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Experimental Study on Development of Concrete Using Glass Fibre

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Abstract-*In the present experimental investigation, attempts are made to study on the various strength properties like compressive strength, split tensile strength, an also durability properties like Acid and Sulphate attack on both ordinary concrete and Glass Fibre Concrete, using alkali-resistant glass fibres at stipulated ages. ISAT and CSAT test were held on long term durability properties of GFRC. Experiments were conducted for both Ordinary Concrete and Glass Fibre Concrete with different percentages of AR-Glass fibres. Studies were made on strength properties of Ordinary Concrete and Glass Fibre Concrete mixes. Studies were made on residual compressive strength, weight loss and pulse velocity of Ordinary Concrete and Glass Fibre Concrete mixes***.** *Experimental test were also held on Glass Fibre Reinforced Concrete and ordinary concrete.*

It was observed that as the addition of glass fibres to concrete mix increases, the workability of concrete mix was found to decrease as compared to control mix. At optimum dosage of GF the increase in compressive strength of glass fibre concrete mixes compared with control mix of concrete at 28 days compressive strength is observed from 18% to 20%. The percentage increase of split tensile strength of glass fibre concrete mixes compared with control mix at 28 days is observed from 15 to 20% for 0.2% glass fibres by weight of binder. The addition of glass fibres into the concrete mixture marginally improves the compressive strength at 28 days. It is observed from the experimental results and its analysis, that the compressive strength of concrete, splitting tensile strength of concrete increases with addition of low Percentage of glass fibers. The 0.2%, 0.45% and 0.7% addition of glass fibres into the concrete shows better result in mechanical properties and durability.

Addition of 0.2% glass fibres by weight of cement shows maximum increase in Compressive strength and Flexural strength varying 18% to 20%, and 15% to 20% respectively with respect to PC mix without fibres at 28 days of curing. The durability of concrete from the aspect of resistance to acid attack on concrete increases by adding AR-glass fibres in concrete .The glass fibres bridge across the cracks causing interconnecting voids to be minimum. UPV value found to be higher for concrete containing 0.45%GF by weight of cement. The value was 4.85 and 5.1 (km/sec.) at 56 and 90 days of curing respectively. The concrete mix containing 0.7%GF by weight of binder showed higher resistance against weight loss in H_2SO_4 *solution i.e.0.69% compared with control mix of concrete without glass fibres.*

I. INTRODUCTION

The present day world is witnessing the construction of very challenging and difficult civil engineering structures. Quite often, concrete being the most important and widely used material is called upon to possess very high strength and sufficient workability properties. Efforts are being made in the field of concrete technology to develop such concretes with special characteristics. Researchers all over the world are attempting to develop high performance concretes by using fibres and other admixtures in concrete up to certain proportions [1-3].

In the view of the global sustainable developments, it is imperative that fibres like glass, carbon, polypropylene and aramid fibres provide improvements in tensile strength, fatigue characteristics, durability, shrinkage characteristics, impact, cavitation, corrosion resistance and serviceability of concrete [6].

Fibre reinforced concrete (FRC) is a concrete made primarily of hydraulic cements, aggregates and discrete reinforcing fibres. FRC is a relatively new material [4,7]. This is a composite material consisting of a matrix containing a random distribution or dispersion of small fibres, either natural or artificial, having a high tensile strength. Due to the presence of these uniformly dispersed fibres, the cracking strength of concrete is increased and the fibres acting as crack arresters. Fibres suitable of reinforcing concrete having been produced from steel, glass and organic polymers [5]. Many of the current applications of FRC involve the use of fibres ranging around 1% by volume of concrete. Recent attempts made it possible to incorporate relatively large volumes of steel, glass and synthetic fibres in concrete. Results of tensile tests done on concretes with glass, polypropylene and steel fibres, indicate that with such large volume of aligned fibres in concrete, there is substantial enhancement of the tensile load carrying capacity of the matrix [8]. This may be attributed to the fact fibres suppress the localization of micro-cracks into macro-cracks and consequently the apparent tensile strength of the matrix increases

II. OBJECTIVES OF PRESENT STUDY

To investigate the benefits of glass fibres as percentage addition of OPC in concrete is a subject of interest to many researchers all over the world and glass fibres have been observed to improve the strength and durability properties of concrete. In the present work, the effect of addition of glass fibres blends on strength , sorptivity, alkalinity, acid resistance, surface absorption characteristics of concrete are investigated. The precise objectives of the study are follows.

