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Transparent Concrete; An Experimental Study

Riya. A. Gite
PG Student
Department of Civil Engineering
Saraswati College of Engineering, Maharashtra, India

Shilpa Kewate
Professor
Department of Civil Engineering
Saraswati College of Engineering, Maharashtra, India

Abstract

Natural light in the building is obstructed by development of high rise buildings and sky scrapers. In order to overcome this problem, use of artificial light has increased in large amount. Thus, it becomes necessary to decrease the amount of artificial light consumption in structure. This leads to the introduction of innovative concrete, Transparent concrete. Fiber reinforced concrete i.e., Transparent concrete is used for aesthetical application by placing the optical fibers in concrete. Artificial and natural both the light passes through the transparent concrete due to the addition of optical fibers in concrete. In this paper, the concrete specimen is casted by reinforcing optical fibers in hollow stainless-steel pipe of diameter 5mm with different percentages, replacing fine aggregates with glass crystals in different percentages and then combining both the materials together and comparing it with conventional concrete. Fine aggregates are replaced by glass crystals by 10%, 15%, 20% and 25% in order to reduce the cost of transparent concrete. Glass crystals enhance the use of waste product and make the concrete environment friendly. In the present study, the mix design of M30 concrete is adopted. Optical fibers are reinforced in to the concrete by 0%, 2%, 4%, 6% and 8% based on surface area. Different tests like Compressive strength test, split tensile strength, Flexural strength and Light transmitting test were carried on the specimen. The results evidently show that as the percentage of optical fiber increases the strength also increases. Use of glass crystals also shows a slight reduction in cost as compared to transparent concrete and the combination of optical fiber and glass crystals in concrete gives the prime result as per strength aspects.
Keywords: Crack, Compressive Strength, Different type of wire mesh, PVC-Coated mesh, Reinforcement Orientation

I. INTRODUCTION

Concrete has been used since Roman times for the development of infrastructure and housing, but its basic components have remained the same. Coarse aggregate, like stones or gravel; fine aggregate, such as sand; and cement, a fine powder material are the three ingredients that make up the dry mix that unite together when water is added.

In 1960s, due to rapid urbanization concrete was often misinterpreted and disapproved by its image. But since that time, concrete has made worthwhile progress, in both technical terms and aesthetic terms. Concrete is a chief material in construction and gives strength considerably, beside strength concrete can also be used for aesthetical view. Concrete has become attractive and dynamic and is no longer the cold, grey and heavy material. By advanced study and innovation, newly developed concrete has been created as lightweight concrete, concrete with high resistant and white or coloured concrete, etc. Concrete adapt almost all the new challenges. The concept of transparent concrete was first introduced in 2001 by Aron Losonzi, a Hungarian architect at Technical University of Budapest. In 2003, large amount of glass fibers was mixed in to the concrete and first transparent concrete block named as LitraCon was successfully produced. Properties of transparent concrete blocks by litracon shown in table 1

Table – 1
Properties of Transparent concrete blocks by Litracon company

Product	*Litracon-Light Transmitting Concrete*
Ingredients	*96% concrete, 4% optical fibre*
Density	*2100-2400 kg/m^2*
Block size	*600mm*300mm*
Thickness	*25-500mm*
Compressive strength	*50 N/mm^2*
Tensile strength	*7 N/mm^2*

The main aim of transparent concrete is to produce transparency and its objective of application connect it to green technology and artistic finish. It is the “combination of optical fibers and fine concrete”. Currently, green structures focus largely on energy saving with indoor thermal systems. Therefore, it is important to produce a new functional material to satisfy the structure in terms of safety monitoring (such as damage detection, fire warning), protection from environment, energy saving and artistic modelling. The use of non- renewable energy sources is increased as the space between the buildings are reduced due to the construction of high-rise buildings, thus smart construction technique like green building and indoor thermal system becomes essential. Transparent concrete blocks are adapted in furniture for decorative purpose even for staircase, partition wall where natural light does not reach with required quantity, dark subway to increase the range of vision, lighting sidewalks at night time, etc. Transparent concrete is new technique not same as normal concrete. Transparent concrete is a lightweight concrete compared to conventional concrete. The main objective of transparent concrete is to use sunlight as the light source instead of electrical energy in order to reduce the load on non- renewable sources and to develop energy saving material. Due to the addition of optical glass fibers in the concrete, light can be transmitted from inside out or outside in. Transparent concrete has the same strength as regular concrete and continues light to travel through walls up to twenty meters (twenty-two feet) thick.

