A
Major Project
On

PERFORMANCE OF FIBER REINFORCED CONCRETE IN ACIDIC ENVIRONMENT

Submitted in partial fulfillment of the requirement
For the award of the Degree of

MASTER OF ENGINEERING
(Structural Engineering)

Submitted by
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(University Roll No. 10308)
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CERTIFICATE

This is to declare that the major project entitled "**Performance of Fiber Reinforced Concrete in Acidic Environment**" is a bonafide record of work done by me for partialy fulfillment of the requirement for the degree of Master of Engineering (Structural Engineering) in Civil Engineering from Delhi College of Engineering, Delhi.

This project has been carried out under the supervision of **Dr.Anil Kumar Sahu, Assistant Professor**, and **Alok Verma, Lecturer,** Delhi College of Engineering, Delhi.

I have not submitted the matter embodied in this report to any other University or Institution for the award of any Degree or Diploma.

Name : **Pravin B. Bhise**
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Certificate:-

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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List of Abbreviations

List Of Abbreviation

IS	Indian standard Code
BIS	Bureau of Indian Standard
FRC	Fiber Reinforcement Concrete
PP	Polypropylene Fiber
Wt.	Weight of Sample
R No.	Rebound Number
UPVT	Ultra sonic pulse velocity Test
Mpa	Mega Pascal (N/M^2)
Gpa	Giga Pascal 10 ^{6}(N/M^2)
Ksi	Killo pound square inch
SFRC	Steel Fiber Reinforced Concrete
P	Normal Cement concrete
P1	Pure cement concrete + 0.5 % volume fraction of polypropylene fiber
P2	Pure cement concrete + 1 % volume fraction of polypropylene fiber
PF	Fly ash Polypropylene fiber concrete
PF1	Fly ash concrete + 0.5 % Polypropylene Fiber
PF2	Fly ash concrete + 1 % Polypropylene Fiber

Abstract

An experimental investigation has been carried out of study the behavior of fiber reinforced concrete in aggressive environment condition. Concrete is very strong in compression but weak in tension. The tensile strength of concrete is less due to widening of micro-cracks existing in concrete subjected to tensile stress. Due to presence of fiber, the micro-cracks are attested. Polypropylene fiber is an inert material and is chemically resistant. So it added to concrete and then immersed in acidic environment to evaluate the properties of fiber reinforced concrete.

The investigation reported in this project, was carried out to study the effects of using Polypropylene fibers in fiber reinforced concrete in acidic environments, The following types of specimen were selected for different type of tests,

- Cubes for normal testing and for non destructive tests such as rebound hammer test , Ultra Sonic Pulse Velocity test etc.
- Cylinder for split tensile strength test
- Prism for modulus of rupture test

A total of 288 numbers of concrete specimens (108 cube of size 150mm x 150mm x150mm, cylinder of size 150mm dia x 300mm height and prizm of size 100 mm x100 mm x 500mm) were cast with and without fiber and were immersed in diluted sulfuric acid of normality 0.2N. These specimen were tested as per relevant codes of practice Bureau of Indian Standard. The p^H of sulfuric acid solution was checked regularly and was maintained constant by addition of concentrated acid from time to time.

The mass, Rebound number, ultrasonic pulse velocity, compressive strength of cubes, split tensile strength of cylinders and modulus of rapture of prisms, made up of ordinary concrete and fiber reinforced concrete increased with time when cured in ordinary water

Losses in all these parameters with time, were observed in both ordinary concrete and FRC, when cured in acidic environments, in comparison to ordinary water. Though, Losses in all the parameters increased with the time of exposure, in case of fiber concrete these were less as compared to that of ordinary concrete at any level of exposure time. Thus the FRC mixes has been proved to be more durable as compared to ordinary concrete under the acidic exposure condition.

Aims and objectives

Aim :-To investigate the effect of acidic environment on Polypropylene fiber concrete with and without fly ash, in comparision to Ordinary concrete

Objective :-

- To determine the basic properties of cement and fly ash and fiber.
- To determine the mechanical properties of Polypropylene fibers.
- To prepare various concrete mixes with and without fly ash and fibers with 0.45 W/C ratio and to test these mixes for workability using cone penetration test, slump test and compaction factor test.
- To examine various properties of these mixes for different curing times in water and sulfuric acid of 0.2 N concentration. Various parameters considered were as follows,
    1) Spilt tensile strength
    2) Compressive strength
    3) Hardness
    4) Flexural strength
- To investigate the non destructive parameters such as mass, Rebound Number, Ultra sonic Pulse Velocity (UPVT) and compressive strength of pure concrete, Fiber Reinforced concrete 7, 28 and 90 days of curing in both the environments.

- To investigate the effect of Polypropylene (PP) fibers on compressive strength and stress-strain relationship of mixes.
- To study the performance of mixes prepared by using fibers in both the environments and to compare their performance with that of other mixes of ordinary concrete.

Chapter *1*

Introduction

As demand for construction in harsh environments increases so does the concern for long service lives of these structures. Typically, concrete structures are designed to perform, even in aggressive environments, for 50 to 100 years with minimal maintenance.

Concrete is susceptible to sulfate attack from either sulfates present in soils, groundwater, sea water, and decaying organic matter. Industrial effluent surrounding a concrete structure pose a major threat to long-term durability of the concrete exposed to these environments. Although concrete materials are being widely used, there are rising concerns about the changes in strength of concrete materials under long-term exposure to adverse chemical environments. Hence, cement concrete response to chemical environments must be investigated. This study focused on the performance of polypropylene fiber on concrete specimen in acidic environments.

Fiber reinforced concrete (FRC) is a composite material consisting of cement, sand, coarse aggregate, water and fibers. In this composite material, short discrete fibers are randomly distributed throughout the concrete mass. The behavioral efficiency of this composite material in normal exposures has been found to be superior to that of ordinary concrete and many other construction materials of equal cost.

Due to this benefit, the use of FRC has steadily increased during the last two decades and its current field of application includes: airport and highway pavements, earthquake-resistant and explosive-resistant structures, mine and tunnel linings, bridge deck overlays, hydraulic structures, rock-slope stabilization.

Extensive research work on FRC has established that addition of various types of fibers such as steel, glass, synthetic, and carbon, in ordinary concrete improves strength, toughness, ductility, post-cracking resistance, etc. Literature survey indicated that very limited study has been conducted on FRC having polypropylene fiber used in acidic environments.

In this investigation, therefore, an attempt has been made to study the performance of polypropylene fiber concrete in acidic Environments. FRC specimen using polypropylene fibers and Normal cement concrete were cast and tested to compare their results. Test results obtained are presented and discussed in this project.

Chapter:-2

Literature Review

The use of discrete fibers in concrete application has been reported in the literature for over 40 years (Romualdi and Batson 1963; Romualdi and Mandel 1964; Parker 1974; Rollings 1981; Vondran 1991; PCA 1991; ACI 1997; AASHTO 2001; The Concrete Society 1994). Mindess et al. (2003) reports that 60 percent of fiber applications are for concrete for which they have been used as secondary reinforcement (Bentur and Mindess-1990). FRC have been successfully designed and constructed with also some premature failures as reported in the literature. Overall, the failures of FRC were related to insufficient thickness design especially for overlays and/or the use of large joint spacings (>30ft.).

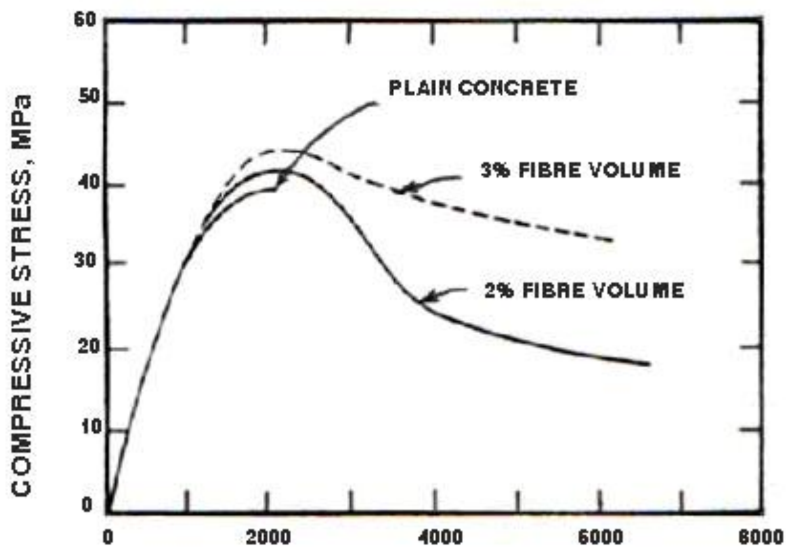
Furthermore,the early concrete projects used high volume fractions (1 to 2%). Hindsight has shown that the selection of certain design features (such as ultra-thin overlays with large slab sizes) when using FRC can result in early-age corner breaks, wide crack openings, and excessive joint spalling.

Some full-scale experimental tests have been conducted over the past two decades to measure the effects of fiber type and volume fractions on the response properties of concrete s (Sham and Burgoyne 1986; KIndiareja et al. 1987; Beckett and Humphreys 1989; Beckett 1990,1999; Tatnall and Kuitenbrouwer 1992; Falkner and Teutsch 1993). These research programs primarily focused on the effect fibers have on the toughness and ultimate load carrying capacity of concrete . Studies have shown that steel fibers increase the flexural and ultimate load carrying capacity of concrete and the magnitude of the increase is related to the fiber volume and aspect ratio (Sham and Burgoyne 1986; Beckett 1990; Falkner et al. 1995; Beckett etal. 1999). Beckett (1990) concluded that as the steel fiber content increased from 20 to 30 kg/m3 for an aspect ratio of 60 (fiber length divided by diameter), the increase over ordinary concrete first flexural crack strength of the slab went from 11 to 33 percent. Tatnall and Kuitenbrouwer (1992) concluded that the theoretical results based on Westergaard (1926) elastic analysis did not accurately predict the flexural cracking loads of slabs (based on concrete beam flexural strengths). Similarly, Roesler (1998) showed that concrete under monotonic loading had an increased flexural strength over companion beam specimens by as much as 30 percent, while the calculated Westergaard stress resembled the concrete beam flexural strength

2.1 Background of fiber reinforced concrete

Steel fibers offer increased toughness, abrasion and impact resistance, and allow for increased slab sizes. Synthetic fibers, such as Polypropylene, have primarily been used in concrete materials to control and reduce plastic shrinkage cracking (Naaman et al. 1984; Zollo and Ilter 1986; Grzybowski and Shah 1990; Bentur and Mindess 1990; Shah et al.1994)
Reinforcing brittle matrices to improve there mechanical properties is an age-old concept. However, the modern development of fiber reinforced cement composites dates bank only to the 1960s .In the beginning, only straight steel fibers were used .The acceptance of fiber reinforced concrete by the construction industry had led to a number of developments. Among these developments are new fiber types made of steel , stainless steel, polymeric and mineral materials, and naturally occurring materials. New manufacturing techniques and applications has also been developed.A large number of researchers around the world have investigated the various aspects of fiber reinforced concretes.

The use of fibers as reinforcement for Concrete has been developed long time back and widely used in the different part of the world, particularly in EUROPE, INDIA , JAPAN and USA. The ancient Egyptians used straw to reinforce Sun-baked bricks and horse hair was used to reinforce Plaster for ceilings and renderings. Steel fibers were used in the Concrete in 1874. Since then, it has been used in a wide range of applications. Among the first being the patching of bomb craters in runways during world war II, subsequently asbestos fibers were incorporated to reinforce Portland cement products, such as roofing sheets. Steel, Carbon, Glass Plastic & Polypropylene fibers have been used in range of concrete applications in the recent years.



Longitudinal Strain

Fig 2.1:-Stress Strain Curves in compression for SFRC

Ref : "Nguyen Van CHANH " workability study of fiber reinforcement concrete

FRC is a concrete in which fiber are mixed at the time of mixing of the concrete so that the fibers are uniformly distributed through out the mass of concrete and would act as micro reinforcement to improve almost all the properties of Concrete. The fibers interlock and entangle around aggregate particles and considerably reduce the workability, while the mix become more cohesive and less prone to segregation. The fibers restrain the shrinkage and creep movements of un reinforced matrix. However, fibers have been found to be more effective in controlling compression creep than tensile creep of un reinforced matrix. Fibers act as crack arrestor restricting the development of crack and thus transforming an inherently brittle matrix i.e. Portland cement with its low tensile and impact resistance into a strong composite with superior crack resistance improved ductility and distinctive post cracking behavior prior to failure.

In FRC, thousands of small fibers are dispersed and distributed randomly in the concrete during mixing, and thus improve concrete properties in all directions. Fibers help to improve the post peak ductility performance, pre-crack tensile strength, fatigue strength, impact strength and eliminate temperature and shrinkage cracks.Several different types of fibers, both manmade and natural, have been incorporated into concrete. Use of natural fibers in concrete precedes the advent of conventional reinforced concrete in historical context. However, the technical aspects of FRC systems remained essentially undeveloped. Since the advent of fiber reinforcing of concrete in the 1940's, a great deal of testing has been conducted on the various fibrous materials to determine the actual characteristics and advantages for each product. Several different types of fibers have been used to reinforce the cement-based matrices. The choice of fibers varies from synthetic organic materials such as Polypropylene or carbon, synthetic inorganic such as steel or glass, natural organic such as cellulose or sisal to natural inorganic asbestos. Currently the commercial products are reinforced with steel, glass, polyester and Polypropylene fibers. The selection of the type of fibers is guided by the properties of the fibers such as diameter, specific gravity, young’s modulus, tensile strength etc and the extent these fibers affect the properties of the cement matrix.

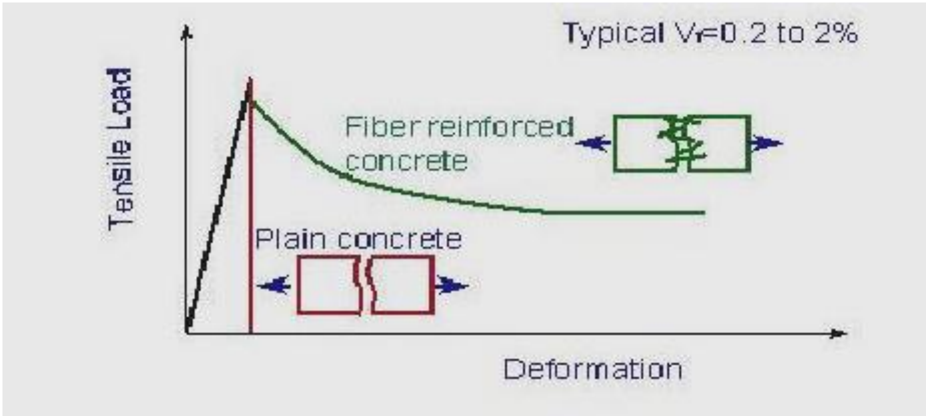


Figure 2.2. Tensile Load versus Deformation for Plain and Fiber Reinforced Concrete.

Ref:- Daniel, J.I., Roller, J.J., and Anderson.E.D., Fiber reinforced Concrete, Portland Cement Association, Chapter 5, pages 22-26,1998

2.2 Mechanism of fiber reinforced Concrete and Interaction between fibers and matrix.

The interaction between the fiber and matrix is the fundamental property that affects the performance of a cement based fiber composite material. An understanding of thesis interaction is needed for estimating the fiber contribution and for predicting the composites behavior. A large number of investigators have studied the various aspects of this interaction.

A variety of factors are involved; the following are the major parameters affecting the fiber interaction with the matrix,

- Condition of the matrix : un-cracked or cracked
- Matrix composition
- Geometry of the fiber
- Type of fiber: for example, steel, polymeric, minerals, or naturally occurring fibers
- Surface characteristics of he fiber
- Stiffness of the fiber in comparison with matrix stiffness.
- Orientation of the fibers : aligned versus random distribution
- Volume fraction of fibers

- Rate of loading
- Durability of the fiber in the composite and the ling terms effects.

2.3 Fiber interaction with homogeneous un-cracked matrix:-

This type of interaction occurs in almost all composites during the initial stages of loading. In certain cases, such as highly reinforced thin sheets, the composite may remain un-cracked during the service life. However, in most cases, the matrix will crack during the service life. The fiber interaction with the un-cracked matrix has therefore limited importance in practical applications.Study of this interaction dies yield useful information for understanding the overall behavior of the composite. In addition, even when cracks develop in the composite, the un-cracked portions of the structure affect the overall behavior of the structural system.

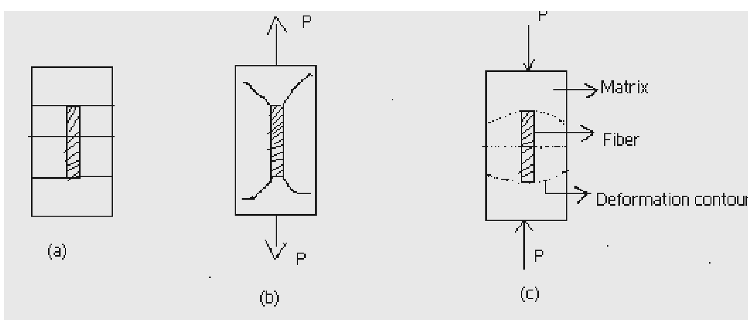


Figure2.3 Fiber matrix interaction, uncraked material (a) unloaded, (b) tension, (c) compression.

Ref:- V.Ramakrishanan' 'Materials and properties of fiber reinforced concrete'.Proceeding of the international symposium on fiber reinforced concrete,vol-1, December 19-19,SERC.Madras.India,pp 2.3-2.28

A simple fiber matrix system containing a single fiber is shown in fig.2.3 In the unloaded stage, the stresses in both the matrix and the fiber are assumed to be zero fig2.3 (a) .Applying tensile or compressive load to the composite or subjecting the composite to temperature change results in the development of stressed and deformation that must remain compatible. In the case lf a cement matrix, the hydration of cement a line ma induce stresses both in the matrix and in the fiber. When the load is applied to the matrix, part of the load is transferred to the fiber along its surface. Because of the difference in stiffness between the fiber and the matrix, shear stress develops along the surface of the fiber, Thus shear stress helps to transfer some of the applied load to he fiber, If the fiber is stiffer than the a matrix , the deformation at and around the fiber will be smaller, as shown in figure (b)and (c).This type of situation arises with steel and mineral fibers, If the fiber modulus is less than the matrix modulus, then the deformation around the fiber will be higher, This occurs in composites with polymeric and some naturally occurring fibers.

2.4 Fiber interaction in cracked matrix:-

When the composite containing the fiber is loaded in tension fig 4 at a certain stage the matrix cracks fig 2 .4 Once the matrix cracks , the fiber carries the load across the crack, transmitting load from one side of the matrix to the other. In practice, several fibers will bridge the crack, transferring the load across the crack. If the fibers can transmit sufficient load across the crack, more cracks will form along the length of the specimen. This stage of loading is called the multiple cracking stage .In most practical application. this multiple cracking stage occurs under service load conditions.The finer interaction characteristic also determine the peak load carrying capacity of the composite and the post peak load deformation behavior.

