M. Tech (Structural Engineering) AMIT KUMAR SRIVASTAVA 2021

STUDY ON THE BEHAVIOUR OF GLASS FIBRE REINFORCED CONCRETE

A DISSERTATION

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF DEGREE
OF
MASTER OF TECHNOLOGY
IN
STRUCTURAL ENGINEERING

Submitted by:
Amit Kumar Srivastava
2K19/STE/03

Under the supervision of

Prof. Alok Verma

DEPARTMENT OF CIVIL ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

July,2021

DEPARTMENT OF CIVIL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

CANDIDATE'S DECLARATION

I, Amit kumar Srivastava, Roll No. 2K19/STE/03 student of M. Tech (Structural Engineering), hereby declare that the project dissertation titled "**STUDY ON THE BEHAVIOUR OF GLASS FIBRE REINFORCED CONCRETE**" which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

Place: Delhi **AMIT KUMAR SRIVASTAVA**

Date: 04/08/2021

DEPARTMENT OF CIVIL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

CERTIFICATE

I hereby certify that the Project Dissertation titled "**STUDY ON THE BEHAVIOUR OF GLASS FIBRE REINFORCED CONCRETE**" which is submitted by Amit Kumar Srivastava, Roll No. 2K19/STE/03, Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any degree or diploma to this university or elsewhere.

04/08/2021

Place: Delhi **Prof. Alok Verma**

Date: 04/08/2021 **Supervisor**

ACKNOWLEDGEMENT

I sincerely take this opportunity to acknowledge the debt of gratitude that I owe to my supervisor Prof. Alok Verma for her consistent guidance throughout the journey. He has helped me by means of her vast knowledge and expertise of the course content. He provided the desired impetus when things were not turning in the favor, which really helped me to achieve the anticipated goals within a given time frame. It is my fortune that, I got an opportunity to work under his guidance for both of my Major Projects. I wish that my learning under his guidance continues forever. At the last, I would like to extend a token of thanks to my parents, whose uninterrupted efforts have been a constant motivation throughout the journey.

Amit Kumar Srivastava

ABSTRACT

It is a well known fact that the tensile strength of concrete is very less in comparison to its compressive strength. Addition of fibre improves the tensile strength of concrete and improves various other properties and is called Fibre Reinforced Concrete. Different types of fibres are available which are added in concrete such as Steel fibre, Carbon fibre, Aramid, asbestos, natural fibres etc. Among various types of fibres used in preparation of Fibre Reinforced concrete, Glass fibre comes under the category of metallic and inorganic type.In this thesis, experimental investigation was carried out to study the effect of glass fibre on concrete. About 30 cubes, 30 beans, 30 cylinders were casted and cured at varying fibre content of 0%, 0.5%, 1.0%, 1.5%, & 2.0%. Various Destructive test such as Compressive strength test, Flexural Strength test, Split cylinder test andnon destructive test such as Rebound hammer test and Ultrasonic pulse velocity test were carried out on the specimen with varying fibre content. Compressive strength, flexural strength, split tensile strength all were found to increase with increase in fibre content. Maximum strength was gained at a fibre content of 1.5%. Rebound hammer test and Ultrasonic pulse velocity test were conducted to check for the effect of fibre content on test results. Results obtained from rebound hammer were compared to actual cube compressive strength and was found to be in correlation with the destructive test. The concrete quality was assessed using Ultrasonic pulse velocity test. UPV readings showed that the concrete casted were mostly found in good quality.

TABLE OFCONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1General

Concrete is a material used in building construction that consists of a hard, chemically inert particle substance known as aggregate (typically manufactured for different types of sand and gravel) that is bounded by cement and water..The construction business relies heavily on materials. They determine the ultimate product's quality as well as the technology used to create it. The qualities of the materials used in the development of civil engineering constructions have a significant impact on their performance. The development of sophisticated construction materials and technologies is directly related to construction innovation.

Concrete is the most fundamental component of every building project. The concrete used should be strong and compacted, regardless of the type of building structure. Coming up next are the essential purposes behind compacting any kind of concrete:

- To guarantee greatest density by eliminating any entrapped air.
- To guarantee that the concrete utilized is in full contact with both the steel support and the formwork.

Assuring the aforementioned factors not only adds strength to the framework, but also improves the final product's polish and aesthetic. Any standard concrete is compacted using external force and mechanical devices.

1.2Evolution of Reinforced Concrete

In the year 1849, a French gardener named Joseph Monier invented reinforced concrete. Most modern buildings would not be standing today if it weren't for reinforced concrete. Frames, columns, foundations, and beams can all be made out of reinforced concrete. The material used for support ought to have astounding holding properties, high rigidity, and great warm similarity. Reinforcement necessitates a smooth transfer of load from the concrete to the concrete-reinforcement-material interface, and subsequently to the reinforcement material. As a result, the concrete and the reinforced material will be under the same strain.

1.2.1Steel Reinforced Concrete

The substantial is fortified with steel bars. The unpleasant, folded surface of the bars takes into consideration better holding with steel rebars, giving the substantial added elasticity. The compression strength and bending properties of steel rebar's have improved significantly, and the thermal expansion characteristics of steel rebars and concrete must match. For slabs and beams, the rebar must have a cross sectional area of 1%, while columns might have a cross sectional area of 6%. The alkaline composition of the concrete generates a passivating coating around the bars, protecting them from corrosion. In neutral or acidic conditions, this passivating coating will not form. Carbonation of concrete occurs in conjunction with chloride absorption, resulting in steel rebar failure. At the point when the strain limit of steel bars is contrasted with the pressure limit of cement + steel fortifications, the built-up cement can be named under supported (bar ductile limit is not exactly concrete + bar) or over built up (bar elastic limit is more prominent than concrete + steel rigidity). The overbuilt-up segment comes up short abruptly, while the under-supported part fizzles with a mis-happening notice. Therefore, it is desirable over use under-supported cement.

1.3 FIBRE REINFORCED CONCRETE

The construction material is always changing. Fiber reinforced concrete was developed in response to a desire for high-strength, crack-resistant, and lighter concrete. Steel, nylon, asbestos, glass, carbon, sisal, jute, coir, polypropylene, and kenaf are among the fibre sused..

1.3.1Development of FRC

Adding particular fibres to construction materials has been practised since ancient times. Straws were utilised to reinforce the bricks when horse hair was employed. Porter discovered that fibre could be utilised in concrete in 1911. Asbestos fibre was first used in the early 1900s. Asbestos was discovered to be a health hazard in 1950, fibre reinforced concrete became a hot topic..Romualdi and Batson released their study on FRC in 1963. Glass, steel, and polypropylene fibre have all been employed in concrete since then.

1.3.2 Importance of FRC

Brittleness, poor tensile strength, and poor resistance to impact strength, fatigue, low ductility, and low durability limit the use of concrete as a structural material to some extent.It is also severely limited in its ability to accept dynamic loads induced by explosions. The inclusion of reinforcing (or) pre-stressing steel in the tensile zone compensates for brittleness in structural members. However, it has no effect on concrete's basic properties. It's just a way of combining two materials to achieve the desired result.The essential issue of low elasticity and the prerequisites for high strength endure, and a few sorts of supporting materials are being utilized to address it. Concrete is additionally ailing in flexibility, exhaustion obstruction, and effect opposition. With its numerous and complex applications in pre-projected and pre-manufactured structures, the need of delivering required amounts in concrete is developing. The addition of fibres and admixtures to the required qualities of concrete will address the structural engineers' testing concerns. Strands viably go about as a band-aid for advancing breaks by applying punching stresses at the rack tips, postponing break engendering across the network. Thus, the composite's definitive breaking strain is ordinarily more prominent than that of an unreinforced framework. Fly debris, silica smolder, granulated impact heater slag, and metakaolin are instances of such added substances. 4 However, adding strands and mineral admixtures causes blending issues since filaments will in general frame balls and functionality diminishes during the interaction.

1.3.3Behaviour of fibre in concrete

Fibers aid in the reduction of bleeding in fresh concrete and make it more impermeable in the cured stage. In comparison to the strength provided by rebars, a particular percentage of fibres in concrete contributes less to flexural strength. Most importantly, fibre slows the progression of cracks under strain, effectively stopping final cracking. Chemical resistance is provided by nonmetallic fibres such as alkali resistant glass fibre and synthetic fibres. Fiber's reinforcing capability is determined by its length, diameter, proportion of fibre, mixing condition, fibre orientation, and aspect ratio.The perspective proportion is the proportion of a fiber's length to its breadth, and it has a crucial influence in the building up measure.

1.4 DIFFERENT TYPES OF FIBRES

1.4.1 Asbestos fibre

This falls within the category of mineral fibre that occurs naturally. Asbestos fibre has excellent heat, electrical, chemical, and fire resistance. It has a tensile strength that is average. As a result, it became quite popular in the late 1800s. Asbestos is comprised of six distinct sorts of normally happening silicates. They were initially utilized as electrical protection for hot plate relieving in structures. Because of the high absorption, more water is necessary when asbestos fibre is combined with cement. However, it was eventually revealed that asbestos was carcinogenic in nature, making it extremely dangerous to human health. As a result, it was completely outlawed.

1.4.2 Carbon Fibre

Carbon fibre has a high tensile strength and enhances flexibility. They are made up of polyacronitrile fibres that have been oxidized. Thermal pyrolysis is carried out after oxidation, resulting in the production of carbon fibres. They have a lot of flexibility and have a lot of tensile strength. This fibre is used to make the rudders of aeroplanes..

1.4.3 Aramid Fibre

This is a man-made fibre. Aromatic polyamide is exactly what it sounds like. Another reinforcing material that could be employed is aramid fibre. They are created when an amine group reacts with a carboxylic acid halide group. Technora, kevlar, and nomex are some of the trade names for this fibre. Kevlar was first utilised as a composite material for making the airframe of commercial planes since it is very light and strong. Because the chain molecules in these fibres are all orientated along the fibre axis, they have a high chemical binding strength. DuPont was the first to notice this. They were an effective asbestos alternative.

