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AN EXPERIMENTAL INVESTIGATION ON STRENGTH PROPERTIES OF POLYPROPYLENE FIBERS

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ABSTRACT

Concrete made with Portland cement has certain characteristics: it is relatively strong in compression but weak in tension and tends to be brittle. These two weaknesses have limited its use. Another fundamental weakness of concrete is that cracks start to form as soon as concrete is placed and before it has properly hardened. These cracks are major cause of weakness in concrete particularly in large on site applications leading to subsequent fracture and failure and general lack of durability. Plain, unreinforced concrete is a brittle material, with a low tensile strength and a low strain capacity. The role of randomly distributes discontinuous fibers is to bridge across the cracks that develop, provides some post – cracking "ductility". Fiber reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibers. In this experimental investigation, an attempt has made to find out strength related tests like Compressive Strength, Split Tensile Strength, Flexural Strength using PolyPropylene Fibers with to volume fraction of 0.5% and 1% and for aspect ratio and considered for M50 Grade of concrete. A total No.of 40 specimens were casted, cured and tested. The real contribution of the fibers is to increase the toughness of the concrete, under any type of loading and permit the fiber reinforced concrete to carry significant stress over a relatively large strain capacity in the post cracking stage. The results of the tests showed that the strength properties are enhanced due to addition of fibers.

KEYWORDS: Aspect Ratio, Fiber Reinforced Concrete, PolyPropylene Fibers, Compressive Strength, Split Tensile Strength, Flexural Strength, Volume Fraction).

1. INTRODUCTION

1.1 General

Concrete made with Portland cement has certain characteristics: it is relatively strong in compression but weak in tension and tends to be brittle. These two weaknesses have limited its use. Another fundamental weakness of concrete is that cracks start to form as soon as concrete is placed and before it has properly hardened. These cracks are major cause of weakness in concrete particularly in large on site applications leading to subsequent fracture and failure and general lack of durability. The weakness in tension can be overcome by the use of conventional rod reinforcement and to some extent by the inclusion of a sufficient volume of certain fibers. Concrete is used extensively as a construction material because of its versatility. It is good in compression, but weak in tension. This drawback can be overcome by providing steel in tension zone. This technique called **"**REINFORCED CEMENT CONCRETE**"**, improves the load carrying capacity of concrete members. At the same time durability of concrete is also important. Durability is mainly affected due to cracks developed by creep and shrinkage. In an attempt to control the so formed cracks has led to the development of FIBRE REINCORCED CONCRETE (FRC), obtained by dispersing in concrete, very small sized reinforcement called fibres. The small closely spaced fibres so used act like crack arresters, substantially improve the static and dynamic strengths.

Polypropylene fibers reduce damage from freeze-thaw cycles and reduce the chances of explosion if there is a fire. Steel Fibers transforms the brittle to ductile type of material would increase substantially the energy absorption characteristics of the Fiber composite and its ability to with stand repeatedly applied, shock or impact loading

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1.2 Technology For Producing FRC

FRC in general, can be produced using conventional concrete practice, though there are obviously some important differences. The basic problem is to introduce a sufficient volume of uniformly dispersed to achieve the desired improvements in mechanical behaviour, while retaining sufficient workability in the fresh mix to permit proper mixing, placing and finishing. The performance of the hardened concrete is enhanced more by fibers with a higher aspect ratio, since this improves the fiber-matrix bond. On the other hand, a high aspect ratio adversely affects the workability of the fresh mix. In general, the problems of both workability and uniform distribution increase with increasing fiber length and volume. In view of this, care must be taken in the mixing procedures. Most commonly, when using a transit mix truck or revolving drum mixer, the fibers should be added last to the wet concrete. The concrete alone, typically, should have a slump of 50-75 mm greater than the desired slump of the FRC. Of course, the fibers should be added free of clumps, usually by first passing them through an appropriate screen. Once the fibres are all in the mixer, about 30-40 revolutions at mixing speed should properly disperse the fibers. Alternatively, the fibers may be added to the fine aggregate on a conveyor belt during the addition of aggregate to the concrete mix. FRC can be placed adequately using normal concrete equipment. FRC has also got wide potential for application in situation where toughness is important in structures requiring resistance to thermal shocks such as refractory linings, explosive stores. Pads for vertical take off and air craft tank turning pads.

1.3 Scope of Present Investigation

The adequate and economic application of any material to field problems demands extensive knowledge of its performance under different loads. An extensive application of FRC can be seen in both industrial structures and civil engineering fields. Therefore, the thorough knowledge of the properties of FRC is quite essential. A lot of work has been carried out on FRC using low strength concrete like M20, M30,M40 etc. A little work has been done on FRC high strength concrete. Here in this work an attempt has been made to bring out certain characteristics of high strength FRC using M50, grades of concrete. The characteristics studied are compressive strength (cube strength and cylinder strength), flexural strength, modulus of elasticity, split tensile strength.

1.4 Synopsis

Fiber reinforcement is widely used as the main and unique reinforcing for industrial concrete floor slabs, shot Crete and prefabricated concrete products. It is also considered for structural purposes in the reinforcement of slabs on piles, tunnel segments, concrete cellars, foundation slabs and shear reinforcement in prestressed elements. Ensuring the quality and performance of the fibers and ultimately the FRC is critical and the challenge faced by engineers involved in designing this project is to unambiguously specify the performance required by the FRC so as to achieve in the finished structure the performance that was assumed in the design

2. LITERATURE REVIEW

2.1 General

It is now well established that one of the important properties of fiber reinforced concrete (FRC) is its superior resistance to cracking and crack propagation. As a result of this ability to arrest cracks, fiber composites possess increased extensibility and tensile strength, both at first crack and at ultimate, particular under flexural loading; and the fibers are able to hold the matrix together even after extensive cracking. The net result of all these is to impart to the fiber composite pronounced post-cracking ductility which is unheard of in ordinary concrete. The transformation from a brittle to a ductile type of material would increase substantially the energy absorption characteristics of the fiber composite and its ability to withstand repeatedly applied, shock or impact loading.

. A brief review of the important investigations concerned with FRC is presented in the following articles

1. Shah,S.P., and Rangan,B.v., **"**Fibre Reinforced Concrete Properties,**"** ACI journal, Tital No.68-14,February 1971,pp.126-135.
2. Narayanan,R., and Kareem-Palanjian, A.S., **"** Effect of Fibre addition on concrete Strengths,**"** Indian Concrete Journal, Apr-1984,pp.100-103.
3. Gopalratnam,V.S.: Shah,S.P.: Batson, G.B: Criswell,M.E.,; Ramakrishna,V., and Wecharatanna,M., **"**France Toughness of Fibre Reinforced Concrete.**"** Materials Journal, Title No. 88-M41, V.88, No.4, July-August. 1991,pp.393-353.