II. LITERATURE REVIEW

Nagdive and Bhole (2013) manufactured a novel construction material with optical fibre by drilling through the cement and mortar in order to utilize the light guiding ability of optical fibre. Their main purpose was to use sunlight as a light source in order to reduce the power consumption of illumination. They concluded that the smart transparent concrete has good light guiding property. The optical fibre volume ratio of concrete is proportionate to transmission light guiding property. Transparent concrete weighs about the same as conventional concrete. It carries the same amount of light through a brick no matter how thick it is. Thus, creating an ecologically solution that reduces to minimum energy consumption of this project.

Shanmugavadivu et al (2014) investigated to check whether the introduction of fiber wire in to concrete will help or influence to change the engineering properties of the member. Compressive strength and flexural strength test is performed. The results evidently show that the decorative concrete also performance based on strength aspect is also considerably high. This paper concludes that the efficiency of the application of optical fiber is studied by comparing the strength with normal M20 grade concrete and the test results proved that the efficiency is more in all aspects. Hence the application of optical fiber will make the concrete decorative as well as can make the concrete structural efficient.

P. Deshmukh and R. Deshmukh (2014) investigated the use of waste glass as cement replacement in concrete construction sector in order to decrease the production cost of concrete and industry would become more environmental friendly. According to strength criteria, replacement of cement by glass powder is feasible. It is concluded that the utilization of waste glass powder in concrete as cement replacement is possible.

Sawant et al (2014) casted light transmitting concrete by using optical fibers. Regarding cost it concluded that even if initial cost of the light transmitting concrete is more than conventional concrete by 12 time, but due to continuous increase in energy consumption it can be concluded that a wall of 16 block (0.360 sqm area) constructed then the saving of electricity bill is Rs.838.03/-. 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.

III. MATERIALS AND ITS PROPERTIES

A. *Cement:*

Ordinary Portland cement of 53 grade conforming to Indian Standard IS 12269-1987 was used throughout the experimental program. The standard consistency was 30.5%, whereas the initial and final setting times were 152 min. and 213 min. respectively. The specific gravity of cement was 3.14 and its compressive strength after 28 days was 70.6 MPa.

B. *Fine Aggregate:*

In this investigation, only one type of fine aggregates was used for preparation of concrete, i.e. Crushed fine aggregates. (NFA & CFA) passing through 4.75 mm I.S. Sieve. The specific gravity of the crushed sand is found to be 2.61 and was confining to zone-I of IS:383-1970.

C. *Coarse Aggregate:*

Crushed hard basalt chips of maximum size 10 mm were used in the concrete mixes. The bulk density of aggregates was 1475 kg/m3 and specific gravity was found to be 2.77.

D. *Water:*

Potable water conforming to IS 456-2000 was used for casting and curing.

E. *Optical Fibers:*

Optical fibers are flexible, transparent fibers made up of glass as well as plastic and are thin as human hairs. It transmits light between two ends of the fibers by process of total internal reflection. In this experiment, the holes of 5mm diameter were drilled and glass optical fibers of 0.5mm diameter were used.

F. *Waste Glass:*

The waste toughen glasses are collected from industrial waste. Industrial waste glass was hammered and crushed in to smaller pieces with the help of Impact test machine. These crushed pieces were sieved with 4.75 passing and 2.36 retained and then the required quantity was taken for casting.

G. *Admixture:*

Glenium named admixture is used in this work. An evolution of translucent concrete was done in which is it was discussed that cement composites with high performance necessitate the use on one hand, of high performance cement matrices and on the other hand of high performance reinforcements characterized by both a high tensile strength and a high tensile elastic modulus. When comparing high performance FRP meshes (or textiles or fabrics) with steel meshes, it is likely that the race will be very close and that the advantage of one over the other will depend on criteria other than strength or moduli of rupture[1].

IV. METHODOLOGY

Concrete of M30 grade was design with the basic materials as per Indian standard,

A. In CASE- I ***where fine aggregate – 4.75mm, + 600microns was replaced with glass crystals by 10%, 15%, 20% and 25% coded as G10, G15, G20 and G25 respectively.***

B. In CASE - II ***Optical fibers embedded in stainless steel rod of 5mm having 0.5mm thickness are introduced in concrete by replacement of objective concrete surface area by 2%, 4%, 6% and 8% coded as OP2, OP4, OP6 and OP8 respectively.***

C. In CASE – III ***both each glass crystals replacement and each optical fiber replacement was conducted and coded.***

D. ***All the combination was design for M30 grade of concrete and was compared with control mix. Graphical figure for all combinations and cases shown in figure no 1.***

E. *Concrete Mix design*

Control mix of M30 grade concrete as per IS:10262-2009 is adopted in this study mentioned in table no 2.

