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. Also, concrete is an environmental - friendly material and in areas of growing environment – related awareness that is of prime importance. Many of investigations were attempted by the researchers to improve the quality, strength and durability against adverse exposures, since decades. 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. Portland cement concrete is considered to be a relatively brittle material. When subjected to tensile stresses, unreinforced concrete will crack and fail. Since the mid 1800's steel reinforcing has been used to overcome this problem. As a composite system, the reinforcing steel is assumed to carry all tensile loads. 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 ordinary port land Cement (i.e. OPC). The details of investigation along with the analysis and discussion of the test results are reported here in.

Keywords: Cement, Aggregate, Concrete, Fiberreinforced Concrete.

INTRODUCTION

Concrete is the most widely utilized "man-made" material globally for construction in many developing countries in all types of civil engineering works. Also, concrete is an environmental - friendly material and in areas of growing environment - related awareness that is of prime importance. It is construction material due to its many advantages such as high compressive strength, availability of ingredients at reasonable cost, mould-ability to any shape giving aesthetic appearance and resistance to fire and weathering. 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 Ordinary Portland 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 overcomethe above disadvantage. The concept of fiber reinforcement is an old as the use of brittle materials as clay, bricks or concrete. 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.
1.2FIBER REINFORCED CONCRETE (FRC):-

***1.2History of Fiber Reinforced Concrete (FRC)**:-*
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.

1.2.2 Classification of Fiber:-

According to Swami R.N the fibers can be classified into two basic divisions. Those having higher elastic modulus than cement matrix, which depends on stress transfer for their efficiency and those with a lower elastic modulus. The higher elastic modulus fibers such as steel, asbestos and glass lead to strong composites. Low elastic modulus fiberslose their load carrying capacity at around 100 degrees centigrade.

STEEL FIBERS: -

It is one of the most commonly used fibbers it may vary from 0.25 to 1.00mm dia. Use of steel fibers makes significant improvements in flexural , impact and fatigue strength of concrete . It has been extensively used in various types of structures. The efficiency of fiber distribution depends on the geometry of the fiber, the fiber content, the mixing and compaction techniques, the size and shape of the aggregates and the mix proportions.

The following types of steel fibers are available in prevailing market.

(A) CARBON STEEL FIBER:-

1. COLD DRAWN STEEL FIBER
2. SLIT SHEET STEEL FIBER
3. GLUED STEEL FIBER

(B) STAINLESS STEEL FIBER:-

1. MEIL EXTRACT STAINLESS STEEL FIBER
2. SLIT SHEET STAINLESS STEEL FIBER
3. COLD DRAWN STAINLESS STEEL FIBER

COLD DRAWN CARBON WIRE STEEL FIBER:-

Carbon steel fiber is produced from high-strength cold-drawn steel wire, conform to ASTM 820, widely used for concrete reinforcement.

SLIT SHEET CARBON STEEL FIBER	
	Slit sheet carbon steel fiber is used as a replacement for traditional reinforcement in various concrete applications.
	GLUED STEEL FIBER

	Glued steel fibers are filaments of wire, deformed and cut to lengths, for reinforcement of concrete, mortar and other
	MELT EXTRACT STAINLESS STEEL FIBER
	Melt extract stainless steel fiber is produced by melting elements in a crucible. A flywheel is then introduced
	SLIT SHEET STAINLESS STEEL FIBER
	Slit sheet stainless steel fiber is manufactured from coil by chopping the width of the stainless coil. Used for precast shapes.
	COLD DRAWN STAINLESS WIRE STEEL FIBER
	Cold drawn stainless steel fiber is manufactured by high quality stainless steel wire. Used for castable requirements

POLYPROPYLENE AND NYLON FIBERS: -

These are found to be suitable to increase the impact strength . They posses very high tensile strength , but their low modulus of elasticity and high elongation do not contribute to flexural strength . Nylon is heat stable, hydrophilic, relatively and resistantto a wide variety of materials. Polypropylene fibers have the disadvantage of poor bond characteristics with cement matrix, low melting point and high combustibility.

The following various types of polypropylene fines are available in the prevailing market.

