EXPERIMENTAL STUDY AND STRENGTH OF CONCRETE BY USING GLASS AND STEEL FIBRES

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ABSTRACT*: Concrete deteriorates due to either original construction errors and/or environmental effects. Due to those effects, cracks will develop in concrete and are sources for the further deterioration of the concrete structure. Mainly when subjected to tensile stresses, unreinforced concrete will crack and fail. When fibers are added to the concrete mix, it too can add to the tensile loading capacity of the composite system. In fact, research has shown that the ultimate strength of concrete can be increased by adding fiber reinforcing.*

In this study, an attempt is made to use mixed steel and glass fibers with varying percentages of fibers from 0.5, 0.75, 1.0 percentages of total fiber content for M 25 grade structural concrete with locally available aggregates (i.e. fine & coarse aggregates) and Portland pozzolanic Cement (i.e. PPC). The details of investigation along with the analysis and discussion of the test results are reported here in.

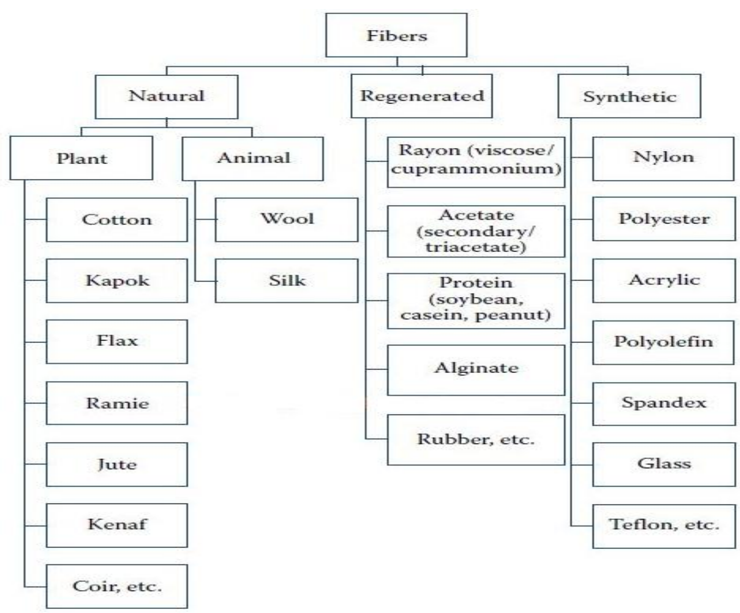
1. INTRODUCTION:

Fibers have been used since ancient times to reinforced brittle material. Horse hair was used to reinforce plaster, straws and asbestos fibers were used to reinforce bricks and Portland cement in early yearly in 1910, Porter first put forward the idea that concrete can be strengthened by inclusion of fibers. In the early 1970s Steel Fiber Reinforced Concrete (SFRC) has been used in pavement construction.

In 1964-65, pioneering work on the use of glass fibers in cement and concrete was done by Krenchel in Denmark and by Biryukouachetal in USSR. In the latter work the problem of the attack by alkali on the E-Glass (non-alkali resistance fiber) fibers had been overcome by the use of alumina cement of low alkaline content. The development of a glass fiber with a sufficient degree of alkali resistance such that it could be used in Portland cement environment was achieved by Dr.A.J. Majumdar at the Building Research Establishment in U. K in 1967 in collaboration with Pilkington Bros Ltd., the alkali-resistant "Cem-Fil"(trade name) fiber was launched which led to worldwide commercial exploitation of glass reinforced cement (GRC).

In the early 1960's polymer fibers such as nylon, polypropylene and polyethylene were used as reinforcement for concrete subjected to dynamic loading. In 1966 the shell company developed a process for producing a fiber concrete, designated "caricrete" containing polypropylene fibers in fibrillated film form, where by the products, such as driven pile segment, and were benefited from the improved impact resistance of the concrete. More recently, it was realized that with their low price, high strength and ready availability, polymers such as polypropylene also have the potential to increase the tensile strength and failure strain of cement - based matrix in competition with particularly, glass and asbestos fibers in thin-sheet applications.

