AN EXPERIMENTAL STUDY AND INVESTIGATION ON STRENGTH PROPERTIES OF CONCRETE WITH FIBRES

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Abstract - *Concrete is the most widely utilized "man-made" material globally for construction in many developing countries in all types of civil engineering works. Many of investigations were attempted by the researchers to improve the quality, strength and durability against adverse exposures, since decades. Concrete that includes imbedded metal (usually steel) is called reinforced concrete or ferroconcrete. Reinforced concrete combines the tensile or bendable strength of metal and the compressional strength of concrete to withstand heavy loads. Reinforced concrete combines the tensile or bendable strength of metal and the compressional strength of concrete to withstand heavy loads .Varying percentages of fibers are 0.5, 0.75, 1.0 percentages of total fiber content for M 25 grade structural concrete with locally available aggregates. The details of investigation along with the analysis and discussion of the test results are reported here in.*

***KeyWords*: Cement, Aggregate, Concrete, Fiber-reinforced Concrete.**

1. INTRODUCTION :

Concrete is the most widely utilized "man-made" material globally for construction in many developing countries in all types of civil engineering works. Concrete is a material used in civil engineering constructions, consisting of a hard, chemically inert particulate substance, known as an aggregate (usually made from different types of sand and stone), that is bonded together by cement and water. In this experimental investigation cement used is Portland Pozzolanic Cement (RAASI GOLD' 53 grade). Concrete is weak in tension and strong in compression. The low tensile strength is due to the propagation of internal micro cracks present even before loading. So, concrete exhibits little fracture. Hence steel fibers are used to overcome the above disadvantage. The modern use of fiber reinforced concrete started in the 1960s using after various sorts of fiber materials have been investigated ever since and are utilized for different applications. Steel fibers are the dominating material, but there are many others, such as polymeric fibers, mineral fibers and naturally occurring fibers. In this experimental investigation fibers of Perma-Fil E Glass Fibers and **Cold Drawn Carbon Wire Steel Fibers are used.** Fiber reinforced concrete is a composite material essentially consisting of conventional concrete or mortar reinforced by randomly oriented, short continuous and discrete fibers of specific geometry. The fiber is a piece of reinforcing material usually described by aspect ratio.

1.1 Need for Reinforced Concrete:

Plain concrete is weak in tension and has limited ductility and little resistance to cracking. Micro cracks in concrete are formed during its hardening stage. A discontinuous system exists even before the application of any external load. Further application of the load leads to uncontrolled growth of the micro cracks. The low resistance to tensile crack propagation in turn results in a low fracture toughness and limited resistance to impact and explosive loading. Conventionally reinforced concrete is a true two- phase material only after cracking when cracked matrix is held by the reinforcing bars. Existence of one phase (i.e., steel or concrete) does not improve the basic strength characteristics of the other phase and consequently the overall performance of the traditional reinforced concrete composite is dictated by the individual performance of the concrete and steel phase separately. These deficiencies have led researchers to investigate and develop a material, which could perform better in areas where conventional concrete has several limitations. One such development has been two phase composite materials i.e., Fiber Reinforced Concrete, in which cement-based matrix, is reinforced with ordered or random distribution of fibers.

Objective of the Study:

The present work is made to investigate experimentally and the following tests were carried out namely: Compressive Strength , Split Tensile Strength and Flexural Strength Tests. This experimental investigation comprises with the replacement of glass with steel fiber by 0%, 25%, 50% 100% from total content of 0.50, 0.75 and 1.00 percentages by weight have been attempted over the concrete specimens such as cubes, cylinders and beams respectively. The program consists of casting and testing of specimens for various mixes. A detailed test program and results of testing are presented in the subsequent chapters.

2. MIX CALCULATIONS:

2.1 Quantities of fibers for 0.5%total fiber content (steel fibers &glass fibers) for concrete cubes:

Glass Fiber	Weight(Kgs)	Steel Fiber	Weight (Kgs)
0%	0	100%	0.217
25%	0.054	75%	0.163
50%	0.1085	50%	0.1085
75%	0.163	25%	0.054
100%	0.217	0%	0

2.2 Quantities of fibers for 0.5% total fiber content (steel fibers &glass fibers) for concrete cylinders:

Glass Fiber	Weight(kgs)	Steel Fiber	Weight(kgs)
0%	0	100%	0.344
25%	0.086	75%	0.258
50%	0.172	50%	0.172
75%	0.258	25%	0.086
100%	0.344	0%	0

2.3. Quantities of fibers for 0.75%total fiber content (steel fibers &glass fibers) for concrete cubes:

Glass Fiber	Weight (Kgs)	Steel Fiber	Weight (Kgs)
0%	0	100%	0.322
25%	0.081	75%	0.241
50%	0.161	50%	0.161
75%	0.241	25%	0.081
100%	0.322	0%	0