2.2 Literature Survey on Concrete

Concrete is the most widely used human-made product in the World. In contrast to its internal complexity, versatility, durability, and economy, it has been the most extensively used construction material with a

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production over six billion tons every year. Concrete is used to make pavements, building structures, foundations, roads, overpasses, parking structures, brick/block walls and bases for gates, fences and poles. Concrete is primarily a proportionate mixture of aggregate, cement, and water. The cement and water will form a paste that hardens as a result of a chemical reaction between the cement and water. This paste acts as glue, binding the aggregates (sand and gravel or crushed stone) into a solid rock-like mass. The quality of the paste and the aggregates dictate the engineering properties of this construction material. During hydration and hardening, concrete will develop certain physical and chemical properties, among others, mechanical strength, low permeability and chemical and volume stability. Concrete has relatively high compressive strength, but significantly lower tensile strength (about 10% of the compressive strength).

2.2.1 High Performance Concrete

High Performance Concrete is a special type of concrete meeting typical combination of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practices. It possesses high-workability, high-strength, and high durability. The High Performance Concrete ensures long-time durability in structures when exposed to aggressive environments. Durability of concrete is its ability to resist weathering action, chemical attack, abrasion and all other deterioration processes. Weathering includes environmental effects such as exposure to cycles of wetting and drying, heating and cooling, as also freezing and thawing. Chemical deterioration process includes acid attack, expansive chemical attack due to moisture and chloride ingres

2.2.2 High Strength Concrete

From the general principles behind the design of high-strength concrete mixtures, it is apparent that high strengths are made possible by reducing porosity, in homogeneity, and micro cracks in the hydrated cement paste and the transition zone. The utilization of fine pozzolanic materials in high strength concrete leads to a reduction of the size of the crystalline compounds, particularly, calcium hydroxide. Consequently, there is a reduction of the thickness of the interfacial transition zone in high-strength concrete. The densification of the interfacial transition zone allows for efficient load transfer between the cement mortar and the coarse aggregate, contributing to the strength of the concrete. For very high-strength concrete where the matrix is extremely dense, a weak aggregate may become the weak link in concrete strength.

2.3 Definition Of FRC

Fiber reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibers. ACI committee 544(1,2) Now, why would we wish to add such fibers to concrete? Plain, unreinforced concrete is a brittle material, with a low tensile strength and a low strain capacity. The role of randomly distributes discontinuous fibers is to bridge across the cracks that develop provides some post-cracking “ductility”. If the fibers are sufficiently strong, sufficiently bonded to material, and permit the FRC to carry significant stresses over a relatively large strain capacity in the post-cracking stage

2.4 History of FRC

Polypropylene fibers were first suggested as an admixture to concrete in 1965 for the construction of blast resistant buildings for the US Corps of Engineers. The fiber has subsequently been improved further and at present it is used either as short discontinuous fibrillated material for production of fiber reinforced concrete or a continuous mat for production of thin sheet components. Since then the use of these fibers has increased tremendously in construction of structures because addition of fibers in concrete improves the toughness, flexural strength, tensile strength and impact strength as well as failure mode of concrete. Polypropylene twine is cheap, abundantly available, and like all manmade fibers of a consistent quality.The history of modern glass fibers really only stretches back to the 1930s.Mass production of glass stands was accidentally discovered in 1932. By a researcher at the owenslllions, who accidentally directed a jet of compressed air at a stream of molten glass and produced fibers

2.5 Applications OF FRC

The applications of FRC will depend on the ingenuity of designer and builder in taking advantage of the static and dynamic tensile strength, energy absorption characteristics and fatigue strength.

1. For overlays and over slabbing for roads, pavements of air fields, bridge decks industrial and other flooring particularly those subjected to wear and tear and chemical attack.

2. In blast resistant structures, foundations for machinery where shock and vibrating loads are evident, for refractories where thermal gradient exists, in precast thin elements such as thin folded plates and shells, wall panels, precast roofing and flooring elements, manhole covers, car park deck slab etc.
3. As a biological shielding of atomic rectors and also to water front marine structures such as jetty armour, breakwater caissons etc. which have to resist deterioration at air water surface and impact loading.
4. In under water storage structures, water front wave house floors and wharf decking.
5. Used for repairs and new constructions on major dams and other hydraulic structures to provide resistance to cavitations impact and severe erosion.
6. Used in mining, tunneling and rock slope stabilization by gunite or shortcrete process.

2.6 Structural Use of FRC

As recommended by ACI Committee 544, 'When used in structural applications, steel fiber reinforced concrete should only be used in a supplementary role to inhibit cracking, to improve resistance to impact or dynamic loading, and to resist material disintegration in structural members where flexural or tensile loads will occur…..the reinforcing steel must be +capable of supporting the total tensile load'. Thus, while there is no. of techniques for predicting the strength of beams reinforced only with steel fibers, there are no predictive equations for large SFRC beams, since these would be expected to contain conventional reinforcing bars as well. An extensive guide to design considerations for SFRC has recently been published by the American concrete institute. In this section, the use of SFRC will be discussed primarily in structural members which also contains conventional reinforcements

2.7 Objectuves

The main objective is to study the following properties of fiber reinforced concrete for the aspect ratio of 100 with different volume fraction of fibers as 0.5% and 1%. **1.**Develop suitable mix design **2.**To study the compressive strength **3.**To study the split tensile strength **4.**To study the flexural strength

3. FIBER REINFORCED COCNRETE (Polypropylene Fibers)

3.1 General

FIBRE REINCORCED CONCRETE (FRC), obtained by dispersing in concrete, very small sized reinforcement called fibres. The small closely spaced fibres so used act like crack arresters, substantially improve the static and dynamic strengths. That is the properties like toughness, impact resistance and stiffness under different loading conditions are improved. Naturally the properties of fibres influence the properties of FRC composites. When the fibre reinforcement is in the form of short discrete fibres, they act effectively as rigid inclusions in the concrete matrix. Physically, they have thus the same order of magnitude as aggregate inclusions; steel fibre reinforcement cannot therefore be regarded as a direct replacement of longitudinal reinforcement in reinforced and prestressed structural members. However, because of the inherent material properties of fibre concrete, the presence of fibres in the body of the concrete or the provision of a tensile skin of fibre concrete can be expected to improve the resistance of conventionally reinforced structural members to cracking, deflection and other serviceability conditions.

3.2 Basic Concepts of FRC

All cement based materials are essentially anisotropic and heterogeneous in nature. These contain micro cracks and interfacial discontinuities which are root causes for the propagation of cracks and result in low tensile strength. Such problems caused the evolution of the FRC. The incorporation of short fibres in a relatively brittle cement matrix transforms uncontrolled tensile crack propagation into a slow controlled process. These fibres when provided in adequate proportion, the tensile strains in the concrete can be raised to several folds before failure.