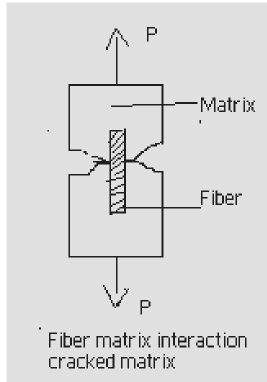


Figure 2.4 Fiber matrix interaction cracked matrix

Ref:-CreszczIndia, L.B. "Theoretical Studies of the Mechanics of the Fiber Matrix Interface in Composites,"

In practical cased, fibers are randomly distributed at least in two dimensions. In the case of fiber reinforced concrete they are randomly distributed in all three (mutually perpendicular).In addition .Most steel fibers and some polymeric fibers a have surface or end deformation. In almost all case there is interaction between fibers, giving rise to the complexity of the problem. Hence, mathematical models for use in practical applications are still in rarely stages of development

2.5 Behavior of Polypropylene fibers in a cement matrix:

This research is oriented towards concrete reinforced with Polypropylene fibers, so it is most important to understand how Polypropylene fibers behave in the cement composite matrix. The study of this mechanism helps model the behavior of the composites in a real world Environment. The behavior of FRC under loading can be understood from the Figure 2.5

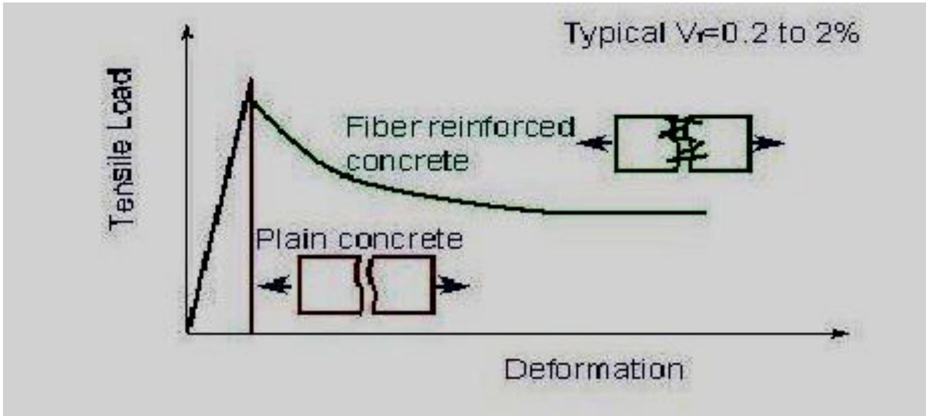


Figure 2.5:- **Tensile Load Versus Deformation for Plain and Fiber Reinforced concrete**

Ref:-V.Ramakrishanan' 'Materials and properties of fiber frinforced concrete'.Proceeding of the international symposium on fiber reinforced concrete,vol-1, December 19-19,SERC.Madras.India,pp 2.3-2.28

The ordinary concrete structure cracks into two pieces when the structure is subjected to the peak tensile load and cannot withstand further load or deformation. The fiber reinforced concrete structure cracks at the same peak tensile load, but does not separate and can maintain a load to very large deformations. The area under the curve shows the energy absorbed by the FRC when subjected to tensile load. This can be termed as the post cracking response of the FRC. The real advantage of adding fibers is when fibers bridge these cracks and undergo pullout processes, such that the deformation can continue only with the further input of energy from the loading source. Reinforcing fibers stretch more than concrete under loading. Therefore, the composite system of fiber reinforced concrete is assumed to work as if it were non reinforced until it reaches its "first crack strength." It is from this point that fiber reinforcement takes over and holds the concrete together. With reinforcing, the maximum load carrying capacity is controlled by fibers pulling out of the composite. Reinforcing fibers do not have a deformed surface unlike larger steel reinforcing bars which have a non smooth surface which helps mechanical bonding. This condition limits performance to a point far less than the yield strength of the fiber itself. This is important because some fibers pull out easier than others when used as reinforcing and will affect the toughness of the concrete product in which they are placed. Toughness is based on the total energy absorbed prior to compete failure. The main properties influencing toughness and maximum loading of fiber reinforced concrete are based on the type of fibers used, volume percent of the fiber, the aspect ratio and the orientation of the fibers in the matrix.

The other factors that control the performance of the composite material are physical properties of the reinforced concrete and matrix, the strength of the bond between fibers and matrix. The chemical properties of the fiber in terms of their inertness or reactivity with the surrounding environment plays an important role in determining the bonding characteristics of the fiber and the composite as they may or may not from a chemical bond between the fiber and matrix. 6 The environmental effects on the Polypropylene fibers used for reinforcement need to be studied to understand the changes in the behavior of FRCs when placed in various environments. It has been understood that the change in the properties of the Polypropylene fibers over a period of time when subjected to similar environments also affects the bonding characteristics of the fibers with the matrix, which subsequently alters the performance of the FRC loaded conditions,. The objective of this research is to determine the environmental properties of the polymer fibers and how that affects the performance of the fiber reinforced composite. The environmental properties under investigation are the effect of temperature, and the effect of a marine environment on the tensile strength of the fibers. By studying the change in the tensile properties of the Polypropylene fibers by themselves, these effects can be separated out from any general change in properties of the fiber reinforced concrete. Therefore matrix effects can be separated from fiber effects.

2.6 Advantages

- Fiber reinforced concrete has started to find its place in many areas of civil infrastructure applications where the need for repairing, increased durability arises. Also FRC are used in civil structures where corrosion can be avoided at the maximum.
- Fiber reinforced concrete is better suited to minimize cavitations /erosion damage in structures such as sluice-ways, navigational locks and bridge piers where high velocity flows are encountered. A substantial weight saving can be realized using relatively thin FRC sections having the equivalent strength of thicker ordinary concrete sections. When used in bridges it helps to avoid catastrophic failures. Also in the quake prone areas the use of fiber reinforced concrete would certainly minimize the human casualties.
- In addition, Polypropylene fibers reduce or relieve internal forces by blocking microscopic cracks from forming within the concrete

- Prevent Plastic Shrinkage Cracks
- Increases Tensile Flexible Strength
- Increases Impact Resistance
- Increases Abrasion Resistance
- Increases Toughness
- Increases Fatigue Resistance
- Increases Freeze thaw Resistance
- Increases Shear Strength
- Increases overall durability
- Provide Anti crack Strength

2.7 Disadvantages

The main disadvantage associated with the fiber reinforced concrete is fabrication. The process of incorporating fibers into the cement matrix is labor intensive and costlier than the production of the ordinary concrete. The real advantages gained by the use of FRC overrides this disadvantage.

2.8 Application

Ref:-Walia International company, delhi,

www.thesies\walia\WaliaFibers.333.html

2.8.1 Slab on Ground

• Industrial floor • Commercial floor • Equipment Foundation • Railway Platform	• Ammunition Depot • Cold Storage Plant • Multipurpose Basement • Sport Complex
	✓ Increase in wear resistance ✓ Increase against cracking ✓ resistance ✓ Increases the toughness of floor ✓ Minimum Dusting ✓ Low Production Cost ✓ Reduction in the ✓ maintenance cost

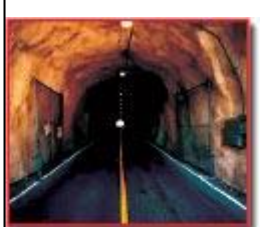
2.8.2 Highway pavement and Airport

• Concrete Road • Airport Runways • Taxi Tacks	• Hanger • Space • Shuttle Launchers
○ Increase the impact Resistance ➢ Reduced slab thickness ➢ Earlier utilization ➢ Increases cohesiveness ➢ More dense concrete ➢ Better load bearing capacity	

2.8.3 Hydraulic Structures

• Dams • Spillway • Hydroelectric Plant	• Port and Harbour • Water Treatment plant • Sewage Treatment Plant
  	
Excellent resistance to cavitation or erossion damage by high velocity water flow **Most economical for repairing of spillways The concrete is reinforced throughout the concrete section.**	

2.8.4 Shortcrete (Dry and Wet)

♦TUNNEL LININGS ♦MINE LININGS ♦ROCK SLOPE STABILISATION ♦AQUEDUCT REHABILITATION	♦WATER CONTAINMENT RESERVOIR ♦RETAINING WALLS ♦EXTERNAL & INTERNAL PLASTERS ♦DOME STRUCTURES.
	➢ **Improves flexural ductility** ➢ **Improves impact resistance** ➢ **Eliminates welded wiremesh fabric problem at Site (Safe & easy to use.)** ➢ **Reduces construction time** ➢ **Reduces plastic shrinkage and settlement cracks.**

2.8.5 Precast Products

♦CONCRETE PIPES ♦MANHOLE COVERS and FRAMES, ♦DRAIN COVERS ♦BRIDGE SPAN SEGMENTS	♦PRECAST PAVER BLOCK FOR WALKWAYS ♦KERB- STONE ♦COFFINS
➢ **Eliminates Cumbersome placement ofre-bar and wire mesh** ➢ **Reduces thickness of concrete for precast application (saving in material cost)** ➢ **Different Shapes and Sizes are possible** ➢ **Increases toughness & crack resistance** ➢ **Works as a micro reinforcement**	

2.8.6 Overlays

♦OVERLAYS FOR BRIDGE DECKS ♦CITY FLYOVERS OVERLAY ♦FACTORY FLOOR	♦PARKING DECKS ♦PETROL PUMPS ♦WORKSHOPS	♦WALKWAYS ♦AUTOMOBILESSHOW ROOMS ♦ROAD & FLOOR REPAIRS

Only 75 to 100 mm thick concrete layer is good enough over damage surface It is possible to lay an overlay over the deteriorated Asphalt pavements Lower production cost * Increased in wear resistance upto 100% - 150% Monolithic surface is obtained

2.9 Types of fiber

The fibers can be broadly classified as

- Metallic Fibers
- Polymeric Fibers
- Mineral Fibers
- Naturally occurring Fibers

They can be classified into two basic categories, namely, those having a higher elastic modulus than concrete matrix (called hard intrusion) and those with lower elastic modulus (called soft intrusion). Steel, Carbon and Glass have higher elastic modulus than cement mortar matrix and Polypropylene and natural vegetable fibers are the low modulus fibers. High modulus fibers improve both flexural and impact resistances, simultaneously whereas low modulus fibers improve the impact resistance of concrete.

Different type of fibers such as Steel, Carbon,Polypropylene, Nylon, Polyester, Rayon Glass etc. are available. The Fibers suitable for reinforcing the concrete have been produced from steel, glass and organic polymers. Fibers are available in different sizes and shapes.

2.9.1 Metallic fibers

2.9.1Steel

Steel fibers have been used in concrete since the early 1900s. The early fibers were round and smooth and the wire was cut or chopped to the required lengths. The use of straight, smooth fiber has largely disappeared and modern fiber have either rough surfaces, hooked ends or are crimped or undulated through their length. Modern commercially available steel fiber are manufactured from drawn steel wire, from slit sheet steel or by the melt- extraction process which produces fiber that have a crescent-shaped cross section. Typically steel fiber have equivalent diameters (based on cross sectional area) of from 0,15 mm to 2 mm and lengths from

7 to 75 mm. Aspect ratios generally range from 20 to 100. *(Aspect ratio* is defined as the ratio between fiber length and its equivalent diameter, which is the diameter of a circle with an area equal to the cross-section area of the fiber.)

Carbon steels are most commonly used to produce fiber but fiber made from corrosion-resistant alloys are available. Stainless steel fibers have been used for high-temperature application. Some fiber are collated into bundles using water-soluble glue to facilitate handling and mixing. Steel fiber have high tensile strength (0,5- 2Gpa) and modulus of elasticity (200 Gpa), a ductile/plastic stress- strain characteristic and low creep. Steel fiber have been used in conventional concrete mixes, shot-Crete and slurry-infiltrated fiber concrete. Typically, content of steel fiber ranges from 0,25% to 2,0% by volume. Fiber contents in excess of 2% by volume generally result in poor workability and fiber distribution, but can be used successfully where the paste content of the mix is increased and the size of coarse aggregate is not larger than about 10mm.

Steel-fiber-reinforced concrete containing up to 1,5% fiber by volume has been pumped successfully using pipelines of 125 to 150 mm diameter. Steel fiber contents up to 2% by volume have been used in shortcrete applications using both the wet and dry processes. Steel fiber contents of up to 25% by volume have been obtained in slurry-infiltrated fiber concrete. Concretes containing steel fiber have been shown to have substantially improved resistance to impact and greater ductility of failure in compression, flexure and torsion.

Compression and modulus of rigidity in torsion are no different before cracking when compared with ordinary concrete tested under similar conditions. It has been reported that steel-fiber-reinforced concrete, because of the improved ductility, could find applications where impact resistance is important. Fatigue resistance of the concrete is reported to be increased by up to 70%. It is thought that the inclusion of steel fiber as supplementary reinforcement in concrete could assist in the reduction of spalling due to thermal shock and thermal gradients. The lack of corrosion resistance of normal steel fibers could be a disadvantage in exposed concrete situations where spalling and surface staining are likely to occurs.

2.9.2 Synthetic fibers.

Synthetic fiber are man-made fiber resulting from research and development in the petrochemical and textile industries. There are two different physical fiber forms: monofilament fiber, and fiber produced from fibrillated tape. Currently there are two different synthetic fiber volumes used in application, namely low-volume percentage (0,1 to 0,3% by volume) and high-volume percentage (0,4 to 0,8% by volume)

Most synthetic fiber applications are at the 0,1% by volume level. At this level, the strength of the concrete is considered unaffected and crack control characteristics are sought. Fiber types that have been tried in cement concrete matrices include:acrylic,aramid, carbon, nylon, polyester, polyethylene and Polypropylene.

Table 1 summaries the range of physical properties of some synthetic fibers.

2.9.3 Acrylic

Acrylic fibers have been used to replace asbestos fiber in many fiber-reinforced concrete products. In this process fibers are initially dispersed in a dilute water and cement mixture. A composite thickness is built up in layers using a pressure forming process and vacuum dewatering. Acrylic fibers have also been added to conventional concrete at low volumes to reduce the effects of plastic-shrinkage cracking.

2.9.4 Aramid

Aramid fibers are two and a half Umes as strong as glass fibers and five times as strong as steel fibers, per unit mass. Due to the relatively high cost of these fibers, aramid-fiber reinforced concrete has been primarily used as an asbestos cement replacement in certain high-strength applications.

2.9.5 Carbon

Carbon fiber is substantially more expensive than other fiber types. For this reason its commercial use has been limited. Carbon fibers are manufactured by carbonizing suitable organic materials in fibrous forms at high temperatures and then aligning the resultant graphite crystallites by hotstretching. The fibers are manufactured as either Type I (high modulus) or Type II (high strength) and are dependent upon material source and extent of hot stretching for their physical properties Carbon fibers are available in a variety of forms and have a fibrillar structure similar to that of asbestos.

Carbon fiber made from petroleum and coal pitch is less expensive than the conventional carbon fiber made from fibrous materials. The Type I and II carbon fibers produced by carbonizing suitable organic materials other than petroleum-based types are 20 to 40 times stronger and have a modulus of elasticity up to 100 times greater than the pitch- based carbon fiber. Carbon fiber is available as continuous strands or as individual chopped fibers. Continuous strands are normally pre-placed and aligned to provide the optimum fiber orientation during fabrication. Chopped fibers are generally incorporated during the mixing process and are therefore orientated randomly throughout the mix. A satisfactory mix of chopped carbon fiber, cement and water is difficult to achieve because of the large surface area of the fiber. Research has shown that uniform dispersion of discontinuous low-modulus carbon fiber has been achieved using an omni mixer and admixture. Carbon fiber has high tensile strength and modulus of elasticity and a brittle stress-strain characteristic. Additional research is needed to determine the feasibility of carbon-fiber concrete on an economic basis. The fire-resistant properties of carbon-fiber composites need to be evaluated, but ignoring economics, structural applications appear promising.

2.9.6 Nylon

Nylon is a generic name that identifies a family of polymers. Nylon fiber's properties are imparted by the base polymer type, addition of different levels of additive, manufacturing conditions and fiber dimensions. Currently only two types of nylon fiber are marketed for concrete. Nylon is heat stable, hydrophilic, relatively inert and resistant to a wide variety of materials. Nylon is particularly effective in imparting impact resistance and flexural toughness and sustaining and increasing the load carrying capacity of concrete following first crack.

2.9.7 Polyester

Polyester fibers are available in monofilament form and belong to the thermoplastic polyester group. They are temperature sensitive and above normal service temperatures their properties may be altered. Polyester fibers are somewhat hydrophobic. Polyester fibers have been used at low contents (0,1% by volume) to control plastic-shrinkage cracking in concrete.

2.9.8 Polyethylene

Polyethylene has been produced for concrete in monofilament form with wart-like surface deformations. Polyethylene in pulp form may be an alternate to asbestos fibers. Concrete reinforced with polyethylene fibers at contents between 2 and 4% by volume exhibits a linear flexural load deflection behavior up to first crack, followed by an apparent transfer of load to the fibers permitting an increase in load until the fibers break.

2.9.9 Polypropylene

Polypropylene fiber was first used to reinforce concrete in the 1 960s. Polypropylene is a synthetic hydrocarbon polymer, the fiber of which is made using extrusion processes by hot-drawing the material through a die. Polypropylene fibers are produced as

Table 2.1 Various Types of Synthetic Fibers

Ref- website http://www.cnci.org.

Fiber type	Equi. dia. pm	Relative density	Tensile strength MPa	Elastic modulus CPa	Ultimate elongation %	Ignition temp. c	Melt, oxidation or decomposition temp.	Water absorption per ASTM D 570, % by mass
Acrylic	13-104	1,16 - 1,18	270-1 000	14-19	7,5-50,0	-	220- 235	1,0-2,5
Aramid I	12	1,44	2900	60	4,4	high	480	4,3
Aramid IIt	10	1,44	2350	115	2,5	high	480	1,2
Carbon, PAN HMA	8	1,6 - 1,7	2 500 -3 000	380	0,5 - 0,7	high	400	nil
Carbon, PAN HT	9	1,6-1,7	3450-4000	230	1,0 - 1,5	high	400	nN
Carbon, pitch GP**	10- 13	1,6 - 1,7	480-790	27-35	2,0 - 2,4	high	400	3-7
Carbon, pitch HPtt	9-18	1,8 - 2,15	1 500-3100	150-480	0,5 - 1,1	high	500	nil
Nylon	23	1,14	970	5	20	-	200-220	2,8 - 5,0
Polyester	20	1,34 - 1,39	230-1100	17	12-150	600	260	0,4
Polyethylene	25-1.000	0,92 - 0,96	75 - 590	5	3 - 80	-	130	nil
Polypropylene	-	0,90 - 0,91	140-700	3,5 - 4,8	15	600	165	nil

continuous mono-filaments, with circular cross section that can be chopped to required lengths, or fibrillated films or tapes of rectangular cross section. Polypropylene fibers are hydrophobic and therefore have the disadvantages of poor bond characteristics with cement matrix, a low melting point, high combustibility and a relatively low modulus of elasticity. Long Polypropylene fibers can prove difficult to mix due to their flexibility and tendency to wrap around the leading edges of mixer blades. Polypropylene fibers are tough but have low tensile strength and modulus of elasticity; they have a plastic stress-strain characteristic.