1.4.4 Metallic Fibre

They're made by heating metal until it vaporizes, then depositing it on polyester film under extreme pressure. The most widely recognized sort of metallic fiber is aluminized nylon yarn. Metallic fiber is comprised of a blend of plastic and metal filaments. Steel wool can also be used to create them. Carbon steel fibre or stainless-steel fibre are the metallic fibres.

1.4.5 Polypropylene, Polyethylene, Nylon Fiber

These have good alkaline and acid resistance properties. Polypropylene is a polymer of the polyolefin family of polymers. Polypropylene strands as fibrillated film filaments have extraordinary lattice holding on the grounds that the grid mixes effectively into the fibrils, bringing about great effect obstruction. The rigidity of nylon and polypropylene is very high, going from 561.0 to 867.0 N/mm2. Due to their high lengthening (15-25%), they could be utilized in circumstances where generous energy assimilation is required.The fiber's low modulus decreases its reinforcing ability. They're often employed in pile shells, non-load bearing corrosion proof members, cladding panel flotation units, and crack inhibitors in guniting. On account of precast parts, it is an excellent steel support substitute as far as postage on the grounds that utilizing plastic fiber diminishes the size (more slender segments are made) and expands the break obstruction, saving material, transportation, and erection costs.

1.4.6 Glass Fibre

Glass fibre is incorporated with cement or cement sand mortar at a rate of 4 to 4.5 percent by volume, resulting in glass reinforced cement. This glass reinforced cement mortar is used to make concrete products with sections ranging from 3 to 12mm thick. Spraying, casting, spinning, extruding, and pressing are some of the manufacturing methods. The resulting product has varying features depending on the approach used. Shower testimony is an incredibly successful and all around created strategy for preparing. Synchronous splashes of concrete normal mortar slurry and hacked glass fiber are put into or onto a proper shape in the most straightforward kind of shower preparing. Mortar slurry is atomized by packed air and conveyed to the shower gun by means of a metering siphon unit. The chopper and feeder unit are introduced on a similar firearm gathering as the glass fiber. Glass quarry items are utilized to make the filaments. The glass quarry items are dissolved in a heater, and the fiber fibers are made utilizing a bushing interaction. These are obviously appropriate for use as a revamping development material in the reclamation of old legacy structures and for design rebuilding.

1.4.7 Natural Fibre

Wood fibre, such as bamboo seed, fruit fibre (coir), stem fibre, such as jute, kenaf, san, flax, and leaf fibre, such as henqueen, sisal, and coconut, are examples of natural fibre. This fiber's cost-effective and energy-efficient manufacture provides a natural advantage. Nonetheless, due to their high-water assimilation, low soluble base obstruction, vulnerability to creepy crawly and contagious assault, and low flexible modulus, they are not appropriate for use in concrete. Agave sisalana leaves are used to make sisal fibres. Pectin, lignin, and hemicelluloses make up this substance. They are powerful, yet they are vulnerable to alkali attack. The most commonly used natural fibre in concrete is wood fibre, also known as cellulose fibre. The principal benefits are the high modulus of versatility, rigidity, and plenitude of supply. Pulping is the process of extracting wood fibre from wood. Cellulose, hemicelluloses, and lignin are all found in wood fibre. Because lignin affects fibre strength, a chemical pulping procedure known as Kraft or sulphate is employed to remove it. Wood fiber's very low alkali resistance can be enhanced by adopting techniques that minimize fibre disintegration in an alkaline environment.

1.5 GLASS FIBRE REINFORCED CONCRETE (GFRC)

In the 1940s, Russians were the first to see the possibilities of glass as a construction material. However, because the glass has a low alkali resistance, mixing it with alkaline concrete has proven to be troublesome. In 1970, the British added Zirconium to the slurry to create a superior glass that is alkali resistant. Casting, spray premix, press molding, extrusion, and pultrusion are some of the production procedures for generating glass fibre reinforced concrete premix products. AR glass fibre, sand, cement, water, chemical and mineral admixtures, and aggregate make up glass fiber-reinforced concrete premix. These fibers reduce crack width and spacing between cracks. They have a high temperature resistance because they absorb a lot of energy, giving them ductility. Because of their small weight, they are widely used in concrete mixes. Today, they are used in a variety of industries. When utilized at a thickness of 10 mm and a surface mass of 20 kg/m2, they act as sound absorbers. They are employed as restoration materials for ancient buildings as well as for the enlargement of existing structures. Due to their exceptional design flexibility, any shape product may be created with good binding strength. They're employed in sewer relining, earth retaining walls, architectural products like building facades, claddings, cable troughs, and noise reduction barriers, among other things.

1.5.1 Advantages of GFRC

The GFRC is

- It's light.
- Shrinkage properties are better than plain concrete.
- GRC properties are accurate and environmentally favorable.
- Used in the production of precast concrete.
- Anti-corrosive, chemically resistant, high flexural strength, impact strength, and tensile strength
- Exceptional design versatility Products of any shape can be manufactured with good bending strength.
- Significant heat savings are possible.
- Because glass has a higher specific resistance, it can be utilized to make strands. Glass filament thickness ranges from 10 microns to 20 microns.

1.5.2 Glass fibre vs. others

Despite the fact that polypropylene is less expensive and more readily accessible, it has a far lower flexural strength than GRC. Although Aramid and carbon fibres are stronger than GFRC, their high cost makes them unpopular. Steel and GFRC have nearly identical bending moment properties, although GRC can be moulded into any shape, whereas steel fibrecannot.GRC are of three kinds, consistent strands, network type and little cut strands type. AR glass is generally appropriate for GFRC.

CHAPTER 2

LITERARTURE REVIEW

2.1 INTRODUCTION

Concrete's most valuable attributes are its strength and durability. They are linked to the microstructure of hydrated cement paste and concrete. These are directly related to other concrete qualities such as elasticity, stress, and strain. Concrete reinforcing improves these strength properties even more. Fiber reinforced concrete can be a cost-effective and beneficial construction material due to its versatility in fabrication procedures. The flexible reach is the place where most cement is utilized, so comprehend the connection between stress, strain, and versatility, which is an element of concrete. This will give data on the best way to control the mis-happening of the substantial.

Faiz A et. al., (1) The effect of alkali resistant glass fibre reinforcement on crack resistance, flexural strength, ductility restricted shrinkage cracking, and temperature resistance in light weight concrete was explored. The authors conducted their research using glass fibre with a mass fraction of up to 3%. The authors determined that alkali-resistant glass fibres are very good at reducing constrained shrinkage cracking in light-weight concrete, and that the fibres promote repeated cracking, which reduces crack widths. The fibres are highly successful in increasing the characteristics of the concrete at 1% mass fraction or 0.25 volume fraction.

Sanjay Kumar et.al., (2) have studied the flexural behavior of short steel fiber reinforced concrete beams.The tests were done on substantial grade M40 with extents of 1: 0.75: 2.55 and a W/C proportion of 0.38. Viewpoint proportions of 25 and 35 were utilized with fiber volume parts of 0%, 0.5 percent, 1.0 percent, and 1.5 percent. The flexural strength of 125 mm x 150 mm x 1100 mm radiates was assessed under two-point load. The test outcomes uncovered that pillar with filaments performed better as far as strength and flexibility, with an ideal fiber volume of 1.0 percent. The provided equations were used to compute the moment carrying capabilities of the beams. The authors determined that a lower aspect ratio of 25 results in a slight improvement in compressive strength, whereas a higher aspect ratio of 35 results in a further rise in compressive strength. In specimens with 0.5 percent fibre and aspect ratios of 25 and 35, the moment bearing capacity was enhanced from 11 to 15%. The examples with 1.0 percent fiber and viewpoint proportions of 25, 35 expanded by 16 and 17 percent, separately. In radiates with 1.5 percent fiber, the second conveying limit was brought down. The heap 64 redirection bend was found to follow a direct relationship until a specific point, after which the bend became non-straight.

Yeol Choia et. al., (3)conducted compression, split tension, and flexural properties tests on Glass fibre reinforced concrete and polypropylene fibre reinforced concrete, based on experimental and analytical results, they attempted to establish a relationship between compression strength and split tensile strength of GFRC and PRFC. The authors came to the conclusion that the split tensile strength of SFRC is 0.67 times the flexural strength and 0.09 times the compressive strength, and developed an empirical equation as a function of fibre reinforcing index based on linear regression analysis.

Yuwaraj M. Ghugal et. al., (4) in their paper investigated the performance of alkali resistant glass fiber reinforced concrete. On different example estimates, the impact of glass strands on usefulness, thickness, and properties like pressure, flexure, split strain, and bond strength was examined, with the ideal fiber content being discovered to be strength subordinate. They concluded that when the amount of fibre in GFRC increases, the workability decreases and the density increases somewhat. The strength parameters of the concrete are stronger and the load carrying capacity is higher when compared to reference concrete, indicating an increase in flexural stiffness and ductility.Flexural strength, split rigidity, versatile modulus, poisson proportion as far as fiber volume rate, compressive strength, and perspective proportion not really set in stone utilizing exact conditions.

K. Holschemacher et. al., (5) conducted an experiment to see how steel fibres affected the flexure, stress, and fracture properties of high-strength concrete reinforced with standard steel bars. To obtain a basis for selecting a suitable fibre type and conte, three types of various fibres were evaluated, each with two hooked ends with differing ultimate tensile strength and corrugations. The pillars fizzled in pressure and shear with fiber content of 20 kg/m3 and 40 kg/m3, the examples fizzled in pressure with fiber content of 60 kg/m3, and the HSC radiates with longitudinal support of 1% fizzled in pressure just, as indicated by the creators.

M. J. Roth et. al., (6) Experiments on ultra-high-strength glass fibre reinforced concrete were carried out. The creators researched the mechanical and material conduct of the flexural reaction utilizing the third point twisting direct strain technique, and led examinations with exploratory information. The creators arrived at the resolution that the heap removal reaction of incredibly high strength GFRC boards was for all intents and purposes bilinear beginning versatile solidness esteem multiple times that of customary cement. Because of the stochastic distribution orientation and concentration of the glass fibres, a wide range of displacement at final failure was considered.