(A) POLYPROPYLENE FIBER

1. FIBRILLATED FIBER
2. MONOFILAMENT FIBER

(B)POLYESTER FIBER

(C) POLYACRYLONITRILE FIBER

POLYPROPYLENE FIBRILLATED FIBER	
	Polypropylene fibrillated fibers are specifically engineered for use in concrete as secondary reinforcement.
POLYPROPYLENE MONOFILAMENT FIBER	
	Polypropylene monofilament fibers effectively control the micro cracks resulting from ductile shrink of concrete.
POLYESTER FIBER	
	**P**olyester fibers are designed as a new version of crack proof materials.
POLYACRYLONITRILE FIBER	
	Polyacrylonitrile fibers are designed as a new material for crack resistance especially for asphalt-based concrete.

PROPERTIES OF FIBERS:-

Fiber	**Specific gravity**	**Young's Modulus KN/mm2**	**Tensile Strength KN/mm2**	**Elongation Break (%)**
Acrylic	1.1	2.1	0.2 to 0.4	25 to 45
Asbestos	3.2	8 to 14	0.56 to 0.99	0.6
Glass	2.6	70 to 80	2 to 4	2 to 3.5
Polypropylene	0.91	6 to 7	0.5 to 0.7	20
Polycrystalline Alumina	3.9	245	0.65	……..
Polyethylene	0.95	0.15 to 0.4	0.7	10
Rayon	1.5	7 to 8	0.4 to 0.6	10 to 25

Steel	7.84	200	1 to 3	3 to 4
Sisal	1.5	…….	0.8	3
Nylon	1.1	4.2	0.78 to 0.85	160 0

1.2.3 Need for Fiber Reinforced Concrete (FRC):-

Plain concrete is weak in tension and has limited ductility and little resistance to cracking. Micro cracks are present in concrete and because of its poor tensile strength; the cracks propagate with the application of load, leading to brittle fracture of concrete. Micro cracks in concrete are formed during its hardening stage.

Fiber in the cement based matrix acts as crack arrester, which restricts the growth of flaws in the matrix, preventing these from enlarging under load into cracks, which eventually cause failure. Prevention of propagation of cracks originating from internal flaws can result in improvement in static and dynamic properties of thematrix.

1.2.4Advantages of Steel Fiber Reinforced Concrete (SFRC): -

1. Addition of steel fibers improves the toughness.
2. Steel fiber reinforcement improves the shear strength and direct tensile strength of concrete considerably.
3. Fibers tend to reduce the bleeding and improve the cohesion of a mix.
4. The presence of steel fibers in concrete is known to increase abrasion anderosion.
5. Fibers improve the serviceability conditions substantially by controlling cracking and deflection, besides increasing flexural strength marginally.

REVIEW OF LITERATURE

2.1 INTRODUCTION: -

The art and science of construction developed through the pre-historic ages itself. The unending quest for the better building materials and better construction practices lead to the discovery of many building composite. History envisages Romans as the first to recognize the pozzolanic action of certain volcanic ashes. The modern recognition of ash materials as a pozzolana and using various types of fibers in concrete had lead to revolutionary developments in the construction industry and research.

2.1 Pozzolanic and Fibers activity: -

Ash materials exhibits pozzolanic activity. A pozzolana is defined as “a siliceous and aluminous material which in itself possesses little or no cementitious value but which will, in finely divided form and in presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties”. Pozzolanic activity is mostly related to the reaction between reactive silica and alumina of the pozzolana and calcium hydroxide. In this experimental investigation cement used is ordinary portland Cement (RASI GOLD’ 53 grade) and mixed fibers (i.e Glass and Steel) as composite material. The ability of these materials to be tailored to suit particular environment and structural forms in different ways and their acceptance as reinforcement for enhancement of concrete properties is rapidly for use in civil infrastructure.

2.2 LITERATURE REVIEW: -

A PORTER (1) has investigated as early as 1970, the concept of concrete as a truly homogeneous materials strengthened by the inclusion of short pieces of steel. GRAHAM (2) in 1911 suggested that the use of steel fibers in addition to conventional reinforcement to increase the strength and stability of reinforced concrete. Suggestions were also made as early as the 1920’s to produce a mouldable and mechinable material made of cement plates and reinforced with 40% - 50% volume of small steel fibers, 0.3 mm dia and 2mm long. The need to improve fiber shape and the significance of bond was recognized by MEISCHKE – SEMITH (3) in 1920 and ETHEERIDGE (4) in 1933, the former used flat twisted wires with flat faces, while the latter used annulled fibers of different sizes and diameters to improve crack resistance and fracture of concrete.