1.1. Classification of Fiber:



2. CONCRETE MIX DESIGN:

2.1. Mix design for M_{25} Grade:

a) Design specification:-

Characteristic compressive strength M_{25} grade at 28 days

(f_{ck}) = 25 N/mm²

Maximum size of aggregate (Angular) = 20mm

Degree of workability in terms of slump = 50 to 75 mm (C F)

Degree of quality control (assumed) = Good

Assumed type of exposure = Moderate

b) Test data of materials: -

53 grade Cement used (RASI GOLD)= PPC

Specific gravity of cement = 3.15

Specific gravity of C.A = 2.68

Specific gravity of F.A (Zone-II) = 2.55

c) Target mean strength of concrete: -

Standard deviation for M_{25} grade and good degree of control(S) = 5.3

Target average compressive strength at 28 days

F_{ck} = f_{ck} + tS

= 25 + 1.65 X 5.3

= 33.745 N/mm²

d) Selection of water cement ratio: -

From the graph given is IS: 10262:1982 corresponding to target strength (f_{ck}) and curve we have

Water cement ratio = 0.50

For 20 mm size coarse aggregate percentage of entrapped air = 2.0%

e) Selection of water content and fine to total aggregate ratio :--(Table-4 of IS: 10262-1982)

For 20 mm size of aggregate water content per m³ of concrete = 186 Kg.

Percentage of sand = 35%

f) Adjustment of values in water content and sand percentage of other conditions:

For sand confirming to zone II, percentage of reduction of sand = 0

Sand percentage = 35%

Increase in water content for increase in value of compaction factor by 0.1

Required water content = 186 +186X (1.5/100)

= 188.79 Kg

= 189 Kg

g) Calculation of cement content

Water cement ratio = 0.50

Water = 189 Kg.

Cement content = 189/0.5

= 378 Kg > 300 Kg.

h) Adopting the equation from IS: 10262-1982 for Calculation of aggregates

$$V = [w + \frac{C}{S_c} + \frac{1}{P} X \frac{F_S}{S_{Fa}}] X \frac{1}{1000}$$

Where,

V = Absolute volume of fresh concrete, which is equal to gross volume minus the volume of entrapped air = 0.98

W = Mass of water (Kg) per cubic meter of concrete = 189 Kg

C = Mass of cement (Kg) per cubic meter of concrete = 378 Kg

P = Ratio of F.A (Kg) per cubic meter of concrete = 0.335

S_c = Specific gravity of cement = 3.15

S_{fa} = Specific gravity of fine aggregate = 2.55

S_{ca} = Specific gravity of course aggregate = 2.68

F_s = Total mass of F.A (Kg) per cubic meter of concrete

C_a = Total mass of C.A (Kg) per cubic meter of concrete

Weight of fine aggregate, $V = [w + \frac{C}{S_c} + \frac{1}{P} X \frac{F_S}{S_{Fa}}] X \frac{1}{1000}$

F_a = 573.04 Kg (Or) 573 Kg

Weight of course aggregate $V = \left[W + \frac{C}{S_c} + \frac{1}{1-p} X \frac{C_a}{S_{ca}}\right] X \frac{1}{1000}$

C_a = 1195.72 Kg (Or) 1196 Kg.

The quantity of cement for the above grades to obtain one cum of compacted concrete has shown in the following table.

2.2 Quantities of Materials Used For Nominal Mixes: -

Water	Cement	Fine aggregates F_a	Coarse aggregates C_a
189	378	573	1196
0.5	1	1.52	3.16

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

Total quantities of materials used for 1 cum of concrete
=378 + 573 + 1196
=2147 Kg

Fibers quantity for 0.5% total fiber content
= 2147 X 0.50/100 = 10.735 kg.

Total no. of cubes to be casted = 6 Nos.

Concrete quantity for 6 cubes = 0.15 X 0.15 X 0.15 X 6
= 0.020 cum.

Quantity of fibers for 6 concrete cubes = 0.020 X 10.735
= 0.217 Kg.

Glass Fiber	Weight (Kg)	Steel Fiber	Weight (Kg)
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

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

Total quantities of materials for 1 cum of concrete
= 378 + 573 + 1196
= 2147 Kg.

Fibers quantity for 0.5% total fiber content
= 2147 X 0.50/100 = 10.735 kg.

Total no. of cylinders to be casted = 6 Nos.

Concrete quantity for 6 cylinders,
= (22/7) X 0.15^2 /4 X 0.30 X 6 = 0.032 cum.

Quantity of fibers for 6 concrete cylinders,
= 0.032 X 10.735 = 0.344 Kg.

Glass Fiber	Weight (kg)	Steel Fiber	Weight (kg)
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

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

Total quantities of materials used for 1 cum of concrete
= 378 + 573 + 1196 = 2147 Kg

Fibers quantity for 0.75% total fiber content,
= 2147 X 0.75/100 = 16.103 kg.

Total no. of cubes to be casted = 6 Nos.

Concrete quantity for 6 cubes
= 0.15 X 0.15 X 0.15 X 6 = 0.020 cum.

Quantity of fibers for 6 concrete cubes
= 0.020 X 16.103 = 0.322 Kg.