2.4 Quantities of fibers for 0.75% total fiber content (steel fibers &glass fibers) for concrete cylinders:

Glass Fiber	Weight(kgs)	Steel Fiber	Weight(kgs)
0%	0	100%	0.515
25%	0.129	75%	0.386
50%	0.2575	50%	0.2575

75%	0.386	25%	0.129
100%	0.515	0%	0

2.5 Quantities of fibers for 1.00% total fibers content (steel fibers &glass fibers) for concrete cubes:

Glass Fiber	Weight (Kgs)	Steel Fiber	Weight(Kgs)
0%	0	100%	0.429
25%	0.107	75%	0.322
50%	0.2145	50%	0.2145
75%	0.322	25%	0.107
100%	0.429	0%	0

2.6 Quantities of fibers for 1.00% total fibers content (steel fibers &glass fibers) for concrete cylinders:

Glass Fiber	Weight(kgs)	Steel Fiber	Weight(kgs)
0%	0	100%	0.687
25%	0.172	75%	0.515
50%	0.3435	50%	0.3435
75%	0.515	25%	0.172
100%	0.687	0%	0

2.7 Water Cement Ratio:

Water cement ratio has been fixed depending on the compacting factor test the workability tests are carried out by tallying different water cement ratios to find-out the compacting factor as moderate, w/c ratio is maintained as 0.5 in this investigation.

3.EXPERIMENTAL INVESTIGATION:

In the present experimental investigation, the following tests were carried out namely: Compressive Strength , Split Tensile Strength and Flexural Strength Tests for replacement of glass with steel fiber by 0%, 25%, 50% 100% from total content of 0.50, 0.75 and 1.00 percentages by weight have been attempted over the concrete specimens such as cubes, cylinders and beams respectively. The program consists of casting and testing of specimens for various mixes. In the present investigation, it is intended to study the behavior of concrete and various strength parameters that are compressive, tensile and flexural strength with laboratory samples are evaluated. The mixed glass and steel short fibers with varying percentages of 0%, 25%, 50% 100% from 0.5, 0.75, 1.0 percentages of total fiber content are used for structural concrete. For each replacement of glass with steel fibers by 0%, 25%, 50% 100% from each 0.5, 0.75, 1.0 percentages of total fiber content, 6 cubes& 6 cylinders were cast. Totally 18 cubes &18 cylinders were cast with locally available good materials and are taken for testing in this investigation. These 18 cubes& 18 cylinders for 28 days were used for finding compressive strength, split tensile strength and flexural strength test respectively.

3.1 TESTING PROGRAMME:

In the present investigation, it is intended to study the behavior of concrete and various strength parameters that are compressive, tensile and flexural strength with laboratory samples are evaluated. The mixed glass and steel short fibers with varying percentages of 0%, 25%, 50%

100% from 0.5, 0.75, 1.0 percentages of total fiber content are used for structural concrete. For each replacement of glass with steel fibers by 0%, 25%, 50% 100% from each 0.5,

0.75, 1.0 percentages of total fiber content, 6 cubes& 6 cylinders were cast. Totally 18 cubes &18 cylinders were cast with locally available good materials and are taken for testing in this investigation. These 18 cubes& 18 cylinders for 28 days were used for finding compressive strength, split tensile strength and flexural strength test respectively.

3.2 PREPARATION OF SPECIMENS:

Preparation of specimens involves preparation of samples (i.e., cubes, cylinders and beams) and the various steps involved starting from the materials required to the handling of samples (i.e., cubes, cylinders and beams). The various physical properties of materials are found out and recorded.

From these properties mix proportions for M25 Grade concrete are worked out using the mix design principles of IS : 10262:1982. Mix proportions are worked out keeping in view the durability requirements. The water cement ratio used is 0.5, Since the maximum water-cement ratio is 0.5 for moderate environment .The materials required for cubic meter of concrete worked out . The details of formwork, casting procedure and curing of samples (i.e., cubes, cylinders and beams). are dealt with.

3.3 MATERIALS:

The properties and specifications of various materials used in the preparation of test specimens are as follows.