- The objectives of the present investigation are to get the thoroughness with the existing mix design procedures for glass fiber reinforced concrete by varying the percentage addition of glass fibers in concrete mix.
- To carry out the literature review in the area of the study
- To carry out the study to check the hardened properties of the glass fibre reinforced concrete (compressive and split tensile strength).
- To carry out the study to check the long term durability properties of glass fibre reinforced concrete (ISAT, CSAT, UPV, Acid and Alkalinity resistance tests).

III. EXPERIMENTAL PROGRAM

Testing of hardened concrete plays an important role in controlling and confirming the quality of cement concrete works. Systematic testing of raw materials, fresh concrete and hardened concrete are inseparable part of any quality control programme for concrete, which to achieve higher efficiency of the material used and greater assurance of the performance of the concrete with regards to both strength and durability. The test methods should be simple, direct and convenient to apply.

One of the purposes of testing hardened concrete is to conform that the concrete used at site has developed the required strength. As the hardening of concrete takes time, one will not come to know, the actual strength of concrete for some time. This is an inherent disadvantage in conventional test. But, if strength of concrete is to be known at early period, accelerated strength test can be carried out to predict 28 days strength. But mostly when current materials are used and careful steps are taken at every stage of the work, concretes normally gives the required strength. The tests also have a deterring effect on those responsible for construction work. The result of the test on hardened concrete, even if they are known later, helps to reveal the quality of concrete and enable adjustment to be made in the production of further concretes. Tests are made by casing the cubes or cylinders from the representative concrete or cores cut from the actual concrete. It is to be remembered that standard compressive strength specimens give a measure of the potential strength of the concrete in structure. Knowledge of strength of concrete in structure cannot be directly obtained from tests on separately made specimens.

Materials:

Cement: Ordinary Portland cement (OPC) from a single lot was used throughout the course of the investigation. The physical properties of the cement as determined from various tests 30 conforming to Indian Standard IS: 1489-1991(Part-1) are listed in Table 3.1. All the tests were carried out as per recommendations of IS: 4031-1988. Cement was carefully stored to prevent deterioration in its properties due to contact with the moisture.

Table 1: Properties of OPC

Characteristic Properties	Observed Value	Codal Requirements IS:8112-1989(Part 1)
Fineness (m^2/kg)	300	225 minimum
Standard consistency (%)	32	- - -
Initial Setting time (minutes)	62	30 Minimum
Final setting time (minutes)	270	600 Maximum
Specific gravity	3.15	- - -
Compressive strength (MPa) 3 days 7-days 28-days	 24.6 34.3 45.2	 23 Minimum 33 Minimum 43 Minimum

Coarse Aggregate: Crushed angular granite metal from a local source was used as coarse aggregate. The specific gravity was 2.71, flakiness index of 4.58 percent and elongation index of 3.96.

Fine Aggregate: River sand was used as fine aggregate. The specific gravity and fineness modulus was 2.55 and 2.93 respectively. Crushed angular granite metal from a local source was used as coarse aggregate. The specific gravity was 2.71, flakiness index of 4.58 percent and elongation index of 3.96.

Glass Fibre: The glass fibres used are of Cem-FIL Anti-Crack HD with modulus of elasticity 72 GPa, Filament diameter 14 microns, specific gravity 2.68, length 12 mm and having the aspect ratio of 857, the number of fibres per kg is 212 million fibres.

Admixtures: Water-reducing and set-retarding admixtures are permitted in order to increase the workability of the concrete and to extend the time of discharge from 60 to 90 minutes. These admixtures are permitted and often required for superstructure concrete. Chemical admixtures and mineral admixtures as defined by ASTM C 494 are as follows:

Super plasticizer CONPLAST SP 430 is a chloride free workability retention admixture based on selected organic polymers. Designed to provide workability retention where rapid workability loss is caused by high ambient temperatures or to compensate for delays in transportation. It is particularly suited to concrete mixes containing micro silica.

Silica fume was used as a mineral admixture. It acts as a filler material, and gives the early strength to the concrete.

Mix Design:

Concrete mix was designed as per IS 10262-2009 and the design procedure was as follows;

1. Determine the mean target strength ft from the specified characteristic compressive strength at 28-day fck and the level of quality control. $f_t = f_{ck} + 1.65$ S, where S is the standard deviation obtained from the IS 10262- 2009.
2. Adopt the water cement ratio for the desired mean target strength using the Table 5 of IS 456 and water cement ratio so chosen is checked against the limiting water cement ratio.
3. Select the water content, for the required workability and maximum size of aggregates (for aggregates in saturated surface dry condition) using table 2 of IS 10262- 2009. Super plasticizer was used so water content was adjusted for the required workability.
4. Calculate the cement content from the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.
5. Determine the proportion of coarse and fine aggregate in total aggregate by absolute volume corresponding to the adjusted water cement ratio from IS 10262-2009.
6. From the quantities of water and cement per unit volume of concrete and the proportion of fine and coarse aggregates already determined in step 5 above, calculate the content of coarse and fine aggregates per unit volume of concrete from the following relations.
7. Determine the concrete mix proportions for the first trial mix. Prepare the concrete using the calculated proportions and cast three cubes of 100 mm size and test them wet after 28-days moist curing and check for the strength.
8. Prepare trial mixes with suitable adjustments till the final mix proportions are arrived at.