F. *Testing of samples*

Total 675 samples were casted out of which 225 nos of cubes, 225 nos of beams and 225 nos of cylinder was casted and tested for compression, flexural and split tensile strength respectively. Cube of size 150x150x150mm, beam of size 150x150x600 mm and cylinder of size 150 as diameter with height of 300 mm as per IS 10086 were casted, cured for 3, 7 and 28 days and tested for Compressive strength on cubes, flexural test on beams and split tensile test on cylinder respectively.

Table - 2
Mix Design for M30 grade Concrete

A/C	*W/C*	*FA*	*CAI*
4.5	*0.45*	*54*	*46*

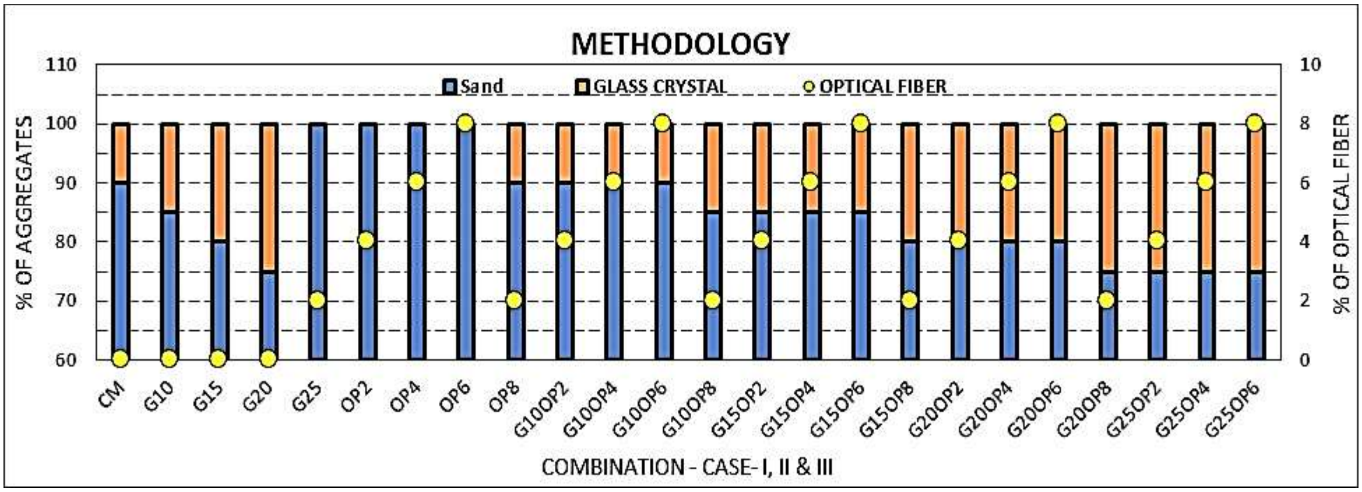

Fig. 1: Combination – Case – I, II & III

Photos before and after conducting the experimental work shown in fig 2 & 3 respectively

Fig. 2: Showing Glued optical fibers

Fig. 3: showing concrete cube with Glued optical fiber

V. RESULTS AND DISCUSSION

The average compressive strengths, Flexural, split tensile strength &light transmission measure in lux for fiber concrete observed during this test are listed below in graphical way in fig 4, 5, 6 & 7 respectively.