1)CEMENT:

Portland pozzolana cement (PPC) 53 grade cement: -

The cement used in the work was procured in a single consignment and was properly stored. The brand name of the Portland pozzolana cement used for the investigation is 'RASI GOLD' cement (PPC 53 grade) conforming to IS 12269-1987, IS 1489 (Part1&2)-1991, IS 3812-1981 and IS

1344-1981. The cement is fresh and uniform in colour. The cement is free from lumps and foreign matter. The fineness of cement is 9 % (as percentage residue on I.S sieve No.9). The Specific gravity is 3.15 and normal consistency is 30%.The initial setting time is 150 minutes and final setting time is 480 minutes. The compressive strength of cement mortar cubes at 3days, 7days and 28 days are 31.0 N/mm^2,

42.5 N/mm^2 and 56.5 N/ mm^2 respectively.

(b) Fine aggregate:

The fine aggregate i.e., sand used in the present experimental investigation is river sand conforming to zone-II as per IS : 383-1970 . The sand is clean inert and free from organic matter, silt and clay. Its specific gravity is 2.55. The sand is completely dried before use. The fineness modulus of fine aggregate is 3.55.

(c) Coarse aggregate:

The coarse aggregate i.e., metal used in the present experimental investigation is natural aggregate conforming to IS : 383-1970. Coarse aggregate consists of particles of maximum size 20mm .The specific gravity is 2.68. The fineness modulus is 6.15. The aggregate is of uniform angularity.

(d) Water:

The water used in the present experimental investigation is clean and free from oils, acids, alkalies, sugar, organic materials and other substances as per IS 456-2000. The portable water was used for casting concrete specimens and for curing.

(e) Fibers:

The fibers used in the present concrete mix are Glass and steel. The percent of fibers in the concrete mix are based on volume and is expressed as a percent of the mix. The main properties of fibers used in the present experimental investigation are:

- Type of fibers used.
- Volume percent of fiber.
- Orientation of the fibers in the matrix.
- Aspect ratio (the length of a fiber divided by its diameter).

(e1) Glass Fibers:

The concrete mix contains the glass fibers are of alkali-resistant glass fibers. Glass fiber is especially resistant to ordinary deterioration caused by environmental conditions. It is also an ecologically friend kind of fiber reinforced concrete because the glass fibers are made from natural materials and take comparatively little energy to produce.

The glass fibers in combination of steel short fibers with varying percentages of 0%, 25%, 50% 100% from 0.5, 0.75,

1.0 percentages of total fiber content are used for testing concrete specimens. The Orientation of the glass fibers is generally random, simply because they are not placed one at a time in a straight line. Fibers are either added to the dry cement or sprayed onto a form and covered with the wet concrete mix. Both of these procedures will produce a random pattern of fiber reinforcing. Aspect ratio is simply the length of a fiber divided by its diameter. This property is used to represent the amount of surface area of the fiber against the concrete mix. This aspect ratio is an important for another reason. It has been determined that bailing of fibers in the mix increases as the aspect ratio increases. An aspect ratio of 100 for fibers was found to be optimum. Perma-Fil E Glass Fibers of diameter 15µ and 12mm in length and an aspect ratio of about 800 were used in the present experimental investigation.

4. Features and Benefits:

It improves the strength as glass fiber in concrete and minimize the cracking pattern when loaded the test specimens. Also enhances the thermal properties. The product is durable and lighter in weight, which significantly reduces the cost of freight transportation and installation. The fiber-wrapped skin is more resistant to environmental degradation and corrosion under the attack of chemicals. Easily adopts to any shape of the concrete allowing flexibility in design. It demonstrates higher resistance to environmental deterioration and strength retention than the less expensive. Adding fibers improvement in impact resistance and reduce the chances of spalling. Also, it increases the tensile strength in concrete.

5.CASTING, CURING AND TESTING OF TEST SPECIMENS: Casting and Curing:

This chapter deals with the Casting and Curing of test specimens. The details of procedure of casting and curing are dealt with as per I.S : 516-1959.The work details with the preparation of M25 Grade of concrete using 'RASI GOLD' cement (PPC 53 grade). The sand passing through 4.75mm sieve and surface dry in condition, the crushed stones of surface dried, and clean potable water were used. M25 grade of concrete is designed by the IS:10262:1982 method with water cement ratio of 0.50. The same mix is prepared by different percentages of fibers by weight and for various fiber volume fractions of 0.50, 0.75 and 1.00 percentages.

All the materials were proportional by weigh batch. Machine mixing was adopted for all the concrete mixes. Immediately after thorough mixing, the fresh concrete was tested for workability by determining the slump as per specifications I.S.:1139-1959. The slump value is 65mm.