3.3 Effect of Fibers in Concrete

Fibers are usually used in concrete to control plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion and shatter resistance in concrete. Generally fibers do not increase the flexural strength of concrete, so it can not replace moment resisting or structural steel reinforcement. Some fibers reduce the strength of concrete. Some recent research indicated that using fibers in concrete has limited effect on the impact resistance of concrete materials. This finding is very important since traditionally people think the ductility increases when concrete reinforced with fibers. The results also pointed out that the micro fibers is better in impact resistance compared with the longer fibers

3.4 Classification of Fibers

The natural fibres like jute, coir, horse hair etc. have got low tensile strength and low elastic modulus. By addition of such fibres static strengths are not improved, while the dynamic properties are improved.

The Artificial fibres can be of both low or high tensile strength. For ex. Nylon, Polypropylene, polyethylene have got low tensile strength. Steel, Glass, Carbon have got high strength. The earlier three fibres are suitable for the mains structures as they are lease affected by the corrosion

3.5 Types of Fibers

3.5.1 Polypropylene fibres: The polypropylene fiber-reinforced concrete (PFRC) has provided a technical basis for improving these deficiencies. This paper presents an overview of the effect of polypropylene (PP) fibers on various properties of concrete in fresh and hardened state such as compressive strength, tensile strength, flexural strength, workability, bond strength, fracture properties, creep strain, impact and chloride penetration

3.5.2 Steel fibres: The use of steel fibers has led to the improvement of the concrete's mechanical properties such as material toughness in tension and also durability. Many types of steel fibers are used for concrete reinforcement. Round fibers are the most common type and their diameter ranges from 0.25 to 0.75 mm. Rectangular steel fibers are usually 0.25 mm thick, although 0.3 to 0.5 mm wires have been used in India. Deformed fibers in the form of a bundle are also used. The main advantage of deformed fibers is their ability to distribute uniformly within the matrix.

3.5.3 Glass fibres: The Glass fiber-reinforced concrete uses fiber glass, much like you would find in fiber glass insulation, to reinforce the concrete. The glass fiber helps insulate the concrete in addition to making it stronger. Glass fiber also helps prevent the concrete from cracking over time due to mechanical or thermal stress. In addition, the glass fiber does not interfere with radio signals like the steel fiber reinforcement does.

3.5.4 Nylon fibres:

Synthetic fiber-reinforced concrete uses plastic and nylon fibers to improve the concrete's strength. In addition, the synthetic fibers have a number of benefits over the other fibers. While they are not as strong as steel, they do help improve the cement pumpability by keeping it from sticking in the pipes. The synthetic fibers do not expand in heat or contract in the cold which helps prevent cracking. Finally, synthetic fibers help keep the concrete from spalling during impacts or fires.

3.6 Polypropylene Fibers

The capability of durable structure to resist weathering action, chemical attack, abrasion and other degradation processes during its service life with the minimal maintenance is equally important as the capacity of a structure to resist the loads applied on it. Although concrete offers many advantages regarding mechanical characteristics and economic aspects of the construction polypropylene fiber-reinforced concrete (PFRC) has provided a technical basis for improving these deficiencies. This paper presents an overview of the effect of polypropylene (PP) fibers on various properties of concrete in fresh and hardened state such as compressive strength, tensile strength, flexural strength, workability, bond strength, fracture properties, creep strain, impact and chloride penetration

Figure No-3.8.1 Polypropylene fibers

Polypropylene fiber is added to concrete during batching. Thousands of individual fibers are then evenly dispersed throughout the concrete during the mixing process creating a matrix-like structure. The performance of fibers depends on both the dosage (kg/m3) and the fibers parameters (tensile strengths, length, diameter and anchorage). A key factor for quality fiber is the relationship between the length and diameter of the fibers. The higher l/d ratio, the better the performance.

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3.6.1 Benefits of Polypropylene Fibers

- → Improves ductility, compressive, flexural and tensile strength
- → Reduces water permeability
- → Improves homogeneity of concrete by reducing segregation of aggregates
- → Improves durability of concrete
- → Replaces or reduces "non-structural steel" in floors, roads and Pavement

3.6.2 Uses of Polypropylene Fibers

- → Increases strength of mortar
- → Used in concretes for tunnels, bridge decks
- → Used for precast concrete blocks
- → Used in pavements and in runways
- → Makes wall surfaces cohesive and less porous

4. MATERIALS

4.1 General

In the present investigation, locally available materials have been used as ingredients for the preparation of concrete specimens. The concrete mixes are designed for strengths 50 N/mm2 as per IS:10262-1982

4.2 Material Selection

The results of various physical tests are reported in methodology for ordinary Portland cement of grade 53 is used in the preparation af al the specimens. The fact that this cement confirms to specifications of IS:12269-1987 standards has been checked as per the results of physical tests recommended by IS:4031-1988. The locally available river sand belonging to zone II of IS:383-1963 has been used as the fine aggregate. For coarse aggregate, 10 mm and downsized granite metal of angular shape is utilized. Keeping in the view the restrictions on the size of the coarse aggregate as recommended in the literature. Ordinary portable tap water is used in the preparation of the concrete. The round type Human Hair fibers wire cut to required size is used as fibers.

4.3 Ingredients of Concrete

Concrete is used extensively as a construction material because of its versatility. It is good in compression, but weak in tension. This drawback can be overcome by providing steel in tension zone. This technique called **"**REINFORCED CEMENT CONCRETE**"**, improves the load carrying capacity of concrete members. At the same time durability of concrete is also important. Durability is mainly affected due to cracks developed by creep and shrinkage. This can be avoided by using certain chemical admixtures. But once a crack develops in the member there are no barriers to stop the propagation of such cracks. In RCC it leads the corrosion of the reinforcement slowly and finally it results in the failure of the structure

4.3.1 Cement

Cements may be defined as adhesive substances capable of uniting fragments or masses of solid mater to a compact whole. Portland cement was invented in 1824 by an English mason, Joseph Aspin, who named his product Portland cement because it produced a concrete that was of the same colour as natural stone on the Isle of Portland in the English Channel. Raw materials for manufacturing cement consist of basically calcareous and siliceous (generally argillaceous) material. The mixture is heated to a high temperature within a rotating kiln to produce a complex group of chemicals, collectively called cement clinker. Cement is distinct from the ancient cement.