Byung Wan Jo et. al., (7) SFRC's stress strain behavior and elastic modulus were investigated experimentally. Concrete with plan qualities of 30 MPa, 50 MPa, and 70 MPa was tried in pressure with steel fiber volume parts of 0%, 0.5 percent, 0.75 percent, 1.0 percent, and 1.5 percent. 150 mm x 300 mm round and hollow examples were used. The creator contrasted the test discoveries with existing flexible modulus computations and presumed that SFRC was bendable at the most extreme burden and that versatile modulus expanded quickly as fiber content expanded.

Akash Jain et. al., (8) the influence of concrete materials, mix, workmanship related variables such as intentionally induced flaws, improper compaction and different lengths of moist curing on Rebound No. and UPV is studied Rebound Hammer readings increased with the compressive strength of concrete. Ultrasonic pulse velocity values were greatly influenced by the cements and aggregate, extent of moist curing and presence of flaws and voids in concrete, more than their influence on the measured strengths

Mohammadreza Hamidian et. al., (9) the experimental investigation using NDT methods showed that A good correlation exists between compressive strength, SRH and UPV. The SRH offers accuracy of ±15 to ±20% and the UPV offer accuracy within ±20% .The ‘ultrasonic pulse velocity method’ is a perfect instrument for launching whether concrete is uniform. Accuracy obtained were in the range of 15 to ±20%.

Hisham Y. Qasrawi et. al., (10) Both the traditional well-known rebound hammer and ultrasonic pulse velocity tests were used in the study. Various charts showing the results are presented. All charts show the 95% prediction intervals, thus enabling professionals to predict concrete strength simply and reliably. the relationship between rebound number and the crushing cube strength of concrete:

$$S = 1.353R - 17.393$$

CHAPTER 3

OBJECTIVE AND SCOPE OF THE PRESENT INVESTIGATION

In present study it is planned to make use of glass fibre in concrete to investigate various properties of Glass fibre reinforced concrete.

- To study the effect of glass fibre on Compressive Strength of GFRC by varying the fibre content.
- To study the effect of glass fibre on flexural strength of GFRC by varying the fibre content.
- To study the effect of glass fibre on the split tensile strength by varying the fibre content.
- To find the optimum fibre content by weight of cement in which maximum strength parameter occurs.
- To study the effect on compressive strength by Rebound hammer apparatus by varying the fibre content.
- To find the quality grading of concrete by the use of Ultrasonic Pulse velocity test as per IS: 13311 (Part 1)-1992.
- To find whether Non destructive test results can be used on GFRC structures.

CHAPTER 4

MATERIAL USED

- Cement
- Coarse Aggregate
- Fine Aggregate (Rock Dust)
- Water
- Super plasticizers
- Glass Fibre

4.1 Cement

The cement used was of Portland Pozzolana cement type which was locally available. PPC grade 33 of BANGUR CEMENT brand was used conforming to B.I.S .The cement is tested for various qualities in accordance with IS: 4031 – 1988, and it is found to meet the standards of IS: 1489-1999 Part-1.

Table 4.1 Property of cement

S. NO.	PROPERTY	RESULTS
1	CONSISTENCY	30%
2	SPECIFIC GRAVITY	2.91
3	INITIAL SETTING TIME	47 min
4	FINAL SETTING TIME	168 min
5	SOUNDNESS	2mm

4.2 Fine Aggregate

Locally available rock dust of zone 2 was used as fine aggregate in accordance to IS:2386 and IS:383 . The details such as specific gravity and sieve analysis etc are given below in table 4.2

Table 4.2: Properties of fine aggregates

S. No.	PROPERTY	RESULT
1	Specific Gravity	2.65
2	Bulk Density(kg/m^3)	1640

Table 4.3: Sieve Analysis of Fine Aggregates

S.NO.	I.S SIEVE	WEIGHT RETAINED (gm)	CUMULATIVE WEIGHT RETAINED (gm)	CUMULATIVE % WEIGHT RETAINED (%)	CUMULATIVE % WEIGHT PASSING (%)
1	4.75	0	0	0	100
2	2.36	105	105	10.5	89.5
3	1.18	91	196	19.6	80.4
4	600µ	196	392	39.2	60.8
5	300µ	432	824	82.4	17.6
6	150µ	105	929	92.9	7.1
7	75µ	54	983	98.3	1.7

4.3 Coarse Aggregate

Locally available coarse aggregate was used. The Specific gravity was found to be 2.69. Aggregate of normal size 20 mm in which 60% passed on 20.0 mm sieve, and the remaining 40% is taken from the sieve which is passing from 10.0 mm and retained on 4.75 mm, which is acceptable according to IS: 383. Properties of CA used is given below in table 4.4

Table 4.4: Properties of Coarse Aggregate

S. NO.	PROPERTY	VALUE
1	Specific Gravity	2.69
2	Bulk Density(kg/m^3)	1700

4.4 Water

As water is an important component of concrete, it should be given special consideration throughout its preparation and quality monitoring. The reaction of cement and water (hydration) develops the strength and other qualities of concrete, hence water plays an important role. Potable water which was locally available in the Concrete lab was used for mixing as well as for curing of concrete in curing tank.

4.5 Super plasticizer

Admixture used was of brand GREENO LANTER MIX BASED on a blend of specially selected high molecular weight poly carboxylate ether (PCE) and organic polymer. Normal dosage specified by the company was 200ml to 250ml per 50 kg of cement. S.P.'s main function is to make the mix more fluid and improve the workability of concrete. Wet concrete will have a tendency to flocculate because Portland Pozzolana cement is in a fine stage of division. This flocculation traps a specific amount of water used in the process. Water is not freely available to lubricate the mix. Plasticizers are absorbed by cement particles when they are employed. When a charged polymer is absorbed by a cement particle, repulsive forces between the particles are created, which outweigh the attraction forces. The zeta potential is a repulsive force that varies depending on the base, solid content, and quality of superplasticizer utilized. The end consequence is that the cement particles are deflocculated, and the water trapped inside the flocks is released, making the mix more fluid.

Figure 4.1: Super plasticizer used in the mix.

4.6 Glass Fibre

Glass fibre was purchased online from website www.amazon.com from BUDDHA BUILDING TECH company. Fibres of ALKALI RESISTANT (AR) GLASS FIBRE having filament length of 12 mm were used. Glass fibre mixed with concrete was by proportion of weight of cement used in percentage.

Table 4.5: Properties of Alkali Resistant (AR) Glass fibre.

Fibre Type	Density (kg/m^3)	Elastic Modulus (GPa)	Tensile Strength (MPa)	Diameter (micron)	Length (mm)	No. Of Fibres (million/kg)
Alkali resistant(AR)	2600	73	1700	14	12	212

Figure 4.2: Alkali Resistant Glass fibre.

CHAPTER 5

EXPERIMENTAL INVESTIGATION ON GLASS FIBRE REINFORCED CONCRETE

The experimental program was designed to study the mechanical properties of GFRC on different fibre content. M40 strength of concrete was casted with different fibre content of 0%, 0.5%, 1.0%, 1.5%, 2.0%. Total 30 cubes of size 150mm*150mm*150mm were casted in 5 different batches. Also 30 beams were casted of size 100mm*100mm*500mm to perform flexural strength test and 30 cylinder of dia 150 mm and length 300mm were casted to perform split cylinder test on different fibre content.

Table 5.1: Details on number of specimen casted.

S.NO.	FIBRE CONTENT	COMPRESSIVE STRENGTH		FLEXURAL STRENGTH		SPLIT CYLINDER	
		7 DAYS	28 DAYS	7DAYS	28 DAYS	7 DAYS	28 DAYS
1	0.00%	3	3	3	3	3	3
2	0.50%	3	3	3	3	3	3
3	1.00%	3	3	3	3	3	3
4	1.50%	3	3	3	3	3	3
5	2.00%	3	3	3	3	3	3
TOTAL		15	15	15	15	15	15
GRAND TOTAL		90					

5.1 Material Quantities

In this study M40 grade of concrete were casted with different fibre content. The mix proportion adopted was 1:1.38:2.67:0.35.

Table 5.2: Amount of material used

S.NO.	FIBRE CONTENT	CEMENT	FA	CA	WATER	SUPER PLASTICIZER	GLASS FIBRE
1	0.00%	448kg	622.7kg	1197.2kg	161kg	1800ml	0kg
2	0.50%	448kg	622.7kg	1197.2kg	161kg	1800ml	2.24kg
3	1.00%	448kg	622.7kg	1197.2kg	161kg	1800ml	4.48kg
4	1.50%	448kg	622.7kg	1197.2kg	161kg	1800ml	6.72kg
5	2.00%	448kg	622.7kg	1197.2kg	161kg	1800ml	8.96kg

5.2 Preparation of Test Specimens

- **Cubes:** Total 30 cubes were casted in mould of size 150mm*150mm*150mm made of cast iron for performing compressive strength test a well as Rebound hammer and UPVT.
- **Cylinders:** total 30 cylinders were casted in mould of dia 150mm and length 300mm for performing Split cylinder test.
- **Beams:** Total 30 beams were casted in mould of size 100mm*100mm*500mm made of cast iron for performing flexural strength test.

5.3 Casting of Specimens

The entire casting was done in 5 batches for each , with components being added in proportion to their weight in each batch. The above elements are placed in a concrete mixer and carefully mixed. Then, to the measured water in the jar, a predetermined amount of super plasticizer is added. The water from above was poured into the dry mix and carefully stirred to achieve a uniform colour. The fibres are then spread over the mixture and vigorously stirred again until the fibres are evenly dispersed. A FRESH CONCRETE is the name given to the mixture we receive.

The concrete has been mixed and is ready to be poured into the moulds. The casting moulds were greased and all of the mould's edges were firmly tightened. The fresh concrete was then neatly poured into the moulds. The top surface of the mould is smoothed with a trowel after casting. Table vibration is used so as to alow the concrete to subsidies in the mould. After 24 hours of casting, the specimens were taken out of the mould. The specimens designations were marked using a permanent marker and then were put in curing tank for curing.

Figure 5.1: Casting of concrete in different moulds.

5.4 Curing

Curing was done for a period of 7 days and 28 days in curing tank and then the specimens were removed from water and were sent for the purpose of testing.