The moulds of required size confirming to I.S : 10086-1982 were arranged on smooth platform amid every care was taken to avoid any irregular dimensions. The inner sides and bottom of moulds were lubricated using waste oil. Required quantities of cement, sand, coarse aggregate and specified fibers were taken on a water tight/nonabsorbent platform. First cement and aggregate were mixed thoroughly in dry state. The required amount of fibers were added manually and thoroughly mixed. In the process of mixing half the quantity of water was added to the materials placed in the mixer. This was intended to avoid sticking of finer particles to mixer. As the mixing was in progress, the balance quantity of the water is added and mixing is continued. Care is to be taken so that fibers are dispersed uniformly and to avoid baling of fibers. Proper care has to be taken to avoid sticking of finer particles to mixer. The mixing process was continued until all the ingredients were thoroughly mixed to form a uniformly and coherent mix. All the types of test specimens namely cubes (12 Nos.), cylinders were simultaneously caste. The mix was placed in two equal layers. Each layer was compacted using platform vibrator to obtain dense concrete. The specimens were removed from the moulds after a lapse of 24 hours. The identification mark, date of casting and grade of concrete are written on each specimen. After that the specimens were transferred to curing tank. Curing was done for a period of 28 days by submerging the specimen in water. The cubes 18 Nos. are cast in steel moulds of inner dimension 150 x 150 x 150 mm, the flexural beams 18 Nos. are cast in steel moulds of inner dimension 500x 100x 100 mm and the cylinders 18 Nos. are cast in steel moulds of inner dimension of Height 300mm and Diameter 150mm. Totally 54 Nos. test samples are proposed for this experimental investigation.

6. Testing of Test Specimens: Test Setup:

The cube and cylindrical specimens were tested in Compression Testing Machine.

6.1 Compression Testing Machine:

The compressive strength of concrete is taken as an important index of its general quality. Since it is a first requisite of the structural engineer, this property is most frequently found .The tensile strength of concrete is roughly 10% of its compressive strength. The loads required to be applied in compression tests are generally high when compared to that in other tests and the normal universal testing machines do not provide such high loads. Hence the need for this particular type of compression testing machine. The salient futures of compression testing machine are as follows:

1.Make : Killern and Co., New Delhi.

2.Year : 1987

3.Capacity : 300 / 150 / 60 Tones.

4.Testing : Compression test on concrete/Gauge Calibration.

The 300 / 150 / 60 Tones hydraulic compression testing machine consists of two parts fitted in two different mountings , the pumping unit being separate from the combined mounting of the straining unit and the loading indicating unit. Since the machine is used for compression tests only, no special grips are required and the specimen is held between two steel surfaces and compressed. The upper compression plate is a stout steel surface, which can be adjusted to touch the specimen and hold it intact. The adjustment is affected by means of the hand-wheel at the top. A ram works inside pressure cylinder at the bottom of the machine. The top of the ram acts as the bottom compression plate .Concentric circles are marked on this platen to facilitate the centering of the specimen. Plywood or cardboard sheets may be placed above and below the specimen incase the specimen surfaces are rough and not quite plane. Oil pressure applied into the cylinder, forces the ram up and load the specimen. A small portion of this oil under pressure taken into the load indicating unit gives the load directly.

Procedure: -

The identification marks, size and weight of the cube are noted. The machine is started and sufficient lubrication is ensured before commencing the test the specimen is placed centrally over the bottom compression plate, and so positioned that the load is applied at right angles to the as- cast position. The upper cross –head is lowered by means of the wheel until it touches the top of the cube. Turning the wheel little further holds the specimen tight. Load is applied gradually, at the rate specified by the code of practice. The loads are noted a first crack and at the final crushing of the specimen. The type of failure is observed. The normal practice is to test three cubes of concrete from one batch. If any value varies by 15% of the average strength, three more cubes of the same batch may be tested. While computing the average compressive strength the values that which are

+15%away from the average are not considered.

7. TEST PROGRAMME:

7.1 Compressive Strength: -

At the end of the curing period, the cube specimens were tested under the compression testing machine of 3000KN capacity. Testing machine has different loading ranges (in each range) of 600KN, 1500KN and 3000KN. The least count for the said loading ranges is 10KN. The test specimen was placed in the correct position and then the load was applied. The rate of loading was maintained at 10MPa per minute.

The cubes were tested for compressive strength using compression testing machine. In the machine, the cube is placed with cast faces at right angles to that of compressive faces .according to I.S specification, the load on the cube is applied at constant rate of 140kg

/sq.cm/minute up to failure and the ultimate load is noted. The crushing load is noted from the dial gauge and the crushing strength of the cube is obtained from the formula.

