost		Total Cost
	Concrete	Optical Fibers	
Conventional Concrete	4198.53	0.00	**4199.00**
Concrete 4 % OFRC	4051.31	53376.00	**57427.36**
Concrete 5 % OFRC	4015.35	71168.00	**75183.35**

Table 4: Comparison Of Cost

Sr. No	Number of Cubes	Volume in CUM	Cost	
			Conventional Blocks	Optical Concrete Blocks
1	20	0.068	285.50	3876.35
2	16	0.054	226.72	3101.08
3	12	0.041	172.14	2325.81
4	09	0.030	125.96	1744.36

5.1 Power Consumption by Artificial Lighting

- Power consumption when one 60 Watt light bulb is :-

Use for illumination for 30 days for 8 hours = 60 X 30 X 8 = 14400 = 14.4 Units

Table 5: Tariff/Charges For Power Supply To Homes (Residential Establishments)

MSEB (Average Unit Rates)	
Residential	Public
Rs.4.85	Rs.7.92

VI. PAY BACK PERIOD

6.1 For 0.45 sqm area (20 Blocks)

- With reference to comparison of cost table;

  Difference in Initial Cost for 20 No. of Cubes

  = Rs. 3876.35 - Rs. 285.50 = Rs. 3590.85 /-
- Energy saving in residential room in one year

  = 14.4 X 4.85 X 12 = Rs. 838.08 /-
- Period require to recover extra amount for OFRC transparent block

  $= \frac{3590.85}{838.08}$ = 4.285 Years ≈ **4.3 Years**
- Energy saving in commercial/Industrial room in one year

  = 14.4 X 7.92 X 12 = Rs. 1368.58 /-
- Period require to recover extra amount for OFRC block

  $= \frac{3590.85}{1368.58}$ = 2.624 Years ≈ **2.7 Years**

From above cost analysis and payback period calculation it was confirmed that, the recovery period for light transmitting block is 4.3 years for residential use and it is 2.7 years for commercial use. This payback period is too less as compared to benefits of light transmitting concrete.

6.2 Payback Period for Other Areas

Table 6: Cost for Other Areas

Area In Sqm	No. Of Blocks	Cost of		Energy Saving	
		Conventional Blocks	Optical Concrete Blocks	Residential	Commercial
0.45	**20**	285.5	3876.35	838.08	1368.58
0.36	**16**	226.72	3101.08	838.08	1368.58
0.27	**12**	172.14	2325.81	838.08	1368.58
0.2	**9**	125.96	1744.36	838.08	1368.58

Table 6: Payback Period For Other Areas

Area in Sqm	No. of blocks	*Payback Period*	
		Residential	Commercial
0.45	20	4.3	2..7
0.36	16	3.5	2.1
0.27	12	2..6	1.6
0.2	9	2	1.2

VII. CONCLUSION

7.1 General

With reference to previous discussions on manufacturing of Light Transmitting Concrete, capability of light transmission through it, and effectiveness of cost the following conclusions can be made.

7.2 Conclusions Regarding Transmission Of Light Through Light Transmitting Block

The transmission of light through light transmitting block is depends on percentage of optical fiber used of that surface area. The transmission of light is increases with increase in percentage of optical fiber.

The intensity of light passing through the block is maximum at 13 P.M. The maximum intensity of light passing through the block for 1% of fiber is 219.8 lux at cube face similarly, for 2% of fiber is 258 lux , for 3% of fiber 295 lux, 4% of fiber 321 lux, for 5% of fiber is 375 lux.

Earlier it was common with light levels in the range 100 - 300 lux for normal activities. Today the light level is more common in the range 500 - 1000 lux - depending on activity. For precision and detailed works, the light level may even approach 1500 - 2000 lux.

Result drawn from Table 1 and 2, it can be concluded that, the condition of outdoor light varies from overcast day and full day light, but for maximum time during experimental analysis it is overcast outdoor light. Outdoor light intensity ranges from 0 lux to 1193 lux in day time between 7:00 A.M to 7:00 P.M. this average value of transmission of light through block is sufficient for daily activities such as general visits, Normal Office Work , PC Work, Detailed Drawing Work, Very Detailed Mechanical Works, Performance of visual tasks of low contrast and very small size for prolonged periods of time and at location such as Supermarkets, Mechanical Workshops, Office Landscapes, Study Library, Groceries, Show Rooms, Laboratories, Warehouses, Homes, Theaters, Archives, Classes. This diffused light is very useful for the place where mainly computer work is done.

7.3 Conclusions Regarding Cost

Even if initial cost of the light transmitting concrete is more than conventional concrete by 12 time, but due to continuous increase in tariff and pay back calculation done in chapter number 6, from the payback analysis it can be concluded that a wall of 16 block (0.360 sqm area) constructed then the saving of electricity bill is 838.03/-Rs. So the payback period for excess amount invested for light transmitting block will be recovered in 3.5 years for domestic consumption and 2.1 years for commercial and industrial consumption. It will also reduce the carbon emission which is dangerous for the environment.

Hence this can be treated as one of the high performance concrete. The use of this high performance light transmitting concrete is beneficial for protecting mother earth.

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