5.5 Testing for Compressive Strength

Concrete's compressive strength is the most essential measure and a good indicator of the material's overall quality. It is mostly determined by the mix's water/cement ratio, as well as curing and age after casting. Concrete's compressive strength is assessed by employing a compression testing machine to test cylindrical or cubical specimens of concrete at various ages, such as 7 days and 28 days.

Procedure:

- This test is done in accordance to IS:516-1959
- Compression testing machine used was manufactured by AIMIL company and was of 5000KN capacity.
- A 150mm X 150mm X 150mm concrete cube is put on the Compressive Testing Machine and securely gripped between the top and bottom plates.
- Apply a load of 140 kg/sq.cm/minute on the specimens until they fail.
- When the load is applied, make a note of the ultimate load at the specimen's failure.
- The compressive strength is computed by dividing the ultimate load by the specimen area.

Compressive Strength (in MPa)=Failure load/Area

Figure 5.3: Compressive testing machine of 5000KN capacity.

5.6 Testing for Flexural Strength

Flexural tensile strength is determined with the help of 100mm*100mm*500mm concrete beam if the maximum size of aggregate is less than 20 mm. This test have been performed in accordance to IS:516-1959 .

Procedure:

- The specimens are prepared for testing after being removed from the water after 7/28 days of curing.
- On the flexure testing equipment, the beam is supported over a clear span of 400 mm by keeping 50 mm bearing on both sides.
- In this test, two sites of loading are used, and the load is delivered at 180 kg/min until the specimen fails. The maximum load is measured.
- The concrete beam's flexural strength is computed using the flexural strength formula-

  Flexural strength f=PL/bd^2 (in MPa)

  Where,

  P = ultimate load applied, L = Effective length of specimen

  b = breadth of the specimen, d = depth of the specimen
- Based on the I.S. Code formula, the ultimate flexural stress was calculated. Knowing the location of the major crack, which appeared closer to the centre of the span, the suitable code formula was applied.
- This formula is valid, according to the code, if the fracture distance from the nearest support is more than 133 mm.

Figure 5.4: Flexural testing machine performing test on beams.

5.7 Testing for Split Tensile Strength

Cylinders of dia 150mm and length 300mm are used to perform this test. This test is performed on Compressive Testing machine. In these tests, a compressive force is applied to a concrete specimen in such a way that tensile stresses are developed in the specimen, causing the specimen to crack.

Procedure:

- Test is performed as per IS: 5816-1999
- The 7-day and 28-day cured specimens are put between the compression testing machine's plates
- The load is applied at a constant rate until the cylinder fails as shown in figure
- The load at which failure happens is recorded
- For all specimens, the same method is followed**.**
- The formula used to compute the split tensile strength as per code is:

Split tensile strength $=2P/\pi dL$(in MPa)

where,

P=ultimate load,

D=cylinder diameter,

L=cylinder length (or height).

Figure 5.5: Performing Split cylinder test on compressive testing machine.

5.8 Rebound Hammer Test

This test is performed using an apparatus called REBOUND HAMMER. It consist of a spring control mass that slides over the plunger in tabular casing. When the hammer is pressed against the concrete surface to be tested and retracts against the force of the spring carrying along the rider with it, movement of which is noted over the scale and is referred as rebound number, which is further used to indicate the strength of concrete.

Procedure:

- This test has been performed in accordance to IS: 13311(Part 2)-1992.
- The specimen should be dry before testing. So the cubes were taken out of curing tank 24 hours before testing.
- Concrete surface was thoroughly cleaned
- The concrete cube specimen is placed in Compression testing machine and a load of about 7N/mm^2 is applied to fix the cube in machine.
- Grid was made for taking 9 readings, leaving 20mm from all edges
- Rebound hammer is pressed against the cube at right angle properly
- Reading obtained digitally directly refers to compressive strength .
- Average of 9 readings gives compressive strength.

Figure 5.6: Digital Rebound hammer. Figure 5.7: Performing Rebound hammer test.

5.9 Ultrasonic Pulse Velocity Test

The principle of this test is based upon the fact that velocity of the sound in solids depends upon the modulus of elasticity and density of the solid. The apparatus of this test consist of a transmitter and a reliever. Transmitter is used to generate the pulse of ultrasonic velocity that is detected by the receiver on th other face of specimen. The time required by the pulse to travel through the know distance in the specimen is noted which is further used to calculate the velocity of the pulse and in turn it is related to the quality of the concrete under the test.

Procedure:

- This test has been performed in accordance to IS: 13311 (Part 1)-1992.
- The surface of the specimen is cleaned where transducer and receiver are kept.
- Couplants like grease, petroleum jelly, liquid soap, kaolin glycerol paste etc. is applied to ensure adequate acoustic coupling between the face of each transducer and concrete.
- The transmit time (T) of the pulse is noted.
- The Pulse velocity(V) is given by

  $V=L/T$ where, L= length of specimen.

Figure 5.8: Ultrasonic Pulse velocity test setup.

Figure 5.9: Performing Ultrasonic pulse velocity test on cube specimen.

CHAPTER 6

RESULTS AND DISCUSSION

The experimental investigation carried out on different proportion of fibre in GFRC is shown below:

6.1 Compressive Strength test results of GFRC at different age

The Compressive test had been performed in accordance to IS: 516-1959. The compressive strength result on cube specimen of size150mm*150mm*150mm on different fibre content by weight of cement has been shown in Table 6.1 and Table 6.2 on different age of 7 days and 28 days.

Table 6.1 Compressive Strength at 7 days of GFRC at different fibre content

FIBRE CONTENT (%)	LOAD AT FAILURE (KN)	STRESS AT FAILURE (MPa)	COMPRESSIVE STRENGTH (MPa)	CHANGE (%)
0	591.3	26.28	25.03	-
	623	27.69		
	473.4	21.04		
0.5	612.9	27.24	26.77	+6.95
	666.2	29.61		
	528	23.47		
1	660.6	29.36	27.9	+11.46
	604.8	26.88		
	648.7	28.83		
1.5	618.3	27.48	29.08	+16.18
	680.4	30.24		
	664.2	29.52		
2	614.92	27.33	27.46	+9.71
	651.1	28.94		
	587.7	26.12		

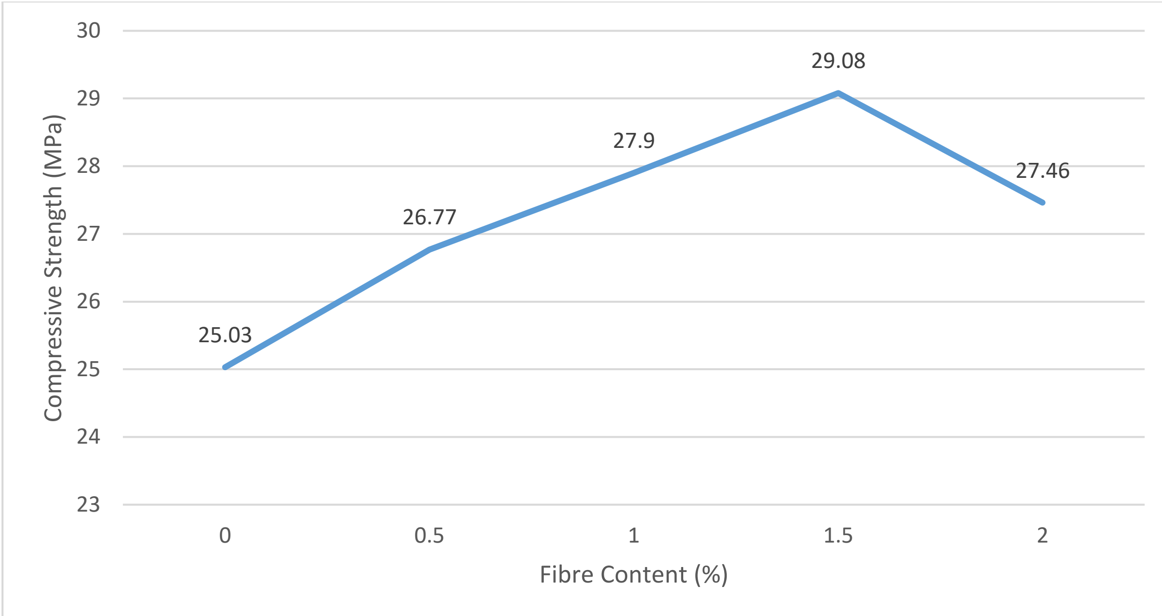

Figure 6.1: Variation of compressive strength with fibre content at 7 days.

Table 6.2 Compressive Strength at 28 days of GFRC at different fibre content

FIBRE CONTENT (%)	LOAD AT FAILURE (KN)	STRESS AT FAILURE (MPa)	COMPRESSIVE STRENGTH (MPa)	CHANGE (%)
0	885.6	39.36	40.03	-
	941.4	41.84		
	875.48	38.91		
0.5	907.2	40.32	41.82	+4.47
	984.15	43.74		
	931.9	41.42		
1	1030.7	45.81	43.71	+9.19
	995.4	44.24		
	924.3	41.08		
1.5	1026.4	45.62	46.53	+16.23
	1095.9	48.71		
	1018.8	45.28		
2	995.4	44.24	43.92	+9.71
	953.8	42.39		
	1015.6	45.14		

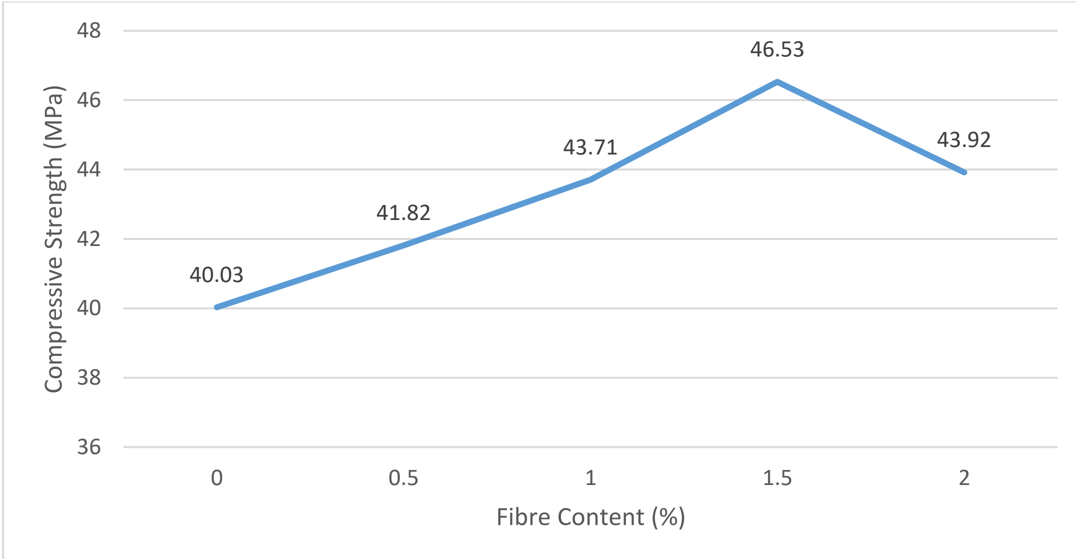

Figure 6.2:Variation of compressive strength with fibre content at 28 days.