A. *Compressive Strength for all cases (CCS @ 3, 7 & 28 days all combinations as shown in fig 4)*

- For case 1, which represents replacement of "glass crystals", by 10%, 15%, 20%, 25% compressive strength at 28 days increases by 2.9%, 7%, 4.6%, 5.3% respectively.
- Similarly, for case 2, which represents replacement of "optical fibers" by 2%, 4%, 6%, 8% shows that compressive strength at 28 days goes on increasing by 20.9%, 38%, 46%, 48.9% respectively.
- Case 3 represents partial replacement of glass crystals with optical fibers. Glass crystals with 10%, 15%, 20%, 25% was replaced with 2%, 4%, 6%, 8% of optical fibers with every percentage by glass crystals.
- When 4% of optical fiber is introduced in glass crystals replacement i.e. 10%, 15%, 20%, 25% compressive strength at 28 days shows increasing curve by 28.5%, 22.9%, 20.6%, 17.5% respectively.
- When 6% of optical fiber is introduced in glass crystals replacement i.e. 10%, 15%, 20%, 25% 25% variation shows linear increase in compressive strength of percentage by 23.5% and 24%, in percentage replacement of 10% and 15% of glass crystals whereas, it shows little deviation in percentage of compressive strength by 21.3% and 20.2% in percentage replacement of 20% and 25% of glass crystals respectively.
- Similarly, replacement of optical fibers by 8% with different percentage of glass crystals (10%, 15%, 20%, 25%) shows continuously increasing graph of compressive strength at 28 days by 18%, 23.8%, 24.6%, 28.7% respectively. Similar pattern of variation of percentage at 3 and 7 days was observed.