Compressive Strength (fcu)= ---- Pu -----

A

Where, fcu = Ultimate cube strength in N/mm^2

Pu= Ultimate load or load at which the cube is crushed

A =Contact area of the specimen in mm^2

7.2 Split Tensile Strength:

For the split tensile strength, cylindrical specimens were

Compressive Strength Test:

Concrete Specimens Details:-

Mix : M25

Concrete specimen No.	Glass Fiber %	Steel Fiber %	Ultimate Compressive Load in KN	Compressive Strength in N/mm2	Increase in Strength %
C_{1-1}	0	100	1180	52.44	27.12
C_{1-2}	25	75	1160	51.56	25.87
C_{1-3}	50	50	1060	47.11	18.87
C_{1-4}	75	25	980	43.56	12.25
C_{1-5}	100	0	930	41.33	7.53
C_{1-6}	Conventional Concrete		860	38.22	00.00

Specimens' designation : C1-1 to C1-6

(B)SPLIT TENSILE STRENGTH TEST:

Concrete specimen No.	Glass Fiber %	Steel Fiber %	Ultimate Split Tensile Load in KN	Split Tensile Strength in N/mm2	Increase in Strength %
1	2	3	4	5	6
S_{1-1}	0	100	320	4.53	21.85
S_{1-2}	25	75	305	4.31	17.87
S_{1-3}	50	50	295	4.17	15.11
S_{1-4}	75	25	275	3.89	9.00
S_{1-5}	100	0	260	3.68	3.80
S_{1-6}	Conventional Concrete		250	3.54	00.00

tested in compression testing machine. This test was developed in Brazil in 1943. Therefore, this is sometimes referred to as "Brazilian Test". The cylindrical specimens are placed horizontally the loading surfaces of a comprehension testing machine and the load was applied until the failure of the cylinder, along the vertical diameter. The split tensile strength of cylinder is obtained from the formula.

$$\text{Split Tensile Strength} = \frac{2P}{\pi DL}$$

Where , P = Comprehensive load on the cylinder.

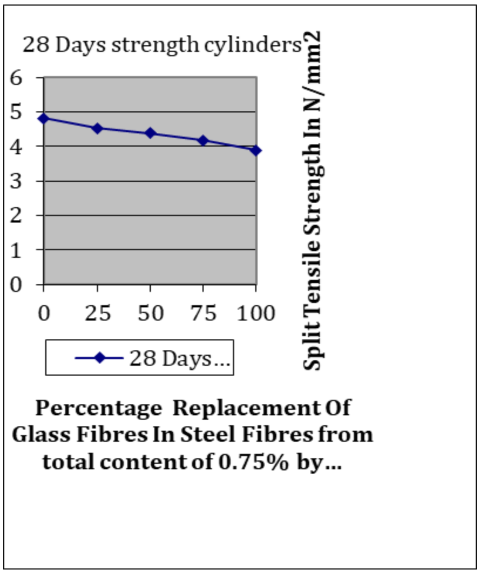
L = Length of the cylinder.

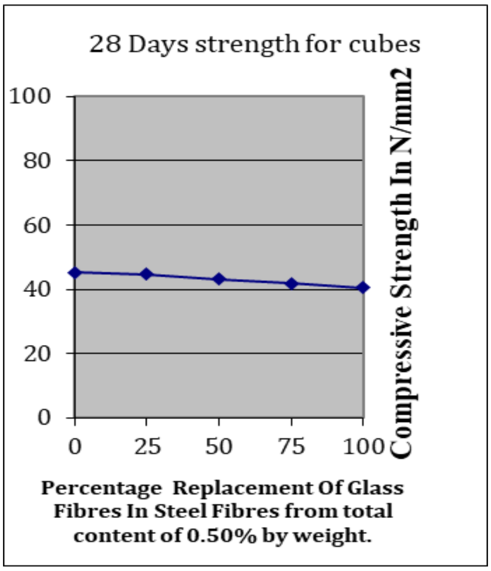
D = Diameter of the cylinder.

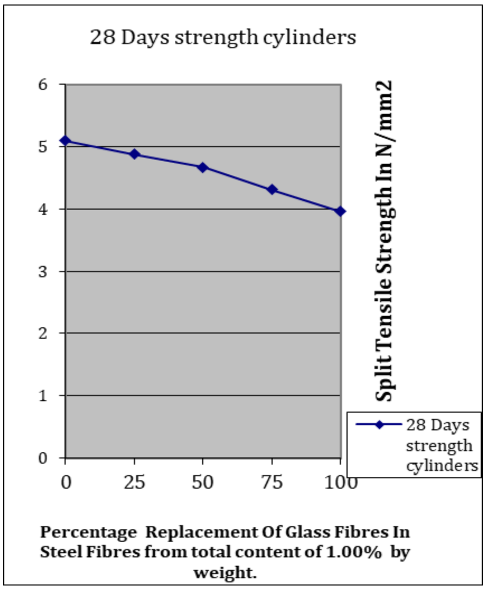
8. TEST RESULTS AND GRAPHS:

