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Destructive and Non-Destructive Analysis of Polypropylene Fibre Reinforced Concrete

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ABSTRACT

Plain Cement Concrete (PCC) is brittle and has low tensile strength. The brittleness can be avoided by adding fibre. Fibre-reinforced concrete (FRC) is concrete containing fibrous material spread across concrete, which increases its structural integrity. Addition of fibres to concrete makes it an isotropic material and converts its brittle behaviour to ductile behaviour. In the Fibre Reinforced Concrete, polypropylene fibres are rationally combined to produce a cementitious composite that derives benefits from each of the individual fibres and exhibits a synergistic response. Based on I.S. Code method of mix design, proportion of different ingredients was obtained to get M30 grade concrete. Samples were prepared with varying the volume fraction of fibres from 0.50% to 2.50%. The optimum dosage is determined from among the above mixes. The result shows that optimum dosage is obtained at 1.50% addition of fibre. The main aim of the present experimental investigation was to use different volume fractions of polypropylene fibres to produce FRC and thus to evaluate its performance by comparing Destructive tests such as compression, tension, flexure and Non-destructive tests such as Rebound Hammer, Ultrasonic Pulse Velocity and Durability Parameters such as Water Absorption, Sorpitivity etc., .From the results obtained fibre reinforced concrete shows higher values than normal concrete under Compression, Split Tensile and Flexural Strength. The water absorption is reduced for FRC compared to Normal Concrete.

Keywords : Fibre Reinforced Concrete, Polypropylene Fibre, M30 Grade, Destructive and Non-Destructive Tests, Durability Tests

I. INTRODUCTION

In Concrete is a construction material composed of cement, fine aggregates(sand) and coarse aggregates mixed with water which hardens with time. Portland cement is the commonly used type of cement for production of concrete. Concrete technology deals with study of properties of concrete and its practical applications.

There is various type of concrete available in the market based on its functionality, strength and structure. For construction purposes, if someone goes to the market to buy the concrete for his/her building-it is available in two forms:

a) Normal Mix Concrete
b) Design Mix Concrete

The grade of concrete specifies the required strength for the structure. For example, M30 Grade denotes that the compressive strength required for construction is 30MPa.The first letter in grade 'M' represents mix and 30 is the required strength in MPa.

Fibre-reinforced Concrete (FRC) is a type of concrete that contains fibrous material which improves structural stability. It is made up of short discrete fibres that are uniformly distributed and randomly orientated. Steel fibres, glass fibres, synthetic fibres and natural fibres are all examples of fibres that contribute to the qualities of concrete. Furthermore, the nature of fibre-reinforced concrete varies with different concretes, fibre materials, geometrics, distribution, orientation, and densities. Since early 1960's there has been an upsurge in interest in fibre reinforced concrete (FRC). This is an important turning point in the development of FRC. Rapid Progress in technology is matched by an increase in applications. While additional new applications were discovered, several different types of fibres were introduced. By the 1960's steel, glass (GFRC), and synthetic (polypropylene) fibres were being employed in concrete. Research into distinctive fibre-reinforced concrete is ongoing till today. The addition of fibres to structural materials is required to raise the strength of the concrete and mortar as well as to decrease the crack propagation.

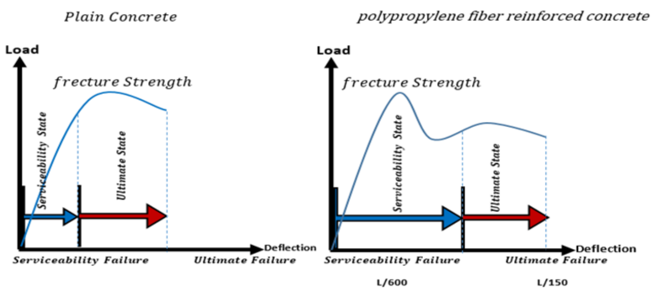

Fig - 1: Variation of Failures in PCC & FRC

This study delivers a complete assessment of various characteristics of polypropylene fibre reinforced concrete including its behaviour, applications and performance of polypropylene fibre reinforced concrete.