Much of the pioneering work on the use of fiber reinforcement in cement material was carried out by ROMUALDI and BATSON (6), KRENCEH (7) and BIRYKOVICH Since then considerable research on a clear understanding of the mechanism of fiber reinforcement has been in progress.

Theoretical and experimental investigations aimed at assessing the increase in tensile strength, and to determine the suitable combination of the parameters of fibers to get the maximum increase the effective wire spacing were done by ROMULDI and MANDLE (8). SRIDHAR RAO and PARIMI (28), SHAH and RANGAN (15), KAR and PAL etc., also been carried out to study the mechanical behavior of fiber reinforced

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2.3 Fiber Reinforced Concrete: -

Much of developments in fiber reinforced cement composites are derived from the successful development over the past three decades of fiber and whisker reinforcement.

Through the development of the reinforced cement and concrete is barley two decades old, several examples exist on the use of reinforcing elements in cement matrix as far back 1874.

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Bayesian (1989) teal , the effects on fresh and hardened material properties for fly ash caused by substituting cement with fly ash and silica fume in SFRC were studied experimentally. The percentage substitution of cement ranged from 0 to 40% and from 0 to 20% for silica fume. The workability of fresh fibrous mixtures was characterized by measuring the inverted slump cone time. The hardened material was tested at 28 days under compressive and flexural loads. The development of compressive strength with time was also assessed in SFRC incorporating fly ash.

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The topics discussed in his work are as follows:

1. Method of fixing the laminate with RC beams.
2. Effect of temperature and frost cycles on concrete laminate bond.
3. Effect of bending and shear cracks in concrete.
4. Analytical model of beam-laminate combination.
5. Safety factor to be used for such constructions
6. Fatigue characteristics

The main advantages of carbon fiber composite laminates have been found to be

1. No corrosion and therefore, no corrosion protection is necessary
2. No problem of transportation as it is available in rolls
3. Higher ultimate strength
4. Higher young's modulus
5. Very good fatigue properties
6. Low weight
7. Large rolls available, therefore , no joints

The main disadvantages are

1. Erratic plastic behavior and less ductility
2. Susceptible to local unevenness
3. High cost

General Conclusion: -

With the review of the existing literature, the need to improving strength in cement concrete by using fibers as a admixture. Therefore it becomes necessary to make laboratory studies by using fibers in cement concrete for future applicability and efficiency. Such studies will also help the structural engineer to tackle above such problems which arise in the field. Information on strength data, rigidity, durability and ductility of concrete is limited . Portland Pozzolanic Cement is used as cement and Fibers are proposed to use as composite material to strengthen concrete and render the structure immune against ingress of deleterious substances such as chlorides.

The present study is made to investigate experimentally and the following tests were carried out namely: Compressive Strength and Split Tensile Strength. This experinmental investigation comprises with the replacement of glass fibers 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 and cylinders 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.

MIX CALCULATIONS MIX DESIGN FOR M25 GRADE OF CONCRETE BY I.S. METHOD (IS: 10262 - 1982)

1) **3.1 Concrete mix design: -**

a) **3.1.1 Mix design for M25 Grade: -**

(a). Design specification: -

Charateristic compressive strength M25 grade at 28 days (fck)	= 25 N/mm^2
Maximum size of aggregate(Angular)	=20mm
Degree of workability in terms of slump (Compaction Factor)	=50to75 mm
Degree of quality control (assumed)	= Good
Assumed type of exposer	= 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 concret: -

Standard deviation for M25grade and good degree of control(S) = 5.3

Target average compressive strength at 28 days

Fck = fck + t X S

= 25 + 1.65 X 5.3

= 33.745 N/mm^2

(d). Selection of water cement ratio: -

From the graph given is IS:10262:1982 corresponding to target strength (fck) and curve we have