Observation:

- The strength at 7 days is found to be approximately 65% in comparison to 28 days
- As the fibre content increases, compressive strength also increases.
- Compressive strength is found to be maximum at fibre content of 1.5% in both.
- Improvement in compressive strength is about 16% as compared to controlled specimen containing 0% fibre.

6.2 Flexural Strength test results of GFRC at different age

The Flexural strength test had been performed in accordance to IS: 516-1959. The flexural strength test results on beam specimen of size100mm*100mm*5000mm on different fibre content by weight of cement has been shown in Table 6.3 and Table 6.4 on different age of 7 days and 28 days.

Table 6.3: Flexural strength at 7 days of GFRC at different fibre content

FIBRE CONTENT (%)	LOAD AT FAILURE (KN)	STRESS AT FAILURE (MPa)	FLEXURAL STRENGTH (MPa)	CHANGE (%)
0	9	3.6	3.73	-
	9.5	3.8		
	9.5	3.8		
0.5	11.5	4.6	4.4	+17.96
	11	4.4		
	10.5	4.2		
1	12	4.8	4.73	+26.8
	11	4.4		
	12.5	5		
1.5	13	5.2	5.33	+42.89
	13.5	5.4		
	13.5	5.4		
2	12.5	5	5	+34.04
	13	5.2		
	12	4.8		

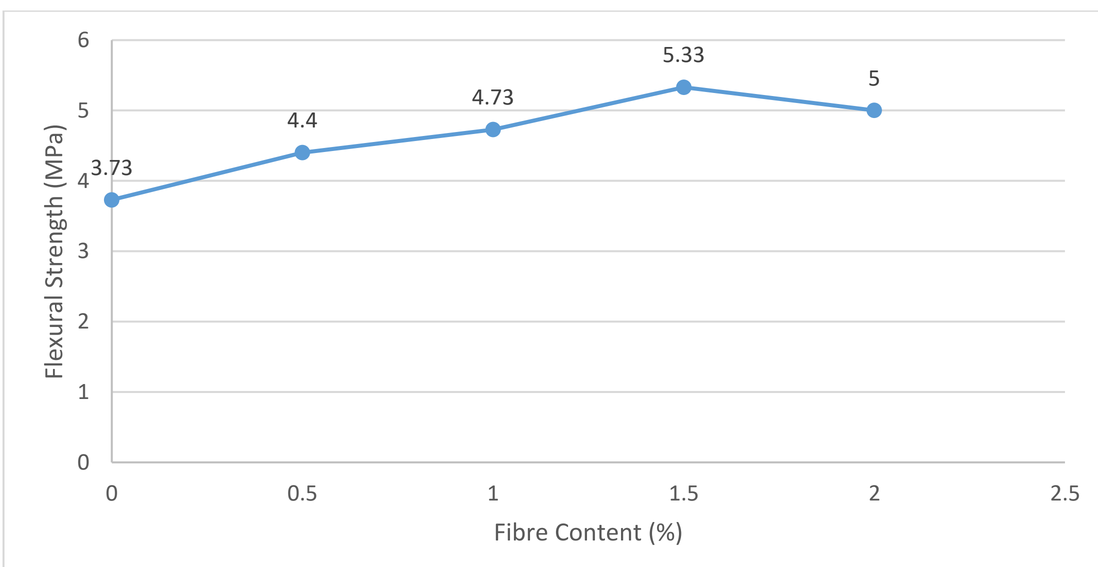

Figure 6.3: Variation of flexural strength with fibre content at 7 days.

Table 6.4: Flexural strength at 28 days of GFRC at different fibre content

FIBRE CONTENT (%)	LOAD AT FAILURE (KN)	STRESS AT FAILURE (MPa)	FLEXURAL STRENGTH (MPa)	CHANGE (%)
0	10.5	4.2	4.3	-
	10.5	4.2		
	11	4.4		
0.5	12.5	5	4.8	+11.62
	11.5	4.6		
	12	4.8		
1	14	5.6	5.5	+27.9
	13.5	5.4		
	13.5	5.4		
1.5	15	6	5.86	+36.27
	15	6		
	14	5.6		
2	14.5	5.8	5.73	+33.25
	14	5.6		
	14.5	5.8		

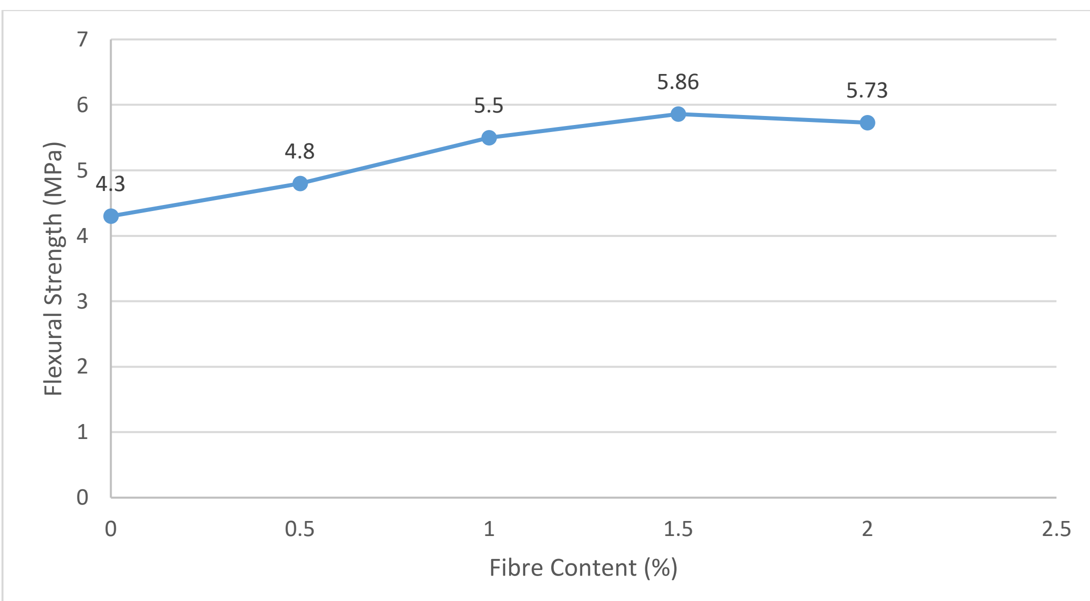

Figure 6.4: Variation of flexural strength with fibre content at 28 days.

Observation:

- As the fibre content increases, flexural strength also increases.
- Flexural strength is found to be maximum at fibre content of 1.5% in both i.e. 7 days and 28 days.
- Flexural strength has been found to increase by 42.89% at 7 days and by36.27% at 28 days, in comparison to controlled specimen of 0% fibre.

6.3 Split Tensile Strength of GFRC at different age

The Split tensile strength test had been performed in accordance to IS: 5816-1999. The Split tensile strength test results on Cylindrical specimen of dia 150mm and length 300mm on different fibre content by weight of cement has been shown in Table 6.5 and Table 6.6 on different age of 7 days and 28 days.

Table 6.5: Split tensile strength at 7 days of GFRC at different fibre content

FIBRE CONTENT (%)	LOAD AT FAILURE (KN)	STRESS AT FAILURE (MPa)	SPLIT TENSILE STRENGTH (MPa)	CHANGE (%)
0	196.7	2.78	2.7	-
	186.1	2.63		
	191.1	2.7		
0.5	234.1	3.31	3.28	21.48
	222.6	3.14		
	241.3	3.41		
1	238.9	3.37	3.37	24.81
	233.3	3.3		
	244.1	3.45		
1.5	262.2	3.71	3.78	40.12
	266.8	3.77		
	274.3	3.88		
2	251.7	3.56	3.6	33.33
	259.6	3.67		
	254	3.59		

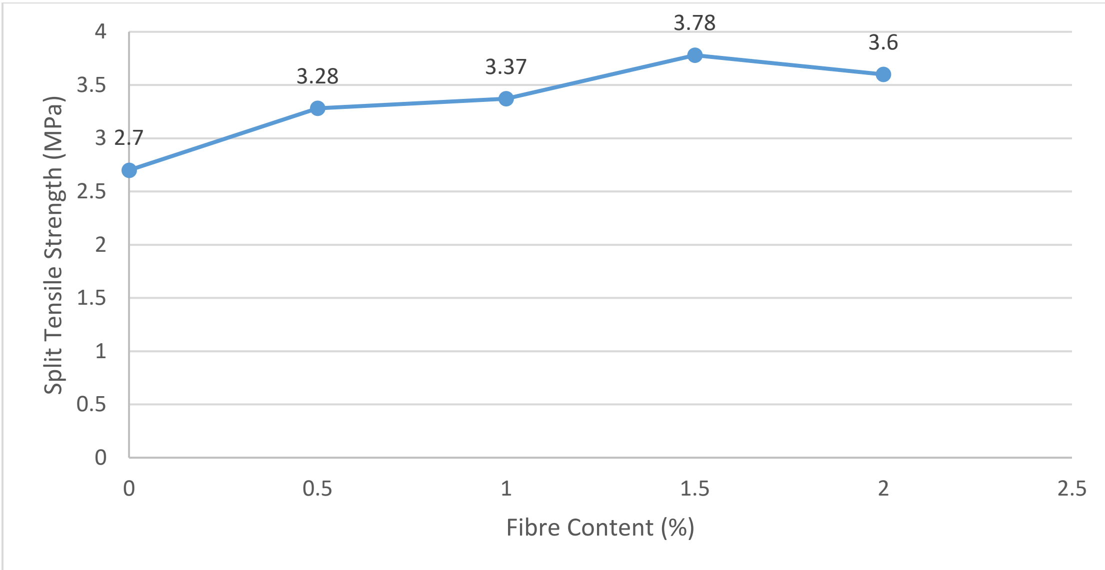

Figure 6.5: Variation of split tensile strength with fibre content at 7 days.