4.3.2 Fine and Coarse Aggregates

The problem is more complicated when the fibres are introduced into a concrete rather than a mortar matrix because they are separated not by a fine grained material which can move easily between them, which may lead to bunching of fibres.The uniform fibre distribution is more difficult to achieve as the aggregate size increases from 5mm to 10 mm to 20mm. In a normal concrete mix the particle finer than 5 mm occupy about 54% of the volume

4.3.2.1 Fine Aggregates

River sand passing through 4.75 mm sieve and conforming to grading zone II of IS: 383-1970 was used as the fine aggregate. Normal river sands are suitable for high strength concrete. Both crushed and rounded sands can be used. Siliceous and calcareous sands can be used for production of HSC

4.3.2.2 Coarse Aggregates

Crushed granite stone with a maximum size of 20 mm was used as the coarse aggregate. The properties of aggregates used

4.3.3 Polypropylene Fibers

Polypropylene Fibers with 0.025 mean diameter (Neglazable)and Length of 25 mm was used at a volume fraction of 0%, 0.5% and 1%.of its weight

4.3.4 Water

The requirements of water used for mixing and curing shall conform to the requirements given in IS: 456-2000. However use of sea water is prohibited. **Water Cement Ratio:**Experience has shown that for a satisfactory for fibre concrete it should contain a mortar volume of above 20% consisting of particles between 5mm to 10mm.(6). The strength of FRC achieved will be maximum when it is cast without any segregation at the maximum water cement ratio. It is found that FRC cast under good control will achieve its maximum strength at water cement ratio around 0.3 to 0.35. But due to the problem of balling at low water cement ratio it is advised to use either increased water cement ratio.

5. METHODOLOGY

5.1 General

This chapter describes the materials used, the preparation of the test specimens and the test procedures. They are listed down in this section.

5.2 Materials

The materials used in this study were cement, sand, aggregates (both fine and coarse) and water. The description of each of the material is described in the following sections.

5.2.1 Cement

Cement used in this study was KCP brand Ordinary Portland Cement of grade 53. The cement was kept in an airtight container and stored in the humidity controlled room to prevent cement from being exposed to moisture. and various tests were conducted as per codal provisions

5.2.1.1 Initial and Final Setting Time

We need to calculate the initial and final setting time as per IS: 4031 (Part 5) – 1988. To do so we need Vicar apparatus conforming to IS: 5513 – 1976, Balance, Gauging trowel conforming to IS: 10086 – 1982

Procedure to determine initial and final setting time of cement

- Take 500gms of Cement sample and gauging it with 0.85 times the water required to produce a Cement paste of standard consistency.
- Start a stop-watch, the moment water is added to the cement.
- Fill the Vicar mould completely with the cement paste gauged as above, the mould resting on a non-porous plate and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared in the mould is the test block.
- The temperature of water and that of the test room, at the time of gauging shall be within 27ºC ± 2ºC
  - **Initial setting time**

Place the test block under the rod bearing the needle. Lower the needle gently in order to make contact with the surface of the cement paste and release quickly, allowing it to penetrate the test block. Repeat the procedure till the needle fails to pierce the test block to a point 5.0 ± 0.5mm measured from the bottom of the mould. The time period elapsing between the time, water is added to the cement and the time, the needle fails to pierce the test block by 5.0 ± 0.5mm measured from the bottom of the mould, is the initial setting time.

- **Final setting time**

Replace the above needle by the one with by a circular attachment. The cement should be considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression therein, while the attachment fails to do so. The period elapsing between the time, water is added to the cement and the time, the needle makes an impression on the surface of the test block, while the attachment fails to do so, is the final setting time. In other words the paste has attained such hardness that the centre needle does not pierce through the paste more than 0.5 mm

5.2.1.2 Consistency Test

The basic aim is to find out the water content required to produce a cement paste of standard consistency as specified by the IS: 4031 (Part 4) – 1988. The principle is that standard consistency of cement is that consistency at which the Vicar plunger penetrates to a point 5-7mm from the bottom of Vicar mould.

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Apparatus – Vicat apparatus conforming to IS: 5513 – 1976, Balance, Gauging trowel conforming to IS: 10086 – 1982.

Procedure to determine consistency of cement

- Weigh approximately 400g of cement and mix it with a weighed quantity of water. The time of gauging should be between 3 to 5 minutes.
- Fill the Vicar mould with paste and level it with a trowel.
- Lower the plunger gently till it touches the cement surface.
- Release the plunger allowing it to sink into the paste.
- Note the reading on the gauge.
- Repeat the above procedure taking fresh samples of cement and different quantities of water until the reading on the gauge is 5 to 7mm

5.2.1.3 Specific Gravity Test

Specific gravity: It is the ratio between the weight of a given volume of material and weight of an equal volume of water. To determine the specific gravity of Cement, kerosene which does not react with cement is used.

Apparatus: Density bottle (or) Specific gravity bottle, Cement, weighing balance capable of weighing accurately up to 0.1gm, kerosene (free from water).

Table No.- 5.2.1 Test Results of Cement obtained

Characteristics	Test results	IS:12269-1897 specifications
Initial setting time (minutes)	45 minutes	>30 minutes
Final setting time (minutes)	580 minutes	<600 minutes
Consistency	29%	-
Specific gravity	3.15	3.15
Fineness	4.9%	<10%

5.2.2 Fine and Coarse Aggregates

Locally available graded aggregate of maximum size of 20mm is used for our present investigation. Testing of coarse aggregates was done as per IS: 383-1970. The 20mm aggregates used were first sieved through 20mm sieve and then retained on 4.75 mm sieve. They were then washed to remove impurities such as dust, clay particles and organic matters thereby dried to surface at dry condition. The coarse aggregate is also tested for its various properties by using IS: 2386-1963

5.2.2.1 Sieve Analysis (Fine and Coarse Aggregates)

Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates as per IS: 2386 (Part I) – 1963. In this we use different sieves as standardized by the IS code and then pass aggregates through them and thus collect different sized particles left over different sieves.

Apparatus - A set of IS Sieves of sizes – 80mm, 63mm, 50mm, 40mm, 31.5mm, 25mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm,4.75mm, 3.35mm, 2.36mm, 1.18mm, 600µm, 300µm, 150µm and 75µm.,Balance with an accuracy to measure 0.1 percent of the weight of the test sample.

$$\textit{Fineness Modulus} = \frac{\sum(\textit{Cumulative retained percentage})}{100}$$

5.2.2.2 Specific Gravity (Fine and Coarse Aggregates)

Apparatus: Pycnometer bottle (or) Specific gravity bottle, Aggregates (Fine and Coarse), weighing balance capacity not less than 3kg, water.

$$\textit{Specific Gravity} = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}$$

5.2.2.3 Bulk Density Test (Fine and Coarse Aggregates)

Apparatus: Density containers, Weighing balance, Tamping rod of 16mm dia. and 60cm long.