II. LITERATURE REVIEW

Review of work done by various researchers discusses the mechanism of fibre-matrix interaction, where various models are used to compute the bonding between the fibres and cement matrix. As the bonding of fibre and the matrix plays a major role in the composite behaviour. Furthermore, this chapter also presents a review of literature relevant to the investigation and tests done for fibre reinforced concrete in general with a prominence of civil engineering application. Fibre reinforced concrete was successfully used in variety of engineering applications, because of its satisfactory and outstanding performance in the industry and construction field. However, most of the engineers and researchers have thought that how and why the fibres perform so successfully. So, to recognize the usage of fibres in concrete, in these last four decades, most of the research was done on mechanical behaviour of fibre reinforced concrete and the fibres itself.

According to M Jayaram (2022) the fresh and hardened Properties are successfully achieved their desired values. The material polypropylene fibre is a good admixture to the reinforced concrete that satisfies all the requirements and it can be used for all constructional purposes.[1]

Rishabh Chaturvedi (2020) The inclusion of polypropylene fibre will also increase the fire resisting capability of the concrete. Due to the small content of fibre addition, the elastic modulus of the concrete does not get affected.[2]

R Ajeeth Kumar (2019) Optimum result of high compressive strength, split tensile strength and flexural strength has been achieved in 1.6% of polypropylene fibre in the concrete and thus that fibre has ability to reduce the cracks, shrinkage in the concrete.[3]

Petr Muller (2019) The deviation of the value of plain concrete strength at elevated temperature is significantly higher in comparison with the deviation of the value of PFRC strength. This is likely caused by highly various pore pressure in the PCC specimens while being tested. In the case of the PFRC, the presence of the polypropylene fibres enabled the formation of a stable environment with low pore pressure in the material microstructure, and thus, the PFRC specimens were exposed to almost identical conditions during their compression tests.[4]

G. Anwar (2016) The comparison between the different values of compressive strength of concrete for (7 and 28 days) shows a decrease gradually due to the addition of polypropylene fibre from 0.00% to 1.5%. There is a decrease in compressive strength as compared with normal plain concrete (without Fibres).[5]

III. METHODOLOGY

All the literatures discussed above gives an idea about the effect of Polypropylene fibre addition on concrete and the importance of addition of fibres. Only limited studies were reported on the fibre reinforced concrete. Under this context there is an importance to conduct study on FRC with Polypropylene Fibre.

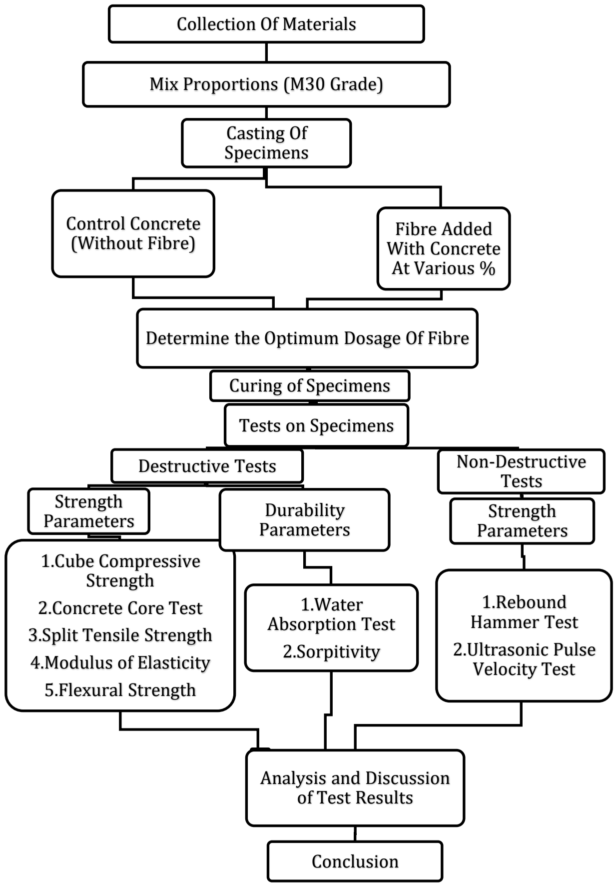

Fig - 2: Methodology of Project

2.1 Objectives of the Work

- To prepare M30 grade conventional concrete mix and to test the specimens for mechanical properties.
- To prepare FRC with Polypropylene fibre at 0.50%,1.00%,1.50%,2.00% and 2.50% of volume of concrete and determine the optimum dosage of polypropylene fibre.
- To prepare FRC by addition of optimum dosage of fibres.
- To evaluate the physical properties for materials used in conventional concrete and fibre reinforced concrete.
- To study the mechanical properties of FRC with polypropylene fibres.