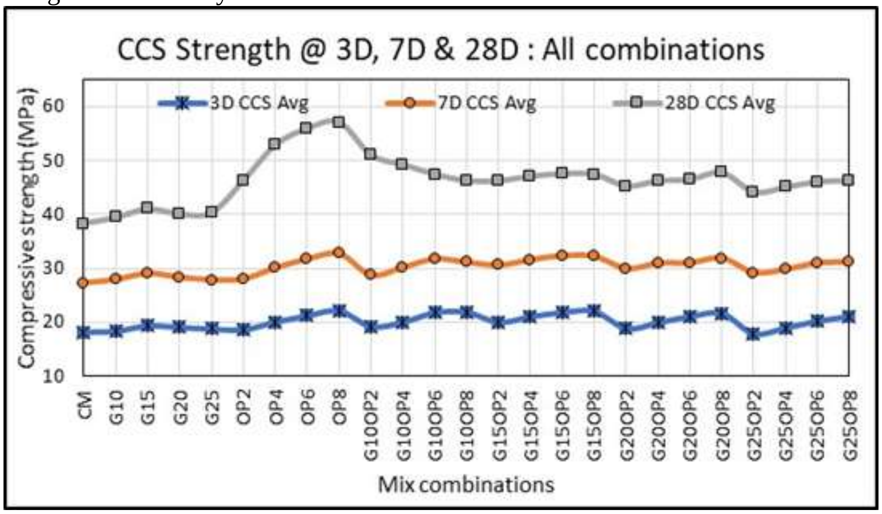

Fig. 4: Compressive Strength for all Cases

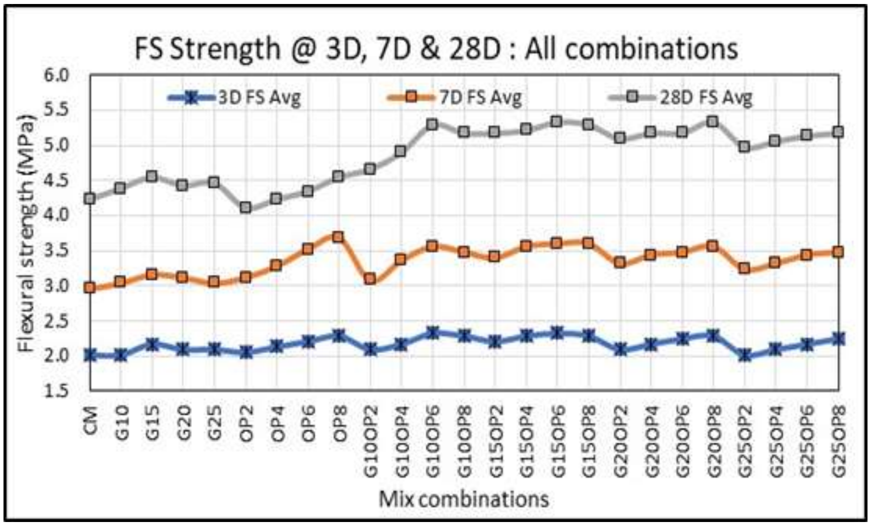

Fig. 5: Flexural Strength for all Cases

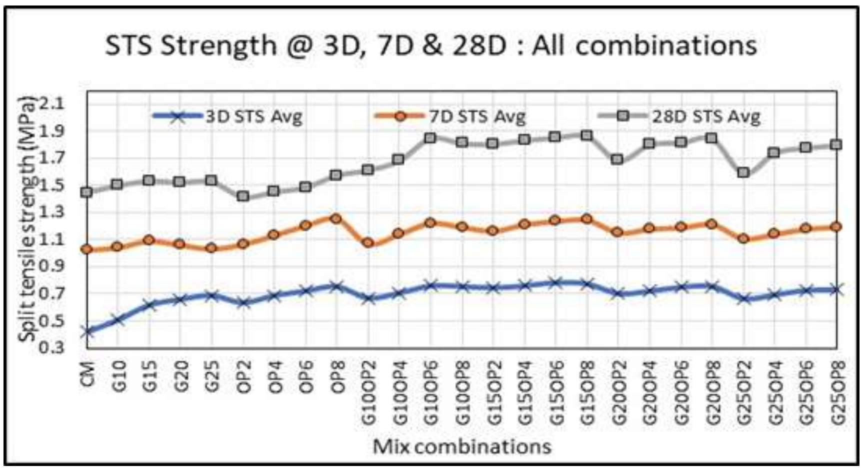

Fig. 6: Split Strength for all Cases

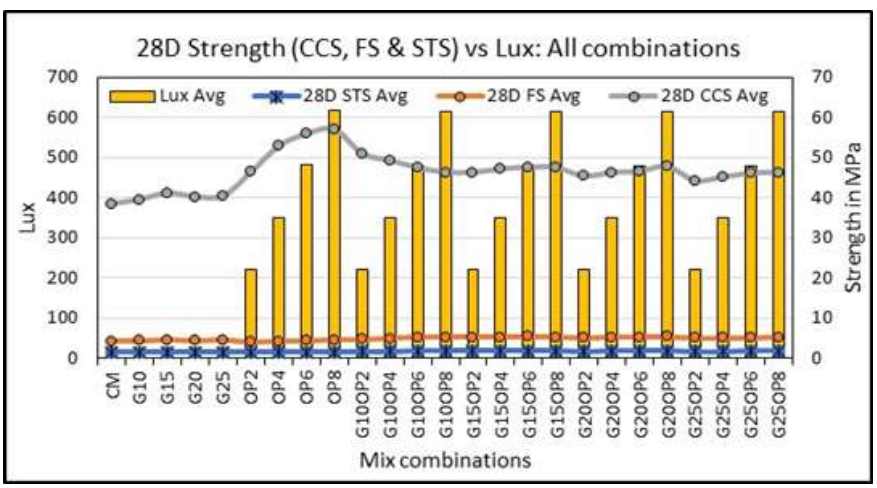

Fig. 7: Light Transmission and Strength comparison

B. Compressive Strength for all cases (CCS @ 3, 7 & 28 days all combinations as shown in figure 4)

- For case 1, which represents replacement of “glass crystals”, by 10%, 15%, 20%, 25% compressive strength at 28 days increases by 2.9%, 7%, 4.6%, 5.3% respectively.
- Similarly, for case 2, which represents replacement of “optical fibers” by 2%, 4%, 6%, 8% shows that compressive strength at 28 days goes on increasing by 20.9%, 38%, 46%, 48.9% respectively.

- Case 3 represents partial replacement of glass crystals with optical fibers. Glass crystals with 10%, 15%, 20%, 25% was replaced with 2%, 4%, 6%, 8% of optical fibers with every percentage by glass crystals.
- When 4% of optical fiber is introduced in glass crystals replacement i.e. 10%, 15%, 20%, 25% compressive strength at 28 days shows increasing curve by 28.5%, 22.9%, 20.6%, 17.5% respectively.
- When 6% of optical fiber is introduced in glass crystals replacement i.e. 10%, 15%, 20%, 25% 25% variation shows linear increase in compressive strength of percentage by 23.5% and 24%, in percentage replacement of 10% and 15% of glass crystals whereas, it shows little deviation in percentage of compressive strength by 21.3% and 20.2% in percentage replacement of 20% and 25% of glass crystals respectively.
- Similarly, replacement of optical fibers by 8% with different percentage of glass crystals (10%, 15%, 20%, 25%) shows continuously increasing graph of compressive strength at 28 days by 18%, 23.8%, 24.6%, 28.7% respectively. Similar pattern of variation of percentage at 3 and 7 days was observed.