- For F. A- 3lit capacity, 15cm inside dia. and 17cm inside height containers are used.
- For C. A- 15lit capacity, 25cm inside dia. and 30cm inside height containers are used.

$$Bulk\ Density = \frac{(W_2 - W_1)\ in\ kg}{Capcity\ of\ container\ in\ lit}$$

5.2.2.4 Aggregate Crushing Value Test

This test helps to determine the aggregate crushing value of coarse aggregates as per IS: 2386(Part IV)–1963. The apparatus used is cylindrical measure and plunger, Compression testing machine, IS Sieves of sizes – 12.5mm, 10mm and 2.36mm

$$Aggregate\ Crushing\ Value = \frac{B}{A} \times 100\%$$

Table No.- 5.2.2. Properties of Fine Aggregate obtained by Investigation

Property	Test results	IS:2386-1963 Specifications
Fineness modulus	3.4	-
Specific gravity	2.65	2.6-2.8
Bulk density	1475kg/m³(untraded)	-
	1624kg/m³(ridded)	-

Table No.- 5.2.2 Properties of Coarse Aggregate obtained by Investigation

Property	Test results	IS:2386-1963 Specifications
Fineness modulus	7	-
Specific gravity	2.7	2.6-2.8
Crushing value	22%	<30%
Bulk density	1483kg/m³(untraded)	-
	1563kg/m³(ridded)	-

5.2.3 Details of Fibers

1. Fibres used – Polypropylene Fibers 2.Diameter of Polypropylene Fibers -0.025 mm 3. Length of Polypropylene Fibers – 25 mm

Table 5.2.3 Details of steel fibers

Synod	ASPECT RATIO (L/D)	Length of fiber (mm)
1	100	25

5.2.4 Water

Water is needed for the hydration of cement and to provide workability during mixing and for placing. There is not much limitation for water except that the water must not severely contaminated. In this study, normal tap water was used

5.4 Mix Design

Mix design for M50,**Target strength:**In order that not more than the specified portions of test results are likely to fall below the characteristic strength (F_{act}), the concrete mix has to be designed for somewhat higher target average compressive strength (Fa_{ct}).**Fc_k=f_{ck}+ts (s)**,Where Fc_k = target average compressive strength at 28 days. F_{ck} = characteristic compressive strength at 28 days = 50 Map.,S=Standard deviation=5 (from TableNo.- 1 of IS: 10262:2009),t=1.65 (from Table No.- 2 of IS: 10262:2009) **Fc_k = 50+1.65(5) = 58.25 N /mm². Mix design of M50 is = 1: 1.472: 3.043: 0.35**

QUANTITIES OF INGREDIENTS

Mix	Cement(Kg)	Fine aggregate(kg)	Coarse aggregate(kg)	Water (kg)	W/C
M50	422	621	1284	147.6	0.35

MIXES ADOPTED:C1- Nominal concrete, C2-0.5% Polypropylene Fibers added,, C3-1.0% Polypropylene Fibers added,

5.5 Mixing Procedure

The mixing procedures were divided into three stages. In the first stage, all the binders (cement, met kaolin) were weighted accordingly and mixed by hand until all the constituents mixed uniformly. This was to make sure that all the binders were mixed thoroughly to produce a homogenous mix. The second stage involves mixing the

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binders with the aggregates for about 5 minutes. At the final stage, measured water was added into the concrete mix. This step was crucially important to make sure that the water was distributed evenly so that the concrete will have similar water-binder ratios for every specimen. After that, the concrete was then poured into the mould

5.5 Preparation of Test Specimen

Moulds of distinct sizes and shapes (cubes, cylinders and beams) are used to produce the specimens. The concrete was poured into the mould in three layers where each layer was compacted using a tamping rod. The specimens were removed from the moulds after 24 hours and are cured by dipping in moist environment

5.6 Curing

In this study, the specimens were cured by placing in water for about 7,14 and 28 days. The specimens were cured until they were ready to be tested at the designated ages.The test specimens shall be stored on the site at a place free from vibration, under damp matting, sacks or other similar material for 24 hours ± ½ hour from the time of adding the water to the other ingredients. The temperature of the place of storage shall be within the range of 22° to 32°C. After the period of 24 hours, they shall be marked for later identification, removed from the moulds and, unless required for testing within 24 hours, stored in clean water at a temperature of 24° to 30°C until they are transported to the testing laboratory. They shall be sent to the testing laboratory well packed in damp sand, damp sacks, or other suitable No.- material so as to arrive there in a damp condition not less than 24 hours before the time of test. On arrival at the testing laboratory, the specimens shall be stored in water at a temperature of 27° ± 2°C until the time of test. Records of the daily maximum and minimum temperature shall be kept both during the period of the specimens remain on the site and in the laboratory.

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6. EXPERIMENTAL STUDY

In this chapter, The experimental program is designed to understand whether the addition of fibers in high strength concrete and normal strength concrete favours strain hardening and increase of amount of fibers produces identical enhancement of mechanical properties. Different strengths are determined by creating specimens of normal mix ,0.5% and 1.0% of Polypropylene Fibers mixes and subjecting it to loadings until failure.

6.1 Lab Tests on Fresh Cocnrete

Each batch of concrete shall be tested for consistency immediately after mixing, by one of the methods described in IS: 1199-199. The Methods are:**1. Slump Test- Workability** **2. Compaction Factor**

Provided that care is taken to ensure that no water or other material is lost, the concrete used for the consistency tests may be remixed with the remainder of batch before making the test specimens. The period of re-mixing shall be as short as possible yet sufficient to produce a homogeneous mass.

6.1.1 Slump Cone Test -Workbility

Slump test is used to determine the workability of fresh concrete. Slump test as per IS: 1199 – 199 is followed. The apparatus used for doing slump test are Slump cone and tamping rod. **Slump cone dimensions:** Bottom diameter: 20cm,Top diameter : 10cm,Cone height : 30cm

Fig No: 6.1.1 B) SLUMP CONE TEST

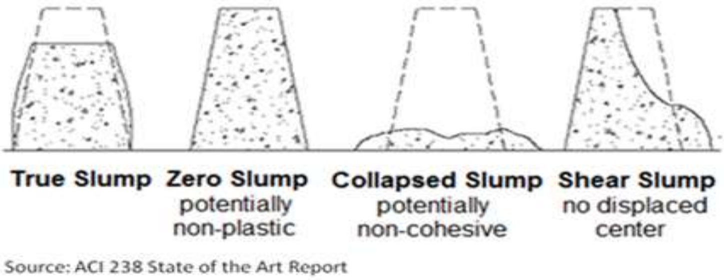

Fig No: 6.1.1 A) SLUMP CONE TEST

S.NO	Concrete Type	Slump Value(mm)
01	C1 – Nominal mix	45
02	C2 – 0.5% Polypropylene Fibers added	44
03	C3 – 1.0% Polypropylene Fibers added	40

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6.1.2 Companion Factor Test

The compacting factor test is designed primarily for use in the laboratory, but it can also be used in the field. The test works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height. The degree of compaction, called the compacting factor is measured by the density ratio.

FIG NO: 6.1.2 COMPACTION FACTOR TEST

Table No.- 6.1.2 Compaction factor Test Results

S.NO	Concrete Type	Partially compacted weight (kg)	Fully compacted weight (kg)	Compacting factor
01	C1 – Nominal mix	17.120	19.710	0.860
02	C2 – 0.5% Polypropylene Fibers added	17.4416	19.820	0.880
03	C3 – 1.0% Polypropylene Fibers added	17.790	19.910	0.890

6.2 Lab Tests on Hardened Concrete

There are two kinds of tests which are done on hardened concrete. These are: Destructive tests., 2.Non-destructive tests

6.2.1 Destructive Tests

In destructive test a sample is made and then destroyed to find out the strength of concrete. The destructive tests conducted on concrete are as follows:**1. Compressive strength test 2. Tensile strength test 3.Flexural strength test** The tests adopted in this study are only the destructive tests. These tests are done by using Universal Testing Machine (UTM).