Monofilament Polypropylene fibers have inherent weak bond with the cement matrix because of their relatively small specific surface area. Fibrillated Polypropylene fibers are slit and expanded into an open network thus offering. a larger specific surface area with improved bond characteristics. Polypropylene fiber contents of up to 12% by volume are claimed to have been used successfully with hand-packing fabrication techniques, but volumes of 0,1% of 50-mm fiber in concrete have been reported to have caused a slump loss of 75 mm.

Polypropylene fibers have been reported to reduce unrestrained plastic and drying shrinkage of concrete at fiber contents of 0,1 to 0,3% by volume.

2.9.10 Natural Fibers.

Natural reinforcing materials can be obtained at low cost and low levels of energy using local manpower and technology. Utilization of natural fibers as a form of concrete reinforcement is of particular interest to less developed regions where conventional construction materials are not readily available or are too expensive. Sisal-fiber reinforced concrete has been used for making roof tiles, corrugated sheets, pipes, silos and tanks. Elephant-grass-reinforced mortar has been used for low-cost housing projects. Wood-cellulose-fiber-reinforced cement has commercial applications in the manufacture of flat and corrugated sheet and non-pressure Pipes natural fibers can be either unprocessed or processed.

2.9.11 Unprocessed natural fibers

Products made with unprocessed natural fibers such as coconut coir, sisal, sugarcane bagasse, bamboo, jute, wood and vegetable fibers have been tested in a number of countries. Problems have been reported with the long-term durability of some of the products.

The properties of concrete made using unprocessed natural fibers depend on a number of factors including the type and length of fiber as well as the volume fraction. To show some improvement in mechanical properties, the minimum fiber content is of the order of 3% by Volume. ..

2.9.12 Processed natural fibers.

Wood cellulose is the most frequently used natural fiber. It is most commonly obtained using the Kraft process. This process involves cooking wood chips in a solution of sodium hydroxide, sodium carbonate and sodium sulphide. Different grades of wood-cellulose fiber containing more or less of the three main constituents, cellulose, hemi cellulose and ligna can be obtained by bleaching.

Wood-cellulose fiber has relatively good mechanical properties compared with many man-made fibers such as Polypropylene, polyethylene, polyester and acrylic. Delignified cellulose fiber can be produced with tensile strengths up to approximately 2,0 GPa from selected grades of wood, and using suitable pulping processes. Fiber tensile strengths of 500 MPa can be routinely obtained using a chemical pulping process and the more common, less expensive, grades of wood.

Using conventional mixing techniques, the amount of fiber that can be incorporated into the cement matrix at low water contents is limited by the capacity of the fibers to be mixed uniformly into the matrix. Fabrication techniques that involve mixing fiber with the matrix at initially high water contents and then using dewatering procedures are therefore effective and common.Wood-cellulose fiber that has not been delignified can adversely affect the curing of the cement matrix. This is because leaching of sugar and other organic impurities into the cement matrix can retard or completely inhibit cement set. Results obtained from autoclaved wood-cellulose cement composites indicate that such products can be sensitive to moisture content. Published information on the performance of wood-cellulose fiber composites is conflicting. However, Bentur and Mindess state "Although the strength and other properties of the cellulose-pulp fiber are inferior to those of many other fibers, such as asbestos, they are highly cost effective. This, combined with their compatibility with processes for producing asbestos cement, makes the cellulose-pulp fibers an attractive alternative to asbestos. As a result of intensive research and development, cellulose- pulp fibers are now used in some places as partial or full replacement for asbestos in cement composites.'

Table 2.2 Types of synthetic fibers

Ref:-website http://www.cnci.org.za

Fiber type	**Cocout**	**Sisl**	**Sugar cane bagase**	**Bambo**	**Jute**	**Flx**	**Ele-phant grass**	**Water reed**	**Pla n-tam**	**Musamba**	**Wood fiber (Kraft pulp)**
Fiber length, mm	50- 100	NA	NA	NA	75 - 300	500	NA	NA	NA	NA	2.5-5.0
Fiber diameter, mm	0.1-0.4	NA	0.2-0.4	0.05-0.4	1-0.2	NA	NA	NA	NA	NA	0.025-0.075
Relative density	1.12-1.5	NA	1.2-1.3	1.5	5-1.(	NA	NA	NA	NA	NA	1.5
Modulus of elasticity, GPa	19-26	13-26	15-19	33-40	6-32	100	5	5	1,5	1,0	NA
Ultimate tensile strength, MPa	120-200	275-570	180-29(	350-500	50-3	1000	180	70	90	80	700
Elongati at break,	10-25	3-5	NA	NA	1.5-	1.8-2	3.6	1.2	5.9	9.7	NA
Water	130- 180	60-70	70-75	40-45	NA	NA	NA	NA	NA	NA	50- 75

absorption, %										
Notes N/A Properties not readily available or not applicable.										

2.10 Polypropylene Fibers

2.10.1 Introduction.

Polypropylene is widely used in the production of fibers, for use in carpeting, rope and twine, automobile interiors, textiles and in other applications . Production of Polypropylene in U.S. during 1994 reached 2688 million lbs. for fibers. Consumption reached to 1,000,000,000 lbs per year for non-woven fabric application with staple fiber product showing about 475,000,000 lb. and spun-bond fabrics about 400,000,000 lb .

Fibers are one of the most important applications for Polypropylene homopolymer. Due to its melt flow properties, fiber formation is easier when compared to other polymers. Its low density results in a higher yield of fiber per pound of material . Polypropylene chips can be converted to fiber/filament by traditional melt spinning processing, though the operating parameters need to be changed depending on the final products. Spun-bonded and melt-blown are also very important fibers producing techniques for non-wovens . Melt spinning is a process in which the molten polymeris forced through a spinneret, a metal plate that contains as many as 100-200 holes or capillaries, each with a diameter less than 0.008 inches.

The molten polymer emerges from the spinneret as continuous strands of fiber that are cooled or quenched using water or current of air. The fibers are then drawn by heating to a temperature close to the melting point and stretched. This process reduces the cross-section and produces orientation in fibers, resulting in increased tensile strength . The mode of polymerization, its high molecular weight and molecular orientation and the process that is adopted for manufacturing determines the properties of the Polypropylene fibers.

Figure 2.6 shows Types of 12mm Polypropylene fiber (PP12M), mono-filament type10 mm and 30 mm.

Ref:- Loo Y. H., "New method for micro crack evaluation in concrete under compression", Materials and Structures.

Polypropylene demonstrates an interesting example of the need for regularity of structure to secure crystallization in a polymer. During polymerization, the successive chain sequences of --CH_2--$CH(CH_3)$ can be added on in either a right-handed or a left handed screw direction, owing to the stereochemistry of the chain. If these forms occur at random, the chain will have an irregular shape and will not crystallize.

Polypropylene fibers are available in two different forms; Monofilaments and Multi-filaments. Monofilaments are ribbons of Polypropylene composed of a single extruded filament produced by melt spinning followed by water quenching. Sizes of monofilaments range from 75-5000 denier (1 denier = weight in grams of 9000 m of fiber) Monofilaments are used in weaving stiffer products such as rope or twine Ropes thus produced have high wear resistance, do not absorb water, float due to the low density and they retain strength when they are wet. Monofilament fibers are characterized by highly reflective and translucent surface, limited absorption capacity, high stiffness and good tensile strength. Several individual monofilaments that are ≤ 75 denier are grouped into a single continuous bundle to produce Multi filaments. Filaments that are of size ≤ 30 denier are air quenched. Slow cooling results in the very highly ordered crystal structure and hence fibers possess high thermal stability and low creep. Larger filaments cool more slowly and air quenching is not economically and hence water quenching is used instead. Due to this rapid cooling, enough time is not available for the formation of crystalline structures. Consequently water quenched fibers are tough with high tenacity. Multifilament fibers are characterized by flexibility, lightweight and hydrophobic nature. The properties of monofilament and multifilament fibers vary considerably. Depending on the diameter the Young's modulus of the monofilaments will be up to 725 ksi and for the fibrillated multi filaments, it will be up to 500 ksi. The tensile strength of the monofilaments will be up to 65 ksi whereas the multi filaments have the tensile strength within the range of 80 to 110 ksi.

2.10.2 Structure of Fiber:

Polypropylene (PP) is a versatile thermoplastic material, which is produced by polymerizing monomer units of Polypropylene molecules into very long polymer molecules or chains in the presence of a catalyst under carefully, controlled heat and pressure. Propylene is an unsaturated hydrocarbon, containing only carbon and hydrogen
atoms:

CH2=CH

!

CH3

(Propylene)

There are many ways of polymerization of the monomer r units, but PP as a commercially used material in its most widely used form is produced with catalysts that produce crystallize able polymer chains. With Ziegler-Natta or metallocene catalysts, the polymerization reaction is stereo-specific. Propylene molecules add to the polymer chain only in a particular orientation, depending on the chemical and crystal structure of thecatalyst, and a regular, repeating three-dimensional structure is produced in the polymer chain. Propylene molecules are added to the main polymer chain, increasing the chain length, and not to one of the methyl groups attached to alternating carbon atoms that are termed as pendant methyl groups

A typical structure of Polypropylene chain is shown below,

----CH_2 ---- CH ---- CH_2 ---- CH ---- CH_2 ---- CH ----

1 1 1

CH_3 CH_3 CH_3

Polypropylene is one of the fastest growing classes of commodity thermoplastics, with a market share growth of 6-7% per year and the volume of Polypropylene produced is exceeded only by polyethylene and polyvinyl chloride. The moderate cost and favorable properties of Polypropylene contribute to its strong growth rate. Polypropylene is one of the lightest of all thermoplastics (0.9 g/cc). The reason for the popularity of the Polypropylene fibers is because of the versatility of the material. It has a good combination of properties, cheaper than many other materials that belong to the family of polyolefins and it can be manufactured using various techniques. These benefits are derived from the very nature and the structure of Polypropylene.

2.10.3 Mechanical, Thermal Properties and Chemical resistance:

Mechanical Properties.

Traditional materials tend to be relatively little affected by temperature and time with in the normal service conditions. But thermoplastics exhibit a different behavior. Stresses and strains that a thermoplastic can withstand when they are applied slowly maybe quite sufficient to shatter when they are applied rapidly. A stress that creates no problem for a short period may cause the material to deform or creep over a longer period of time. These are instances of the time-dependency of plastics. The mechanical properties of Polypropylene are strongly dependent on time, temperature and stress. Furthermore, it is a semi-crystalline material, so the degree of crystallinity and orientation also affects the mechanical properties. Also the material can exist as homo polymer, block copolymer and random copolymer and can be extensively modified by fillers, reinforcements and modifiers. These factors also affect the mechanical properties.

2.11 CHEMICAL ATTACK ON CONCRETE

2.11.1 General

This Part deals first with sulfate attack and acid attack, these being the principal types of chemical attack that are of concern for concretes placed in the ground in the INDIA . The aggressive chemical agents responsible commonly occur in both natural ground and land contaminated by activities of mankind.

Additionally, this Part identifies the more rarely occurring forms of chemical attack, caused by high levels of chemical species such as ammonium and chromium, and organics such as phenols. Generally these agents are found in troublesome concentrations only in contaminated land. With some exception, specific guidance is not given in this Special Digest in respect of protecting concrete from the action of these less commonly destructive agents. Generally the protective principles applied in will be beneficial, for example, specifying a well-compacted concrete, with a low water/cement ratio or providing an appropriate protective coating. Specialist advice should be sought when appropriate. Finally, this Part explains the action of aggressive carbon dioxide in respect of concrete in contact with flowing water. While not taken into account in a standard ground investigation or general concrete specification, the possible damaging effect of high levels of aggressive carbon dioxide are catered for in Part F in the design of specific precast concrete products such as pipeline systems. The potential for this form of attack should also be taken into account when designing cast-in place structures that carry flowing water, e.g. culverts.

2.12. Principal types of chemical attack on concrete

2.12.1 Sulfate Attack

The essential agents for sulfate attack are sulfate anions These are transported to the concrete in various concentrations in water, together with cations, the more common of which are calcium, magnesium and sodium. Where porous concrete is in contact with saturated ground the water phase is continuous across the ground/concrete interface and sulfate ions will be readily carried into the body of the concrete. Well compacted, dense, low water/cement ratio concrete in such an environment will, however, initially restrict access of the ions to the surface layer. Migration of sulfate ions from unsaturated ground into the concrete can take place by diffusion provided there is sufficient water to coat the particles of soil, but the rate will be slow and dependent on the sulfate concentration.

The reactions that take place when sulfates enter the concrete matrix are complex and contentious. There is extensive research literature on the topic, including some recent collaborative books and conferences A simple guide is given here in order to understand the basic chemistry and resultant effects. The reactions have been demonstrated to depend on the type of cement, on the availability of reactive carbonate in, for example, the aggregate and groundwater, and on the temperature. Two separate forms of sulfate attack on Portland cement concretes are described here:

1) A well-known type (commonly called the ‘conventional form of sulfate attack’) leading to the formation of ettringite and gypsum;

2) A more recently identified type producing thaumasite. In practice, both can operate together to some extent in field conditions in buried concrete.

Sulfate attack can only be diagnosed when the concrete in question is showing physical signs of degradation such as expansion (with or without notable cracking), surface erosion or softening of the cement paste matrix. The identification of levels of sulfate significantly greater than 4% by weight of cement within the surface of a visually sound concrete does not automatically imply that sulfate attack has taken place; it may only be a warning of potential attack in the future.

2.12.2 Conventional form of sulfate attack

For sulfate attack to occur leading to the formation of ettringite and gypsum in susceptible concrete the following must be present.

1) A source of sulfates, generally from sulfates or sulfides in the ground;

2) The presence of mobile groundwater.

3) Calcium hydroxide and calcium aluminate hydrate in the cement matrix. In the highly alkaline pore solution (pH>1O) provided by the sodium, potassium and calcium hydroxides liberated during the cement hydration reactions, sulfate ions that have penetrated the hardened concrete react with calcium aluminate hydrate to form calcium sulfoaluminate hydrate (ettringite,$CaO.A1_20_3.3CaSO_4.31H_20$)

The formation of this mineral can be destructively expansive since it has a solid volume greater than the original constituents and it grows as myriad acicular (needle-shaped) crystals that can collectively generate high internal stresses in the concrete.

In sulfate-resisting Portland cement (SRPC), the tricalcium aluminate (C_3A in cement notation) level is kept to a minimum so reducing the extent of this reaction Incoming sulfate ions may also react with calcium hydroxide $Ca(OH)_2$ to form gypsum (calcium sulfate dihyd rate, $CaSO_4.2H_2O$). This reaction product also has a greater solid volume than the original constituents and in some cases can contribute to degradation of the concrete. If magnesium ions accompany the sulfates, they may also react with calcium hydroxide, producing brucite (magnesium hydroxide,

$Mg(OH)_2$) which because of its low solubility precipitates out of solution, also leading to increase in solid volume. Magnesium ions may also attack calcium silicate hydrates, the principal bonding material in set concrete.Laboratory tests show that the first effect of the conventional form of sulfate attack is to increase the strength and density of the concrete as the reaction products fill the pore space. When it is filled, further ettringite formation induces expansive internal stresses in the concrete which, if greater than the tensile strength of the concrete, will expansively disrupt the affected region. This cracking together with white crystalline accumulations are the characteristic signs of the conventional form of sulfate attack.

2.13 Acid attack

The acids most commonly encountered by concrete (all found in some natural ground waters) are carbonic acid, humic acid and sulfuric acid. The first two are only moderately aggressive and will not produce a pH below about 3.5. Sulfuric acid is a highly ionised mineral acid and may result in a pH lower than 2. Other similarly aggressive mineral acids may occasionally be found in ground contaminated by industrial processes. The primary effect of any type of acid attack on concrete is the dissolution of the cement paste matrix. This weakens the affected concrete, but unlike sulfate attack,the degradation does not involve significant expansion. Neither ettringite nor thaumasite are stable in acid solution so that the reaction product from sulfuric acid attack will be primarily gypsumIn concrete with siliceous gravel, granite or basalt aggregate, the surface attack will produce an 'exposed aggregate' appearance. However, in concrete with limestone (calcium carbonate) aggregates, the aggregate may dissolve at a rate similar to that of the cement paste and leave a smoother surface.

The rate of attack depends more on the rate of water movement over the surface and on the quality of the concrete, than on the type of cement or aggregate:

1) Acidic groundwaters that are not mobile appear to have little effect on buried concrete.

2)Mildly acidic (pH above 5.5) mobile water will attack concrete significantly, but the rate of attack will be generally slow, particularly if the acids are primarily organic in origin.

3) Flowing acidic water may cause rapid deterioration of concrete, therefore high quality concrete is needed. In the case of humic acid, reaction products formed on the surface of concrete are mainly insoluble and tend to impede further Attack.Several cases of acid attack on concrete in the INDIA are described by Eglinton (1975) Occurrence of acidic ground conditions is dealt with in Section and assessment of the ground conditions in relation to acidity and mobility of water is included in Section.

2.13.1 Other types of chemical attack on concrete:- A large number of chemicals have been reported as attacking concrete, albeit most in the longer term at high concentrations. For instance a USA document lists more than 100 potentially destructive inorganic and organic substances. The chance of encountering the vast majority of these in the ground is remote.

2.13.2 Magnesium ions

Magnesium is a common element in soil and groundwater but is generally only hazardous to concrete when the Mg2 cation is present in high concentrations in association with certain other chemical agents the key one being sulfate anions. Laboratory studies have found concretes made with some cements are by equivalent concentrations of sodium sulfate.Because of this effect, recommendations for concrete specification in this and previous Digests have differentiated between low and high magnesium levels when combined with high sulfate concentrations. In practice the high Mg levels will be found in the INDIA only in ground having industrial residues. Other than the above, magnesium chloride ($MgCI_2$)is reported to be especially aggressive.

The action of magnesium ions in concrete is complex, but a key mechanism is the replacement of Ca in calcium- silicate-hydrates that form much of the cement paste. This leads to a loss of the binding properties. Formation of brucite ($Mg(OH)_2$) and Mg-silicate hydrates is an indication of attack.