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Table 2: Mix details

MIX	OPC (%)	SILICA FUME (%)	GLASS FIBRE (%)
M1	90%	10%	0.0%
M2	90%	10%	0.2%
M3	90%	10%	0.45%
M4	90%	10%	0.7%
M5	90%	10%	0.8%
M6	90%	10%	1.0%
M7	90%	10%	1.5%
M8	90%	10%	2.0%

Tests Performed

Tests on Fresh Concrete – Workability

Workability is considered to be that property of plastic concrete which indicates its ability to be mixed, handled, transported and most importantly, placed with a minimum loss of homogeneity. More precisely, it defines that it can be fully compacted with minimum energy input. There should be no sign of any segregation or bleeding in a workable concrete. The workability of all the mixes of concrete used in this work was controlled by conducting slump test, test apparatus was shown in Fig 3.1. It was observed that the slump value for all the mixes was maintained in the range of 90-110 mm, which is acceptable. A super plasticizer, SP-430 was used in the concrete mix varying from 1.0% -1.25% by weight of binder.

Fig.1: Slump cone apparatus

Compressive Strength Test

The test was conducted on cubes of size 100mm x 100mm x 100mm. specimens were taken out from curing tank at the age of 7, 14, 28, 56 and 90 days of curing. Surface water was then allowed to drip down. Specimens were then tested on 200 tones capacity Compression Testing Machine (CTM) (Figure3.2). The position of cube while testing was at right angles to that of casting position. Axis of specimens was carefully aligned with the centre of thrust of the spherically seated plates. The load was applied gradually without any shock and increased at constant rate of 3.5 N/mm^2/minute until failure of specimen takes place. The average of three samples was taken as the representative value of compression strength for each batch of concrete. The compressive strength was calculated by dividing the maximum compressive load by the cross sectional area of the cube specimens. Thus the compressive strength of different specimens was obtained.

Curing: The test specimens are stored in place free from vibrations, in most air of at least 90% relative humidity and at a temperature of 27 degree centigrade for 24 hours from the time of addition of water to the dry ingredients. After this period, the specimens are marked and remove from the moulds and unless required for the test within 24 hours, immediately submerged in clean and fresh water or saturated lime solution and keep there until taken out just prior to test. The water or solution in which the specimens are submerged, are renewed every seven days and are maintained at a temperature of 27 degrees centigrade. The specimens are not to be allowed to become dry at any time until they have been tested. The specimens are tested at 7, 14, 28, 56 and 90 days of curing.

Fig.2: Compressive testing machine

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Splitting Tensile Test

This test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine (Fig.3.3) and load is applied until failure of the cylinder, along the vertical diameter.

The test was conducted on cylinders of size 100mmdia and of 200 mm length. Specimens were taken out from curing tank at the age of 28, 56 and 90 days of water curing. Surface water was then allowed to drip down. Specimens were then tested on 200 tones capacity Compression Testing Machine (CTM). And test as per IS: 516 and 1199.

The split tensile strength was determined by using the following formula.

Split tensile Strength (MPa) = 2P / ΠDL

P = Splitting Load in KN

D= diameter of cylinder sample

L = length of cylinder sample

Fig.3: Splitting tensile test

Fig.4: Cube, cylinder and beam moulds

Initial Surface Absorption Test (ISAT)

This test method provides data for assessing the uni-axial water penetration characteristics of a concrete surface. This test was conducted as per BS 1881-208 (1996).

For this test cube of size 150mm1× 50mm× 150mm were prepared. Cube were tested after age of 56 and 90 days. Prior to testing, conditioning of specimen was done. Cubes were kept in oven for drying at 105 ^{0}C until constant mass was achieved. i.e., not more than 1% weight changes over any 24 h drying period. After that cubes were placed in the desiccators to cool down. The temperature in the cabinet was allowed to fall to within 2 degree centigrade of that of room. Silica gel was kept in the desiccators in powdered form to absorb any moisture. Specimen were kept in the cabinet until required for testing after conditioning of cubes, these were tested for initial surface absorption.