6.4.1 Compressive Strength Test

According to Indian Standard specifications **(IS : 516-1959)** ,the compression test on cubes of size 150mm X 150 mm X 150 mm were conducted. Compressive test is the most common test conducted on hardened concrete , partly because it is an easy test to perform and partly because most of the desirable characteristics properties of the concrete are qualitatively related to its compressive strength . Metal moulds preferably steel bar 16mm in diameter , 0.6m long and bullet pointed at the lower end serves as a tamping bar. The test cube specimens are made as soon as practicable concrete with neither segregation nor excessive laitance . The concrete is filled in to the moulds in layers approximately 5cm deep , each layer is compared by the tamping rod in 25 strokes. The test specimens are stored in a place free from vibration , in moist air of at least 90% relative humidity and at a temperature of 27°C for 24 hours. After thus period the specimens are marked and removed from the moulds and unless required for test within 24 hours, immediately submerged in clean fresh water or saturated lime solution and kept their until taken out just prior to test. The dried specimens are then tested on compressive testing machine

$$\textit{Compression Strength} = \frac{\textit{Load in N}}{\textit{Area in mm}^2}$$

Note: Minimum three specimens should be tested at each selected age. If the strength of any Specimen varies by more than 1 per cent of average strength, results of such specimen should be rejected. Average of three specimens gives the crushing strength of concrete.

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Fig No: 6.4.1 F) Specimens Under Testing

Table No.- 6.4.1 Test Results of Compressive strength (M50 Grades of concrete at 7,14 and 28 days)

S.No	Type of Concrete	Compressive strength (Mpa)		
Number of days		7 days	14 days	28 days
01	C1 – Nominal mix	50.47	56.29	62.50
02	C2 – 0.5% Polypropylene Fibers added	52.28	61.12	64.38
03	C3 – 1.0% Polypropylene Fibers added	54.07	63.14	65.45

6.4.2 Split Tensile Strength Test

The tensile strength is one of the basic and important properties of the concrete . The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However , the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure As there are many difficulties associated with the direct tension test a, number of indirect methods has been developed to determine the tensile strength In these tests in general a compressive force is applied to a concrete specimen in such a way that the specimen fail s due to tensile stresses developed in the specimen. The tensile stress at which the failure occurs is termed as the tensile strength of concrete.The splitting tests are well known indirect tests used for determining the tensile strength of concrete sometimes referred to as split tensile strength of concrete. The test consist of applying a compressive line load along the opposite generators of a concrete cylinder 15 cm diameter and 30 cm long placed with its axis horizontal between the compressive platens . Due to the compression loadinga fairly uniform tensile stress is developed over nearly 2/3 of the loaded diameter as obtained from an elastic analysis.

$$\textit{Split Tensile Test}, Tsp = \frac{2P}{\pi DL}$$

Fig No:6.4.2 A) Placing Of Concrete In Mould

Fig No : 6.4.2 B) Specimens Under Testing

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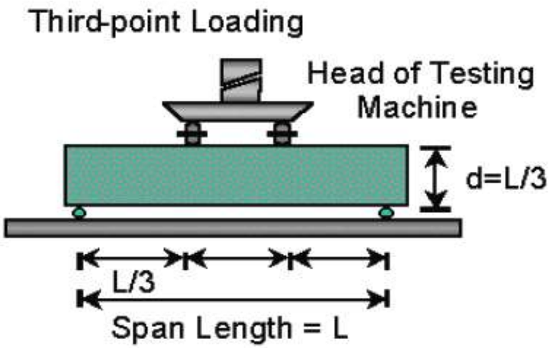
Table No.- 6.4.2 Test Results Of Split Tensile Strength Test
(M50 Grades of concrete at 7,14 and 28 days)

S.No	Type of Concrete	Split Tensile Strength (Mpa)		
Number of days		7 days	14 days	28 days
01	C1 – Nominal mix	2.40	3.150	4.10
02	C2 – 0.5% Polypropylene Fibers added	2.85	3.60	4.55
03	C3 – 1.0% Polypropylene Fibers added	3.35	3.99	5.01

6.4.3 Flexural Strength Test

It is the ability of a beam or slab to resist failure in bending. It is measured by loading un-reinforced 5x5 inch (10 x 10 cm) concrete beams with a span three times the depth (usually 18 in.). The flexural strength is expressed as "Modulus of Rupture" (MR). Flexural MR is about 12 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used. However, the best correlation for specific materials is obtained by laboratory tests for given materials and mix design.



The testing machine used is UTM (universal testing machine). The permissible errors shall be not greater than ± 0. percent of the applied load where a high degree of accuracy is required and not greater than ± 1. percent of the applied load for commercial type of use. The bed of the testing machine shall be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from centre to centre is 50 cm for 1.0 cm specimens or 40 cm for 10.0 cm specimens. The load shall be applied through two similar rollers mounted at the third points of the supporting span that is spaced at 20 or 13.3 cm centre to centre. The load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any tensional stresses or restraints.


Fig No:6.4.3 A) After Placing Of Concrete in mould


Fig No:6.4.3 B) Specimens under testing

$$f_s = \frac{P \times l}{b \times d^2}$$

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Table No.- 5.4.3 Test Results Of Flexural Strength Test

(M50 Grades of concrete at 7,14 and 28 days)

S.No	Type of Concrete	Flexural Strength (Mpa)		
Number of days		7 days	14 days	28 days
01	C1 – Nominal mix	5.60	6.50	7.10
02	C2 – 0.5% Polypropylene Fibers added	5.90	6.99	7.45
03	C3 – 1.0% Polypropylene Fibers added	6.25	7.30	7.94

7. RESULTS AND DISCUSSION

In this chapter, all the strength performance of various mixes containing different percentage of steel fibers will be discussed. All the tests conducted were in accordance with the methods described in this chapter. Different strengths are determined by creating specimens of normal mix , 0.5% and 1.0% Polypropylene Fibers mixes and subjecting it to loadings until failure.

7.1 Compressive Strength Test

In this section, the main concern is to study the compressive strength of concrete containing various percentages of hair fibers in combination. Control specimens are concrete with 100% cement which is compared with the strength performance of concrete containing 0.5% and 1.0% of Polypropylene Fibers .

Cubes with the size of 150mm X 150 mm X 150 mm were tested at the ages of 7,14 and 28 days. The results of the compressive strength test are shown in Table No.- **6.4.1** Where each value from the results of the cubes. From the graph shown in the Fig. **7.2.1.**.specimens are concrete with 100% cement which is compared containing 0.5% and1.0% Polypropylene Fibers, (normal mix , 0.5% and1.0% Polypropylene Fibers) has been observed as an optimal strength than other proportions at 7, 14 and 28 days.