2.13.3 Ammonium ions

Ammonium ions (NH_4) will only be a problem to concrete in ground having chemical residues left by man (including in this case agriculture). Ammonium salts are reported to act as cation-exchange compounds, transforming the insoluble calcium in the hardened cement paste into readily soluble calcium salts that are subsequently leached away. During the reaction, ammonia is liberated and escapes as a gas. The removal of both reaction products results in an increase in the porosity of the concrete, leaving it vulnerable to further attack.

Ammonium salts are also reported to act as weak acids and neutralise the alkaline hardened cement paste; the removal of the hydroxide ions results in softening and gradual decrease in strength of the concrete.

In addition to the corrosive action of the ammonium ion, some further deterioration may be caused by the action of the associated anions. Ammonium sulfate, (NH_4), is one of the most aggressive salts to concrete; cases of attack have occurred resulting from spillage of the material around fertilizer stores.

Because of the rarity of chemical attack attributed to ammonium ions, assessment of ammonium concentration is not specifically included in the scheme presented in this document for assessment of ground aggressive to concrete, or for guidance given for specification of chemically resistant concrete. Specialist advice should be sought if the presence of ammonium ions is suspected.

2.13.4 Chloride ions

Chloride (Cl^-) is a common anion in soil and groundwater, in most cases being associated with sodium (NaCI is common salt). However, the levels of chloride found in the ground are generally chemically innocuous; indeed, they may be beneficial since there is considerable evidence, from seawater studies, that the presence of chloride generally reduces sulfate attack. This is taken into account for brackish water (12000 - 17000 mg/I chloride) The risk of corrosion of embedded metals in buried concrete in non-aggressive soil is generally lower than in externally exposed concrete. However, high chloride concentrations in the ground will increase the risk of corrosion, since chloride ions may migrate into the concrete and lead to a reduction in passivity at the metal surface. The recommendations for the protection of steel reinforcement given in BS 8500-1 should be followed.

On brown field sites that have industrial residues, the presence of chloride ions, together with a pH below 5.5, could indicate the existence of hydrochloric acid that may cause acid attack. It will, therefore, be important to determine the amount of chloride in the soil and / or groundwater during site investigation,. The procedure for taking account of the measured chloride content in this particular circumstance. Apart from this and the need to identify brackish and sea waters, no account is taken of chloride concentration in the procedure for concrete specification given in Section . Specialist advice should be sought if exceptionally high chloride levels are encountered, for example, related to past industrial use of land. Such high concentrations have been reported as chemically affecting hardened concrete. Detrimental mechanisms include the reaction of calcium and magnesium chlorides with calcium aluminate hydrates to form chloroaluminates which may result in low-medium expansion of concrete.

2.13.5 Organic compounds

Phenols are the most commonly encountered troublesome organic group. These are contaminants typically generated as by-products during the manufacture of town gas, tar and coke. The concentrations present are rarely sufficient to attack hardened concrete. However, their presence may well affect the setting of concrete through an inhibition or modification of the hydration of the cement Where in- situ concrete is placed directly against ground suspected of substantial contamination by phenols, consideration should be given to the use of a barrier, such as polyethythene sheeting, as protection during the setting and hardening period. It has been reported that where phenol is present in exceptionally high concentrations (eg several thousand mg/I), it has the potential to attack hardened concrete. The phenol is said to react with calcium hydroxide in the cement paste to form calcium phenolate. This crystallises in the pores of the concrete causing deterioration as a result of physical expansion. In addition to naturally occurring humic acid derived from decay of organic matter, acids may also occasionally be produced by activities of man, for example lactic acid, acetic acid and butyric acids

2.13.6 Attack from aggressive carbon dioxide

Aggressive carbon dioxide is relevant only to certain situations where water is continually flowing over (or seeping through) the concrete. Diversion pipes or culverts around dams retaining moorland waters containing high concentrations of aggressive carbon dioxide can be subject to erosion, as can poorly compacted concrete, or permeable concrete products (for example some aggregate concrete blocks) used in foundations.

Calcium carbonate ($CaCO_3$) is practically insoluble in water but calcium bicarbonate ($Ca(HCO_3)_2$) is soluble. Where carbon dioxide dissolves in water, carbonic acid (H_2C0_3) is formed and this will react with any carbonated cement (or limestone aggregate) to form calcium bicarbonate that goes into solution. This is how swallow holes and caves are formed in limestone. With bicarbonate ions (HCO_3) now in solution, a certain amount of the dissolved carbon dioxide will be needed to stabilise it, so there will be less available to attack further carbonated concrete. It is this remaining available portion of the dissolved carbon dioxide that is referred to as 'aggressive'. Measures to take account of aggressive carbon dioxide for some uses of specific precast concrete products are incorporated into guidance for specific precast concrete products. These measures are also relevant to cast-in-situ structures that are in contact with flowing water containing aggressive carbon dioxide.

2.13.7 Attack from pure water

'Pure' (soft) water, which contains low concentrations of dissolved ions is aggressive when it flows in quantity over a concrete surface. Concrete surfaces that are carbonated are less prone to this form of attack.

2.13.8 Damage to concrete from crystallization of salts.

In addition to causing chemical attack on concrete, soluble compounds originating in the ground can lead to degradation of concrete through a physical mechanism involving crystallization of salts, usually sulfates or chlorides, near to the concrete surface. A classic scenario for this is where concrete of high permeability is partly buried in wet sulfate or chloride-bearing ground and partly exposed to air. Sulfates or chlorides in solution may be drawn through the concrete by capillary suction to evaporate at or close to the free surface.

Crystallisation of salts in pores close to the surface of the concrete may generate expansive stresses that disrupt the concrete, while surface salt deposits form a characteristic efflorescence. The process may be aggravated by repeated wetting and drying of the exposed concrete surface; this leads to cyclical salt precipitation and dissolution and fatigue stressing of the concrete fabric. Additionally, where crystallisation initially occurs at a relatively high temperature producing an anhydrous salt, subsequent wetting may lead to conversion to a hydrous crystalline form of substantially greater volume. A salt particularly implicated in this latter mechanism is sodium sulfate which, subjected to alternate wetting and drying, may alternate between anhydrous thenardite (Na_2SO_4) and hydrous mirabilite ($Na_2504.10H_20$), with a change in crystalline volume of some 300% and a potentially large cyclical stress change. A comprehensive discussion of the topic is included in *Sulfate attack on concrete* .In the INDIA, degradation of partly buried concrete due to crystallisation of salts originating from the ground is rarely a problem. . For most ground conditions, the measures recommended here to mitigate chemical attack on concrete (and in particular specified free water/cement ratios of 0.5 or less) should also be effective against physical degradation due to crystallisation of likely salts.

2.13.9 Microbial contribution to chemical attack on concrete

Activity of micro-organisms in the ground can result in changes to the chemical environment that can contribute indirectly to concrete attack. The most widely recognized damage of bacterial origin is the deterioration of concrete in sewers caused by sulfate-reducing bacteria which feed on sulfate in the effluent. Sulfuric acid is produced which attacks the concrete. In contrast, sulfate-oxidising bacteria such as thiobacillus ferroxidans aid in oxidation of pyrite (FeS2) in the ground, producing both sulfuric acid and sulfates that subsequently lead to sulfate attack of concrete. The need to take pyrite oxidation into account where pyritic soils will be disturbed by construction is discussed in Section .

CHAPTER NO 3
EXPERIMENTAL PROGRAM

3.0 Materials

The Materials used for the manufacturing of Ordinary concrete and Fiber reinforced concrete and properties of various materials used in the investigation are determined by as per recommendations of BIS in the following paragraph,

3.1 Cement

The shree ultra 43 grade cement(OPC) of one batch was procured in the laboratory. The determination of physical properties of the cement is carried out in laboratory is explained briefly in the following paragraph.

The chemical properties of cement were determined by Shreeram Testing institute, Delhi by using spectrophotometer

Table 3.1 Physical characteristics of cement

Sr.No	Properties	Referred Code	Value	Codal Requirement
1	Fineness (cm^2/g) by Blains apparatus	IS:4031(P-2)-1999	2950	222 Min
2	Specific Gravity		3.2	-
3	Soundness	IS:4031(P-3)-1988	1.8	30
4	Normal consistency		29.5	30
5	Initial Setting Time (min)	IS:4031(P-5)-1988	30	-
6	Final Setting time (min)		225	600 Max

Table 3.2 Chemical Properties of Cement

Sr No.	Chemical compound/parameter	Value (%)
1	Loss of ignition	2.05
2	SiO_2	20.84
3	Al_2O_3	3.85
4	Fe_2O_3	5.4
5	CaO	62.44

6	MgO	1.4
7	SO_3	4.16
8	Free Lime	1.49

3.2 Fly Ash

The Fly ash was procured from Indraprath power plant, Delhi. It was collected from bottom of the boiler The physical and chemical properties of fly ash were determined shown in following table No.3.3.and 3.4

Table 3.3 Physical Properties of Fly ash

Sr, No	Properties	Apparatus used	Value Obtained
1	Specific Gravity	By density bottle	3.12
2	Density	Core cutter	17 kN/m3
3	Fineness	Blain apparatus	6500 cm^2 /gm
4	Natural water content	Oven drying	8 %

Table 3.4. Chemical Characteristics of Fly ash

Sr No	Chemical Parameter	Chemical Composition (%)
1	SiO_2	20.84
2	Al_2O_3	3.85
3	Fe_2O_3	5.4
4	CaO	62.44
5	MgO	1.4
6	SO_3	4.16
7	K_2O	1.64
8	Na_2O	0.37
9	Tio2	2.08
10	Loss of Ignition	1.71

3.3 AGGREGATES

A Aggregates are the important constituent in concrete. They give body to the concrete , reduce shrinkage and effect economy. The mere fact that the aggregate occupy 70-80 per cent of volume of concrete, their impact on various characteristics and properties of concrete is undoubtedly considerable.

3.3.1 Coarse aggregates. For this study the natural coarse aggregate was used two test, namely specific gravity and Sieve analysis for gradation, were performed.

(A) Specific Gravity using Pycnometer is given by expression

Specific gravity = $(W_2 – W_1) / ((W_2- W_1)-(W_3 – W_4).)$

= (873 - 555) / ((863 -555) – (1847 - 1651))

= 3.633

Where,

W_1 = Wt. of empty Pycnometer = 555 gm

W_2= Wt. of Pycnometer + Wt. of oven dried sand = 873 gm

W_3 = Wt. of pycnometer + sand + water = 1847 gm

W_4= wt. of Pycnometer + water. = 1651 gm

(B) Sieve Analysis

Table 3.5 Sieve Analysis of Aggregate

IS Sieve Size	Wt. Retained kg	Cumulative Wt. Retained kg	Cumulative percentage .Retained	Cumulative percentage passing
20 mm	6	6	40	60
10 mm	5	11	73.3	26.7
4.75 mm	4	15	100	00
2.36 mm	--	--	100	00
1.18 mm	--	--	100	00
600 micron	--	--	100	00
300 micron	--	--	100	00
150 micron	--	--	100	00
	Σ 15 kg		Σ713.33	
Fineness Modulus = (7133.33/100) = 7.133				

3.3.2 Fine aggregate : For this study Badarpur sand was used as a fine aggregate. Test for specific Gravity, silt content, sieve analysis and bulking of sand were performed, All test result on aggregates are follows,

(A)Sand

(a)Specific Gravity using Pycnometer is given by expression

Specific gravity = $(W_2 - W_1) / ((W_2 - W_1) - (W_3 - W_4).)$

= (873 - 555) / ((863 -555) – (1847 - 1651))

= 2.633

Where,

W_1 = Wt. of empty Pycnometer = 555 gm

W_2= Wt. of Pycnometer + Wt. of oven dried sand = 873 gm

W_3 = Wt. of Pycnometer + sand + water = 1847 gm

W_4= wt. of Pycnometer + water. = 1651 gm

(B)Bulking of sand

The bulking of fine aggregate was determined in laboratory using measuring jar, the result obtained is given in table No 3.6

Table 3.6 Observation Table of Bulking of Sand

% of water	Initial Reading (h1)	Final Reading (h2)	Volume of Bulking (H1–h2)/h1 x 100
5 %	200	215	6.97 %
10 %	200	220	9.09 %
15 %	200	195	2.56 %
20 %	200	150	1.33 %

(C)Silt content test.

The silt content of fine aggregate was determined as shown in Table NO.3.7

Table 3.7 Silt content Test

Sr.No.	Silt above Sand height Sand	Sand height below silt	Silt Content
1	2 ml	55	(2/55)x100 =3.6%

(D) Sieve analysis

Sand sample :- Wt of sample 1000 gm

Table 3.8 : Recommended Grading for coarse and fine aggregate from natural sources for concrete as per IS : 383-1970

Sr. No	IS Sieve Size in mm	Percentage passing for				Sand Sample
		Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV	
1	10	100	100	100	100	100 %
2	4.75	60-95	90-100	90-100	90-100	100 %
3	2.36	30-70	75-100	85-100	95-100	100%
4	1.18	35-59	55-90	75-100	90-100	87.5%
5	0.600	15-34	60-79	80-100	80-100	66.50 %
6	0.300	5-20	8-30	12-40	15-50	26.40%
7	0.150	0-10	0-10	0-10	0-15	3 %

The grading of fine aggregate used was found to be Zone III As per IS : 383-1970

Table 3.9 Grading of fine aggregate

Wt of sample	Sr.No.	Sieve Size	Wt. Retained	Wt. Passed	% age Passing	Requirement of Zone III Type
1000 gm	1	10 mm	0	1000	100 %	100%
	2	4.75 mm	0	1000	100 %	90-100
	3	2,36 mm	0	1000	100 %	85-100
	4	1.18 mm	122	878	87.8 %	75-100
	5	600 micron	213	665	66.50 %	60-100
	6	300 micron	401	264	26.40 %	12-40
	7	150 micron	234	30	3 %	0-10

3.4 Fiber

The Polypropylene fiber was procured from fairmate chemical Pvt. Ltd, Vadodara, Gujrat. The properties of Polypropylene fiber are given in table No 3.10

Table 3.10 Properties of Polypropylene fiber

Sr. No	Particular	Form / value
1	Specific gravity	1.4
2	Aspect ratio	60 to 70
3	Alkali content	Nil
4	Sulfate content	Nil
5	Air Entrainment	Air content of concrete will not be significantly uncreased
6	Fiber thickness	18 to 30 microns
7	Fiber length	12 to 6 mm
8	Young's modulus	5500 to 7000 Mpa
9	Tensile strength	350 N/mm2
10	Melting point	160°C

3.5 Water and Acid

water for curing of concrete was normal portable water and it was free form organic and suspended impurities. Water used was free of any odour and conformed to recommendations of IS : 456-2000.For acidic environment a dilute solution of H_2SO_4,of 0.2 N normality, was used.

3.6 Admixture :

Superplasticizer admixtures procured from the fosroc chemical Ltd. was used in the study. The amount of superplasticizer used was 1.5% of the weight of cement.

3.7 Mix DESIGN

According to IS:456:2000 and IS: 1343-1980 the design of concrete mix should be based on the following factors:

- ✓ Grade of designation
- ✓ Types of Cement

- ✓ Maximum nominal size of aggregates
- ✓ Grading of combined aggregates
- ✓ Water- Cement ratio
- ✓ Workability
- ✓ Durability
- ✓ Quality control.

As with any other type of concrete, the mix proportions for FRC depend upon the requirements for a particular job, in terms of strength, workability, and so on. Several procedures for proportioning concrete mixes are available, which emphasize the workability of the resulting mix. However, there are some considerations that are particular to FRC.

In general, FRC mixes contain higher cement contents and higher ratio of fine to coarse aggregate than ordinary concretes, and so the mix design procedures the apply to conventional concrete may not be entirely applicable to FRC. Commonly, to reduce the quantity of cement, up to 30% of the cement is replaced with fly ash. In addition, to improve the workability of higher fiber volume mixes, water reducing admixtures and, in particular, Superplasticizer are often used, in conjunction with air entrainment.

A particular fiber type, orientation and percentage of fibers, the workability of the mix decreased as the size and quantity of aggregate particles greater than 5 mm increased; the presence of aggregate particles less than 5 mm in size had little effect on the compacting characteristics of the mix. Figure 3.1 shows the effects of maximum aggregate size on workability.

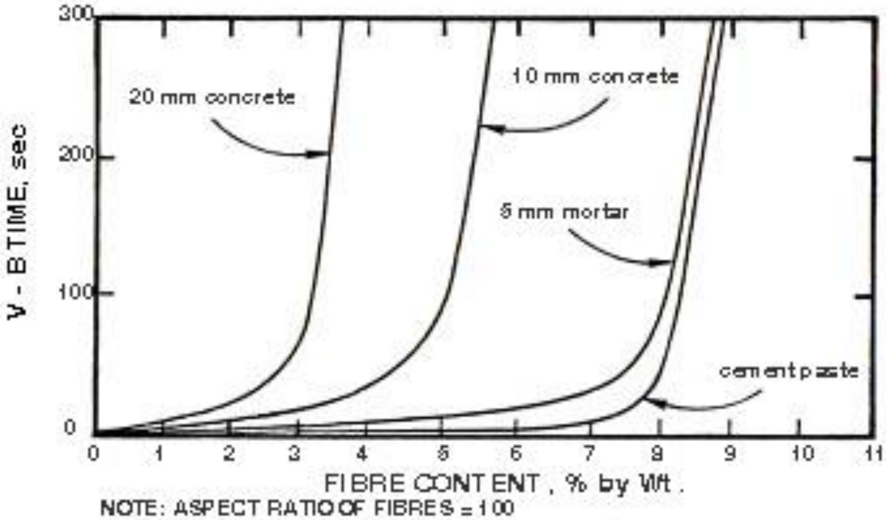


Figure 3.1 Workability versus fiber content for Matrices with different maximum aggregate size

Ref:- Nguyen Van chanh, "The Workability of fiber reinforced concrete" ASCE journal,1990,pp45-51.

The second factor which has a major effect on workability is the aspect ratio (*l/d*) of the fibers. The workability decreases with increasing aspect ratio, as shown in figure 3.2, In practice, it is very difficult to achieve a uniform mix if the aspect ratio is greater than about 100.