A cap of diameter 78 mm was clamped to the test surface. The position of cube while testing was right angle to that of casting position. Two pipes lead from the cap. The inlet tube to the cap was connected to the reservoir, fitted with a tap, by a flexible tube of sufficient length to enable a head of water 200 mm above the surface of the concrete under test. The outlet tube was connected to a calibrated capillary tube, set horizontally at ahead of water 200 mm above the surface of concrete under test, to measure the rate of absorption of water into the concrete below the cap on closure of the tap. Reservoir was of plastic material of about 100 mm diameter. Capillary tube 500 mm long and with a bore of 0.9101 mm radius, determine as described in BS 1881-208(1996), was fixed to a scale calibrated by the procedure described in BS 1881-208(1996). Initial surface absorption test apparatus was shows in Fig. 3.5.

Calibration of Apparatus

The calibration of the capillary tube was arranged so that the movement of water along it during 1 min, as read directly from the scale, equals the initial surface absorption in ml/(m^2.Sec) at a constant head and temperature during the test. Radius of bore of capillary tube was calculated from the following expression as per code: -

$$r^4 = \frac{KL}{t}$$

Where,

L is the length of the capillary, i.e. 500 mm

t is the mean time to collect 10 ml of water i.e. 82.67 Sec

K is a coefficient incorporating the viscosity of water and the geometry of the apparatus obtained from the values below using linear interpolation between adjacent values.

Water temperature (^{0}C)	10	15	20	25	30
Factor K	0.0167	0.0145	0.0128	0.0114	0.0100

At the time of calibration water temperature was found to be 16.8ºC. So, value of K came out to be 0.0139

Knowing the values of K and t, the value of r came out to be = 0.5383 mm

From the dimensions of the cap, the area of contact of the water with the specimen,

A1= 4775.94 mm^2

Area of the bore of the capillary, A2= 0.9101 mm^2

A scale was prepared to mount behind the capillary tube spaced 6×10^{-4} A1/A2 mm apart

i.e. = 3.15 mm.

Each division of scale represented 0.01 units of ml/ (m^2.Sec).

Starting the Test

Before starting the test, the temperature of the concrete surface adjacent to the cap was reported to the nearest 1°C. Then the reservoir was filled with water keeping the tap closed. After that tap was opened to allow the water to run into the cap and stopwatch was started. Air from the cap was flushed off through the capillary tube. The reservoir was replenished regularly to maintain the head of 200 mm of water. One end of the capillary tube was raised just above the water level to prevent further outflow. It was taken care that the reservoir does not empty itself.

Readings

Readings were taken after the following intervals from the start of the test:

— 10 min;

— 30 min; and

— 1 h.

Just before the specified intervals the capillary tube was lowered so that water runs in to fill it completely and then it was fixed in a horizontal position at the same level as the surface of the water in the reservoir. At each of the specified test intervals the tap was closed to allow water to flow back along the capillary tube. When the meniscus reached the scale stopwatch was started. Number of scale divisions moved by meniscus in 1 min was noted down. Same procedure was repeated at each specified interval. Between test

Intervals, the tap was left opened and head of water in the reservoir was maintained. Testing was done on any two opposite faces of cube, perpendicular to the casting position.

Fig.5: Initial surface absorption test

IV. RESULTS AND DICUSSIONS

The objectives of this study were to examine the strength, water permeation and durability properties of concrete at different percentages of glass fibres. Properties which were examined are:

1. Workability of concrete mixes
2. Compressive strength
3. Splitting tensile strength
4. Initial surface absorption

Compressive Strength test and splitting tensile strength was conducted on a 200T Compression Testing Machine, while the water permeation properties i.e. Initial Surface Absorption and Capillary Suction were performed as per BS-1881 208 and ASTM C 1585 – 04 respectively.

The detailed analysis and discussion of the test results as obtained from the experimental programme is presented in following sections.

Workability of Concrete Mixes

The workability of concrete mixes was found out by slump test as per procedure given in chapter 3. W/b ratio was kept constant 0.4 for all the concrete mixes. Super-plasticizer SP 430 was used to maintain the required slump. Dosage of super-plasticizer was varied from 1.0% to 1.25% by weight of binder depending up on the type of mix.