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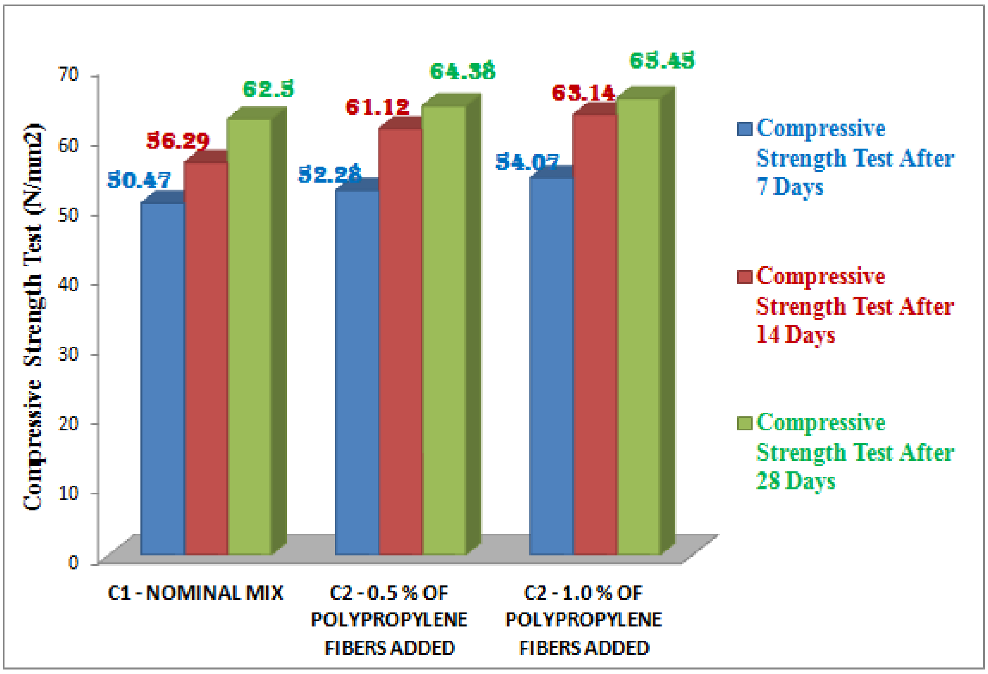

Fig No-7.2.1 Graph Shows Different Compressive strengths of concrete (C1,C2,&C3)

7.2 Split Tensile Strength Test

In this section, the main concern is to study the Split Tensile strength of concrete containing various percentages of steel fibers in combination. Control specimens are concrete with 100% cement which is compared with the strength performance of concrete containing 0.5% and 1.0% of Polypropylene Fibers.

The Cylinder consist of 150 mm diameter and 300mm Long were tested at the ages of 7,14 and 28 days. The results of the Split Tensile strength test are shown in Table No.- **6.4.2** Where each value from the results of the Cylinders.

From the graph shown in the Fig.. **7.2.2** specimens are concrete with 100% cement which is compared containing 0.5% and 1.0% of Polypropylene Fibers, (0.5% and 1.0% of Polypropylene Fibers..) has been observed as an optimal strength than other proportions at 7,14 and 28 days

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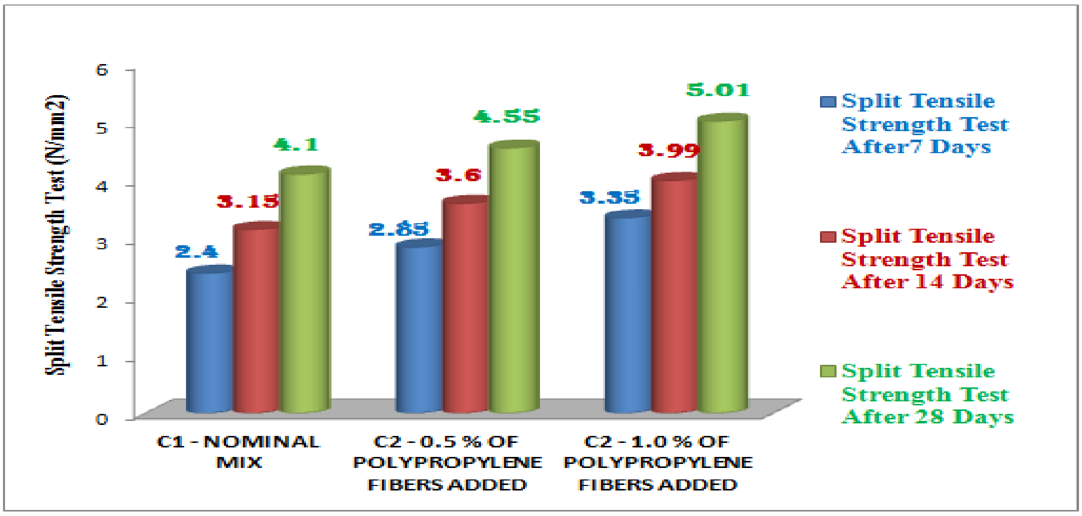

Fig No-7.2.2 Graph Shows Different Split Tensile strength of concrete (C1,C2,&C3)

7.3 Flexural Strength Test

In this section, the main concern is to study the flexural strength test of concrete containing various percentages of steel fibers in combination. Control specimens are concrete with 100% cement which is compared with the strength performance of concrete containing 0.5% and 1.0% of Polypropylene Fibers.

The size of specimen shall be 10 × 10 × 50 cm tested at the ages tested at the ages of 7 ,14 and 28 days. The results of the Split Tensile strength test are shown in Table No.- **6.4.3** Where each value from the results of the beams.

From the graph shown in the Fig **7.2.3** specimens are concrete with 100% cement which is compared containing 0.5% and 1.0% of Polypropylene Fibers., (0.5% and 1.0% of Polypropylene Fibers.) has been observed as an optimal strength than other proportions at 7,14 and 28 days