Glass Fiber	Weight (Kg)	Steel Fiber	Weight (Kg)
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

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

Total quantities of materials for 1 cum of concrete
= 378 + 573 + 1196 = 2147 Kg.

Fibers quantity for 0.75% total fiber content
=2147 X 0.75/100 = 16.103 kg.

Total no. of cylinders to be casted = 6 Nos.

Concrete quantity for 6 cylinders
= (22/7) X 0.15^2 /4 X 0.30 X 6 = 0.032 cum.

Quantity of fibers for 6 concrete cylinders
= 0.032 X 16.103 = 0.515 Kg.

Glass Fiber	Weight (kg)	Steel Fiber	Weight (kg)
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

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

Total quantities of materials used for 1 cum of concrete
=378 + 573 + 1196 = 2147 Kg.

Fibers quantity for 1.00% total fiber content

= 2147 X 1.00/100 =21.470 kg.

Total no. of cubes to be casted = 6 Nos.

Concrete quantity for 6 cubes =0.15 X 0.15 X 0.15 X 6
= 0.020 cum.

Quantity of fibers for 6 concrete cubes

= 0.020 X 21.470 = 0.429 Kg.

Glass Fiber	Weight (kg)	Steel Fiber	Weight (kg)
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

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

Total quantities of materials for 1 cum of concrete
= 378 + 573 + 1196 = 2147 Kg.

Fibers quantity for 1.00% total fiber content

= 2147 X 1.00/100 = 21.470 kg.

Total no. of cylinders to be casted = 6 Nos.

Concrete quantity for 6 cylinders

= (22/7) X 0.15^2 /4 X 0.30 X 6 = 0.032 cum.

Quantity of fibers for 6 concrete cylinders

= 0.032 X 21.470 = 0.515 Kg.

Glass Fiber	Weight (kg)	Steel Fiber	Weight (kg)
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

2.9. 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 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. 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. These 18 cubes & 18 cylinders for 28 days were used for finding compressive strength, split tensile strength and flexural strength test respectively.

3.1. Preparation of specimens: -

Mix proportions for M25 grade concrete are worked out by considering the durability requirements and using the mix design principles of IS: 10262:1982.

a) Cement used:

Portland Pozzolona cement (PPC) 53 grade (RASI GOLD)

The fineness of cement : 9 % (as % residue on I.S sieve No.9)

The Specific gravity : 3.15
Normal consistency : 30%
The initial setting time : 150 minutes
Final setting time : 480 minutes

The compressive strength of cement mortor cubes at
3days :31.0 N/mm²
7days :42.5 N/mm² and
28 days : 56.5 N/ mm²

b) Fine aggregate:-

River sand conforming to zone-II as per IS: 383-1970 is used.
Specific gravity : 2.55
The fineness modulus : 3.55

c) Coarse aggregate: -

Natural aggregate conforming to IS : 383-1970 with uniform angularity is used.

Maximum size : 20mm
The specific gravity : 2.68
The fineness modulus : 6.15

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.

1. Glass Fibers:

Perma-Fil E Glass Fibers of diameter 15µ and 12mm in length is used
Aspect ratio : 800
Density : 200 kg/m^3
Non flammable and thermal resistance up to 600^0 C

i. Chemical Composition:

Type of material is E' Glass

Chemical	Pecentage
SiO_2	54.1%
CaO	17.3%
Al_2O_3	15.3%
MgO	4.7%
Na_2O	0.6%
B_2O_3	8.0%

ii. Physical Properties: -

Physical form water : white to light straw liquid
Molecular weight : 248.4
Specific gravity (25/25):1.045
Boiling point (780mm hg) :255^0 C (491 ^{0} F)
Refractive Index, n_0 (250 C) :1.429
Flash point : 108 (226)
Tag closed cup (a). ^{0} C (^{0} F)

2. Steel Fibers:

Cold drawn carbon wire steel fibers confirming to ASTM 820

Length : 50mm
Diameter : 1mm
Aspect ratio : 50

f) Test Specimens:

Cube : 150x 150x 150 mm
Flexure beam : 500x 100x 100 mm
Cylinder : Height 300mm & Dia 150mm

3.2. TEST PROGRAMME: -

Compressive Strength (f_{cu}) : $\frac{Pu}{A}$ N/mm^2

Where,
P_u = Ultimate load at which the cube is crushed
A = Contact area of the specimen in mm^2

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

Where,
P = Comprehensive load on the cylinder.
L = Length of the cylinder.
D= Diameter of the cylinder.