- To compare the Destructive and Non-Destructive tests for conventional concrete mix and optimum fibre concrete mix.
- To study the durability parameters for control mix and optimum fibre concrete mix.

2.2 Scope of the Work

- The study is limited to concrete of grade M30.
- Mix design is done as per IS standards.
- Here Super-plasticizer (SP-430 Conplast) is used.
- Fibre used in this study is polypropylene whose optimum combination is found out.
- This study is carried out to determine the mechanical properties of conventional concrete and fibre reinforced concrete and the findings are analysed using destructive, non-destructive and durability tests.

2.3 Materials used

For making PPFRC we required different materials which are described below.

Fig - 3 : Materials used in Project

Cement:

Zuari brand 53 Grade Ordinary Portland cement (OPC) with a specific gravity of 3.13 was utilized. Cement has a fineness of 6%. The cement's initial and final setting times were 105min and 440min, respectively.

Aggregates:

Good quality river sand was used as a fine aggregate of specific gravity 2.65, fineness modulus of 2.74 and grade of sand in Zone-II. The material whose particles are of size as are retained on I.S Sieve No.480 (4.75mm) is termed as coarse aggregate. The size of coarse aggregate is determined by the nature of the activity. The coarse aggregate utilised in this experiment is crushed angular in shape and is 60% of 20mm size and 40% of 12mm size. The aggregates are dust-free before using them in concrete. The nominal size of aggregate is 20mm, specific gravity of 2.71 and fineness modulus of 7.15 is used.

Water:

In this work tap water of P^H (7.76) is used for both concreting and curing purposes, which is available in Structural Engineering laboratory. The values of all analyzed parameters are within the permissible limits as per IS 456:2000. Hence the water is suitable for casting specimens and curing the specimens.

Admixture:

Conplast (SP-430) of specific gravity (1.12) is used to give high water reductions without loss of workability.

Polypropylene Fibre:

In this project polypropylene fibre used is manufactured by Bajaj Reinforcements with brand name as FibreTuff. FibreTuff is a macro synthetic fibre designed specifically for the reinforcement of concrete and other cementitious mixes. FibreTuff has regular dosage of 3 to 9 kg per cubic meter of concrete. Dosage rate is decided as per structural toughness.

Table - 1: Specifications of Polypropylene Fibre

Specification	**Bajaj Fibre Guard**
Diameter	30-50 Micron
Cut Length	20/12/6mm
Sp. Gravity	0.91
Water Absorption	Nil
Aspect Ratio	400-666.67

2.4 Mix Design

Table - 2: Mix Proportions

Mixture	Control Mix	Mix Ratio
Cement (Kg/m³)	360	1
Coarse Aggregate (Kg/m³)	678	1.88
Fine Aggregate (Kg/m³)	1227	3.41
Water (Kg/m³)	162	0.45
Super Plasticizer (Kg/m³)	0.36	0.001

- Designed as per IS: 10262 – 2009 and IS 456 – 2000.
- Grade of concrete designed -M30
- Max. Water to cement ratio -0.45.

IV. RESULTS AND DISCUSSIONS

This section focuses on the experimental results obtained from each test and analysis of the test results. The experimental tests were carried out to obtain the mechanical properties and behaviour of polymer fibre reinforced concrete. The comparisons of mechanical properties and behaviour include the workability, compressive strength, concrete core test, tensile strength, modulus of elasticity test, flexural strength, durability tests (water absorption and sorpitivity) and Non-destructive tests (Rebound Hammer and Ultrasonic Pulse Velocity test).