Table 6.6: Split tensile strength at 28 days of GFRC at different fibre content

FIBRE CONTENT (%)	LOAD AT FAILURE (KN)	STRESS AT FAILURE (MPa)	SPLIT TENSILE STRENGTH (MPa)	CHANGE (%)
0	230.6	3.26	3.34	-
	241.1	3.41		
	238.1	3.36		
0.5	268.3	3.79	3.78	13.17
	271.6	3.84		
	262.9	3.71		
1	306.8	4.34	4.32	29.34
	298.7	4.22		
	311.1	4.40		
1.5	330.6	4.67	4.64	38.92
	328.2	4.64		
	326.9	4.62		
2	318.9	4.51	4.52	35.32
	322.1	4.55		
	320.1	4.52		

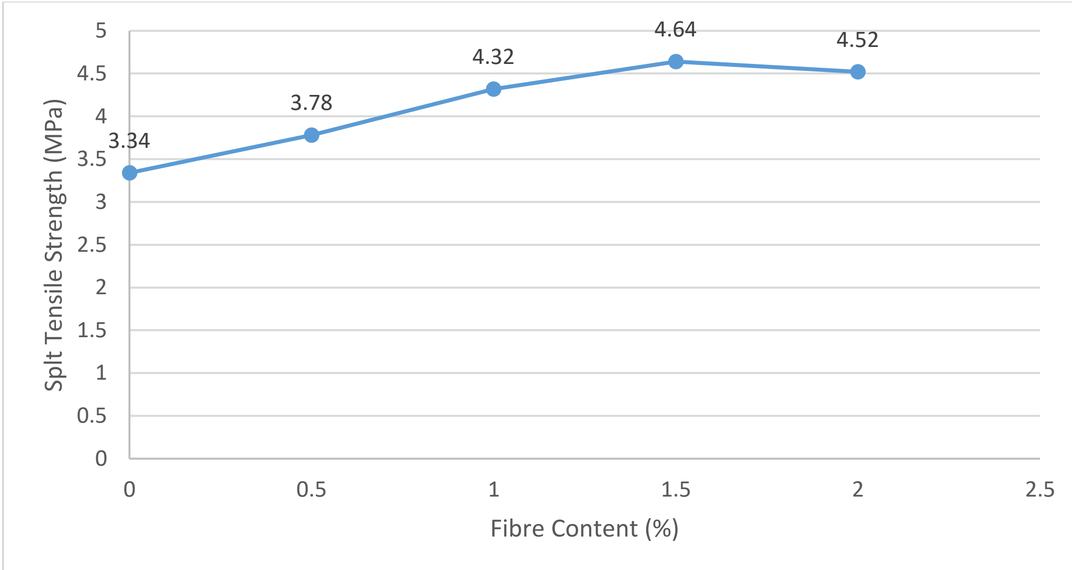

Figure 6.6: Variation of split tensile strength with fibre content at 28 days.

Observation:

- As the fibre content increases, Split tensile strength also increases.
- Split tensile strength is found to be maximum at fibre content of 1.5% in both i.e. 7 days and 28 days.
- Flexural strength has been found to increase by 40.12% at 7 days and by 38.92% at 28 days, in comparison to controlled specimen of 0% fibre.

Table 6.7: Comparison between compressive strength, flexural strength and split tensile strength at varying fibre content of GFRC at 7 days.

FIBRE CONTENT	COMPRESSIVE STRENGTH	FLEXURAL STRENGTH	SPLIT TENSILE STRENGTH
(%)	(MPa)	(MPa)	(MPa)
0	25.03	3.73	2.7
0.5	26.77	4.4	3.28
1	27.9	4.73	3.37
1.5	29.08	5.33	3.78
2	27.46	5	3.6

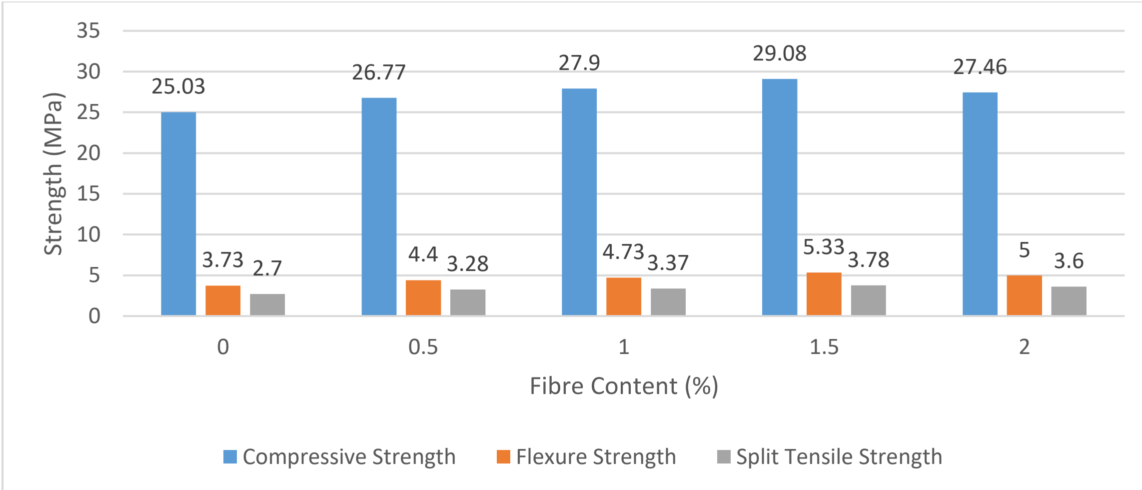

Figure 6.7: Comparison between compressive strength, flexural strength and split tensile strength at varying fibre content of GFRC at 7 days

Table 6.8: Comparison between compressive strength, flexural strength and split tensile strength at varying fibre content of GFRC at 28 days.

FIBRE CONTENT (%)	COMPRESSIVE STRENGTH (Mpa)	FLEXURAL STRENGTH (MPa)	SPLIT TENSILE STRENGTH (MPa)
0	40.03	4.3	3.34
0.5	41.82	4.5	3.78
1	43.71	5.5	4.32
1.5	46.53	5.86	4.64
2	43.92	4.52	4.52

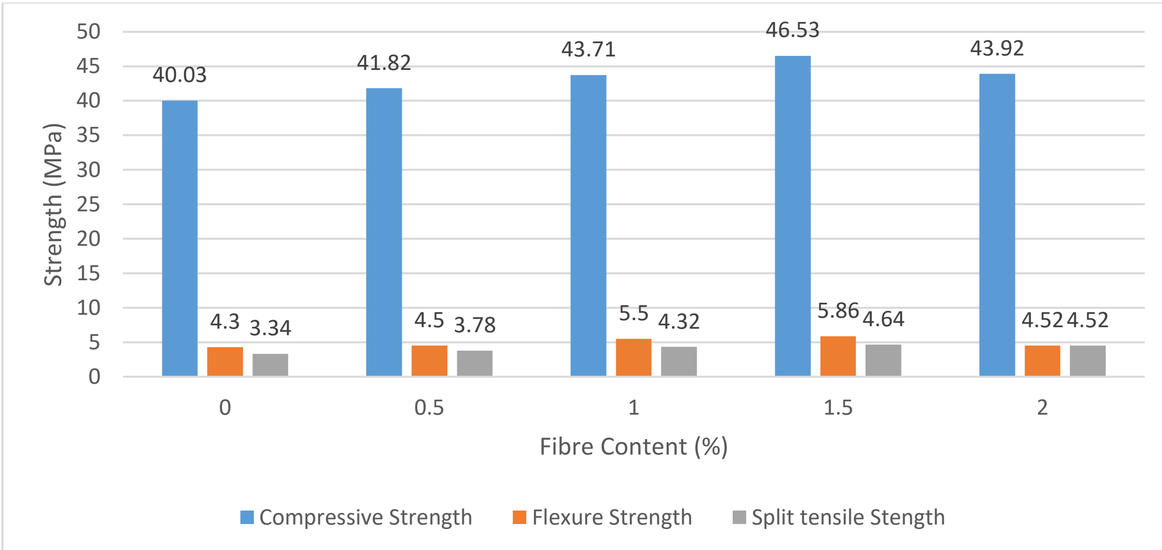

Figure 6.8: Comparison between compressive strength, flexural strength and split tensile strength at varying fibre content of GFRC at 28 days.

6.4 Rebound hammer test results on GFRC at different fibre content

The rebound hammer test had been performed in accordance to IS: 13311(Part 2)-1992. This test was performed by Rebound hammer on cube specimen of size 150mm*150mm*150mm, before performing destructive compressive strength test. Unlike conventional rebound hammer which give the result inform of rebound no., which further needed curve to get the compressive strength, here digital type rebound hammer was used which directly gave the compressive strength. The result obtained is shown in Table 6.9 and Table 6.10. Result obtained is compared with compressive strength.