(i) water cement ratio = 0.50

(ii) Estimation of air content:-

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 m^3 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. (Or) 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 I.S : 10262-1982 for Calculation of aggregates

$$V = \left[w + \frac{C}{Sc} + \frac{1}{P} X \frac{\text{Fs}}{Sfa}\right] X \ \frac{1}{1000}$$

Water	Cement	Fine aggregates Fa	Coarse aggregates Ca
189	378	573	1196
0.5	1	1.52	3.16

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 conrete	= 189 Kgs.
C	= Mass of cement(Kg) per cubic meter of concrete	= 378 Kgs.
P	= Ratio of F.A (Kg) per cubic meter of concrete	= 0.335
Sc	= Specific gravity of cement	= 3.15
Sfa	= Specific gravity of fine agregate	= 2.55
Sca	= Specific gravity of course agregate	= 2.68
Fs	= Total mass of F.A(Kg) per cubic meter of concrete	
Ca	= Total mass of C.A(Kg) per cubic meter of concrete	

Weight of fine aggregate $V = \left[w + \frac{C}{Sc} + \frac{1}{P} X \frac{\text{Fs}}{Sfa}\right] X \ \frac{1}{1000}$
=573.04 kg (or) 573 kg

Weight of coarse aggregate =

$$V = \left[w + \frac{C}{Sc} + \frac{1}{1-P} X \frac{\text{Ca}}{Sca}\right] X \ \frac{1}{1000}$$

= 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) *3.2 Quantities of Materials Used For Nominal Mixes: -*
3) *3.3. Quantities of fibers for 0.5%total fiber content (steel fibers &glass fibers) for concrete cubes: -*

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

Fibers quantity for 0.5% total fibercontent: 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(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*

4) *3.4. 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 :2147kg:Fibers quantity for 0.5% total fibercontent:
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 X6 : 0.032 cum.
Quantity of fibers for 6 concrete cylinders:
0.032 X 10.735 : 0.344 Kg.

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

5) *3.5. Quantities of fibers for 0.75%total fiber content (steel fibers &glass fibers) for concrete cubes: -*

Total quantities of materials used for for 1 cum of concrete : 378 + 573 + 1196 : 2147 Kg.
Fibers quantity for 0.75% total fibercontent
: 2147 X 0.75/100 : 16.103 kg.
Total no. of cubes to be casted :6 Nos
quantity for 6 cubes :0.15X 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.

Table 3.6

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

6) *3.6: Quantities of fibers for 0.75% total fiber content (steel fibers &glass fibers) for concrete cylinders: -*

Total quantities of materials for for 1 cum of concrete : 378 + 573 + 1196 : 2147 Kg.
Fibers quantity for 0.75% total fibercontent:
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 X6 : 0.032 cum.
Quantity of fibers for 6 concrete cylinders:
0.032 X 16.103 : 0.515 Kg.

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

a) **3.7. Quantities of fibers for 1.00% total fibers content (steel fibers &glass fibers) for concrete cubes: -**

Total quantities of materials used for for 1 cum of concrete : 378 + 573 + 1196 : 2147 Kg.
Fibers quantity for 1.00% total fibercontent
: 2147 X 1.00/100 : 21.470 kg.
Total no. of cubes to be casted : 6 NosConcrete 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(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

b) **3.8. Quantities of fibers for 1.00% total fibers content (steel fibers &glass fibers) for concrete cylinders: -**

Total quantities of materials for for 1 cum of concrete : 378 + 573 + 1196
: 2147 Kg.
Fibers quantity for 1.00% total fibercontent:
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 X6 : 0.032 cum.
Quantity of fibers for 6 concrete cylinders:

0.032 X 21.470 : 0.515 Kg.

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

c) **3.9.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.

EXPERIMENTAL INVESTIGATION

For the past few decades, aerospace industry was the major use of advanced composite materials in concrete. Recently civil engineers and the construction industry began to realize the potential of these materials in providing remedies for problems associated with cracking and deterioration of structures. In light of this, comprehensive experimental investigations were conducted by using various types of fibers in concrete.

The structural elements of concrete show distress by cracking. This may be caused by short term effects, such as over loading and/or impact loading or long term effects such as creep and drying shrinkage. In reinforced concrete elements, very thin cracks are considered to be of little significance and will be neglected without affecting the serviceability of the structure, which may in turn result in corrosion of reinforcement and thereby aggregates the situation resulting in large deflections and weakening of the structure.