3.1 Optimum Dosage of Fibre

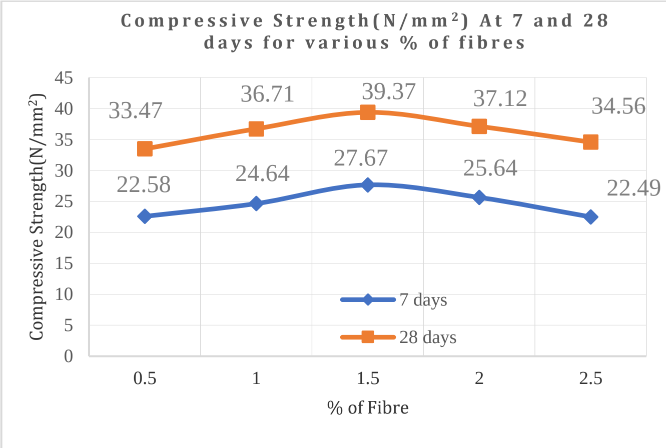

Chart - 1: Compressive Strength at various % for 7 & 28 days

Chart -1 clearly shows that fibre addition @1.50% results in maximum values for 7 and 28 days. We also refer to the standard journals that were previously published as part of this study and determined that @1.50% is the optimum fibre dosage.

3.2 Compressive Strength Test Results

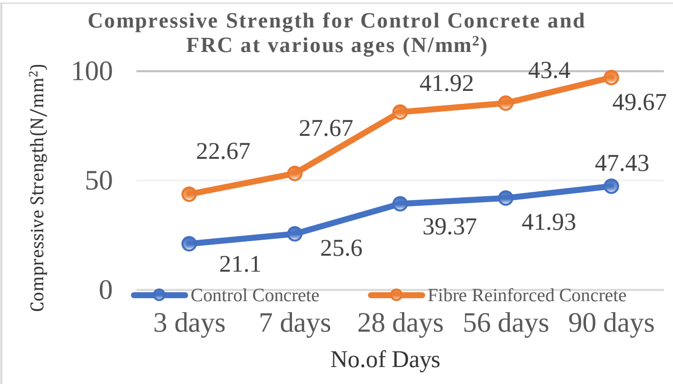

Chart - 2: Compressive Strength for FRC and CC

The compressive strength is increased for fibre reinforced concrete than control concrete, and the percentage increase is 7.440%, 8.080%, 6.477%, 3.506% and 4.723% for 3 days,7days,28 days,56 days and 90 days respectively.

3.3 Concrete Core Test Results

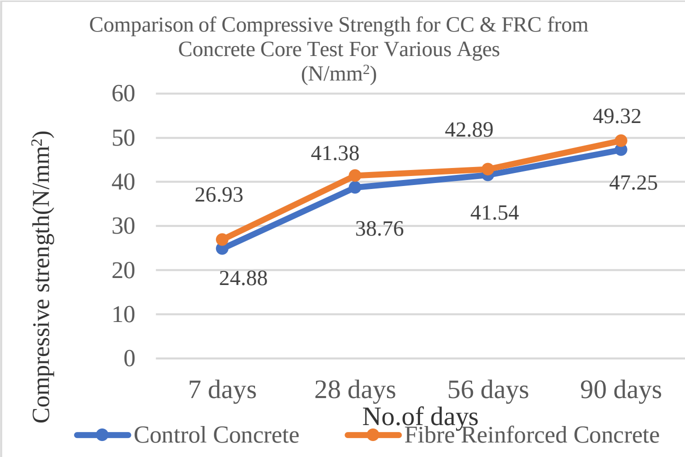

Chart - 3: Compressive Strength for Concrete Core Test

The compressive strength from concrete core test is increased for fibre reinforced concrete than control concrete, and the percentage increase is 8.239%, 6.759%, 3.249% and 4.381% for 7days,28 days,56 days and 90 days respectively.