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Mix no	Description	Super plasticizer (%) by weight of binder	Slump (mm)
1	90%OPC+10%SF+0%GF	1.00	110
2	90%OPC+10%SF+0.2%GF	1.00	100
3	90%OPC+10%SF+0.45%GF	1.00	100
4	90%OPC+10%SF+0.7%GF	1.00	100
5	90%OPC+10%SF+0.8%GF	1.00	100
6	90%OPC+10%SF+1.0%GF	1.00	90
7	90%OPC+10%SF+1.50%GF	1.25	90
8	90%OPC+10%SF+2.0%GF	1.25	90

Table 3: Workability values for different concrete mixes

The addition of glass fibres into concrete mix further decreases the workability. To achieve the required slump super plasticizer was added to concrete mix. As percentage of fibres increases quantity of super plasticizer was increased. The lowest value of slump was obtained with mix 90%OPC+10%SF+2.0%GF and highest value was obtained with 90%OPC+10%SF+0%GF. There is decrease in workability of concrete with increase in glass fibre content. The content of super plasticizer was increased to maintaining required slump value. Due to high content of glass fibres it is very difficult to get required slump values without addition of super plasticizer.

Compressive Strength Test Results

The results of the compressive strength tests conducted on concrete specimens of different mixes cured at different ages are presented and discussed in this section. The compressive strength test was conducted at curing ages of 7, 14, 28, 56 and 90 days.

Mix no	Description	7 days	14 days	28 days	56 days	90 days
1	90%OPC+10%SF+0%GF	31.00	34.00	35.00	39.00	40.20
2	90%OPC+10%SF+0.2%GF	37.00	39.00	41.60	43.90	47.80
3	90%OPC+10%SF+0.45%GF	38.30	38.40	41.20	42.60	47.40
4	90%OPC+10%SF+0.7%GF	36.20	37.80	40.10	41.60	46.10
5	90%OPC+10%SF+0.8%GF	34.10	35.90	38.50	39.30	44.30
6	90%OPC+10%SF+1.0%GF	32.00	34.20	36.50	38.40	41.50
7	90%OPC+10%SF+1.50%GF	29.00	31.30	34.20	35.20	39.40
8	90%OPC+10%SF+2.0%GF	25.60	28.00	32.00	33.40	36.80

Table 4: Compressive strength (MPa) results of all mixes at different curing ages.

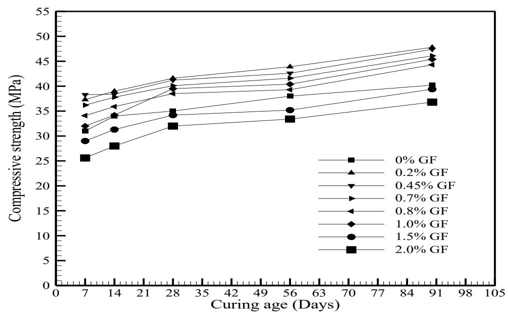

Fig.6: Variation of compressive strength of concrete with age

Compared to control mix of concrete, concrete containing 0.2%GF the compressive strength of concrete mix was found to increase by 18% at 28 days of curing. At 2.0%GF addition, the compressive strength of concrete mix was found to decrease by 8.57% at 28 days of curing compared with control mix of concrete. The maximum value of compressive strength obtained for concrete mix with 90%OPC+10%SF+0.2%GF was 41.60 and 47.8MPa at 28 and 90 days of curing respectively. . The value of compressive strength obtained for concrete mix with 90%OPC+10%SF+0.45%GF was 41.20 and 47.40MPa at 28 and 90 days of curing respectively. Beyond the 1.0% addition of GF the compressive strength of concrete mixes was found to be decreased at 7, 14, 29, 56, and 90 days of curing. The addition of relatively small amount of

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fibres can effectively eliminate shrinkage problem by controlling early age plastic shrinkage cracking. Cem-FIL Anti-Crack AR glass fibres has been specially developed for the reinforcement of cementation mortars and concrete mixes. When introduced into a conventional concrete mix, it reinforces effectively the same by adding millions of dispersed fibres per cubic metre of concrete.

Split Tensile Strength Test Results

The results of the splitting tensile strength tests conducted on concrete specimens of different mixes cured at different ages are presented and discussed in this section. The splitting tensile strength test was conducted at curing ages of 7, 14, 28, 56 and 90 days. The splitting tensile strength test results of all the mixes at different curing ages are shown in Table 4.3.Variation of splitting tensile strength of all the mixes cured at7,14, 28,56 and 90 days is also shown in Fig. 4.2. Fig. 4.2 shows the variation of splitting tensile strength of concrete mixes w.r.t control mix (90%OPC+10%SF) after 7,14, 28,56 and 90 days respectively.

Mix no	description	7 days	14 days	28 days	56 days	90 days
1	90%OPC+10%SF+0%GF	4.00	4.33	4.46	4.92	5.32
2	90%OPC+10%SF+0.2%GF	4.71	5.11	5.54	5.72	5.98
3	90%OPC+10%SF+0.45%GF	4.50	5.15	5.31	5.64	5.69
4	90%OPC+10%SF+0.7%GF	4.65	4.75	4.81	4.93	5.12
5	90%OPC+10%SF+0.8%GF	4.65	4.75	5.24	5.6	5.71
6	90%OPC+10%SF+1.0%GF	3.76	3.80	4.00	4.10	4.63
7	90%OPC+10%SF+1.50%GF	3.11	3.16	3.76	3.83	4.22
8	90%OPC+10%SF+2.0%GF	3.00	3.30	3.81	3.96	4.34

Table 5: Splitting tensile strength (MPa) results of all mixes at different curing ages.