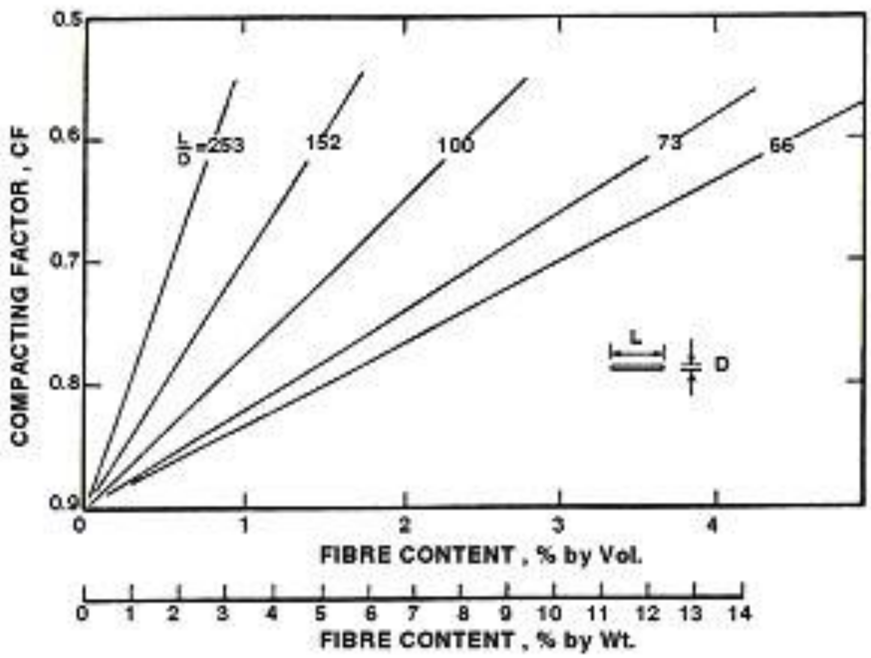


Figure No 3.2 ; Effect of fiber aspect ratio on the workability of concrete, as measured by the compacting factor

Ref:- Nguyen Van chanh, “The Workability of fiber reinforced concrete” ASCE journal,1990,pp45-51.

3.7.1 Mix design calculation

1) Design stipulations:

   Compressive Strength = 30 Mpa

   Degree of workability =0.80

   Degree of quality control = Good

   Types of Exposure = Mild

2) Test Data for materials

   Cement Specific .Gravity =3.2

   Sp. Gravity of coarse =2.67

   Sp gravity of fine sand=2.7

3) Target mean Strength = fs + K*S

   = 30+ 6.5*1.65

   =38.25

4) Water cement Ratio- = from graph of SP-23-1982

The w/c ratio for 38.25 Mpa is 0.42 < 0.65

5) Selection of water content= from tables and graph of grading zone III of sand the water content is 180 kg + Adjustment
   = 180 + 5.22 = 185 kg
6) Cement content = W/C ratio is 0.42

   Cement = 185/0.42

   = 440 Kg
7) Determination of coarse and sand content= Taking 2% of amount of air in the wet concrete.

   V=(W +(C/SP.G) + (1/p)*(FA/Sp.G)) * (1/1000)

   FA=342.95 KG

   AND CA = 1201.3 KG

Table 3.11 The final mix proportion taken for ordinary concrete mixes.

Properties	Cement	W/C ratio	Coarse aggregate	Fine Aggregate	Fiber Volume Fraction	Admixtures
Mix	440 kg /m	0.43	1201.1	342.95	0.5 % and 1 %	1.5 % wt.of cement

3.8 Test Procedure

The test specimens were de-moulded after 24 hours at room temperature, cured in a water bath at a temperature of 20 ± 2^0C and then tested after 7 day , 28 day and 90 days immersion.

Control specimens (without fiber i.e. ordinary concrete specimen) were also made for carrying out comparison of compressive strength tests and tensile strength. All the specimen were compacted by table vibration.

After the specimen were De-moulded, after 24 hours the specimens were immersed in 0.2 N sulfuric acid Solution. All the solutions were prepared by adding concentrated acid to tap water. The *pH* levels of the solutions were monitored weekly with a portable *pH*-meter of the type WTW pH 597, and concentrated acids were added to maintain the *pH* values at the stated tolerances. During pH monitoring, a wooden blade was used for mixing each of the solutions thoroughly. All solutions were renewed time to time.

At least six specimens of cube (150mm x150mm) and six specimen of cylinder having (150mm dia. x 300mm long) were tested for each grade of concrete in two curing environment (i.e. acid and water)for 7 day,28 day and 90 days., All the tests reported here were carried out at the same constant accuracy and Procedures. Preparation of sample is shown in table no.3.12

Table 3.12 Preparation of various kind of sample

Sr No	Designation	No of sample Taken		
		Cube (150x150x150mm)	**Cylinder (150mm diax 300 Height)**	**Prism (100 mmx 100mmx 500mm)**
1	P	18	18	12
2	P1	18	18	12
3	P2	18	18	12
4	PF	18	18	12
5	PF1	18	18	12
6	PF2	18	18	12
		Total 288 No of sample casted		

3.9 Experimental set-up and Test Procedure :-

All concrete mixes were made as per Indian Standard codal guidelines.

- All Instruments are calibrated before the one day of actual testing day particularly in NDT test such as Rebound Hammer Test and UPVT.
- Type **FAIREFIBER** Polypropylene fiber 18 to 30 micron of diameters were used. Fairmate Polypropylene fiber were used in volume fraction of 0.5 % and 1%.
- The cement matrix was mixed with fiberswith 0.43 water cement ratio. When cement was added to the water and mixed,the fibers were sprinkled randomly into the cement matrix and after 3 minutes, mixing was completed. All specimens were made in steel moulds.

3.10 Test on fresh Concrete

3.10.1 Workability Test - Workability are carried out by conducting the slump test, compaction factor test and cone penetration test on ordinary concrete and FRC .The Workability Test results are shown in Table No 3.13

Table 3.13 Workability Test on Concrete

Sr .No	Slump test	Compaction Factor	Cone penetration in mm
P	40	0.82	126
P1	46	0.80	118
P2	48	0.83	112
PF	44	0.81	98
PF1	47	0.78	85
PF2	50	0.82	70

3.11 Test on Hardened concrete

3.11.1 Mass Test: The mass test was performed on cube size 150x150x150 mm. The Electronic balance was used to determined the mass of cube samples of six grade of concrete. The details of test results is given in test result chapter 4

3.11.2 Rebound hammer Test

The rebound hammer was carried on the cube sample and rebound number was correlated with the compressive strength of concrete. The details of rebound number is given table No 4.2

3.11.3 Ultra sonic Pulse Velocity Test:

Suggested Values of UPVT as per IS : 13311 –Part I are shown in Table No. 3.14 .UPVT results of this study are provided in Table No. 4.7 of chapter No. 4

Table 3.14 Velocity criteria for concrete quality grading (As per IS : 13311 – Part I)

Ref:- Concrete Technology by M.S Shetty and Gambir.

Pulse Velocity	Concrete Quality control
4575	Excellent
3660 – 4575	Good
3050 – 3660	Questionable
2135 – 3050	Poor
2135	Very Poor

3.11.4 Compressive Strength Test : The compressive strength of concrete is one of most important properties of concrete in most structural applications concrete is employed primarily to resist compressive stresses. Cube of 150x150x150mm size were used to determine the compressive strength of the normal and FRC concrete the mix design we taken for the M30. The test result came from the 7 ,28, and 90 days are given in table no 4.5.

3.11.5 Spilt Tensile Strength :

Split tensile strength test of concrete cylinder was conducted as per Indian Standard Specification. The spilt tensile strength is carried on the cylinder , and result obtained given in table No 4.6.

3.11.6 Flexural Strength Test The determination of flexural tensile strength is conducted to estimate the load at which the concrete members may crack. The modulus of rupture is determined by testing standard test specimens of 100 mm x 100 mm x 500 mm over a span of 400 mm, under the symmetrical two point loading. The details of test result obtained is given in table No 4.7

CHAPTER NO : 4

RESULTS AND DISCUSSION

On the basis of the experiments conducted on ordinary concrete and FRC concrete various results obtained are presented below. Results of test conducted on materials have been presented in chapter 3

4.1 Results discussion on the workability Test

Slump test, compaction factor test and cone penetration test were conducted on all concrete mixes in the fresh state. The results are shown in following tables

Table 4.1 Workability Test on Concrete

Sr .No	Slump test	Compaction Factor	Cone penetration in mm
P	40	0.82	126
P1	46	0.80	118
P2	48	0.83	112
PF	44	0.81	98
PF1	47	0.78	85
PF2	50	0.82	70

Table 4.2 – Cone penetration reading table

Wt. Applied	Cone penetration reading in (cm)											
	P		P1		P2		PF		PF1		PF2	
	30^0	45^0	30^0	45^0	30^0	45^0	30^0	45^0	30^0	45^0	30^0	45^0
1 kg	3.6	4.9	3.4	4.2	3.0	4.6	3.3	4.9	3.3	4.1	3.25	4.0
2	5.1	6.2	5.6	5.4	5.3	6.1	5.4	6.2	4.9	5.8	4.1	6.3
3	5.7	8.7	5.8	7.9	5.3	8.6	5.6	8.7	5.2	7.8	5.4	8.3
4	6.8	12.5	6.6	11.8	6.3	11.5	6.5	12.5	6.1	11.2	6.3	11.4
5	7.2	10.5	7.5	12.5	7.2	10.9	7.4	10.5	7	11.6	7.2	11.5
6	7.6	9.8	7.6	9.6	7.5	10.1	7.8	9.8	7.3	10.2	7.5	11.9
7	8.3	12.1	8.1	12.4	8.6	12.2	8.5	12.4	8.0	12.8	8.3	12.6
8	8.7	13.6	8.8	13.4	9.1	13.8	9.2	13.9	8.5	14.2	8.5	13.4
9	8.4	13.8	8.0	13.7	10.3	12.8	9.5	13.6	9.2	13.9	8.9	13.8
10	12.6	14.2	11.8	13.2	11.2	13.4	9.8	14.2	9.1	14.3	8.0	14.6

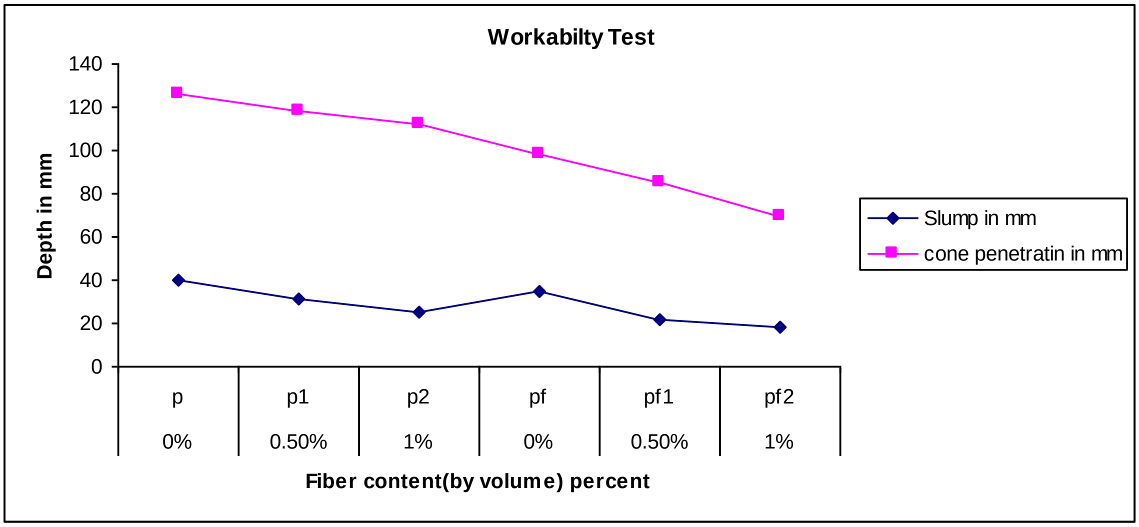


Fig 4.1 Variation of workability values with fiber content

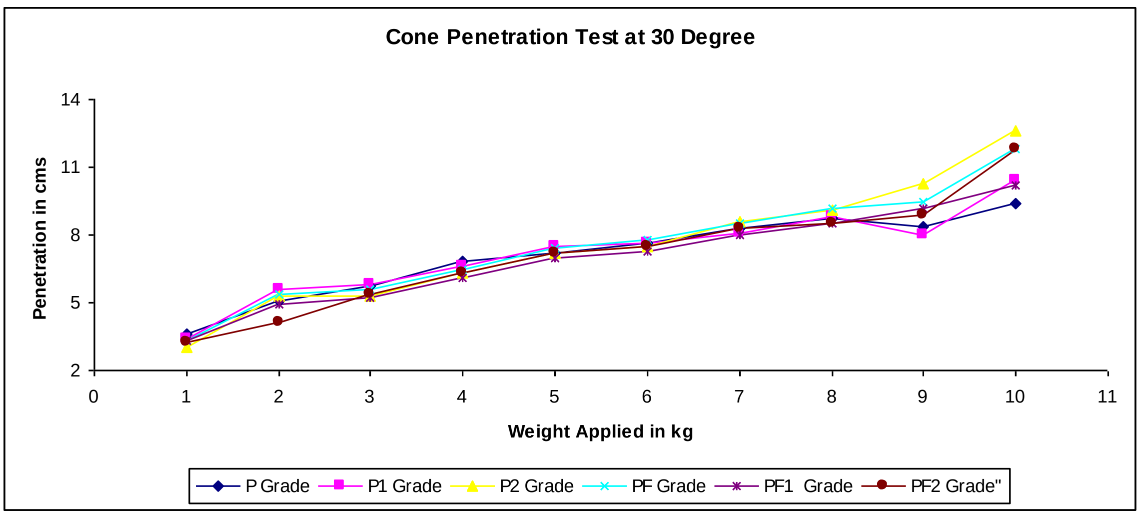


Fig 4.2 Cone penetration test

- All grades of FRC shows medium workable concrete. As the fiber content in concrete is increased , workability is decreased.
- As per workability test performed on FRC concrete it is found that, the Greater the aspect ratio, lesser the Workability of concrete

4.2 Mass Test

Results of mass test conducted on various mixes are shown in Table No. 4.3

Table 4.3:- Mass test for grade

Grade	Curing Type	Mass of Specimen in (gms)		
		7 Day	28 Day	90 Day
P	Water	8360	8370	8430
	Acid	7942	6947.5	4805.10
P1	Water	8253.3	8490	8535
	Acid	7758.10	6876	4950
P2	Water	8345	8330	8450
	Acid	7802.5	6830	4475
PF	Water	8246.5	8283	8350
	Acid	7916.5	6625	5427.5
PF1	Water	8390	8410	8480
	Acid	8012.5	7215.5	5251.50
PF2	Water	8380	8390	8420
	Acid	8005	7300	5055

Table 4.4 Percentage loss in mass test

Sr. No	Grade	Loss in Mass (%) exposed for		
		7 Day	28 Day	90 Day
1	P	5	17	45
2	P1	6	19	47
3	P2	7	20	40
4	PF	4	15	35
5	PF1	4.5	14	38
6	PF2	4.8	13.9	39.5

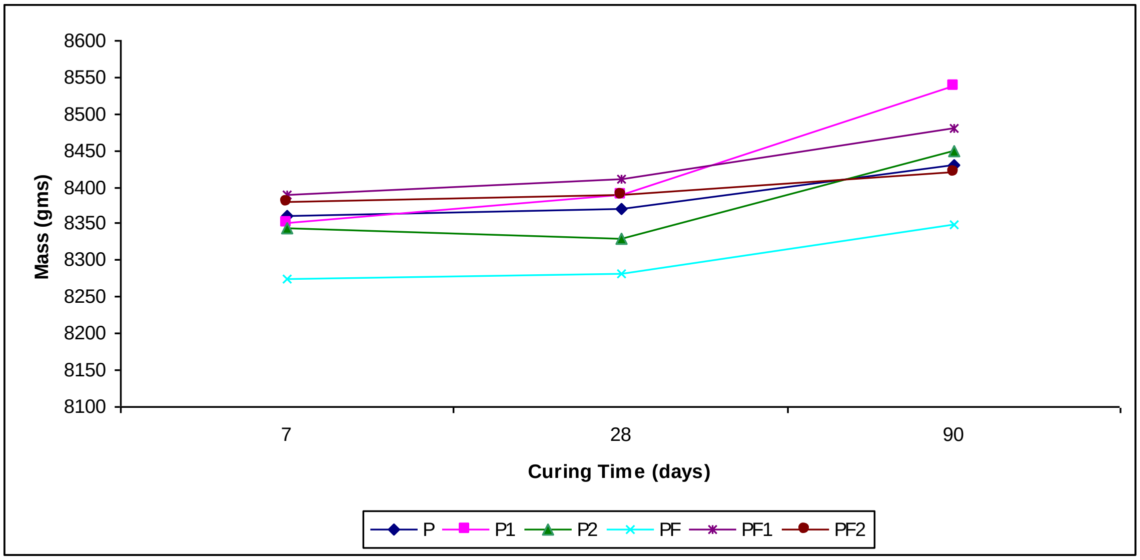


Fig 4.3. Variation of mass in ordinary concrete and FRC cured in water

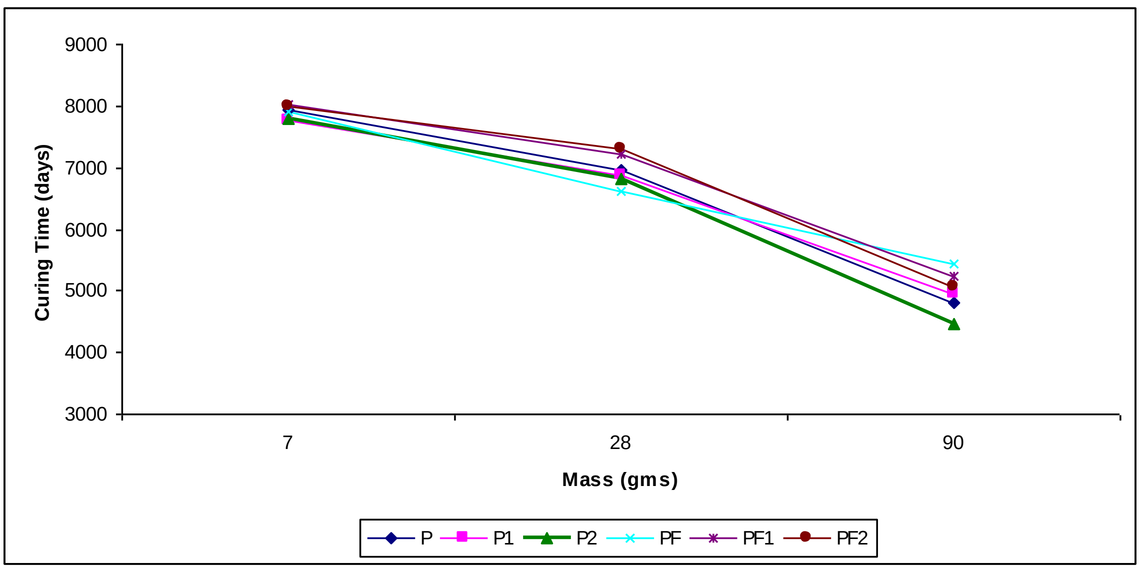


Fig 4.4. Variation of mass in ordinary concrete and FRC cured in Acid

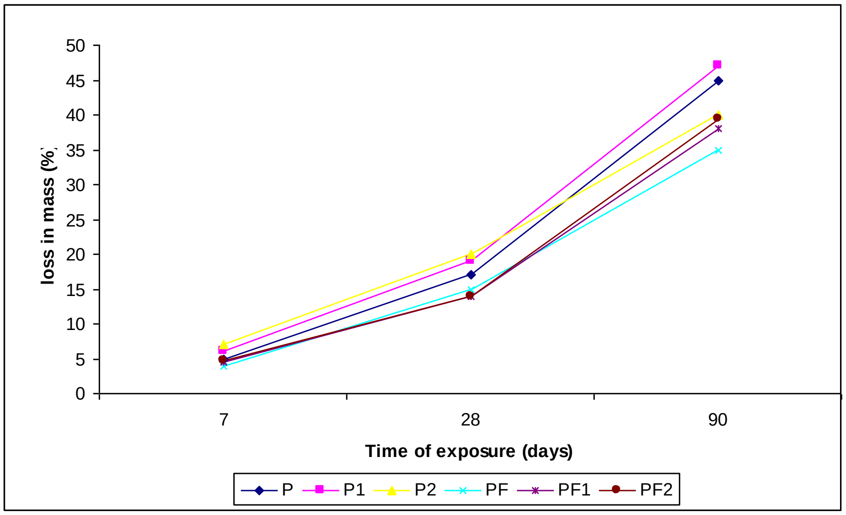


Fig 4.5 Variation in the percentage loss in mass of ordinary and FR concrete exposed to sulfuric acid of concentration of 0.2