3.4 Split Tensile Strength Test Results

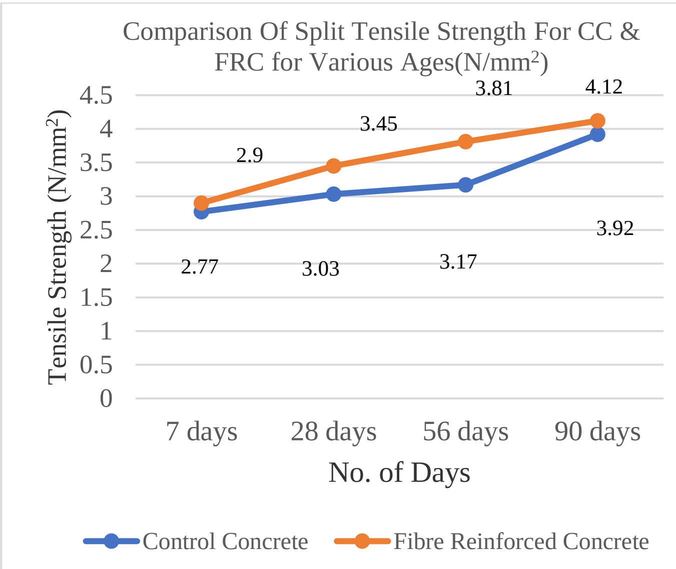

Chart - 4: Split Tensile Strength for CC & FRC

The tensile strength is increased for fibre reinforced concrete than control concrete, and the percentage increase is 4.693%, 13.860%, 20.19%, and 5.10% for 7days,28 days,56 days and 90 days respectively.

3.4 Modulus of Elasticity Test Results

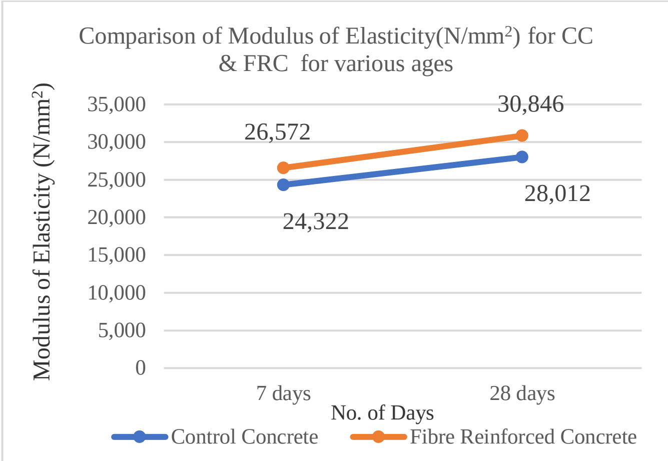

Chart - 5: Modulus of Elasticity for CC & FRC

The Modulus of Elasticity is increased for fibre reinforced concrete than control concrete, and the percentage increase is 9.25% and 10.12% for 7days and 28 days respectively.

3.5 Flexural Strength Test Results

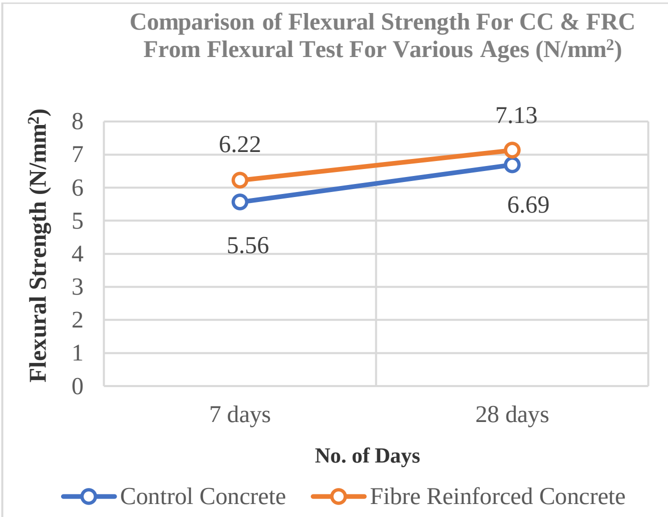

Chart - 6: Flexural Strength for CC & FRC

Flexural strength is higher in fibre reinforced concrete than in control concrete, with percentage increases of 11.87% and 6.577% for 7days and 28 days respectively.

3.6 Rebound Hammer Test Results

The compressive strength of fibre reinforced concrete is higher than that of control concrete, with percentage increases of 4.736%, 8.508%, 4.589%, 5.686% and 3.927% for 3 days,7days,28 days,56 days and 90 days respectively.