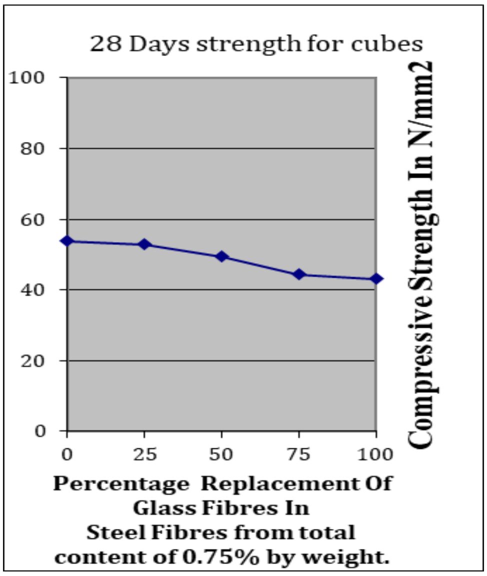
(a)Test-I:

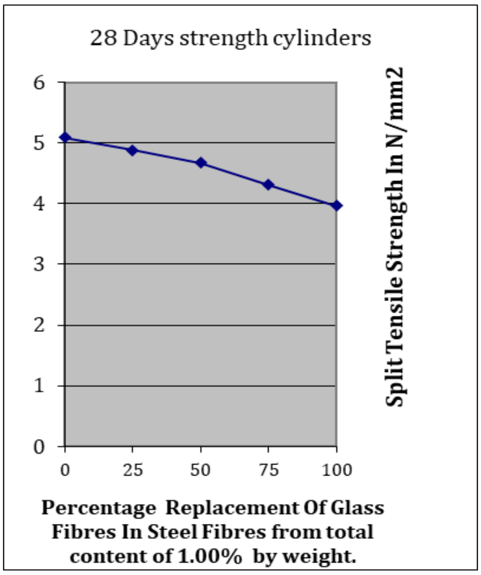
GRAPHS:

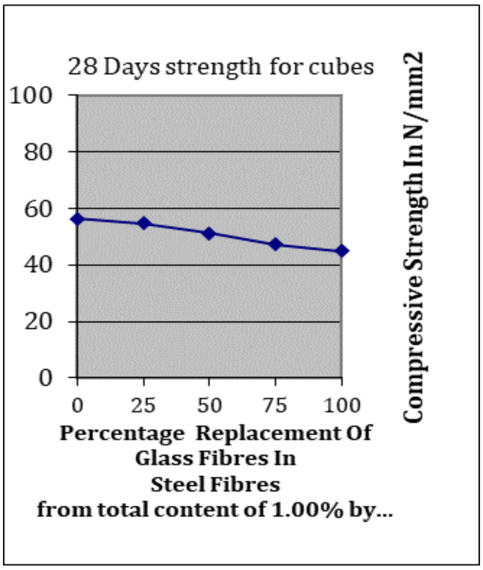












9. DISCUSSION ON TEST RESULTS :

The tests results are studied with reference to the results of the Compressive Strength, Split Tensile Strength and Flexural Strength at 28 days are reported.

9.1 Observations Made:

Glass fiber reinforced concrete can be advantageously used for practical applications. The GFRC mix is cohesive with sufficient workability. Glass fiber combines well with the other ingredients of the concrete to impart uniform color and texture. Shrinkage characteristics are very much improved. As glass fiber is not affected by corrosion as steel fiber. Hence GFRC can be preferred for corrosion resistant structural components. It can be used for chemical resistance and in the case of water tanks etc. Though not tested in the present work, it can be taken that glass fiber improves the shear strength of concrete. Because of its superior crack arresting and ductility characteristics, GFRC performs better against shockorimpactloadsandblasts.Its energy absorption quality is better.

9.2 Workability Of Fiber Reinforced Concrete Using Dual Fibers (Steel Fibers and Glass Fibers):

In the present experimental investigation total fiber content (steel fibers and glass fibers) of 0%,0.5 %, 0.75 %, 1.0%, by volume has been used in the preparations of fiber reinforced concrete. With a water cement ratio of 0.5, M25 plain cement concrete mixes are found to have a compaction factor of nearly 0.90. With 100% steel fibers in 1.0% total fiber content, for the same cement ratio, the workability is found to be nearly 0.88. With 100% glass fibers and with the same water cement ratio, the workability is found to be 0.89 in terms of compaction factor. Hence it can be observed, that the above percentages of fibers used in the present investigation affect the workability marginally. The workability is almost same with steel or glass fibers.