4.3 Rebound Hammer Test

The compressive strength of concrete is increased with time so corresponding the rebound number i.e. hardness of the concrete is also increase up to a certain limit

Results of Rebound hammer tests are shown in Table No. 4.5

Table 4.5: Rebound hammer number table

Grade	Curing Type	Rebound Number		
		7 Day	28 Day	90 Day
P	Water	32.23	33	36
	Acid	31.2	30	28.8
P1	Water	30	34	36
	Acid	28.9	30.45	27
P2	Water	33	34	35
	Acid	31.50	29.5	26
PF	Water	29	31.66	35
	Acid	28.5	27.50	27.8
PF1	Water	31	34	35
	Acid	30	30.5	26
PF2	Water	29	31.1	34
	Acid	28.5	28	24.80

Table 4.6: Percentage-loss for rebound hammer Test

Grade	Percentage Loss(%) in Rebound Number		
	7 Day	28 Day	90 Day
P	3	9	20
P1	3.2	10.5	25
P2	4	12	30
PF	2.5	12.5	21
PF1	3	11	26
PF2	2.9	10.5	27

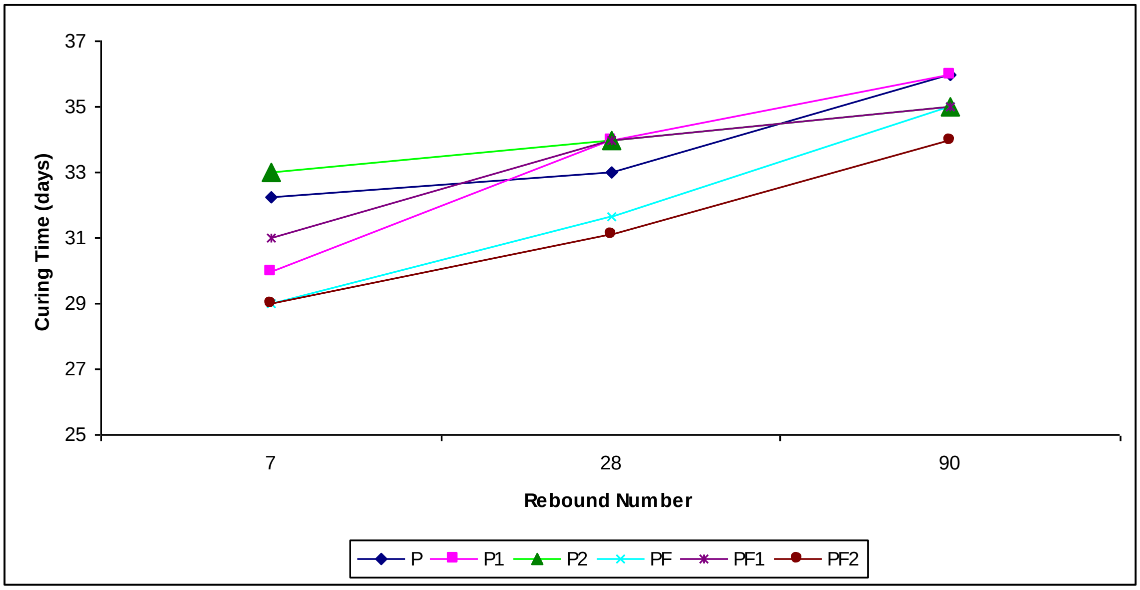


Fig 4.6 Variation of Rebound Number in ordinary concrete and FRC cured in water

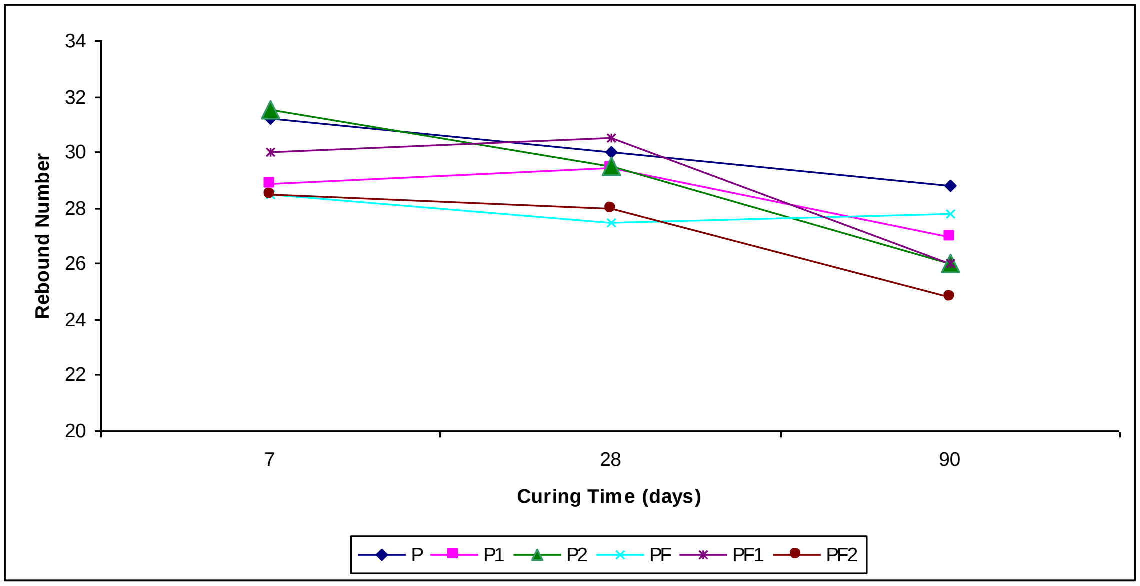


Fig 4.7. Variation of rebound number in ordinary concrete and FRC cured in acid

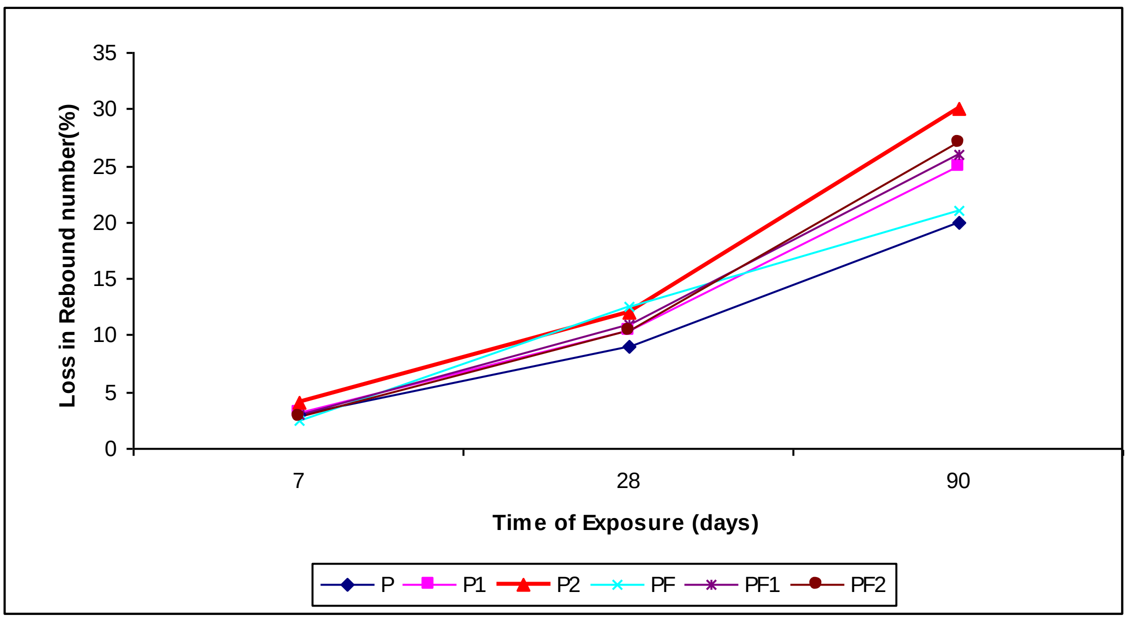


Fig 4.8 Variation in the percentage loss in Rebound Number of plain and FR concrete exposed to sulfuric acid of concentration of 0.2

4.4 Ultra Sonic Pulse Velocity Test

Results of UPVT conducted in the study are shown below

Table 4.7 : Ultra sonic pulse velocity test

Grade	Curing Type	Pulse Velocity in (m/sec)		
		7 Day	28 Day	90 Day
P	Water	3886.0	4054.05	3947.36
	Acid	3393.66	3243.24	2810.25
P1	Water	3571.42	4087.19	3947.36
	Acid	3209.92	3228.50	2980
P2	Water	3865.97	4109.58	3906.25
	Acid	3393.66	3185	3005
PF	Water	3846.15	3926.70	3649.63
	Acid	3363.28	3275	2995
PF1	Water	4032.25	3906.25	3750
	Acid	3694.58	3290	3037.5
PF2	Water	3906.25	3819.79	3750
	Acid	3625.56	3295	3135

Table 4.8 Percentage loss for UPVT

Grade	Loss in percentage (%) for		
	7 Day	28 Day	90 Day
P	12.66	20.5	25
P1	10.66	21.6	24.5
P2	12.21	22.5	23
PF	12.55	16.5	18
PF1	8.38	15.8	19
PF2	7.52	13.8	16.5

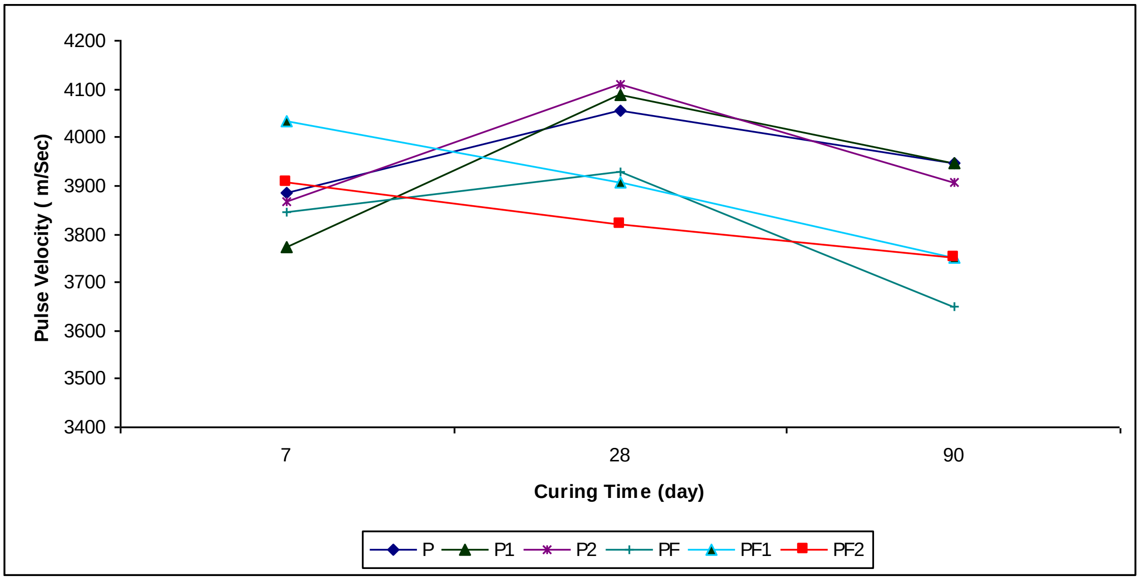


Fig 4.9 Variation of pulse velocity of ordinary concrete and FRC cured in water

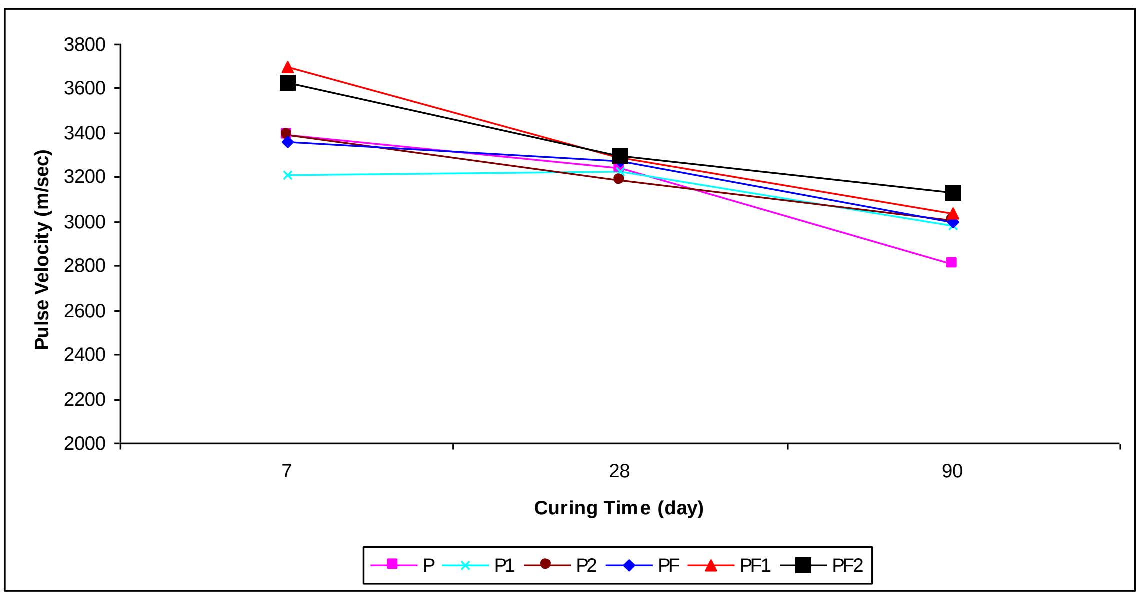


Fig 4.10. Variation of pulse velocity of ordinary concrete and FRC cured in acid

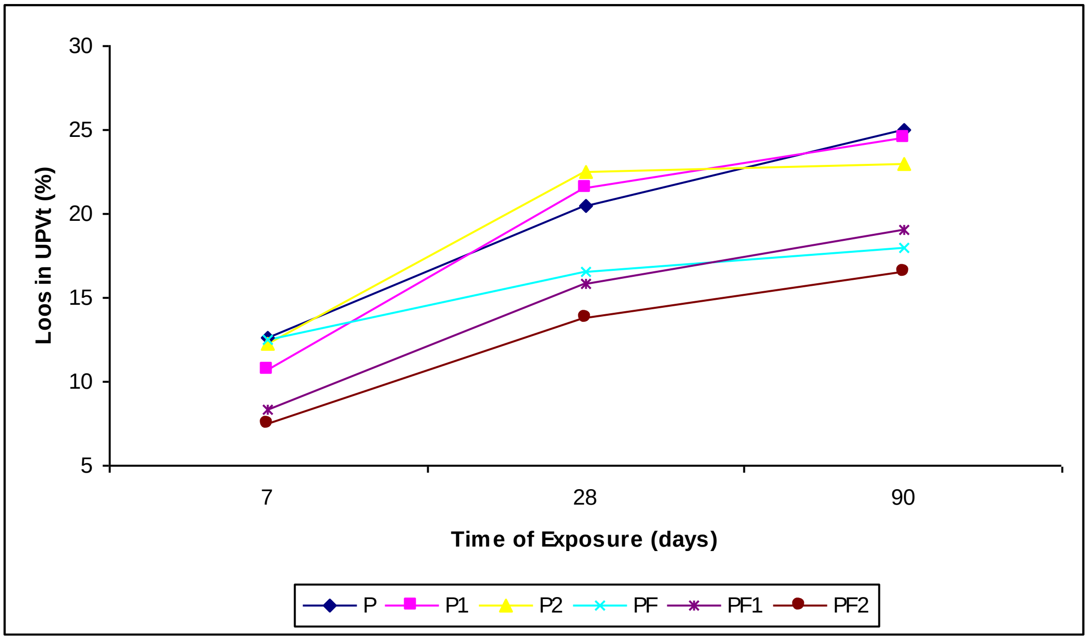


Fig 4.11 **Variation in the percentage loss in pulse velocity of plain and FR concrete exposed to sulfuric acid of concentration of 0.2**

4.5Compressive Strength Test

Compressive Strength: The average 28th day unconfined compressive strength for Ordinary concrete and FRC is found to be 33.4 and 38.6 Mpa. The maximum strength loss occurred in 90 days in ordinary concrete and FRC are 24 to 20 % respectively.