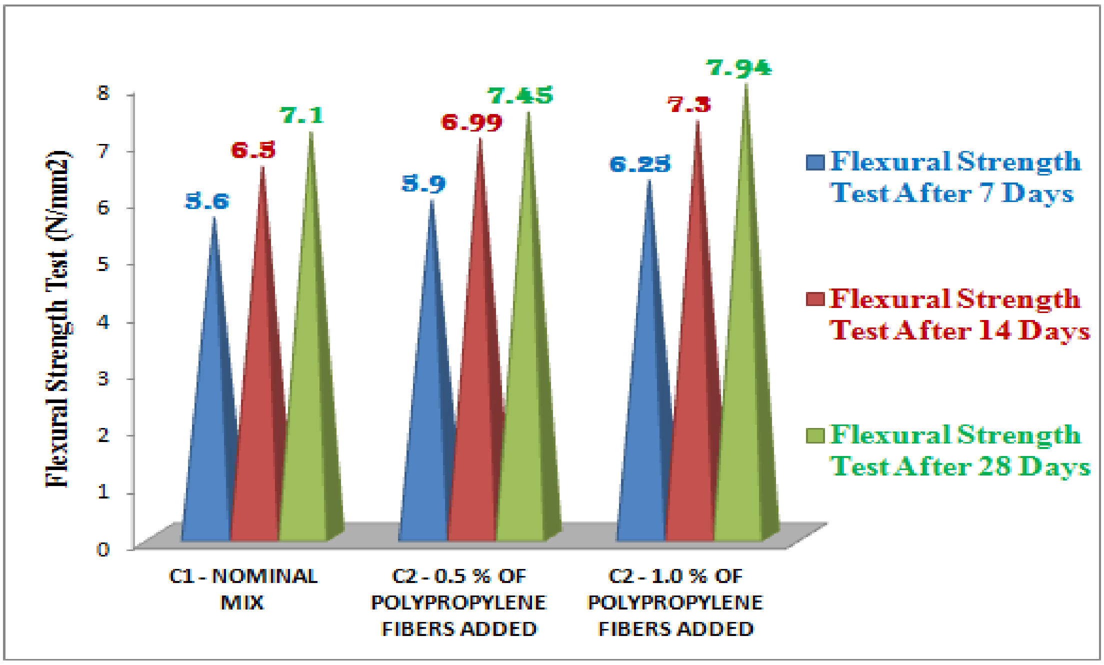

Fig No-7.2.3 Graph Shows Different flexural strengths of concrete (C1,C2,&C3)

8. CONCLUSION & FUTURE SCOPE

Fiber reinforced concrete and high strength concrete are being widely used as important constructional materials due to their excellent properties. An extensive knowledge of the properties is necessary in order to make best and economic use of the material. In this context, present experimental investigation aims to find the different strength characteristics of high strength HFRC. (M50)

8.1 Conclusion

Crack formation and propagation are very much reduced showing that hair fibre reinforced concrete can have various applications in seismic resistant and crack resistant constructions, road pavement constructions etc.

- During our research work we also faced the problem of uniform distribution of Polypropylene Fibers in the concrete. So an efficient method of mixing of of Polypropylene Fibers to the concrete mix is to be found out.
- Applications fiber on other properties of composites such physical, thermal properties and appearances.
- In Compressive strength test results the Concrete mix containing 1.0% Steel fibers (C - 3) as maximum improvement of 26.3% is observed.
- In Split Tensile strength test results the Concrete mix containing 1.0 Steel fibers (C - 3) as maximum improvement of 39.9% is observed
- Flexural strength Test results the concrete mix containing 1.0 Steel fibers (C - 3) as maximum improvement of 84.4% is observed.
- For heavy structures in order to decrease secondary reinforcement steel fibers is very much useful.
- In certain critical places the crack penetration can be arrested by using fibers.
- By using polypropylene in concrete, micro crack can be arrested.
- HFRC have more strength in compression ,tension and Flexural Strength test

8.2 Future Scope

The present work leaves a wide scope for future investigators to explore many other aspects of Polypropylene Fibers reinforced concrete composites. Some recommendations for future areas of research include:

- To increase mechanical strength of these composites for their use in different sectors can be studied.
- Possible use of other fibers/flakes obtained from bio-wastes in the development of new composites.
- The use of animal and human hairs in concrete.
- The use of other Natural and Artificial fibers in concrete. To improve the Strength parameters

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REFERENCES

1. Nguyen Van CHANH " Experimental and theoretical investigation on steel fiber reinforced concrete"
2. Alan Richardson, "A study on compressive strength of concrete with polypropylene fibers"
3. Saied Ahmed*, Imran A Bukhara, Jived Irbil Siddiqui, Shahzad Ali Qureshi " A study on properties of polypropylene fiber reinforced concrete"
4. Roger Leinen " A study on Steel Fiber Reinforced concrete (SFRC) for industrial floors especially slabs without joints and slabs on piles".
5. Brown J. R. and Mathys Z., (1997). ―Reinforcement and matrix effects on the combustion properties of glass reinforced polymer composites‖,Composites Part A: Applied Science and Manufacturing. Vol. 28, Issue 7, pp: 675-681J. D.
6. Cardon A. H., Qin Y. and Van Vossole C., (2000). ―Durability analysis of polymer matrix composites for structural applications‖, Computers & Structures. Vol. 76, Issues 1-3, pp: 35-41
7. Daniel I.M., Anastassopoulos G. and Lee J.-W., (1993). ―The behavior of ceramic matrix fiber composites under longitudinal loading‖, Composites Science and Technology. Vol. 46, Issue 2, pp: 105-113.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

8. Lugovy M., Orlovskaya N., Berroth K. and Kuebler J. , (1999).Macrostructural engineering of ceramic-matrix layered composites‖,Composites Science and Technology, Vol. 59, Issue 9, pp: 1429-1437.
9. Chou T.W., Kelly A. and Okura A., (1985). ―Fiber reinforced metal matrix composites‖, Composites, Vol. 16, Issue 3, pp: 187-206.
10. B.T. Astron, ―Manufacture of polymer composites‖ Chapman and Hall publication (1997).
11. Donnel A. O., Dweib M. A. and Wool R. P., (2004). ―Natural fiber composites with plant oil-based resin composites‖, Composites Science and Technology, Vol. 64, Issue 9, pp: 1135-1145.
12. Maldas D, Kokta B.V. and Daneault C, (1989). Composites of polyvinyl chloride–wood fibers: IV. Effect of the nature of fibers, J Vinyl Addit Technol
13. Dweib M.A., Hu B., Shenton III H.W. and Wool R.P., (2006).Bio-basd composites roof structure manufacturing and processing issues‖,Composite Structures, Vol. 74, Issue 4, pp: 379-388.
14. Schneider J.P., Myers G.E., Clemons C.M. and English B.W., (1995). Biofibres as reinforcing fillers in thermoplastic composites‖, Engineering plastics, Vol. 8, Issue 3, pp: 207-222.
15. alaguru Perumalsamy N., Shah Sarendra P., Fiber reinforced cement composites, McGraw Hill International Editions **(1992)**R. Dilmirghani, M. Ghavami, "Wavelet Vs Fourier Based UWB Systems", 18th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, pp.1-5, Sep. 2007.
16. Johnston Colin D., Fiber reinforced cements and concretes, Advances in concrete technology volume **3**–Gordon and Breach Science publishes **(2001)**
17. Shetty M.S., Concrete Technology,
18. Indian Standard Plain and Reinforced Concrete – Code of Practice IS: 456- 2000
19. Nguyen Van CHANH " Experimental and theoretical investigation on steel fiber reinforced concrete"
20. Alan Richardson, "A study on compressive strength of concrete with polypropylene fibers

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