The cube compressive strength results obtained at the age of 28 days are presented in the above table for 0%,0.5%, 0.75% and 1.00% total fiber content. The glass fiber content is varied from 0% to 100% in the above table and the results

compared with that of plain concrete specimens. Likewise, the results of 0.75% total fiber content and the results for 1% total fiber content are compared with that of plain concrete specimens. Hence the results presented in the below table shows the variation of compressive strength at the end of 28 days with various percentages of glass fibers of 0%, 25%, 50%, 100% by volume used as replacement of steel fiber in total fiber content of 0%,0.5%,0.75% and 1.0% by volume,

Percentages of fibers in concrete specimens		For 0.50% total fiber content Compressive Strength in N/mm2	For 0.75% total fiber content Compressive Strength in N/mm2	For 1.00% total fiber content Compressive Strength in N/mm2
Glass Fiber %	Steel Fiber %			
1	2	3	4	5
0	100	52.44	53.78	56.44
25	75	51.56	52.89	54.67
50	50	47.11	49.33	51.11
75	25	43.56	44.44	47.11
100	0	41.33	43.11	44.89
Conventional Concrete		38.22	38.22	38.22

10 Discussion:

It is observed that as the percentage of total fiber content (steel fibers and glass fibers) is increased, the compressive strength also increases. It may also be observed that as the percentage replacement of steel fiber by glass fiber increased and steel fiber percentage is decreased, the compressive strength goes on decreasing.

In the present experimental investigation regarding the compressive strength, the following is observed from the above table. The compressive strength at the end of 28 days, for the concrete of nominal M25 Mix with 1.0% total steel fiber content and with 0% glass fiber replacement i.e. 100% Steel fiber) is found to be maximum and the same is found to be excess over the strength of plain concrete. As the relative percentage of glass fiber in the total fiber content is increased, the compressive strength (28 days) is gradually decreased compared to the mix with 100% steel fiber. It is clear from the above table, that the increase in glass fiber content decreases the compressive strength. The compressive Strength also increases considerably over the plain cement concrete, by adding Glass fibers.

10.1 SPLIT TENSILE STRENGTH:

Percentages of fibers in concrete specimens		For 0.50% total fiber content Split Tensile Strength in N/mm2	For 0.75% total fiber content Split Tensile Strength in N/mm2	For 1.00% total fiber content Split Tensile Strength in N/mm2
Glass Fiber %	Steel Fiber %			
2	3	4	5	6
0	100	4.53	4.81	5.09
25	75	4.31	4.53	4.88
50	50	4.17	4.38	4.67
75	25	3.89	4.17	4.31
100	0	3.68	3.89	3.96
Conventional Concrete		3.54	3.54	3.54

Similarly, the split tensile strength test results are presented in the above table for 0%,0.5%, 0.75%, 1.0% total fiber content. The glass fiber content is varied from 0% to 100% in the above table. The variation of split tensile strength at the end of 28 days with various percentage of glass fibers of 0%, 0.5%, 0.75%, 1.0% is also shown in the above table.

11 Discussion:

It is observed that as the percentage of total fiber content (steel fiber and glass fiber) is increased, the split tensile strength also increases. It may also be observed that as the percentage replacement of steel fiber by glass fiber is increased and steel fiber percentage decrease, the split tensile strength goes on decreasing. In the present experimental investigation regarding the split tensile strength, the following is observed from the above table. The split tensile strength, at the end of 28 days, for the concrete of M25 Mix with 1.0% total steel fiber content and with 0% glass fiber replacement i.e. (100% steel fiber) is found to be maximum and the same is excess over the strength of plain concrete. As the relative percentage of glass fiber in the total fiber content is increased, the split tensile strength (28 days) is gradually decreased compared to the mix with 100% steel fiber. It is clear from the above table, that the increase in glass fiber content decreases the split tensile strength. The split tensile strength also increases considerably over the plain concrete, by adding Glass fibers.

12 Cracking Characteristics:

Typical failed specimens of cube & cylinder. It is observed that failure has taken place gradually with the formation of cracks. In the case of plain concrete specimens, the failure is sudden and brittle. Hence it is established that the presence of fibers in the matrix has contributed towards arresting sudden crack formation. Even during failure, the specimens have not been splintered as in the case of plain concrete specimens. This is true with the presence of steel or glass fiber. It may also be noted that the increase in glass fiber content though caused reduction in the strength but has contributed towards arresting the crack formation.

13 Ductility Characteristics:

Beam specimens of Nominal M25 mix with various percentages of fibers have been tested for flexural strength under two point loading as per the standard specifications. The procedure followed and the values obtained have already been discussed. The flexural specimens tested have exhibited ductility characteristics. At the failure load a diagonal crack has appeared in between the loading points and the specimen have not failed suddenly. The failure is not brittle and is entirely different from that of plain concrete, where failure is brittle. The ductility characteristics exhibited by the specimens are due to the introduction of fiber in the mix. This shows that in general introduction of fibers in specimens exhibits the improved ductility. The crack pattern of beams is presented in Fig. All the beams failed about skew axis showing typical skew bending failure. The increase in glass fiber content has caused reduction in the strength compared to steel fibers. But with the glass fiber in the matrix the ductility is very much increased.