Table 4.9 Compressive strength test table

Grade	Curing Type	Compressive strength in (Mpa)		
		7 Day	28 Day	90 Day
P	Water	20	32.2	34
	Acid	18.2	25.77	26.1
P1	Water	20.8	33.6	35.3
	Acid	18	26.2	27.8
P2	Water	22.1	31.3	33.1
	Acid	20.1	26.292	26.48
PF	Water	23.1	36.7	38.6

	Acid	20.6	29.8	31.6
PF1	Water	24	38.2	39.4
	Acid	21	30.9	28.80
PF2	Water	22.3	35.6	37.4
	Acid	19.3	28.48	30.914

Table 4.10 Percentage loss in compressive strength

Specimen Type Grade	**Loss in compressive strength (%)**		
	7 Day	**28 Day**	**90 Day**
P	9	19.5	23.23
P1	13.46	21.02	22.24
P2	9.5	16	20
PF	10.32	18.30	19.76
PF1	12.5	20.36	20.90
PF2	13.45	20.5	21.5

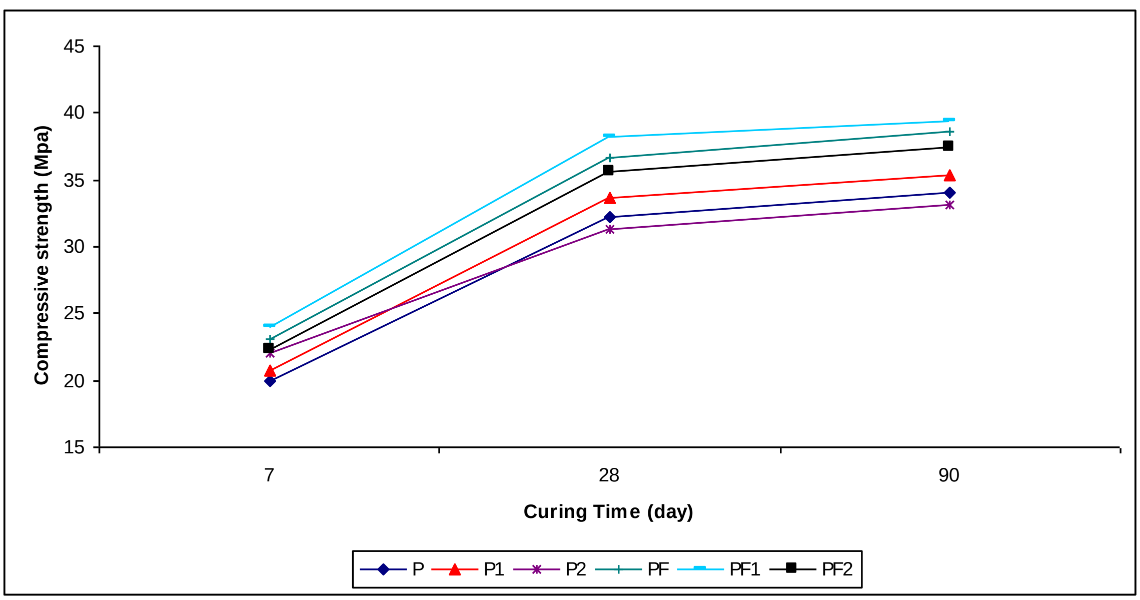


Fig 4.12 Variation of compressive strength of ordinary concrete and FRC cured in water

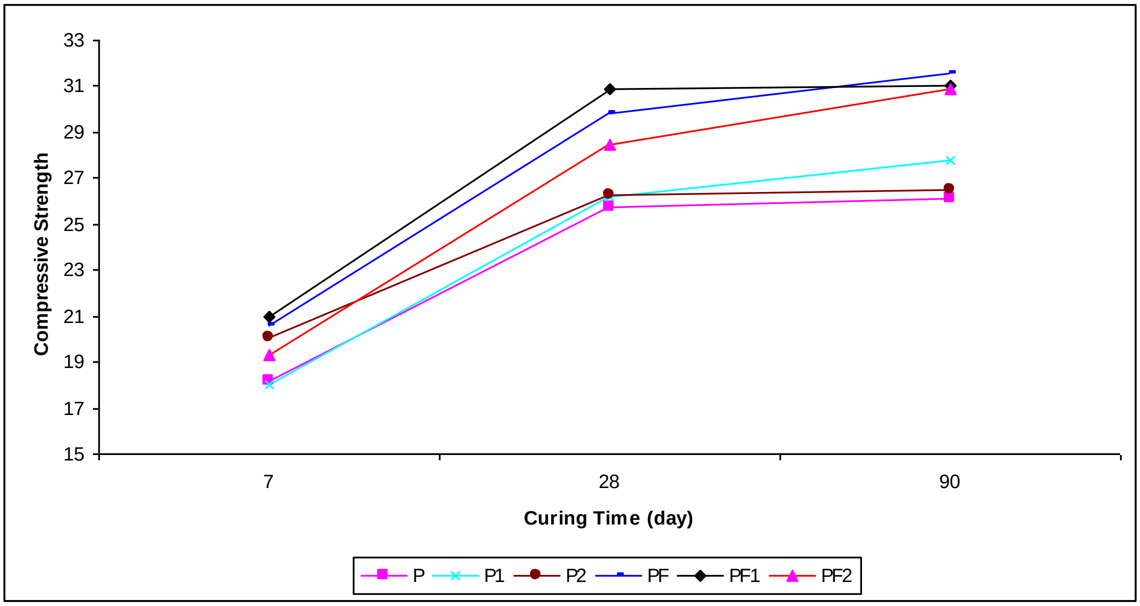


Fig 4.13. Variation of compressive strength in ordinary concrete and FRC cured in acid

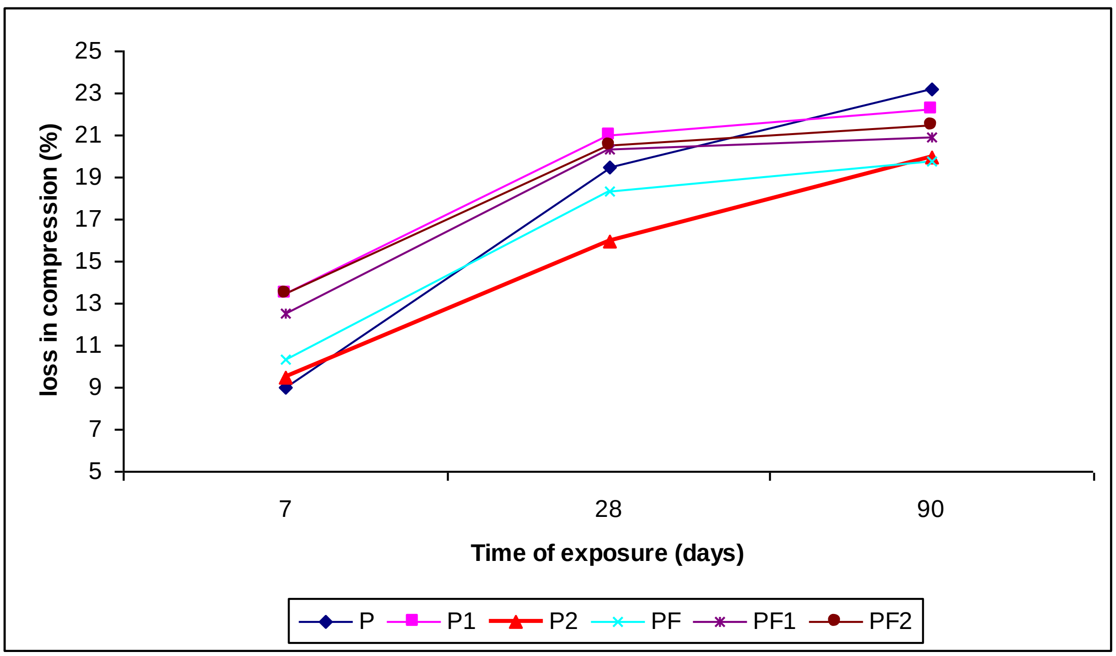


Fig 4.14 Percentage loss in compressive strength of plain and FR concrete exposed to sulfuric acid of concentration of 0.2

4.6Tensile Strength Test

The Addition of polypropylene fiber in concrete did not increase the tensile capacity of the concrete. Synthetic fibers, such as Polypropylene, have primarily been used in-concrete materials to control and reduce plastic shrinkage cracking.Results of split tensile strength test conducted on concrete specimen are shown in Table No. 4.11

Table 4.11 Tensile strength test table

Grade	Curing Type	Spilt Tensile Strength in (Mpa)		
		7 Day	28 Day	90 Day
P	Water	1.4	2.23	2.48
	Acid	1.248	1.675	1.69
P1	Water	1.47	2.38	2.50
	Acid	1.215	1.768	1.87
P2	Water	1.59	2.25	2.38
	Acid	1.36	1.93	1.98
PF	Water	1.75	2.78	2.93
	Acid	1.46	2.11	2.24
PF1	Water	1.7	2.82	2.91
	Acid	1.49	2.19	1.9
PF2	Water	1.65	2.63	2.76
	Acid	1.42	1.99	2.10

Table 4.12 : Percentage Loss occurred in Tensile strength

Specimen Type Grade	Loss in percentage (%) for		
	7 Day	28 Day	90 Day
P	10.85	24.88	23.54
P1	17.34	25.71	34.70
P2	14.46	20.22	23.91
PF	16.57	24.10	31.85
PF1	12.35	22.34	25.2
PF2	13.93	21.33	22.80

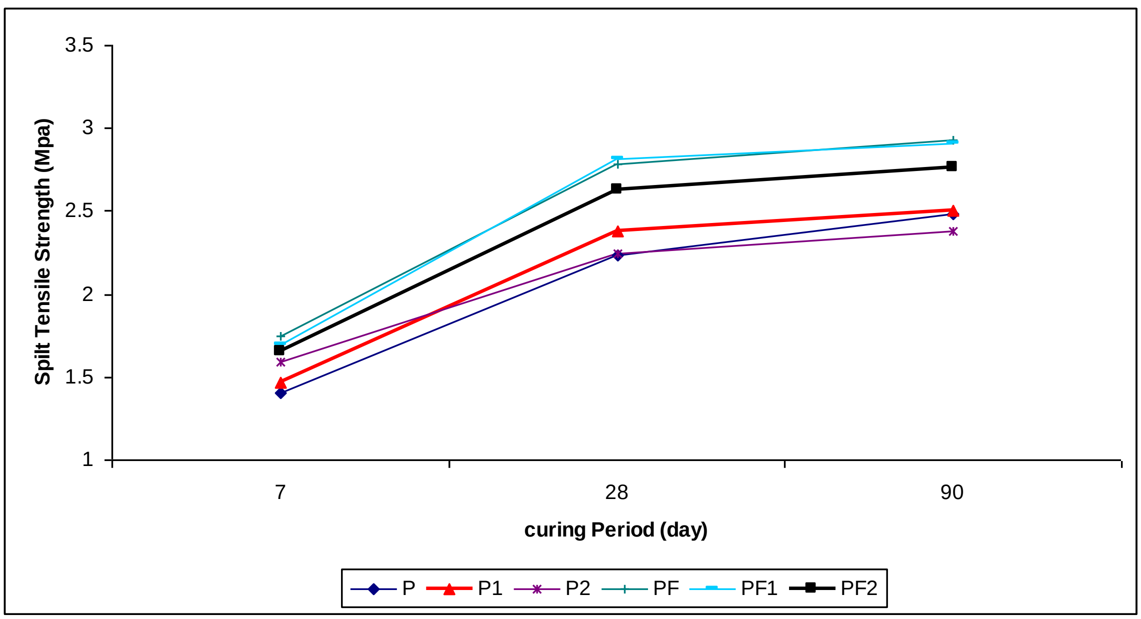


Fig 4.15 Variation of spilt Tensile strength in ordinary concrete and FRC,cured in water

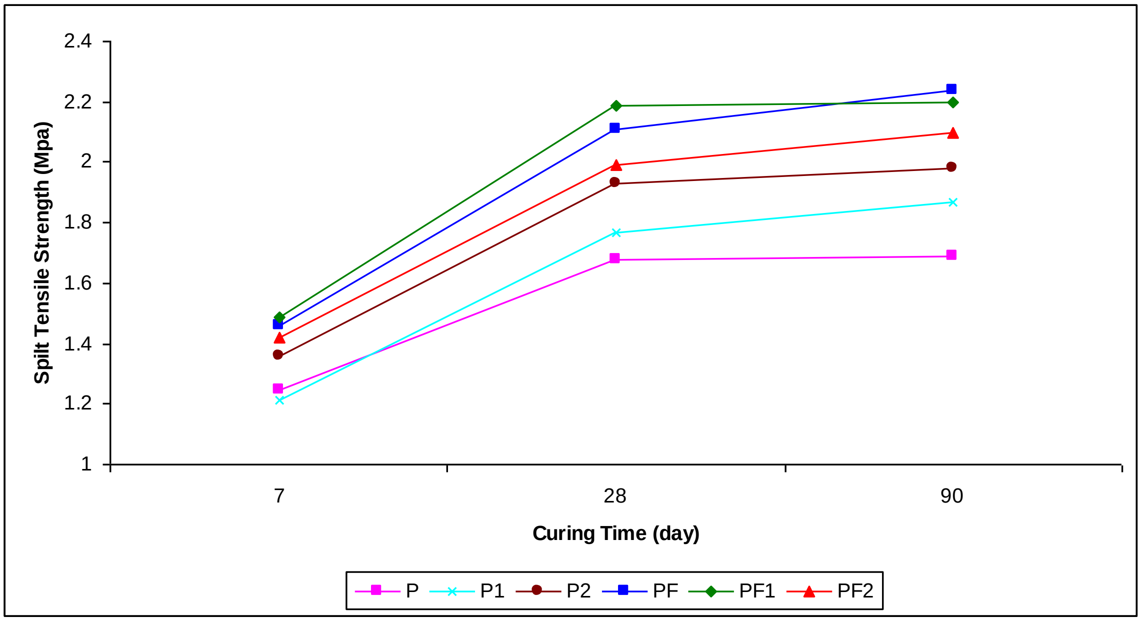


Fig 4.16. Variation of spilt tensile strength for ordinary concrete and FRC cured in acid

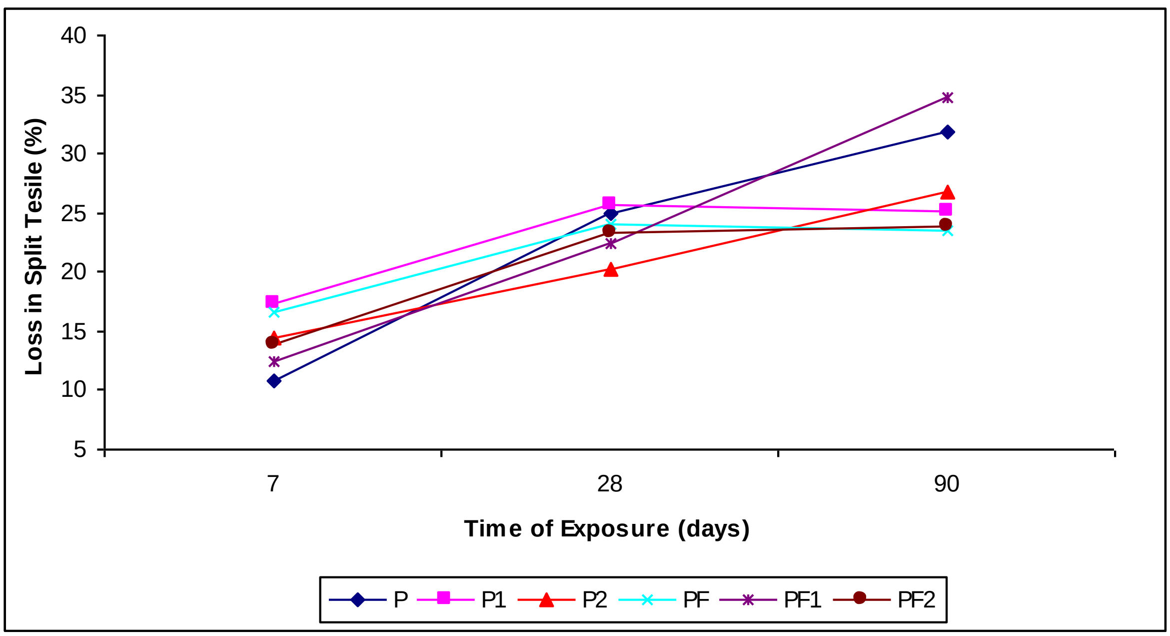


Fig 4.17 Variation in the loss in Tensile strength of plain and FR concrete exposed to sulfuric acid of concentration of 0.2

4.7 Modulus of rupture

Results of MOR Tests conducted are shown below,

Table 4.13 : Flexural Modulus test results

Grade	Curing Type	Flexural Modulus in (Mpa)		
		7 Day	28 Day	90 Day
P	Water	3.2	3.3	3.7
	Acid	2.95	2.8	2.81
P1	Water	3.4	3.45	3.75
	Acid	3	2.6	2.90
P2	Water	3.4	3.5	3.80
	Acid	3.15	3.5	2.89
PF	Water	3.5	3.7	4.2
	Acid	3.2	3.2	3.15
PF1	Water	3.6	3.65	4.10
	Acid	3.27	3.10	3.12
PF2	Water	3.2	3.5	4.30
	Acid	2.95	2.9	3.268

Table 4.14 Loss in percentage for flexural Modulus of concrete

Specimen Type Grade	Loss in percentage (%) for		
	7 Day	28 Day	90 Day
P	6.7	15	28
P1	9	16	24.6
P2	8.2	14	26.3
PF	8.4	13.5	25.23
PF1	8.9	15	23.5
PF2	7.2	17	20

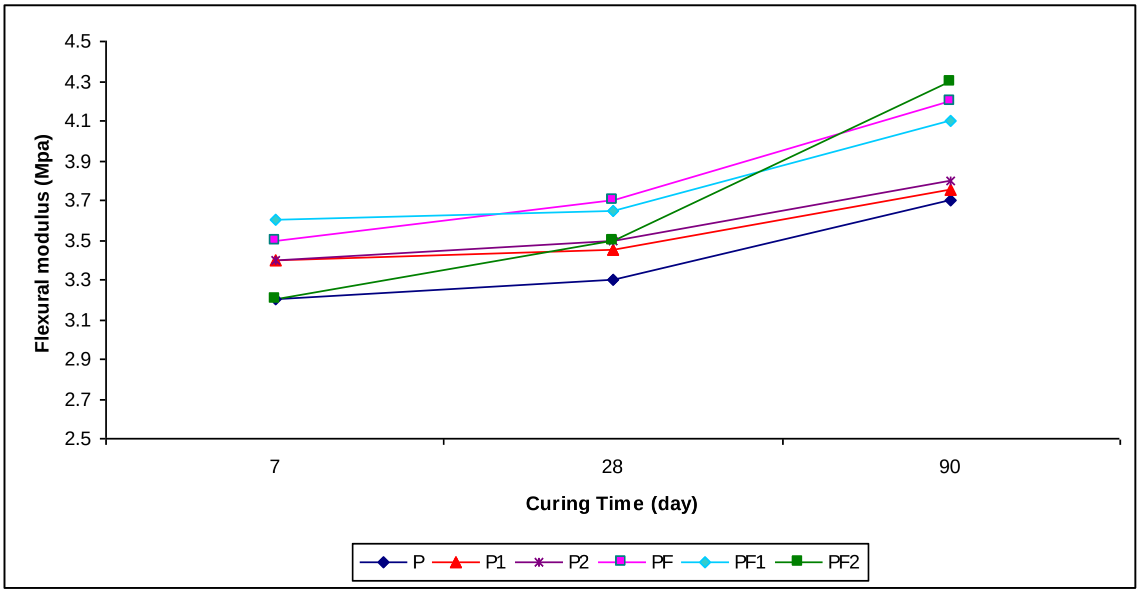


Fig 4.18 Variation of flexural Modulus of ordinary concrete and FRC cured in water.