3.3. TEST RESULTS AND GRAPHS

(A) Test-I: Replacement of steel and glass fiber by 0, 25, 50, and 100 % from total content of 0.5 by weight

Compressive Strength Test

Mix : M25
Specimen's designation : C_{1-1} to C_{1-6}

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

Split Tensile Strength Test

Mix : M25
Specimen's designation : S_{1-1} to S_{1-6}

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

(B) Test-II: Replacement of steel and glass fiber by 0, 25, 50, 100 percentages from total content of 0.75 by weight.

Compressive Strength Test

Mix : M25
Specimen's designation : C_{2-1} to C_{2-6}

Concrete specimen No.	Glass Fiber %	Steel Fiber %	Ultimate Compressive Load in KN	Compressive Strength in N/mm2	Increase in Strength %
1	2	3	4	5	6
C_{2-1}	0	100	1210	53.78	28.93
C_{2-2}	25	75	1190	52.89	27.74
C_{2-4}	75	25	1000	44.44	14.00
C_{2-5}	100	0	970	43.11	11.34
C_{2-6}	Conventional Concrete		860	38.22	00.00

Split Tensile Strength Test

Mix : M25
Specimen's designation : S_{2-1} to S_{2-6}

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_{2-1}	0	100	340	4.81	26.40
S_{2-2}	25	75	320	4.53	21.85
S_{2-3}	50	50	310	4.38	19.18
S_{2-4}	75	25	295	4.17	15.11
S_{2-5}	100	0	275	3.89	9.00
S_{2-6}	Conventional Concrete		250	3.54	00.00

(C) Test-III: Replacement of steel and glass fiber by 0, 25, 50, 100 percentages from total content of 1.00 by weight.

Compressive Strength Test

Mix : M25
Specimen's designation : C_{3-1} to C_{3-6}

Concrete specimen No.	Glass Fiber %	Steel Fiber %	Ultimate Compressive Load in KN	Compressive Strength in N/mm2	Increase in Strength %
1	2	3	4	5	6
C_{3-1}	0	100	1270	56.44	32.28
C_{3-2}	25	75	1230	54.67	30.09
C_{3-3}	50	50	1150	51.11	25.22
C_{3-4}	75	25	1060	47.11	18.87
C_{3-5}	100	0	1010	44.89	14.86
C_{3-6}	Conventional Concrete		860	38.22	00.00

Split Tensile Strength Test

Mix : M25
Specimen's designation : S_{3-1} to S_{3-6}

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_{3-1}	0	100	360	5.09	30.45
S_{3-2}	25	75	345	4.88	27.46
S_{3-3}	50	50	330	4.67	24.20

S_{3-4}	75	25	305	4.31	17.87
S_{3-5}	100	0	280	3.96	10.61
S_{3-6}	Conventional Concrete		250	3.54	00.00

(D) Workability Of Fiber Reinforced Concrete Using Dual Fibers (Steel Fibers And Glass Fibers): -

With water cement ratio of 0.5, Workability in terms of Compaction factor,

For plain cement concrete mixes : nearly 0.90.

With 100% steel fibers : nearly 0.88.

With 100% glass fibers : 0.89.

Hence it can be observed, that the workability is almost same with steel or glass fibers.

Compressive Strength: -

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

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.

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

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.

(e) Cracking Characteristics: -

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.

(f) 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.

4. 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. It can be concluded that the concrete mixed with dual fiber would also have much more life in comparison with the conventional concrete.
4. The fibrous concrete is found to have maximum ultimate load carrying capacity as conventional concrete.
5. The fibrous concrete is stiffer than the conventional concrete in appreciable way.
6. In addition to the fibrous contents, some of the admixtures/plasticizer can be mixed to enhance some of the strength properties of concrete satisfactorily.
7. It can be concluded that the concrete mixed with dual fiber would also have much more life in comparison with the conventional concrete.
8. The fibrous concrete is found to have maximum ultimate load carrying capacity as conventional concrete.
9. The fibrous concrete is stiffer than the conventional concrete in appreciable way.
10. 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.
11. 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.
12. There is substantial increase in the compressive strength for mixed fiber combination.
13. 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.
14. 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.
15. 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.
16. 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.
17. The ductility characteristics were found to improve by adding steel fibers.
18. 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.
19. The ductility characteristics have improved with the addition of glass fibers. The failure is gradual compared to that of brittle failure of plain concrete.
20. 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.
21. Compared to metallic fibers likes' steel, alkali resistant glass fiber gives corrosion free concrete.
22. The crack widths in the mixed fibrous concrete are less.

23. The mixed fibrous concrete has adequate code prescribes ductility.
24. 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.
25. The arguments about cost versus enhanced life, equally holds here as well.

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