In view of the above situations, the Engineer may have to use the fibers as a admixture in cement concrete. Use of fibers in concrete as a construction material, it has some of the attractive and unique features are their low specific gravities, high strength-to weight ratio, durability, resistance to marine environment, toughness at low temperatures, dimensional stability over a wide range of loading and/or impact
loading.
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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.

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.

Preparation of specimens: -

This chapter deals with the materials required for the 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.

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

(a). Cement: -

Ordinary portland 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 ordinary port land 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 mortor 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 fiberreinforcedconcrete because the glass fibers are made from natural materials and take comparatively little energy to produce. The photo copy of the test pieces are shown in plate No.1.

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.

Perma-Fil E Glass Fibers:-

The Company:-

The Indus Insul Private Ltd. is Private Limited company and its factory is located at Medchal Industrial area, Ranga Reddy Dist. The company has entered into an agreement with M/s Asglawo, GmbH, Germany for the supply of Perma-Fil E Glass Fibers Technology and required plant and machinery. M/s Asglawo, GmbH, Germany has more than 50 years of experience in the manufacture of specialist Insulation Materials from Perma-Fil E Glass Fiber.

The typical properties of the Perma-Fil E Glass Fibers as per the literature supplied by the manufacturer are given in tabular form.

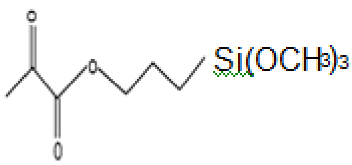
(1) Chemical: Type of material is E' Glass

SiO2	54.1%		
Al2O3	15.3%		
CaO	17.3%	MgO	4.7%
Na2O	0.6%	B2O3	8.0%

(2) Physical Properties:-

Physical formwater 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, n0(25^0 C)	1.429
Flash point,	108 (226)
Tag closed cup (a). ^{0} C (^{0} F)	

The chemical representation of Perma-Fil E Glass Fiber is :



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 and slump measurement is shown in Photo Plate No.2.

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 150x 150x 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. The test specimens casting and curing yard is shown in Photo Plate No. 3.

TESTING OF TEST SPECIMENS: -

This chapter deals with the testing of concrete specimens as per I.S : 516-1959 (Methods Of Tests For Strength Of Concrete). The details of experimental test setup and the procedure of testing are dealt with. This chapter also gives details of load application and measurement. A check list of precautions taken during testing is also given and loads of test samples were noted. The tables containing the test results of Compressive Strength, Split Tensile Strength and Flexural Strength are given in

TEST SETUP: -

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

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 tensilestrength ofconcrete 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.

TEST PROGRAMME: -

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 andthen 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 atconstant 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.

Pu
Compressive Strength (fcu) = -------------
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
The test set up is shown in Photo Plate No. 7

SPLIT TENSILE STRENGTH: -

For the split tensile strength, cylindrical specimens were 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.
2 P
Split Tensile Strength = ------
JIDL

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

TEST RESULTS AND GRAPHS

The concrete specimens using steel and glass fibers are prepared in the laboratory have been tested as per the standard specifications. The results of the Compressive Strength, Split Tensile Strength and Flexural Strength for 0.5, 0.75 & 1.0 percentage total fiber content at 28 days are reported. Further the Cracking characteristics and ductility characteristics were studied. The graphs are plotted based on the test results. The test results are tabulated for easy and better evaluation.

B. Test Reports on Concrete Specimens

Compressive strength test results for replacement of steel and glass fiber by 0, 25, 50, 100 percentages from total content of 0.50 by weight:

(A) Test-I:

Compressive Strength Test

Concrete Specimens Details:-
Mix : M25
Specimens designation : $C1_{-1}$to$C1_{-6}$

Concrete specimen No.	Glass Fiber %	Steel Fiber %	Ultimate Compressive Load in KN	Compressive Strength in N/mm2	Increase in Strength %
C1-1	0	100	1180	52.44	27.12
C1-2	25	75	1160	51.56	25.87
C1-3	50	50	1060	47.11	18.87
C1-4	75	25	980	43.56	12.25
C1-5	100	0	930	41.33	7.53
C1-6	Conventional Concrete		860	38.22	00.00