Table 6.9: Comparison of Compressive strength by Non destructive Rebound hammer test and destructive compressive strength test at 7 days

FIBRE CONTENT (%)	REBOUND HAMMER VALUE (MPa)	AVERAGE COMPRESSIVE STRENGTH BY REBOUND HAMMER (MPa)	ACTUAL COMPRESSIVE STRENGTH (MPa)	VARIATION IN PERCENTAGE (%)
0	18.5,21,31,25,19.5,22.5,20,23,29	23.27	26.28	-11.45
	22,27.5,20,34,29,24,31.5,30,38	28.44	27.69	+2.7
	24,15,23,24,18.5,18,19,16.5,17	17.44	21.04	-17.11
0.5	26.5,33,22,27,19.5,21.5,23,27.5,21	24.55	27.24	-9.87
	31,24,26,28.5,32,35,29,30.5,32	26.88	29.61	-9.21
	30.5,23,25,19,37.5,36,27.5,29,22,21	28.94	23.47	+23.30
1	33,29,27.5,39,26,26,24,22.5,20	27.44	29.36	-6.53
	25.5,21,29,36,35.5,34.5,23.5,31,28	29.33	26.88	+9.11
	36,41,24,38,19,39.5,36,39,39.5	34.66	28.83	+20.22
1.5	30,34.5,18,21,20.5,23,29,18.5,19	23.72	27.48	-13.68
	24,19,37.5,22,36,27.5,26,24.5,27.5	27.05	30.24	-10.54
	23.5,41,29.5,28.5,36.5,34,31,38,35.5	33.05	29.52	+11.95
2	22.5,39.5,26,36,24,26.5,35.5,36.5,31	30.83	27.33	+12.8
	41,22,23.5,36.5,39.5,29,39.5,38,37.5	34.05	28.94	+17.65
	29.5,32,21,20,20.5,35.5,24,29.5,18	25.55	26.12	-2.18

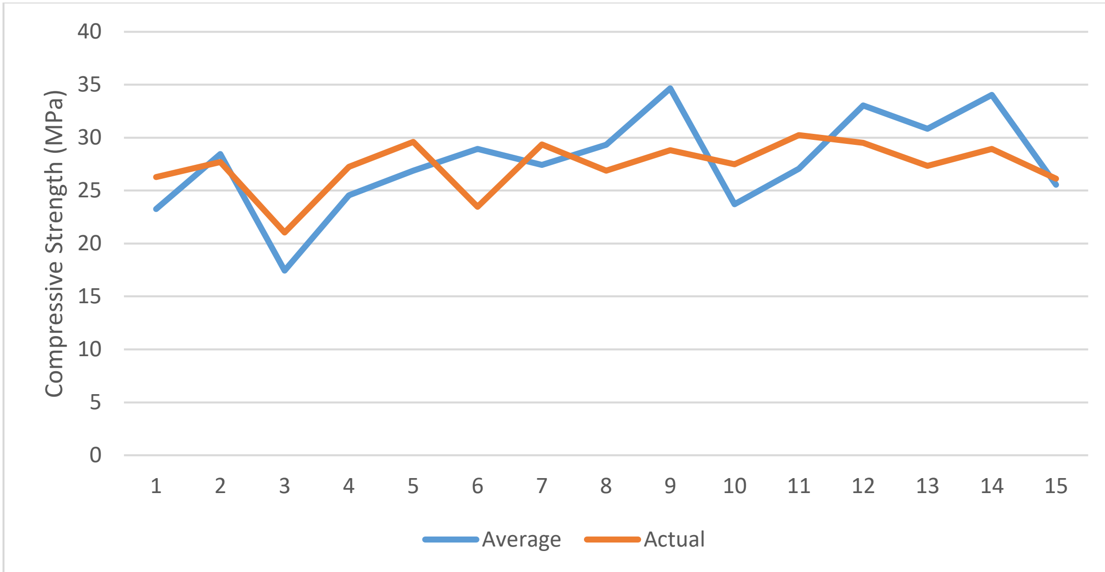

Figure 6.9: Variation of average compressive strength by rebound hammer with cube compressive strength at 7 days.

Table 6.10: Comparison of Compressive strength by Non Destructive Rebound hammer test and destructive compressive strength test at 28 days

FIBRE CONTENT (%)	REBOUND HAMMER VALUE (MPa)	AVERAGE COMPRESSIVE STRENGTH BY REBOUND HAMMER (MPa)	ACTUAL COMPRESSIVE STRENGTH (MPa)	VARIATION IN PERCENTAGE (%)
0	48.5,39.5,48,48,37.5,43.5,45,49.5,37.5	44.11	39.36	+12.06
	41.5,40,41.5,44,45,47,47.5,46.5,44.5	44.16	41.84	+5.54
	44.5,45,41,37,51,48,43,42.5,41	43.66	38.91	+12.2
0.5	31,41.5,39,41,31.5,40.5,32,27.5,31.5	35.05	40.32	-13.07
	29,38.5,37.5,48.5,45.5,33,39.5,49.5,42	40.33	43.74	-7.79
	36.5,51,54,42.5,49.5,58.5,37.5,54.5,49.5	48.16	41.42	+16.29
1	35.5,48.5,41,36.5,37.5,41,42.5,33,37	39.16	45.81	-14.51
	34.5,48,42,33.5,39,44,36,32,41.5	38.22	44.24	-13.6
	43.5,55,42,42.5,42.5,56.5,39.5,45,48.5	46.11	41.08	+12.24
1.5	51.5,55,49.5,47.5,44,59.5,53.5,55,54	52.16	45.62	+14.33
	44,51,55,49.5,58.5,56.5,54.5,52,50	52.33	48.71	+7.43
	41,39.5,37,33,39.5,45.5,41,36,45.5	39.77	45.28	-12.16
2	47.5,44,59.5,53,55.5,54.5,51,52,49	51.77	44.24	+17.03
	40.5,33,39.5,41.5,30,41,32.5,29,31	35.33	42.39	-16.65
	48.5,42.5,33,44,39.5,33,42,32.5,37	39.11	45.14	-13.35

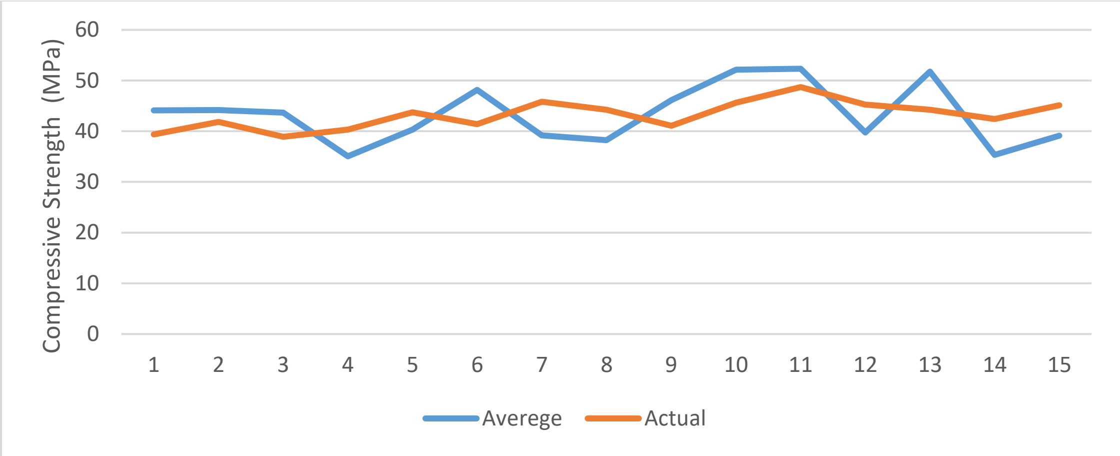

Figure 6.10: Variation of average compressive strength by rebound hammer with cube compressive strength at 28 days.

Observation:

- The compressive strength found from rebound hammer increases with increase in fibre content.
- At the fibre content of 1.5%, Rebound hammer gives maximum value of compressive strength.
- Variation of compressive strength obtained from rebound hammer is found to be 23.30% (max) at 7 days
- At 28 days, variation in compressive strength obtained from rebound hammer is found to be 17.03%
- With increase in age of specimen hardness increases, as a result value obtained from rebound hammer increases.

6.5 Ultrasonic Pulse Velocity test results at different fibre content

UPVT had been performed in accordance to IS: 13311 (Part 1)-1992. In this test, cube specimen, which were to be used to perform compressive strength test, were used to perform Rebound hammer and UPVT before the destructive test. Length of the specimen was 150mm. transmit time (T) was noted which was used to find the velocity of the ultrasonic pulse wave, which in turn tells us about the quality of concrete. This test is based on the principle that the waves travel faster in denser medium. Result obtained is shown in Table 6.11 and Table 6.12 at 7 days and 28 days.

Table 6.11: Ultrasonic pulse velocity test result at different fibre content at 7 days

FIBRE CONTENT (%)	COMPRESSIVE STRENGTH (MPa)	TRANSMIT TIME (μ-sec)	PULSE VELOCITY (KM/SEC)	REMARK AS PER IS: 13311(PART 1)
0	26.28	33.9	4.42	Good
	27.69	34.9	4.29	Good
	21.04	33.4	4.49	Good
0.5	27.24	32.1	4.67	Excellent
	29.61	34.1	4.39	Good
	23.47	33.2	4.51	Excellent
1	29.36	33.2	4.51	Excellent
	26.88	33.6	4.46	Good
	28.83	32.8	4.57	Excellent
1.5	27.48	34.1	4.39	Good
	30.24	32.2	4.65	Excellent
	29.52	31.5	4.76	Excellent
2	27.33	34.6	4.33	Good
	28.94	35.1	4.27	Good
	26.12	35.3	4.24	Good