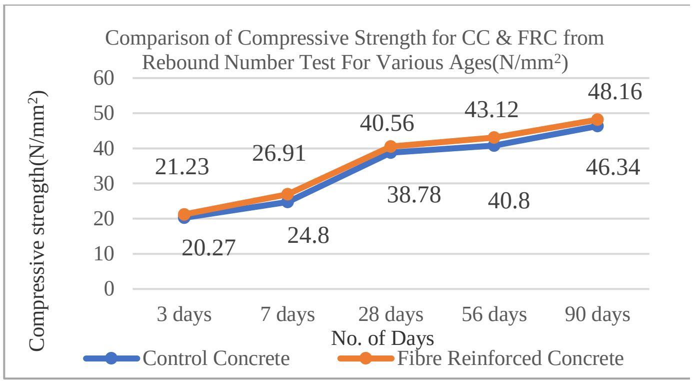

Chart - 7: Compressive Strength from Rebound Number

According to the table below, the quality of concrete falls into the Fair to Good category for Normal concrete and Good to Very Good category for FRC.

Table - 3: Quality of Concrete from Rebound Number

Mean Rebound Number	Concrete Quality
>40	Very Good
30 to 40	Good
20 to 30	Fair
<20	Poor
0	Delaminated

3.7 Ultrasonic Pulse Velocity Test Results

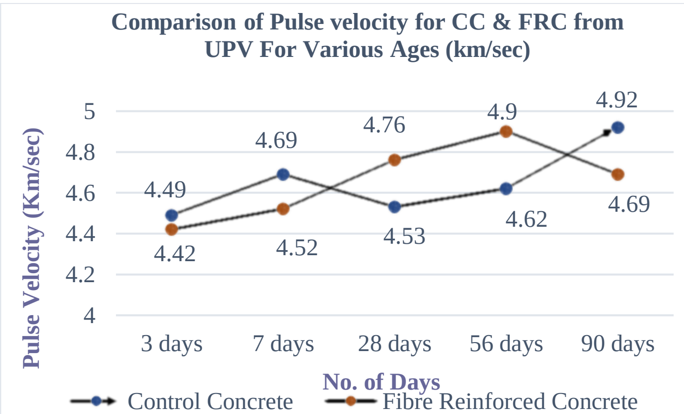

Chart - 8: UPV for CC & FRC

From the Pulse velocity, concrete quality comes under Excellent to Good category for CC and FRC.

Table - 4: Quality of concrete from Pulse Velocity

Pulse velocity	Concrete quality
> 4.5 km/s	Excellent
3.5 – 4.5 km/s	Good
3.0 – 3.5 km/s	Medium
< 3.0 km/s	Doubtful

3.7 Water Absorption Test Results

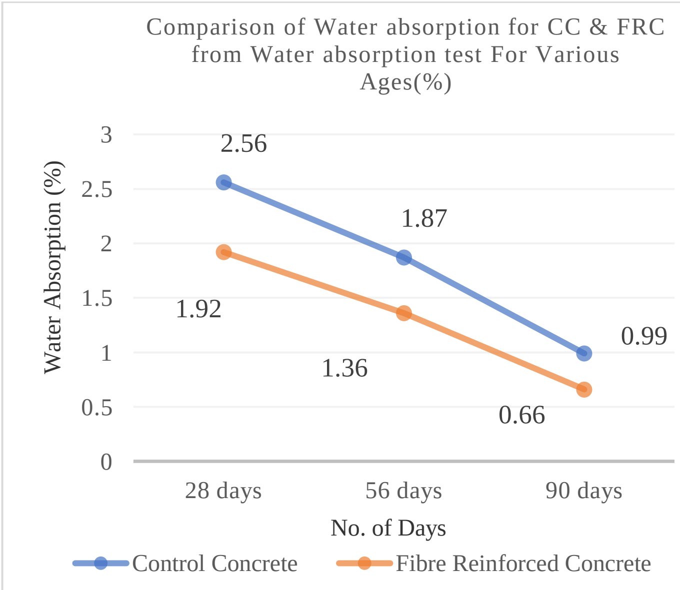

Chart - 9: Water Absorption for CC & FRC

The water absorption is decreased for fibre reinforced concrete than control concrete, and the percentage increase is -25%, -27.27% and -33.33% for 28 days,56 days and 90 days respectively.