14 CONCLUSIONS AND SCOPE FOR FUTURE STUDY:

14.1 Conclusions:

On the basis of experimental studies carried out and the analysis of test results, the following conclusions are drawn.

1. The structural integrity of the tested concrete specimens is found to be good under loading.
2. With the above test results, the concrete mixed with dual fibers can be recommended for earthquake resistance structures.
3. In addition to the fibrous contents, some of the admixtures/plasticizer can be mixed to enhance some of the strength properties of concrete satisfactorily.
4. It can be concluded that the concrete mixed with dual fiber would also have much more life in comparison with the conventional concrete.
5. The fibrous concrete is found to have maximum ultimate load carrying capacity as conventional concrete.
6. The fibrous concrete is stiffer than the conventional concrete inappreciable way.
7. For the nominal M25 mix with a water cement ratio of 0.5 used in the present investigation, the workability of concrete is only marginally affected even with a total fiber content of 1.0 percent by volume.
8. The compressive strength of dual fiber concrete is found to be maximum at 1.0% total fiber content of steel at 28 days compared to plain concrete. Also, with a total of 1.0 % glass fiber by volume the increase of compressive strength at 28 days compared to plain concrete.
9. There is substantial increase in the compressive strength for mixed fiber combination.
10. As the percentage of steel fiber is reduced and glass fiber is increased, the compressive strength is getting reduced compared to that of 100% steel fiber in the matrix.
11. Steel fiber of 1 mm diameter and length of 50 mm having an aspect ratio of 50 can be satisfactorily mixed along with glass fiber having an aspect ratio of nearly 800 to increase the strength and other characteristics.
12. The split tensile strength of dual fiber concrete is found to be maximum at 1.0 % total steel fiber content at 28 days compared to plain cement concrete. Also, with a total of 1.0 % glass fiber by volume the increase of split tensile strength in 28 Days compared to plain cement concrete.

13. As the percentage of steel fiber is reduced and glass fiber is increase, the split tensile strength is getting reduced compared to that of 100 % steel fiber in the matrix.

14. The ductility characteristics were found to improve by adding steel fibers.

15. The flexural strength of dual fiber concrete is found to be maximum at 1.0 % total steel fiber content at 28 days compared to plain concrete. Also, with a total of 1.0 % glass fiber by volume the increase of flexural strength in 28 days compared to plain cement concrete.

16. The ductility characteristics have improved with the addition of glass fibers. The failure is gradual compared to that of brittle failure of plain concrete.

17. Cracks can be controlled by introducing glass fibers. Cracks have occurred and propagated gradually till the final failure. This phenomenon is true with all the percentages of glass fiber. Glass fiber also helps in controlling the shrinkage cracks.

18. Compared to metallic fibers likes' steel, alkali resistant glass fiber gives corrosion free concrete.

19. The crack widths in the mixed fibrous concrete are less.

20. The mixed fibrous concrete has adequate code prescribes ductility.

21. The present experimental investigation has been taken up with a view to open new paths and vistas for the use of dual fiber reinforced concrete for structural applications and the results are encouraging.

22. The arguments about cost versus enhanced life, equally holds here as well.

15. Scope for Future Study:

Various research activities on properties of concrete in aggressive media are carried out; there is a wide scope for further research. The advert of various mineral admixtures and chemical admixtures necessities active exploration and experimental investigation. The following avenues may be investigated.

1. Further study can be made for the same case of loading with different cements and different grades of concrete.

2. The comparative study can be made on the strength properties of concrete with various dual fibers such as Carbon fibers and Steel fibers, Glass fibers and Carbon fibers and other combinations of fibers.

3. Present work can be studied further by using mineral admixtures, Fly ash & glass fibers with partial replacement of cement.

4. This study can also be extended by considering the effect of single and two points loading with effect of shear also.

5. Creep, Impact and Fatigue tests for beams with different percentages of fibers under different loading conditions can be studied.

6. Further investigations can be carried out on the permeability property of concrete with fibers.

7. Behavior of fiber reinforced concrete with dual fibers under uni-axial and biaxial bending for columns can be studied.

8. Further work may be carried out on the high strength concrete/self-compaction concrete using dual fibers.

9. Tests on slabs and beams (prototype) may be conducted to arrive at the design strength of fiber reinforced concrete with dual fibers.

10. Further investigation can be done at the end of 45 days, 90 days and 1 year to life time.

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