C. Flexural Strength for all cases (FS @ 3, 7 & 28 days all combinations as shown in figure 5)

- Flexural strength at 28 days for case 1, which represents the replacement of "glass crystals", by 10%, 15%, 20%, 25% was observed such that it shows that percentage variation in flexural strength at 28 days by 37%, 75%, 37%, 56% respectively.
- While in case 2, which represents partial replacement of optical fibers by 2%, 4%, 6%, 8% was studied such that it gives rise to increase in percentage curve by 2.3% and 7.5% for 6% and 8% of optical fibers. Whereas, for 4% mix of optical fiber flexural strength is not affected.
- Case 3 represents that various percentage of glass crystals replaced with optical fibers by 2%. 4%, 6%, 8% so as to determine optimum dosage.
- When glass crystals of 10% and 15% was replaced by 2%. 4%, 6%, 8% of optical fiber than it is observed that percentage of flexural strength goes on increasing from 2% to 6% whereas it shows little deflection in percentage of strength for 8% replacement of optical fibers.
- For replacement of 10% of glass crystals with different percentage of optical fibers shows variation in percentage of strength by 10.3%, 15.9%, 25.2%, 22.4%; while, replacement of 15% of glass crystals with different % of optical fibers shows variation in % of strength by 22.4%, 23.4%, 26.3%, 25.2%.
- When glass crystals of 20% and 25% was replaced with 2%. 4%, 6%, 8% of optical fibers then it is observed that % of flexural strength increases linearly.
- For replacement of 20% glass crystals with optical fibers of different % give rise to increase in strength by 20.6%, 22.4%, 22.4%, 26.2% whereas for 25% it shows increase in strength by 17.3%, 19.6%, 21.5%, 22.4% respectively. Similar pattern of variation of percentage at 3 and 7 days was observed.

D. Split Tensile Strength for all cases (STS @ 3, 7 & 28 days all combinations as shown in figure 6)

- Case 1 represents that replacement of glass crystals by 10%, 15%, 20%, 25%, the observation reveals that % of split tensile strength at 28 days for this mix goes on increasing by 3.6%, 5.9%, 5.2%, 5.5% linearly when compared with control mix.
- In case 2, which shows replacement of optical fiber by 2%. 4%, 6%, 8%, split tensile strength decreases by 2.35 for 2% of optical fiber when compared with control mix whereas, it goes on increasing by 0.3%, 2.6%, 3.8% respectively.
- While in case 3, various composition mix was made by partial replacement of optical fiber by 2%. 4%, 6%, 8% with glass crystals (10%, 15%, 20%, 25%)
- When glass crystals of 10% was replaced with 2%. 4%, 6%, 8% of optical fibers then observation reveals that split tensile strength goes on increasing up to 5% of optical fiber as replacement then it decreases i.e. for replacement of 2% to 8% of optical fiber to glass crystals of 10% reveals the variation in % of strength by 11.4%, 16.3%, 27.7%, 25.1%.
- Where glass crystals of 15, 20 and 25% was replaced with different % of optical fibers shows that linearly increase in split tensile strength such that replacement of optical fibers by 2%. 4%, 6%, 8% for 15% of glass crystals shows that increase in strength by 24.8%, 26.7%, 28%, 28.7%. Similarly, for 20% of glass crystal shows increase in strength by 16.3%, 24.4%, 25.4%, 27.4%. Also for 25% of glass crystal, strength increases by 9.8%, 20.2%, 22.8%, 24.1% respectively. Similar pattern of variation of percentage at 3 and 7 days was observed.

VI. CONCLUSION

After considering all the results and graphs and their pattern of strengths following conclusion was drawn

- When glass crystal is used in concrete then increase in compressive strength was observed from 10 to 25%. Thus, optimum dosage for replacement for glass fiber was found as 15% since it gives more strength when compared to control mix.
- When optical fibers were replaced in concrete mix from 2 to 8% with rising interval of 2% it was observed that strength goes on increasing as % of replacement increases.
- When optical fibers were replaced from 2 to 8% with equal interval of 2% with glass crystals with % ranges from 15 to 25% with rising interval of 5%, then optimum dosage was found as 2% replacement of optical fibers with glass crystals of 10% as compared to control mix.

- Flexural strength was observed for replacement of glass crystals and it can be concluded that flexural strength increases as % of replacement increases when compared to control mix.
- Similarly, when optical fiber is replaced in concrete, flexural strength increases with increase in %.
- For variation combination of mix of glass crystals and optical fiber best mix was found as 8% replacement of optical fiber with 20% of glass crystals.
- When glass crystals are used as partial replacement in concrete, it gives linear increase in split tensile strength compared to control mix, whereas it would be advisable to replace optical fiber rather than glass crystals since it gives more increase in strength compared to glass crystals optimum dosage was found to be 8% of optical fibers as replacement.

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