As per ASTM C 642 Classification our concrete comes under *Excellent* category.

Table - 5: Classification as per ASTM C 642

Classification	Water Absorption (%)
Excellent	< 5%
Good	5 to 6 %

Normal	6 to 7 %
Marginal	7 to 8 %
Bad	> 8%

3.8 Sorpitity Test Results

From the Sorpitivity results, we have observed that sorpitivity increases with increase in time for both Normal Concrete and FRC and the percentage gain is slightly increases up to certain time interval and became constant.

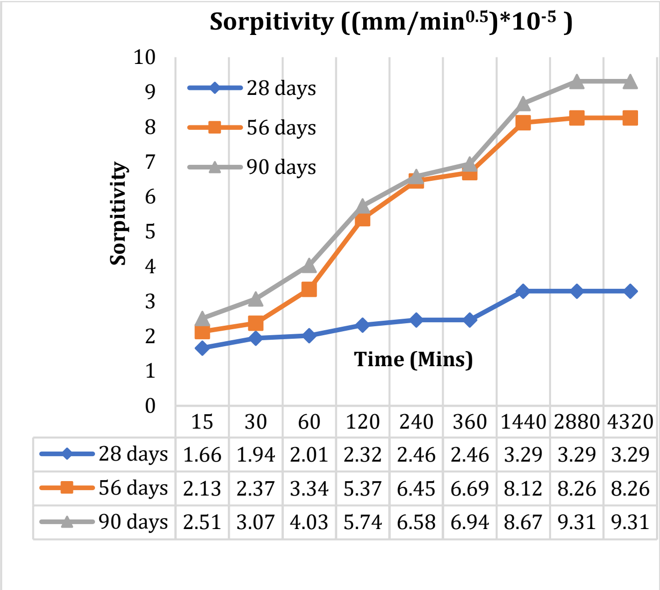

Chart - 10: Sorpitivity for Control Concrete

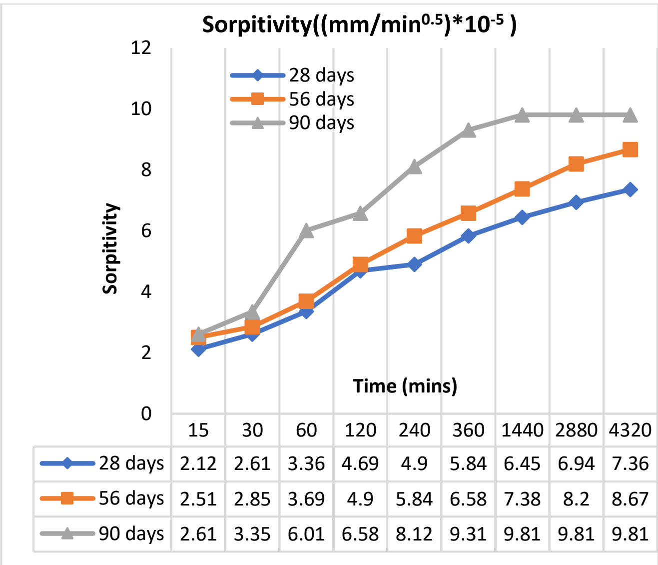

Chart - 11: Sorpitivity for Fibre Reinforced Concrete

3.9 Comparision of Compressive Strength between Destructive and Non-Destructive Tests

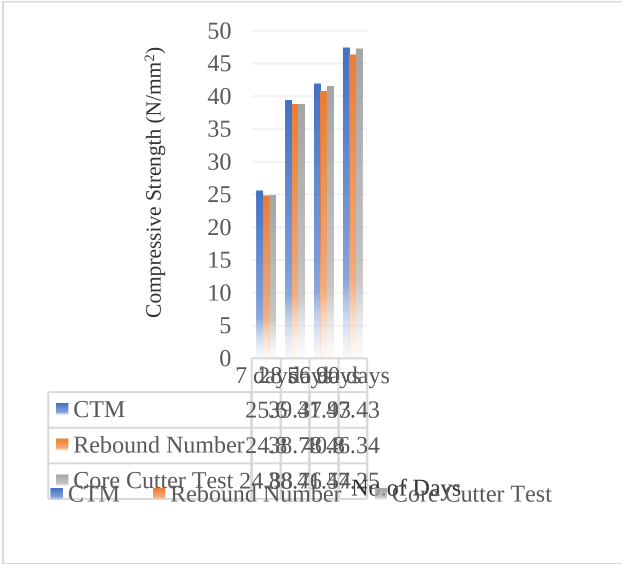

Chart - 12: Comparision of Compressive Strength for CC

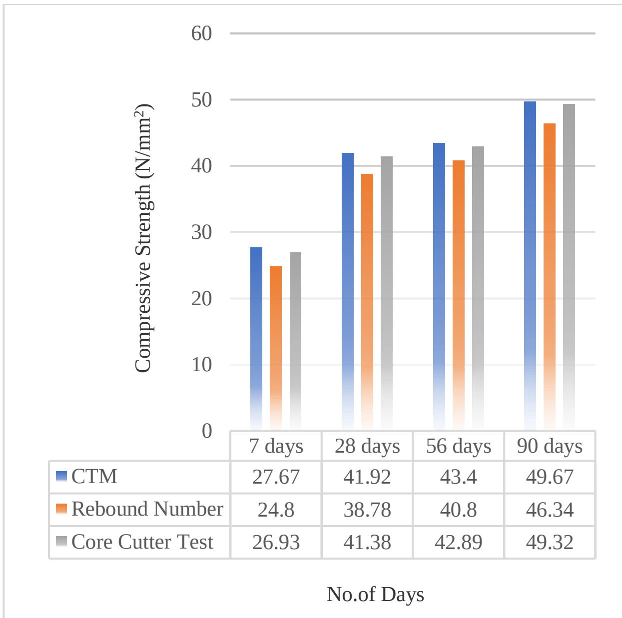

Chart - 13: Comparision of Compressive Strength for FRC

V. CONCLUSIONS

From the tests that I have performed I came to the following conclusions:

1. For M30 Grade concrete the compressive strength achieved is 39.37 N/mm².
2. With varying dosage of Polypropylene Fibre ratio from 0.5% to 2.50% in M30 grade concrete with

maximum compressive strengths of 27.67 N/mm² and 39.37 N/mm² after 7 days and 28 days curing is obtained at 1.5% dosage of fibre. This is considered as optimum mix.

3. The Compressive Strength is increased for Polypropylene Fibre reinforced concrete with 1.5% dose outperforms control concrete by 7.440% ,8.080% ,6.477%, 3.506% and 4.723% after 3 days,7days,28 days,56 days and 90 days respectively.