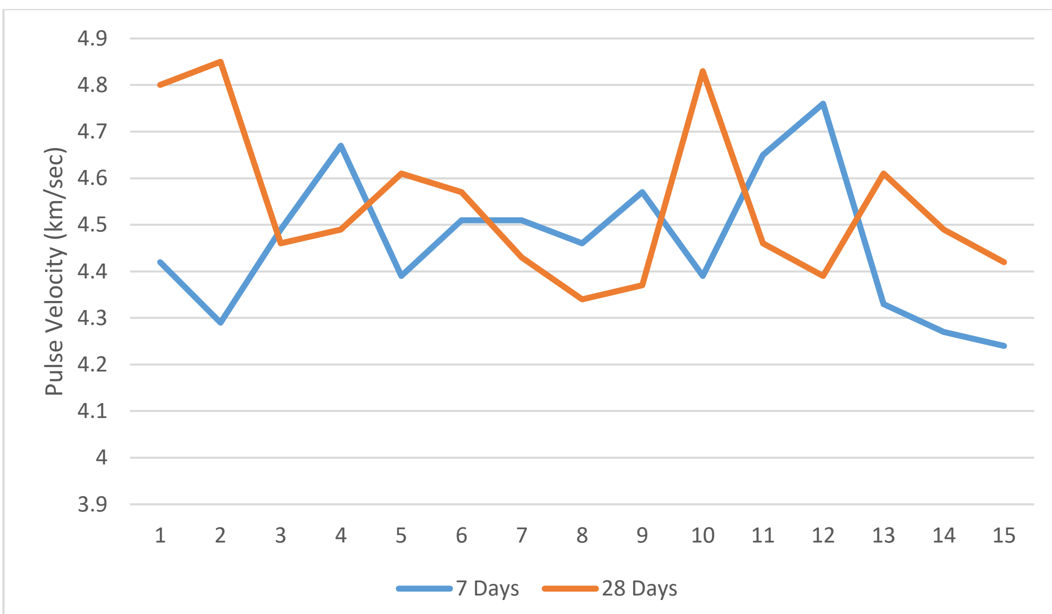

Figure 6.11: Ultrasonic pulse velocity test result at different fibre content at 7 days &28 days

Table 6.12: Ultrasonic pulse velocity test result at different fibre content at 28 days

FIBRE CONTENT (%)	COMPRESSIVE STRENGTH (MPa)	TIME (μ-sec)	PULSE VELOCITY (KM/SEC)	REMARK AS PER IS: 13311(PART 1)
0	39.36	31.2	4.8	Excellent
	41.84	30.9	4.85	Excellent
	38.91	33.6	4.46	Good
0.5	40.32	33.4	4.49	Good
	43.74	32.5	4.61	Excellent
	41.42	32.8	4.57	Excellent
1	45.81	33.8	4.43	Good
	44.24	34.5	4.34	Good
	41.08	34.3	4.37	Good
1.5	45.62	31	4.83	Excellent
	48.71	33.6	4.46	Good
	45.28	34.1	4.39	Good
2	44.24	32.5	4.61	Excellent
	42.39	33.4	4.49	Good
	45.14	33.9	4.42	Good

Observation:

- With the increase in fibre content Velocity increases, although the increase is very marginal.
- With the increase in age of specimen velocity increases but the increase is very marginal.
- The velocity is related to quality of concrete casted which shows that the casted concrete was mostly of good quality as specified in IS: 13311 (Part 1)-1992.

Table 6.13: Non-Destructive test result on GFRC at 7 days with varying fibre content

FIBRE CONTENT (%)	COMPRESSIVE STRENGTH (MPa)	REBOUND HAMMER (MPa)	PULSE VELOCITY (km/sec)	REMARK AS PER IS: 13311(PART 1)
0	26.28	23.27	4.42	Good
	27.69	28.44	4.29	Good
	21.04	17.44	4.49	Good
0.5	27.24	24.55	4.67	Excellent
	29.61	26.88	4.39	Good
	23.47	28.94	4.51	Excellent
1	29.36	27.44	4.51	Excellent
	26.88	29.33	4.46	Good
	28.83	34.66	4.57	Excellent
1.5	27.48	23.72	4.39	Good
	30.24	27.05	4.65	Excellent
	29.52	33.05	4.76	Excellent
2	27.33	30.83	4.33	Good
	28.94	34.05	4.27	Good
	26.12	25.55	4.24	Good

Table 6.14: Non-Destructive test result on GFRC at 28 days with varying fibre content.

FIBRE CONTENT (%)	COMPRESSIVE STRENGTH (MPa)	REBOUND HAMMER (MPa)	PULSE VELOCITY (km/sec)	REMARK AS PER IS: 13311(PART 1)
0	39.36	44.11	4.8	Excellent
	41.84	44.16	4.85	Excellent
	38.91	43.66	4.46	Good
0.5	40.32	35.05	4.49	Good
	43.74	40.33	4.61	Excellent
	41.42	48.16	4.57	Excellent
1	45.81	39.16	4.43	Good
	44.24	38.22	4.34	Good
	41.08	46.11	4.37	Good
1.5	45.62	52.16	4.83	Excellent
	48.71	52.33	4.46	Good
	45.28	39.77	4.39	Good
2	44.24	51.77	4.61	Excellent
	42.39	35.33	4.49	Good
	45.14	39.11	4.42	Good

CHAPTER 7

CONCLUSION

Based on the experimental investigation carried out in chapter 6 it is evident from various graphs and tables that the hardened properties of Glass fibre reinforced concrete (GFRC) improves with increase in fibre content. Following conclusion can be drawn based on discussion carried out in previous chapter:

- The compressive strength is found to increase with increase in fibre content. At fibre content of 1.5%, compressive strength of GFRC was found to be 16.18% & 16.23% more than the controlled specimen of fibre content 0%, at 7 days and 28 days respectively.
- Addition of fibre improves the flexural strength quite well, thereby decreasing the area of steel required for same strength. Also with less area of steel the cost can be decreased.
- The flexural strength is found to increase with increase in fibre content and attains a maximum value at fibre content of 1.5%.The flexural strength was found to be 42.89% & 36.27% more than the controlled specimen at 0% fibre content, at 7 days and 28 days respectively.
- The nature of failure was more or less brittle only in flexural strength test. Higher percentage of fibre may be required to change the nature of failure to ductile.
- As it is a very well know fact that concrete is weak in tension, addition of glass fibre has led to increase in tensile strength of concrete.

- The split tensile strength of GRFC is found to be 40.12% & 38.92% more than the controlled specimen at 0% fibre, at 7 days and 28 days respectively at fibre content of 1.5%
- Based on the investigation it can be concluded that optimum fibre content is 1.5%, which improves all the properties investigated here.
- Non destructive test performed were in good correlation with destructive test.
- The results of Rebound hammer test was compared with destructive compressive strength test and it was found that the accuracy of rebound hammer is of order ±25% which is as per IS: 13311 (Part 2)-1992.
- Rebound hammer readings were found to increase with increase in age as with increase in age hardness of concrete increases.
- Ultrasonic pulse velocity test readings showed that with increase in fibre content the pulse velocity increases which relates to the concrete quality grading. Quality found was mostly in good range and some specimen even fell in excellent category.
- The increase in velocity with increase in age was marginal.
- Combination of both the Non destructive test is required to access the quality of concrete.

BIBLIOGRAPHY

1. Faiz A. Mirza a, ParvizSoroushian, ‘Effects of alkali-resistant glass fiber reinforcement on crack and temperature resistance of lightweight concrete’. Cement & Concrete Composites 24 (2002) 223–227.

2. Sanjay Kumar and M M Prasad, ‘Flexural Behavior of Short Steel Fiber Reinforced Concrete Beams’. Seventh Intnl. RILEM Symposium on Fiber Reinforced Concrete Design and Applications, BEFIB-2008, Chennai, India. 2008. PP. 209-217.

3.Yeol Choia, Robert L. Yuanb, ‘Experimental relationship between splitting tensile strength and compressive strength of GFRC and PFRC’. Cement and Concrete Research, 35, (2005), PP. 1587– 1591.

4.Yuwaraj M. Ghugal and Santosh B. Deshmukh, ‘Performance of Alkali-resistant Glass Fiber Reinforced Concrete’. Journal of Reinforced Plastics and Composites, vol. 25, No. 6, 2006, PP. 617-630.

5. K.Holschemacher, T. Mueller, Y. Ribakov, ‘Effect of steel fibres on mechanical properties of high-strength concrete’. Materials and Design, 31, (2010), PP. 2604–2615.

6.M. J. Roth, C. D. Eamon, T. R. Slawson, T. D. Tonyan, A. Dubey, ‘Ultra High Strength Glass Fiber Reinforced Concrete Mechanical Behavior and Numerical Modeling’. ACI Materials Journal, V. 107, No. 2, March-April 2010. PP 185-194

7. Byung Wan Jo, Young Hyun Shen, Young Jim Kim, ‘The Evaluation of Elastic Modulus for Steel Fiber Reinforced Concrete’.

8. Jain Akash, Kathuria Ankit ‘Combined Use of Non-Destructive Tests for Assessment of Strength of Concrete in Structure’.

9. Hamidian Mohammadreza,Ali Shariati ‘Application of Schmidt rebound hammer and ultrasonic pulse velocity techniques for structural health monitoring’

10. Qasrawi Hisham Y ‘Concrete strength by combined non destructive methodsSimply and reliably predicted’

. 11. I.S. 383-1970, 'Specification for course and fine aggregate from natural sources for concrete'. BIS

12.I.S. 456-2000, 'Code of practice of plain and reinforced concrete'. BIS.

13. I.S. 516-1959, 'Method of test for strength of concrete', BIS.

14. I.S. 2386 (Part 1) 1963 'Methods of test for Aggregates for Concrete, Part 1 Particle Size and Shape', BIS.

15. I.S. 6461 (Part 7) 1973 'Mixing, laying, compaction, curing and other construction aspects', BIS.

16. I.S. 7246 1974 'Recommendations for use of table vibrators for consolidating concrete', BIS.

17. I.S 13311(Part 1)-1992 'Non destructive testing of concrete-methods of test Part 1-Ultrasonic pulse velocity test'

18. I.S 13311(Part2)-1992 'Non destructive testing of concrete-methods of test Part 2-Rebound hammer'

19.I.S. 9103-1999, 'Specification for admixtures for concrete'. BIS

20. I.S. 10262-1982, 'Recommend guidelines for concrete mix design'. BIS.

21. I.S. 10262-2009, 'Recommended guidelines for concrete mix design'. BIS.

22. I.S. 12269-1987, 'Specification for 53 grade ordinary Portland cement'. BIS

23. 'Studies on glass fiber reinforced concrete composites – strength and behavior'. Challenges, Opportunities and Solutions in Structural Engineering and Construction – Ghafoori (ed.) © 2010 Taylor & Francis Group, London, ISBN 978-0-415-56809- 8, pp 601-604.