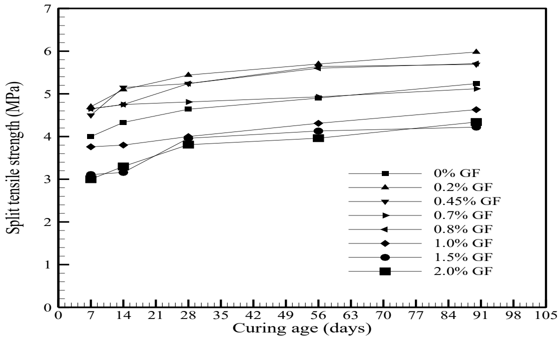

Fig.7: Variation of split tensile strength of concrete with age

Glass fibres in the concrete increases splitting tensile strength and low weight fraction of glass fibres gives maximum increase in the strength. The maximum value of splitting tensile strength obtained was 5.54 MPa, for a mix with 0.2% GF addition to OPC at 28 days of curing age. At 90% OPC+10SF+0.2%GF the splitting tensile strength increased by 19.5%, for 28 days of curing compared to control mix and addition of fibres from 0.2% to 0.8% increase the splitting tensile strength and was highest with 0.2% volume fraction of fibres. At 90% OPC+10%SF with 2.0%% fibres, the splitting tensile strength was decreased by 14.57% for 28, days of curing compared to control mix. Beyond 0.8%GF addition by weight of the binder, it was observed that there is decrease in split tensile strength of concrete compared to control mix concrete at 28 days of curing. It was observed that concrete mix containing 90%OPC+10%SF+0.2%SF shows higher value split tensile strength i.e 5.54 and 5.8MPa at 28 and 90 days of curing respectively. The addition of relatively small amount of fibres can effectively eliminate shrinkage problem by controlling early age plastic shrinkage cracking. Cem-FIL Anti-Crack AR glass fibres has been specially developed for the reinforcement of cementation mortars and concrete mixes. When introduced into a conventional concrete mix, it

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reinforces effectively the same by adding millions of dispersed fibres per cubic metre of concrete.

Initial Surface Absorption Test Results

The ISAT was performed to have an idea about the water permeation of concrete particularly at the concrete surface. Concrete cover is the weakest, most permeable and absorptive part of the concrete matrix as compared to the internal microstructure. The near surface concrete is highly heterogeneous in nature, due to the relative movement of cement paste and aggregates during the compaction of fresh concrete and bleeding of mix water in the early stages of cement hydration. As a result, there is a porosity gradient in the near surface concrete, where the porosity of near surface is higher than that of internal part of concrete. Therefore, the durability of the whole concrete can be characterized by simply determining the permeation characteristics of the concrete surface, which is considered as the most critical and vulnerable part towards external fluid ingress. The results of the ISAT conducted on concrete specimens of different mixes cured at different ages are presented and discussed in this section. For a particular curing age, the absorption was measured at 3 different time periods i.e. 10, 30 and 60 minutes. The absorption of water or flow of water decreased with time. This was because the rate of absorption of water becomes less as time increases when the outer zone of the surface is saturated and it is more difficult for water to be absorbed by the inner pores. It was found that the flow data at interval of 10 minutes give a more representative trend of the surface absorption characteristics. Flow rate at less than 10 minutes might not represent a stable and constant flow of water into the concrete, and the flow rates at 30 and 60 min. intervals would not be suitable since the concrete surface would already be in a saturated state and the data obtained will not be suitable for comparative purposes. The initial surface absorption values (ISAT-10) of various mixes at different curing ages is shown below in Table-4.4. From the values it can be seen that the absorption decreases with increase in curing time.

Mix no.	Description	Initial Surface Absorption [ml/(m^2.Sec)] at 10 min.	
		56 days	90 days
1	90%OPC+10%SF+0%GF	0.312	0.2696
2	90%OPC+10%SF+0.2%GF	0.264	0.221
3	90%OPC+10%SF+0.45%GF	0.242	0.203
4	90%OPC+10%SF+0.7%GF	0.230	0.196
5	90%OPC+10%SF+0.8%GF	0.288	0.240
6	90%OPC+10%SF+1.0%GF	0.336	0.288
7	90%OPC+10%SF+1.50%GF	0.388	0.320
8	90%OPC+10%SF+2.0%GF	0.406	0.344

Table 6: Initial Surface Absorption values in [ml/(m^2.Sec)] at 10 min.