4. The Compressive strength determined by the Concrete Core test of Polypropylene Fibre reinforced concrete with 1.5% dosage is higher than control concrete with percentage increases of 8.239%, 6.759%, 3.249% and 4.381% for 7days,28 days,56 days and 90 days respectively.
5. The Percentage improvement in Split Tensile Strength for Polypropylene Fibre reinforced concrete with 1.5% dosage is greater than for control concrete with percentage increases of 4.693%, 13.860%, 20.19%, and 5.10% for 7days,28 days,56 days and 90 days respectively.
6. The Modulus of Elasticity is higher in Polypropylene Fibre reinforced concrete with a 1.5% dosage than in control concrete, with percentage rise of 9.25% and 10.12% for 7days and 28 days respectively.
7. The Flexural strength is increased for Polypropylene Fibre reinforced concrete with 1.5% dosage than control concrete, and the percentage increase is 11.87% for 7 days and 6.577% for 28 days respectively.
8. When tested with a Rebound Hammer, the quality of Concrete falls into the Fair to Good category for Normal concrete and Good to Very Good category for FRC.
9. From the Pulse velocity, concrete quality comes under Excellent to Good category for Normal Concrete and 1.5% Polypropylene FRC.
10. From ASTM C 642 Classification for Water Absorption, the concrete comes under Excellent category for Normal Concrete and 1.5% Polypropylene FRC.
11. From the Sorpitivity results, we have observed that sorpitivity increases with increase in time for both Normal Concrete and FRC and the percentage gain is slightly increases up to certain time interval and became constant.

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