(B) Test-II:
Split Tensile Strength Test

Concrete Specimens Details:-

Mix : M25
Specimens designation : $S1_{-1}$to$S1_{-6}$

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
S1-1	0	100	320	4.53	21.85
S1-2	25	75	305	4.31	17.87
S1-3	50	50	295	4.17	15.11
S1-4	75	25	275	3.89	9.00
S1-5	100	0	260	3.68	3.80
S1-6	Conventional Concrete		250	3.54	00.00

a) *Test Reports on Concrete Specimens*

5.2. Compressive strength test results for replacement of steel and glass fiber by 0, 25, 50, 100 percentages from total content of 0.75 by weight.

(A) Test-I:
Compressive Strength Test
Concrete Specimens Details:-

Mix : M25
Specimens designation : $C2_{-1}$to $C2_{-6}$

(B) Test-II:

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
C2-1	0	100	1210	53.78	28.93
C2-2	25	75	1190	52.89	27.74
C2-4	75	25	1000	44.44	14.00
C2-5	100	0	970	43.11	11.34
C2-6	Conventional Concrete		860	38.22	00.00

Split Tensile Strength Test

i *Concrete Specimens Details:-*

Mix : M25

Specimens designation : $S2_{-1}$to$S2_{-6}$

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
S2-1	0	100	340	4.81	26.40
S2-2	25	75	320	4.53	21.85
S2-3	50	50	310	4.38	19.18
S2-4	75	25	295	4.17	15.11
S2-5	100	0	275	3.89	9.00
S2-6	Conventional Concrete		250	3.54	00.00

Test Reports on Concrete Specimens:

5.3. Compressive strength test results for replacement of steel and glass fiber by 0, 25, 50, 100 percentages from total content of 1.00 by weight.

(A) Test-I:

Compressive Strength Test

Concrete Specimens Details:-

Mix : M25

Specimen's designation : $C3_{-1}$ to C3-

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
C3-1	0	100	1270	56.44	32.28
C3-2	25	75	1230	54.67	30.09
C3-3	50	50	1150	51.11	25.22
C3-4	75	25	1060	47.11	18.87
C3-5	100	0	1010	44.89	14.86
C3-6	Conventional Concrete		860	38.22	00.00

(B) Test-II:

Split Tensile Strength Test

Concrete Specimens Details:-

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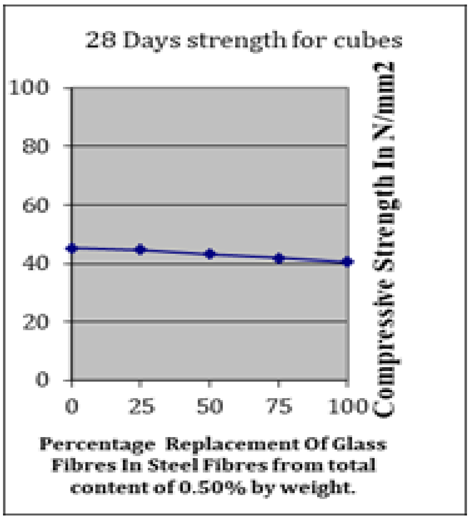
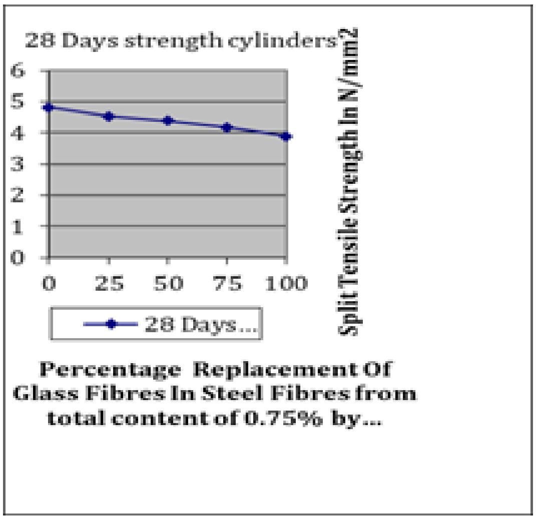
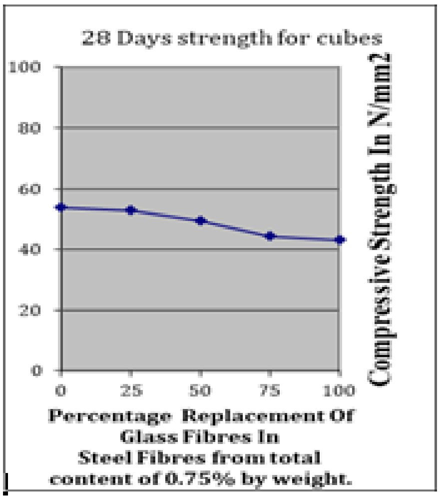
Mix : M25
Specimens designation : $S3_{-1}$to$S3_{-6}$