Mix no.	Description	Initial Surface Absorption [ml/(m^2.Sec)] at 30 min.	
		56 days	90 days
1	90%OPC+10%SF+0%GF	0.187	0.161
2	90%OPC+10%SF+0.2%GF	0.158	0.132
3	90%OPC+10%SF+0.45%GF	0.145	0.122
4	90%OPC+10%SF+0.7%GF	0.138	0.117
5	90%OPC+10%SF+0.8%GF	0.172	0.144
6	90%OPC+10%SF+1.0%GF	0.201	0.172
7	90%OPC+10%SF+1.50%GF	0.232	0.192
8	90%OPC+10%SF+2.0%GF	0.243	0.206

Table 7: Initial Surface Absorption values in [ml/(m^2.Sec)] at 30 min.

Mix no.	Description	Initial Surface Absorption [ml/(m^2.Sec)] at 60 min.	
		28 days	56 days
1	90%OPC+10%SF+0%GF	0.124	0.107
2	90%OPC+10%SF+0.2%GF	0.105	0.088
3	90%OPC+10%SF+0.45%GF	0.096	0.081
4	90%OPC+10%SF+0.7%GF	0.092	0.078
5	90%OPC+10%SF+0.8%GF	0.115	0.096
6	90%OPC+10%SF+1.0%GF	0.134	0.115
7	90%OPC+10%SF+1.50%GF	0.155	0.128
8	90%OPC+10%SF+2.0%GF	0.162	0.137

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Table 8: Initial Surface Absorption values in [ml/(m^2.Sec)] at 60 min.