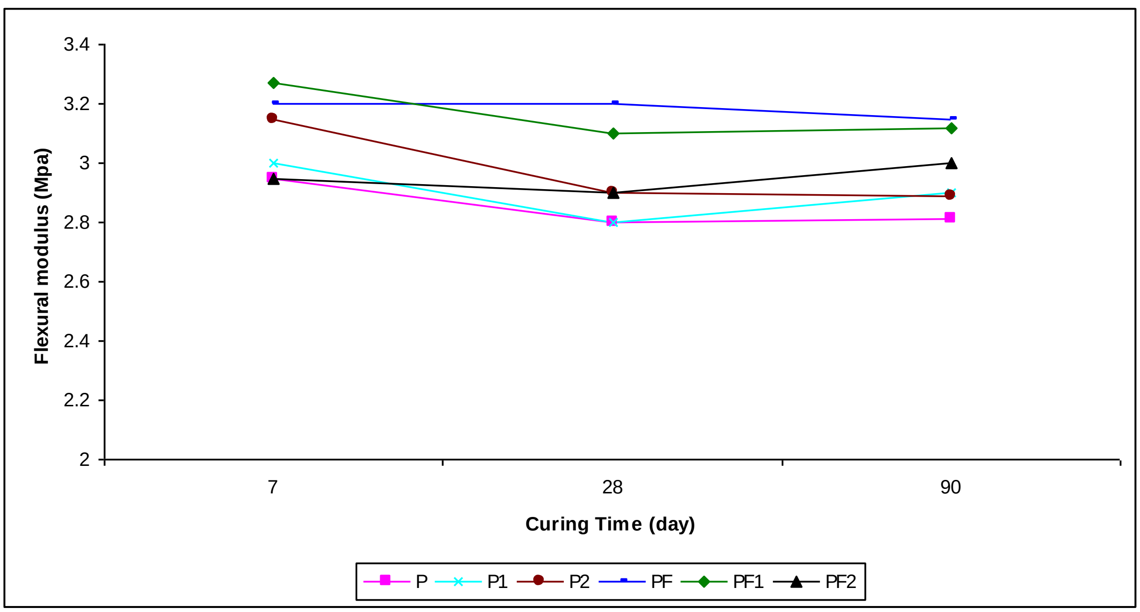


Fig 4.19. Variation of mass of ordinary concrete and FRC cured in acid

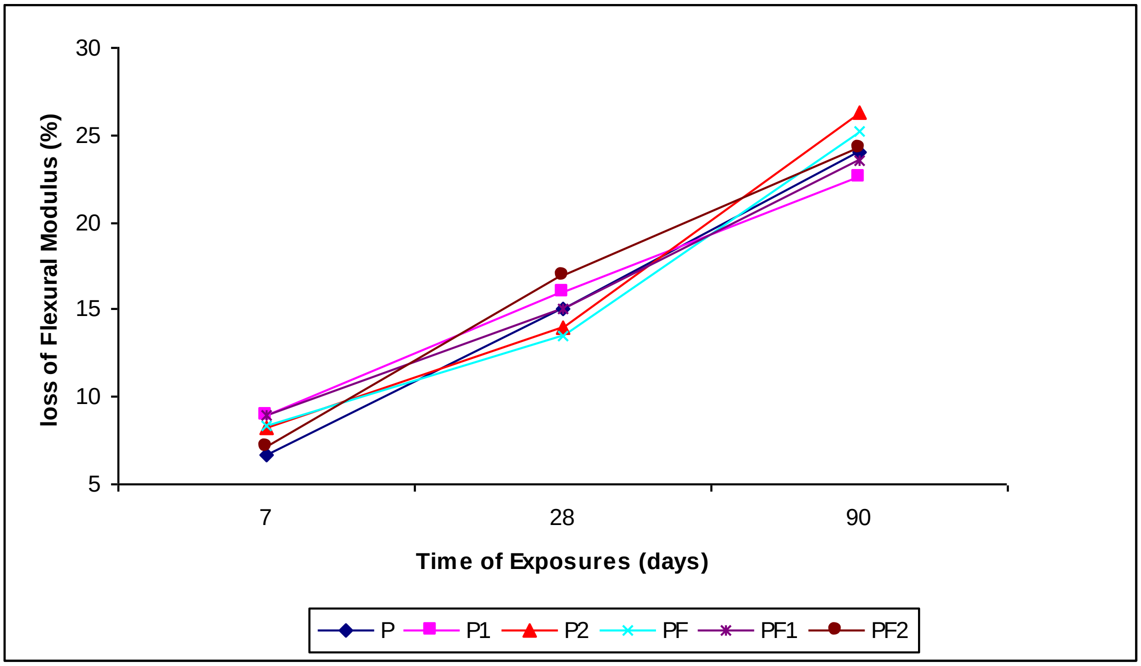


Fig 4.20 Variation in the percentage loss in Flexural modulus of plain and FR concrete exposed to sulfuric acid of concentration 0.2 N

4.8 RELATION BETWEEN ORDINARY CONCRETE AND FR CONCRETE

4.8.1 Relation between the compressive strength Vs Rebound Number

Correlation amongst compressive strength, spilt tensile strength, Modulus of rapture and rebound number, pulse velocity is carried out.

Following points are observed.

- The rebound number of concrete mixes is proportional to the compressive strength of concrete .The surface hardness of FRC mixes are improved due to addition of fibers and mineral additives

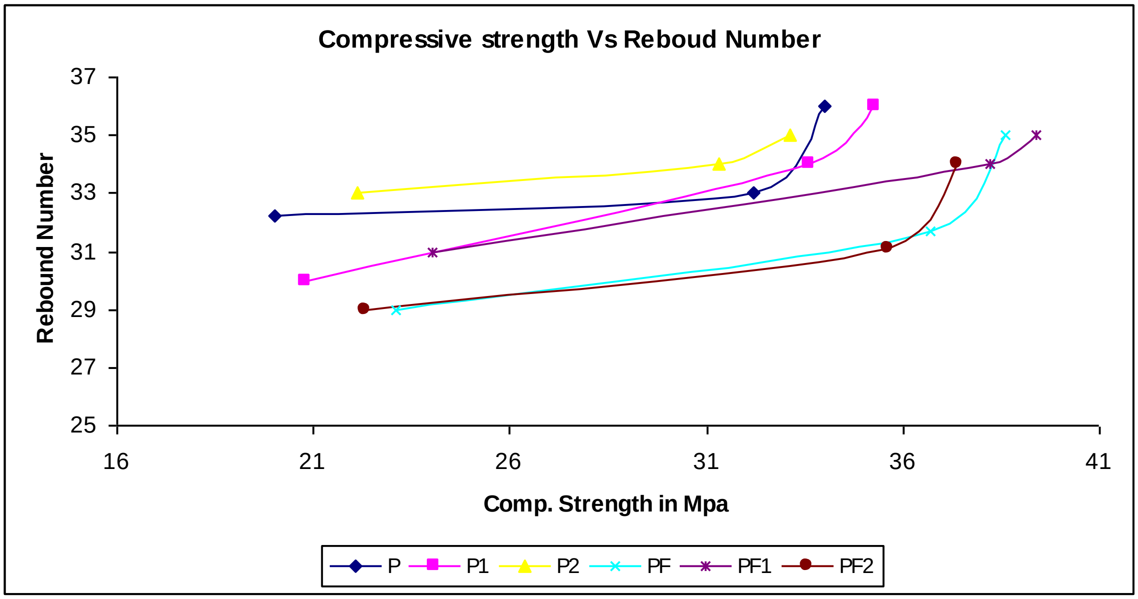


Fig 4.21 Relationship between the compressive Strength and Hardness No.

4.8.2 Relation between Compressive Strength and spilt tensile test

- The relationship of compressive strength Vs split tensile strength for various mixes are shown in Fig No.4.22

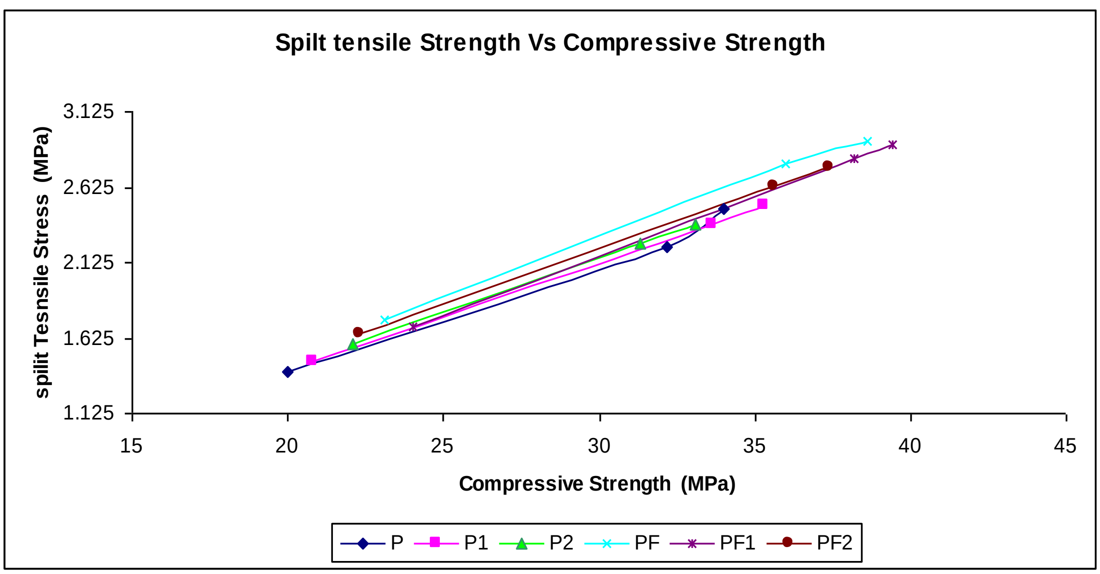


Fig 4.22 Relationship between the compressive Strength and spilt tensile Strength

4.8.3 Relation Between compressive strength Vs Modulus of Rupture

The relation between compressive strength vs MOR is shown in Fig.4.23 The normal concrete has found the less MOR in comparision to FR concrete

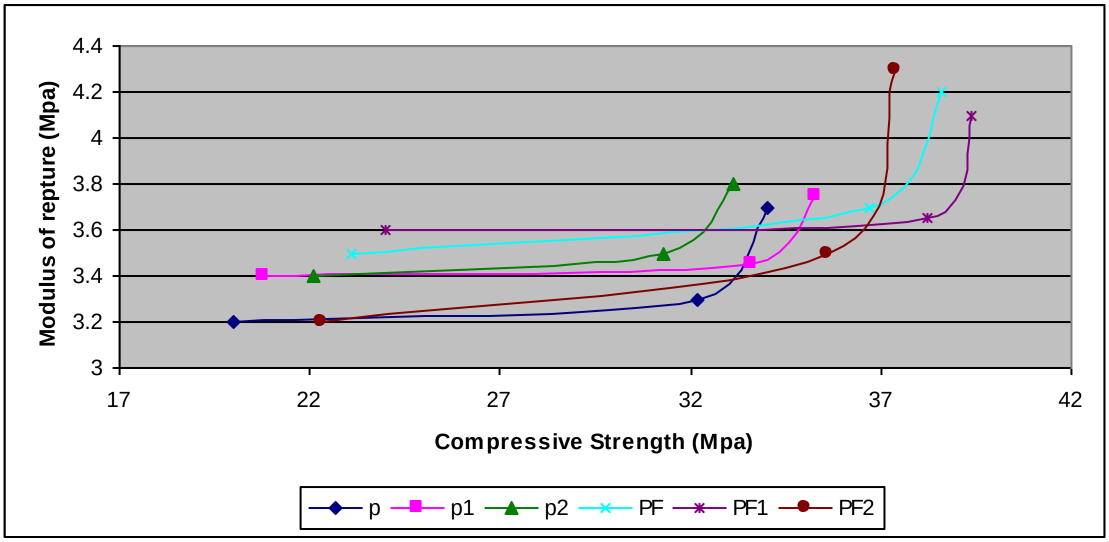


Fig 4.23 Relationship between the compressive Strength and modulus of rupture

4.8.4 Relationship of mass test Vs compressive strength

Relation between the mass and compressive strength of ordinary concrete and FR concrete, is shown in Fig no 4.24

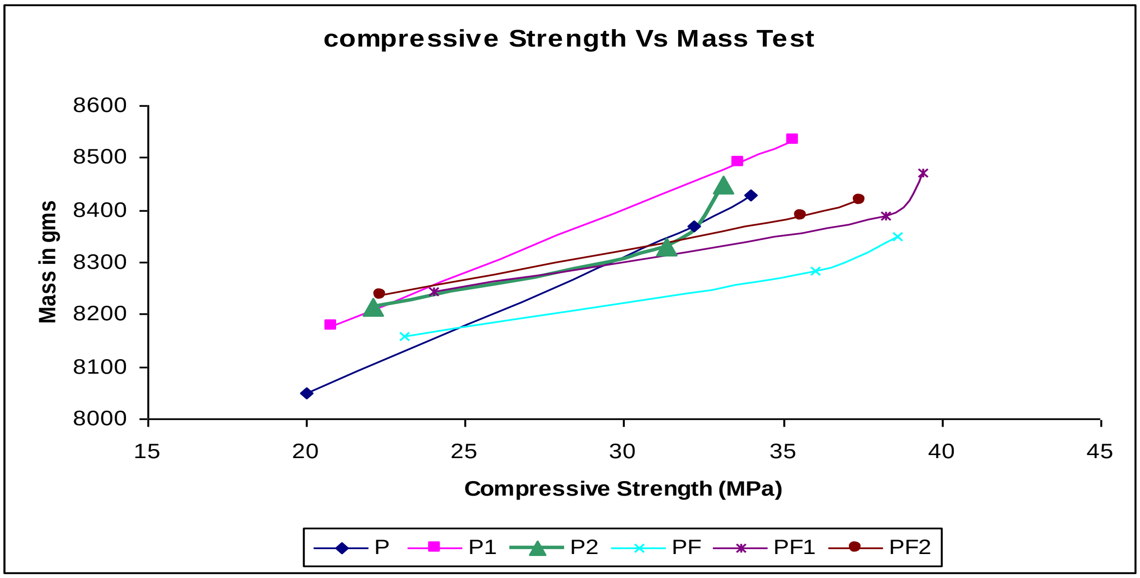


Fig No 4.24 : Relationship between the compressive Strength and Mass Test

4.8.5 Relationship of UPVT Test Vs Compressive strength

The relation of compressive strength and UPVT values is shown in fig NO 4.25

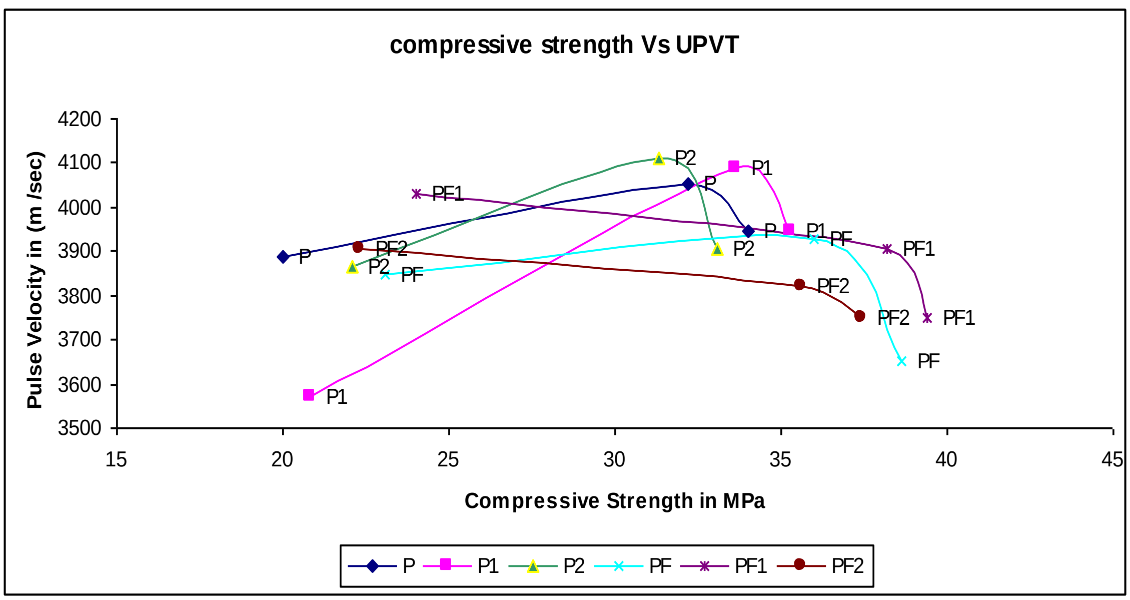


Fig 4.25 Relationship between the compressive Strength and pulse Velocity.

Chapter No. 5

CONCLUSIONS

This study was performed to understand the effect of addition of Fibers and mineral additives in concrete on the deterioration caused by sulfuric Acid (Acidic Environment) . The effects of the of sulfuric acid, concentration of sulfuric acid solution, use of mineral Admixtures (Fly Ash) and use of Polypropylene fiber on the deterioration of concrete were investigated.

FRC may be advantageous seeing to the following observations made in this study,

- The percentage loss of mass is found to be 40 to 45% for ordinary concrete and 30 to 35 % for FRC concrete at the same age. The critical grade are (P=45% and PF1=35%)
- The percentage loss of hardness is found to be 20 to 25 % in ordinary concrete and 15 to 20% un FRC concrete at the age of 90 days. The critical grade is (P=20% & PF2 =27 %)
- The percentage loss of UPVT values is found to be nearly 25% for a ordinary concrete and 16.5 % for FRC concrete at the same age. The critical grade are (P=25% and PF2=16.5%)
- The percentage loss of compressive Strength test is found to be 20 to 25 % for a ordinary concrete and 19 to 21 % for FRC concrete at the same age. The critical grade are (P=23.23 % and PF1=20.90 %)
- The percentage loss in Tensile strength is found to be 23 to 35 % for a ordinary concrete and 22 to 30.5 % for FRC concrete at the same age The critical grade are (P1=34.70% and PF2=22.80%)
- The percentage loss in MOR test is found to be 24 to 28% for a ordinary concrete and 20 to 25 % for FRC concrete at the same age. The critical grade are (P2=26.3% and PF2=20.0%)

2) The deterioration and the rate of deterioration of concrete caused by sulfuric acid depends upon the concentration of sulfuric acid solution.

3)When a part of cement is replaced with fly ash, the strength of concrete improves.

4) In concrete containing mineral admixture, the sulfuric acid attack is smaller than that of normal ordinary concrete. (P,P1,P2 Grade).

5)The addition of fibers restrains the deterioration of tensile strength due to Sulphate attack

FUTURE SCOPE OF STUDY

Following may provide further scope of work in the direction of this study.

- Exploring properties of FRC with high strength cement Matrices
- Methods to improve the bond between fibers and cement based matrices
- Method to reduced the deterioration of high strength concrete and improve the fiber durability for naturally occurring and some polymeric and mineral fibers
- Investigation of ductility characteristics for potential application in seismic design and construction

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