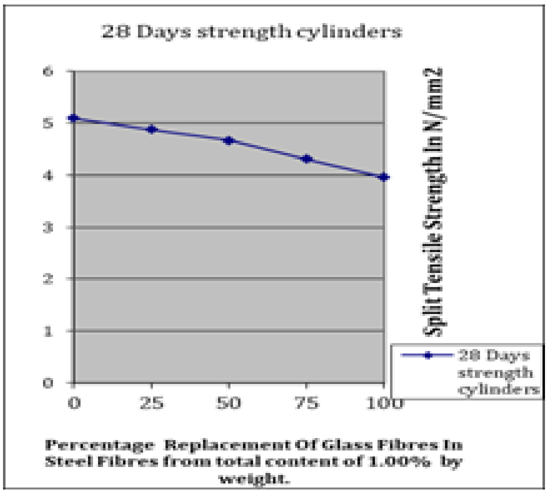
Concrete specimen No.	Glass Fiber %	Steel Fiber %	Ultimate Split Tensile Load in KN	Split Tensile Strength in N/mm2	Increase in Strength %
1	2	3	4	5	6
S3-1	0	100	360	5.09	30.45
S3-2	25	75	345	4.88	27.46
S3-3	50	50	330	4.67	24.20
S3-4	75	25	305	4.31	17.87
S3-5	100	0	280	3.96	10.61
S3-6	Conventional Concrete		250	3.54	00.00

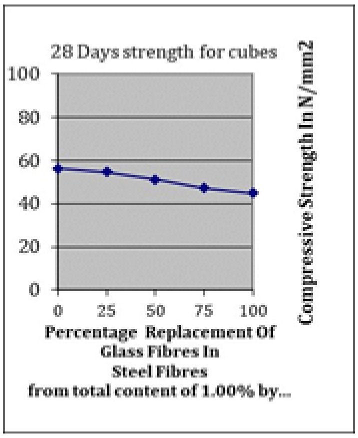
6 - GRAPHS

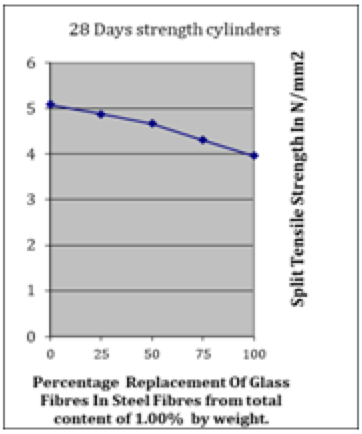












DISCUSSION ON TEST RESULTS

This chapter deals with discussion of 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.

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 shock or impact loads and blasts. Its energy absorption quality is better.

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.

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

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 above 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,

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.

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.

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.

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.

CONCLUSIONS AND SCOPE FOR FUTURE STUDY

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
[18]. percentages of glass fiber. Glass fiber also helps in controlling the shrinkage cracks.
[19]. Compared to metallic fibers likes' steel, alkali resistant glass fiber gives corrosion free concrete.
[20]. The crack widths in the mixed fibrous concrete are less.
[21]. The mixed fibrous concrete has adequate code prescribes ductility.

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

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 and1 year to life time.

PHOTO PLATE NO. 1

GLASS AND STEEL FIBRES
PHOTO PLATE NO. 2

TEST SETUP FOR COMPRESSIVE AND SPLIT TENSILE STRENGTH TEST

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