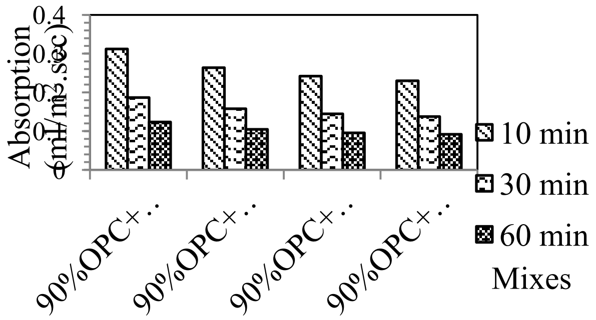

Fig.8: ISAT at 56 days of curing for above mixes

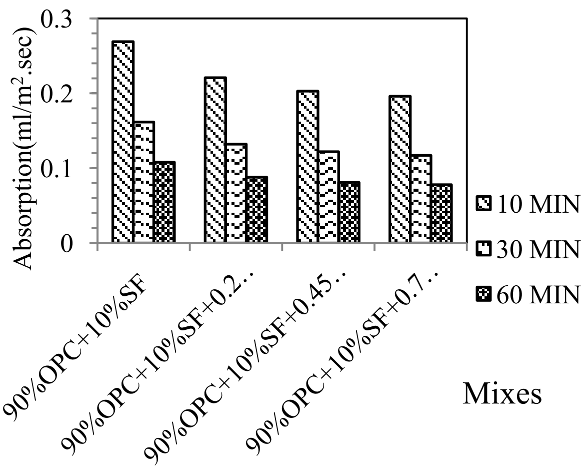

Fig.9: ISAT at 90 days of curing for above mixes

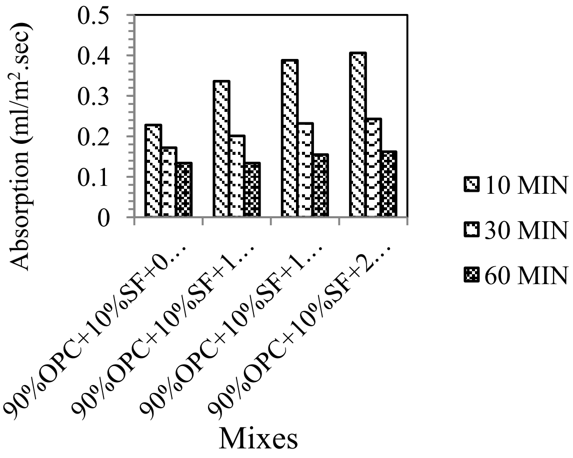

Fig.10: ISAT at 56 days of curing for above mixes

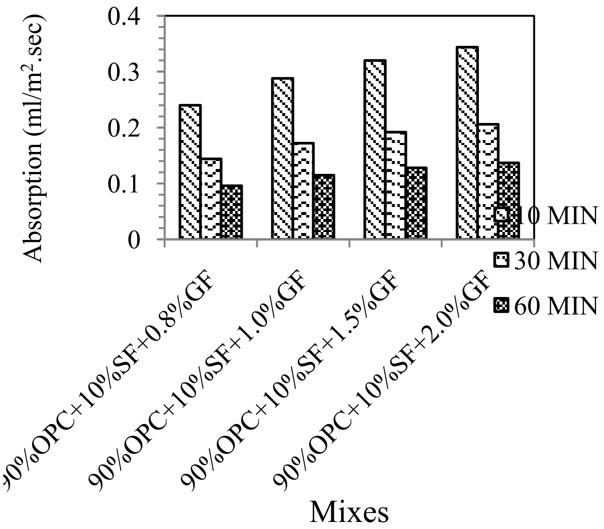

Fig.11: ISAT at 90 days of curing for above mixes

The lowest values of ISAT-10 i.e. 0.230 and 0.196 ml/(m^2.Sec) at curing period of 56 and 90 days respectively are observed for a concrete mix containing 90%OPC+10%SF+0.7% GF, whereas, the highest values of ISAT-10 are observed as 0.406 and 0.344 ml/(m^2.Sec) at 56 and 90 days of curing for a concrete mix containing 90%OPC+10%SF+2%GF.Further, the ISAT-10 values for control mix i.e. 90%OPC+10%SF, are 0.312 and 0.269 ml/(m^2.Sec) at 56 and 90 days of curing, respectively. It was observed that ISAT-10 values of concrete mix containing 90%OPC+10%SF+0.7%GF are approximately 26.28% and 27.13% less than those of control mix at 56 and 90 days of curing, respectively Whereas, mix 90%OPC+10%SF+2.0%GF gave absorption value of 23.15% and 21.80% more than control at 56 and 90 days of curing respectively. Glass fibre reinforced concrete shows less permeability of solutions into concrete when compared with ordinary concrete .The glass Fibres Bridge across the cracks causing interconnecting voids to be minimum.

V. CONCLUSION

In the current investigation, glass fibres (GF) were used to examine the strength and water absorption characteristics using the Initial Surface Absorption Test as per BS-1881 208 and Capillary Suction test

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as per C 1585 – 04, acidity alkalinity resistance tests and UPV test.

Based on the scope of work carried out in this investigation, following conclusions are drawn.

a. Reduction in bleeding is observed by addition of glass fibres in the glass fibre concrete mixes.
b. It was observed that as the addition of glass fibres to concrete mix increases, the workability of concrete mix was found to decrease as compared to control mix.
c. At optimum dosage of glass fibres the increase in compressive strength of glass fibre concrete mixes compared with control mix of concrete at 28 days compressive strength is observed from 18% to 20%.
d. The percentage increase of split tensile strength of glass fibre concrete mixes compared with control mix at 28 days is observed varying from 15 to 20% for 0.2% GF by weight of binder.
e. The addition of glass fibres into the concrete mixture marginally improves the compressive strength at 28 days. It is observed from the experimental results and its analysis, that the compressive strength of concrete, splitting tensile strength of concrete increases with addition of Percentage of glass fibers. The 0.2% and 0.45%addition of glass fibres into the concrete shows better result in mechanical properties and durability.
f. Addition of 0.2% by weight of cement, glass fibres shows maximum increase in Compressive strength and Flexural strength by 18% and 15% respectively with respect to PC mix without fibres at 28 days of curing.
g. The durability of concrete from the aspect of resistance to acid attack on concrete increases by adding AR-glass fibres in concrete .The glass Fibres Bridge across the cracks causing interconnecting voids to be minimum.
h. It was found that addition of the glass fibres strands improves the compressive strength, tensile strength, durability, load carrying capacity of ordinary reinforced cement concrete with small dosage levels of 0.2% & 0.45% by weight of cement.
i. UPV value found to be higher for concrete containing 0.45%GF by weight of cement. The value was 4.85 and 5.1 (km/sec.) at 56 and 90 days of curing respectively.
j. The concrete containing 0.45% and 0.7% GF by weight of binder shows lesser value of initial surface absorption.
k. The concrete containing 0.45% GF by weight of binder shows less capillary rise in concrete.
l. The durability of concrete from the aspect of resistance to acid attack on concrete increases by adding AR-glass fibres in concrete .The optimum value of AR-glass fibres for resistance to acid attack was 0.7% by weight of binder.
m. It was found that mix containing 0.7%GF by weight of binder showed higher resistance against weight loss in H_2SO_4 solution i.e.0.69% compared with control mix of concrete without glass fibres

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